INVESTIGATION OF COMMUNITY ANNOYANCE AS INVOKED BY A HIGH SCHOOL STADIUM AND A TRAIN HORN PROXIMAL TO RESIDENTIALLY-ZONED HOMES

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ABSTRACT

The effects of two different noise sources upon their surrounding communities were investigated with both quantitative and qualitative measures. A high school football game, which presents continuous noise over a relatively short duration on a predictable schedule was found to have a slight annoyance on its surrounding community. In contrast, a train horn blow at a residential intersection was investigated. This sound was unpredictable and could occur at any time. Residents in this community were found to have a moderate level of annoyance. It was found that each of the noises studied violated suggested noise levels for common household activities, in addition to many local, state, and federal noise regulations. It is recommended that both of the sounds studied herein be reduced or eliminated altogether. Limiting the level of sound produced by the PA system at the football game and using a noise reducing barrier would help in the case of the football game. Converting the railroad intersection into one with sufficient safety features, especially a crossing quad-gate that no longer requires trains to blow their horns would be the optimal solution, with the added benefit of precluding vehicles from entering the crossing when a train is present.

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GLOSSARY

Average Sound Level (L_{eq}): An integrated average of sound levels over a period of time

Day-Night Level (DNL or L_{dn}): An average of day time (7:00 am – 10:00 pm) sound level with night time (10:00 pm – 7:00 am) sound level, where the nighttime level is increased by 10 dBA.

Decibel (dB): A logarithmic scale used to measure sound pressure level, wherein a measured pressure or intensity is divide by a reference pressure or intensity usually taken to be 20 µPa or 10^{-12} watt respectively.

Decibel, A-weighted (dBA): Decibel readings which have been weighted in order to reflect the human perception of frequencies at moderate sound levels.

Sound Pressure Level (SPL): Decibel readings provided by a sound level meter.

L_{90}: The SPL which is exceeded for 90% of the collection period.

L_{10}: The SPL which is exceeded for 10% of the collection period.

Masking: When the presence of a secondary sound causes an increase in the level required for another sound to be heard.

Noise Dosimeter: A SLM which averages or integrates sound levels over a period of time.

Peak Sound Pressure Level (L_{max}): The maximum SPL recorded over a period of time.

Preferred Speech Interference Level (PSIL): A value calculated by averaging the decibel levels of 500 Hz, 1000 Hz, and 2000 Hz; this value is used to predict how difficult communication will be in various noise levels.

Sones: An interval scale of perceived loudness, from which different sounds can be compared as to their loudness perception on a linear basis.

Sound Level Meter (SLM): The simplest instrument that may be used in community noise measurements, which provides momentary (non-integrated) SPLs in dB.

INTRODUCTION

Community Noise Annoyance

Community noise can be defined as environmental noise that commonly causes a "disturbance of rest and relaxation, difficulty in falling asleep and awakening," as described by Bjorkman (1991). A common effect "of environmental noise pollution is the annoyance reaction." This response can be evaluated by numerous "personal, physiological and psychological factors" (Bjorkman, 1991). Community noise is becoming an increasing problem as our nation continues to develop and areas become more populated. Unfortunately, excessive and annoying sounds can have many negative impacts on those exposed to it. Not only can it interfere with the lives of those around the noise source by making it difficult or even impossible for such activities as "radio and television listening, conversations, sleep, and rest and relaxation" (Jue, 1984), but it can also impair learning (Evans, 2000). Such annoyance can even be a cause of "poorer subjective general health" of those exposed (Smith, 1986).

Controllable vs. Uncontrollable Sources

A controllable noise source is one that a person has the ability to turn on and off or alter the volume levels. For example, radios and televisions are controllable noise sources because the users are in control of these sources.

In contrast, an uncontrollable noise source gives no power to the people surrounding it. In 1981, Cohen, Krantz, Evans, and Stokols described an "unpredictable and uncontrollable" noise as one that "cannot be escaped or avoided." Examples of uncontrollable sources would be air traffic, thunderstorms, and, in the case of this research project, both football stadiums and train horns.

People may be less annoyed by sound sources which they believe they have control over than they would be by sound that is not within (or perceived to be within) their control (Casali, 1999).

Continuous, predictable vs intermittent unpredictable noise (stadium vs train)

In this study, the aim was to determine how communities react to continuous predictable and intermittent unpredictable noises, as well as how these reactions differ, which may be influenced by factors of perceived control as well as noise predictability.

Furthermore, the individual's perception of their control over the noise source also influences their level of annoyance. Those who feel they have less control over the noise are more likely to become annoyed (Jue, 1984). This is believed to be because an unpredictable noise is presented as an information overload to the brain.

In contrast, predictable noises allow the individual more time to prepare for the stimuli and are inherently less annoying (Cohen, 1978). Kjellberg, Landstrom, Tesarz, Soderberg and Akerlund have shown correlation between noise predictability and ability to focus on an activity in their 1996 research, which supports Cohen’s findings.

BACKGROUND and LIT REVIEW

What is Community Noise Annoyance

There are billions of different sounds, but when it comes to environmental noise, and particularly community annoyance, these sounds can generally be partitioned into a few specific categories, as provided by Berglund and Lindvall (1995). Most notably, these categories include transportation, construction, domestic, and leisurely noise. Berglund et al. defined noise as “unwanted sound” (1995). What specifically renders a noise as community noise, is when it penetrates into a residential area, not an industrial or commercially zoned region. It is not noise that a person is exposed to while working in a plant nor that which they may experience at an amusement park or concert. However, it is important to recognize that these noise sources do become community noise when their sounds propagate into a residential area. Eldred describes community noise in his paper “Assessment of Community Noise” from 1975. He uses the phrase “description of all noises in the outdoor acoustical environment” which “varies greatly in magnitude and character” depending upon the location of and within a community. He presents two different ends of the community noise spectrum. One is characterized as “quiet suburban areas bordering farm land” and the other a “din of traffic in the downtown city canyon.” However, both of these settings’ sound levels vary with the time of day being quieter at night, with peaks of sound in the early morning and late afternoon due to “commuter-traffic rush hours.” He expands upon this notion by explaining that the “outdoor noise environment” may affect people both indoors and outdoors. “The task of describing community noise, therefore, is to determine the time and spatial variations in the outdoor noise environment within the community so that the description is relevant to its effects on people located indoors or outdoors" (Eldred, 1975).

Regulation of Community Noise

Acceptable noise levels in a community cannot be established solely upon the public's response to a noise. It is essential to consider the noises that already exist in a community before the new questionable source is introduced (Schultz, 1978). It is often helpful to conduct public surveys on community noise in the area of question in order to gauge the residents' feelings toward acceptable and unacceptable noise levels. This can help facility a friendly coexistence between the community and noise (Borsky, 1980). Policies and guidelines can be used to help minimize disagreements between a noise source and the community. Oftentimes, such as in the case of aviation noise, land surrounding the airport may have restrictive zoning, so that no residents reside in close proximity of the airport. For locations where this is not the case, residents have the option to sound-insulate their homes (Jue, 1984). While this may decrease sound levels in the home, it requires the resident to have their windows shut, which is often not the case during warmer weather. Additionally, it makes no difference for any activities which are hosted outside of the home, such as barbeques or backyard sports.

Federal

Guidance: EPA Levels Document

The Environmental Protection Agency created a report in 1974 that outlines environmental noise levels in such a manner to protect the public. They suggest that the Day-Night Level (DNL) for a community is acceptable below 55 dBA. However, many communities exist that are both louder and quieter than this number (Berger, 2003). The EPA solely suggests what is typically acceptable, in their opinion. Their document has been used to help create many of the United States' federal guidelines.

Housing and Urban Development

The United States Department of Housing and Urban Development (HUD) has the ability to limit noise levels in regions where they provide funding for housing (HUD, 1979). Unfortunately, many of their developments are located in loud densely populated areas that often exceed a DNL of 55 dBA (Berger, 2003). For these houses, as specified by HUD, sound levels between 65 and 75 DNL are generally unacceptable. However, when the DNL exceeds 70 dBA, a barrier can be used to help reduce the sound levels inside of the home (HUD, 1979).

Code of Federal Regulations

The U.S. Department of Transportation is home to the Federal Highway Administration (FHWA). They are responsible for Title 23, Part 772 of the Code of Federal Regulations which specifies "Procedures for Abatement of Highway Traffic Noise and Construction Noise." It goes as far as to specify the use of an ANSI Type I or Type II integrating sound level meter for measurement of noise levels. The FHWA requires highway agencies to establish an "approach level" which is used in "determining a traffic noise impact." The FHWA requires that the approach level be at least 1 dBA lower than the "Noise Abatement Criteria for Activity Categories A to E" listed in Table 1. Additionally, highway agencies are required to define "substantial noise increase" as a change between 5 dBA and 15 dBA "over existing noise levels." When noise levels need to be reduced, they generally recommend use of a barrier that reduces noise levels by 5 dBA (23 CFR § 772, 2001).

The Code of Federal Regulations, Title 49, Part 210 discusses "Railroad Noise Emission Compliance Regulations." In particular, trains which were manufactured before 1980 may not exceed an Lmax (fast) rating of 90 dBA while moving (49 CFR § 210, 2000). This noise limit applies to those sounds emitted by the moving cars, and not to the train horn.

Only approximately 13 states have regulations for noise produced by industry and business (Berger, 2003). Because of this, regulation is left up to the local governments to manage how they see fit. Such ordinances can be either "general nuisance ordinances or as a combination of nuisance and quantitative components." Of the noise ordinances, they generally specify maximum levels of sound entering a property line.

[Hourly A–Weighted Sound Level_decibels (dB(A))[1]]

Activity category	Activity Leq(h)	Criteria[2] L10(h)	Evaluation location	Activity description
A	57	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[3]	67	70	Exterior	Residential.
C[3]	67	70	Exterior	Active sport areas, amphitheaters, auditoriums, campgrounds, cemeteries, day care centers, hospitals, libraries, medical facilities, parks, picnic areas, places of worship, playgrounds, public meeting rooms, public or nonprofit institutional structures, radio studios, recording studios, recreation areas, Section 4(f) sites, schools, television studios, trails, and trail crossings.
D	52	55	Interior	Auditoriums, day care centers, hospitals, libraries, medical facilities, places of worship, public meeting rooms, public or nonprofit institutional structures, radio studios, recording studios, schools, and television studios.
E[3]	72	75	Exterior	Hotels, motels, offices, restaurants/bars, and other developed lands, properties or activities not included in A–D or F.
F				Agriculture, airports, bus yards, emergency services, industrial, logging, maintenance facilities, manufacturing, mining, rail yards, retail facilities, shipyards, utilities (water resources, water treatment, electrical), and warehousing.
G				Undeveloped lands that are not permitted.

[1]Either Leq(h) or L10(h) (but not both) may be used on a project.

[2]The Leq(h) and L10(h) Activity Criteria values are for impact determination only, and are not design standards for noise abatement measures.

[3]Includes undeveloped lands permitted for this activity category.

Table 1. FHWA's categories and noise abatement criteria "Procedures for Abatement of Highway Traffic Noise and Construction Noise." Title 23 Code of Federal Regulations, Pt. 772 (2001). Used under fair use, 2015.

The day time limits are, on average, 55 to 60 dBA, where the night time averages are 50 to 55 dBA, where night time is generally defined as 10:00 pm to 7:00 am (Berger, 2003).

A qualitative ordinance does not contain a dB value criteria and does not involve measurements. They are based on a subjective determination with a human ear, and hearing varies among people. These qualitative ordinances are also called "reasonable man" laws. In contrast, a quantitative ordinance contains a dB criteria for determination of compliance with a sound level meter. They are objective and not affected by human perception.

Local

Zoning and other ordinances

It is common practice across the United States for noise limits to be set "based on 'receiving land use,' whereby regardless of the source or direction of the noise" these sound level limits are to be adhered to (Casali, 1999). Receiving land use is defined by what the property is used for where the sound is being experienced. For this study, the interest was solely in residential land use, but there are differing regulations for agricultural, businesses, and industrial lands. When residential sound level limits are created, it is essential to write them to facilitate "easy speech communication during the daytime, and yield an environment conductive to rest and sleep at night" (Casali, 1999). In Montgomery County, Virginia, where both noise sources of this study reside, a wide array of zones have been established by the County's Planning Department. Of interest to this study were solely the residential zones: Rural Residential Zoning District, Residential Zoning District (1-3), Residential Multi-Family Zoning District. The County's zoning specifications refer to Section 7-80 - Maximum permissible sound pressure levels which are depicted in table 2 (Montgomery County, Virginia, §7-80, 1988).

Receiving Land Use	7:00 am - 10:00 pm (Day)	10:00 pm - 7:00 am (Night)
Residential & Agricultural Zones	**57**	**52**
Business-Zones	67	62
Industrial-Zones	77	77

Table 2. Maximum permissible sound pressure levels in dBA. Montgomery County, Virginia, Municipal Code art. IX, 7-80 (1982). Used under fair use, 2015.

Displayed in Table 3 are common sound level limits in the United States (Casali, 1999). Similar values of 55 to 60 dBA in the daytime and 50 to 55 dBA at night were reported by Driscoll (2003). Montgomery county sound levels are above these national averages and while it is only a difference of 2 dBA, this difference is noticeable to the human ear according to the research of Small and Gales which found that humans can distinguish between sound levels of less than 0.5 dB for broadband sounds over 20 dB (1991).

Receiving Land Use	Day	Night
Residential & Agricultural Zones	**55**	**50**
Business-Zones	60-65	55-60
Industrial-Zones	70	70

Table 3. Common sound level limits in the United States in dBA. Casali, John G. "Litigating community noise annoyance: A human factors perspective." *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*. Vol. 43. No. 9. SAGE Publications, 1999. Used under fair use, 2015.

In some noise ordinances, the sound level limits are strictly not to be exceeded at any moment in time, that is, they are "momentary" limits. This is the case in Montgomery County and many other localities. However, in other localities, the sound levels are averaged over a specified amount of time (Leq) and this average must be in compliance (Casali, 1999). The first method is much more stringent, whereas the second method allows for more deviation from the sound level limit, which is a statistically-bared criteria, as long as the exceeding levels are rather short. Although this second method may be acceptable during the day, any sound over 55 dBA inside of the home is likely to arouse the residents from sleep, which should be unacceptable.

Montgomery County Code of Ordinances

Article IV of the Montgomery County, Virginia Code of Ordinances details noise regulations. Section 7-77 outlines “Specifics prohibitions,” which include “operating or permitting the use or operation of” any device that is “plainly audible across property boundaries or through partitions common to two (2) residences.” This qualitative regulation was put into place in 1982 (Montgomery County, Virginia, §7-77, 1988).

Additionally, in 1982 Section 7-80 “Maximum Permissible Sound Pressure Levels” was instituted (Montgomery County, Virginia, §7-80, 1988). The sound levels provided in this section are broken down depending upon the zone of the receiving land (Residential & Agricultural, Business, Industrial). As residential zones were of particular interest to this study, it was important to understand the regulations imposed upon them. From 7:00 am to 10:00 pm, the sounds are limited to 57 dBA and from 10:00 pm - 7:00 am the sounds are limited to 52 dBA. However, it is important to note that the ordinance does not specify how measurements of the sound levels are to be gathered, using what type of devices and in what measurements (Lavg, Leq, L10, L90, Max, etc), so it is generally assumed the limits are momentary, not-to-exceed levels and not averages or other statistically bared limits. Section 7-82 “Permissible Mobile Sound Pressure Levels” further describes limits of noise, specifically pertaining to “mobile sources.” A mobile source is not explicitly defined in this Article. Provided that a train is in fact a mobile source of 10,000 pounds or more it is limited to 86 dBA while moving as speeds up to and including 35 mph, and to 90 dBA at speeds above 35 mph (Montgomery County, Virginia, §7-82, 1988).

Blacksburg, Virginia - Code of Ordinances

Chapter 13 of the Blacksburg, Virginia Code of Ordinances details noise regulations. Section 13-103 outlines "Specifics Prohibitions," which is broken down into 13 clauses (Blacksburg, Virginia, §13-103, 2009). The following are relevant to this study:

- Public address systems used between 10:00 pm and 8:00 am which can be heard across a residential property line are prohibited.

- Yelling or shouting between 10:00 pm and 8:00 am which can be heard across residential property lines is prohibited, unless it is a warning of danger.

- "Mass outdoor social gatherings" which use "sound amplifying equipment" are prohibited unless the event has been "registered with the town manager"

Some exceptions to the above statements are provided in Section 13-104 (Blacksburg B, 2009). The relevant ones are:

- Sounds required for the "protection or preservation of property or the health, safety, life or limb of any person" are exempt from the noise restriction.

- Public events which are held on a public property, including school athletic facilities, are also exempt.

Noise Ordinance of the Town of Christiansburg, Virginia

This ordinance was put into law in October 2010. Night-time (10:00 pm - 7:00 am) noise is not permitted to be heard within a home or through the wall of an apartment building. Sounds during this time may not propagate 50 feet or more outdoors. Trains are exempt from the noise prohibitions of the Town of Christiansburg, per the statement “The following specific activities or sources of noise shall be exempt from the regulations set forth in this article: . . . Sounds generated from airplanes and trains” (Christiansburg Town Code §28-2, 1976).

Virginia Legal Statutes

In the case that a public nuisance provides an “imminent and immediate threat to ... property, then the locality may abate, raze, or remove such public nuisance.” Said locality may arise legal “action against the responsible party to recover the necessary costs incurred” in the process of abating the nuisance (Code of Virginia § 15.2-900, 1990).

If tried and found guilty, those responsible for the public nuisance will be ordered to terminate the nuisance or “reimburse the locality for all costs of removal and abatement of said nuisance.” The legal definition of a public nuisance, in the Commonwealth of Virginia, is an “activity or conduct that causes annoyance, inconvenience, or interference with the comfort, health, or safety of the public” (Code of Virginia § 48-5, 1990). Per this definition, both the football stadium and the train horn considered in this research *could be* public nuisances.

Damage to Property Values

Legal courts recognize the detriment to private land that can be caused by public nuisances, described as "substantial and unreasonable interference with the private use and enjoyment of one's land" (Keeton, 1984). In cases where residents have solid proof of the harm caused by a public nuisance, legal action may help right the situation.

Human Effects of Community Noise

Hearing Hazards

As of 2003, 85 dBA was considered a permissible exposure level in most nations. It is important to note that this is the 'upper limit' and not to be confused with the 'action level'." For impulsive noise exposure, the sound pressure level is often limited to 140 dB, whereas continuous noise sources are limited to 115 dBA (Berger, 2003). Of course, these limits are for people wearing properly fitted hearing protection devices. In United States industry, an 8-hour time-weighted average of 85 dBA is the action level, meaning that employees must be notified of the noise levels, make hearing protectors accessible to employees, and the employer must provide audiometric testing for their employees. The permissible exposure limit is 90 dBA. Any sounds over this level must have a noise reduction program in place, which can be composed of both administrative and engineering measures. Employees are also required to wear hearing protection for sounds of these levels. Continuous noise of greater than 1 second is never allowed above 115 dBA and peak levels never above 140 dBA (OSHA, 1974 and 1983).

Rail yard workers standing 15 feet from the side of a train or rail car experienced sound pressure levels of 109 dBA from car coupling concussions, 110 dBA from wheel/track interactions (wheel squealing), and 122 dBA from train horns (Swing and Pies, 1973; Urman, 1978). All of these sounds are exceptionally hazardous to an unprotected ear. While short duration train horn “toots” may be considered impulsive, a longer duration “blow” would be continuous, if greater than one second, making it an even greater danger. In a study of rail yard workers, nearly all full shift workers experienced impact noises and continuous noises above the OSHA limit for exposure (Landon, 2005). It is important to recognize that events such as car coupling do not generally occur in residential areas, however; wheel/track, interactions as well as train horns propagate away from the train tracks and cross into residential zones. With levels of up to 122 dBA (15 feet from the train), these sounds have the power to travel far distances and remain loud enough to put residents at risk for hearing loss and cause annoyance for residence who live considerably further away (Swing and Pies, 1973; Urman, 1978).

Health

Noise has the potential to produce both direct and indirect health effects. The direct effect of hearing damage has been discussed above. The indirect effects of noise exposure have had less research done on them, primarily because they are not of top importance in industry, which is where most consideration for hearing hazards take place.

Noise exposure can elevate blood pressure, which in turn can cause cardiovascular disease (Talbott, 1995). Furthermore, noise can cause “abnormalities in the electrocardiogram; more heart beat irregularities; faster pulse rate; and slower recovery of vascular construction” (Toronto, 2000). They also found evidence of an increased risk of hypertension and ischaemic heart disease for those exposed to heavy road or air traffic. Additionally, noise can “adversely affect sleep, communication, performance and behavior, reading and memory acquisition, and mental health” (Talbott, 1995).

Per Health and Welfare Canada in 1989 annoyance is the most frequent outward symptom of stress. Therefore, gathering data on residents' annoyance from a noise source, will likely correlate with stress caused by the noise.

Emotional and Social

In 2000 Evans and Hygge showed that noise not only has the potential to cause annoyance, but it also can impair both communication and learning abilities. In a study by Smith and Stansfeld (1986), it was shown that residents in an area exposed to high aircraft noise frequently experienced errors, such as forgetting what they were looking for or doing. This occurrence not only inhibits a person's ability to function efficiently, but also may contribute to their level of annoyance by the sound. Noise annoyance has been shown to induce "feelings of irritation, discomfort, distress, frustration, or offence when noise interferes with someone's thoughts, feelings or ongoing activity" (Guski, 1997, 1999; Passchier-Vermeer, 2000, cited in Enmarker et al., 2004, p. 527). All of these qualitative characteristics are variables that depend upon noise source and noise level, as well as the person's perceived control over the sound. Higher noise levels can degrade social behaviors in ways such as less assistance (Mathews, 1975) as well as reduced casual social interactions (Appleyard, 1972). It is clear that sound which is unwelcome in the community can have effects upon a vast number of aspects of human acceptance and behaviors. Many of these effects may not be taken into account by those who are advocates for the noise source, as well as policy makers.

Objective Effects and Their Measurement

dB Events and Exposures

The Environmental Protection Agency (EPA) has set maximum Day-Night Sound Levels (Ldn) that should not be exceeded in order to preserve public health and welfare. They have 55 dBA as the threshold for sound to interfere with outdoor activities and cause annoyance. Similarly, but for indoor activities, the threshold is 45 dBA (EPA, 1974). These Ldn values are essentially Leq values for a 24 hour time period that have penalized any noises from 10:00 pm to 7:00 am by 10 dB. In order to better comprehend the dB scale, Figure 1, created by Casali in 1999, depicts various common sounds and their levels.

Sleep Arousal

In addition to the health effects mentioned above, sleep disturbance is a common occurrence when people are exposed to noise while sleeping. Toronto Public Health has found a "causal relationship between the long-term effects of noise-related sleep disturbances, with changes in sleep patterns, awakening, sleep stages, and subjective sleep quality" (2000). On top of reduced sleep quality, such people may also have a weaker immune system due to poor sleep.

Muzet wrote, in 2007, that while sleeping, humans are still aware and can respond to auditory stimuli. However, the attributes of the noise, such as "type of noise (e.g. continuous, intermittent, impulsive), noise intensity, noise frequency, noise spectrum, noise interval (e.g. duration, regularity, expected), noise signification," as well as the difference between the ambient noise level in the bedroom and the stimuli may have effects on how likely a person is to be aroused by the sound. He continues to explain that other, non-auditory, factors also play a role in this likelihood, such as age, gender, and personal attributes.

Further research has been done showing more detailed effects of noise on sleep. An intermittent sound of 45 dBA or greater, may increase the time it takes one to fall asleep up to approximately 20 minutes (Ohrstrom, 1993). Noises that occur after five hours of sleep are more likely to awake one from sleep and prevent them from falling back to sleep.

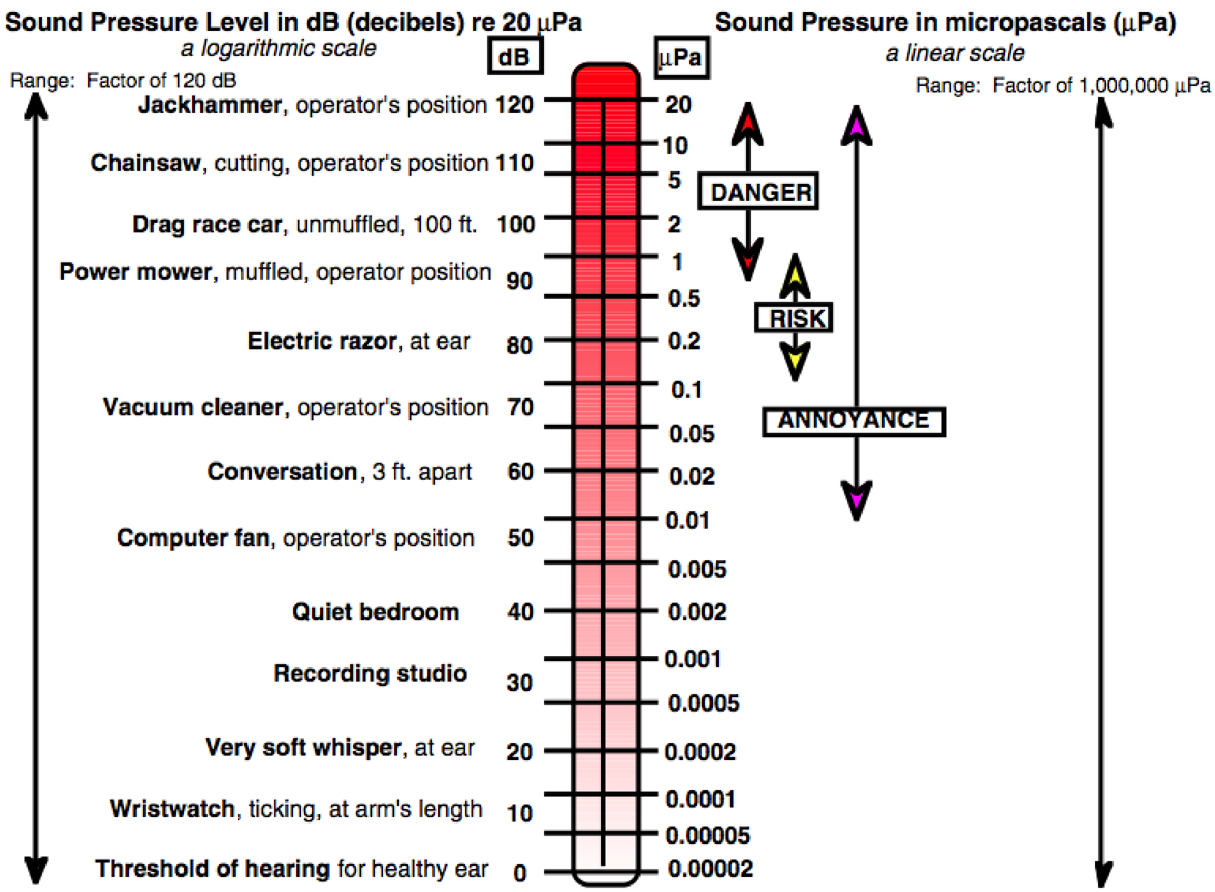

Figure 1. A noise “thermometer-type” scale which compares dB and µPa pressure values, and provides common source benchmarks. Casali, John G. "Litigating community noise annoyance: A human factors perspective." *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*. Vol. 43. No. 9. SAGE Publications, 1999. Used with permission of John G. Casali, 2015.

Speech Interference

A conversation with three feet of distance in between the people occurs at approximately 60 dB. As a rough rule of thumb, to be sure a sound is clearly heard, i.e. not masked, it should be 15 dB louder than any background noise. Using this rule as a guide, the community noise levels should not exceed 45 dB to allow for ease of conversation outdoors. As sounds become progressively louder, community members will have more difficulty speaking loud enough and understanding the spoken word. Also, when the distance is increased between two speakers, as it often is outdoors, whether a father is talking to his children while they play in a backyard or a mother is chatting with the woman across the street who just pulled into the driveway, the background noise has more potential to mask their conversations.

Specifically, conversations can be carried out at voice output levels of 50 - 65 dB (Miller, 1974). In order for the public address systems to be audible, they should be at least 10 dB louder than the background noise. In a study done by Navvab in 2009, they found the crowd noise ranged between 95 and 105 dBA. Of course, maintaining an audible sound system at these levels certainly puts the audience at risk for hearing damage. Noise can directly mask a spoken message (Dunn, 1981). Furthermore, neighborhood noise can interfere with additional forms of auditory communication including telephone, radio, and television (Kono, 1988). People can compensate for this masking, to a certain extent, by “moving closer to the speaker” or by the speaker raising his voice (Miller, 1974). If these do not work, the only other option is for speech communication to reduce or cease for it to be attempted at all (Jones, 1981).

Noise Masking in General

The normal level of background noise can also influence how likely a noise is to intrude upon the activities of those in the community. Per Schultz, "a given level of intrusive noise is less disturbing in locations with high background noise than in quiet locations" (1978). In the 1978 study done by Schultz, it was found that little correlation existed between community annoyance and noise ratings such as the Traffic Noise Index and the Noise Pollution Level, which are representations of a difference in background noise and peak noise levels. Because no correlation was found, it is unlikely that the intrusiveness of a noise depends upon how much louder the noise in question is from the background noise.

Degradation of Use of Property

As explained above, higher sound levels in a community can create problems communicating, whether that is between family members, neighbors, or even watching the television or listening to the radio. For these reasons, it may be impossible for residents to host summer BBQs or have family movie nights, when community noise levels rise above acceptable levels.

Furthermore, if night-time sound levels exceed 55 dBA, residents may have trouble sleeping, which may not only lead to annoyance, but irritability due to lack of sleep, as well as other medical related problems.

Due to high levels of community noise, the residents lose their ability to enjoy their property and use it as they normally would when the excessive noise is not present.

Devaluation of Property Assets

When a football stadium relocates, it has a potential to influence property values in the surrounding areas. Dehring did a study on residential property values in Dallas County when their football stadium was looking to relocate. He found that the property values increased within the city surrounding the stadium. However, values of other properties in the county decreased 1.5%, possibly because they would have been paying taxes to support the stadium (Dehring, 2007).

Many neighborhood activists argue against building new stadiums in their area because "the construction and operation of the stadium will bring about traffic congestion, air and noise pollution, and undesirable crowds to the neighborhood, thus causing property values to decline." However, there can also be a "positive economic impact" from the stadium (Tu, 2005).

Objective Measurement of Community Noise

Measurement Instrumentation

A sound level meter (SLM) is the simplest instrument that may be used in community noise measurements; however, a basic SLM only provides instantaneous sound intensity measurements, so it is not effective for logging noise levels or providing an average (e.g. Leq) over a duration of time. On the other hand, a noise dosimeter will average or integrate the sound levels over a period of time (Casali, 1999). Thus, they are often preferred in collecting community noise measurements.

Metrics

The community noise levels were measured in decibels with an A-weighting scale. The A-weighting filters the noise levels similarly to how they are perceived by the human ear at moderate sound levels of 40 – 60 dB. Thus, this weighting will result in the most accurate noise level that is perceived by the community residents as loudness. To help display the community noise data in a meaningful manner, the dB values will be converted to sones, which is a linear scale of perceived loudness. The sone data will be easier for non-auditory specialists to understand, such as town council members and community members. For the analysis of sones, the Quick A-Weighted method was used. This method was selected because it allowed for the calculation to be done using only the dBA measurements, as opposed to the ISO recommended method which requires spectral data (Rossing, 1990). Although this method has the advantages of ease and requires less expensive measurement devices, it is less accurate than the ISO recommended method. However, at moderate to low frequency sound levels it remains fairly accurate because the dBA curves are very similar to the sensitivity of the ear in this range. This method assumes that at 30 dBA the sound has a rating of 1.5 sones. Then the number of sones doubles for every increase of 10 dBA.

Leq values are the integrated dBA average of all sound levels for a period of time. These Leq data are provided by noise logging dosimeters. It is standard for some dosimeters to provide Leq data for every minute of data collection, as well as the total collection Leq value. Similarly, L10 and L90 are the SPL which is exceeded for 10% and 90% of the collection period respectively.

Procedures and Locations

Casali suggested sampling the perimeter area around the offending noise source in his 1999 paper. In order to get a better picture of how the sound propagates into the community, and how it is effected by terrain, foliage, or barriers, gathering samples from more locations in the community is recommended.

The noise dosimeters and microphones should be mounted on tripods, ensuring the microphone is at median adult standing ear height. It is also pertinent to make the dosimeters tamperproof (locking keyboards or covers), if they are to be left unattended (Casali, 1999).

Reporting of Data and Comparison to Ordinance Levels, Sleep Arousal Levels, PSIL, etc.

An A-weighted sound pressure level is often used to assess noise exposures. This measurement is associated with (perceived) loudness. However, there are multiple other factors that may attribute to a person's perception of loudness (Berglund, 1995). Data from this study has been reported by comparison to meaningful ordinances and benchmarks levels and models.

The data collected in this study during night hours were compared to a 50 dBA sleep arousal level. It is at this point they most people will begin to be aroused from their sleep, and increasingly more likely as the sound becomes louder. The Preferred Speech Interference Level (PSIL) was also used to predict how difficult it would be for two people of "normal" hearing to communicate in different levels of ambient noise, with the two people at varying distances from each other. A PSIL value is calculated by averaging the dB levels of 500 Hz, 1000 Hz and 2000 Hz. Then Figure 2 is used to determine how much interference the ambient sound is placing on the conversation. For example, if two people are 4 feet apart in a 60 dBA environment, they will have to raise their voice slightly above their normal level. Ideally, people would never have to raise their voice in order to have a casual conversation to somebody nearby.

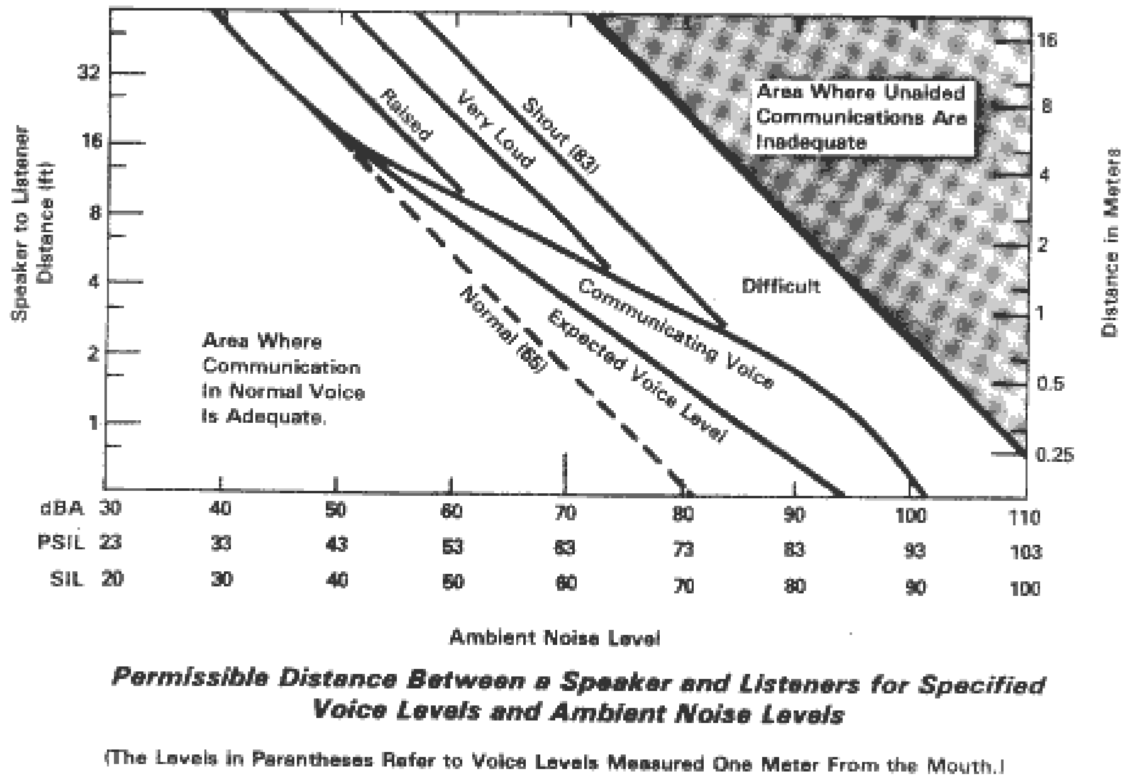

Figure 2. Speech Communication in Noise. Newman, J. Steven, and Kristy R. Beattie. "Aviation noise effects." (1985). Used under fair use, 2015.

Additionally the community noise levels will be compared to the local town and county ordinances, to show the legality of the offending noise sources.

Frequency considerations

The spectrum of a noise is important to take into consideration "when considering the propagation of a sound from a source to a receiver and when considering the most cost-effective means of engineering noise control" (Berglund, 1995).   For example, a low frequency noise (or one with a long wavelength) will travel very far. For this reason, it is more practical to control the noise at its source (Berglund, 1995).

Temporal and Predictability Considerations

Work of Toronto Public Health published in 2000 has found evidenced that "unexpected or impulse noise is more annoying than continuous noise of equivalent energy." The temporal quality of a sound is an important factor when evaluating a community's response to a noise. If two sounds are of equal levels which effectively mask speech, but one is constant and the other pulses on and off, the latter allows for some speech communication, whether the speaker gets words in between the pulsing noise or the listener simply picks up on a sampling of the words being spoken. Regardless, [degraded] speech communication is possible in the later situation.

The predictability of a noise also can play a role in the human response to a noise. If a noise is predictable, the person can prepare for it, whether it is by not being home during the loud time, planning social activities around it, or simply mentally being aware that the sound is going to occur at a given time. On the other hand, if a sound is unpredictable, people are unable to prepare for it. The sound may interrupt them and cause frustration. It may even startle them.

A significant amount of research has been done covering many areas related to community noise. Knowing how a noise within the community can affect the community members' health, property values, social relationships, and ability to sleep, among many other things, can be helpful when creating a case to abate or reduce a noise. This information may also be of use to lawmakers who create noise regulations at both federal and local levels.

Even though all of this information exists, there is still a need for additional research. Examining the noise within a local community can provide additional insight that may be unique to that community. For this reason, this study has identified two noise sources, located within a rural county in Virginia, as well as unique characteristics and effects on the community. Noise levels within the community were taken, then compared to prevailing local ordinances and other benchmark criteria from similar communities. Additionally, this data has been mapped out to show the penetration lengths into the community before it attenuates to the levels of applicable noise ordinances. Lastly, the community members were surveyed in order to gain insight into their reactions to the noise and how it has impacted their daily lives. For each exposure, recommendations have been made, based on the above analyses, as to elimination or reduction of the offending noises.

TWO DIFFERENT COMMUNITY NOISES TO BE EVALUATED

New High School Stadium in Blacksburg, VA

History of the Bill Brown Stadium

Before the Bill Brown Stadium was built for the Blacksburg High School, Mr. Daniel A. Berenato, part of the Facilities and Planning Department at Montgomery County Public Schools, wrote a letter to Mr. Grandol Harvey, Chief of Planning in the Department of Planning and Engineering for the Town of Blacksburg, Virginia. Mr. Berenato's two-page letter contained a list of conditions which the school was willing to adhere to in order to address the noise-related concerns of neighboring residents, mainly addressing use of the public address (PA) system, as well as engineering measures to help reduce noise propagation into the community. The letter contained an additional four pages which included diagrams and maps of the stadium and surrounding land, and descriptions of the PA system. The initial intentions for the stadium's noise level outputs, use, and other details were outlined in this document.

Figure 3. Stadium: Map of the area surrounding the Bill Brown Stadium in Blackskburg, Virginia ("Blacksburg, Virginia", 2012). www.maps.google.com 2012, Used under fair use, 2015.

Notable Points in Mr. Berenato's letter to the Facilities and Planning Department:

- "The school system agrees to change the type and height of the stadium PA speakers. They will be lower powered, and lower mounted than originally submitted. The PA system will be equipped with a real time analyzer connected to a remote microphone so the PA system operators can see what levels of sound are in the stadium. The PA system will also be equipped with a multi band graphic equalizer on the mixing console, so we can control low frequencies. The speakers will be no more powerful than the one shown on the attached cut sheet, and be located generally as shown on the attached stadium profile. We will have a person present at each game that is designated to monitor and control the PA system, and to adjust the volume to the minimum level required for the situation."

- "We would agree to the following daytime (until 10PM) limits for PA system sound at the residential neighborhood property boundaries," represented in Table 4.

- "We will agree not to use the PA system before 1PM or after 10PM except if required in an emergency of health or safety."
- "We agree to limit the playing of recorded music on the PA system to the national anthem."
- "We will provide a <u>future</u> 75 foot wide buffer yard (2.5x the current requirement of 30 feet) with 8 foot high and 32 foot wide earth berm with trees on the slopes and at the top, a 6 foot high chain link fence, all along the eastern property line adjacent to the homes on Tall Oaks Drive. . ." Diagrams of this are provided as part of Berenato's letter in Appendix E.

	Stroubles Mill[1]	Haymarket Square[1]
One minute average level	60 dB(A)	65 dB(A)
Maximum Slow	65 dB(A)	70 dB(A)

Table 4. Stadium: Daytime (until 10PM) limits for the PA system in the Bill Brown Stadium, as provided in Mr. Berenato's letter to the Facilities and Planning Department.
[1] These are the neighborhoods surrounding the Bill Brown Stadium in Blacksburg, Virginia

The specifications of the selected PA system, R.5HP 3-Way Horn Loaded Weather Resistant Fully-Range Loudspeaker, is provided as part of Berenato's letter in Appendix E. This particular system is capable of producing sounds of up to 107 dB SPL. It also produces sounds down to 90 Hz. Any sound 1000 Hz or below is capable of traveling long distances, especially sounds below 500 Hz which can travel through walls and other barriers. An "Evaluation of Sound from

Proposed Football and Soccer Stadium at Blacksburg Middle School" was prepared for Montgomery County Public Schools, by Noral D. Stewart, Ph.D from Stewart Acoustical Consultants out of Raleigh, North Carolina (2006). This 21 page report identifies the sound sources for the stadium as "sounds of crowds cheering, sound from a public address system, and music from the school band" which will propagate into the community. The sound ranges expected in the residential areas nearest the community are expected to vary from below 40 dBA upward to at least 60 dBA, and even exceeding that in areas of Haymarket Square. The report recommended the PA system produce sound levels of 90 dBA (or no louder than 95 dBA) at the crowd's ears, in order for the projected sounds to be intelligible over the crowd's cheering. In sum, the report claims that sounds from the stadium "could at times be noticeable and distracting" within the surrounding community, but not "loud enough to be a major interference with communication." If heard inside of homes, it should not be "loud enough to interfere with communication or listening to television." Stewart also claims that "sound levels inside homes with windows closed will at least approach 25 dB less than the outdoor levels," but it is important to acknowledge that all house windows would not necessarily be shut during the Fall football season. The report discussed the possibility that nearby residents might be opposed to the stadium and the noise from it. It stated that homes without children are often quieter than those with, and thus would be more likely to be disturbed by the stadium noise. However, families with children often see having a school close to home as an advantage and thus would be less opposed to inconveniences due to a high school stadium being near their home. Much of Dr. Stewart's report contained conclusions such as the aforementioned which were not tied to actual measurements, but were instead speculative.

Throughout the entire planning process, residents of the nearby neighborhood resisted building a stadium at the suggested location. They kept each other informed on the plans and progress of the Special Use Permit. They attended Town Council Meetings to protest building the stadium in this location. They wrote letters to Town Council Members, had an acoustics specialist (Dr. John Casali of Virginia Tech) evaluate their neighborhood and the plans for the new stadium. Letters were written to local newspapers. In short, the community members appeared to do everything within their power to show they were against the stadium being built in this location, with much of their objectives relating to noise, but the Town of Blacksburg granted permission for it to be built next to the residents' backyards. Figure 3 depicts the location of the Bill Brown Stadium and proximity to the residential areas.

In October of 2006, after Ordinance 1405 was adopted, Blacksburg resident Dawn Elvinger, living near to the new stadium location, wrote a "letter to the editor" of the Roanoke Times, titled "Misinformation on Stadium at Town Council" where the resident expressed feelings of the Town Council siding with "opinions and emotions" over facts provided by the community's noise expert (Elvinger, 2006).

Planned Creep

Blacksburg High School has since added soccer fields beyond the football stadium, which are located closer to residential property and have altered the barriers that were agreed upon under the Special Use Permit in 2006 when the stadium was built (Blacksburg High School, 2011). These fields are located next to the properties along Tall Oaks Drive. Blacksburg High School has claimed that they have taken measures to comply with the original light and sound conditions outlined in the Special Use Permit from 2006. However, they may find these standards not reasonable, as the soccer fields are much closer to residential properties and the ridge is no longer blocking the sound from propagating into the community, as was claimed by Dr. Stewart for the football stadium.

Ordinance 1405

In 2006, the Town of Blacksburg created Ordinance 1405, which amended the Blacksburg Zoning Ordinance, specifically in instances which would be effected by building the new Bill Brown Stadium in a residential area. This ordinance established regulations for lighting and, of interest to this research, exterior loud speakers.

The three points to the exterior loud speaker regulation are quoted below.

1. *Except provided by subsection (c),* speaker noise shall not be audible by an occupant of adjacent property with a property line nearest the source of speaker noise.
2. No use featuring an external speaker shall be authorized except by special use permit.
3. The use of amplified sound systems associated with public park and recreation area uses shall be conditioned to minimize speaker noise audible by occupants of adjacent properties and surrounding neighborhoods. To determine appropriate conditions, the Zoning Administrator may require the applicant to submit a report from a professional noise control engineer on the impact of the proposed amplified sound system. ***Conditions may include noise limits based on adjoining land uses, noise measurements at property lines, hours of operation, times of day, duration of noise, and noise measuring specifications.***

The Blacksburg High School was granted Conditional Use Permit 11-0004 by the Blacksburg Town Council, which authorized them to use an external loud speaker (2011).

<u>Train crossing at Chrisman Mill Road in Christiansburg, Virginia</u>

<u>Distance to Residences</u>

The Chrisman Mill Road Railway Crossing is a critical intersection within the town limits of Christiansburg, as it is located within a residential community, see Figure 4. Some residents live within a few hundred feet and, many more residents live within a clear audible distance from the intersection, including residents of Diamond Point, Windmill Hills, and Diamond Crest, all well-established large neighborhoods. Some of the homes in these neighborhoods are less than 2,000 feet from the intersection. Although this intersection existed long before some of the residents moved into these neighborhoods, rail traffic has become more frequent in the past decade. There has been an increase of train travel though this region as Norfolk & Southern railroad has started hauling double stacked trains, and needed to reroute due to bridge and tunnel height restraints.

As previously mentioned, research shows that trains produce extremely high noise levels, not only from driving along the tracks, but also the train horn blasts. In formulating the need for this research, it was believed that it was likely that these sounds exceed the maximum levels recommended for unprotected hearing exposure, especially for the residents that live within close proximity to the tracks. It was also believed likely that these sounds travel long distances into the surrounding communities, disturbing indoor and outdoor activities for occupants. Even more of a concern is the potential for a degraded quality of life and health due to the annoyance from a

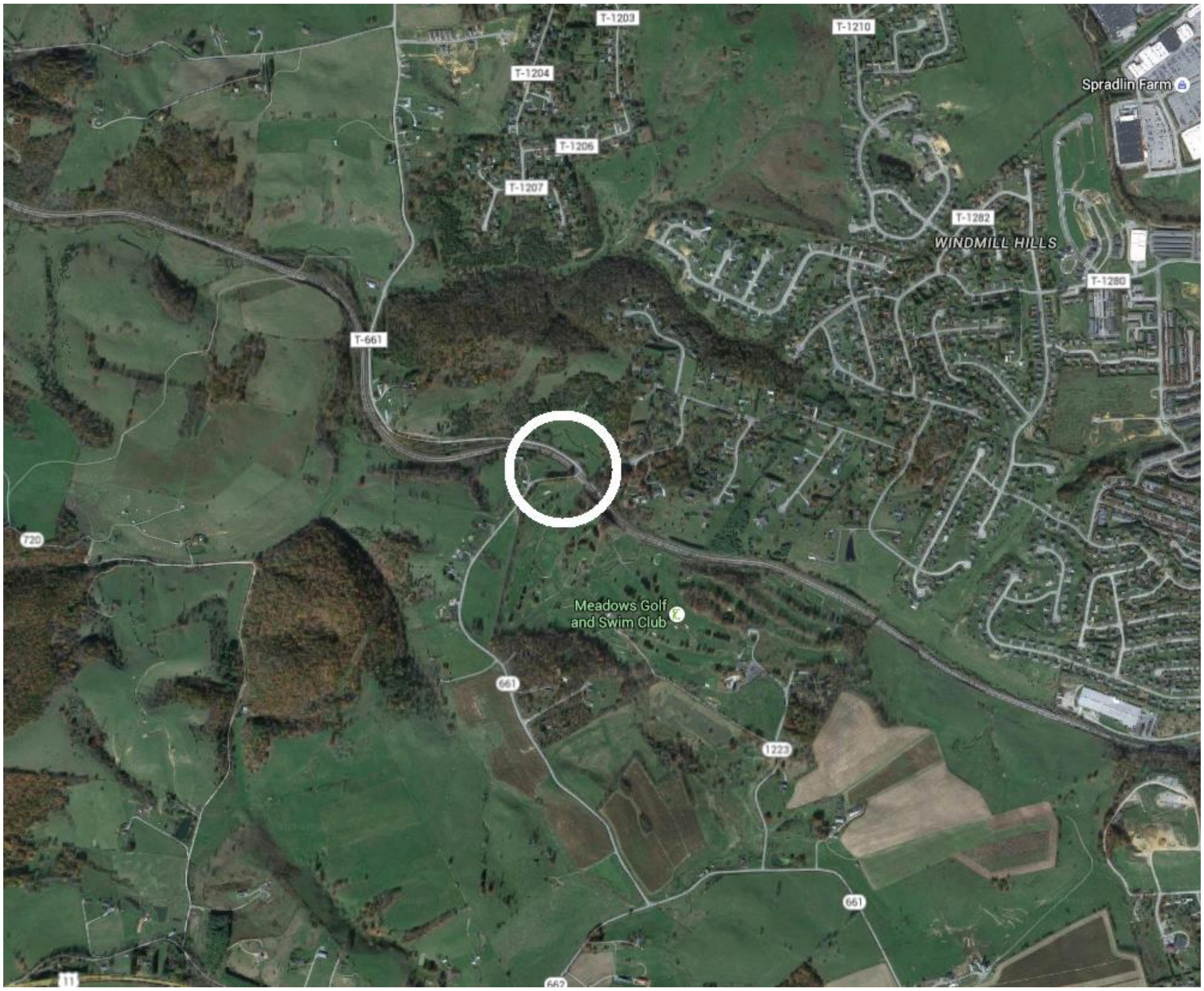

Figure 4. Chrisman Mill Railroad Crossing: A map of the Chrisman Mill Road Crossing and the surrounding area ("Christiansburg, Virginia", 2012). www.maps.google.com 2012, Used under fair use, 2015.

train horn, including interference with sleeping at night. Research has shown that a reduction in quality of sleep may be a root for many other health problems, such as immune system degradation, heart problems, stress, and anxiety.

Why Train Horns Are Required and Quiet Zones to Eliminate Them

The Federal Railroad Administration (FRA) requires all trains to sound their horn as a warning to highway users at public highway-rail crossings. Locations can bypass this by establishing “quiet zones” and communities with pre-existing “whistle bans” may also be exempt (Use, 2006). Usually, these zones have other, sometimes more effective, countermeasures against vehicle-train collisions at crossings.

There is a 20 second maximum horn sounding, but may be violated if train engineer cannot accurately predict their arrival at the approaching intersection (49 CFR § 222, 2006).

In order for an area to become a new quiet zone, it must have flashing lights and special gates at each public railroad crossing. They must all be equipped with constant warning time devices and power out indicators. They also must have supplemental safety measures (SSM) or alternative safety measures (ASM). SSM’s can include night time closure of the roadway, a four-quadrant gate system that precludes drive-arounds, gates with medians or traffic separators or making the street into physically-separated lanes, such that vehicles cannot drive around the gates. ASM are any modifications to a SSM which does not meet standards.

Christiansburg Quiet Zones

Within Christiansburg Town limits, there is an ordinance stating that the whistle or horn of every train must be “sharply sounded at least twice” at a distance between 275 and 300 yards from the railroad and roadway intersection (Christiansburg Town Code §28-2, 1976). After passing this point, the horn must be sounded continuously or alternately until the train has reached the intersection. The only exception to this procedure is for the crossing on Cambria Street (Virginia Route 111), which has a two-quadrant gate, channelization devices, and flashing light pairs at the intersection, where the town code prohibits such horn signals (Christiansburg Town Code §28-2, 1976).

Why Chrisman's Mill?

A fundamental principle in human factors engineering and safety engineering is that it is best to design a hazard out of a system, if that cannot be done, then it is better to remove it from the operator's presence. Failing that, the operator should be guarded from the hazard, warned about it, and lastly trained. However, progressing along that chain increases the likelihood for human error and possibility for a hazardous situation, and warning, which is what a train horn constitutes, is considered the next to weakest countermeasure against accidents.

Chrisman Mill Road has only a two-quadrant gate at its railway intersection. The guards do not completely guard drivers from an oncoming train, as vehicles can drive around the guard (off the road to the right) or they may circumvent the guards by weaving between the two guard beams. This is especially hazardous because there is potential for vehicles to bottom out on the tracks and become stuck, further increasing the likelihood of the vehicle and its passengers to be hit by a train. The current guarding system is simply not safe, and the train horn does not in any way render the two-quadrant gate as safe.

Two safer options are available and also present within the Town of Christiansburg. As previously discussed, the railroad crossing on Cambira Street has a two-quadrant guard consisting with two beams that fully overlap and prevent weaving between them. It also has barriers, both to the left (median) and right (curb), along the edges of the road to prevent cars from passing around the outside of the guard. The other option, which actually should be an augmentation to a guard, is a redundant warning system with lights and bells located at the North Franklin Street (Business 460) railroad intersection. This alerts drivers of an approaching train, while allowing them the option to stay at a safe distance from the railway or pass through the intersection. While it will not preclude the driver's ability to enter the intersection, it will allow them a straight flat path which they will not get stuck trying to cross.

<u>All Other Intersections Are Not "Quiet"</u>

The Cambria Street railroad crossing is the only intersections in Christiansburg that is a "Quiet Zone;" however, the author was informed that making any other intersection a "Quiet Zone" increases the likelihood of the currently existing "Quiet Zone" being revoked, as if any accident were to occur at any quiet intersection, it would bring down the requirements to keep the initial one. One town hall representative has stated a need for a full engineering analysis of the Chrisman Mill railway intersection before further steps can be taken. Another town staff member expressed a concern for the cost of making changes to the intersection.

RESEARCH OBJECTIVES

Fundamental Objectives

The objects of this research were to evaluate both noise emissions from the Blacksburg High School Stadium and the Chrisman Mill crossing, using both objective sound measurements and subjective ratings and opinions of affected residents in order to accomplish the following objectives.

- Compare these measurements of noise emissions against prevailing local ordinances and other benchmark criteria from similar communities,
- Determine if the measurements of noise emissions are in compliance with prevailing ordinances,
- Assess the community residents' reactions and impacts, both real and perceived,
- Accurately display the distance propagation on a map to show noise penetration lengths into the community. This can be calculated by inverse distance law from measurements taken.
- For each exposure, recommendations will be made, based on the above objective and subjective analyses, as to elimination or reduction of the offending noises.

Methodology

Determination of Perimeter Sites for Measurements and Procurement of Permission from Residents

The neighborhoods surrounding the Blacksburg, Virginia Bill Brown high school football stadium and the Christiansburg, Virginia Chrisman Mill railroad crossing have been visually inspected in order to select locations which provide representative measurement locations which were impacted by the noise sources. Four residential locations were selected near the Chrisman Mill railroad crossing and three residential locations were selected near the Bill Brown Stadium with a fourth collection site located inside of the stadium. Locations were selected to strengthen the research by showing the sound propagation both deep into the neighborhoods and in multiple directions.

Residents of the selected properties surrounding the Bill Brown Stadium were asked to fill out a form (Appendix A) granting the researcher permission to enter the premises on three specified game days, as well as three specified non-game days for collection of the normal background noise levels in the community. This provided equal sample sizes for the control group (non-game day sound levels) and the experimental group (game day sound levels). The normal background noise levels were collected on Fridays from approximately 7:00 pm - 10:15 pm, in order to keep day and time of collection a controlled variable and eliminate potential confounding effects.

Residents of the selected properties surrounding the Chrisman Mill railroad crossing were asked to fill out a form (Appendix B) granting the researchers permission to enter the premises on seven days, one each day of the week, which were collected in a randomized order over several months, for collection of sound levels in the community. By collecting data over all seven days of the week, potential bias from high or low rail traffic days is minimized. Also, other effects, such as weather, will be randomized as data is collected over a wide range of weeks.

Data Collection

Once the researcher obtained authorization to use the selected properties, a location on the property was selected to place the dosimeters. The dosimeters were placed at least 3 feet from any significant reflective structures in order to avoid any reflective effects, while maintaining a line of sight with the stadium or train tracks to the extent possible.

Measurements of distances to the residential sound level measurement sites were procured using a measuring wheel and tape measure, once the sites were determined. Measurements were also taken from nearby landmarks, such as the corner of the house, a tree, pole or other notable feature, so that the researcher could ensure the dosimeters were placed in the same location for all sampling periods.

Instrumentation

A Quest Q300 Noise Dosimeter was used for the collection of neighborhood sound levels in this experiment. This was an integrating dosimeter that met the ANSI standards for the Type 2 dosimeter, meaning that the dosimeter has accuracy of +/- 1 dB. This Type 2 accuracy also met OSHA's requirement for noise surveys (ANSI S1.4, 1983), and more importantly for this application, it met the requirements of local zoning ordinances for Blacksburg, Christiansburg, and Montgomery County, Virginia. The dosimeters were used on the lower measuring range of 40 - 110 dB with a 3 dB exchange rate and A-weighting. The dosimeters in the neighborhood were mounted on poles and the microphones were covered with wind screens. For the Stadium noise, the meter's detector dynamics were set to the 1-second (i.e., Slow) response, while for the more transient train horn noise at Chrisman's Mill crossing, it was set to the 1/8-second (i.e., Fast) response.

The calibration of the dosimeters was checked before each use at 114 dB for 1000 Hz using a Quest QC-20 calibrator as the reference source. The dosimeter was considered properly calibrated if it provided a reading within 0.5 dB of the calibrator, on each dB level, as specified in the Q300 Noise Dosimeter instruction manual (Quest, 1998), and adjusted appropriately if not.

The dosimeter was then checked after the data collection for each event. None of the dosimeters failed to calibrate accurately before data collection. The one time that a dosimeter had drifted more than 2 dB after data collection, the data collected on that day was thrown out. An additional three dosimeters resulted in an error extracting the session data over the course of two collection days. The data from these days was also discarded.

Sound Level Metrics to Be Used

First, the dB metrics of the Bill Brown Stadium were covered to see if and how frequently they violate the Montgomery County noise ordinance, as well as the levels Berenato agreed to for Stroubles Mill and Haymarket Square (Berenato, 2006).

An A-weighted sound level average ($L_{Aeq,T}$) was also used as a non-biased (with respect to time penalty) measurement, as many towns' noise ordinances do not considering night time to begin until 11:00 p.m. This rating is an integral of each A-weighted sound level over a period of time, T, as displayed in Figure 5 (Earshen, 2003).

$$L_{Aeq,T} = 10 \log \left[1/T \sum_{i=1}^{N} t_i \, 10^{L_{Ai}/10} \right]$$

Figure 5. Formula for computing an A-weighted sound level average ($L_{Aeq,T}$). Earshen, John J. "Sound measurement: Instrumentation and noise descriptors," In Elliott H. Berger, Larry H. Royster, Julia D. Roster, Dennis P. Driscoll, and Martha Layne (Eds.), The Noise Manual, 5th edition. (2003): 41-100. American Industrial Hygiene Association. Used under fair use, 2015.

Furthermore, a log of 1-second Leq measurements was obtained as a short-term indicant of transient noise levels emitted during a football game. Also, the Lmax (i.e., maximum momentary dBA level reached during the full measurement period) was recorded.

$$L_{dn} = 10 \log 1/24 \left[15 \times 10^{(L_d/10)} + 9 \times 10^{(L_n+10)/10} \right] \text{dBA}$$

Figure 6. Formula for computing DNL. Driscoll, Dennis P., Noral D. Stewart and Robert R. Anderson. "Community noise," In Elliott H. Berger, Larry H. Royster, Julia D. Roster, Dennis P. Driscoll, and Martha Layne (Eds.), The Noise Manual, 5th edition. (2003): 601-637. American Industrial Hygiene Association. Used under fair use, 2015.

It was necessary to utilize different measures at the Chrisman Mill railroad crossing for the train horn. In this case, each sampling consisted of a 24-hour time period, and it was impossible to obtain a sampling without the train horn, so careful thought was given to the metrics used in this data collection. Since data was collected both during the day and the night, the DNL was used as one measurement. The formula for the non-modified DNL has been provided in Figure 6. $L_{Aeq,T}$ will also be used as a non-penalized measurement, as described above. $L_{max,}$ the "highest sound pressure level, in decibels, that occurs during a given time period" (Quest, 1998) was also examined in order to obtain a better idea of how loud the train horn was.

Development of Rating Scales and Interview Questions

Substantial work has been done in the development of rating scales in regards to community noise surveys. Perhaps most notable is the work done by the Community Response to Noise Team put together by the International Commission on the Biological Effects of Noise. Fields, De Jong, Gjestland, Flindell, Job, Kurra, Lercher, Vallet, Guski, Felscher-Suhr, and Schumer reviewed previous noise survey approaches in their paper "Standardized General-Purpose Noise Reaction Questions For Community Noise Surveys: Research and a Recommendation," as well as established a common effective survey format for the community noise field. They pointed out that most scales used to gauge noise annoyance are a "unipolar scale that extends from a negative pole to a neutral point," as the term "noise" refers specifically to unwanted noise and therefore cannot invoke a positive reaction (Fields, 2001). They recommend using two variations of a question, one using a verbal scale and another using a numerical scale, to gauge one's annoyance to a noise. The recommended questions are presented below.

- "Thinking about the last (..12 months or so..), when you are here at home, how much does noise from (..noise source..) bother, disturb, or annoy you; Extremely, Very, Moderately, Slightly or Not at all?"
- "Next is a zero to ten opinion scale for how much (..source..) noise bothers, disturbs or annoys you when you are here at home. If you are not at all annoyed choose zero, if you are extremely annoyed choose ten, if you are somewhere in between choose a number between zero to ten. Think about the last (..12 months or so..), what number from zero to ten best shows how much you are bothered, disturbed, or annoyed by (..source..) noise?"

Fields et al. made some additional recommendations beyond the suggested scales and questions in their paper. They recommended including "basic information about sample size, study location and study design" and also "month/season and year of the social survey" in any publications, so that the research is more likely to be useful to somebody in the future. They provide guidelines as to what extent each topic area should be explained, based upon the type/length of paper.

Beyond the standard noise annoyance questions, the survey for this research aimed to assess how the stadium and train noises were intruding upon leisure, work or school, and sleeping of the adult taking the survey, as well as their children, if any. The five point verbal scale described above was also used throughout this survey, as it provided words that the participant could relate their feelings to versus the numerical scale which could result the in survey responses being more difficult as the participant had twice as many options to choose from. The Bill Brown

Stadium Survey can be found in Appendix C and the Chrisman Mill Survey can be found in Appendix D.

<u>Interviews of Residents</u>

Residents in proximity to the two noise sources were recruited for the surveys by having the researcher stop by their houses during the evening hours of weekdays or during the day on weekends. The researcher introduced herself as a Virginia Tech student and briefly explain that she was doing a confidential survey of responses to the noise from the Bill Brown Stadium or the nearby train horn. The researcher asked if the resident was interested in participating in the survey.

If the resident was, they were be given a copy of the IRB and survey to fill out, which did not take more than 5 minutes, in most cases. The researcher answered any questions that the interviewee had about the IRB, but could not comment on, rephrase, or in any other way influence any of the survey questions. Upon conclusion of the survey, the interviewee was thanked for their time.

After the researcher left the interviewee, she made notes on the back of the survey noting the residents' behavior toward the survey and subject matter. Any important quotes that the resident may have said, or any other potential useful information that did not reveal the identity of the resident was also recorded.

If the resident did not wish to participate in the survey, they were thanked for their time and the researcher politely left their property.

As surveys were collected over a period of multiple days at a site, it was important that the researcher made note of which addresses she had gone to. Whether or not the household participated in the survey will not be recorded. The only data that was associated with an address was whether or not a researcher spoke with an adult at that household. If no adult was home, the researcher returned to that house at a later time. This information was stored in a safe location not accessible by other people. After all surveys were collected, this information was destroyed.

DATA COMPILATION AND ANALYSIS

The average (Leq) in dBA and Peak SPL in dB were recorded for every minute in both the football stadium case and the train horn case. These values were used as the data for the analysis in this research. Maximum Peak levels, in addition to any 1-minute duration Leq levels that exceeded any legal or recommended community noise levels were considered to be of most importance. The values from non-game day samplings and periods without any train horn blows were also critical, as they allowed for comparisons between the ambient noise levels of which residents are used to living with and the noise produced by either of the two noise sources.

Bill Brown Stadium - Quantitative Analysis

Figure 7 shows one representative graphical comparison of 1-minute samplings taken in the Bill Brown Football Stadium study at Site 2. The game noise level was above the ambient noise level for the majority of the collection period. Additionally, the game noise had many more changes in sound level, whereas the ambient noise in the community is significantly steadier over time. This figure also overlays the collected sound levels against a collection of regulations and human activity interference levels. In the sample shown, the ambient noise of the community rarely reached a level that would cause an increase in sleep arousals (awakenings) or interfere with *indoor* activities. However, the game day noise levels were much the opposite. They rarely went *below* these important sleep arousal or activity interference levels. They also reached levels that would cause for sleep disturbance and interference with *outdoor* activities, in addition to exceeding the daytime (7:00 am – 10:00 pm) limit of 57 dBA set by the Montgomery County Ordinance. A similar graph is provided for each site and individual game in Appendix F.

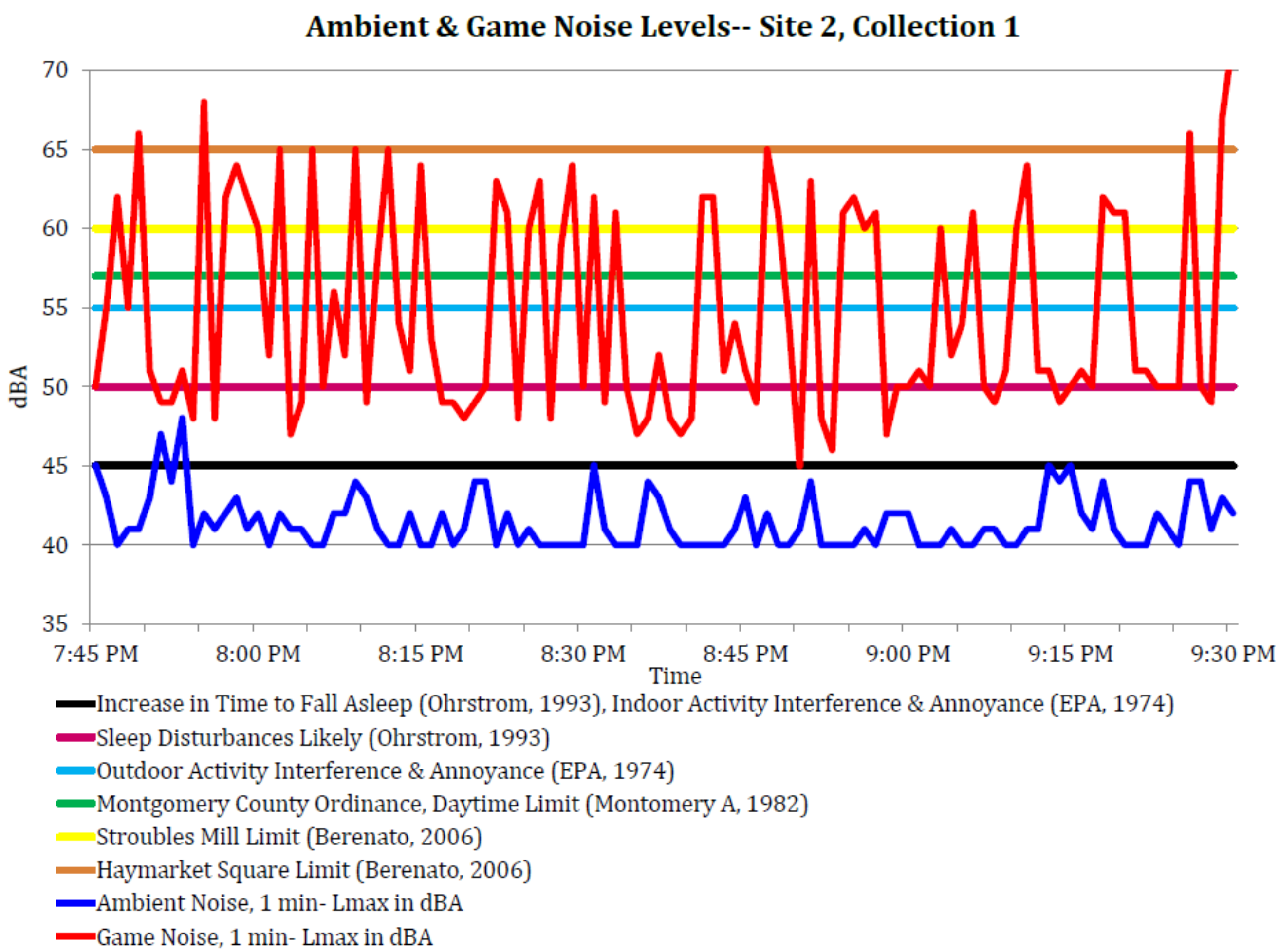

Figure 7. Stadium: A comparison of game day noise and ambient noise to several regulation and recommended levels from human factors references.

Upon examining the time-logged dBA data at all three sites the following trends appeared. At both Site 2 and Site 3 there was at least a substantial change in maximum peak levels, as shown in Table 5, and Leq 1-min average levels, shown in Table 8, between game day sound and ambient sound levels, with game day levels being as much as 22 dBA above ambient levels. This data was used to calculate the percent of 1-minute exceedances of the limits provided in Berenato's letter. Two of the three sites were found to have a higher number of exceedances on game days, as shown in Table 6. The same was found when analyzing the number of exceedances of the Montgomery County Regulation, as shown in Table 7, only a higher percentage of occurrences was found, which follows with the more restrictive noise limit.

Similarly, Figure 8 shows the spread of all 1-minute Leq samples collected at Site 3 across the different dBA levels. A visual shift to the right (more intense sound) is seen from the ambient noise to the game day noise. Additionally, any time there is a change of 5-15 dBA over the ambient noise level this was counted at a substantial change, as this is the target range of increase specified by the FHWA (Use, 2006). These changes are denoted in Table 5 and Table 8 displaying the sound values collected at each site.

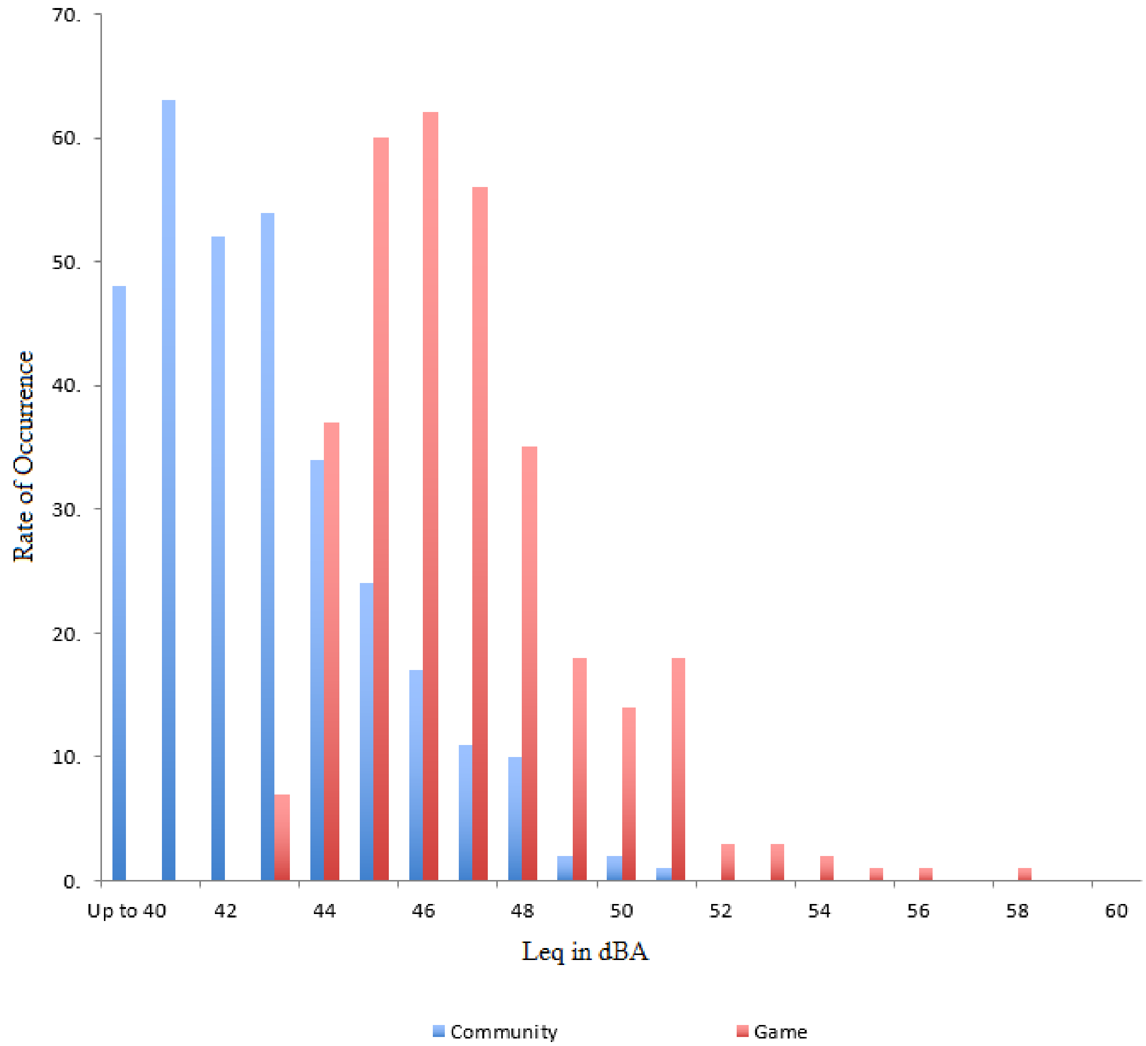

Figure 8. Stadium: Decibel distribution of sound from Site 3

	Site 1	Site 2	Site 3	Stadium
Game Day	69 dB	72 dB *	71 dB *	101 dB
Ambient	68 dB	61 dB	61 dB	--

Table 5. Stadium: Peak levels in dB collected over the duration of this study.
*substantial change of 5-15 dB, as defined by the FHAW (Use, 2006)

	Site 1	Site 2	Site 3
Game Day	67.3%	53.1%	43.1%
Ambient	74.5%	42.5%	42.8%

Table 6. Stadium: Percent 1-minute Maximum Slow dBA Exceedances of Berenato Limits of 65 dBA in Stroubles Mill and 70 dBA in Haymarket (Berenato, 2006)
[out of 318 minute collection samples]

	Site 1	Site 2	Site 3
Game Day	80.2%	57.7%	45.9%
Ambient	82.4%	42.5%	43.1%

Table 7. Stadium: Percent 1-minute Maximum Slow dBA Exceedances of Montgomery County VA Noise Ordinance Limits: 57 dBA for 7AM-10PM; 52 dBA for 10PM-7AM (Montgomery County, Virginia, §7-80, 1988). [out of 318 minute collection samples]

	Site 1	Site 2	Site 3	Stadium
Game Day	51 dBA	48 dBA*	48 dBA*	87 dBA
Ambient	50 dBA	40 dBA	43 dBA	--

Table 8. Stadium: Leq for 318 minute collection samples
*substantial change of 5-15 dBA, as defined by the FHAW (Use, 2006)

Chrisman Mill Train Crossing – Quantitative Analysis

Figure 9 shows the representative comparison of 1-minute samplings taken near the Chrisman Mill Road Railroad Crossing on a Tuesday. Several loud peaks can be seen throughout the day, but the ambient levels in the community are noticeably lower than these peaks. Interestingly, the ambient noise levels also reflect the amount of activity in the area, tapering off in the late evening hours and picking back up again in the morning. This figure also overlays the collected sound levels against a collection of regulations and human activity interference levels. In the sample shown, the peaks exceeded even the highest level of becoming impossible to hold a conversation. They also reached levels that would cause for sleep disturbance and interference with *indoor* and *outdoor* activities, in addition to dramatically exceeding the daytime (7:00 am – 10:00 pm) limit of 57 dBA and nighttime (10:00 pm – 7:00 am) limit of 52 dBA set by the Montgomery County Ordinance. A similar chart for each day of the week has been included in Appendix G.

Upon examining trends at all seven days of the week the following trends appeared. At all four sites there was a substantial change in Leq in dBA and 1-minute Peak in dB, which is depicted in Table 9. The Leq values for the sites was in the mid-to-high 60s, whereas the 1-minute Peak dB values were upwards of 117 dB. A 1-minute Peak dB of 149 was measured at Site 3; however, as this reading exceeded all other readings at both Site 3 and all other sites, this 1-minute value was disregarded. For the sake of the analysis, it has been replaced with the next highest 1-minute Peak reading at Site 3. Taking that into account, 1-minute Peak dB levels were as much as 52.6 dB above the Leq measurement for the site. Site 2 had the smallest difference between Leq and 1-minute Peak values, but was still a substantial change of over 48 dB. The maximum 1-minute Peak values for each collection period are represented in Table 15.

Table 10 shows the percent exceedances of the Montgomery County Regulation over the entire collection period, both based off of Leq and 1-minute Peak values. Table 11 shows the total number of Leq exceedances of the Montgomery County Regulation broken down by site, day, and overall collection period. These values were also converted to percentages and are displayed in Table 12. Similar values calculated using 1-minute Lmax values have been included in Table 13 and Table 14. It is clear that the 1-minute Lmax values capture a better picture of the high sound levels even when they are only momentary. The Leq values provide a more conservative view of the sound levels and show less exceedances. Figure 10 shows the spread of all 1-minute Leq samples collected at Site 3 across the different dBA levels. A visual shift to the right (more intense sound) is seen from the ambient noise to the game day noise.

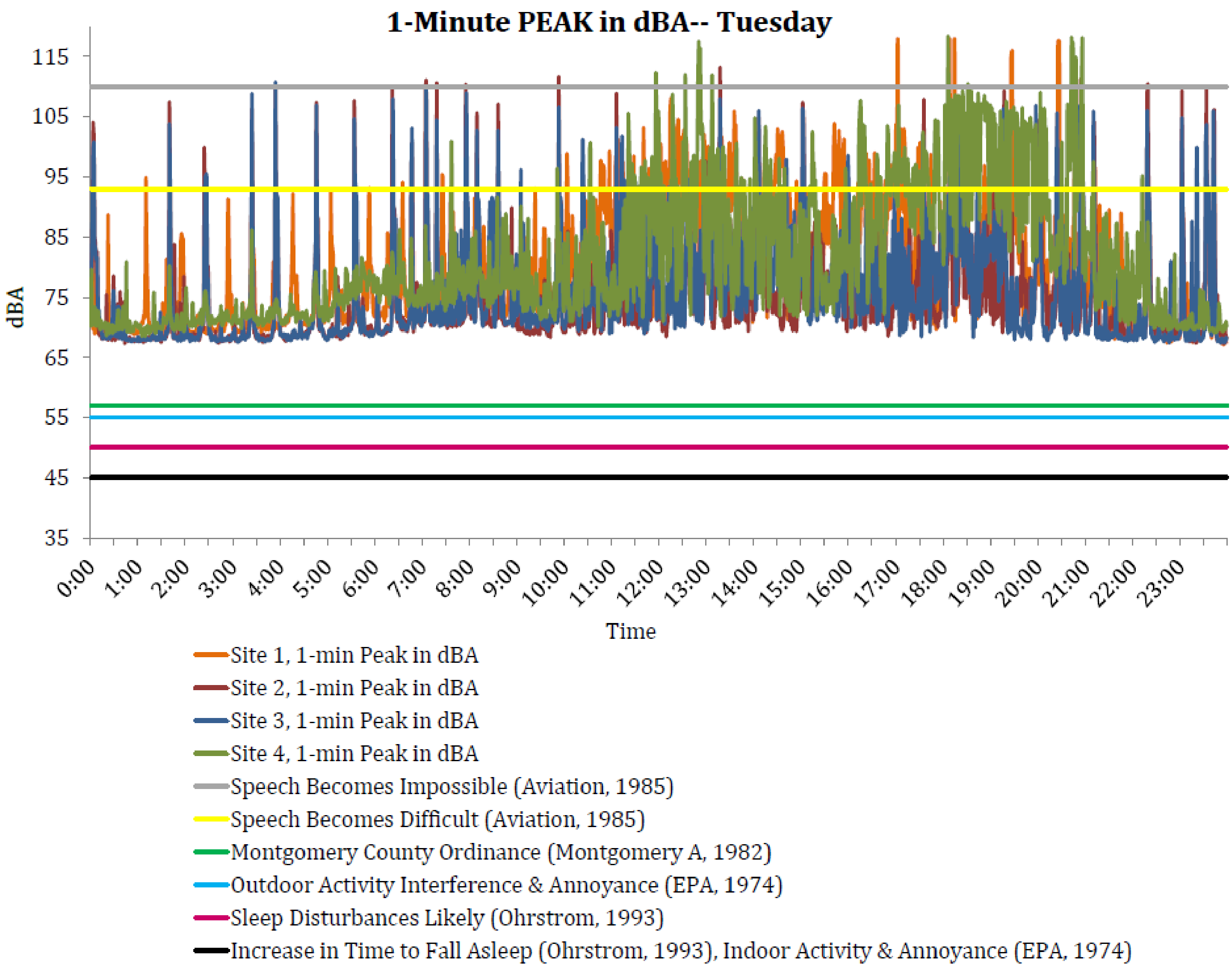

Figure 9. Chrisman Mill Railroad Crossing: A dBA comparison of ambient and train noise throughout a day in comparison to several regulation and recommended levels from human factors references.

	Site 1	Site 2	Site 3	Site 4
1-min Leq in dBA	68.9	68.9	68.9	66.4
1-min Peak dB	118*	117*	149 (118)*	119*

Table 9. Chrisman Mill Railroad Crossing: Peak levels in dB collected over the duration of this study. *substantial change of 5-15 dB, as defined by the FHAW (Use, 2006)

	Site 1	Site 2	Site 3	Site 4
1-min Leq in dBA	16%	10%	13%	13%
1-min Peak dB	95%	100%	100%	100%

Table 10. Chrisman Mill Railroad Crossing: Percent Exceedances of Montgomery County VA Noise Ordinance Limits: 57 dBA for 7AM-10PM; 52 dBA for 10PM-7AM (Montgomery County, Virginia, §7-80, 1988) for the duration of this study.

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	**Total**
Site 1	395	134	119	61	211	482	199	1601
Site 2	260	119	119	124	142	155	127	1046
Site 3	359	136	135	136	137	145	273	1321
Site 4	485	83	89	36	196	208	211	1308
Total	1499	472	462	357	686	990	810	5276

Table 11. Chrisman Mill Railroad Crossing: Number of 1-minute Leq values which exceeded the Montgomery County VA Noise Ordinance Limits: 57 dBA for 7AM-10PM; 52 dBA for 10PM-7AM (Montgomery County, Virginia, §7-80, 1988) by day and site. A day contains 1440 samples, 10080 in a week, and 40320 total.

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	**Total**
Site 1	27%	9%	8%	4%	15%	33%	14%	16%
Site 2	18%	8%	8%	9%	10%	11%	9%	10%
Site 3	25%	9%	9%	9%	10%	10%	19%	13%
Site 4	34%	6%	6%	3%	14%	14%	15%	13%
Total	26%	8%	8%	6%	12%	17%	14%	13%

Table 12. Chrisman Mill Railroad Crossing: Percent of 1-minute Leq values which exceeded the Montgomery County VA Noise Ordinance Limits: 57 dBA for 7AM-10PM; 52 dBA for 10PM-7AM (Montgomery County, Virginia, §7-80, 1988) for all 7 days collected.

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	**Total**
Site 1	730	668	567	263	684	972	513	4397
Site 2	590	292	373	239	295	306	359	2454
Site 3	898	448	373	325	502	402	597	3545
Site 4	721	641	764	509	641	694	719	4689
Total	2939	1939	2077	1336	2122	2374	2188	15085

Table 13. Chrisman Mill Railroad Crossing: Number of 1-minute Lmax dBA exceedances of the Montgomery County VA Noise Ordinance Limits: 57 dBA for 7AM-10PM; 52 dBA for 10PM-7AM (Montgomery County, Virginia, §7-80, 1988) by day and site. A day contains 1440 samples, 10080 in a week, and 40320 total.

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	**Total**
Site 1	50.7%	46.4%	39.4%	18.3%	47.5%	67.6%	35.6%	43.6%
Site 2	41.0%	20.3%	25.9%	16.6%	20.5%	21.3%	24.9%	24.4%
Site 3	62.4%	31.1%	25.9%	22.6%	34.9%	27.9%	41.5%	35.2%
Site 4	50.1%	44.5%	53.1%	35.3%	44.5%	48.2%	50.0%	46.5%
Total	51.0%	33.7%	36.1%	23.2%	36.8%	41.2%	38.0%	37.4%

Table 14. Chrisman Mill Railroad Crossing: Percent of 1-minute Lmax dBA values which exceeded the Montgomery County VA Noise Ordinance Limits: 57 dBA for 7AM-10PM; 52 dBA for 10PM-7AM (Montgomery County, Virginia, §7-80, 1988) by day and site. A day contains 1440 samples, 10080 in a week, and 40320 total.

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	**Total**
Site 1	118	118	114	103	118	118	101	118
Site 2	117	113	116	114	115	115	116	117
Site 3	117	111	109	109	111	114	149 (118)	149 (118)
Site 4	118	118	119	110	118	118	118	119
Total	118	118	119	114	118	118	149	149 (119)

Table 15. Chrisman Mill Railroad Crossing: Max L-Peak by site for each day of data collection in this study.

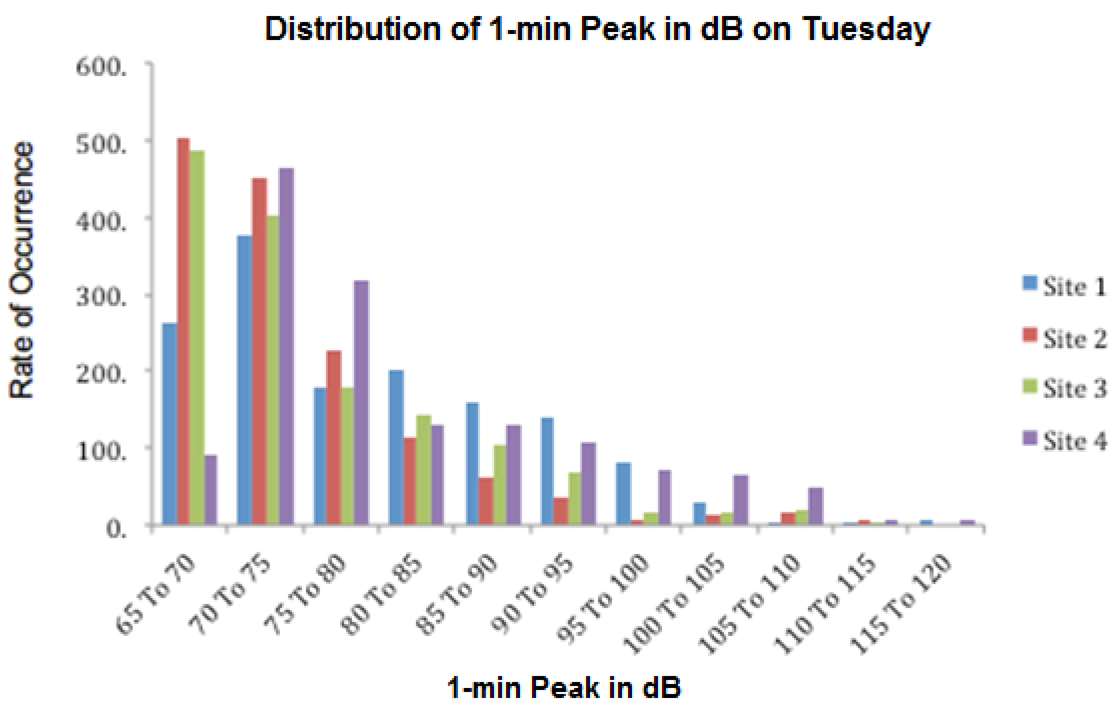

Figure 10. Chrisman Mill Railroad Crossing: dB distribution of sound at all four sites

Regulation Comparisons

The number of times the maximum allowable SPL exceeded a given regulation criterion level was counted for each data collection period (game duration or 24 hours). Out of all the samplings from the Bill Brown Stadium location, there was a substantial increase in the amount of times that the sound levels exceeded the in the Montgomery County regulation of 57 dBA for

7:00 am – 10:00 pm for these Sites 2 and 3 (Table 7). Near the Chrisman Mill Crossing the most violations of the Montgomery County regulation occurred on Monday and Sunday. In contrast, Tuesday, Wednesday, and Thursday had substantially less violations than any other days of the week (Table 12).

In the case of the football stadium, any violation of the agreed upon maximum slow levels of 65 dBA in Stroubles Mill or 70 dBA in Haymarket Square proposed by Berenato (2006) were also "legal" violations if the Montgomery County ordinance is applied as a criterion limit. Figure 11 and Figure 12 put these numbers into perspective by showing how far the noise must propagate from the collection points before it attenuates enough to be in compliance with the laws. These distances were calculated using the Inverse Distance Law, which assumes that a sound will propagate equally in all directions. This is an "ideal" calculation, meaning that if no structures existed to reflect or attenuate sound and the terrain of the land is flat, this is the distance that it would travel.

Similarly, Figure 13 shows the distance that the Leq value collected at the site nearest to the railroad intersection must propagate before it reaches the maximum permissible level as stated in the Montgomery County ordinance for both day and night (Montgomery County, Virginia, §7-80, 1988). This figure depicts a 116 dBA horn blast traveling 1339 meters before it reaches the 57dBA limit set in the ordinance, and 1468 meters before it reaches the night time limit of 52 dBA. The distances depicted in these figures were calculated using the Inverse Square Law.

As the train horn is legally excluded for any noise regulations in Christiansburg codes, anytime it exceeds the maximum sound levels of Montgomery County's noise ordinance (57 dBA Day, 52 dBA Night) is considered a community disturbance. The Town of Christiansburg Ordinance cannot be used in this case, as it simply prohibits plainly audible sounds within the home at night.

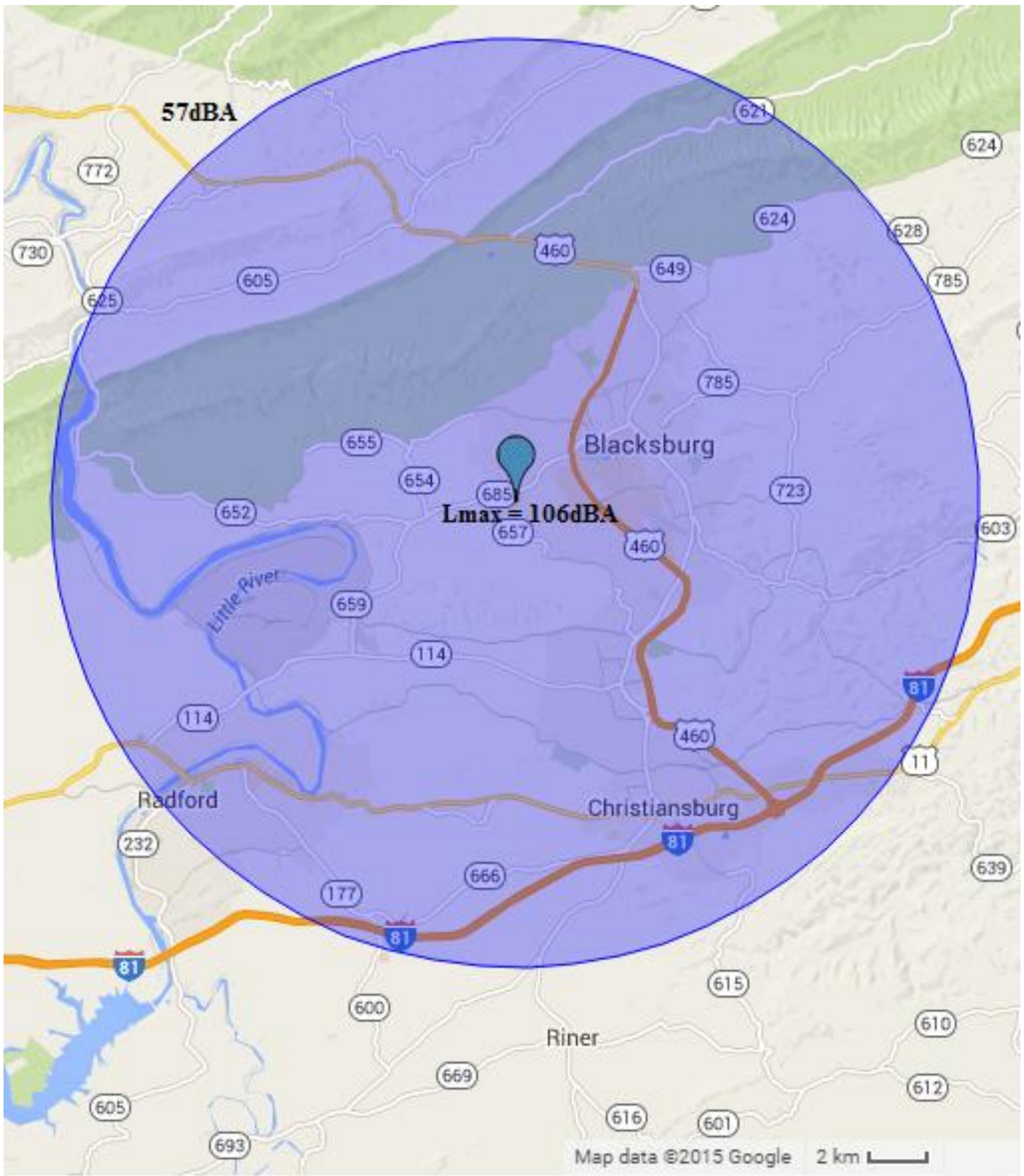

Figure 11. Stadium: Shaded ring displays distance from the stadium that the Lmax sound level propagates before it is attenuated to the level established by the Montgomery County Ordinance (57 dBA daytime limit) ("Christiansburg, Virginia", 2015). www.maps.google.com 2015, Used under fair use, 2015

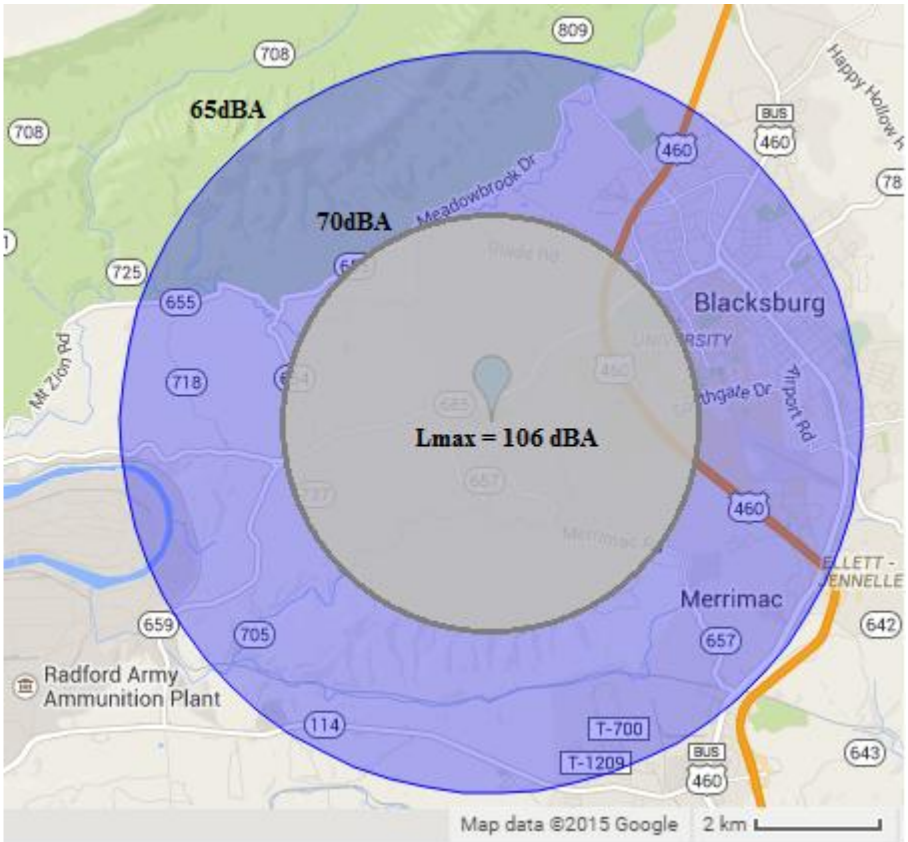

Figure 12. Stadium: Shaded rings display distance from the stadium that the Lmax sound level propagates before it is attenuated to the levels proposed by Berenato (2006) (65 dBA (blue) & 70 dBA (gray)) ("Blacksburg, Virginia", 2015). www.maps.google.com 2015, Used under fair use, 2015

Comparison in Sones

When considering the survey responses, it was helpful to relate them to the loudness of game day noise in comparison to the amount of ambient noise. For this reason, the Leq values for each site on both game day and ambient collections were converted to Sones and have been provided in able 16. On both sites 2 and 3 the Leq values for game day are 10 to 11 dBA greater than on non-game days. However, since calculating the Leq does not accurately represent how loud the peak sounds are, the 1-minute peak values on game days are also provided in sones. These sone values were calculated using the Quick A-Weighted method, where 30 dBA equals 1.5 sones, and the number of sones is doubled for each 10 dBA increase (Rossing, 1990). The peak values recorded for all three sites were over 6 times louder than the ambient sounds recorded in the community.

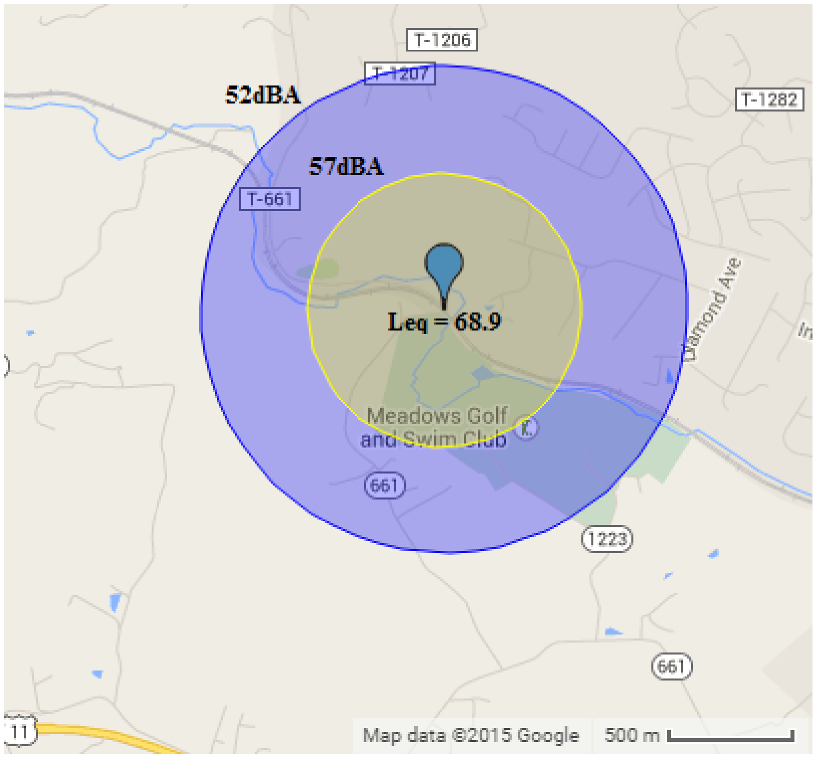

Figure 13. Chrisman Mill Railroad Crossing: Shaded rings display distance from Chrisman Mill train crossing that the Leq sound level propagates before it is attenuated to the levels specified in the Montgomery County Ordinance (57 dBA day (yellow) & 52 dBA night (blue)) ("Christiansburg, Virginia", 2015). www.maps.google.com 2015, Used under fair use, 2015

	Site 1	Site 2	Site 3
Game Day 1-min Leq	6.6 sones	5.4 sones	5.4 sones
Game Day 1-min Peak	22.8 sones	28.8 sones	26.4 sones
Ambient 1-min Leq	6 sones	3 sones	3.9 sones

Table 16. Stadium: Sone values calculated with the Quick A-Weighted Method using the 1-min Leq in dBA and 1-min Peak values in dB provided in Table 5 for the entire collection period.

A similar calculation was done on the data collected near the Chrisman Mill railroad crossing. Table 17 is a comparison of the sone conversions of the "average" Leq and maximum 1-minute Peak from each site. The train horn data that was collected for both sites 2 and 3 the 1-min Peak dB value is nearly twice that of the Leq in dBA; however, dB is not a linear measure, so sones are more useful here. All four of the collection sites show peak sound levels in sones of over 27 times louder than the ambient levels, see Table 17.

	Site 1	Site 2	Site 3	Site 4
1-min Leq in Sones	22.7 sones	22.7 sones	22.7 sones	19.7 sones
1-min Peak Sones	691.2 sones	652.8 sones	691.2 sones	729.6 sones

Table 17. Chrisman Mill Railroad Crossing: Sone values calculated with the Quick A-Weighted Method using the 1-min Leq and 1-min Peak values in dB provided in Table 10 for the entire collection period.

Qualitative Analysis

Perhaps more importantly than the "quasi-legal violations" are the effects these sounds have on the community. For example, if a sound is legal against the prevailing ordinance(s), but is conflicting with a family's ability to converse outside or to get a restful night of sleep, it is still a serious problem. Whereas if a sound is illegal (as compared to an ordinance criterion), but has no negative effects on the community, it is less of a problem. However, the likelihood of the latter case is rather small.

Time of day for the sound is also important, particularly in the case of the train horn data, where data was collected for 24 hours straight. Any sounds that occur during nighttime (10pm - 7am) may interfere with a restful night of sleep for residents and their children.

The surveys completed by the residents were analyzed using a scaling formula. In the case of the survey designed for this research project, a response of "Extremely" shows a negative effect of the noise source, where a rating of "Not At All" shows no negative effects. On this scale, there are 5 options. Each option corresponds with a number value, "Not At All" being one (1) and Extremely being five (5). There is also one question with a zero to 10 number scale. For this question, each response was counted as the number they selected divided by two, as this weighted it the same as every other question on the survey. After these points were totaled up, they were normalized by dividing the total score by the total number of available points (40 for the survey with no children responses, and 70 for the survey responses with children). This calculation results in annoyance ratings between 0 and 1. An annoyance rating of 1 is the maximum score and qualifies as the highest ranking of extremely annoyed. A lower annoyance rating is, that is to say the closer it is to 0, means that the resident filled out the survey with response that classified them as less annoyed. The area allotted for a written response was not used in the scoring of the survey, but has been used in a qualitative evaluation of the effects of the noise. The breakdown of the survey scores interpretation is displayed in Table 18.

	Extremely	Very	Moderately	Slightly	Not At All
No Children	Above 0.7	0.525 – 0.7	0.35 – 0.525	0.2 - 0.35	Below 0.2
Children	Above 0.74	0.557 – 0.74	0.37 – 0.557	0.2 – 0.37	Below 0.2

Table 18. Breakdown of the rating scale points for each descriptor of the Rating Scale used to obtain residents' subjective impressions of the noises' effects.

These breakdowns are based upon the average survey score if all responses were of one type (ie - Moderately). The value which would be obtained by all responses of this type are the upper cutoff for that categorization, to be conservative. For example, if a respondent selected Moderately for most questions but answered any one question with Extremely or Very, that would place them in the Very category for an overall survey response. By using this conservative approach, we ensure that we do not underestimate how much a resident is bothered, and any responses of Extremely or Very should be addressed as major intrusions into their lives.

Bill Brown Stadium – Qualitative Analysis

Location	Number of Surveys Collected	Percent Female	Average Age	Duration in Home	Avg. Annoyance Rating	Avg. Annoyance Rating w/ Children
Site 1	10	63.6%	61 years	19.2 years	**Slightly** (0.30)	**Not at All** (0.19)
Site 2	10	63.6%	51 years	8.0 years	**Slightly** (0.22)	**Slightly** (0.22)
Site 3	10	83.3%	39 years	7.3 years	**Slightly** (0.21)	**Not at All** (0.19)
Overall	30	70.6%	52 years	11.2 years	**Slightly** (0.25)	**Slightly** (0.20)

Table 19. Stadium: The demographic breakdown of survey participants and survey ratings by site.

On average, each of the collection locations was rated a score of "slightly annoyed," as shown in Table 19. When only the survey responses including responses to the questions pertaining to children in the household are considered, the annoyance level increases slightly. While both Site

1 and 3 report a Not at All annoyance level, Site 2 reports a Moderate level of annoyance. Their responses were significant enough to raise the average for all surveyed up to the Moderate level of annoyance.

Those surveyed seem to fall into one of two groups. The first group had a dislike for the effects of the stadium and said things such as “neighborhood input was basically ignored in all planning” and “they took off more than 12 feet from the hill.” Or “A lot louder this year than last year.” The second group felt positively about having a high school football stadium in their neighborhood and expressed themselves with statements such as “We live in a community. School sports make noise. It’s good noise.”

All of the groups surveyed ranked Outdoor Leisure Activities (BBQs, playing sports, gardening, lawn work, etc.) as one of the most affected activities. Site 1 and Site 3 rated it as when they are most annoyed by noise from the stadium. Site 2 also rated it highly, but members of this group said that they were more annoyed while Working or Studying, and most annoyed when they were having Outdoor Conversations. For the responses to the level of interruption to activities of the children, none of the categories stood out as being reported as substantially more or less annoyed or bothered than the others.

All of the groups surveyed felt that they did not have control over the noise produced from the football games at the Bill Brown Stadium. Their reported lack of control paired with their reported low annoyance is contrary to what was expected. This finding is possibly a side effect of the football games’ predictability and short duration. However, they did report that they felt the noise produced from the football games was necessary. This could contribute to the lower ratings of annoyance, as they understood and, as some survey comments reported, even enjoyed the football game noise.

Interestingly, there is a positive relation between the age of the respondents, how long they have lived in their current house, and their annoyance score. These demographic features are presented in Table 19. Future studies should investigate whether this effect is caused by demographic factors or if they simply happen to correlate. It is suspected that duration living in their home would be the biggest factor in being annoyed at the introduction of a new sound.

Chrisman Mill Crossing – Qualitative Analysis

Location	Number of Surveys Collected	Percent Female	Average Age	Duration in Home	Avg. Annoyance Rating	Avg. Annoyance Rating w/ Children
Site 1	11	27.3%	55 years	12.7 years	**Slightly** (0.32)	**Moderately** (0.38)
Site 2	11	18.2%	55 years	10.1 years	**Very** (0.57)	**Moderately** (0.51)
Site 3	11	63.6%	56 years	16 years	**Moderately** (0.37)	**Slightly** (0.36)
Site 4	11	45.5%	41 years	5.3 years	**Slightly** (0.22)	**Slightly** (0.23)
Overall	44	38.6%	52 years	11 years	**Moderately** (0.37)	**Slightly** (0.37)

Table 20. Chrisman Mill Railroad Crossing: The demographic breakdown of survey participants and survey ratings by site.

In contrast to the Bill Brown Stadium findings, the Chrisman Mill railroad crossing average annoyance ratings differ. Near the railroad crossing, those who have lived in their homes for the shortest duration reported a higher level of annoyance, see site 4 in Table 20. However, even those who have lived in their homes for the longest duration, Site 2, still scored moderately high on the annoyance rating scale

The annoyance ratings for the Chrisman Mill crossing area averaged a Moderately Annoyed rating. Site 2 reported the highest annoyance level of Very Annoyed. Site 4 ranked the lowest on the annoyance scale with only a Slightly Annoyed rating. However, out of all the locations, Site 4 was the furthest from the train tracks. Responses including responses for the annoyance levels of children were also in the same ranges, but scored a slightly lower average of "slightly annoyed."

Those surveyed in the area surrounding the Chrisman Mill train expressed feelings that "the train horn seems very loud and unnecessary." They reported taking steps to decrease the noise in their house, such as keeping the windows closed. Furthermore, they were concerned that their guests would not be adapted to the noise produced by the train, as well as reporting that young children were bothered by and often scared of the noise.

On average, the groups surveyed near Chrisman Mill felt that Outdoor Activities, Sleeping, Working and Studying, and Outdoor Conversations were all very affected by the sound produced by the train. The least affected activities were reported as Indoor Activities and Indoor Conversations. This was expected, as the house walls, windows, and doors do provide some attenuation to the train noise, as compared to the outside noise in the same location. While

Sleeping and Working do often take place inside the home, they typically required a quieter atmosphere than other common household activities.

Comparison of the Two Sounds

	Train Horn	Football Game
Control	Slightly (1.5 / 5)	Slightly (1.7 / 5)
Necessary	Moderately (2.8 / 5)	Very (3.5 / 5)
Predictable	Not Predictable	Predictable
Time Affected	All of the Time	Limited Window of Time
Avg. Time in Home	11 Years	11.2 Years
% Female	38.6%	70.6%
% Male	61.4%	29.4%
Avg. Age	51.5 Years	52 Years
Avg. Annoyance Rating (rang of 0 to 1)	Moderately (0.37)	Slightly (0.25)
Difference Between Leq & 1-min Peak in Sones	669.3 Sones	20.2 Sones
1-min Leq's in dBA	68.4 dBA	49.2 dBA
1-min Leq ambient in dBA	-	46 dBA
1-min Lmax in dBA	112 dBA	72 dBA
1-min Lmax ambient in dBA	-	68 dBA

Table 21. Displays key overview metric comparisons for the Chrisman Mill Train Horn and the Bill Brown Football Stadium noise collections & qualitative survey responses. All Leq values are logarithmic averages for the entire collection period. All Lmax values are the maximum value recorded over the entire collection period.

When comparing the analysis of the two locations, there are some key similarities and differences which are highlighted in Table 21. From a demographic standpoint, the groups of residents who participated in the surveys are similar between the two groups. They have both lived in their homes for an average of 11 years and are an average of approximately 52 years old. However, the gender ratios between the two locations were nearly opposite each other, with more women responding for the Bill Brown Stadium survey and more men responding for the Chrisman Mill Train Crossing. It is believed that this difference occurred on account of a difference in the gender ratio of people answering their doors, not a difference in a certain gender declining to answer the survey.

The characteristics of the sounds between the two locations are very different, and of course, this was one reason why the two sound sources were selected originally. The train horn was an uncontrollable noise that was not predictable, and occurred through a continuous timeframe. In contrast, the sound produced from the Bill Brown Football Stadium was more controllable, more predictable, and only affected a short time period that was scheduled. The residents surveyed also felt that the noise produced by the football game was more necessary than the noise produced by the train horn. From these standpoints, it was expected that residents living near the Chrisman Mill Railroad Crossing would be more annoyed than those living near the Bill Brown Stadium.

That is just what the surveys found. On the annoyance scale used in the survey analysis, residents near the Chrisman Mill Railroad Crossing were nearly *two and a half times more annoyed* than residents near the Bill Brown Football Stadium. It is important that we also consider the difference in the levels of sound emitted from the two sources, which greatly differs between the two locations. While each location had a 1-minute peak value significantly greater than the ambient sound in the community, the difference in sound loudness experienced near Chrisman Mill is over 33 times greater on the sone scale than the difference in sound experienced near the football stadium.

RECOMMENDATIONS

For Elimination or Reduction

It is critical that actions are taken to eliminate or reduce these sources of community noise. As previously discussed, there are numerous negative side effects to excessive noise levels. These side effects include the "disturbance of rest and relaxation, difficulty in falling asleep and awakening" (Bjorkman, 1991). They may make it difficult or even impossible for nearby residents to enjoy activities as "radio and television listening, conversations, sleep, and rest and relaxation" (Jue, 1984), plus it can also impair learning (Evans, 2000). They can even be a cause of "poorer subjective general health" of those exposed (Smith, 1986). Noise exposure can elevate blood pressure, which in turn can cause cardiovascular disease (Talbott, 1995). These effects even extend beyond the residents themselves and into the value of their property, as legal courts have recognized the detriment to private land that can be caused by public nuisances (Keeton, 1984).

When sound levels are too high in an industry setting, OSHA requires the use of administrative and/or engineering approaches to reduce the exposure to the worker. A similar approach in the cases of community noise here is recommended. However, the definitions differ slightly as the situation and goals of the noise reduction are different in the community setting. Berglund also identifies three stages of community noise abatement which have been used as guidance in these recommendations (1995).

1. At-Source Abatement - Reducing sound coming from the source itself
2. Community Protection - Providing screens and vegetation to reduce sound propagation
3. Private Protection - Use of sound insulating windows

Similarly to the 5 Human Factors and Engineering Society Steps to reducing hazards (Design, Remove, Guard, Warn, Train), at-source abatement is preferred, then community protection. Private protection should be a last resort effort to reduce sound.

Christiansburg

This research has shown that a 116 dBA horn blast travels 1339 meters before it diminishes to the 57dBA limit set in local ordinance for daytime sound levels, and 1468 meters before it reaches the night time limit of 52 dBA (Montgomery County, Virginia, §7-80, 1988). This means that not only are residents who live right to the railroad crossing affected by these extreme sound levels, but all residents who live within that radius are affected as well. These train horn blasts were found to be over 27 times louder than the ambient levels in this community. Not only are these levels extreme for this neighborhood, but they are also extreme when talking about noise exposure in general.

Administrative Noise Reduction

Changes can be made to applicable regulations to reduce or eliminate the levels of sound produced by the train horn. This would reduce the amount of sound produced from the source, and if the sound was strictly prohibited, there would not be a need for additional noise reduction measures. A lower output at the source will travel less distance and be quieter in the community. It would also pair well with additional measures which may make less of an impact in reducing the dB level, but when they are all implemented simultaneously the reduction levels are combined.

Changing the times in which loud noises are allowed would have a similar effect for the night time hours. Whether this means banning the offending sounds all together during nighttime hours or simply reducing its volume to a more reasonable level, perhaps by the use of bells at the railroad crossing instead of a train horn, it would improve the noise produced during those hours. Unfortunately any improvements made to the noise levels produced during the nighttime hours do not improve conditions for the remainder of the day, when it may have a negative impact on the social lives, enjoyment of property, studying, or other activities.

It has also been shown that the intensity of railway noise can be reduced by the speed of the train and quality, or lack thereof, of the train tracks (Muzet, 2007). While improving the quality of the train tracks would be a highly expensive and time consuming task, requiring lower speeds through towns (at least a night-time) would aid in train noise reduction. Of course, this makes no difference in the peak level sounds that are produced by the train horn, but it would be an additional step to take toward a quieter community.

Engineering Noise Reduction

The best solution would be to completely guard drivers from crossing trails, while also reducing noise as much as possible for the surrounding community members. The guards at Chrisman Mill could be enhanced by upgrading the two-quadrant gates to four-quadrant gates, which would block off traffic on both sides of the road on both the entrance and exit sides of the intersection, in conjunction with barriers which prevent a driver’s ability to drive around the closed gates. Because Chrisman Mill road narrows at the intersection of the railway, a median barrier or channelization device has not been recommended, as that would require the current roadway to be widened. To accomplish this, the use of a "Quiet Zone," which would ban the use of train horns, in conjunction with reducing the speed of the train would greatly reduce the sound levels produced. In Assiut, Egypt, these measures, along with a noise barrier, produced substantial noise abatement. The barrier reduced sound by 12.7 dB, a speed reduction of 100km/h to 20 km/h reduced sound by 10.1 dB, and moving the tracks from 50 m to 100 m away from noise sensitive buildings reduced sound by 4.3 dB (Ali, 2005). However, in the case of the Chrisman Mill railroad crossing, a noise barrier, such the sound walls used along interstates that run near residential areas or several rows of mature evergreen trees, is *not* recommended as it would be ineffective due to the train horn's high dB level and close proximity to homes.

Private Protection

Within the homes there are a few steps residents can take to lessen the intensity of the sound, but these should only be used as a last effort in reducing noise levels, as they are not ideal. Residents could install sound insulating windows in their home; however, this would only aid in noise reduction while the windows remain closed. This method is not preferred because it places costs and labor directly upon the residents and it also does not increase the usability of the property, only within the house. In some cases, such as when airports allow larger aircraft to land, the residents may receive funding to help offset the costs of these home upgrades.

<u>Blacksburg</u>

This study found that the 1-minute peak sounds produced by the football games at the Bill Brown Stadium were over five times louder than the ambient Leq levels within the community. These noises must travel up to 858 meters into the community before they attenuate to the levels agreed upon by Berenato. They have to travel even further, up to 2156 meters, before they reach the 57 dBA daytime limit set forth by Montgomery County (Montgomery County, Virginia, §7-80, 1988).

Administrative Noise Reduction

Changes can be made to applicable regulations to reduce the levels of sound produced by the Bill Brown Stadium. The sound level output by the loudspeakers could be reduced, and the low frequency sounds could be reduced or eliminated, as they will travel the furthest into the community. This would reduce the amount of sound produced from the source, which could be further reduced by the use of additional noise reduction measures

Countermeasures Against the Noise

Improvements could be made at the stadium to help reduce the distance in which the sound will propagate. For instance, the loud speakers should be directed away from the residential areas and low frequency sounds should be reduced as much as possible, as they will travel much further into the community.

Build noise barriers, such as the sound walls used along interstates that run near residential areas, would also be useful in reducing the sound propagation into the community. Vegetation may also be used to help reduce noise; however, such a barrier must be thoughtfully constructed. It is also important to keep in mind that vegetation often is not particularly effective at reducing sound propagation into the properties of nearby residents, especially if deciduous trees are used, as they only have leaves for part of the year (Piercy, 1991). Furthermore, evergreens must be multi-row and very mature, high trees to have any effectiveness (Piercy, 1991). In the case of highway traffic noise, the FHWA recommends a solid barrier that will attenuate sound by at least 5dB. This approach could also be used near the Bill Brown Football Stadium.

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PERMISSION TO ENTER PRIVATE PROPERTY

Permission is hereby granted to Aubrey A. Baker, graduate student at Virginia Tech, and any other researchers affiliated with her project, to enter the property located at:

____ Blacksburg, Virginia 24060

for the purpose of gathering sound level measurements with the use of a Noise Dosimeter. This device solely records the level of sound intensity and will, under no circumstances, make recordings of any sounds. Additionally, measurements will be taken to determine the distance of the selected measurement site from the Bill Brown Football Stadium.

Furthermore, your name and street address will both remain private and unaffiliated with any data that is collected as part of this study.

I understand the above statements and have full authority to grant such permission on this property. If at any time I have any questions, concerns, or wish to revoke the right to enter this property, I will contact Ms. Baker at the email or phone number provide below.

Signature:_________________________ Print Name:______________________ Date: ________
Phone: ___________________________ Email: __________________________

[ ] I prefer to be notified at least two (2) days prior to any instance where the above mentioned parties will be entering this property.

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PERMISSION TO ENTER PRIVATE PROPERTY

Permission is hereby granted to Aubrey A. Baker, graduate student at Virginia Tech, and any other researchers affiliated with her project, to enter the property located at:

____ Christiansburg, Virginia 24073

for the purpose of gathering sound level measurements with the use of a Noise Dosimeter. This device solely records the level of sound intensity and will, under no circumstances, make recordings of any sounds. Additionally, measurements will be taken to determine the distance of the selected measurement site from the Chrisman Mill train tracks.

Furthermore, your name and street address will both remain private and unaffiliated with any data that is collected as part of this study.

I understand the above statements and have full authority to grant such permission on this property. If at any time I have any questions, concerns, or wish to revoke the right to enter this property, I will contact Ms. Baker at the email or phone number provide below.

Signature:________________________ Print Name:______________________ Date: ________
Phone: ___________________________ Email: __________________________

[ ] I prefer to be notified at least two (2) days prior to any instance where the above mentioned parties will be entering this property.

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Appendix C - Stadium: Noise Annoyance Survey

Thinking about the last month, when you are here at home, how much does noise from the football games at the Bill Brown Stadium bother, disturb, or annoy you?

Extremely	**Very**	**Moderately**	**Slightly**	**Not At All**

In regards to yourself, here at home in the past month, how often are the following activities disrupted, delayed or terminated on account of the noise from football games at the Bill Brown Stadium?

Indoor Leisure Activities (watching TV, listening to the radio, playing games, reading books, etc.)	**Extremely**	**Very**	**Moderately**	**Slightly**	**Not At All**
Outdoor Leisure Activities (BBQs, playing sports, gardening, lawn work, etc.)	**Extremely**	**Very**	**Moderately**	**Slightly**	**Not At All**
Sleeping	**Extremely**	**Very**	**Moderately**	**Slightly**	**Not At All**
Working or Studying	**Extremely**	**Very**	**Moderately**	**Slightly**	**Not At All**
Indoor Conversations	**Extremely**	**Very**	**Moderately**	**Slightly**	**Not At All**
Outdoor Conversations	**Extremely**	**Very**	**Moderately**	**Slightly**	**Not At All**

Next is a 0 to 10 opinion scale for how much the Bill Brown Stadium noise bothers, disturbs or annoys you when you are here at home. If you are not at all annoyed choose 0, if you are extremely annoyed choose 10, if you are somewhere in between choose a number between 0 to 10. Think about the last month, what number from 0 to 10 best shows how much you are bothered, disturbed, or annoyed by the Bill Brown Stadium football game noise?

0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Not At All Annoyed										Extremely Annoyed

Do you feel that you have control over the noise produced from the football games at the Bill Brown Stadium?

Extremely **Very** **Moderately** **Slightly** **Not At All**

Do you feel that the noise produced from the football games at the Bill Brown Stadium is necessary?

Extremely **Very** **Moderately** **Slightly** **Not At All**

In this section we would like you to respond to the questions from your child(ren)'s perspective. If you do not have children, please skip this question. In regards to the children in your household, here at home in the past month, how often are the following activities disrupted, delayed or terminated on account of the noise from football games at the Bill Brown Stadium?

Indoor Leisure Activities (watching TV, listening to the radio, playing games, reading books, etc.)	**Extremely** **Very** **Moderately** **Slightly** **Not At All**
Outdoor Leisure Activities (BBQs, playing sports, gardening, lawn work, etc.)	**Extremely** **Very** **Moderately** **Slightly** **Not At All**
Sleeping	**Extremely** **Very** **Moderately** **Slightly** **Not At All**
Working or Studying	**Extremely** **Very** **Moderately** **Slightly** **Not At All**
Indoor Conversations	**Extremely** **Very** **Moderately** **Slightly** **Not At All**
Outdoor Conversations	**Extremely** **Very** **Moderately** **Slightly** **Not At All**

If you wish to share comments, stories or opinions in regards to the noise from the football games at the Bill Brown Stadium, please do so here.

Thinking about the last month, when you are here at home, how much does noise from the train and train horn bother, disturb, or annoy you?

Extremely **Very** **Moderately** **Slightly** **Not At All**

In regards to yourself, here at home in the past month, how often are the following activities been disrupted, delayed or terminated on account of the noise from train and train horn?

Indoor Leisure Activities (watching TV, listening to the radio, playing games, reading books, etc.)	**Extremely** **Very** **Moderately** **Slightly** **Not At All**
Outdoor Leisure Activities (BBQs, playing sports, gardening, lawn work, etc.)	**Extremely** **Very** **Moderately** **Slightly** **Not At All**
Sleeping	**Extremely** **Very** **Moderately** **Slightly** **Not At All**
Working or Studying	**Extremely** **Very** **Moderately** **Slightly** **Not At All**
Indoor Conversations	**Extremely** **Very** **Moderately** **Slightly** **Not At All**
Outdoor Conversations	**Extremely** **Very** **Moderately** **Slightly** **Not At All**

Next is a 0 to 10 opinion scale for how much the train and train horn noise bothers, disturbs or annoys you when you are here at home. If you are not at all annoyed choose 0, if you are extremely annoyed choose 10, if you are somewhere in between choose a number between 0 to 10. Think about the last month, what number from 0 to 10 best shows how much you are bothered, disturbed, or annoyed by the train and train horn noise in the area surrounding your home?

0 **1** **2** **3** **4** **5** **6** **7** **8** **9** **10**

Not At All Annoyed — Extremely Annoyed

Do you feel that you have control over the noise produced from the train and train horns in the area surrounding your home?

Extremely **Very** **Moderately** **Slightly** **Not At All**

Do you feel that the noise produced from the train and train horn in the area surrounding your home is necessary?

Extremely **Very** **Moderately** **Slightly** **Not At All**

In this section we would like you to respond to the questions from your child(ren)'s perspective. If you do not have children, please skip this question. In regards to the children in your household, here at home in the past month, how often are the following activities disrupted, delayed or terminated on account of the noise from the train and train horn in the area surrounding your home?

Indoor Leisure Activities (watching TV, listening to the radio, playing games, reading books, etc.)	**Extremely**	**Very**	**Moderately**	**Slightly**	**Not At All**
Outdoor Leisure Activities (BBQs, playing sports, gardening, lawn work, etc.)	**Extremely**	**Very**	**Moderately**	**Slightly**	**Not At All**
Sleeping	**Extremely**	**Very**	**Moderately**	**Slightly**	**Not At All**
Working or Studying	**Extremely**	**Very**	**Moderately**	**Slightly**	**Not At All**
Indoor Conversations	**Extremely**	**Very**	**Moderately**	**Slightly**	**Not At All**
Outdoor Conversations	**Extremely**	**Very**	**Moderately**	**Slightly**	**Not At All**

If you wish to share comments, stories or opinions in regards to the noise from the train and train horn, please do so here.

Montgomery County Public Schools
Facilities and Planning Department
1175 Cambria Street, Christiansburg, VA 24073
Telephone: 540-382-5141 Fax: 540-381-6118

August 31, 2006

Received 9-6-06

Mr. Brandol Harvey
Chief of Planning
Department of Planning and Engineering
Town of Blacksburg
300 South Main Street
P.O. Box 90003
Blacksburg, VA 24062-9003

RE: Stadium SUP 05-012

Dear Mr. Harvey,

The following is a list of conditions that the school system is willing to comply with to further reduce the impact of the stadium at the proposed site. We hope that you can see that we have listened to the concerns that neighbors have expressed and that we have made a good faith effort to work with the community to alleviate their concerns.

-The School System will restrict use of the stadium Public Address (PA) system to school events only, reducing potential usage by about 40%.

-The School System doesn't use a "buzzer" at the stadium, but we will be happy to discuss and mitigate whatever sound is being perceived as a buzzer. We agree not to use a "buzzer" at the stadium.

-The School System agrees to change the type and height of the stadium PA speakers. They will be lower powered, and lower mounted than originally submitted. The PA system will be equipped with a real time analyzer connected to a remote microphone so the PA system operators can see what the levels of sound are in the stadium. The PA system will also be equipped with a multi band graphic equalizer on the mixing console, so we can control low frequencies. The speakers will be no more powerful than the one shown on the attached cut sheet, and be located generally as shown on the attached stadium profile. We will have a person present at each game that is designated to monitor and control the PA system, and to adjust the volume to the minimum level required for the situation.

-We would agree with the following daytime (until 10PM) limits for PA system sound at the residential neighborhood property boundaries:

	Stroubles Mill	Haymarket
One minute average level	60 dB(A)	65 dB(A)
Maximum Slow	65 dB(A)	70 dB(A)

-We will agree not to use the PA system before 1PM or after 10PM except if required in an emergency of health or safety.

-We agree to limit the playing of recorded music on the PA system to the national anthem.

- We will agree not to allow the use of the stadium on Sundays by any non-school user. There will not be any regularly scheduled games on Sundays. The School System will only use the stadium on a Sunday in the event that a Saturday state finals game is rained out and specific approval is given by the Virginia High School League to play the game on the following Sunday.

-We will provide a **future** 75 foot wide buffer yard (2.5x the current requirement of 30 feet) with 8 foot high and 32 foot wide earth berm with trees on the slopes and at the top, and a 6 foot high chain link fence, all along the eastern property line adjacent to the homes on Tall Oaks Drive. The berm, fence and landscaping will be constructed if and when a school is developed on the site. This buffer yard will count as our buffer yard and as contiguous green space. We will only use the 13 feet of grass on the school side of the berm and fence as part of a cross country course that the schools can use. We can leave the first 30 feet adjacent to the Tall Oaks lots undisturbed and essentially add 30 feet to each backyard that the homeowners can use now and plant with trees now as a "hedge" for possible future development. We will provide a use easement for this purpose. Further, we commit to any future school development of the site to be in the landscaped character of the adjacent neighborhoods. If a school is developed at the site, we will provide 10% more trees than the minimum requirement.

-We will not build or provide road access to the Heathwood neighborhoods' internal roads and streets from the site.

-We will use the MUSCO Light Structure Green sports lighting as previously proposed for the field lighting. It will be mounted no higher than 80 feet above the playing surface on four poles. It is cut off, night-sky-friendly lighting and allows less than .26% of the light to go above the horizontal.

Thank you for this opportunity to summarize these conditions.

Sincerely,

Daniel A. Berenato

Cc Dr. Tiffany Anderson

Community
PROFESSIONAL LOUDSPEAKERS

R.5HP

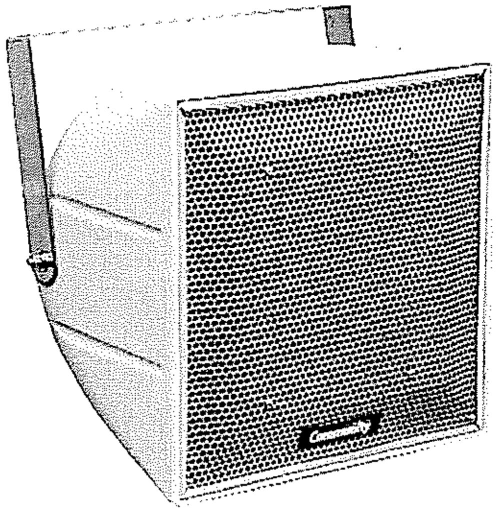
3-WAY HORN LOADED WEATHER RESISTANT FULL-RANGE LOUDSPEAKER

SPECIFICATIONS (See notes 1 and 2)

Loudspeaker Type: 3-way, Horn-loaded co-axial, weather resistant
Operating Range: 90 Hz - 16 kHz
125 Hz - 12500 Hz (+/-6dB)
Max Input Ratings: 200W continous, 500W program
35 volts RMS, 77 volts momentary peak
Recommended Power Amplifier:
420W to 600W @ 6 Ohms
Sensitivity 1W/1m:
106 dB SPL (125 Hz - 10 kHz 1/3 octave bands)
107 dB SPL (250 Hz - 4 kHz speech range)
Maximum Output: 129 dB SPL / 136 dB SPL (peak)
Nominal Impedances: 6 Ohms
Min Impedance: 3.2 Ohms @ 11220 Hz
Nominal -6dB Beamwidth:
60° H (+32° / -17°, 2 kHz - 10 kHz))
40° V (+33° / -1°, 2 kHz - 10 kHz)
Axial Q / Di: 20.5 / 13.1, 2 kHz - 12.5 kHz
Crossover Frequency: 600 Hz / 4 kHz
Recommended Signal Processing:
70 Hz high pass filter
Drivers: LF (1) 12" weather-treated, Ferrofluid-cooled
MF (1) M200A, Ferrofluid-cooled
HF (1) 1" exit, Titanium free, Ferrofluid-cooled
Driver Protection: None
Input Connection: 12' /4m SJOW #16 Gauge
Controls: None
Enclosure: Roto-molded gray polyethylene
Mounting / Rigging Provisions:
(5) 3/8-16 rigging points
Grille: 3-layer Weather-Stop™
(Perforated steel, foam, stainless steel mesh)
Required Accessories: None
Supplied Accessories:
Yoke bracket, brushed stainless steel
Optional Accessories:
TRC400 transformer (400W 70/100/140V)
Dimensions:
Height: 16 in / 406 mm
Width: 16 in / 406 mm
Depth: 16 in / 406 mm
Weight: 42 lb. / 19 kg
Shipping Weight: 49 lb / 22.2 kg

1 Sensitivity: Free field pink noise measurement at 40 ft / 12.2 m at 60% power; extrapolated to 1 meter and an input of 2.45 volts RMS.

2 Watts: All wattage figures are calculated using the rated nominal impedance



FEATURES:

- Roto-molded, UV Enclosure
- Pattern Control down to 630 Hz
- High Efficiency
- Integral Mounting Points
- High Power Passive Crossover

APPLICATIONS:

- Primary Loudpeakers for Stadia, Athletic Fields and Arenas
- Outdoor Background Music / Paging Systems
- Theme and Amusement Parks
- Fairgrounds, Rodeos, Air Shows
- Malls, Cruiseships, Skating Rinks
- Swimming Pools, Convention Centers
- Portable Sound Systems
- Race Track Catch Fence Systems

DESCRIPTION:

The R.5HP is a three-way horn loaded weather-resistant loudspeaker system engineered to provide maximum intelligibility from a most compact design. By the packaging of Community's well-known M200A midrange driver coaxially within the mouth of the 12" LF horn, an extremely powerful tool for voice announcement systems was created. High frequencies are handled by Community's non-metallic diaphragm UC1 1" exit HF driver. The M200A/UC1 creates effortless voice-power with HF sparkle that must be heard to be appreciated. No longer do audiences need to experience the unpleasant sound of "honky" re-entrant paging horns. The R.5HP can act as both a musical entertainment loudspeaker and a voice PA loudspeaker simultaneously. Each system is backed by Community's five-year warranty.

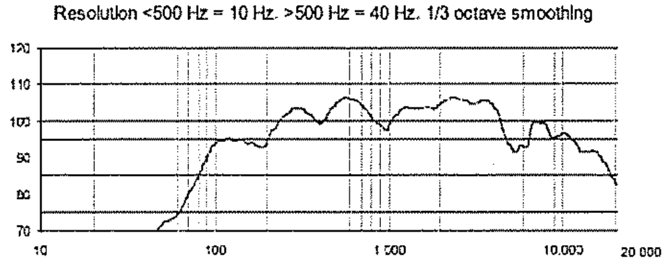
COMMUNITY PROFESSIONAL LOUDSPEAKERS
333 East 5th Street, Chester, PA USA 19013-4511 TEL (610) 876-3400 FAX (610) 874-0190
www.loudspeakers.net

Community
PROFESSIONAL LOUDSPEAKERS

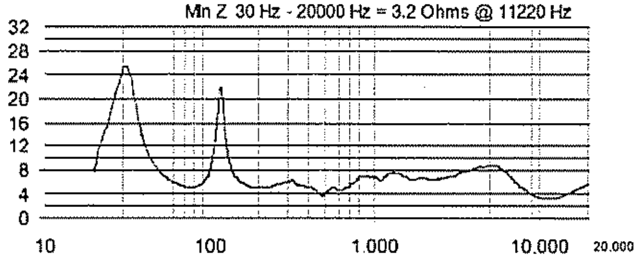
R.5HP

3-WAY HORN LOADED WEATHER RESISTANT
FULL-RANGE LOUDSPEAKER

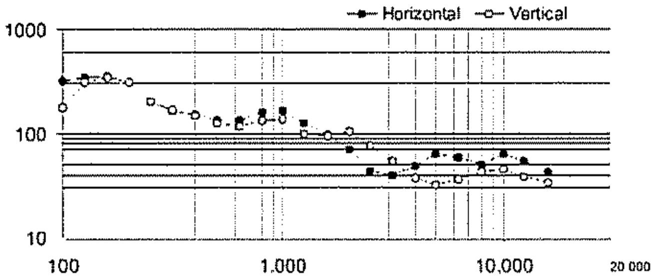
Frequency Response



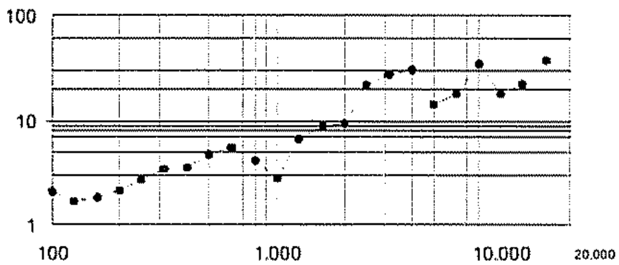
Impedance



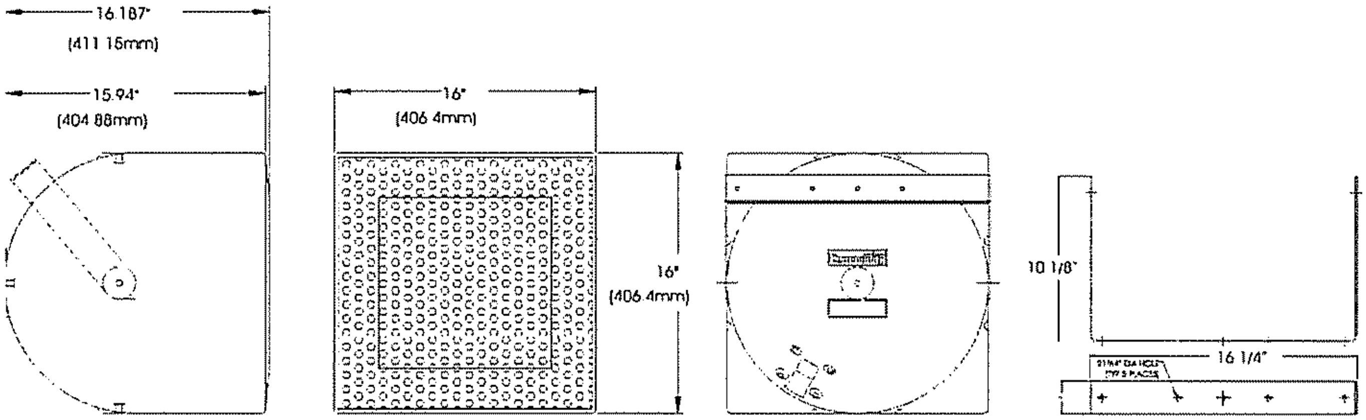
Beamwidth



Axial Q



Dimensions



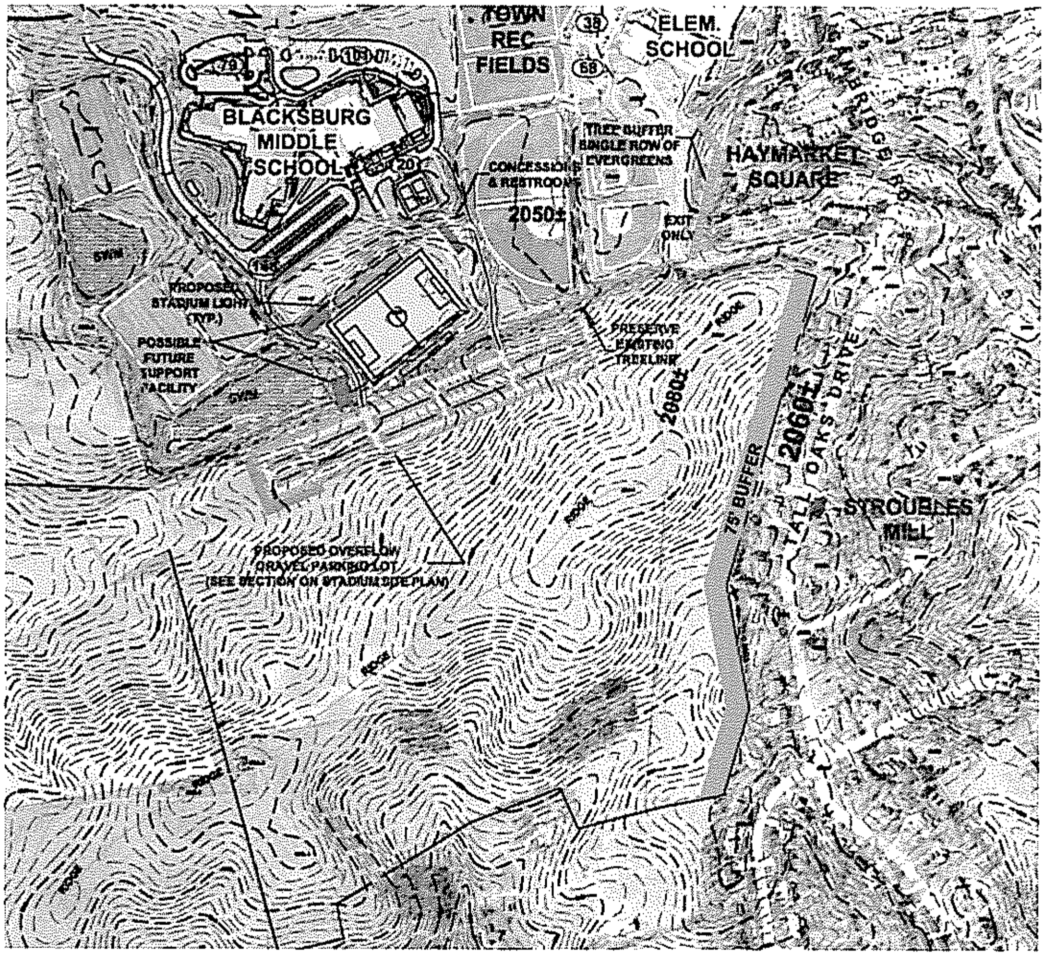
SIDE VIEW FRONT VIEW REAR VIEW YOKE

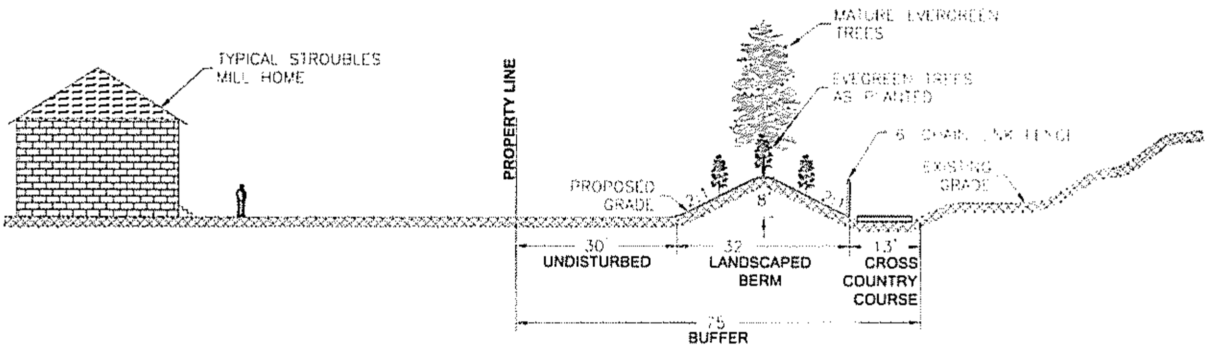
Architects' and Engineers' Specifications

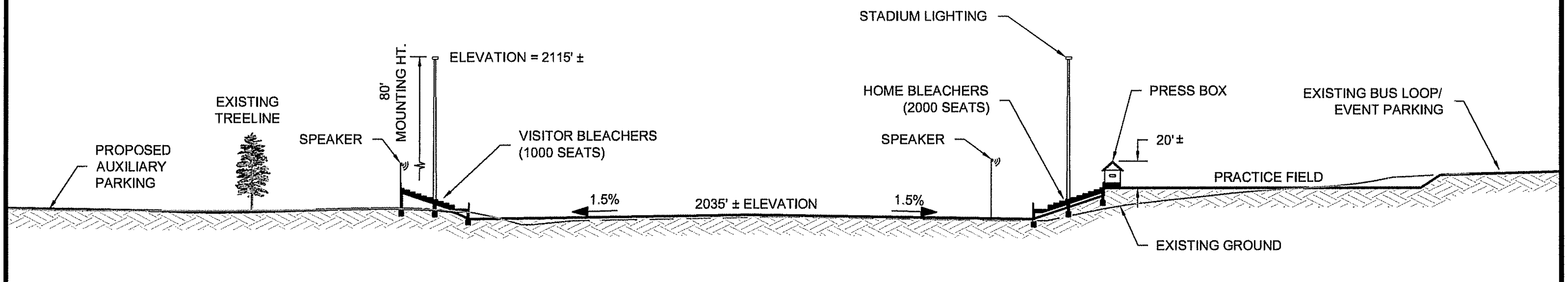
The loudspeaker system shall be a horn-loaded, three-way, coaxial design consisting of one 12" Ferrofluid-cooled driver, one M200A Ferrofluid-cooled compression driver, and one 1"exit compression driver mounted on a horn inside the cabinet. The drivers shall be connected to a passive crossover network with crossover frequencies at 600 Hz and 4 kHz respectively. The cabinet shall be a roto-molded polyethylene enclosure providing weather and UV resistance with three layer weather resistant grille. The input connection shall be one 12' (4m) SJOW #16 gauge cable with stripped ends. The enclosure shall incorporate five 3/8-16 rigging points for multiple mounting options. In addition, the loudspeaker will be supplied with one stainless steel yoke bracket. The loudspeaker system shall have an amplitude response of 125 Hz-12.5 kHz (+/- 6 dB SPL), an input capacity of 35V RMS, 107 dB SPL sensitivity @ 2.45V / 1 meter between 250Hz-4kHz at a nominal 6 Ohm impedance. The nominal dispersion shall be 60° x 40° over a frequency range of 2 kHz to 10 kHz. The dimensions of the enclosure are defined as 16" x 16" x 16" (HWD) at a weight of 42.3lbs.

COMMUNITY PROFESSIONAL LOUDSPEAKERS
333 East 5th Street, Chester, PA USA 19013-4511 TEL (610) 876-3400 FAX (610) 874-0190
www.loudspeakers.net

Illustration A.

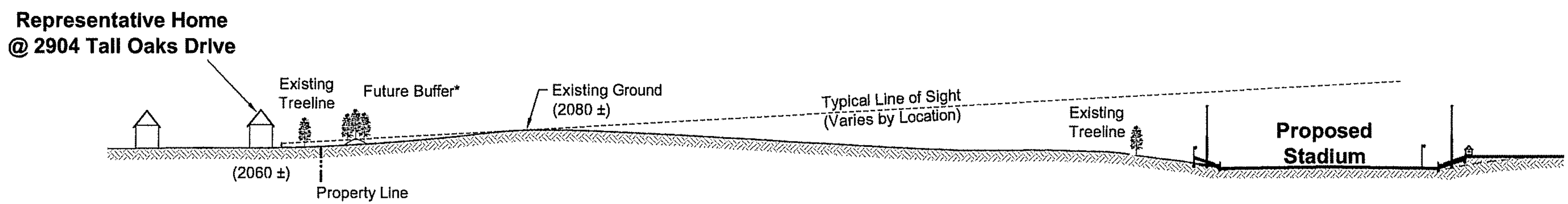






0 50 100
SCALE IN FEET

STADIUM PROFILE



* Future buffer shall be installed if a school is actually developed on this site

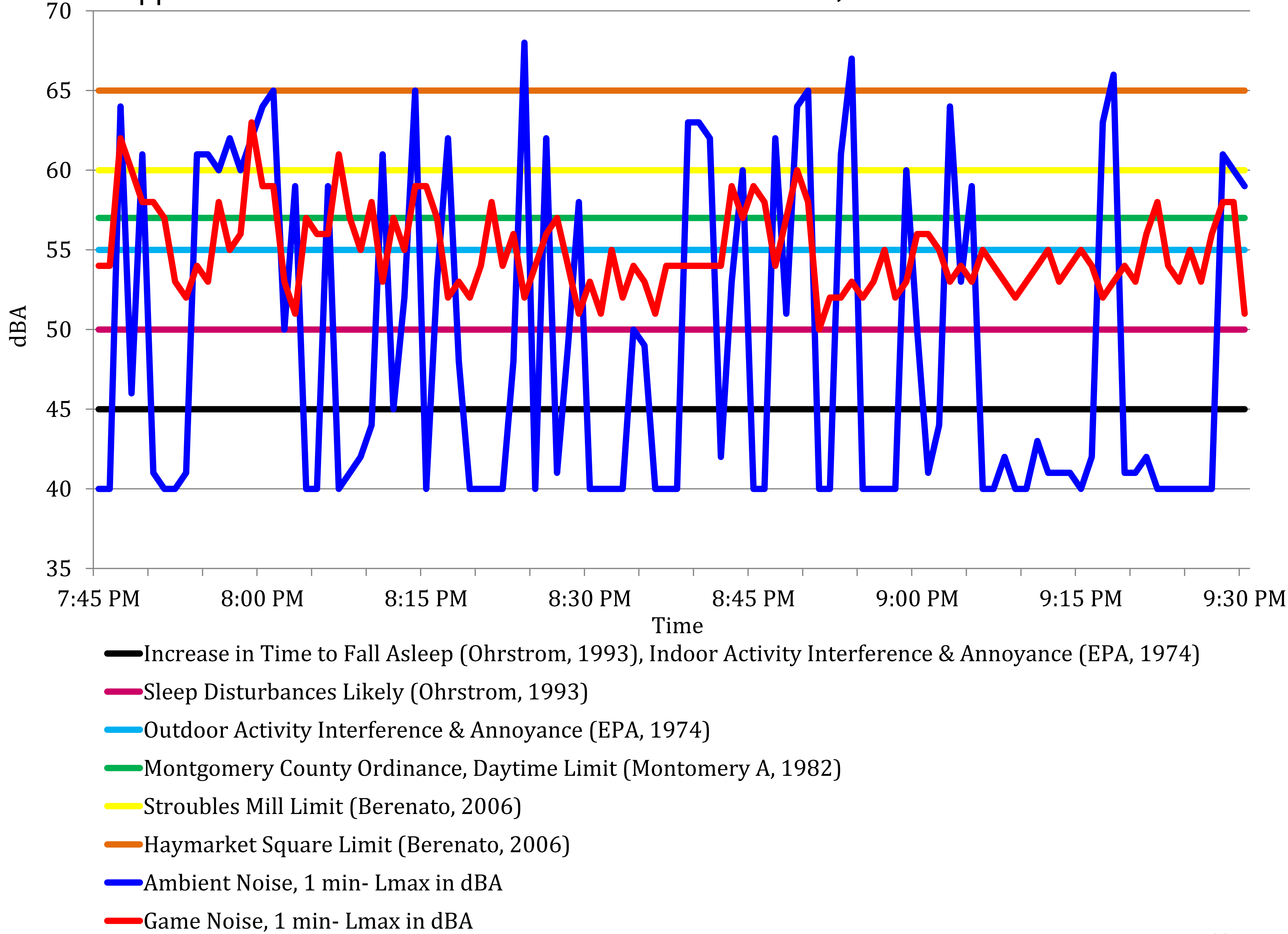
0 150 300
SCALE IN FEET

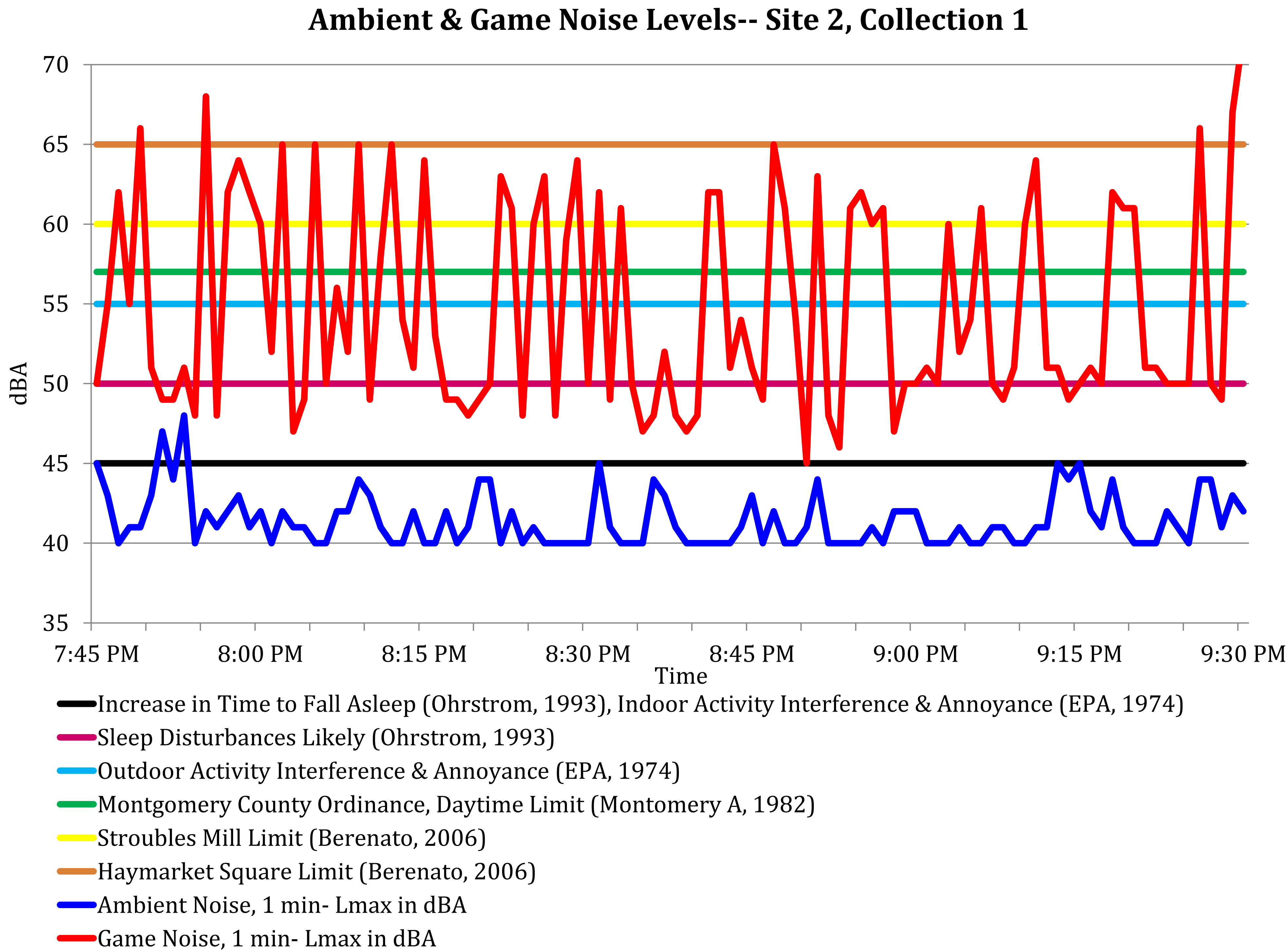
STADIUM PROFILE FROM STROUBLES MILL

ANDERSON & ASSOCIATES, INC. Professional Design Services www.andassoc.com Virginia - North Carolina - Tennessee 100 Ardmore St. Blacksburg, Va. 24060 540-552-5592	DATE : 23 NOV 05 DESIGNED: DRAWN : LBL CHECKED : TMK QA / QC :	REVISIONS: 09 DEC 05 14 APR 06	**BLACKSBURG HIGH SCHOOL STADIUM** BLACKSBURG, VA	**STADIUM SECTION**	DOCUMENT NO. 23020 – 64 SHEET 1 OF 1

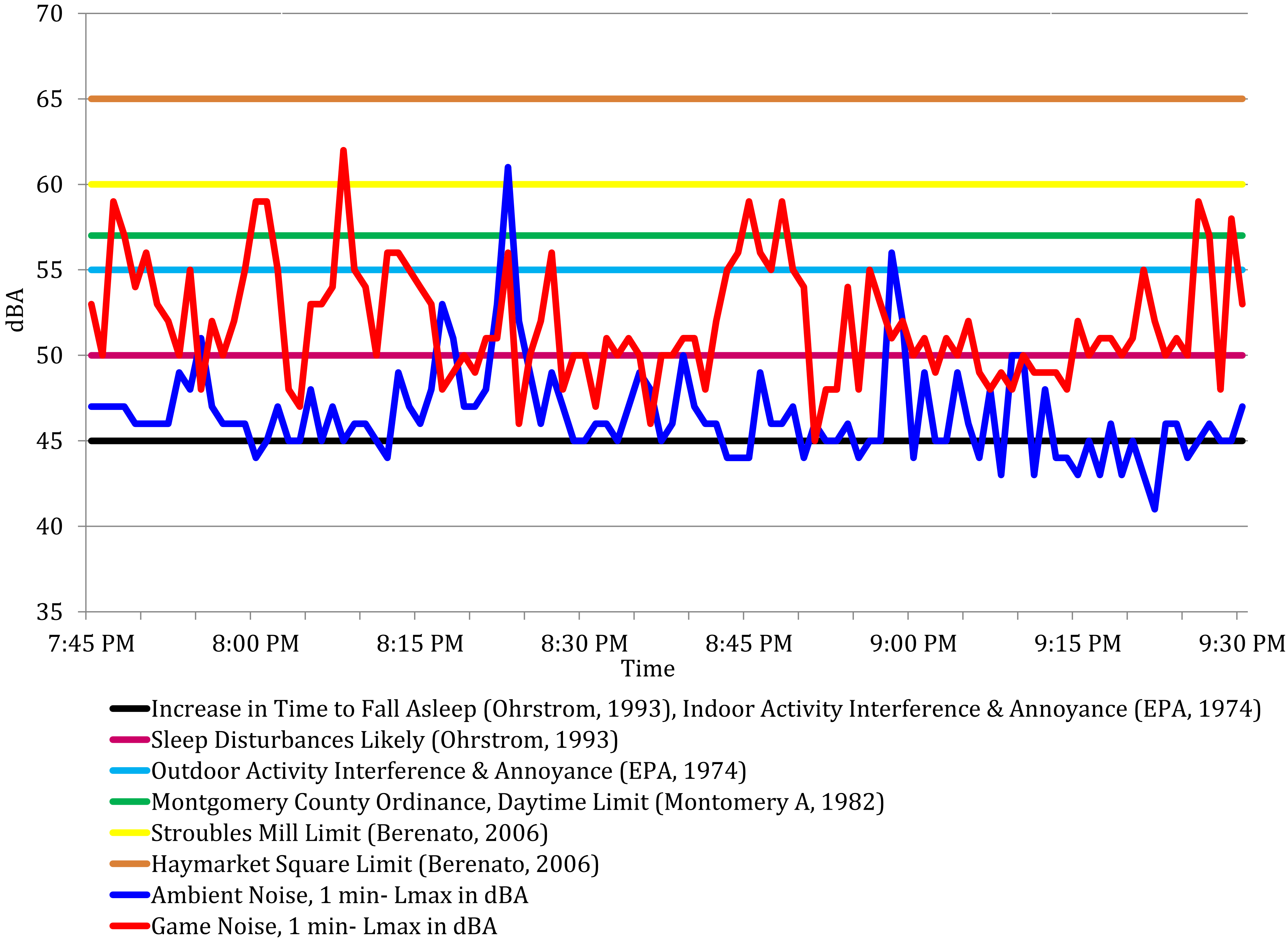
Baker, Robbie / 8/4/2006 1:33 PM / u:\23\23020\23020.60\permits\sup\sup_profiles.dwg

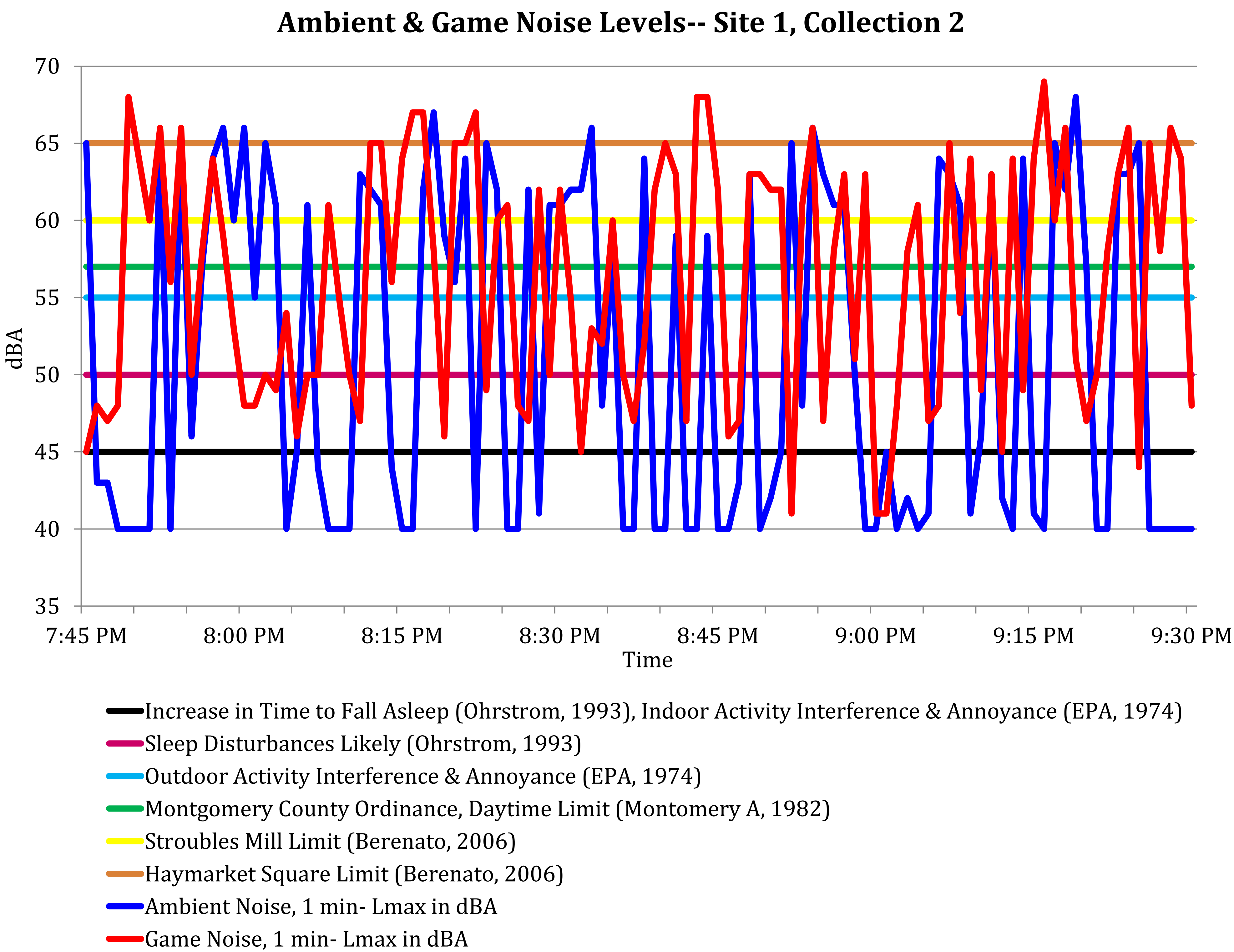
Appendix F - **Ambient & Game Noise Levels-- Site 1, Collection 1**



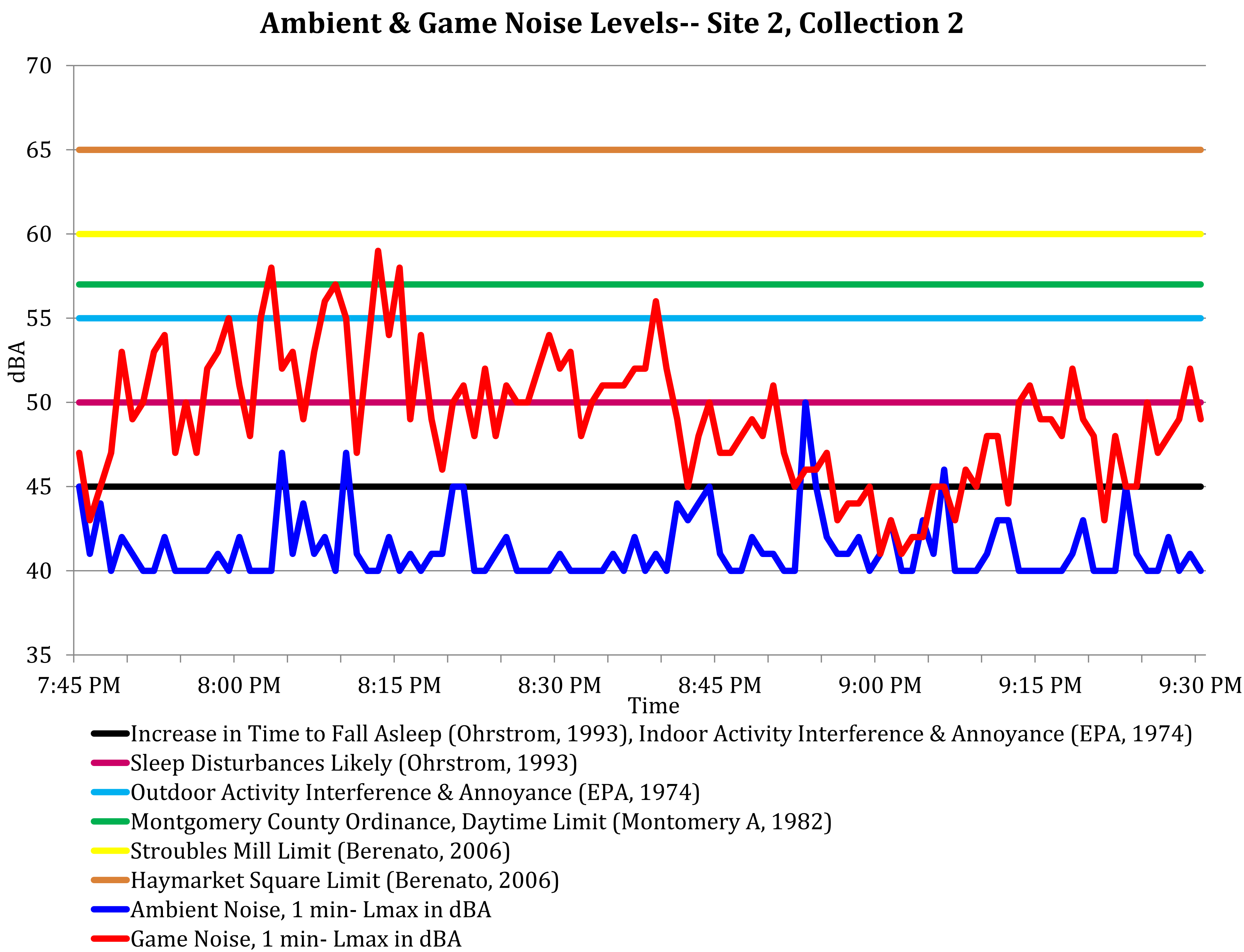

Ambient & Game Noise Levels-- Site 2, Collection 1
70
65
60
55
50
45
40
35
dBA
7:45 PM
8:00 PM
8:15 PM
8:30 PM
8:45 PM
9:00 PM
9:15 PM
9:30 PM
Time
Increase in Time to Fall Asleep (Ohrstrom, 1993), Indoor Activity Interference & Annoyance (EPA, 1974)
Sleep Disturbances Likely (Ohrstrom, 1993)
Outdoor Activity Interference & Annoyance (EPA, 1974)
Montgomery County Ordinance, Daytime Limit (Montomery A, 1982)
Stroubles Mill Limit (Berenato, 2006)
Haymarket Square Limit (Berenato, 2006)
Ambient Noise, 1 min- Lmax in dBA
Game Noise, 1 min- Lmax in dBA

Ambient & Game Noise Levels-- Site 3, Collection 1

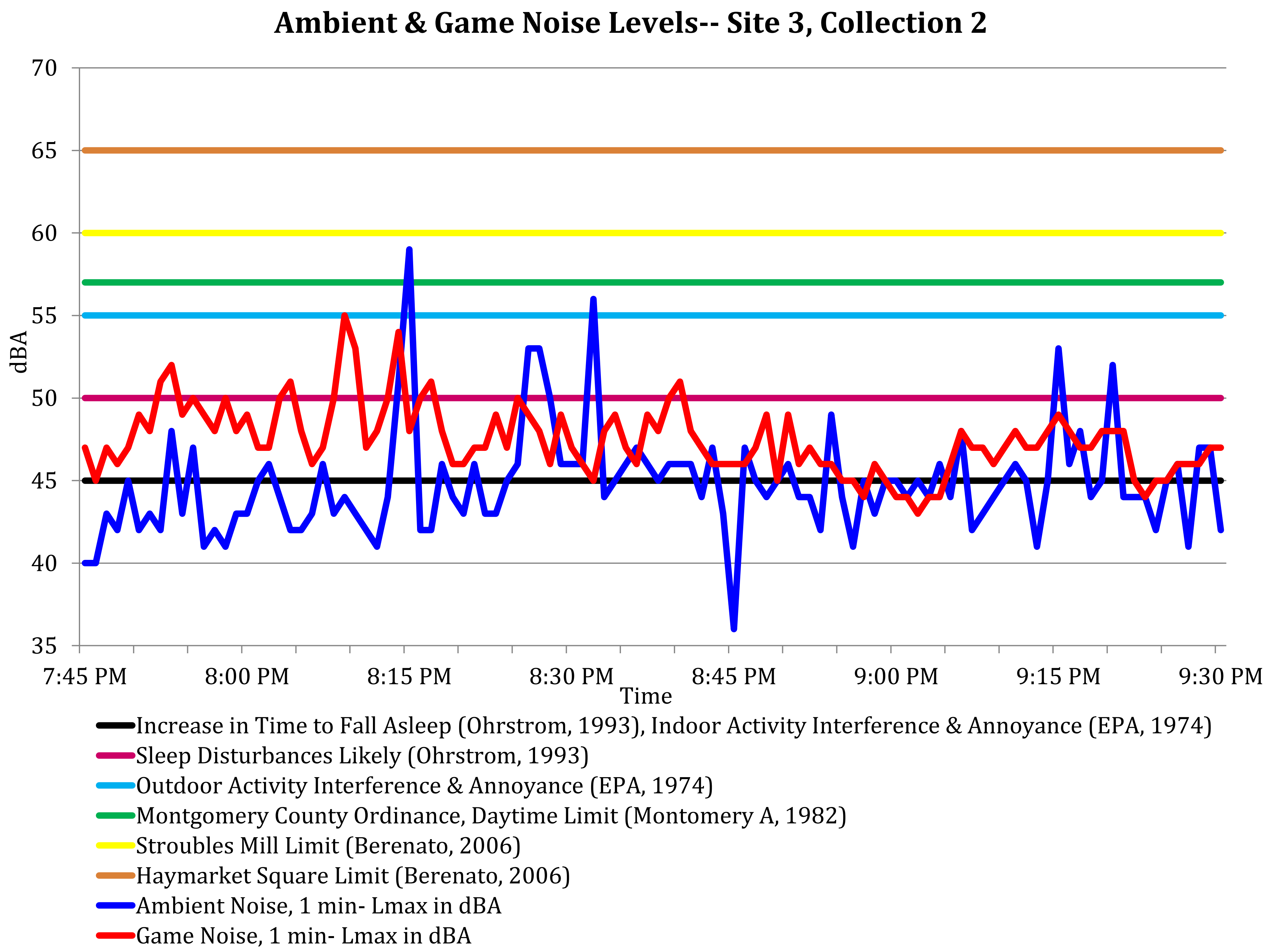


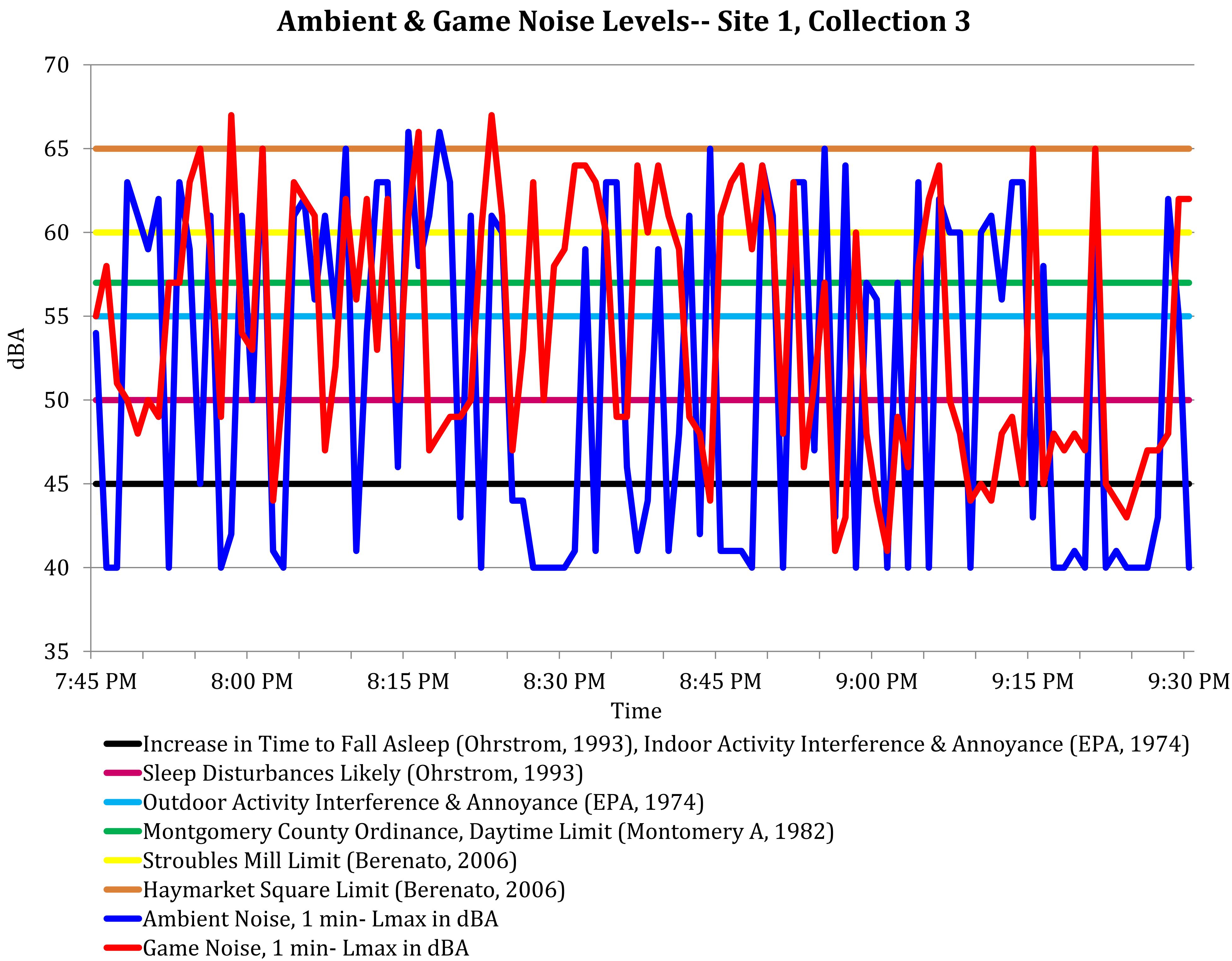


Ambient & Game Noise Levels-- Site 1, Collection 2
70
65
60
55
50
45
40
35
dBA
7:45 PM
8:00 PM
8:15 PM
8:30 PM
8:45 PM
9:00 PM
9:15 PM
9:30 PM
Time
Increase in Time to Fall Asleep (Ohrstrom, 1993), Indoor Activity Interference & Annoyance (EPA, 1974)
Sleep Disturbances Likely (Ohrstrom, 1993)
Outdoor Activity Interference & Annoyance (EPA, 1974)
Montgomery County Ordinance, Daytime Limit (Montomery A, 1982)
Stroubles Mill Limit (Berenato, 2006)
Haymarket Square Limit (Berenato, 2006)
Ambient Noise, 1 min- Lmax in dBA
Game Noise, 1 min- Lmax in dBA

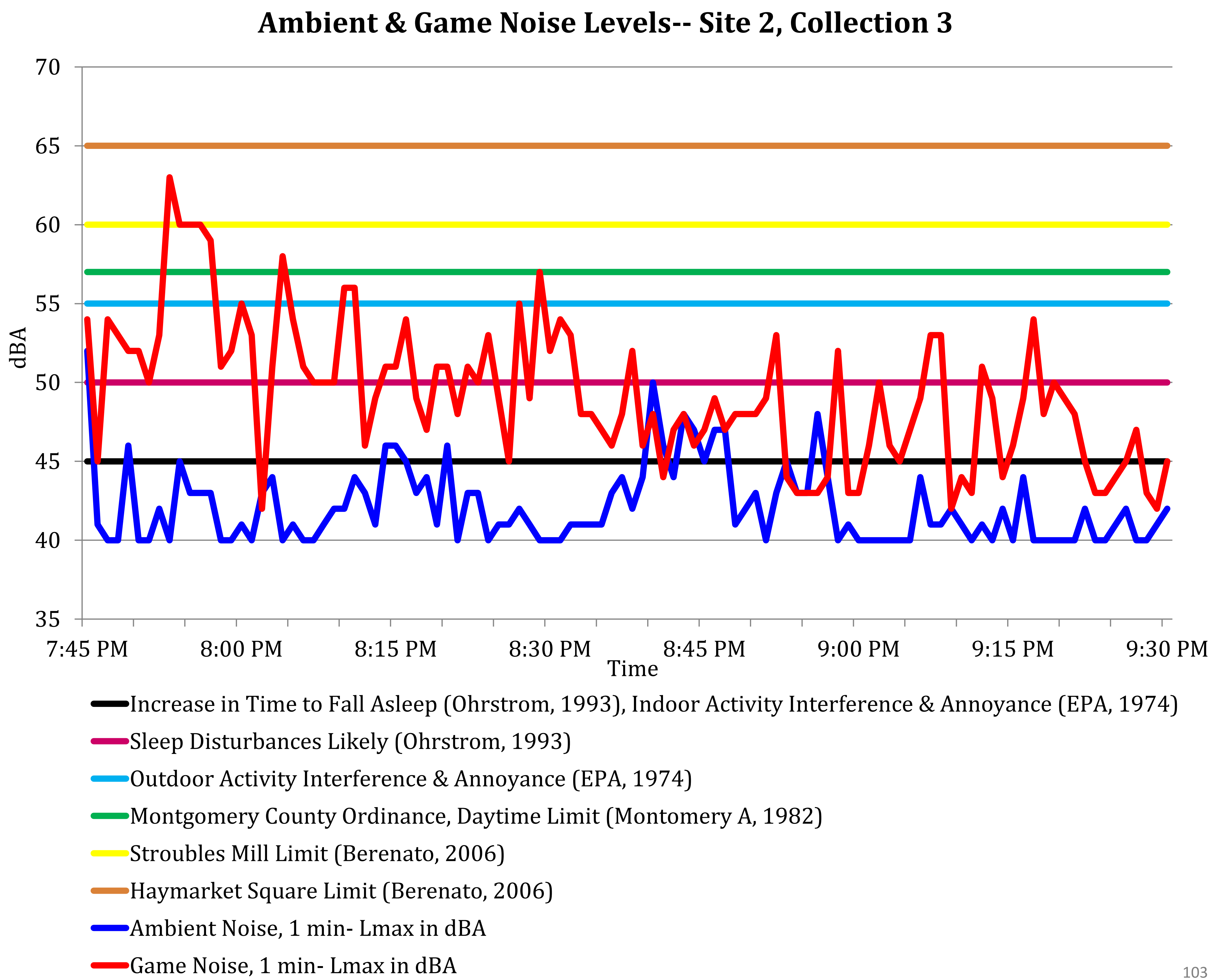


Ambient & Game Noise Levels-- Site 2, Collection 2
70
65
60
55
50
45
40
35
dBA
7:45 PM
8:00 PM
8:15 PM
8:30 PM
8:45 PM
9:00 PM
9:15 PM
9:30 PM
Time
Increase in Time to Fall Asleep (Ohrstrom, 1993), Indoor Activity Interference & Annoyance (EPA, 1974)
Sleep Disturbances Likely (Ohrstrom, 1993)
Outdoor Activity Interference & Annoyance (EPA, 1974)
Montgomery County Ordinance, Daytime Limit (Montomery A, 1982)
Stroubles Mill Limit (Berenato, 2006)
Haymarket Square Limit (Berenato, 2006)
Ambient Noise, 1 min- Lmax in dBA
Game Noise, 1 min- Lmax in dBA

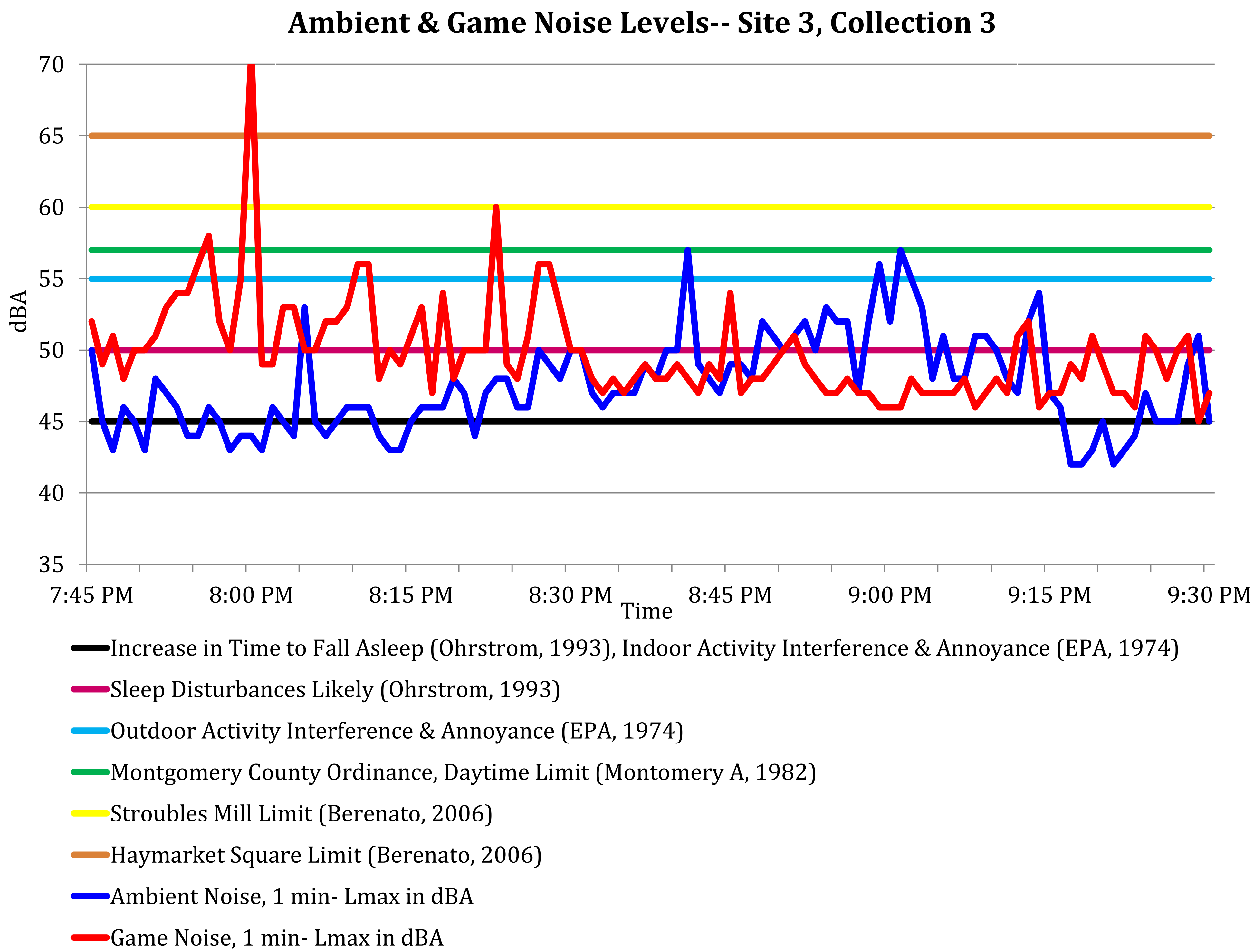

Ambient & Game Noise Levels-- Site 3, Collection 2
70
65
60
55
50
45
40
35
dBA
7:45 PM
8:00 PM
8:15 PM
8:30 PM
8:45 PM
9:00 PM
9:15 PM
9:30 PM
Time
Increase in Time to Fall Asleep (Ohrstrom, 1993), Indoor Activity Interference & Annoyance (EPA, 1974)
Sleep Disturbances Likely (Ohrstrom, 1993)
Outdoor Activity Interference & Annoyance (EPA, 1974)
Montgomery County Ordinance, Daytime Limit (Montomery A, 1982)
Stroubles Mill Limit (Berenato, 2006)
Haymarket Square Limit (Berenato, 2006)
Ambient Noise, 1 min- Lmax in dBA
Game Noise, 1 min- Lmax in dBA



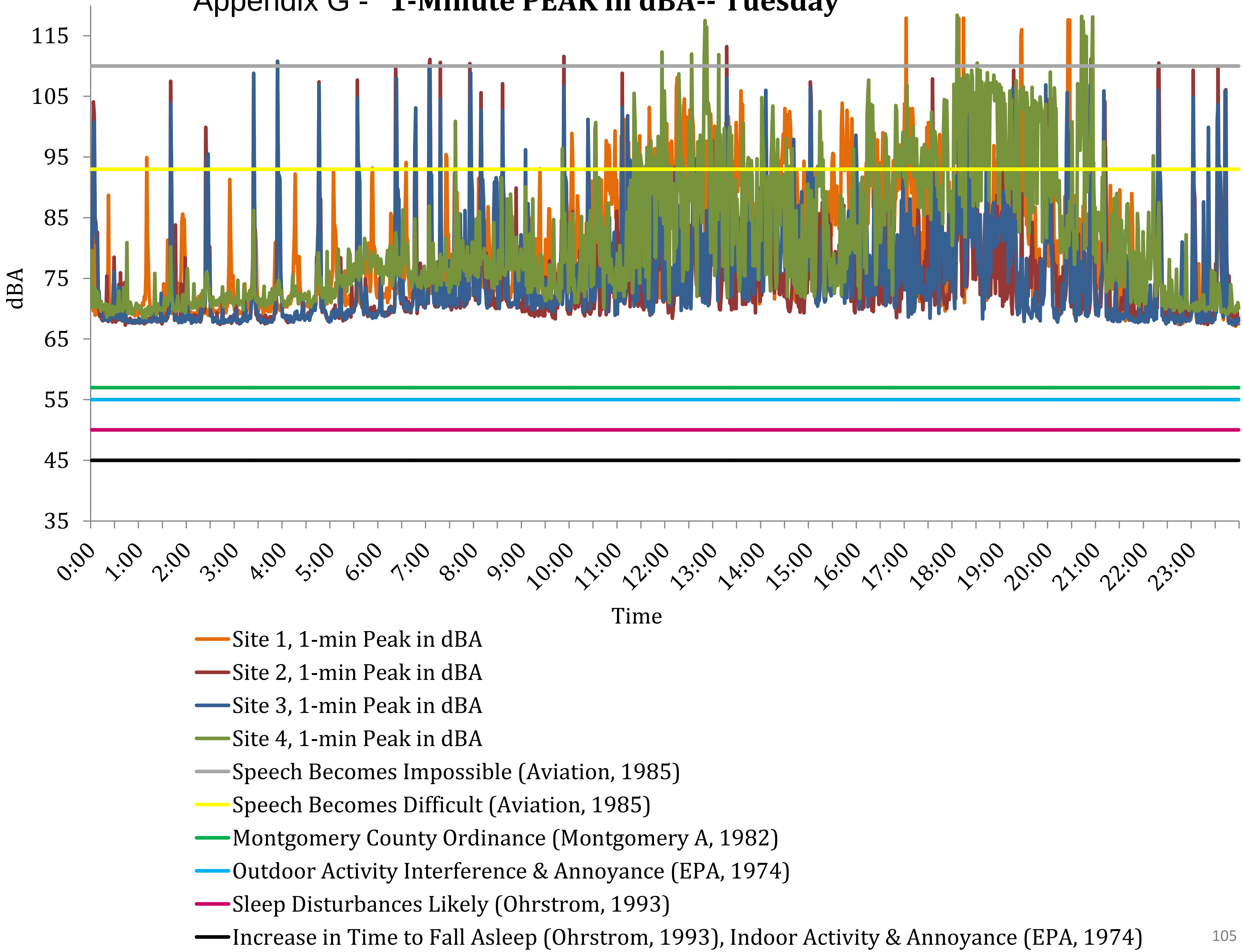
Ambient & Game Noise Levels-- Site 1, Collection 3
70
65
60
55
50
45
40
35
dBA
7:45 PM
8:00 PM
8:15 PM
8:30 PM
8:45 PM
9:00 PM
9:15 PM
9:30 PM
Time
Increase in Time to Fall Asleep (Ohrstrom, 1993), Indoor Activity Interference & Annoyance (EPA, 1974)
Sleep Disturbances Likely (Ohrstrom, 1993)
Outdoor Activity Interference & Annoyance (EPA, 1974)
Montgomery County Ordinance, Daytime Limit (Montomery A, 1982)
Stroubles Mill Limit (Berenato, 2006)
Haymarket Square Limit (Berenato, 2006)
Ambient Noise, 1 min- Lmax in dBA
Game Noise, 1 min- Lmax in dBA



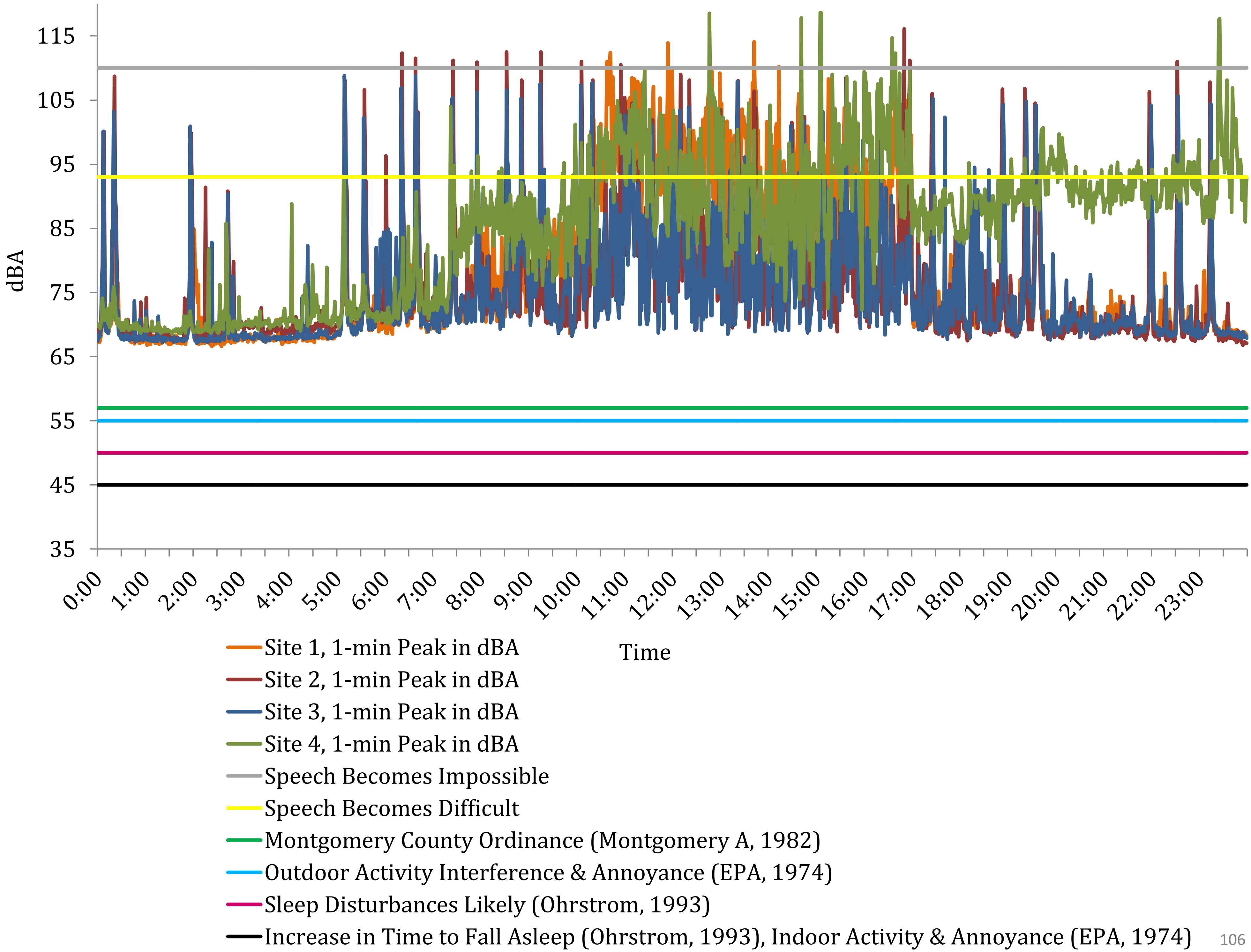
Ambient & Game Noise Levels-- Site 2, Collection 3
70
65
60
55
50
45
40
35
dBA
7:45 PM
8:00 PM
8:15 PM
8:30 PM
8:45 PM
9:00 PM
9:15 PM
9:30 PM
Time
Increase in Time to Fall Asleep (Ohrstrom, 1993), Indoor Activity Interference & Annoyance (EPA, 1974)
Sleep Disturbances Likely (Ohrstrom, 1993)
Outdoor Activity Interference & Annoyance (EPA, 1974)
Montgomery County Ordinance, Daytime Limit (Montomery A, 1982)
Stroubles Mill Limit (Berenato, 2006)
Haymarket Square Limit (Berenato, 2006)
Ambient Noise, 1 min- Lmax in dBA
Game Noise, 1 min- Lmax in dBA

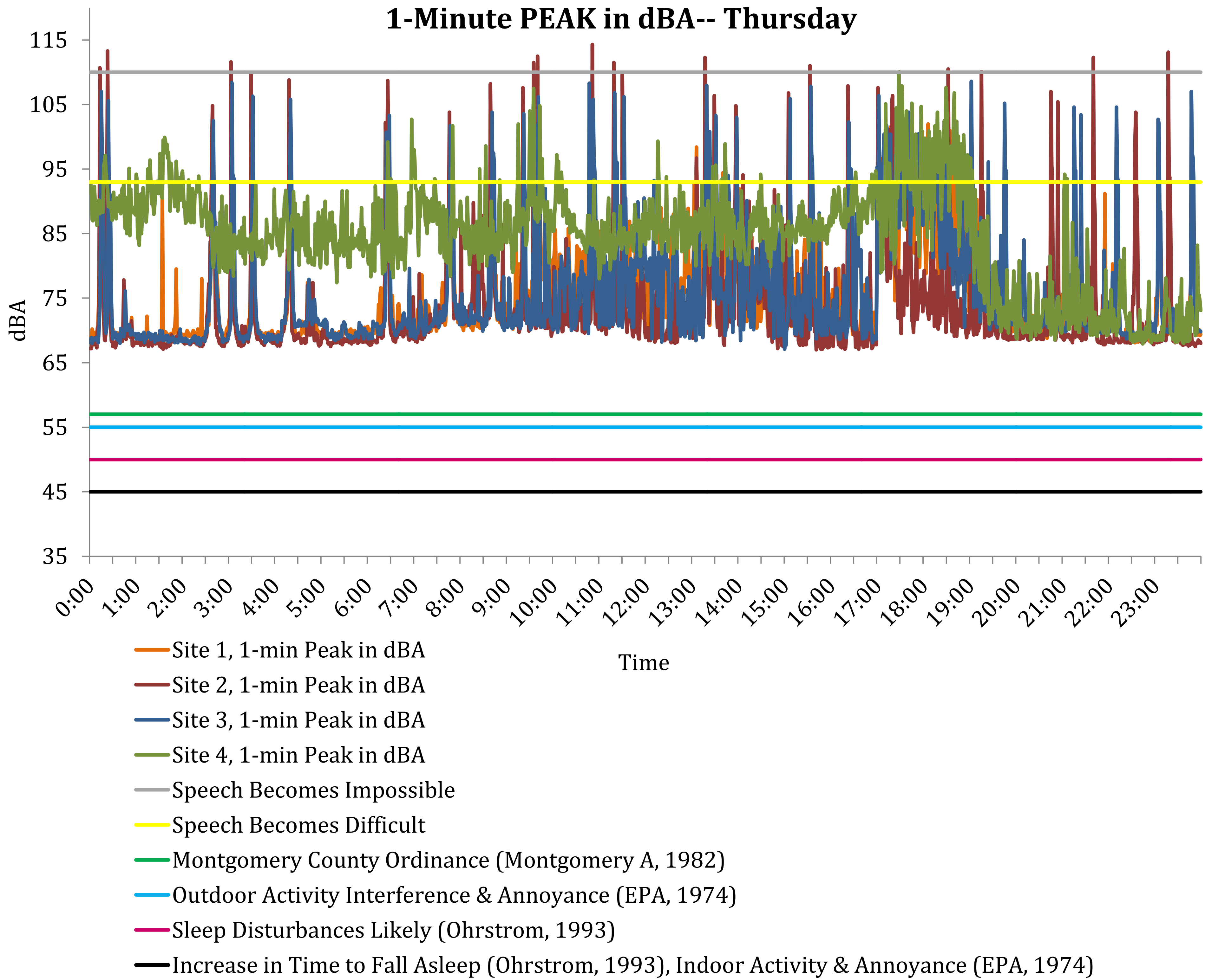

Ambient & Game Noise Levels-- Site 3, Collection 3
70
65
60
55
50
45
40
35
dBA
7:45 PM
8:00 PM
8:15 PM
8:30 PM
8:45 PM
9:00 PM
9:15 PM
9:30 PM
Time
Increase in Time to Fall Asleep (Ohrstrom, 1993), Indoor Activity Interference & Annoyance (EPA, 1974)
Sleep Disturbances Likely (Ohrstrom, 1993)
Outdoor Activity Interference & Annoyance (EPA, 1974)
Montgomery County Ordinance, Daytime Limit (Montomery A, 1982)
Stroubles Mill Limit (Berenato, 2006)
Haymarket Square Limit (Berenato, 2006)
Ambient Noise, 1 min- Lmax in dBA
Game Noise, 1 min- Lmax in dBA

Appendix G - **1-Minute PEAK in dBA-- Tuesday**

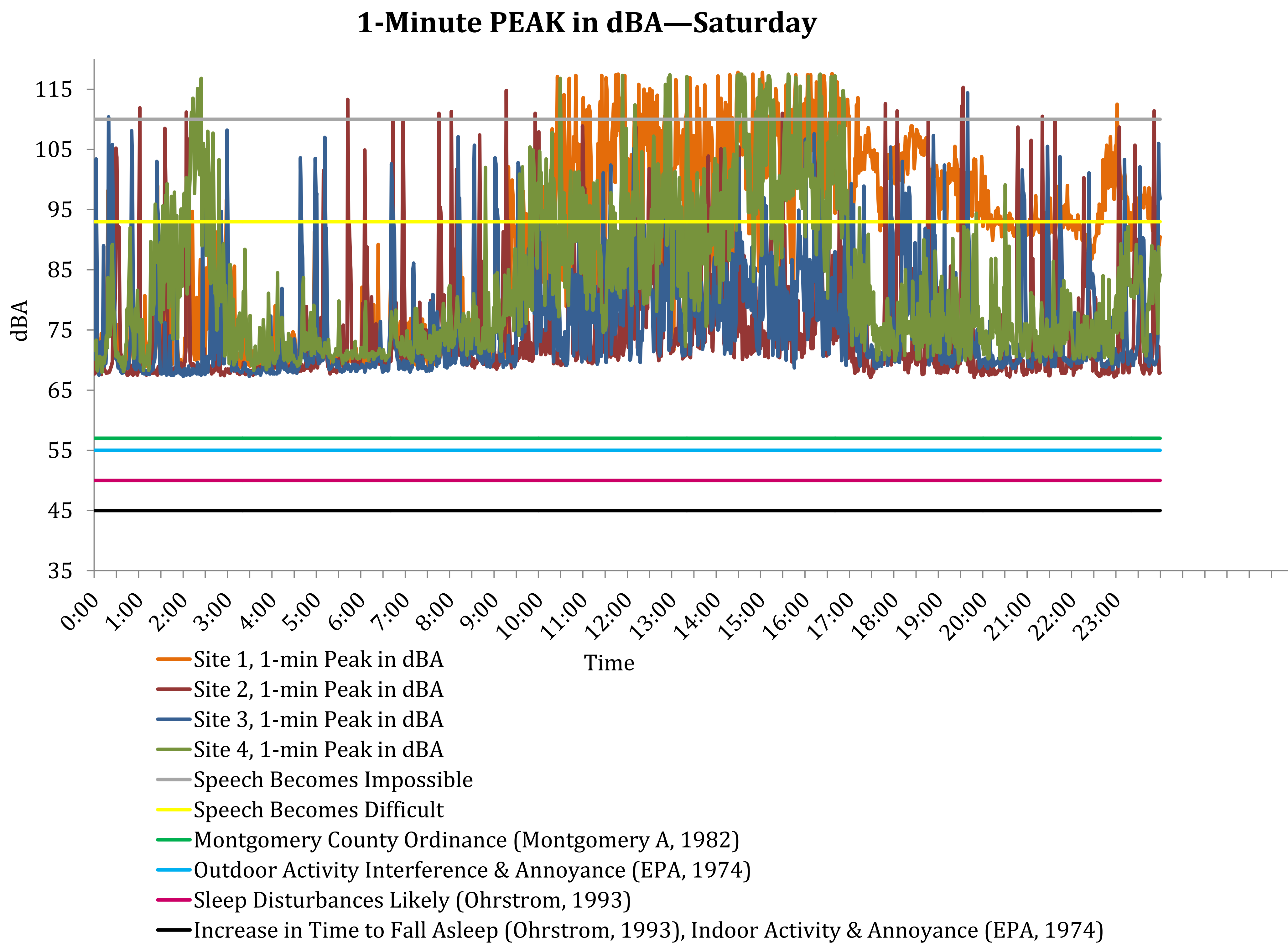


1-Minute PEAK in dBA—Wednesday





1-Minute PEAK in dBA-- Thursday
115
105
95
85
75
65
55
45
35
dBA
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
Time
Site 1, 1-min Peak in dBA
Site 2, 1-min Peak in dBA
Site 3, 1-min Peak in dBA
Site 4, 1-min Peak in dBA
Speech Becomes Impossible
Speech Becomes Difficult
Montgomery County Ordinance (Montgomery A, 1982)
Outdoor Activity Interference & Annoyance (EPA, 1974)
Sleep Disturbances Likely (Ohrstrom, 1993)
Increase in Time to Fall Asleep (Ohrstrom, 1993), Indoor Activity & Annoyance (EPA, 1974)


1-Minute PEAK in dBA—Saturday
dBA
115
105
95
85
75
65
55
45
35
0:00
1:00
2:00
3:00
4:00
5:00
6:00
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17:00
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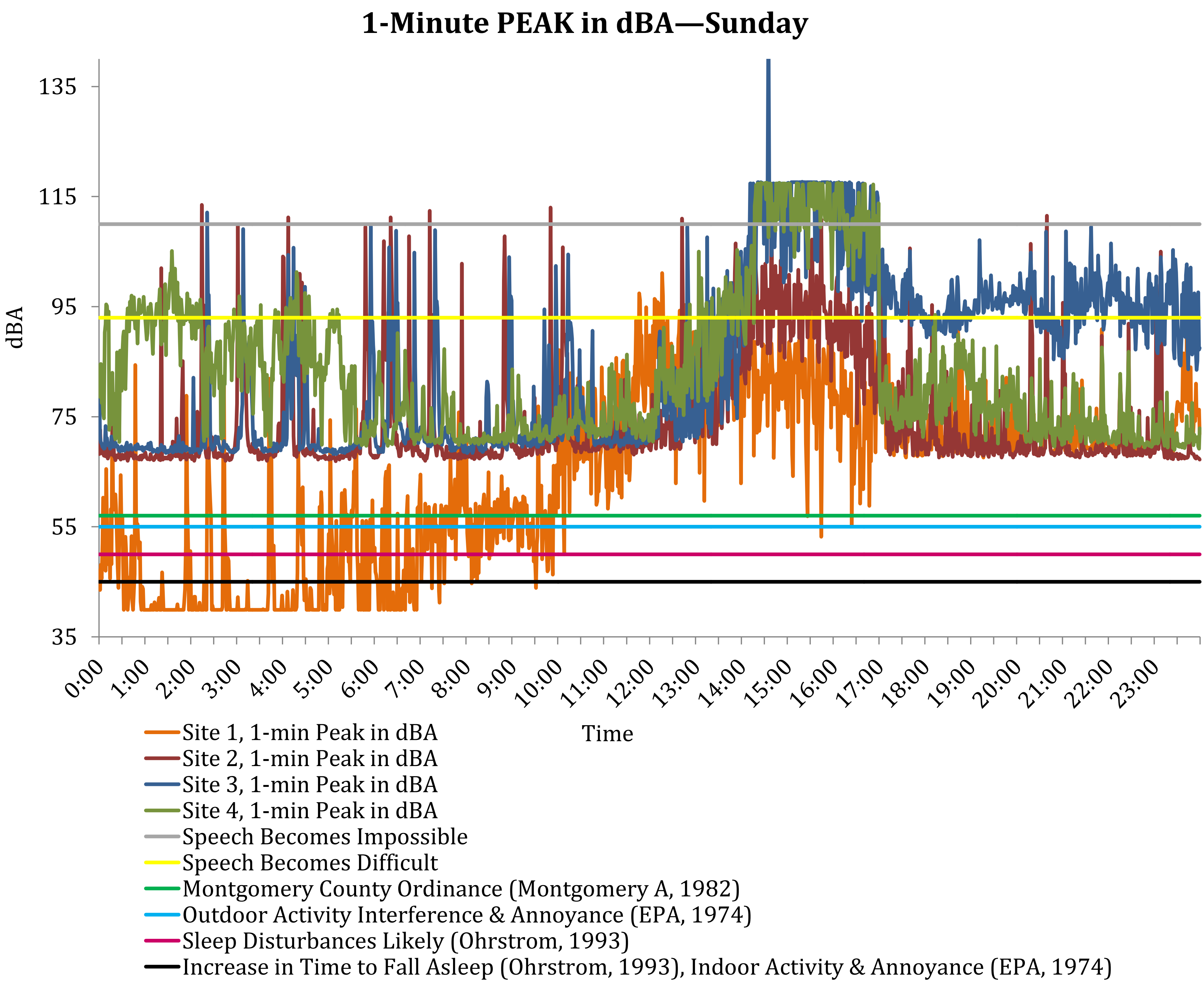
20:00
21:00
22:00
23:00
Time
Site 1, 1-min Peak in dBA
Site 2, 1-min Peak in dBA
Site 3, 1-min Peak in dBA
Site 4, 1-min Peak in dBA
Speech Becomes Impossible
Speech Becomes Difficult
Montgomery County Ordinance (Montgomery A, 1982)
Outdoor Activity Interference & Annoyance (EPA, 1974)
Sleep Disturbances Likely (Ohrstrom, 1993)
Increase in Time to Fall Asleep (Ohrstrom, 1993), Indoor Activity & Annoyance (EPA, 1974)


1-Minute PEAK in dBA—Sunday
dBA
135
115
95
75
55
35
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
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20:00
21:00
22:00
23:00
Time
Site 1, 1-min Peak in dBA
Site 2, 1-min Peak in dBA
Site 3, 1-min Peak in dBA
Site 4, 1-min Peak in dBA
Speech Becomes Impossible
Speech Becomes Difficult
Montgomery County Ordinance (Montgomery A, 1982)
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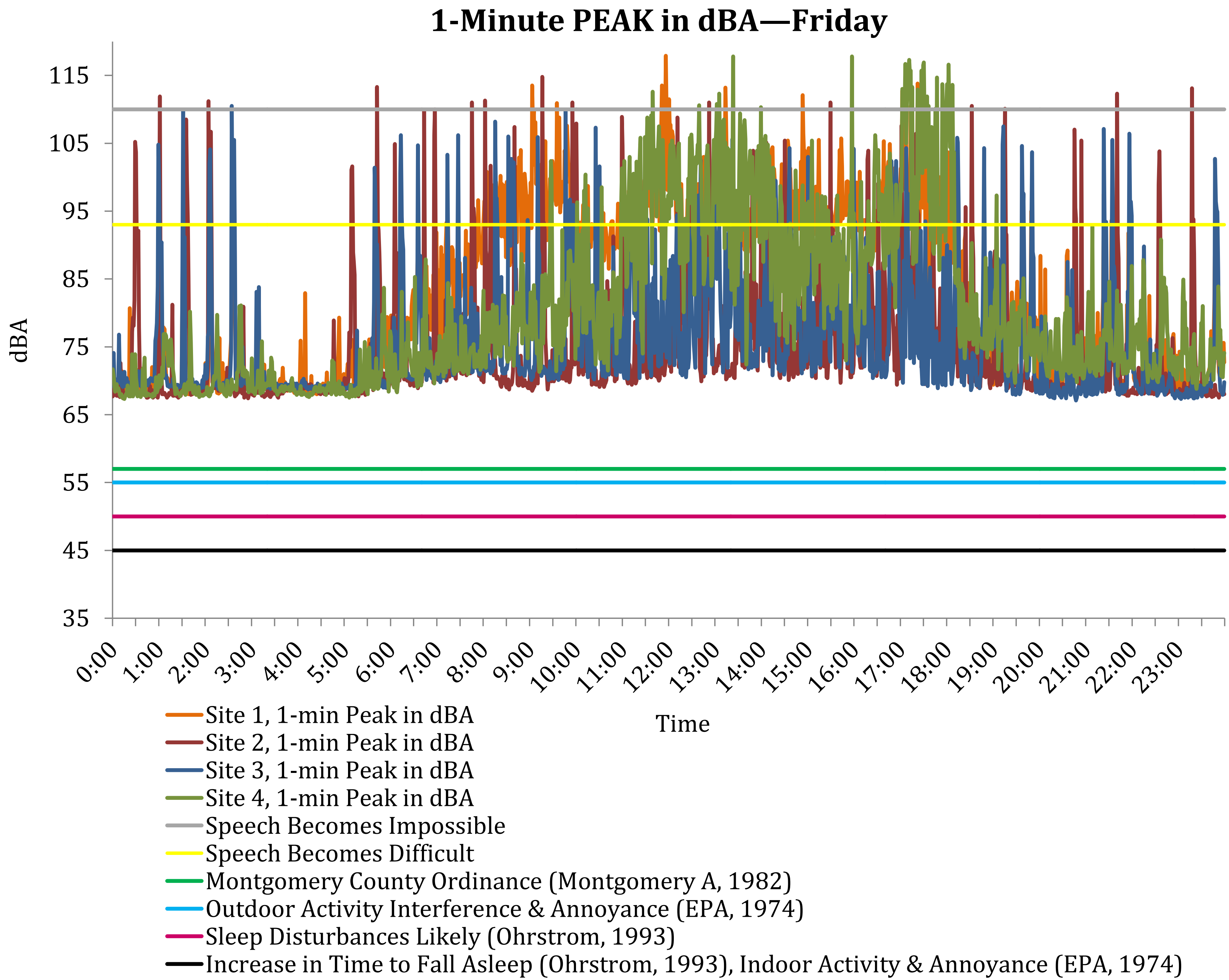
1-Minute PEAK in dBA—Friday
115
105
95
85
75
65
55
45
35
dBA
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
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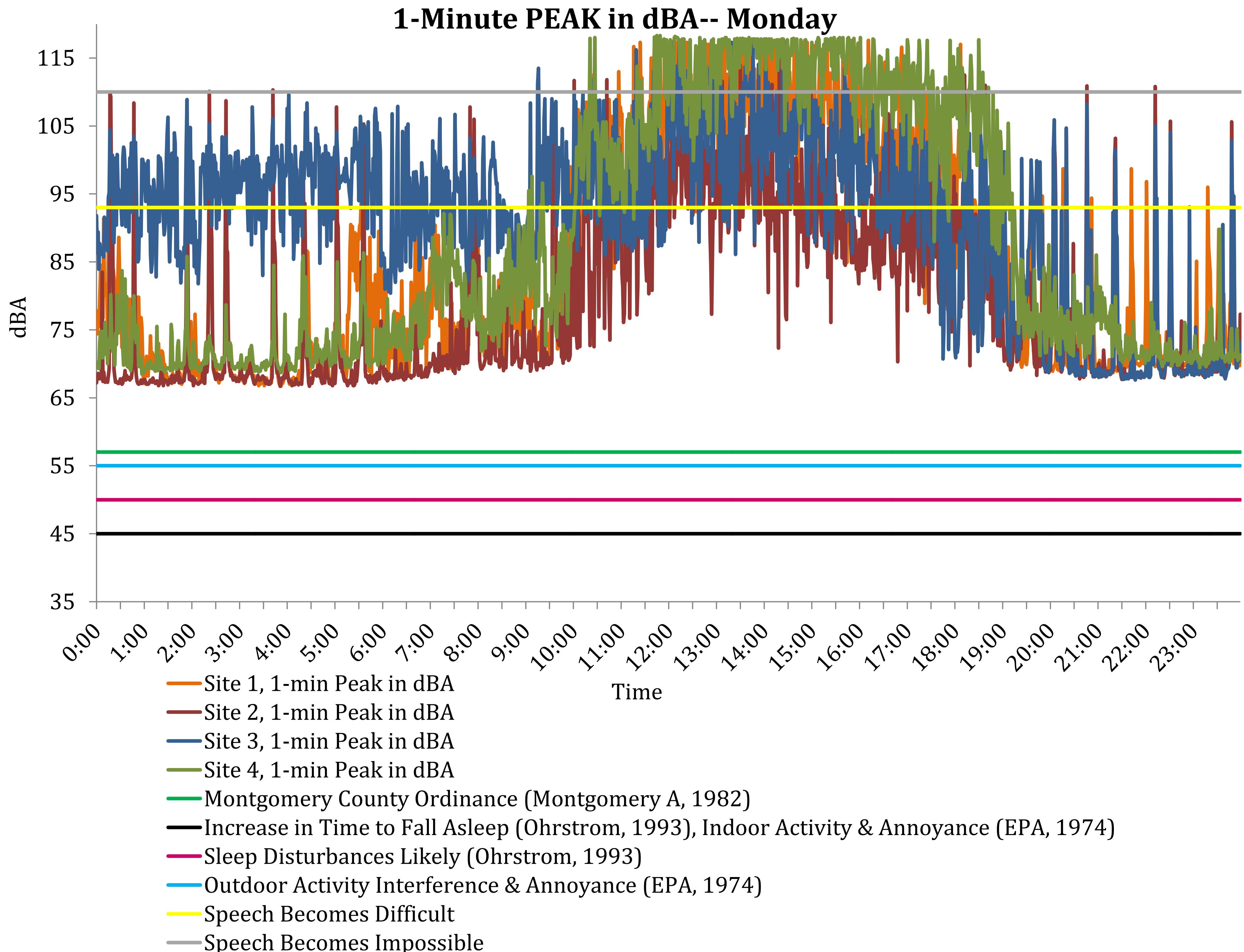
17:00
18:00
19:00
20:00
21:00
22:00
23:00
Time
Site 1, 1-min Peak in dBA
Site 2, 1-min Peak in dBA
Site 3, 1-min Peak in dBA
Site 4, 1-min Peak in dBA
Speech Becomes Impossible
Speech Becomes Difficult
Montgomery County Ordinance (Montgomery A, 1982)
Outdoor Activity Interference & Annoyance (EPA, 1974)
Sleep Disturbances Likely (Ohrstrom, 1993)
Increase in Time to Fall Asleep (Ohrstrom, 1993), Indoor Activity & Annoyance (EPA, 1974)


1-Minute PEAK in dBA-- Monday
dBA
115
105
95
85
75
65
55
45
35
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
Time
Site 1, 1-min Peak in dBA
Site 2, 1-min Peak in dBA
Site 3, 1-min Peak in dBA
Site 4, 1-min Peak in dBA
Montgomery County Ordinance (Montgomery A, 1982)
Increase in Time to Fall Asleep (Ohrstrom, 1993), Indoor Activity & Annoyance (EPA, 1974)
Sleep Disturbances Likely (Ohrstrom, 1993)
Outdoor Activity Interference & Annoyance (EPA, 1974)
Speech Becomes Difficult
Speech Becomes Impossible