July 18, 2022

Neighbors of 25 Kings Highway South
c/o Dr Aaron Hultgren
12 Birchwood Lane
Westport, CT 06880

Re: Birchwood Country Club Pickleball Court Development Noise Assessment

Dr. Hultgren,

Per your request, I have prepared this report summarizing my opinions relating to this issue and the factual basis for my opinions. This report includes my opinions regarding sound levels and emissions that will created by the proposed Birchwood Pickleball Courts and the impact that this noise will have upon the surrounding properties and residents.

The opinions in this report are based on my site sound modelling and analysis and my review of the project documents and plan (including the SHAcoustics noise report). The opinions in this report are also based on my education, knowledge, training, and experience in the fields of engineering/physical acoustics, mechanical vibrations, and noise control. I have completed noise and vibrations projects (ranging from industrial noise control, environmental/community noise, product noise/sound quality, hearing conservation etc.) for approximately 400 clients located throughout North America as outlined in my attached CV.

I hold all of the opinions stated in this report and the subsequent conclusions with a reasonable degree of engineering certainty.

William Thornton, MSME

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BIRCHWOOD COUNTRY CLUB
PICKLEBALL COURT DEVELOPMENT
COMMUNITY NOISE IMPACT STUDY

July 18, 2022

Prepared for:

Neighbors of 25 Kings Highway South
c/o Dr Aaron Hultgren
12 Birchwood Lane
Westport, CT 06880

Submitted by:

Thornton Acoustics
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Mill Run, PA 15464

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EXECUTIVE SUMMARY

I have prepared this report summarizing my opinions relating to this issue and the factual basis for my opinions. This report includes my opinions regarding sound levels and emissions created by the Birchwood Country Club Pickleball Court development and the impact that this noise will have upon the nearby property and residents.

The opinions in this report are based on my site sound modelling and analysis. The opinions in this report are also based on my education, knowledge, training, and experience in the fields of engineering/physical acoustics, mechanical vibrations, and noise control. I have completed noise and vibrations projects (ranging from industrial noise control, environmental/community noise, product noise/sound quality, hearing conservation etc.) for approximately 400 clients located throughout North America as outlined in my attached CV.

I hold all of the opinions stated in this report and the subsequent conclusions with a reasonable degree of engineering certainty.

I hold the following opinions in this case:

- The noise emitted by Pickleball is distinctly different from other racket sports such as tennis and is characterized by staccato, Impulse noise events with each paddle strike that emit loud tones that are highly annoying, due to the loudness and pitch, to the human ear/auditory system.
- The noise emitted by the proposed Pickleball Courts, as incident on the surrounding properties, is grossly in excess of the typical ambient sound and is incompatible with the surrounding suburban community.
- The Pickleball noise, due to the level, frequency content/pitch and temporal nature, creates a clear noise nuisance and interrupts the peace and enjoyment of the adjacent residential properties by any reasonable standards.
- Noise barriers, plantings etc., will not reduce the noise emitted by Pickleball due to fundamental physical limitations and as such are not solutions to this potential problem.

- The Pickleball courts are fundamentally incompatible, due to noise emissions, with the surrounding community.

The opinions in this report are based on my education, professional training and experience, site modelling and analysis and review of documents including (but not limited to):

1. Landtech Pickleball Site Plan Final May 2022
2. SHAcoustics Birchwood Country Club Pickleball Courts Acoustic Analysis Report April 2022

In addition to these opinions, and my foundation for forming these opinions, this report will discuss general noise modelling, measurement and analysis of sound, community and environmental noise and human sound exposure and response.

1 INTRODUCTION

Thornton Acoustics & Vibrations (TAV) performed a community noise impact study of the proposed Birchwood Country Club (BCC) Pickleball Courts noise emissions as incident on the surrounding residential properties. The purpose of the study was to model and predict the noise levels that are emitted by the Courts and to assess the impact on the affected properties. Note that as there are four proposed Courts, there may be up to sixteen (four per court) simultaneous players on these courts. The Court locations are shown in Figures 1 and 2 (a site plan and an existing aerial view respectively).

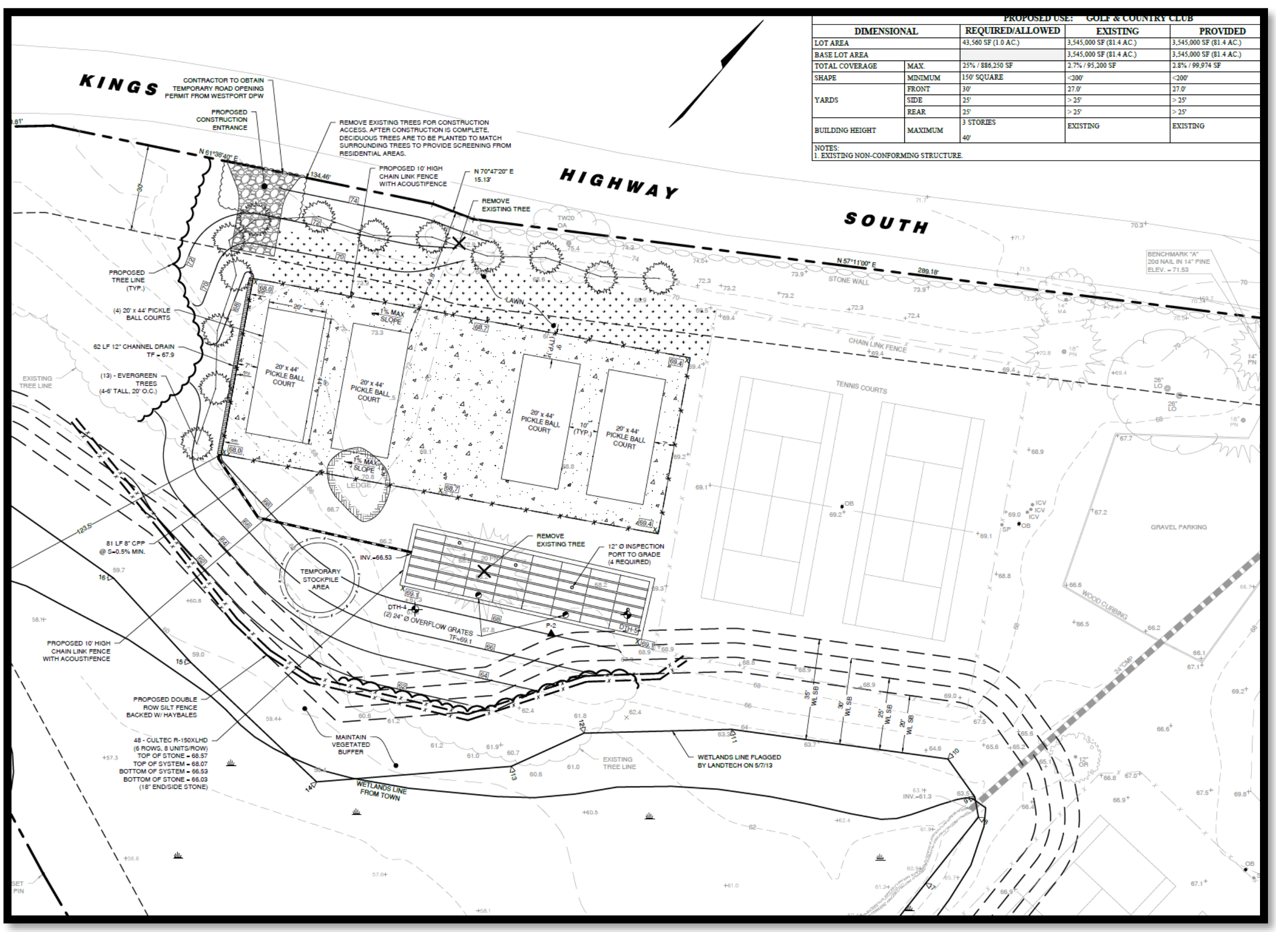

Figure 1 Pickleball Court Site Plan.

Figure 2 Proposed Pickleball Court Site Aerial View

This noise study was completed using well developed, science-based methodologies. It is a routine acoustical engineering task to model and predict the noise emissions and impact of a known noise source in a new or different (from the original source) environment. This type of modelling effort is in fact so routine that methodologies have been established and standardized by organizations such as the American National Standards Institute (ANSI) the International Standards Organization (ISO).

The predicted ambient and Pickleball noise levels were evaluated relative to accepted science-based standards and guidelines for community noise and noise impacts.

I have also reviewed the SHAcoustics Acoustic Analysis Report (April 7, 2022) and this study contains a number of oversimplifications, mischaracterizations and basic engineering errors. The net effect of these deficiencies is that this study mischaracterizes and underestimates the noise emissions that will be created by the proposed Pickleball courts and hence underestimates the noise impact and nuisance that will be created for the surrounding residents.

1.1 Pickleball

Pickleball is a racket/paddle sport, for 2 or 4 players, played on a court that is similar to badminton or tennis. Pickleball was invented in 1965 and has enjoyed exponential growth in recent years. There were 39 “places to play” (with 150 individual courts) in 2003 and these have grown to nearly 7,000 “places to play” (with 21,000 individual courts) in 2018 according to USA Pickleball (the sport’s governing body).

Due to this growth, Pickleball courts have been built in private residential neighborhoods, in public parks, private clubs and communities. It has become common for little used Tennis courts to be converted to Pickleball courts.

As Pickleball proliferates, the courts are often being developed in close proximity to residential land, homes and public spaces on/in which the occupants and users previously enjoyed relative peace and quiet. Pickleball, due to its unique noise which is louder and contains frequency content/tones in the most sensitive frequency range for human hearing compared to other racket/paddle sports, has produced noise problems across the US. As Pickleball noise is introduced into these communities and locations; disputes, conflicts and lawsuits have become commonplace. TAV has been involved with disputes and lawsuits in NY, NJ, PA, VA, TN, FL and KY and we are aware of similar issues in at least 25 other states.

Purported solutions to Pickleball Noise such as “quiet” paddles and noise barriers/walls have NOT produced a significant reduction in Pickleball noise.

Due to our involvement in these disputes, TAV, has compiled a large database of Pickleball noise measured across various sites, landscapes and locations and with players of varying athleticism and a wide range of equipment (including purported “quiet” paddles). It is this database that was used by TAV to model the predicted pickleball noise emitted by the Courts. This database has been used to produce accurate noise source (sound power) level models which are used to model and predict the noise emissions from proposed courts according to a US/Internationally standardized environmental noise propagation model.

1.2 Acoustics/Noise Primer

In order to understand and interpret the noise data, analyses and discussions contained in this report it is essential to understand a number of the technical nuances related to sound, noise (unwanted sound) and the human perception of noise.

Sound is a pressure perturbation propagating through air (in this case) that can be described in terms of the level or intensity, the frequency content (tone/pitch) and temporal variation. These variables affect the perception and impact of the sound, which when unwanted is called noise by convention.

In modelling, measuring and characterizing noise; there exist numerous metrics and descriptors. The metrics/descriptors used must be carefully and correctly chosen such that they capture and accurately describe and characterize the sound or noise problem being addressed. For many of these metrics and descriptors, although they fundamentally differ in their computation, the final results are expressed in terms of decibels (dB) and this can lead to confusion and misinterpretation. The use of the wrong metric will distort the measured results leading to erroneous conclusions. For example, impulsive noises (characterized by short durations and high levels) must be measured with metrics that have sufficiently short time-averaging properties to characterize the levels in a way that can be meaningfully compared to the human perception of loudness. Accordingly, impulsive noises such as Pickleball strikes must be characterized using the Peak sound pressure level (L_{peak}, (dB)). The Peak sound pressure level is the instantaneous maximum sound level occurring over some arbitrary time interval. Note that attempts to measure impulsive noises with meters not capable of accurately measuring the Peak, by using either the Fast (1/8 second) or Slow (1 second) response time found on survey grade sound level meters will dramatically underestimate the actual sound level and resultant loudness of the Impulse noise. This is a common technical mistake when measuring impulsive noise.

The human perception of loudness is based upon an approximately 5-millisecond physiological averaging time and accordingly, the Peak sound pressure level is well correlated with the human perception of the loudness of Impulse noise. When Impulse noise events are measured with erroneously longer averaging times such as the Slow response or Fast response the resulting level grossly underestimates the actual level and loudness as the event is averaged together with the relatively quiet background noise level (producing an average that is biased low).

The Acoustical terminology, used to distinguish between these metrics is objectively standardized and defined in the **ANSI/ASA S1.1-2013 Acoustical Terminology** standard.

In order to characterize the typical ambient sound levels in a community, the sound level exceeded 90 percent of the time ($L_{90,}$ (dB)) metric is often used by convention (in the absence of a formal standard or specific guidance in an ordinance).

The decibel scale used to measure noise is a logarithmic scale rather than a simple linear scale and this leads to misunderstanding and misinterpretation of noise data and levels. Relatively small numerical changes or differences in sound level (expressed in decibels (dB)) are actually relatively large differences in acoustical energy. In order for the reader to interpret and understand the noise data, several simplified rules-of-thumb regarding the sound level/decibel scale are useful. First, every 3-dB increase (or decrease) is a doubling (or halving) of the amount of acoustical energy and is generally considered the smallest change perceptible to an average human listener. Secondly, every 10-dB increase (or decrease) is a doubling (or halving) of the perceived loudness of a sound. For example, if the ambient sound level is increased by 10 dB, the average person would perceive this is twice as loud. An increase by 20 dB, would be perceived as roughly 4-times as loud, 30 dB as 8-times as loud and so on.

Noise may create a deleterious impact based on the absolute level of the noise and/or the level increase above some baseline or ambient condition. A sufficiently loud noise will interfere with human activity, speech, sleep etc. regardless of the ambient noise environment. However, in quiet environments (with low ambient noise levels), even relatively “quiet” sounds may produce a negative impact and a noise nuisance to the degree that they exceed the ambient levels.

1.3 Review of SHAcoustics Report

I have reviewed the SHAcoustics report produced in support of the Pickleball Courts development and I find that there are a number of basic errors that result in a systematic underestimation of the noise and the noise impact that will be produced by the Pickleball Courts. These most serious errors include:

- Ambient noise levels – brief spot measurements rather than longer term monitoring
- Flawed Pickleball Noise Simulation
- Noise Metric Errors
- Misinterpretation of CT Noise Regulations

The ambient noise levels should be measured on the subject properties (as these are ultimately the locations that will be adversely affected) and should be measured for an extended period of time (at least 7-days) to capture a statistically significant sample.

The attempt to simulate Pickleball play used by SHAcoustics does not accurately generate, recreate or capture real-world Pickleball noise. There are a number of variables that occur in Pickleball play that affect the noise emissions that are simply not captured in this attempt, such as player athleticism/strength (and the resulting variations in strike force and speed) and the range of equipment that would occur among real-world courts and players. Furthermore, there are basic technical deficiencies in the approach; measuring in the near-field of the noise source and extrapolating to large distances presents multiple inaccuracies and error. This measurement does not accurately measure the source Sound Power Level (PWL) which is necessary for extrapolation and is subject to the effects of directivity, interference from the testers body, etc. A far more effective and accurate method would be to measure real-world Pickleball noise at various distance for extended periods of time and to develop source models from these data.

Pickleball noise should have been measured using the Peak Sound Pressure Level metric (L_{peak}). The Pickleball simulation noise levels reported by SHAcoustics are far too low to be Peak levels. There are a number of likely explanations for this. Although the report uses the word "peak", another metric may have been used and the terms conflated; such as maximum sound levels, "impulse" setting levels (an obsolescent metric – ironically not suitable for the measurement of impulse noise and no longer used) etc. There may have been a meter setup or calibration error. The levels reported for Pickleball strikes (if they are indeed Peak levels) are on par with those that would be generated due to conversational speech and a competent practitioner should have seen a red flag in this result. The Acoustical terminology, used to distinguish between these metrics is objectively standardized and defined in the **ANSI/ASA S1.1-2013 Acoustical Terminology** standard. The language and discussion in this report does not seem to use or conform to this industry standard.

The Connecticut Department of Environmental Protection Control of Noise Regulations provide Impulse noise limits that differ from the steady state noise limits. As Pickleball noise is a series of Impulse noise events, this limit should have been identified by SHAcoustics and addressed. The CT regulation states that:

> SEC. 22A-69-3.2. IMPULSE NOISE
>
> (a) No person shall cause or allow the emission of impulse noise in excess of 80 dB peak sound pressure level during the nighttime to any Class A Noise Zone.
>
> (b) No person shall cause or allow the emission of impulse noise in excess of 100 dB peak sound pressure at any time to any Noise Zone.

Note that the CT Regulation limits impulse noise based upon the un-weighted (not A-weighted) Peak sound pressure level. The measured un-weighted sound pressure level will be greater than the A-weighted sound pressure level due to the filter effect of the A-weighting network.

2 METHODOLOGY

TAV performed a community noise impact study to model the ambient and Pickleball noise emissions over the BCC site and surrounding residential properties using well developed, science-based engineering techniques and tools. The ambient sound levels were estimated based upon extensive databases of urban, suburban and rural noise studies and Acoustical Engineering conventions. The Pickleball noise emissions were modeled based upon TAV's database of Pickleball source noise levels using the industry standard ISO 9613 environmental noise propagation methodology.

3 Results

3.1 Community Ambient Sound Levels

The predicted ambient sound levels for a suburban community, such as that surrounding the BCC, as characterized by the Level exceeded 90 percent of the time (L_{A90}); will typically be on the order of 30-50 dBA during the daytime (roughly 8AM until 8 PM) and will drop to approximately 20-45 dBA at night. In order to accurately establish what the actual ambient sound levels are, an array of noise monitors should be set up to monitor the levels across the affected residential properties for a period of at least 1-week.

3.2 Pickleball Noise Levels

The predicted A-weighted Peak sound pressure levels (L_{APeak}) over the land surrounding the proposed BCC Pickleball Courts are shown in Figures 3-6 (for play on individual courts, with and without the proposed 10-foot-tall noise barrier).

The results of the noise model were validated by comparing the predicted levels to known measured levels at similar distances and topographies (within the TAV database) to confirm that the predicted levels match real-world measured levels.

Recall that for every 10 dB increase the perceived loudness doubles, such that a 30 dB increase over ambient would be perceived as roughly 8-times as loud as the ambient (for the duration of the Impulse noise).

The Pickleball noise A-weighted Peak Sound Pressure Level will be 89-95 dBA at the nearest property lines without a noise barrier and 84-88 dBA with a 10-foot noise barrier surrounding the courts.

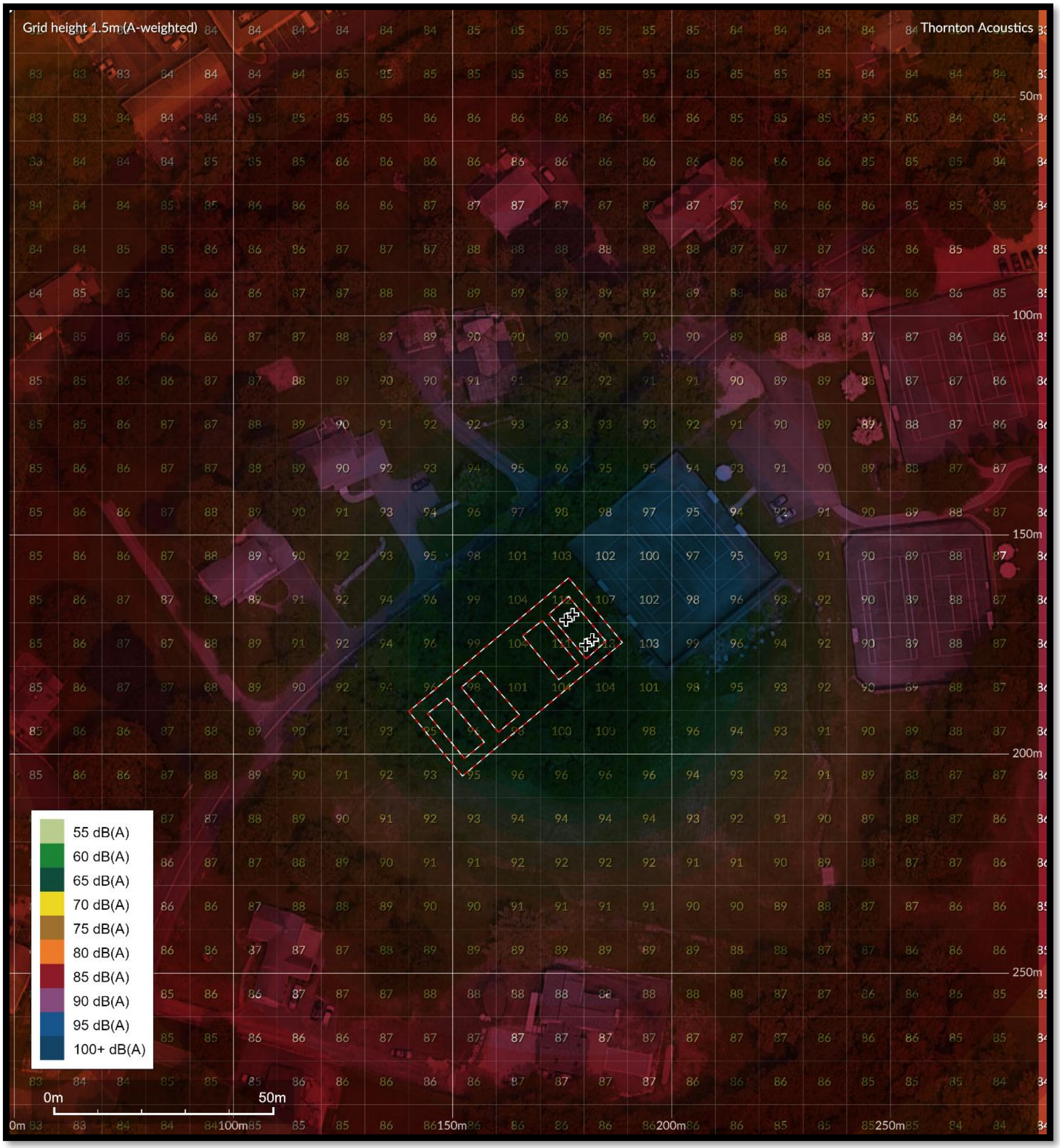

Figure 3 A-weighted Peak Sound Pressure Level contours (L_{APeak}) due to Pickleball noise emissions from single-court play (east most court only) with no noise barrier installed.

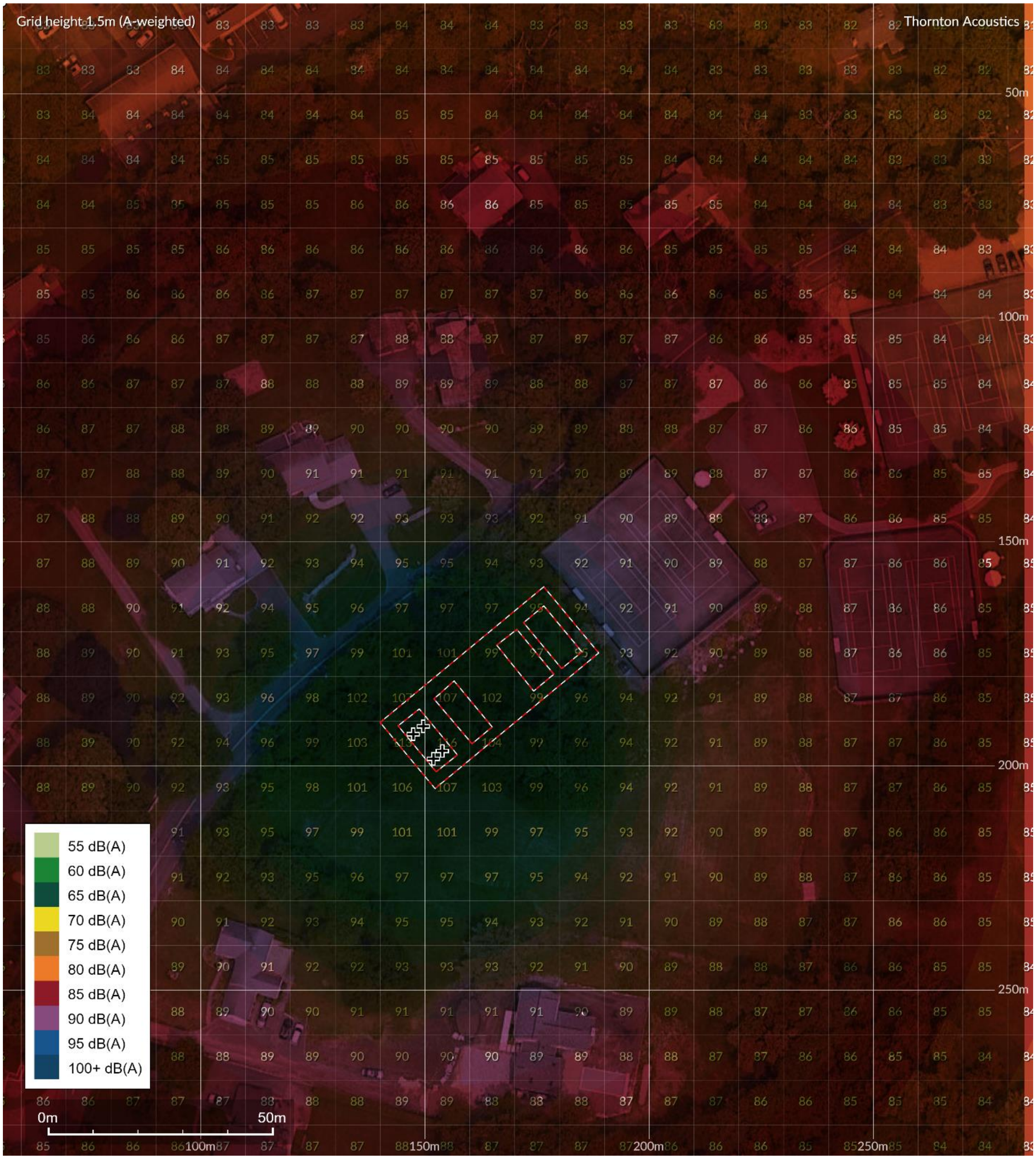

Figure 4 A-weighted Peak Sound Pressure Level contours (L_{APeak}) due to Pickleball noise emissions from single-court play (west most court only) with no noise barrier installed.

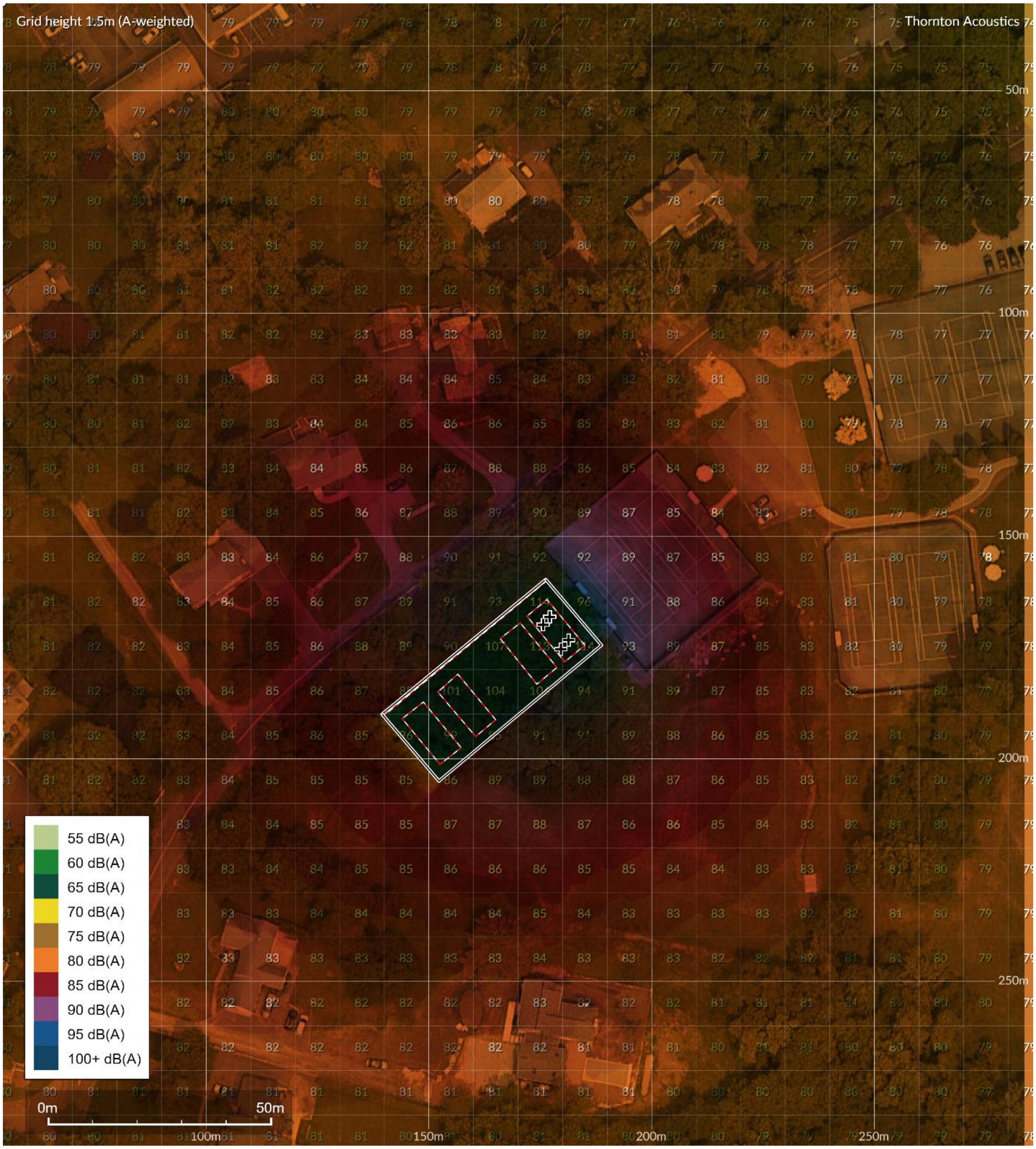

Figure 5 A-weighted Peak Sound Pressure Level contours (L_{APeak}) due to Pickleball noise emissions from single-court play (east most court only) with a 10-foot-tall noise barrier installed around the entire perimeter of the courts.

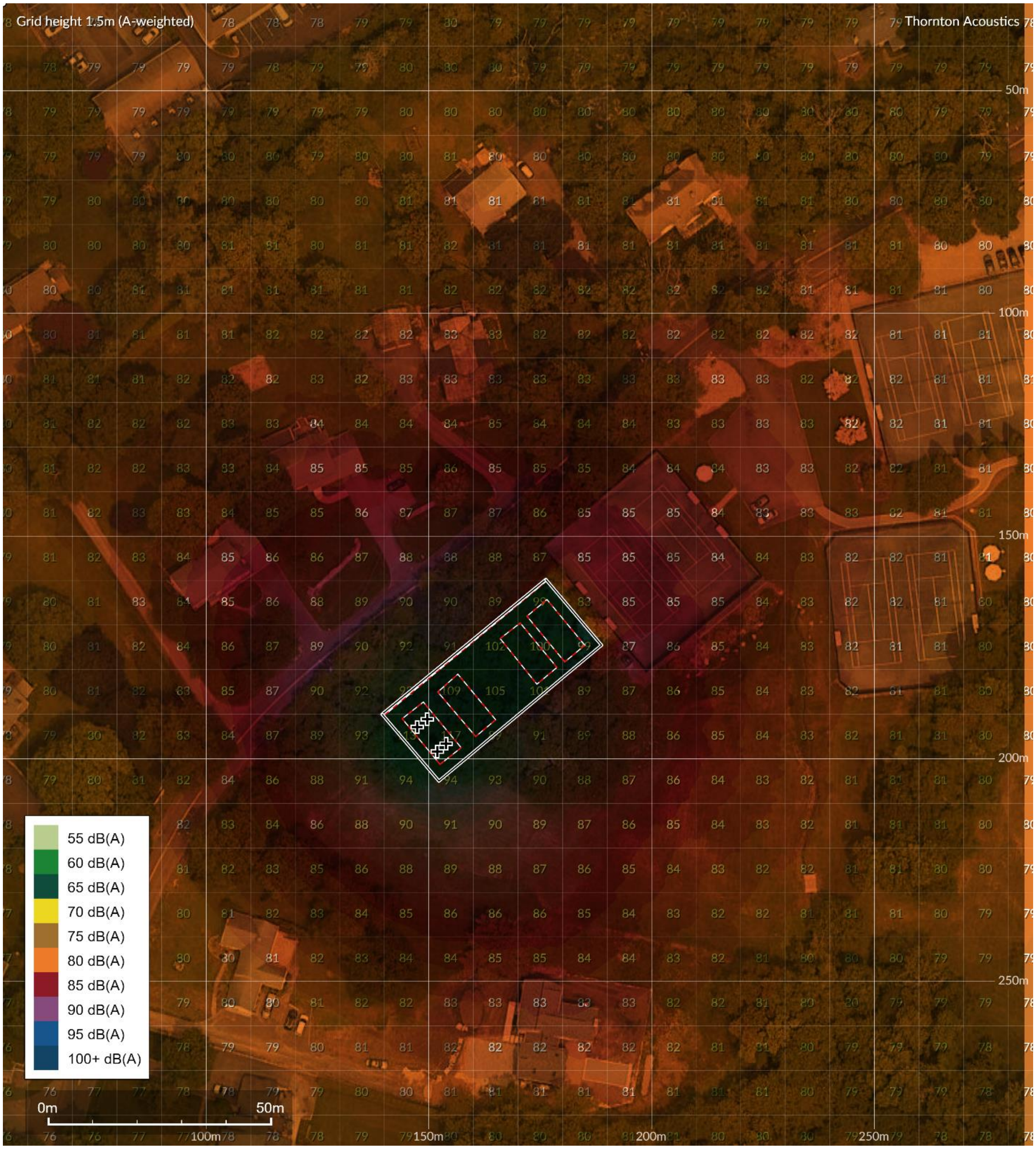

Figure 6 A-weighted Peak Sound Pressure Level contours (L_{APeak}) due to Pickleball noise emissions from single-court play (west most court only) with a 10-foot-tall noise barrier installed around the entire perimeter of the courts.

The A-weighted peak sound pressure levels (which will be lower than the un-weighted Peak sound pressure levels) approach the CT Impulse noise limits at the property line (daytime limit of 100 dB, L_{peak}). It is highly likely that the unweighted levels would actually exceed the limit, but we can not evaluate or confirm this as our database is limited to A-weighted data and there is no accurate means of converting between A-weighted and unweighted.

The frequency content emitted by Pickleball (perceived as pitch or tonality), falls in the center of the most sensitive frequency range of human hearing (humans are most sensitive to sound centered around the 1000 Hz range) and this causes Pickleball noise to be highly annoying and disruptive.

4 CONCLUSIONS

The noise emitted by the Pickleball courts, as incident on the surrounding properties grossly exceeds the ambient community sound levels. The Pickleball noise is sufficiently loud, above ambient levels, and in terms of absolute level, and contains tonal content (pitch) such that it is plainly, loudly audible over the entirety of the surrounding properties. Due to the level and tonality, the Pickleball noise will propagate over the property and through the walls, windows and doors of the homes and although it will be reduced on the interior, the noise will be audible. The Pickleball noise is sufficiently loud to severely detract from the peace and enjoyment of the properties.

4.1 NOISE CONTROL / NOISE BARRIERS

Due to the level and tonality emitted by Pickleball, this Pickleball Court is incompatible with the existing community. Invariably, the subject of noise control arises with this type of noise problem. The most common purported solution is a noise fence/barrier/screen/wall (these terms are used interchangeably). Unfortunately, these purported solutions are not effective, due to fundamental physics, at controlling this type of community/environmental noise problem. Although this approach appeals to erroneous conventional wisdom, which dramatically overestimates the efficacy, the actual performance of a noise barrier is highly predictable and relatively poor for this type of site/problem. As sound is a pressure field phenomenon and does not simply propagate in a line of sight, placing a barrier between the source and receiver does not “block” the sound as a it would a beam of light. Instead, sound waves, being pressure perturbations, diffuse and spread over and around barriers as they propagate. It is useful to envision smoke propagating over the landscape to help in understanding how sound propagates. The primary means by which a barrier works is simply to increase the path over which the sound travels, thereby reducing the energy due to geometric spreading. Accordingly, a barrier’s effective height is only that portion above the direct line between the noise source and the receiver. A barrier must be relatively tall and long compared to the distance between the source and receiver to provide any degree of effectiveness. While a ten-foot-tall barrier may provide a significant noise reduction when the source and receiver are separated by 20 feet, that same barrier will provide much less reduction as the separation distance is increased. As the separation grows, the effect of the barrier approaches zero. Note that despite conventional wisdom, the location of the barrier relative to the source or receiver has little effect.

In considering noise barriers, it is important to point out that the manufacturers and vendors of commercial barriers often grossly misrepresent and overestimate the barriers noise reduction performance by using incorrect and unrelated performance metrics. For example, they will often test and report the Transmission Loss (TL), Noise Reduction (NR) or Sound Transmission Class (STC) of the barrier material which are metrics used to rate the noise through the barrier. While a barrier must block sound from propagating though it as a prerequisite, these metrics do NOT represent the performance of the barrier which will be entirely dependent on geometry. For example, a barrier may be made of a material that will provide 50 dB of TL, but due to the height and separation between source and receiver, may only provide 5 dB of reduction as a barrier. Another common way of misreporting barrier performance is to test a given barrier using a closely spaced noise source and receiver and incorrectly extrapolating this performance to larger separation distances. For example, a 10-foot-tall barrier placed between a source and receiver separated by 20 feet may reduce the noise at the receiver by 15 dB, if the same source and receiver were separated by a larger distance the effectiveness of the barrier may be reduced to 0 dB.

It is also worth noting that foliage, trees, and other plants do not provide any meaningful noise barrier performance and simply planting trees along the property line will not reduce noise propagation onto the affected property.

The only means of reducing the Pickleball noise would be to enclose the Pickleball court in a well-engineered building or structure to contain the noise or to locate the Court further away from the affected properties (the levels will be reduced by approximately 6 dB for every doubling of the separation distance).

Please contact me with any questions regarding this report.

Best Regards,

William Thornton