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Mr. Russell Jennings
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Subject: Proposed Sports and Campground Complex – Charlton, MA
Environmental Sound Study

Dear Mr. Jennings,

Cavanaugh Tocci Associates, Inc. (CTA) has been retained by Sunset City Inc. (Sunset City) to conduct a study of environmental sound associated with the proposed Sunset City Sports and Campground Complex (the Complex). This report and associated figures summarize the results of the environmental sound study.

The primary purposes of this study are to:

- quantify the existing acoustic environment around the project site
- develop design goals for facility sound transmitted to properties around the site
- estimate future sound levels produced by the Complex

Introduction

The proposed Complex is a campground and motocross facility which would be constructed on a portion of a roughly 110-acre site in Charlton, MA which is currently largely forested. The site is generally bounded by Brookfield Road to the north, Interstate 90 to the south, Massachusetts Route 49 to the west, and North Sullivan Road to the east. There are residential land uses located on North Sullivan Road, Brookfield Road, and Ladd Roads, as well as along Route 49.

Figure 1 is an aerial photograph which has been annotated to show the boundaries of the Complex property, as well as the town line between Sturbridge, MA and Charlton, MA. Also shown in Figure 1 are locations where sound measurements of existing ambient conditions were conducted (SM1 – SM4), and the locations of residential receptors considered in acoustical computer modeling of the Complex (R1 – R10) and referred to throughout this report.

The proposed Complex would include two motocross tracks: a practice track that would be used on weekdays between the hours of 8:00 AM and 8:00 PM, and a racing track that would be used on weekends during the same hours. Each motocross race would last approximately 10 minutes, and it is estimated that there would be a maximum of 4 races per hour.

To assess the acoustic impact of the proposed Complex, an environmental sound study has been completed. Significant features of this study include a survey of applicable noise regulations, a baseline acoustic survey of existing conditions, and computer modeling to estimate future sound levels at nearest residential receptors.

Environmental Noise Regulations

Sound is a feature of all environments and is considered objectionable only when it is inconsistent with its environment, by being either too loud or by being distinctive in character. Objectionable sound is often referred to as noise. The purpose of environmental noise regulations is to provide a logical and equitable relationship between facility noise and existing environmental sound.

Noise impact is judged on the basis of two criteria: the extent to which governmental regulations or guidelines may be exceeded, and the extent to which it is estimated that people may be annoyed or otherwise adversely affected by the noise. The governmental regulations applicable to noise caused by activities associated with the proposed Complex are summarized below.

Federal Regulations

To the best of our knowledge, there are no federal noise regulations applicable to sound produced by the proposed Complex.

State Regulations

Massachusetts Department of Environmental Protection (MassDEP) Policy on Noise

MassDEP has issued a policy on noise produced by facilities and transmitted to adjacent properties. The community sound level criteria contained in MassDEP BWP AQ Sound are as follows:

> *A noise source will be considered to be violating the Departments noise regulation (310 CMR 7.10) if the source:*
>
> 1. *Increases the broadband sound level by more than 10 dB(A) above ambient, or;*
> 2. *Produces a "pure-tone" condition – when any octave band center frequency sound pressure level exceeds the two adjacent center frequency sound pressure levels by 3 decibels or more.*

Ambient is defined in the MassDEP Policy as the A-weighted background sound level that is exceeded 90% of the time.

Local Regulations

Based on our review of the Municipal Codes of the Town of Charlton, MA and the Town of Sturbridge, MA, it is our understanding that there are no local noise regulations applicable to sound produced by the proposed Complex.

Summary of Noise Regulations

The MassDEP Policy is the only noise regulation applicable to Complex sound of which we are aware. The limits of the MassDEP Policy are expressed in terms of marginal increases above the existing ambient sound level.

Baseline Sound Study

An environmental sound study was conducted to quantify and characterize the existing acoustic environment in the vicinity of the proposed Complex. In order to document the time-varying characteristics of ambient environmental sounds in the study area, continuous sound monitoring was conducted for a one-week period at three locations on the boundaries of the site.

Week-Long Continuous Sound Monitoring Locations

A review of project drawings and existing land use in the vicinity of the proposed Complex was conducted to identify the closest and most representative receptor locations. On the basis of this review, three continuous sound measurement locations (SM1 – SM3) were selected, as shown in Figure 1.

The sound monitoring locations are summarized as follows:

- Location SM1 was near the eastern terminus of Ladd Road, close to an operating farm owned by the project proponent, and approximately 3000 feet from Interstate 90. Ambient sound measured at this location is representative of sound at the farm, as well as at residences along the east-west portion of Ladd Road (computer model receptor R9).
- Location SM2 was along Brookfield Road, approximately between North Sullivan Road and Massachusetts Route 49. Ambient sound measured at this location is representative of sound at residences on Brookfield Road (computer model receptors R5 – R8).
- Location SM3 was near the eastern property line, approximately 2500 feet south of SM2. Ambient sound measured at this location is representative of sound at residences along and near North Sullivan Road (computer model receptors R1 – R4).

Short-Term Sound Measurement Location

In addition to the three continuous measurement locations described above, two 10-minute sound measurements were conducted during daytime hours near the residence at the southern terminus of Ladd Road. This measurement location is referred to as SM4 in this report, and corresponds to computer model receptor R10. Location SM4 was approximately 900 feet north of Interstate 90.

The objective of the short-term measurements at SM4 was to establish a relationship between long-term acoustical trends measured at the nearest continuous monitor location (SM1) and those that occur at the R10 residence. On the basis of these comparative measurements, it has been concluded that long-term ambient sound levels at the residence near SM4 are expected to be 6 to 7 dB higher than those measured at SM1. This difference is due in large part to the reduced distance to Interstate 90 (approximately 900 feet away), as well as an increased receptor elevation leading to less topographical screening of Interstate 90 highway traffic sound.

Continuous Monitoring Data

To identify typical trends in existing ambient environmental sound levels, and to quantify time varying ambient sound levels in the community, continuous sound monitoring was performed at SM1, SM2, and SM3. The continuous monitors were installed for an approximate 7-day period beginning February 11, 2015.

For the continuous measurements, sound levels were monitored using Rion NL-31 data-logging sound level meters outfitted with ½ inch electret microphones and windscreens. The instruments were calibrated before the measurement period using a Larson Davis CAL-250 acoustical calibrator. During the measurements, the sound monitor microphones were mounted on trees approximately 5 feet above the ground. These instruments and their use conform to ANSI S1.4 for Type 1 precision sound measurement instrumentation, and have calibration certificates traceable to the National Institute of Standards and Technology (NIST).

For this study, the sound monitors were programmed to record the following one-hour A-weighted environmental noise descriptors:

- Maximum and minimum sound levels (L_{Amax}, L_{Amin})
- Percentile sound levels (L_{A99}, L_{A90}, L_{A50}, L_{A10}, L_{A01})
- Equivalent sound level (L_{Aeq})

Figures 2a – 2c present a series of measured one-hour ambient sound levels at the continuous monitoring locations.

Environmental Conditions during Sound Monitoring

During the 1-week monitoring period of the sound study, winds were typically out of the southwest, with speeds between 1 and 20 MPH. There was a significant precipitation event (snow) which occurred between February 14 and 15; this event was accompanied by winds at speeds of up to 35 MPH. In local forests, it was observed that most deciduous trees were bare of leaves, and that all ground was covered in a thick blanket of snow.

These environmental conditions are generally unfavorable to the propagation of sound produced by traffic on Interstate 90 to the study area. Therefore, it is estimated that the ambient sound levels measured during the February 2015 monitoring interval are amongst the lowest that would be observed during the year.

Design Goals for Sunset City Complex Sound

Table 1 presents a summary of measured ambient sound levels at SM1 – SM4, as well as corresponding sound level limits developed on the basis of the MassDEP Policy.

Measurement Location	**Model Receptor**	**Average L_{dn} [dB]**	**Daytime[1] ambient $L_{A90,1\text{-}hr.}$ [dBA]**			**MassDEP Limit [dBA]**
			Minimum [2]	*Avg. minimum* [3]	*Average* [4]	
SM1[5]	R9	51	28	32	36	**42**
SM2[5]	R5 – R8	53	25	30	37	**40**
SM3[5]	R1 – R4	52	27	33	38	**43**
SM4[6]	R10	n/a[7]	34	38	42	**48**

[1] 8:00 AM to 8:00 PM - proposed Complex operating hours
[2] Weekly minimum $L_{A90,1\text{-}hr.}$ daytime sound level
[3] Arithmetic average of daily minimum $L_{A90,1\text{-}hr.}$ daytime sound levels. These levels have been used to define the ambient sound level.
[4] Arithmetic average of all $L_{A90,1\text{-}hr}$ daytime sound levels.
[5] Based on continuous sound monitoring gathered at noted location
[6] Based on continuous sound monitoring from SM1 and intermittent measurements
[7] L_{dn} was not calculated for this location because continuous monitoring data was not available

Table 1. Summary of measured ambient sound levels and MassDEP sound level limits
Sunset City Sports and Campground Complex (Charlton, MA)

Proposed Facility Sound Assessment

Acoustic Modeling Methodology

Sound levels associated with motocross practice and racing at the Complex have been calculated using CadnaA environmental sound modeling software (Version 4.5.147, 32-bit, DataKustic GmbH). The CadnaA sound modeling software uses algorithms and procedures described in International Standard ISO 9613-2:1996 “Acoustics - Attenuation of sound during propagation outdoors – Part 2: General method of calculation”. The methodology described in this standard provides estimates of sound levels for meteorological conditions that are favorable to the propagation of sound (receptor downwind from source, with a wind speed of between 1 and 5 m/s). This methodology is also valid for sound propagation under well-developed moderate ground-based temperature inversions, which commonly occur on clear calm nights.

L_{eq} receptor sound levels were calculated using the following factors:

- Source sound power level (in octave bands)
- Distances between source and receptor locations (geometric divergence)
- Atmospheric absorption (10°C and 70% relative humidity)
- Reflections from building and barrier structures
- Screening by obstacles such as topographic contours and earthen berms
- Attenuation by foliage and ground effects

L_{dn} receptor sound levels were calculated using the following factors:

- Source sound power level (in octave bands)
- Distances between source and receptor locations (geometric divergence)
- Atmospheric absorption (10°C and 70% relative humidity)
- Reflections from building and barrier structures
- Screening by obstacles such as topographic contours and earthen berms
- Attenuation by foliage and ground effects
- ANSI S12.9 corrections for tonal source character and weekend daytime operation

Sunset City Complex Sound Sources

The primary source of Complex sound considered in this analysis is that produced by multiple motocross bikes as they race around a dirt track. The source sound power of these bikes was determined through sound pressure level measurements at a motocross race track conducted by this office in 2011 in connection with an unrelated project.

Sound pressure levels produced by 5 motocross bikes (mixed 2- and 4-stroke fleet) racing in loose formation around a dirt motocross track were measured in 1/3 octave bands at a distance of 20 feet from the side of the track. The L_{eq} sound level spectrum produced by this event was used as the basis for determining the sound power level of the racing group. The sound power level was calculated using adjustments for hemispherical divergence over a reflective ground plane.

An additional correction of $10 \times \log_{10} \frac{n}{5}$ was added to the reference source sound power level to account for the anticipated number of riders on Complex race tracks (where *n* is the number of proposed Complex riders, and 5 was the number of riders which produced the measured sound pressure level used as a reference for this evaluation). During weekdays, it is anticipated that the number of riders on the practice track would be 12; during weekends the number of riders on the racing track would be 20.

Sunset City Complex Sound Level Estimates

As with many environmental sound sources, sound emissions from the Complex will vary considerably over time. As such, L_{eq} and L_{dn} sound levels are appropriate descriptors with which to assess the acoustic impact of Complex sound, as these descriptors evaluate the overall sound energy produced by track operations. In our computer model of L_{eq} and L_{dn} sound levels, we have assumed that there would be four 10-minute motocross races during a one-hour interval, with periods of relative quiet interspersed between.

It is our understanding that the practice track and the racing track would not be operated at the same time. In the following tables, sound levels produced by the practice track and the racing track have been expressed separately, which is appropriate given that these two sources would not operate concurrently.

The results of the computer model have been presented in two ways:

- **Hourly average sound levels, $L_{Aeq, 1\text{-}hr}$** [dBA]. The energy-average Complex sound level for a one-hour period.

  This estimate of Complex sound has been compared to the MassDEP design goals discussed above, which are in the form of L_{A90} sound levels.

Description	**Receptor sound level, $L_{Aeq, 1\text{-}hr}$ [dBA]**									
	R1	*R2*	*R3*	*R4*	*R5*	*R6*	*R7*	*R8*	*R9*	*R10*
Main track	35	36	33	32	34	35	35	31	36	35
Practice track	27	29	25	26	27	30	29	26	30	28
MassDEP design goal [1]	*43*	*43*	*43*	*43*	*40*	*40*	*40*	*40*	*42*	*48*

[1] Based on average of daily minimum $L_{A90, 1\text{-}hr.}$ sound levels measured between 8:00 AM and 8:00 PM over entire monitoring interval (weekdays and weekends)

Table 2. Hourly energy-average sound levels produced by motocross activity – as designed (no berms)
Sunset City Sports and Campground Complex (Charlton, MA)

- **Adjusted day-night average sound level, L_{Ndn}** [dB][1]. The energy-average Complex sound level for a 24-hour period, where sound levels occurring between 10:00 PM and 7:00 AM have been subject to a 10 dB penalty to account for heightened human sensitivity during these hours. Note that in the case of the proposed Sunset City Complex, no motocross sound would be emitted from the Complex after 8:00 PM or before 8:00 AM. As such, no “time of day” penalties have been applied to Complex sound power levels.

In order to estimate the community response to Complex sound levels, the application of two additional penalties described in ANSI S12.9 to Complex L_{Ndn} sound levels is appropriate. The additional penalties that have been applied in computer modeling are intended to account for “tonal character” (+5 dB)[2], and for weekend, daytime operation (+5 dB).

This estimate of Complex sound has been compared to the existing day-night average sound level calculated on the basis of the sound monitoring data. With the exception of the “time of day” penalty, no additional adjustments have been applied in calculating the ambient L_{dn} on the basis of the measured sound monitoring data.

Description	**Receptor sound level, L_{dn} [dB]**									
	R1	*R2*	*R3*	*R4*	*R5*	*R6*	*R7*	*R8*	*R9*	*R10*
Main track	42	43	40	39	40	42	42	38	43	42
Practice track	34	37	32	33	34	37	36	33	37	35
Existing L_{dn}	*52*	*52*	*52*	*52*	*53*	*53*	*53*	*53*	*51*	*51*[1]

[1] Based on L_{dn} measured at SM1, as sufficient data was not available for computation of this descriptor at R10

Table 3. Day-night average sound levels produced by motocross activity – as designed (no berms)
Sunset City Sports and Campground Complex (Charlton, MA)

Note that the Complex day-night average sound levels presented in Table 3 are significantly lower than the existing day-night average sound level. As such, it is estimated that the Complex as it is currently designed will not present a significant risk of community annoyance.

[1] For further information on the adjusted day-night average sound level L_{Ndn} and associated penalties, please refer to ANSI S12.9-2005/Part 4.
[2] This adjustment has been applied to the source sound power level, which exhibits content that would be classified “tonal” on the basis of ANSI S12.9 methods. However, propagation losses and masking by background sound effectively eliminate the tonal character at receiver locations. Nevertheless, we have included the ANSI S 12.9 tonal adjustment that raises the L_{Ndn} level for purposes of evaluating motocross sound at receiver locations. This acts as an extra margin of protection for the community.

Conclusion

CTA has completed a review of environmental sound associated with the proposed Sunset City Sports and Campground Complex. This review has included a survey of applicable noise regulations, baseline acoustic survey, and computer modeling to estimate sound levels at nearest residential receptors.

On the basis of this review it has been concluded that the acoustic impact of the proposed Complex is negligible. Motocross sound levels would comply with the applicable MassDEP noise regulation, and would not appreciably increase day-night average sound levels already present in the community.

It has been a pleasure providing these services to Sunset City. Please don't hesitate to contact us if we can provide any further information.

Yours Sincerely,
CAVANAUGH TOCCI ASSOCIATES, INC.

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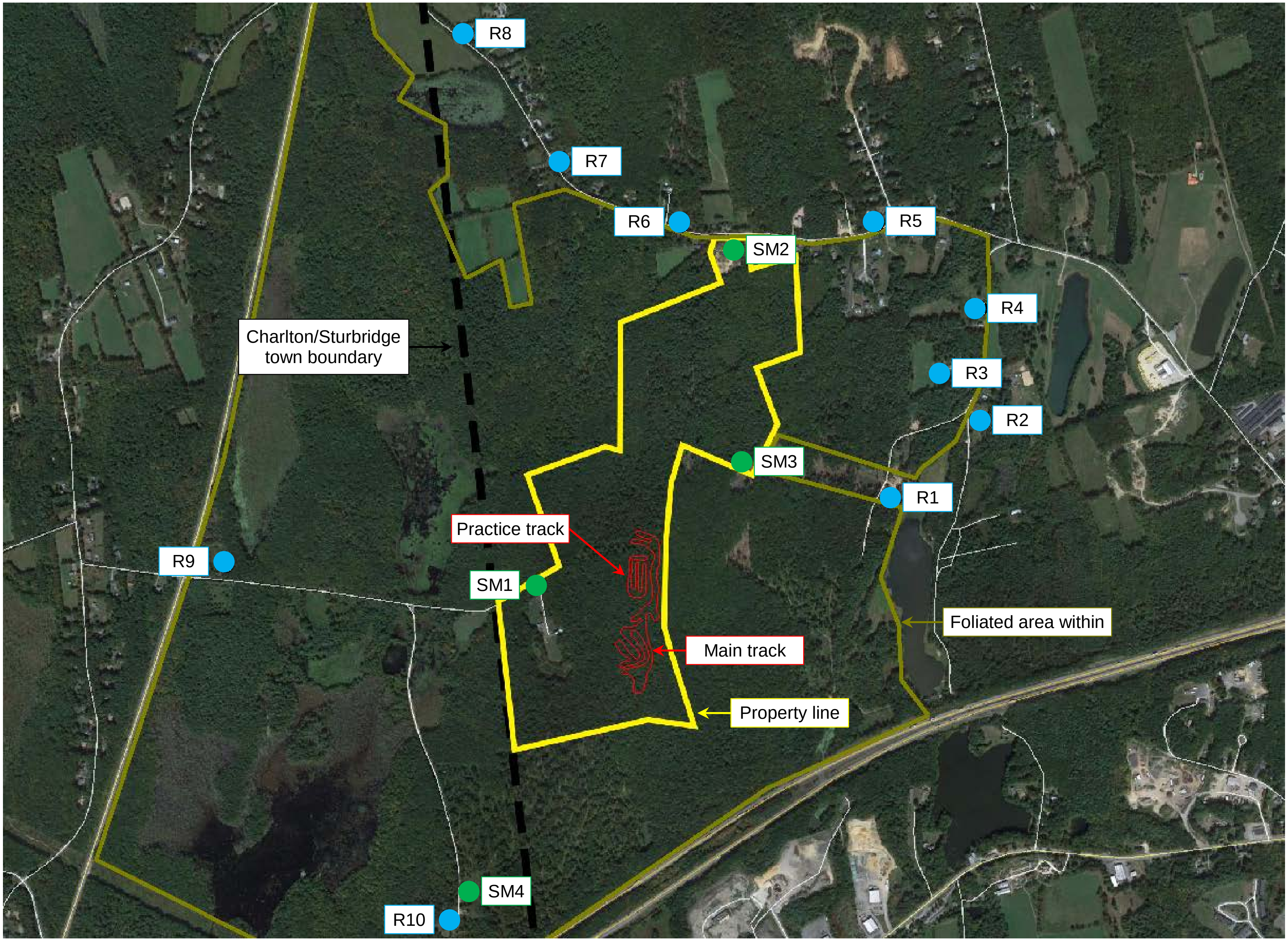

Figure 1. Complex overview showing location of sound measurements (SM1 – SM4) and computer model receptors (R1 – R10)
Sunset City Sports and Campground Complex (Charlton, MA)

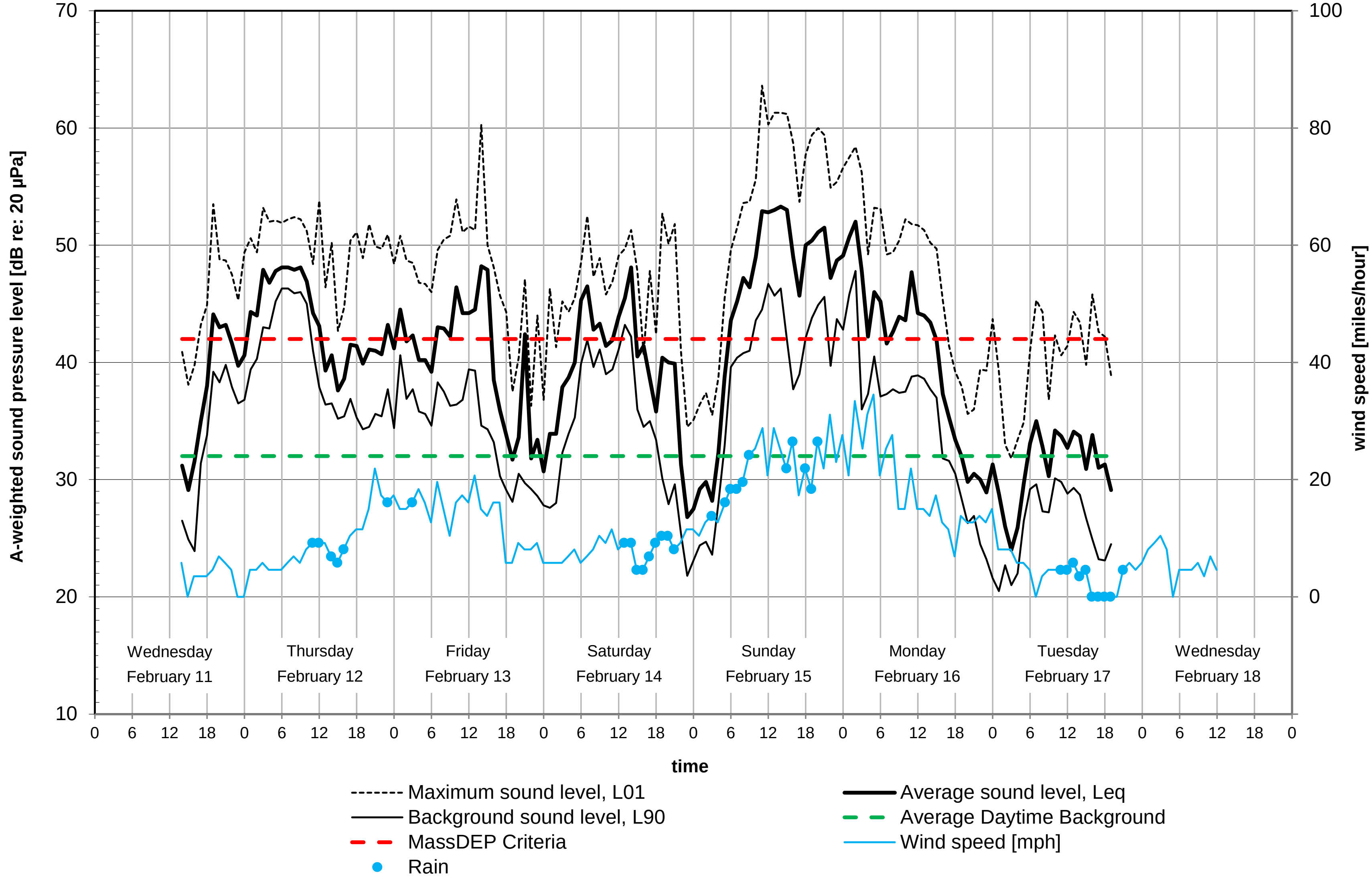

Figure 2a. Sound monitoring data measured near farm on Ladd Road, SM1 [Kit 0]
Sunset City Sports and Campground Complex (Charlton, MA)

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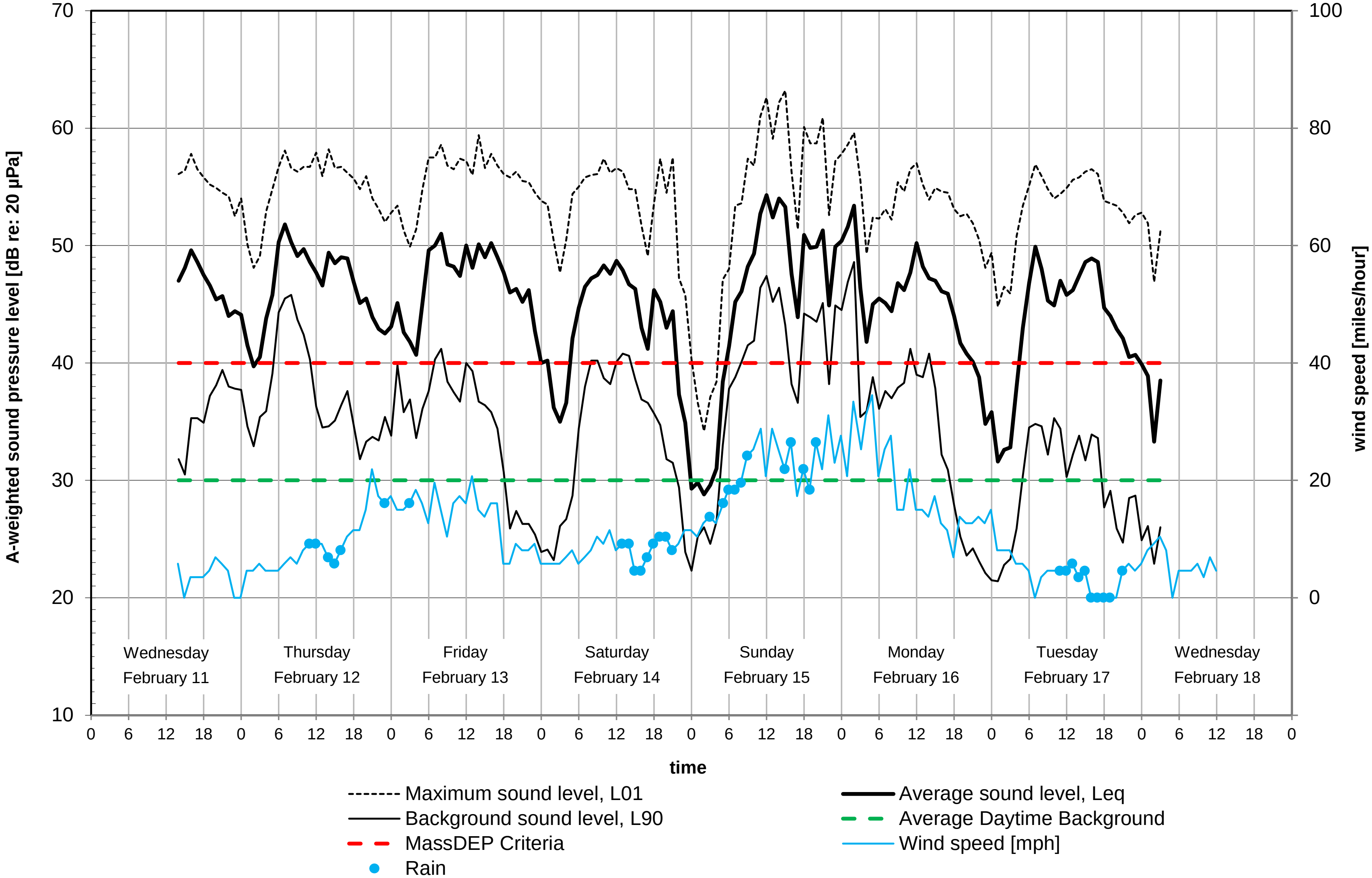

Figure 2b. Sound monitoring data measured near barn on Brookfield Road, SM2 [Kit 5]
Sunset City Sports and Campground Complex (Charlton, MA)

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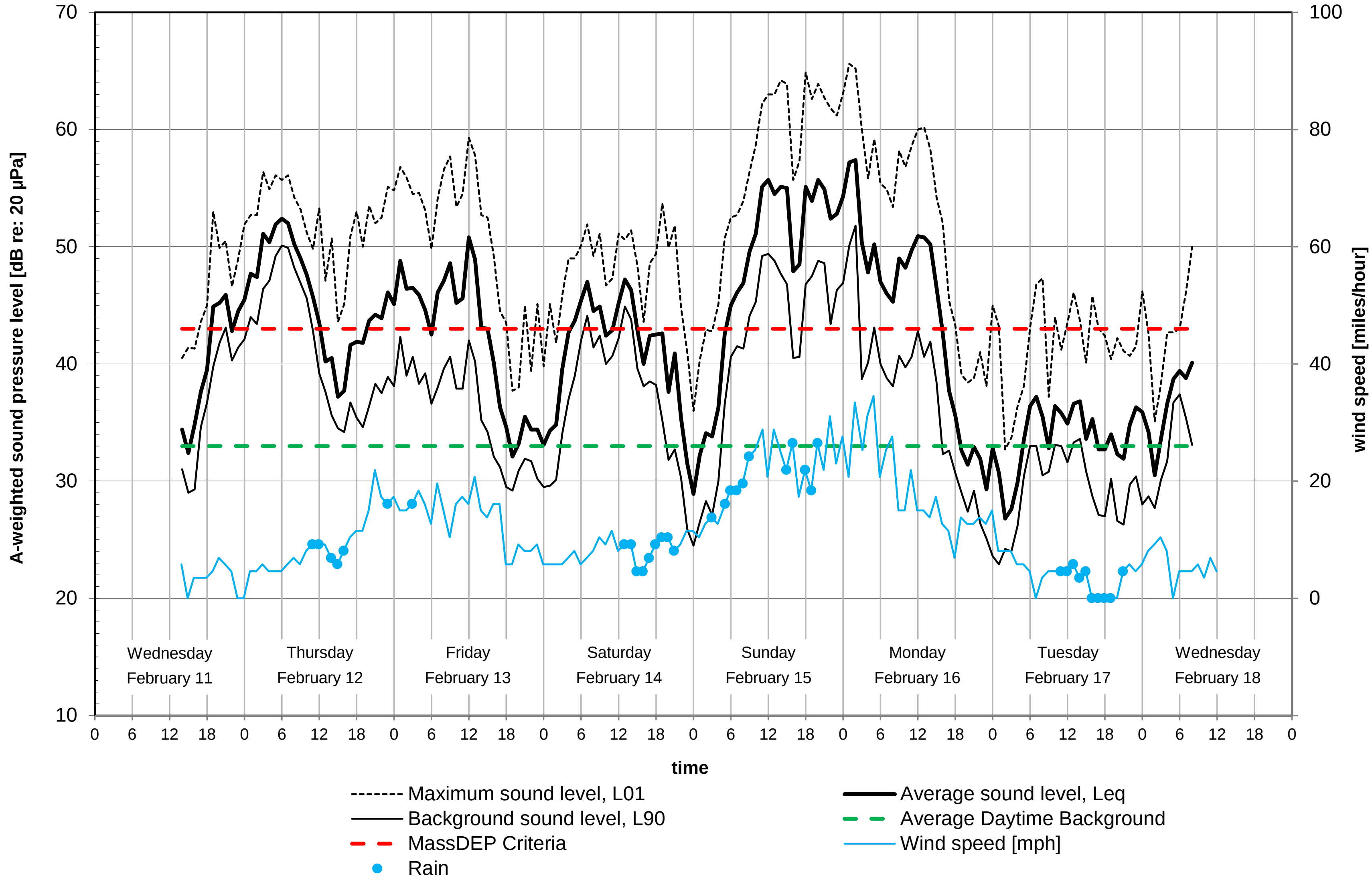

Figure 2c. Sound monitoring data measured in woods along eastern property line, SM3 [Kit 7]
Sunset City Sports and Campground Complex (Charlton, MA)

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Appendix A

Sound Measurement Terminology

Sound Measurement Terminology

In order to quantify the amplitude, frequency, and temporal characteristics of sound, various acoustical descriptors are used. The following is an introduction to acoustic terminology that is used in this report.

Sound Level

Sound levels are typically quantified using a logarithmic decibel (dB) scale. The use of a logarithmic scale helps to compress the wide range of human sensitivity to sound amplitude into a scale that ranges from approximately 0 to 180 dB. Note however, that the use of the logarithmic scale prevents simple arithmetic operations when combining the cumulative impact of sources. For example, two sources of equal sound level operated simultaneously results in a combined sound level that is only 3 dB higher than if only one source was operated alone. 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, and an increase or decrease by 10 dB is perceived as a doubling or halving of noise level.

A-weighting

Generally, the sensitivity of human hearing is restricted to the frequency range of 20 Hz to 20,000 Hz. However, the human ear is most sensitive to sound in the 500 Hz to 5,000 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 filtering of acoustic signals that corresponds to the varying sensitivity of the human ear to sound at different frequencies. This filtering is called A-weighting. Sound level measurements that are obtained using this filtering are referred to as “A-weighted sound levels” and are signified by the identifier, dBA. A-weighted sound levels are widely used for evaluating human exposure to environmental sounds. To help place A-weighted sound levels in perspective, Figure A-1 contains a scale showing typical sound levels for common interior and environmental sound sources.

Spectral Characteristics – Octave and 1/3 Octave Band Sound Levels

To characterize a sound, it is often necessary to evaluate the frequency distribution of the sound energy. As mentioned before, the frequencies of most interest where human exposure is concerned range between 20 Hz and 20,000 Hz. This frequency range is commonly divided into octave bands, where an octave band is a range of frequencies. Each octave band is referred to by its center frequency and has a bandwidth of one octave (a doubling of frequency). To cover the full range of human hearing, it is necessary to measure sound in 10 separate octave bands. Typically, the lowest frequency band measured has a center frequency of 31.5 Hz. The next frequency band has a center frequency of 63 Hz. This geometric series continues to the highest frequency band that has a center frequency of 16,000 Hz.

A set of octave band sound levels to describe a particular sound is called an octave band spectrum. Covering the full range of hearing, an octave band spectrum would have 10 values, one for each band. Under certain circumstances, more frequency resolution in acoustical data is needed to identify the presence of tonal sounds. A 1/3 octave band spectrum uses filters that divide each octave band into 3 separate frequency bands. Note that octave band and 1/3 octave band sound levels are not usually A-weighted, with their units being dB.

<u>Environmental Noise Descriptors</u>

Sound levels in the environment are continuously fluctuating and it is difficult to quantify these time-varying levels with single number descriptors. Statistical approaches, which use *percentile sound levels* and *equivalent sound levels*, are often used to quantify the temporal characteristics of environmental sound.

Percentile sound levels (L_n) are the sound levels that are exceeded for specific percentages of time within a noise measurement interval. For example if a measurement interval is one hour long, the 50th percentile sound level (L_{50}) is the sound level that is exceeded for 30 minutes of that interval. Common practice is to include the frequency weighting used for the measurement, yielding a compound descriptor such as L_{A50} in the case of the previous example.

- L_{90} is the sound level in dBA exceeded 90 percent of the time during the measurement period. The 90th percentile sound level represents the nominally lowest level reached during the monitoring interval and is typically influenced by sound of relatively low level, but nearly constant duration, such as distant traffic or continuously operating industrial equipment. The L_{90} is often used in standards to quantify the existing background or *residual* sound level.

- L_{50} is the median sound level: the sound level exceeded 50 percent of the time during the measurement period.

- L_{10} is the sound level exceeded only 10 percent of the time. It is close to the maximum level observed during the measurement period. The L_{10} is sometimes called the *intrusive* sound level because it is caused by occasional louder noises like those from passing motor vehicles or aircraft.

By using percentile sound levels, it is possible to characterize the sound environment in terms of the steady-state background sound (L_{90}) and occasional transient sound (L_{10}).

The *equivalent sound level* (L_{eq}) is the energy average of the sound level for the measurement interval. Sounds of low level and long duration, as well as sounds of high level and short duration influence this sound level descriptor.

Noise levels at night generally produce greater annoyance than do the same levels which occur during the day. It is generally agreed that a given level of environmental noise during the day would appear to be 10 dBA louder at night – at least in terms of potential for causing community concern.

The day-night average sound level (L_{dn}) is a 24-hour average A-weighted sound level where a 10 dB “penalty” is applied to sound occurring between the hours of 10:00 P.M. and 7:00 A.M. The 10 dB penalty accounts for the heightened sensitivity of a community to noise occurring at night.

When a steady continuous sound is measured, the L_{10}, L_{50}, L_{90} and L_{eq} are all equal. For a constant sound level, such as from a power plant operating continuously for a 24-hour period, the L_{dn} is approximately 6 dBA higher than the directly measured sound level.

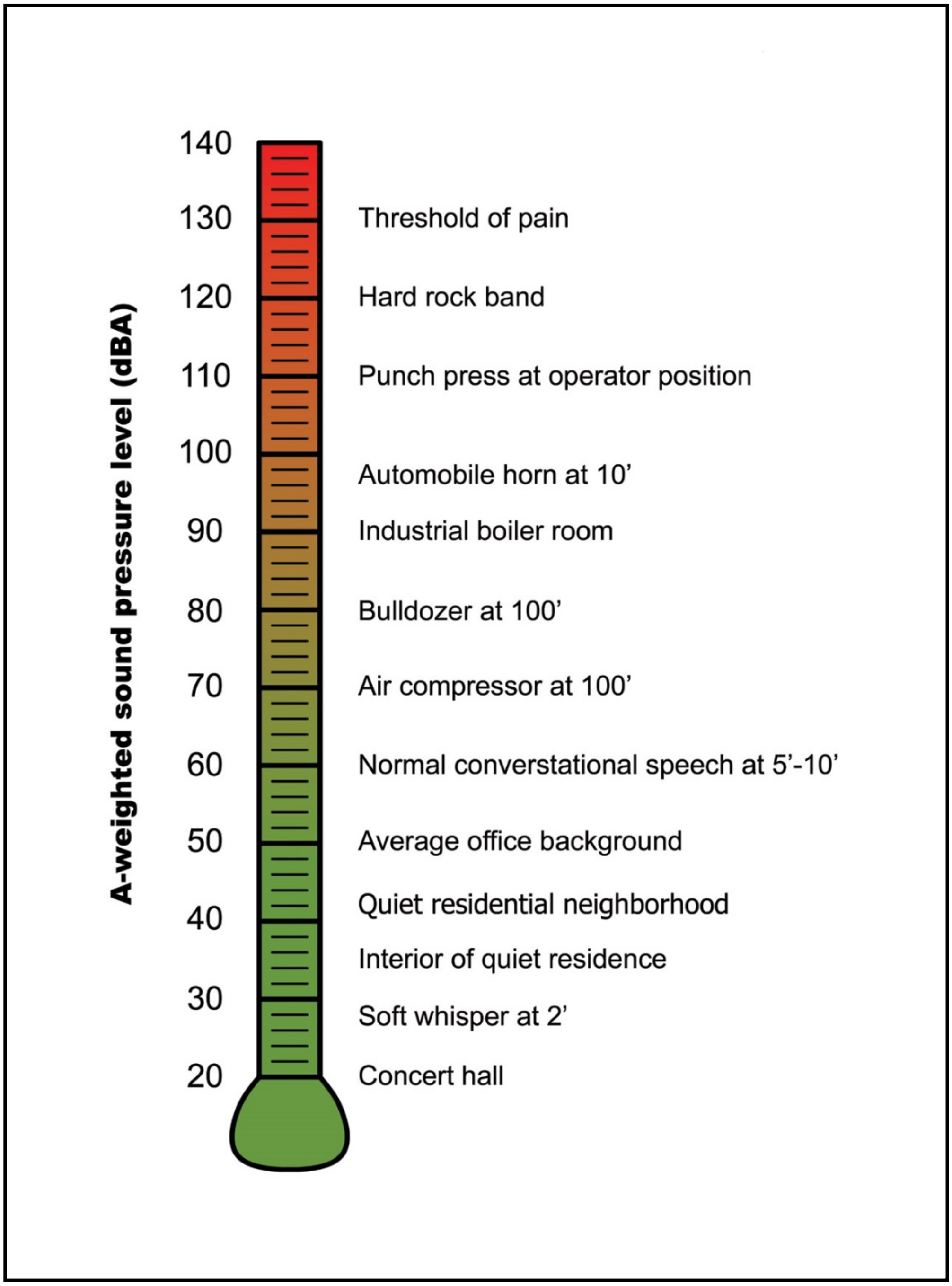

Figure A-1. Typical Sound Levels for Common Interior and Environmental Sources