CAVANAUGH
TOCCI
ASSOCIATES, INCORPORATED

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January 9, 2003

Greendale Avenue Neighborhood Group

c/o Mr. Ronald Sockol
PO Box 920196
Needham, MA 02492

SUBJECT: Review of Acoustical Report for Proposed Greendale Avenue Residential Development

Dear Mr. Sokol,

At your request, Cavanaugh Tocci Associates, Inc. has reviewed an acoustical report dated October 16, 2002 by Tech Environmental, Inc. (TEI), regarding the proposed Greendale Avenue residential development.

The purpose of your request, and our review, is to provide the Town of Needham Zoning Board with an independent professional critique of the TEI report, on behalf of the Greendale Avenue neighborhood group opposed to the project.

In addition, you have also requested that we attend a Zoning Board Public Meeting scheduled for January 30, 2003, to verbally summarize our review and respond to questions and comments, as may be requested by the Zoning Board.

Attachments

Appendix A contains a copy of the TEI report.

Appendix B contains a glossary of pertinent acoustical terminology and United States government agencies and other national standards criteria for environmental noise. A significant portion of our critique refers to numerous acoustical criteria outlined in Appendix B, which are not discussed or evaluated in the TEI report.

The information in Appendix B has been prepared and assembled by Cavanaugh Tocci Associates, Inc. in conjunction with the Solutia Company (manufacturer of Saflex plastic interlayer for "safety glass" windows), and published in the *Saflex Acoustical Glazing Design Guide*. For neighborhood and/or Town of Needham representatives interested in further information on environmental noise and acoustical glazing, the entire Glazing Design book is available from Solutia (phone: 1-800-248-6844). Further information on the capabilities, experience, and professional credentials of Cavanaugh Tocci Associates, Inc. is available on our website (www.cavtocci.com).

Appendix C contains information downloaded January 9, 2003 from a pertinent U.S. government agency website, as further discussed below.

Brief Summary of TEI Report

Briefly, the TEI report presents and discusses:

- Pertinent acoustical terminology and specific acoustical criteria promulgated by the U. S. Department of Housing and Urban Development (HUD). Of most importance to this project, the hourly energy average sound levels (L_{eq}) are used to calculate the Day-Night Sound Level (L_{dn}). The L_{dn} value is used to assess project site environmental sound levels in accordance with the HUD Site Acceptability Standard.

- 24-hour sound monitoring data collected by TEI at the project site, which TEI used to calculate the site L_{dn}.

- Noise reduction performance of and associated brief recommendations for proposed building windows, walls, roof, and exterior vents.

- Acoustical computer modeling, which projects expected changes in the acoustical environment at existing residential areas, as a result of the proposed project development, which would include removal of forest cover and subsequent construction of buildings.

Critique of TEI Report

Our critique of the TEI report includes a discussion of the contents of the report, and perhaps more importantly, includes a discussion of what we believe are critical omissions from the report.

- The TEI report does not indicate the elevation of the measurement microphone above ground level. We presume the microphone was located on a tripod or perhaps a tree branch, approximately 3 to 6 feet above grade. The proposed project drawings show 2-story buildings. The 2nd floor bedroom windows would be approximately 14 to 18 feet above grade. A microphone located at 2nd floor bedroom window height would have significantly better "line-of-sight" to the highway, than a microphone located within just a few feet of the ground. Therefore, sound levels at proposed future building 2nd floor windows would be almost certainly higher than the sound levels reported by TEI.

- Regardless of microphone height, the TEI report states that the measured site L_{dn} value is 71 dB (Specifically, the TEI report presents the Ldn value as 70.7 dBA. By convention, L_{dn} should be reported rounded to whole number integers).

- The report further states that the site Ldn value (71 dB) falls into the HUD "Acceptable with Design Attenuation Category". We are unaware of any HUD document containing this specific phrase or category designation. Rather, in all the HUD documents that we are aware of, a site L_{dn} value of 71 dB is clearly classified as "Normally Unacceptable" (see Appendices B and C).

- We find the TEI report wording to be highly unusual and misleading.

- As shown in Appendices B and C, the HUD "Acceptable" category is for day-night average sound levels not exceeding 65 dB, whereas the L_{dn} value for the site is 71 dB as reported by TEI.

- A HUD project in a "Normally Unacceptable" noise category requires a Special Environmental Clearance in addition to special sound attenuation of the building exterior envelope (windows, doors, walls, roof, vents, etc.). There is no mention of this in the TEI report.

- We suggest that the Needham Zoning Board can independently verify the HUD criteria and any/all other acoustical criteria discussed herein, via the Internet or local library. Appendix C contains the HUD website address at the bottom of each page.

- Although not discussed in the TEI report, we note that the U. S. Environmental Protection Agency (EPA), the Federal Highway Administration (FHWA), and the American National Standards Institute (ANSI) have all published acoustical criteria for environmental noise impact on residences (Appendix B). It is important to note that these are not specific regulations or requirements for the subject project, but are guidelines and recommendations for environmental noise. Most of these federal government agency and national standards criteria are lower (more conservative) than the HUD criteria cited by TEI.

- Most importantly, all of the recommended government agency and national standards criteria are lower than the measured and calculated sound level values reported by TEI for the subject project.

- For instance, according to the EPA, outdoor sound levels are sufficient to "protect public health and welfare" if L_{dn} values do not exceed 55 dB in sensitive areas (specifically including residences) with a 5-decibel margin of safety. Again, the site L_{dn} reported by TEI is 71 dB, which is 16 dB higher than the EPA recommendation (or 11 dB higher, without the 5 dB margin of safety). As noted in the TEI report (Table 1) a 10-decibel change in sound level is perceived as a doubling in loudness level. Although not presented in the TEI report, we note that a 16 decibel change is perceived as a factor of 4 times loudness. In simple terms, the project site is 4 times louder than the EPA recommends for housing.

- The FHWA design guidelines for major highway construction, modifications, noise barrier design goals, etc. recommend that peak hour L_{eq} values should not exceed 67 dBA at residential properties. The TEI report states that the peak hour L_{eq} value measured at the project site was 70 dBA. As noted in the TEI report, two equal sound levels added together results in a 3-decibel increase. In simple terms, there is twice as much acoustical energy impacting the project site than recommended by the FHWA for housing.

- The World Health Organization recommends indoor continuous sound levels (which would include environmental sound transmitted indoors) not to exceed 30 dBA in order to avoid negative effects on sleep. For the proposed project construction, this would require approximately 40 decibels noise reduction provided by the exterior building envelope (windows, doors, walls, roof, etc.

- The TEI report correctly identifies that the HUD guideline for interior sound levels (resulting from exterior sound transmitted indoors) is a L_{dn} of 45 dB. The TEI report also correctly identifies that "standard construction usually provides 20 dBA noise reduction". (Therefore, with "standard" construction, an exterior L_{dn} of 65 dB should result in an interior L_{dn} of 45 dB. This is why HUD initially developed the exterior Ldn criterion of 65 dBA). We agree with this aspect of the TEI presentation of the HUD guidelines for exterior and interior sound Ldn values, and agree with the expected 20 decibel differential between exterior and interior sound levels for standard building construction. However, elsewhere in the report, TEI states that "a typical residential window will reduce outdoor noise by 25 dBA with the windows closed" and states that "Typically residential buildings have single stud exterior walls with one layer of gypsum or drywall on the

interior and wood siding on the exterior. This wall can effectively reduce outdoor sound levels by 40 dBA." Together, these two statements clearly conflict with the previous statement.

- The TEI report section titled *Environmental Impact of the Project on Existing Residential Areas* discusses modeling, refers to the FHWA Traffic Noise Model (TNM) and discusses TNM "attenuation factor algorithms and algorithms found in standard engineering texts". However, the TEI report does not include any modeling spreadsheets, attenuation factors, or provide any other support documentation at all. Without these, we cannot provide a substantive critique of the TEI modeling results for future noise impact on the existing neighborhood residences, beyond noting that the summary Table 4 shows only a 1 decibel change between foliated (+4 dBA) and unfoliated (+3 dBA) conditions, and seems to indicate an increase (stated to be less than 3 dBA) in sound levels that would occur at existing residences as a result of new buildings constructed on the project site. These Table 4 summary values do not make sense to us, particularly the small stated differential between foliated and unfoliated conditions. (These stated could be valid, but we have no substantive means to evaluate these TEI values and associated conclusions regarding noise impact.)

- The TEI report does not discuss potential apartment complex parking area noise (car alarms, garbage trucks, snow removal, etc.).

- The TEI report does not discuss potential noise nuisance in the existing neighborhood associated with apartment complex heating, ventilating and air conditioning (HVAC) systems.

Conclusions

In summary, it is our opinion that the TEI report is inaccurate and misleading in reporting the site sound level classification in accordance with the HUD criteria cited in the report. Equally importantly, the report omits reference to numerous other, well known environmental noise criteria that are more stringent (conservative) than the HUD criteria chosen by TEI (and then used incorrectly in the TEI evaluation).

Certain statements regarding building envelope noise reduction within the TEI report conflict with other statements in the report.

The brief discussion of acoustical modeling in the TEI report and the presentation of modeling results are not supported by any technical backup. The very brief modeling results presented in the report (Table 4) are unusual at best, and appear inaccurate based on the previous experience of this office.

Absent from the report are a number of other potentially critical acoustical issues regarding potential annoyance in the existing Greendale Avenue neighborhood that may occur as a result of proposed project construction.

Sincerely,
CAVANAUGH TOCCI ASSOCIATES, INC.

Brion G. Koning

Brion G. Koning, *Senior Consultant*

APPENDIX A

Tech Environmental, Inc. Report

Tech Environmental, Inc.

1601 Trapelo Road
Waltham, MA 02451
(781) 890-2220 Fax (781) 890-9451
www.techenv.com

October 16, 2002

Ref 2206

Mr. Stephen R. Burtt
Burtt Development Co., Inc.
20 Ledyard Street
Wellesley Hills, MA 02481

Re: Greendale Avenue Residential Development -
Acoustical Study

Dear Mr. Burtt:

Tech Environmental, Inc. (TEI) is pleased to submit this letter report that documents the existing baseline ambient sound level at the proposed site of the Greendale Avenue residential development in Needham, MA. The analysis also includes acoustic modeling results for the predicted change in environmental sound levels from Route 128 traffic on the existing residential community caused by the removal of forest cover and the subsequent construction of the residential structures.

Sound Level Concepts

Noise is defined as an undesirable or annoying sound in the community. The unit of sound pressure is the decibel (dB). The decibel scale is logarithmic to accommodate the wide range of sound intensities to which the human ear is subjected. A property of the decibel scale is that the sound pressure levels of two separate sounds are not directly additive. For example, if a sound of 70 dB is added to another sound of 70 dB, the total is only a 3-decibel increase (or 73 dB), not a doubling to 140 dB.

In terms of the human perception of sound, a halving or doubling of loudness requires changes in the sound pressure level of about 10 dB, and for broadband sounds, 3 dB is the minimum perceptible change.[1] The human response to changes in sound levels is summarized in Table 1. Typical sound levels associated with various activities and environments are presented in Table 2.

Non-steady noise exposure in a community is commonly expressed in terms of the A-weighted sound level (dBA); A-weighting approximates the frequency response of the human ear. Levels of

[1] ASHRAE, 1989 ASHRAE Handbook--Fundamentals, p. 7.7, Atlanta, GA.

many sounds change from moment to moment. Some are sharp impulses lasting one second or less, while others may rise and fall over much longer periods of time. There are various measures of sound pressure designed for different purposes. The L_{eq}, or equivalent sound level, is the steady-state sound level over a period of time that has the same acoustic energy as the fluctuating sounds that actually occurred during that period. It is commonly referred to as the average sound level. The L_{dn} is a 24-hour time average L_{eq} to which a 10-dBA penalty is added for sound occurring during the nighttime hours, to account for increased sensitivity to sound during this period. The L_{eq} and L_{dn} provide an accurate and uniform method for comparing time varying sound levels of a residential community to a steady source of sound, such as a nearby highway.

The acoustic environment in the vicinity of the Greendale Residential Development in Needham results from numerous sources, but is chiefly due to motor vehicles traveling on I-95.

HUD Environmental Sound Level Design Guidelines

The U.S. Department of Housing and Urban Development (HUD) has established noise guidelines and criteria to ensure the land use compatibility of HUD funded projects. While not federally funded, this guideline does provide a means to assess land use compatibility. These guidelines are based on day-night average sound levels (L_{dn}). The HUD land use compatibility guidelines are presented in Table 3. The HUD noise guidelines establish standards for interior and exterior noise for housing. The HUD guidelines promote a goal of not exceeding 45 dBA L_{dn} for interior sound levels. This level allows compatible residential land use in areas experiencing an outdoor 65 dBA L_{dn}, since standard construction usually provides 20 dBA of noise reduction. The HUD guidelines also allow residential land use in "normally unacceptable" areas, provided that additional building sound insulation will bring interior levels to the HUD goal of 45 dBA L_{dn} or less.

Existing Sound Level Measurement Protocol and Results

Following HUD guidance, a 24-hour L_{dn} measurement was made at the location of the building closest to the major background noise source (Route 95), utilizing the Site Plan prepared by Burtt Development Corp and dated Aug 15, 2002. Measurements were made, with a Quest model 1900 sound level meter (ANSI Type 1 precision instrument), programmed to log the sound levels over a continuous 24-hour period. Measurements were made from Tuesday October 8 at 4 p.m. through Wednesday October 9 at 5 p.m. This meter meets or exceeds all requirements set forth in the American National Standards Institute (ANSI) Standards for Type 1[2] for quality and accuracy. Prior to and immediately following the measurement session, this sound analyzer was calibrated (no level adjustment were required) with an ANSI Type 1 calibrator which has an accuracy

[2] American National Standards Institute, ANSI S1.4-1983, American National Standard Specification for Sound Level Meters, revised 1990. ANSI S1.40-1984, American National Standard Specification for Acoustical Calibrators, revised 1997.

traceable to the National Institute of Standards and Technology (NIST). All instrumentation was laboratory calibrated within the previous 12-month period. For the measurement session, the microphone was fitted with a 3" windscreen to reduce the effect of airflow over the microphone and mounted at approximately five feet above the ground in open areas away from vertical reflecting surfaces. Weather conditions during this period were conducive for accurate sound level monitoring with temperatures in the range of 37-56°F, mostly clear skies, light winds below 5 mph at the site, and dry road surfaces. All data were downloaded to a computer, printed and analyzed at the offices of Tech Environmental, Inc. in Waltham, Massachusetts.

Measurement printouts and equipment calibration certifications are provided as an appendix to this letter report. Existing exterior 24-hour energy-averaged sound levels produce a calculated L_{dn} value of 70.7 A-weighted decibels (dBA). The 24-hour L_{eq} is 67.4 dBA, with a maximum one hour L_{eq} of 70 dBA, occurring during the morning rush hour from 7 – 8 a.m. These measured data were compared to relevant sound guidance set forth by the U.S. Department of Housing and Urban Development (HUD). The measured 24-hour L_{dn} for the site falls within the 65 to 75 dBA range, which is the "Acceptable with Design Attenuation Category". Since the design phase of the project is only at a schematic level, this report provides general recommendations for mitigation.

The reduction of sound provided by a building façade is a mathematical composite of the individual building components. Indoor noise control is usually accomplished most efficiently by improving the buildings windows since they are acoustically the weakest link in an exterior wall. Roof, walls, air intakes, and attic vents are also important particularly for noise sources such as high speed highway traffic. The project proponent has committed to building design components that will ensure adequate attenuation of highway noise to ensure an interior 45 dBA sound level recommended by the HUD Guidelines. Candidate mitigation options include:

Windows

Sound travels through window pane glass as well as around through small openings in the window frame. A typical residential window will reduce outdoor noise by 25 dBA with the windows closed. When opened, the building façade reduces sound by only 10 to 15 dBA. The acoustical performance of the window can be significantly improved by increasing glass thickness, incorporating a double paned window design with an airspace between the two panes, and improving the air tightness of the weather-stripping. For this project we are recommending a double pane design with a minimum STC (Sound Transmission Class) rating of 35. In addition, we are recommending that the buildings be designed with an adequate air conditioning system that will allow the building occupants to keep the windows closed during high noise periods while still providing a comfortable interior temperature.

Exterior Walls

Typically residential buildings have single stud exterior walls with one layer of gypsum or drywall on the interior and wood siding on the exterior. This wall can effectively reduce outdoor sound levels by 40 dBA. If more reduction is required, alternatives such as additional layers of gypsum or drywall, resilient channels, staggered or double-stud construction can be incorporated. Due to the close proximity of the proposed buildings to I-95, the exterior wall should be double stud construction and in addition heavier and thicker wall construction should be considered.

Roof and Exterior Vents

Roof vents and air intakes for mechanical and ventilation systems can become a significant source of sound leaks. To limit the possibility of highway noise entering the houses via these flanking paths, all vents should be placed on the side of the building opposite the highway or turned horizontal at their openings and pointed away from the highway. If such a design consideration is deemed infeasible, internally lined ducts and carefully designed vents may be needed to limit interior noise intrusion. An often overlooked component, the roof, must be designed such that it does not introduce unwanted sound into sensitive upper story bedrooms.

Environmental Impact of the Project on Existing Residential Areas

The second objective of the noise analysis is to determine the net change in environmental sound levels from Route 128 traffic at the existing residential community, as a result of the removal of forest cover and the construction of the townhouse building structures. The future change in community sound levels following full project build-out has been predicted for both summer (foliate conditions) and winter (defoliate conditions) seasons. The modeling used for this analysis relied on Federal Highway Administration (FHWA) Traffic Noise Model (TNM) attenuation factor algorithms and algorithms found in standard engineering texts[3]. Due to changes in terrain height between the existing Greendale Avenue residences and Route I-95, only a portion of the forested land is accounted for in the acoustic model. Per FHWA guidance, the existing tree stand must be dense and high enough to break the visual line of site between the receptor of source to provide attenuation. The net change in future sound levels was calculated at the Greendale Avenue residents and the results are shown in Table 4.

The maximum change between existing and future sound levels will occur during foliate seasons when a net increase of 4 dBA is predicted. During defoliate seasons such as winter and early spring, the net difference under this condition is 3 dBA. Following full project Build-out, it is was determined that the new residential building structures will act as noise barriers, reducing sound levels well below a change of 3 dBA in all seasons. Since changes below 3 dBA are not perceptible, the only time when the highway sound levels might be barely perceived as louder than

[3] Beranek, Leo. Noise and Vibration Control. Institute of Noise Control Engineering 1988.

the existing condition would be during a summertime period immediately following site clearing and before the buildings are erected. This will be a temporary condition. Once the project has been completed, there will be no perceivable increase in community environmental sound levels in the existing residential areas.

Conclusion

As people live closer to noise sources and each other, careful planning is required in designing projects that will take into account noise in their design and the effect on the existing acoustical environment. The Greendale Avenue residential development is currently being designed to meet stringent HUD Guidelines for interior sound levels deemed acceptable for residential occupancy. Acoustic modeling with the current FHWA modeling algorithms and using standard acoustic modeling techniques shows that the proposed project will not cause a perceptible increase in community sound levels or adversely effect the existing residential neighborhood.

Please call if you have any questions or require any additional assistance on this project.

Sincerely yours,

TECH ENVIRONMENTAL, INC.

Erik Kalapinski, INCE
Senior Sound and Vibration Engineer

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TABLE 1
SUBJECTIVE EFFECT OF CHANGES IN SOUND PRESSURE LEVEL

Change in Sound Pressure Level (dB)	Apparent Change in Loudness
3	Just barely perceptible
5	Noticeable
10	Twice (or half) as loud

TABLE 2
COMMON SOUND LEVELS

Activity	dBA
Threshold of pain	130
Chipping on metal	120
Loud rock band	110
Jack hammer	100
Jet airliner ½ mile away	95
Threshold of hearing damage	90
Freeway traffic - downtown streets	80
Urban residential area	70
Normal conversation	60
Normal Suburban Area	50
Quiet suburban area	40
Rural area	30
Wilderness area	25
Threshold of audibility	0

TABLE 3
U.S. HUD GUIDELINES FOR EVALUATING NOISE IMPACTS AT RESIDENTIAL RECEPTOR LOCATIONS

Acceptability for Residential Use:	Outdoor L_{dn} Levels (dBA)
Acceptable	65 or less
Acceptable With Design Attenuation	65 - 75
Unacceptable	greater than 75

TABLE 4
PREDICTED SOUND LEVEL CHANGES UNDER THREE MODELING SCENARIOS AT THE EXISTING GREENDALE RESIDENTIAL COMMUNITY

Modeling Scenario:	Net Change in Outdoor Sound Levels (dBA)
Foliate Conditions	+4 dBA
Defoliate Conditions	+3 dBA
Net Change Following Full Project Build Out, Foliate and Defoliate Conditions	<< 3 dBA

QUEST TECHNOLOGIES
1900 PRECISION INTEGRATING/LOGGING SOUND LEVEL METER

Unit Version Number: 02.4 Serial Number: CC5020007

Name Burtt Development Co., Inc.

Work Area Greendale Avenue - Route 95

Comments Unit deployed at closest unit in relation to Route 95

Meter Calibration: 94.0dB 08-OCT-02 @ 15:45:37

Calibrator:
Serial Number J 6050012 Calibration Date 26-Sep-2002

SESSION SUMMARY 1
Notes Measurements completed by Tech Environmental, Inc.

Starting Study: 1 Ending Study: 1 No. of Studies: 1
Session 1
Measuring Parameters:

Range	40-100dB	Weighting	A	Time Constant	FAST
Threshold	OFF	Exchange Rate	3dB	Peak Weighting	A

Study Started	Study Stopped	Run Time
08-OCT-02 @ 15:00:38	09-OCT-02 @ 15:00:38	24:00:00
Peak Level 89.1dB	08-OCT-02 @ 15:48:04	
Max Level 82.2dB	08-OCT-02 @ 15:48:03	
Min Level 35.2dB	09-OCT-02 @ 03:06:17	
Overload 0.00%		

LOGGING (1 HR) Study 1	LEQ	LMAX	LPK	L10	L90
16:00:38	68.6dB	82.2dB	108.1dB	69.9dB	67.1dB
17:00:38	69.1dB	78.1dB	87.9dB	70.5dB	67.4dB
18:00:38	69.3dB	76.6dB	86.1dB	70.6dB	67.8dB
19:00:38	69.1dB	78.1dB	90.5dB	70.4dB	67.2dB
20:00:38	68.2dB	75.8dB	85.9dB	70.1dB	65.4dB
21:00:38	67.8dB	80.1dB	88.0dB	69.8dB	64.5dB
22:00:38	66.9dB	74.9dB	85.5dB	69.1dB	63.2dB
23:00:38	65.7dB	74.8dB	87.3dB	68.6dB	60.7dB
00:00:38	63.8dB	76.0dB	85.9dB	67.0dB	56.4dB
01:00:38	61.8dB	77.2dB	104.6dB	65.3dB	51.9dB

02:00:38	61.3dB	76.6dB	85.1dB	65.4dB	48.5dB
03:00:38	59.6dB	76.8dB	85.6dB	63.7dB	46.4dB
04:00:38	58.6dB	75.5dB	83.5dB	62.2dB	43.5dB
05:00:38	57.6dB	74.8dB	84.6dB	63.4dB	44.4dB
06:00:38	60.1dB	74.9dB	86.6dB	64.4dB	49.9dB
07:00:38	66.6dB	75.8dB	85.6dB	68.7dB	52.4dB
08:00:38	70.0dB	80.9dB	89.8dB	71.6dB	67.8dB
09:00:38	68.9dB	74.3dB	87.4dB	70.5dB	66.8dB
10:00:38	69.1dB	76.8dB	88.3dB	70.9dB	66.7dB
11:00:38	69.7dB	76.8dB	88.1dB	71.4dB	67.3dB
12:00:38	68.9dB	75.2dB	88.9dB	70.8dB	66.3dB
13:00:38	68.6dB	74.7dB	85.3dB	70.4dB	66.0dB
14:00:38	68.7dB	73.8dB	84.9dB	70.6dB	66.1dB
15:00:38	69.0dB	77.0dB	88.4dB	70.6dB	66.9dB

APPENDIX B

Pertinent Acoustical Terminology

and

Environmental Noise Criteria

PART I

A-weighting

Generally, the sensitivity of human hearing is restricted to the frequency range of 20 Hz to 20,000 Hz. The human ear, however, is most sensitive to sound in the 500 to 8,000 Hz frequency range. Above and below this range, the ear becomes progressively less sensitive. To account for this feature of human hearing, sound level meters incorporate a filtering of acoustic signals according to frequency. This filtering is devised to correspond to the varying sensitivity of the human ear to sound over the audible frequency range. This filtering is called **A-weighting**. Sound pressure level values obtained using this weighting are referred to as A-weighted sound pressure levels and are signified by the identifier **dBA**. To provide some perspective, Figure 2.1 gives typical A-weighted sound pressure levels of various common sounds.

An important feature of the human perception of continuous sound is that an increase or decrease in sound pressure level by 3 dB or less is barely perceptible; an increase or decrease of 5 dB is clearly perceptible; and an increase or decrease of 10 dB is perceived as a doubling or halving of noise level.

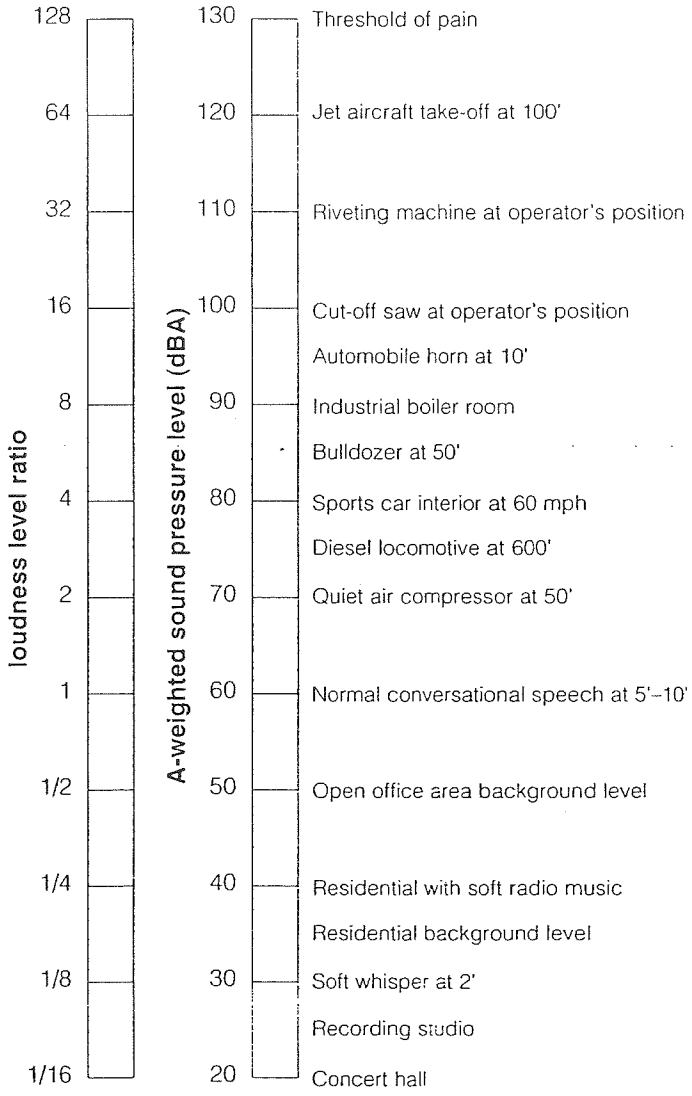

Figure 2.1
Loudness ratio and decibel scale (dBA) for common sounds.

Octave Band Sound Pressure Level

For general environmental sounds, inside and outside of buildings, acoustic analysis usually involves determining the sound pressure level in groups or bands of frequencies. It is customary to divide the audible frequency range into octave frequency bands. Figure 2.2 provides a list of octave band frequencies which have been defined in ANSI Standard S1.6–1984 Preferred Reference Quantities for Acoustical Measurements [10]. The ANSI standard does not define octave band numbers. These have been given in Figure 2.2 as they are commonly used in technical literature, particularly information pertinent to buildings.

Octave Band No.	Low Frequency Limit (Hz)	Center Frequency* (Hz)	High Frequency Limit (Hz)
	22.4	31.5	44.7
1	44.7	63.0	89.1
2	89.1	125.0	178.0
3	178.0	250.0	355.0
4	355.0	500.0	708.0
5	708.0	1,000.0	1,413.0
6	1,413.0	2,000.0	2,818.0
7	2,818.0	4,000.0	5,623.0
8	5,623.0	8,000.0	11,200.0
9	11,220.0	16,000.0	22,387.0

*Nominal Values

Figure 2.2

Preferred octave band frequencies.

Sound level meters often are outfitted with octave band measurement capabilities. This allows the instrument user to directly measure the sound pressure level in each octave band. Although this data can be listed in tabular form, it is more useful to graph octave band values on a chart, as shown in Figure 2.3. This allows the user to more easily identify specific features of background noise which might be of concern. Data presented in this fashion are referred to as an **octave band spectrum**. Also shown in Figure 2.3 is an octave band spectrum of noise produced by an aircraft taking-off at a distance of 1,000 feet.

Under certain circumstances, more frequency resolution in acoustical data is needed so that one-third octave band sound level spectra are used. For example, the 1,000 Hz octave band is divided into one-third octave bands with center frequencies at 800 Hz, 1,000 Hz and 1,250 Hz. In Section 3 of this guide, sound transmission loss (TL) for various glass configurations is reported in one-third octave band frequencies as required by applicable standards.

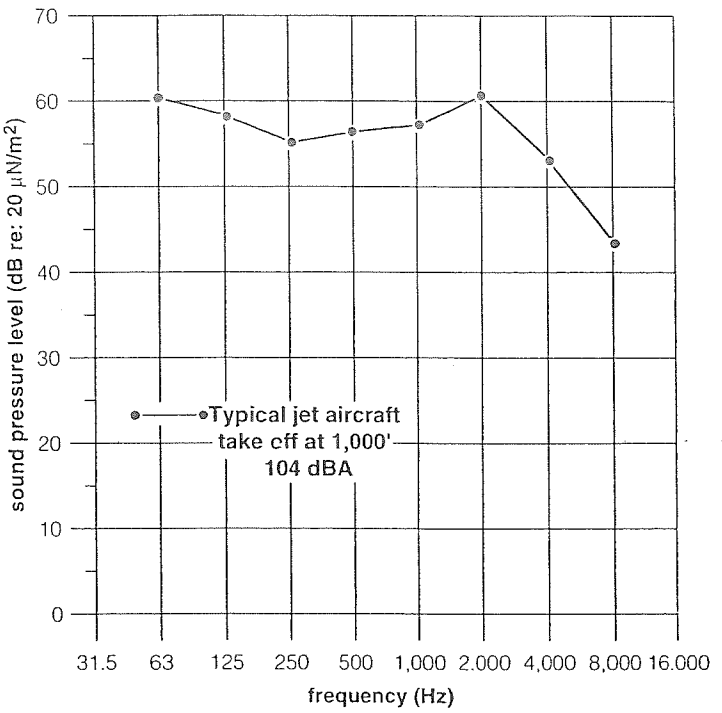

Figure 2.3

Octave band sound pressure level spectrum for typical commercial jet aircraft take-off.

Environmental Noise Descriptors

Besides frequency and level, environmental sounds exhibit a time-varying or temporal characteristic. The temporal character of noise level can be illustrated by considering noise levels that occur near a highway. During the day, noise levels are generally high, increasing to higher peaks when a noisy truck passes and decreasing to a lower level between vehicle platoons. At night, when traffic volumes are lower, the same variation occurs, but is centered around a lower level.

Noise descriptors are quantifications of noise that combine, into a single value, the three chief features of environmental noise: level, frequency and temporal characteristics. The use of A-weighted sound pressure level combines the first two characteristics — level and frequency — into a single number. Then, by averaging A-weighted sound pressure levels over time in various fashions, noise descriptors that combine all three features can be developed.

A commonly used descriptor is **percentile A-weighted sound levels**, A-weighted sound pressure levels exceeded for specific percentages of time within a noise monitoring period. For example, the one-hour 50 percentile A-weighted noise level, symbolized as the L_{50} (1 hour), is the A-weighted noise level exceeded a total of 30 minutes out of a continuous 60-minute period. Likewise, the L_{10} (20 minutes) is the A-weighted noise level exceeded a total of two minutes out of a continuous 20-minute period.

Percentile A-weighted noise levels most often are used to assess the time-varying character of noise. The **residual noise level** (defined as the nearly constant, low level of noise produced by distant motor vehicle traffic or industrial activity) is indicative of the lowest level in a monitoring period. Residual noise level is commonly defined as the L_{90}, i.e., the A-weighted sound level exceeded 90% of a monitoring time period. Intrusive noise is characterized as a high noise level that endures for only a short period and is produced by such events as aircraft flyovers and truck passbys.

Intrusive noise level is often defined as the L_{10}, i.e., the A-weighted sound level exceeded 10% of a monitoring time period. Although the L_{10} is useful for understanding environmental noise, it is no longer used by any federal agency in setting standards. Instead, the equivalent sound level has become commonly adopted as discussed below.

Equivalent Sound Level

For several years, the U.S. Environmental Protection Agency (EPA) has encouraged the use of the **equivalent sound level**: a descriptor that uses the average A-weighted energy and differs significantly from 50th percentile, or median, sound pressure level. Unlike the 50th percentile sound level which is not influenced by peak noise levels of short duration, the equivalent sound level is. Therefore, the A-weighted equivalent sound level combines level, frequency and temporal character into a single-valued descriptor. Equivalent sound level, symbolized as L_{eq}, is always higher than the L_{50}, as it is influenced by noise contributions of high level and short duration such as aircraft flyovers or noisy truck passbys.

Day-Night Average Sound Level

Noise levels occurring at night generally produce greater annoyance than do the same levels which occur during the day. It is generally agreed that community perception of nighttime noise levels is 10 dBA higher [11]. That is, a given level of environmental noise during the day would appear to be approximately 10 dBA louder at night — at least in terms of its potential for causing community annoyance. This is largely because nighttime ambient environmental noise levels in most areas are approximately 10 dBA lower than daytime noise levels.

This feature of nighttime annoyance has been incorporated into a day-night noise descriptor which uses the equivalent sound level. This descriptor, referred to as the **day-night average sound level** (DNL) applies a 10 dBA "penalty" to noise levels occurring between 10:00 p.m. and 7:00 a.m., thus accounting for increased community sensitivity to nighttime noise levels. To help place day-night average sound levels into perspective, Figure 2.4 contains a scale showing DNL values for various types of outdoor locations.

Note that the mathematical symbol for day-night average sound level is L_{dn}. L_{dn} and DNL (the abbreviation) are often used interchangeably, as has been done in this guide.

Because of their sensitivity to frequency and temporal characteristics of noise, both the L_{eq} and the DNL have become widely accepted for use in environmental noise regulations and criteria. Among the federal agencies using L_{eq} or DNL sound levels are the U.S. Environmental Protection Agency, the Federal Highway Administration, the U.S. Department of Housing and Urban Development, the Federal Aviation Administration and the Department of Defense.

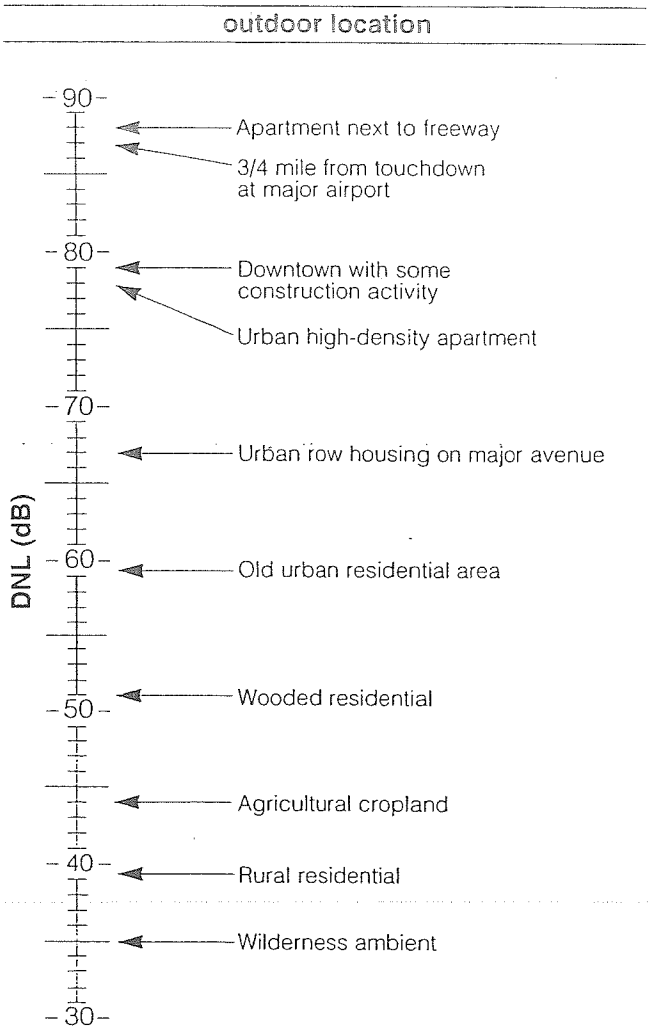

Figure 2.4

Examples of outdoor day-night average sound levels in dB measured at various locations [11].

PART II

Agency Regulations and Guidelines

The following discussion of various agency regulations and guidelines should be helpful in understanding how noise limits are expressed. It also provides much needed guidance in assessing environmental noise exposure. It must be noted, however, the federal government recognizes that it is the states' and local governments' right and responsibility to set noise limits as a function of land use. Federal agencies do not have the authority to do so. In discussing noise exposure and land use, information is presented only as recommended guidelines. Such guidelines function as regulations only when used within an agency's statutory authority.

For example, the U.S. Department of Housing and Urban Development (HUD) has the authority to establish regulations relative to noise exposure for housing projects that it supports under its jurisdiction. The Federal Highway Administration (FHWA) has the right to regulate the design and construction of highways that are federally supported, etc. Hence, how these guidelines function in connection with a specific project depends upon applicable authority over a project.

U.S. Environmental Protection Agency

The U.S. Environmental Protection Agency (EPA) has taken the lead among all federal agencies in studying the general impact of environmental noise. In spite of this, however, it has not promulgated specific regulations setting limits on general environmental noise levels. (It has promulgated noise limits for specific types of equipment such as air compressors.)

More importantly, the EPA has unified usage of environmental noise descriptors among federal agencies and has produced an extensive log of environmental noise measurements in different environmental settings. Also, it has recommended day-night average sound levels which represent "... values that protect public health and welfare with a margin of safety." A summary of these levels is provided in Figure 2.5 (taken from Table VIII of *Protective Noise Levels —Condensed Version of EPA Levels Document*) [11].

The EPA carefully guards against misuse of these levels by stating that:

"On the basis of its interpretation of available scientific information, EPA has identified a range of yearly day-night sound levels sufficient to protect public health and welfare from the effects of environmental noise. It is very important that these noise levels summarized in Table VIII not be misconstrued. Since the protective levels were derived without concern for technical or economic feasibility and contain a margin of safety to ensure their protective value, they must not be viewed as standards, criteria, regulations, or goals. Rather, they should be viewed as levels below which there is no reason to suspect that the general population will be at risk from any of the identified effects of noise."

According to the EPA, outdoor yearly levels are sufficient to protect public health and welfare if they do not exceed a day-night average sound level (DNL) of 55 dB in sensitive areas (residences, schools and hospitals). Inside buildings, yearly levels are sufficient to protect public health and welfare if they do not exceed a DNL of 45 dB. Maintaining a DNL of 55 dB outdoors should ensure adequate protection for indoor living. To protect against hearing damage, one's 24-hour equivalent sound level exposure at the ear should not exceed 70 dB.

	Level		
Effect	DNL	L_{eq}(24 hrs)	Area
Hearing		≤ 70 dBA	All areas (at the ear)
Outdoor activity	≤ 55 dB		Outdoors in residential areas and farms and other outdoor areas where people spend widely varying amounts of time and other places in which quiet is a basis for use
		≤ 55 dBA	Outdoor areas where people spend limited amounts of time such as schoolyards, playgrounds, etc.
Indoor activity	≤ 45 dB		Indoor residential areas
		≤ 45 dBA	Other indoor areas with human activities such as schools, etc.

Source: U.S. Environmental Protection Agency (Table VIII, ref. 11)

Figure 2.5

Yearly DNL and L_{eq} values that protect public health and welfare with a margin of safety.

U.S. Department of Housing and Urban Development

The U.S. Department of Housing and Urban Development (HUD) is the lead federal agency setting standards for interior and exterior noise for housing. These standards, outlined in 24 CFR Part 51, establish Site Acceptability Standard based on day-night average sound levels [6]. These are presented in Figure 2.6.

	Day-night average sound level in decibels (DNL)
Acceptable	Not exceeding 65 dB
Normally unacceptable	Above 65 dB but not exceeding 75 dB
Unacceptable	Above 75 dB

*Taken from 24 CFR PART. 51.103 Criteria and Standards

Figure 2.6

HUD site acceptability criteria [6].

U.S. Department of Housing and Urban Development Site Acceptability Criteria*

In Figure 2.6, ranges of DNL are correlated with various dispositions that classify HUD approval procedures and identify the need for noise abatement, either at the site property line or in the construction of the building exterior. These have been devised to achieve the HUD goal for interior noise levels, i.e., a day-night average sound level not exceeding 45 dB. "Acceptable" sites are those where noise levels do not exceed a DNL of 65 dB. Housing on acceptable sites does not require additional noise attenuation other than that provided in customary building techniques.

"Normally unacceptable" sites are those where the DNL is above 65 dB, but does not exceed 75 dB. Housing on normally unacceptable sites requires some means of noise abatement, either at the property line or in the building exterior construction, to assure that interior noise levels are acceptable. From a practical standpoint, this usually means that buildings must be air-conditioned so that windows can be closed to reduce exterior sound transmission into interior spaces.

"Unacceptable" sites are those where the DNL is 75 dB or higher. The term "unacceptable" does not necessarily mean that housing cannot be built on these sites, but rather that more sophisticated sound attenuation would likely be needed and that there must exist some benefits that outweigh the disadvantages caused by high noise levels. Most often, housing on unacceptable sites requires high sound transmission loss glazing and air-conditioning.

Federal Highway Administration

Among criteria established by the Federal Highway Administration (FHWA) for the design of highways is a set of design goals for traffic noise exposure. The FHWA noise abatement criteria are given in 23 CFR Part 772. These define various categories of land use and ascribe corresponding maximum hourly equivalent sound levels. Figure 2.7 contains a table presenting the FHWA limits expressed as hourly equivalent sound levels for various categories of land use identified as A through E.

These limits are viewed by the FHWA as goals in the design and evaluation of highway facilities and are helpful for planning building projects near existing or future highways. Also of use to the building designer are various traffic noise prediction methodologies that have been developed. Up to now, the most widely used methodology is that developed by the U.S. Department of Transportation and described in FHWA Publication RD-77-108. Through the use of various charts and tables, and by knowing traffic volume, speed, auto and truck mix and highway geometry, it is possible to predict noise levels at building locations. This methodology has been developed into a FORTRAN program by FHWA and is called STAMINA II. Various other institutional and commercial enterprises have produced versions able to be used on personal computers and have incorporated various input/output enhancements beyond the basic program.

In 1996, the RD-77-108 methodology and the STAMINA program are being replaced by a new computer program called FHWA Traffic Noise Model Version 1.0. This new program will operate on personal computers under Windows 3.1. It will incorporate convenient data handling and graphing capabilities, and a means for defining new classes of vehicles. Besides automobiles, medium and heavy trucks, the new program will also include motorcycles and buses as additional standard classes of vehicles.

In the case of a proposed building site near an existing highway, actual measurement of traffic noise levels can be used in lieu of traffic noise modeling. Traffic noise measurements may also be preferred as they can usually be completed more quickly than can computer modeling of traffic noise levels. This is especially true if all that is required is determining the maximum traffic sound level typically occurring at a building site during weekday rush-hour periods.

Activity Category	$L_{eq}(h)$	$L_{10}(h)$	Description of Activity Category
A	57 (Exterior)	60 (Exterior)	Lands on which serenity and quiet are of extraordinary significance and serve an important public need and where the preservation of those qualities is essential if the area is to continue to serve its intended purpose
B	67 (Exterior)	70 (Exterior)	Picnic areas, recreation areas, playgrounds, active sports areas, parks, residences, motels, hotels, schools, churches, libraries and hospitals
C	72 (Exterior)	75 (Exterior)	Developed lands, properties or activities not included in Categories A or B above
D			Undeveloped lands
E	52 (Interior)	55 (Interior)	Residences, motels, hotels, public meeting rooms, schools, churches, libraries, hospitals and auditoriums

[1]Either $L_{10}(h)$ or $L_{eq}(h)$ (but not both) may be used on a project.

Figure 2.7

FHWA Traffic Noise Abatement Criteria [23 CFR Part 772].

Federal Aviation Administration

The Federal Aviation Administration (FAA) does not set specific aircraft noise exposure limits in the community. Instead, it sets limits on noise emissions from individual types of aircraft. These limits are not of any particular interest in the design of buildings; however, the limits have been useful to airport operators enabling them to assess aircraft noise exposure around airports. This information is usually available in an airport master plan. An airport master plan is a document which outlines all airport activity, assesses environmental effects and forecasts future airport growth.

Aircraft noise exposure information is normally presented as yearly day-night average sound level contours around the airport. Aircraft noise contours are generally presented in increments of 5 dB beginning with a yearly day-night average sound level of 65 dB. Around major urban airports, day-night average sound levels as high as 80 dB sometimes occur at locations near the end of major runways. A building designer can use these contour maps to interpolate the aircraft noise exposure at his/her project site.

It should be noted that the FAA, through its 14 CFR Part 150 Airport Noise Compatibility Planning Program [4], has recommended sound transmission loss (TL) characteristics of exterior building constructions. TL characteristics have been related to aircraft noise exposure expressed as ranges of day-night average sound level.

Figure 2.8 contains a table summarizing the recommended FAA noise reductions from the 14 CFR Part 150 document.

Average Annual Aircraft DNL in dB

	Below 65	65-70	70-75	75-80	80-85	Over 85
Residential	Y	N(25)[1]	N(30)[1]	N(35)[2]	N	N
Public Schools, hospitals, Churches, auditoriums	Y	Y(25)	Y(30)	N	N	N
Commercial office, retail	Y	Y	Y(25)	Y(30)	Y(35)	N

( ) Parenthesized values are the minimum required aircraft noise reductions.

[1] To obtain aircraft NRs indicated, special wall and window sound isolation techniques may be needed. To maintain this noise reduction, buildings require mechanical ventilation or air-conditioning in order for windows to remain closed. Mobile homes are not acceptable in these areas.

[2] Only recommended for transient hotel occupancy.

Y = Yes, land use is compatible with aircraft noise exposure.

Y(30) = Yes, land use is compatible with aircraft noise exposure if the building exterior construction has an A-weighted aircraft noise reduction of at least 30 dB.

N = No, land use is not compatible with aircraft noise exposure.

N(30) = No, land use is not compatible with aircraft noise exposure with respect to exterior activities, but interior noise levels can be acceptable if the building exterior construction has an A-weighted aircraft noise reduction of at least 30 dB.

Figure 2.8

Summary of land use compatibility with various aircraft noise levels (DNL) in dB based on Appendix A 14 CFR Part 150.

American National Standards Institute

The American National Standards Institute (ANSI) has published ANSI Standard S12.40-1990 Sound Level Descriptors for Determination of Compatible Land Use [12]. This document focuses on defining basic environmental noise descriptors suggested for use in assessing the acceptability or compatibility of ambient noise for various types of land use.

Among the types of environmental noise descriptors defined are the time-average sound level (same as the equivalent sound level), sound exposure level (usually used for assessing transient sound events) and the day-night average sound level.

The standard also defines the yearly day-night average sound level for community sound averaged over a continuous 365-day period.

ANSI S12.40 also presents the bar graph shown in Figure 2.9. The document indicates that this is not part of the standard *per se*, but is given in an appendix for informational purposes only. It establishes classifications defined as "compatible," "marginally compatible," "compatible indoors with building sound isolation installed" and "incompatible." For each land use. the classifications are expressed as ranges of yearly day-night average sound level. This document also recommends that interior sound levels due to exterior noise should not exceed a yearly day-night average sound level of 45 dB. This is the same as the interior noise level goal used by the U.S. Department of Housing and Urban Development.

It should also be noted that levels given in Figure 2.9 are in agreement with recommendations of the U.S. Environmental Protection Agency (EPA). As with EPA recommendations, ANSI S12.40 should be viewed as a recommended guideline and is not an enforceable regulation.

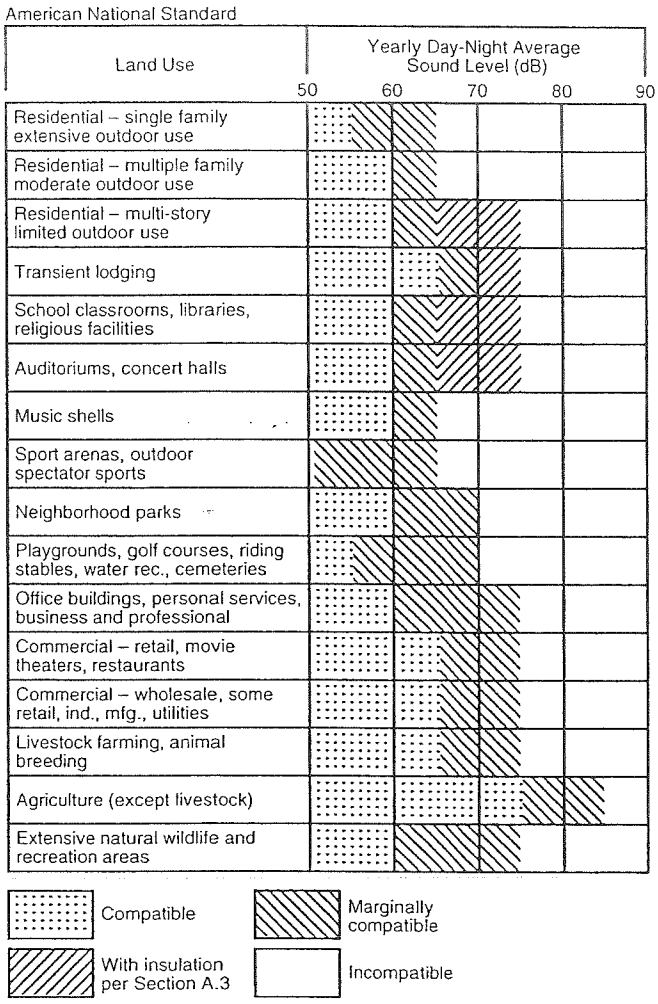

Figure 2.9

Land use compatibility with yearly day-night average sound level at a site for buildings as commonly constructed. (For information only: not a part of American National Standard for Sound Level Descriptors for Determination of Compatible Land Use S12.40-1990.)[12]

APPENDIX C

United States
Department of Housing and Urban
Development (HUD)
Site Acceptability Critieria

Community Planning and Development
- Energy/ Environment
- Environment
- Laws and regulations
  - Laws
  - Regulations

HUD news

Homes

Communities

Working with HUD

Resources

Tools

Let's talk
Webcasts
Mailing lists
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Help

Sec. 51.103 Criteria and Standards

[Code of Federal Regulations][Title 24, Volume 1][Revised as of April 1, 2001]
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TITLE 24--HOUSING AND URBAN DEVELOPMENT

PART 51--ENVIRONMENTAL CRITERIA AND STANDARDS--Table of Contents

Subpart B--Noise Abatement and Control

Sec. 51.103 Criteria and standards.

These standards apply to all programs as indicated in Sec. 51.101.

a. Measure of external noise environments. The magnitude of the external noise environment at a site is determined by the value of the day-night average sound level produced as the result of the accumulation of noise from all sources contributing to the external noise environment at the site. Day-night average sound level, abbreviated as DNL and symbolized as L<INF>dn!</INF>, is the 24-hour average sound level, in decibels, obtained after addition of 10 decibels to sound levels in the night from 10 p.m. to 7 a.m. Mathematical expressions for average sound level and day-night average sound level are stated in the Appendix I to this subpart.

b. Loud impulsive sounds. On an interim basis, when loud impulsive sounds, such as explosions or sonic booms, are experienced at a site, the day-night average sound level produced by the loud impulsive sounds alone shall have 8 decibels added to it in assessing the acceptability of the site (see Appendix I to this subpart). Alternatively, the C-weighted day-night average sound level (L<INF>Cdn</INF>) may be used without the 8 decibel addition, as

indicated in Sec. 51.106(a)(3). Methods for assessing the contribution of loud impulsive sounds to day-night average sound level at a site and mathematical expressions for determining whether a sound is classed as "loud impulsive" are provided in the Appendix I to this subpart.

c. Exterior standards. (1) The degree of acceptability of the noise environment at a site is determined by the sound levels external to buildings or other facilities containing noise sensitive uses. The standards shall usually apply at a location 2 meters (6.5 feet) from the building housing noise sensitive activities in the direction of the predominant noise source. Where the building location is undetermined, the standards shall apply 2 meters (6.5 feet) from the building setback line nearest to the predominant noise source. The standards shall also apply at other locations where it is determined that quiet outdoor space is required in an area ancillary to the principal use on the site.
(2) The noise environment inside a building is considered acceptable if: (i) The noise environment external to the building complies with these standards, and (ii) the building is constructed in a manner common to the area or, if of uncommon construction, has at least the equivalent noise attenuation characteristics.

Site Acceptability Standards

Day-night average sound level (in decibels)	Special approvals and requirements
Acceptable..... Not exceeding 65 dB(1)	None.
Normally Unacceptable..... Above 65 dB but not exceeding 75 dB.	Special Approvals (2) Environmental Review (3). Attenuation (4).
Unacceptable..... Above 75 dB.....	Special Approvals (2). Environmental Review (3). Attenuation (5).

Notes:

1. Acceptable threshold may be shifted to 70 dB in special circumstances pursuant to Sec. 51.105(a).

2. See Sec. 51.104(b) for requirements.

3. See Sec. 51.104(b) for requirements.

4. 5 dB additional attenuation required for sites above 65 dB but not exceeding 70 dB and 10 dB additional attenuation required for sites above 70 dB but not exceeding 75 dB. (See Sec. 51.104(a).)

5. Attenuation measures to be submitted to the Assistant Secretary for CPD for approval on a case-by-case basis.

[44 FR 40861, July 12, 1979, as amended at 49 FR 12214, Mar. 29, 1984]

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Back to top

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