Analysis of Pickleball Sound from Louisville Recreation Center Louisville, Colorado

by

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Executive Summary

PSM Consulting LLC (PSMC) used sound modeling software to create sound maps for pickleball sound from the proposed court location at the Louisville Recreation Center, Louisville, Colorado. The sound maps included elevations around the court because several homes at elevations above the courts have a direct line of sight into the courts. A direct line of sight means a direct path of sound propagation.

Sound levels with no sound mitigation were estimated at the property lines of homes closest to the courts on Larkspur Court, Trails Edge Drive, West Mulberry Street, and West Pinyon Way. Next, sound barriers of several heights and designs were positioned at the hockey fence perimeter so that the reduced sound levels could be estimated at these locations. A design objective of 50 dB LAFmax that has been successfully used by PSMC to address pickleball sound at pickleball sites was used for this site.

With no sound mitigation in place, the highest sound levels from pickleball were 60 dB and 56 dB LAFmax at Larkspur Court and Trails Edge Drive, respectively. These sound levels are louder than the recommended design objective and would be considered objectionable. This is caused by the nearness of the courts to these property lines. The sound levels to the east at West Pinyon Court were 40 dB, well below the design objective. This is due to the greater distance to the courts and lower sound at 90 degrees to the courts.

With an 8 foot sound barrier on the 8 foot hockey fence, a negligible sound reduction was estimated at the closest homes. This barrier is not high enough to block the direct line of sight from the courts to the homes. Alternative sound barrier heights and sound barrier materials were evaluated. Four sound mitigation options were identified that yield acceptable sound reduction. They are:

For 5 courts in a north south direction -

1. Hockey perimeter - 18 foot sound absorbing barrier on north side, 10 foot sound absorbing barrier on south side, open east and west sides
2. Court perimeter - 16 foot sound absorbing barrier on north side, 10 foot sound absorbing barrier on south side, 16 foot barrier on west side; open east side

For 4 courts in an east west direction -

3. Hockey perimeter - 16 foot sound absorbing barrier on north side, 10 foot sound absorbing barrier on south side, open east and west sides
4. Court perimeter - 14 foot sound absorbing barrier on north side, 10 foot sound absorbing barrier on south side, 14 foot barrier (transparent) on west side, open east side

These designs would not require the use of quieter paddles and quieter balls from the Blue List (Appendix B). This mandate is often unfavorable to both recreational and competitive players and was not preferred by the Louisville Recreation Center. If equipment restrictions were implemented, then the barrier heights could be reduced to meet the design objective. The Louisville Recreation Department should review the structural capabilities of the hockey fence and the fence foundation along with the zoning height restrictions to select the sound mitigation option that provides the best balance of player enjoyment, homeowner comfort from sound, and project cost.

Introduction

Pickleball is a game played with two to four players using paddles, a ball, and a net on a court that is approximately one half the length and one half the width of a tennis court. The paddles are made of wood, plastic, or composite materials, and the ball is made of plastic. Each paddle and ball impact during a game creates a short pulse of sound that varies in intensity, duration, and frequency content. For homeowners near pickleball courts, pickleball sounds can become objectionable, depending on the distance from the courts and the sound mitigation in place. These objections are also because the frequency of a paddle and ball impact is near 1000 Hz, which aligns with the maximum sensitivity of human hearing.

To help explain the details in this sound study, background information is provided on the properties of sound, pickleball sound impulses, sound measurements, human hearing, sound ordinances, design objectives, and sound mitigation options.

Pickleball sound levels are then presented at several locations surrounding the proposed pickleball courts at the Louisville Recreation Center, Louisville, Colorado using sound maps. Sound maps are presented first with no mitigation and then with mitigation in place.

The Sounds of Pickleball

A typical pickleball game will produce a series of random paddle and ball impacts each time the ball is struck. These impacts are described as "popping sounds of varying loudness." The loudness of each impact varies based on a player's position on a court, the paddles and balls being used, the skill level of each player, and the force of each impact. Higher skill players will generate louder sound from pickleball via their forceful paddle strikes than lower skill players.

A paddle/ball impact is an impulsive sound with a duration of 10 to 20 milliseconds. The maximum loudness occurs in the first 5 milliseconds and then the loudness subsides. Impulsive sounds are defined as sounds lasting less than one second with an abrupt onset and abrupt decay (1). The peak acoustical energy is near 1000 Hz, which corresponds with the most sensitive region of human hearing.

In a game of pickleball, a rally will generate several random impacts until the rally is over. A game involves several rallies (and impacts) until a team wins. A typical pickleball game will generate 12 to 15 impacts per minute or 720 to 900 impacts per hour – per court. If multiple courts are in use at the same time, then the number of impacts per hour will be increased by the number of courts. However, not all impacts are of the same loudness. Soft paddle strikes can be barely audible and forceful paddle strikes can be much louder. This results in a range of sound levels from any game. An effective sound study must consider the highest sound levels rather than an average sound level. This has been done in this study.

In addition, the probability of any two paddle strikes occurring at the same time is extremely low. This is because the loudest sound of any single impact lasts only 5 milliseconds or 1/200th of a second. A typical sound measurement interval is 125 milliseconds. More than 25 courts would have to be in use for two impacts of 5 milliseconds each to overlap in this interval and increase the loudness of a single impact. The resulting sound with more courts in use is therefore not greater loudness but more pickleball impacts in any period of play.

The goal in sound mitigation is to reduce the loudest impacts – regardless of the number of courts - to a low enough level so that the loudest impacts will not be objectionable. If the loudest impacts are not objectionable, then lower loudness impacts will not be a problem. In this manner, the number of courts will not be a problem.

Measurement of Pickleball Sound

Sound is measured with a sound level meter as shown in Figure 1. The units of sound measurement are decibels, abbreviated as dB. Higher dB levels represent louder sounds.

Figure 1 - Sound Level Meter

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Reference dB levels for common sounds follow.

- 120 dB – ambulance sirens, jet planes at takeoff
- 110 dB - car horns
- 100 dB – factory machinery
- 90 dB – lawnmowers, blenders, power tools
- 80 dB – truck traffic, alarm clocks, garbage disposals
- 70 dB – washing machines, hairdryers, highway sound, city streets
- 60 dB – dishwashing machines, electric toothbrushes
- 50 dB – moderate rainfall, large offices
- 40 dB – refrigerators, quiet offices, quiet residential area
- 30 dB – library, a whisper

The human ear does not hear all sounds equally. It has more sensitivity in a mid-frequency range of 1000 to 4000 Hz and has diminished sensitivity at frequencies above and below this range. A frequency weighting can be applied to any sound measurement to match the hearing sensitivity of the human ear. This is called the A-weighting. Decibel measurements with the A-weighting are listed as dBA.

Because sound is not constant and varies with time, the sound level meter has several measurement settings to average these sound fluctuations over the measurement period (1). These settings report the sound level for the measurement period selected. The meter setting must be properly selected to capture the sound level based on the duration of the sound and the response time of the human ear.

What meter setting is best for pickleball play? For short duration sounds like pickleball impacts, the fast meter response with an A weighting best corresponds to the averaging time and sensitivity of the human ear (2). A maximum hold setting on the meter can also be used. The maximum hold setting "listens" for the maximum sound level within the measurement time interval and continues to update the maximum level. In this manner, the maximum level of these rapid fluctuations can be captured over the measurement period.

The fast meter setting will always measure a higher sound level for a pickleball impact than a slow setting. The slow meter setting averages sound over a longer averaging period that includes intervals with no pickleball impacts. The slow setting is appropriate for continuous sound and for background sound but is not appropriate for pickleball impacts. The slow setting understates the loudness of the short duration pickleball impact heard by the human ear. Different time averaging intervals will therefore report different dB levels for the same sound event.

When the A-weighting setting on a sound level meter is selected, dB measurements are described as dBA. If the sound level (L) is measured with an A-weighting (A) and a fast (F) setting, it is described as LAF. When the maximum level is captured in the measurement interval, this is called LAFmax. Unless otherwise noted, pickleball sounds in this report will be described in units of LAFmax. LAFmax measures the maximum sound, regardless of the number of impacts. If the LAFmax sound level can be reduced through sound mitigation to a low enough level to not be objectionable, then the number of impacts (or the number of courts in use) will not be important.

LAFmax is the preferred metric over LAeq, which is the continuous equivalent-energy level (3) or an average sound level. The LAeq is the level of a continuous sound having the same sound energy as a given time-varying sound. For an impulsive sound that is only present for a short period of time, the time averaged LAeq dB level will understate annoyance. For pickleball, the LAeq will be lower than the LAFmax level for the short duration pickleball sound impulse.

LAFmax addresses the maximum sound in the measurement interval. If LAFmax is reduced to a low enough level to not be objectionable, then the number of lower level pickleball impacts will not be an issue. The maximum value of the LAFmax sound level to avoid objections from pickleball has been determined by PSMC from site evaluations and from human response and is described in a later section.

Sound Maps

Sound maps were created using the dBmap.net Sound Mapping Tool, which is a commercial software (4). The topography of the surrounding area was applied to the sound map before the positions for a sound source and for receivers were selected. Ground elevations were selected from Google Earth. In addition, buildings and homes were added in the vicinity of the pickleball courts. The size of each building together with the roof height were selected from Google Earth or from Zillow and applied to the model for the site. The pickleball sound source was then placed on the court, and the receiver locations were selected. Because this is European software, all distances, site elevations, building sizes, and barrier heights must be added to the model in meters. The resulting sound maps with distance scales can only be shown in meters. (One meter = 3.3 feet)

All colored sound maps have the legend shown in Figure 2. Each colored band represents a 5 dB change in sound level. The number beside each band indicates the lowest sound level within the band. In addition, sound maps shown in color have white lines within each band of colors to show the 1 dB changes within this 5 dB interval.

For example, the yellow band indicates sound levels from 50 dBA to 54.9 dBA; the orange band indicates sound levels from 55 dBA to 59.9 dBA; and the pink band indicates sound levels from 60 dBA to 64.9 dBA The colors represent increasing sound levels from 30 dBA in dark green to over 80 dBA in dark grey.

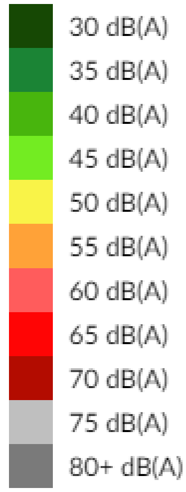

Figure 2 – Color legend for sound maps

All sound maps are shown with north oriented to the top of each map. This provides a link to any local maps which also have north oriented to the top of the map.

<u>Sound Propagation</u>

Sound travels away from its source with a reduction of 6 dB for each doubling of distance from the source. This means that sound decreases in loudness as the distance from the sound source increases. Figure 3 shows sound propagating away from a point source over level ground using the sound modeling software (4). This figure shows the horizontal plane of sound propagation. Each colored ring represents a 5 dB decrease of sound as indicated by the legend. Sound decreases in level as either a listener moves away from a sound source or as the sound source is moved farther away from a stationary listener. (Distances in sound plots can only be shown in meters because the software used is a European software which only displays meters. One meter = 3.3 feet) The 6 dB reduction for every doubling of distance is evident with the increasing diameter of each ring outward from the center.

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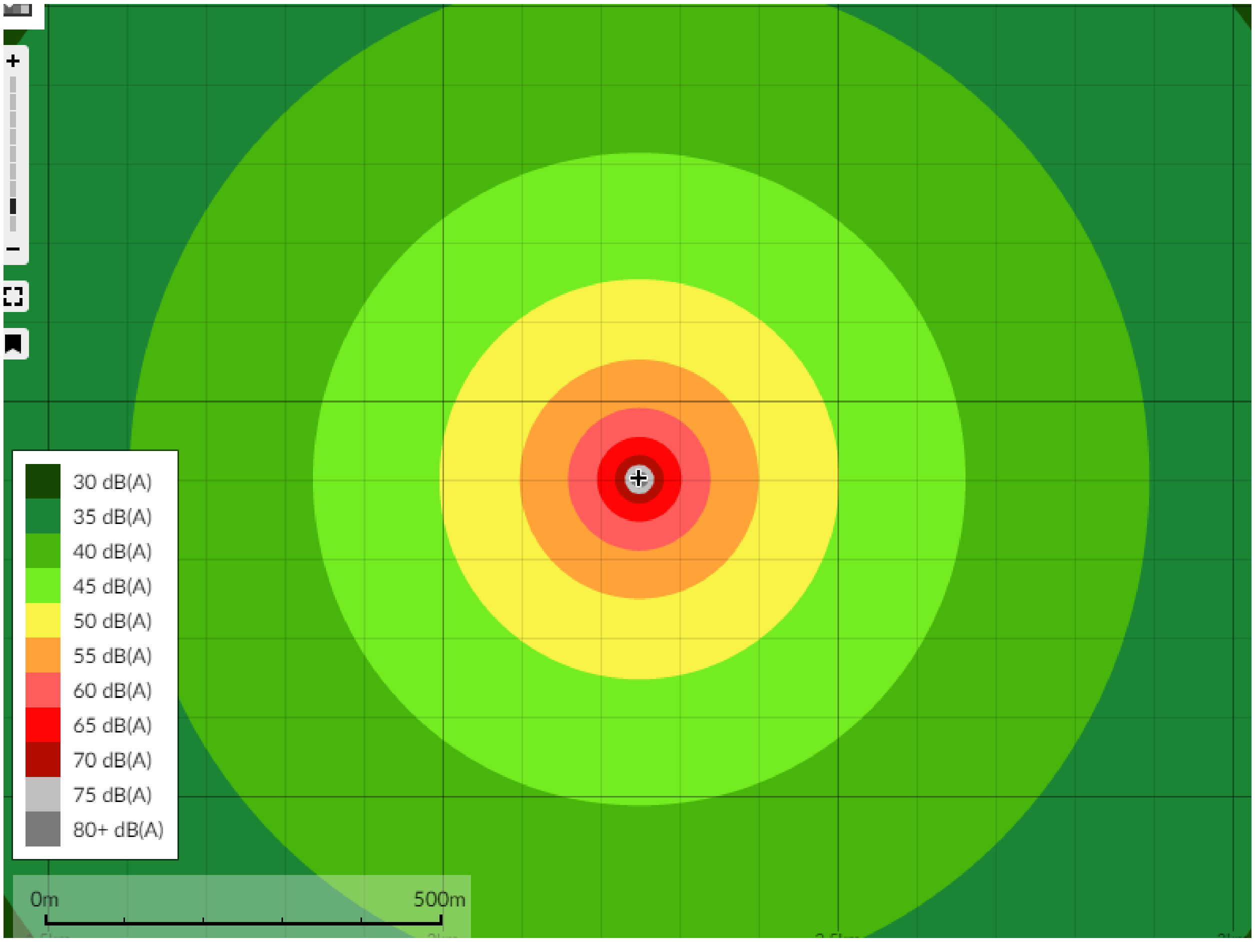

Figure 3 – Sound propagating away from a point source in a horizontal plane (1 meter= 3.3 feet)

Sound also propagates away from a source in a vertical direction. Figure 4 shows a three dimensional view of the vertical plane of sound propagation together with the horizontal plane. (The sound mapping software does not display distances in three dimensional plots.) The three dimensional behavior of sound becomes important to estimate the sound traveling up a hill, to a second story window, over a building, or to an apartment/condominium balcony.

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Figure 4 – Sound propagating away from a point source in a horizontal and vertical plane

Human Hearing and Annoyance

The human ear is sensitive to a sound's level, its frequency content, its duration, and its frequency of occurrence (2). All of these contribute to annoyance. The higher the sound level, the greater the annoyance becomes. The human ear is only sensitive enough to detect a change in sound level of 3 dB. Each 10 dB increase in sound level is perceived as a doubling in the sound level. In the same manner, each decrease of 10 dB is perceived as one half the loudness. A 20 dB increase is perceived as 4 times as loud. Similarly, a 20 dB decrease is perceived as 1/4 as loud.

Hearing is more sensitive to high frequency sounds than to low frequency sounds. Sound measurements made with an A weighting scale match the frequency sensitivity of the human ear. These are described as dBA levels.

Another factor in annoyance is the interval or space between sounds. Intermittent sounds or impulsive sounds are considered more annoying than a steady state sound of the same dB level. All these elements contribute to annoyance and are critical to the sound measurements in sound ordinances.

To reduce the annoyance of any sound level, the distance between the source and receiver must be increased or sound control measures must be implemented.

Sound Ordinances

Community sound ordinances establish dB sound levels so that sound is not objectionable, even though it may be audible. These ordinances are not intended to establish a dB level where sound is inaudible. They are intended to establish a dB level where the presence of sound above a background sound level will not be objectionable to a person with normal hearing sensitivity. The background sound level is the result of wind, trees, birds, normal ambient sounds, and traffic. Sound ordinances use different sound metrics to quantify the time varying loudness of different types of sound.

Continuous sounds and impulsive sounds have distinct characteristics that cause them to be perceived differently by human hearing. Therefore, the measurement intervals for both types of sounds must be separately stated. This is because the ear responds differently to continuous and impulsive sounds. Nearly all sound ordinances lack enough information or proper metrics to properly quantify the annoyance from the impulsive sound associated with pickleball.

Noise Ordinance for Louisville, Colorado

The Louisville municipal code, Sec 9.34.010. – Disturbance of the Peace (5), states that is unlawful to disturb the peace and quiet of others by making unreasonably loud or unusual noises. This is described as a nuisance ordinance because it lacks a dB level or measurement method for the noise. The resolution of any “disturbance” is decided in a courtroom, and the outcomes vary.

Recommended PSM Consulting Design Objective for Pickleball Sound

PSM Consulting (PSMC) has used its experience with pickleball sound measurements to develop a design objective for pickleball sound. The PSMC design objective for pickleball sound is based on the pickleball sound level in relation to the background sound. Background sound should be measured using A-weighted equivalent sound level (LAeq) or A-weighted slow response (LAS). These are both long term averages of sound fluctuations with an A-weighting. These measurements are commonly used for environmental studies of background sound. PSMC sets an LAFmax level as a design objective where pickleball sound would not be objectionable.

The recommended design objective at a property line for pickleball play to avoid objections follows.

- When the background sound level is at or below 47 dB LAeq, the design objective for pickleball sound should be 50 dB LAFmax.
- When the background sound level is above 47 dB LAeq, the design objective for pickleball sound should be 3 dB LAFmax above the background level.

These design objectives refer to sound levels at a property line. This location follows the standard practice for most community sound ordinances of setting sound levels at a property line. The sound levels at a pool, at a backyard patio, or at the house will be even lower due to the added distance from the property line.

If pickleball courts are in a quiet residential neighborhood with background sound at 47 LAeq, then a design objective for pickleball sound at 50 dB LAFmax should be set. With the background sound level at 47 dB LAeq, pickleball impacts at 50 dB LAFmax will be faintly audible. For any lower levels of background sound, pickleball impacts may be more perceptible.

Pickleball sound at 50 dB LAFmax should not be objectionable to a person with normal hearing sensitivity for these reasons.

- 50 dB LAFmax is the sound level of a large, busy office or of moderate rainfall.
- 50 dB LAFmax is not loud enough to be objectionable even due to its intermittent nature.

Our experience has been that sound levels above 50 dB LAFmax and up to 55 dB LAFmax may cause complaints and sound levels above 55 dB LAFmax frequently can be objectionable.

If pickleball courts are near a location with high background sound at 55 LAeq, then a design objective for pickleball sound at 58 dB LAFmax (55+3) should be set.

This guideline provides a variable design objective for pickleball sound at a property line depending on the background sound levels. Its use has been supported by successful applications at multiple pickleball sites. This design objective for pickleball sound is recommended to avoid community or homeowner objections to pickleball play.

PSM has successfully applied these design objectives to several pickleball facilities and to homeowner associations concerned with pickleball sound. They have been used to judge annoyance at specific home locations with no mitigation in place and to confirm the performance of sound mitigation strategies.

Louisville Recreation Center

Figure 5 shows an aerial view from Google Earth of the proposed pickleball court location on an existing hockey rink at Louisville Recreation Center with the nearest homes or receiver locations to the north, the south, and the east (6). The distance from the hockey fence to the closest property line to the northwest on Larkspur Court is 100 meters. The distance from the fence to the closest property line to the north on Trial Ridge Drive is 160 meters. The distance from the fence to the closest property line to the south on West Mulberry Street is 170 meters. The distance from the fence to the closest property line to the east on West Pinyon Way is 300 meters. The distance from the fence to the police station parking area to the west is 305 meters. Figure 6 shows the planned layout of 5 courts in a north south direction.

In general, pickleball sound will be louder for locations closest to the courts than farther from the courts. Also, at the same distance from the courts, pickleball sound will be slightly louder in the direction of play than at 90 degrees to the direction of play.

Figure 5 – Proposed pickleball court location at Louisville Recreation Center

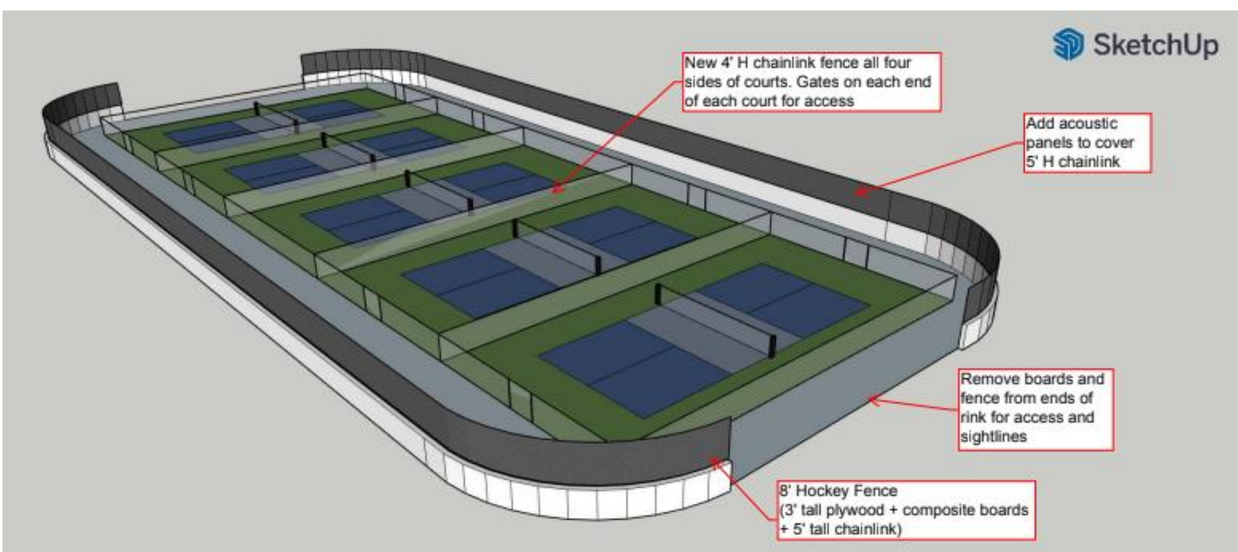


Figure 6 – Proposed pickleball courts at Louisville Recreation Center

The topography for the area was taken from Google Earth and was included on the sound map. The area has higher elevation north of the courts and slightly lower elevation south of the courts. Figure 7 shows the topography with a higher elevation from Trail Ridge Drive to West Mulberry Street.

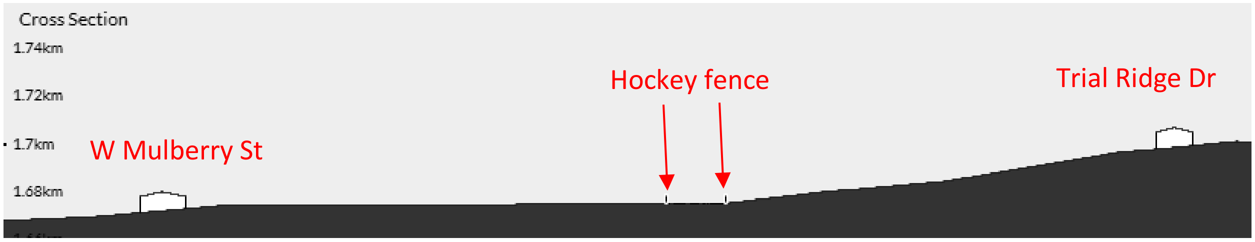


Figure 7 – Ground elevation to the north and south of courts

The closest homes on each of the streets mentioned were added to the sound map. The dimensions of the homes and the roof heights for nearby homes were taken from Google Earth for inclusion in the sound map. Figure 8 shows a three dimensional view of the homes to the northwest and north and the fire station to the northeast. Additional homes were included in the south and east directions. The background sound level was assumed to be 47 dB LAeq, which is typical of a residential neighborhood. The PSMC design objective of 50 dB LAFmax was therefore used.

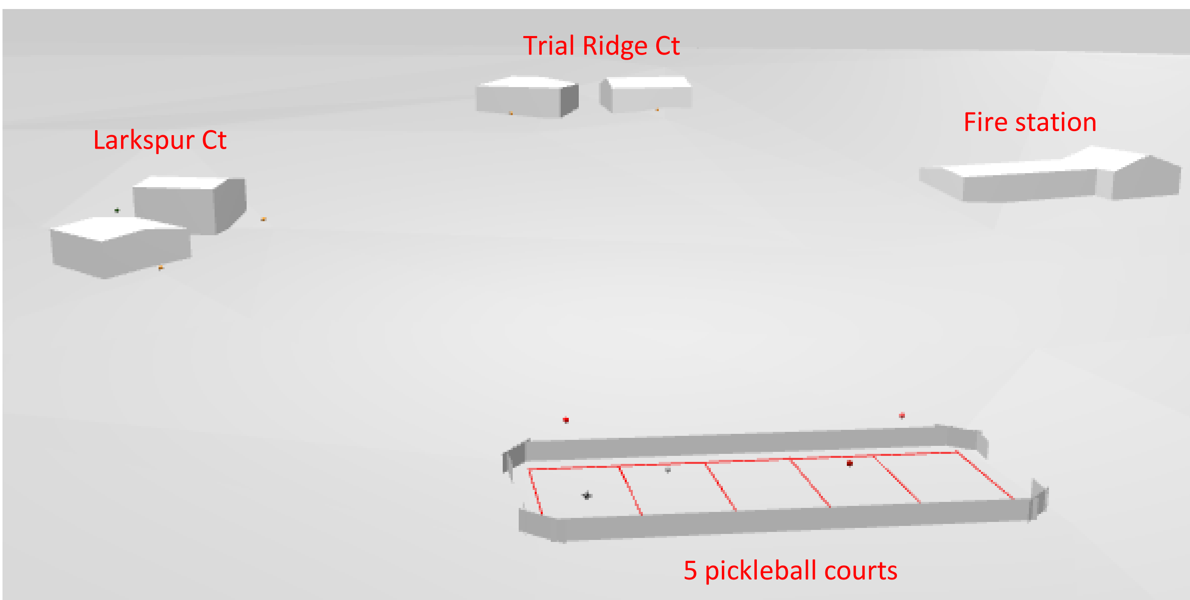


Figure 8 – Sound map details for Louisville pickleball courts – three dimensional model

Pickleball sound can come from any location on a pickleball court when a player strikes a ball. Pickleball sound travels away from the source in all directions. The loudest pickleball sounds will occur in the primary direction of ball travel across the net. Lower sound levels occur to the side, at 90 degrees to the direction of ball travel. In addition, the positions of players change frequently during a game so that some shots (and the direction of sound) will continually change. The sound maps will display sound levels at multiple receiver positions for sound in the direction of play and for sound at 90 degrees to the direction of play.

Four court positions were selected on the pickleball courts to show the sound propagation from these positions in all directions to the nearby homes. Figure 9 shows the four sound source locations. The following sound maps will show the relationship between the source location (on the court) and the distance to a receiver (a home).

Figure 9 – Sound sources for the proposed 5 court layout

As a reference point for pickleball sound levels, the sound levels from tennis were estimated in all directions. In general, tennis is one half as loud as pickleball with a lower tone at impact and fewer impacts per minute of play. One half as loud means 10 dB lower sound level. Figure 10 shows the sound levels from a tennis source position closest to the homes to the north. The white circles indicate LAFmax levels in dB at each receiver at a height of 1.5 meters or 5 feet. This is the height at ear level for most people. This color map shows how sound propagates away from the courts. The design objective would be to have all homes in a green zone where sound is below 50 dB LAFmax. This is achieved with tennis.

Several points about sound propagation from tennis are seen in this figure.

- The sound level decreases at greater distances from the source.
- The sound level on the side of a house away from the source is lower than on the side facing the source – the house acts as a sound barrier and creates a shadow zone for sound.
- A shadow zone exists on the side of the house away from the courts – the house and the roof line function as sound blockers or barriers.
- All the sound levels are below 50 dB LAFmax – no complaints would be expected.

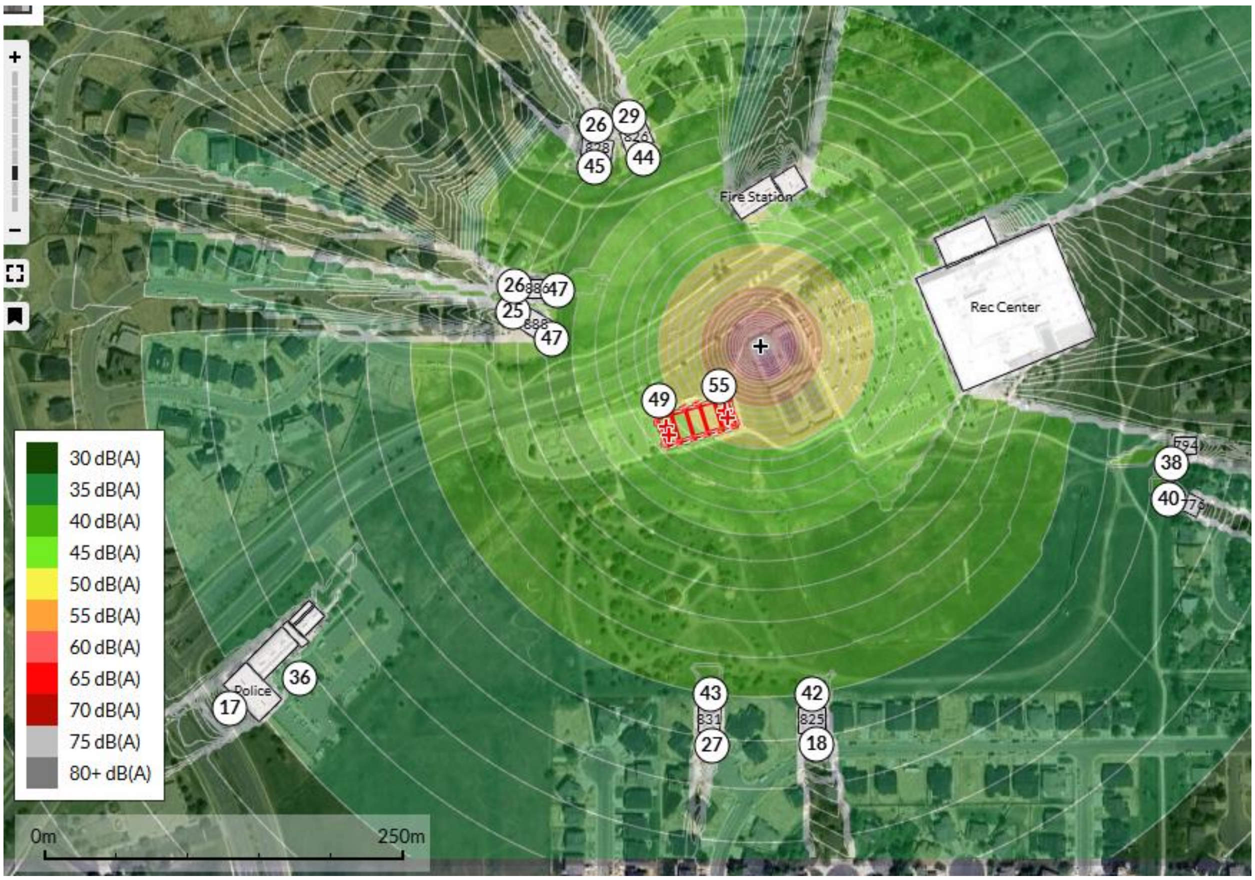


Figure 10 – Sound estimates from tennis

Pickleball sound is louder than tennis. Figure 11a shows the pickleball sound levels from source 1 at multiple locations for sound traveling to the north if no sound mitigation were in place. The black "plus symbol" shows the sound source at a height of 1.5 meters above the ground. This source location is at the non-volley zone line closest to the north. The non-volley zone is the position where the hardest paddle strikes are made and where most rallies occur. The white circles indicate LAFmax levels in dB at each receiver at a height of 1.5 meters or 5 feet. This is the height at ear level for most people. Home addresses are indicated on each roof. This color map shows how sound propagates away from the courts and transitions from zones of red to pink to orange to yellow and to green. The design objective would be to have all homes in a green zone where sound is below 50 dB LAFmax.

Sound levels at 56 dB to 61 dB LAFmax occur at the closest property lines to the north with no mitigation in place. These are above the design objective and would be objectionable. Figure 11b shows the pickleball sound levels from source 1 for sound traveling to the south if no sound mitigation were in place. Lower sound levels are seen due to the greater distance to the homes, but these levels at 56 dB LAFmax are still above the design objective. Figures 11a and 11b will serve as a baseline for later estimating the effectiveness of a sound barrier in reducing pickleball sound. Receiver positions just north of the courts are included to later show the effectiveness of a barrier at receivers near the court versus greater distances.

Note: Table 1 at the end of the report has a summary of these sound plots for source position 2 for all simulations and for all 4 source positions for the preferred designs.

Figure 11c shows a cross section of sound moving up the hill and down the hill from the courts. The higher elevation becomes critical for selecting the height of a sound barrier to reduce sound.

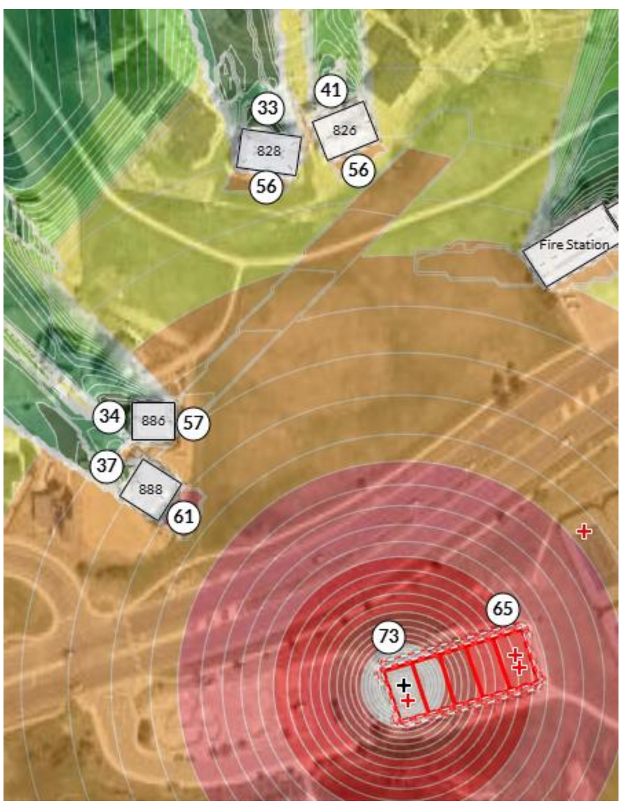


Figure 11a – North, Source 1, no barrier

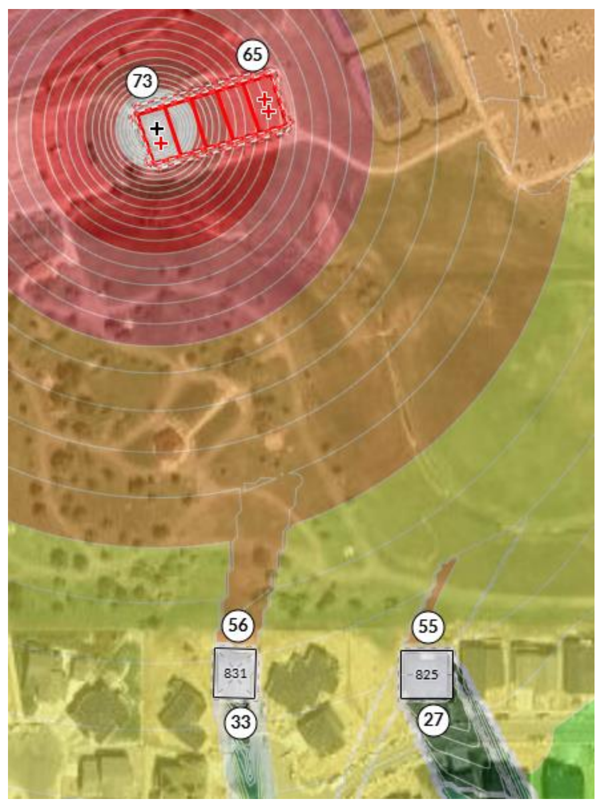


Figure 11b – South, Source 1, no barrier

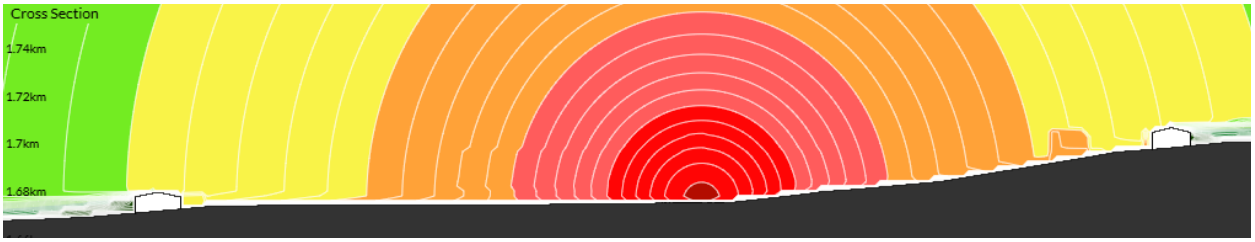
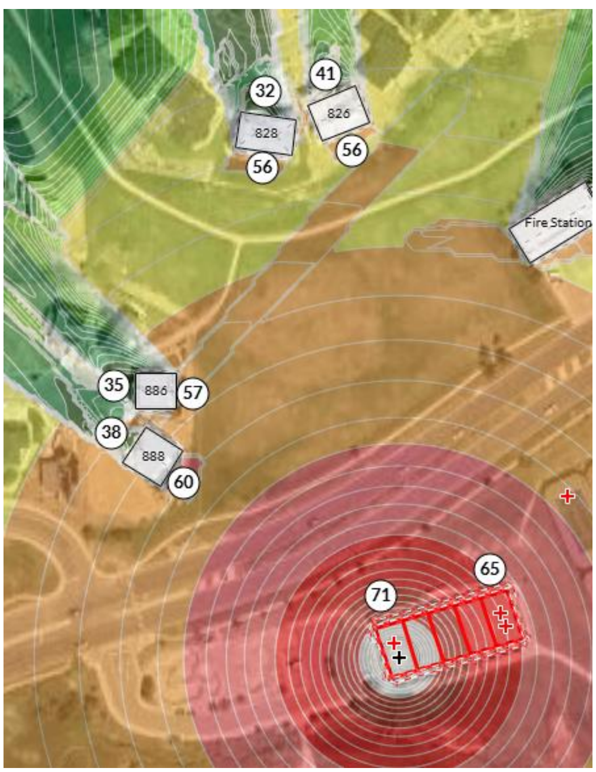


Figure 11c – Sound to the north and south, Source 1, no barrier

Next, the sound source was moved to location 2 on the courts. This is done to establish a second baseline with no mitigation since the effectiveness of a sound barrier can change based on distance from the sound source.

Figure 12a shows the pickleball sound levels from source 2 for sound traveling to the north if no sound mitigation were in place. Figure 12b shows the pickleball sound levels from source 2 for sound traveling to the south if no sound mitigation were in place. Sound levels change slightly due to this source position change but still range from 56 dB to 60 dB LAFmax. These sound levels would be considered objectionable. However, the source position change is more noticeable with a barrier in place.



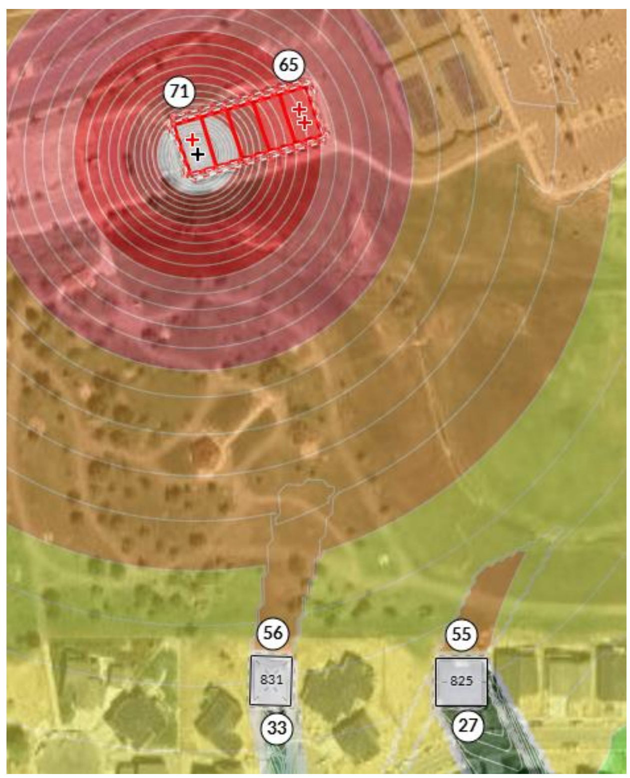


Figure 12a – North, Source 2, no barrier

Figure 12b – South, Source 2, no barrier

Figure 12c shows the pickleball sound levels from source 2 for sound traveling to the east and west if no sound mitigation were in place. The sound levels at West Pinyon Way and the police station are lower due to a greater distance from the courts and due to lower pickleball sound at 90 degrees to the direction of play. No objections would be expected in this case as sound levels are below 50 dB LAFmax.

These results show this behavior for pickleball sound with no mitigation.

- The sound level decreases at greater distances from the source.
- With no homes blocking a direct line of sight to the courts, sound levels decrease with distance from the courts.
- Homes with a backyard facing the courts will have a direct line of sight to the courts and sound levels are above the design objective.
- The sound level on the side of a house away from the source is lower than on the side facing the source – the house acts as a sound barrier and creates a shadow zone for sound.
- A shadow zone exists on the side of the house away from the courts – the house and the roof line function as sound blockers or barriers.

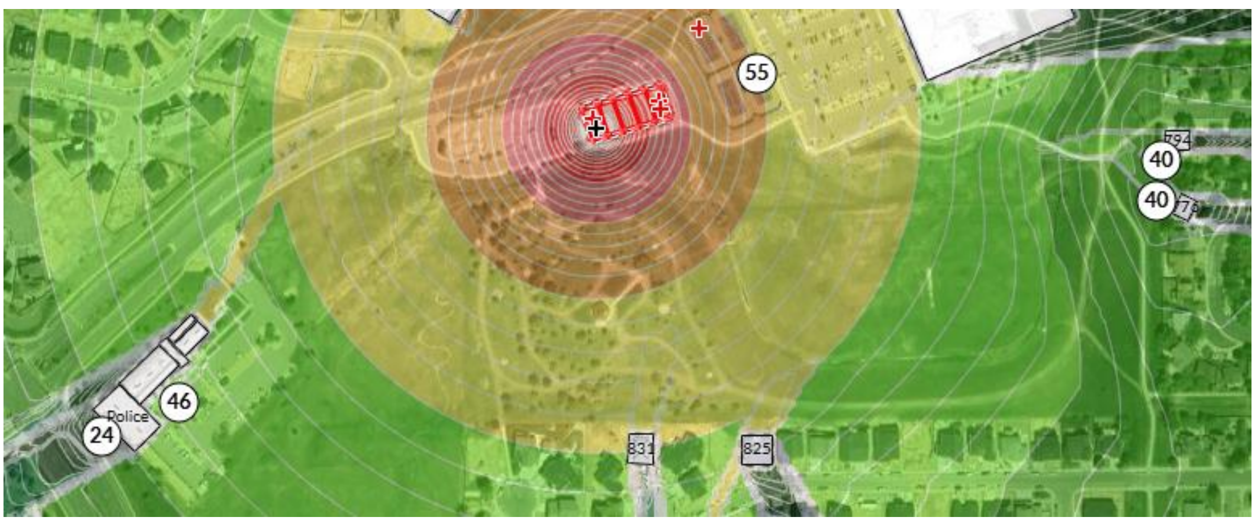


Figure 12c – Sound to the east and west, Source 2, no barrier

Sound mitigation strategies were next evaluated to create green sound zones for homes nearest the courts. The most effective way to reduce pickleball sound is a sound barrier of a height that will block the horizontal path of sound and limit the amount of sound "spilling" over the top of the barrier. A description of sound barriers, best practices for installing sound barriers, and sound barrier suppliers is presented in Appendix A.

When sound barriers are used to mitigate the sound, they are most effective when placed nearest the source (or receiver). The higher the barrier, the more effective it is in limiting the sound spilling over the top. To reduce the sound levels at higher elevations above the courts (Larkspur Court and Trail Ridge Drive), the line of sight between the sound source and the receiver must be blocked.

The most cost effective sound barrier system would use the existing eight foot fencing of the hockey rink with a simple mass loaded vinyl barrier. A mass loaded vinyl barrier is a sound blocking barrier, but it also reflects sound in the opposite direction. An 8 foot sound barrier was placed on the hockey fence on the north and south sides of the courts, including the corners. The east and west sides are kept open because of the lower sound levels at the more distant homes in these directions. Figures 13a, 13b, 13c, and 13d show the sound levels at the nearest properties to the north and south with an 8 foot sound barrier for source positions 1 and 2.

Figures 13a and 13b compare sound to the north from source positions 1 and 2, respectively. Slightly higher sound levels are seen at the same receiver positions with the source farther from the sound barrier. Comparing 13a with an 8 foot barrier to Figure 11a with no barrier, only a 1 dB reduction in sound levels is seen. The barrier is not high enough to provide sound reduction at higher elevations above the court.

Figure 13e shows the cross section of sound from source 2 with the 8 foot barrier. Trivial difference in the sound pattern is seen when compared to Figure 11c with no barrier.

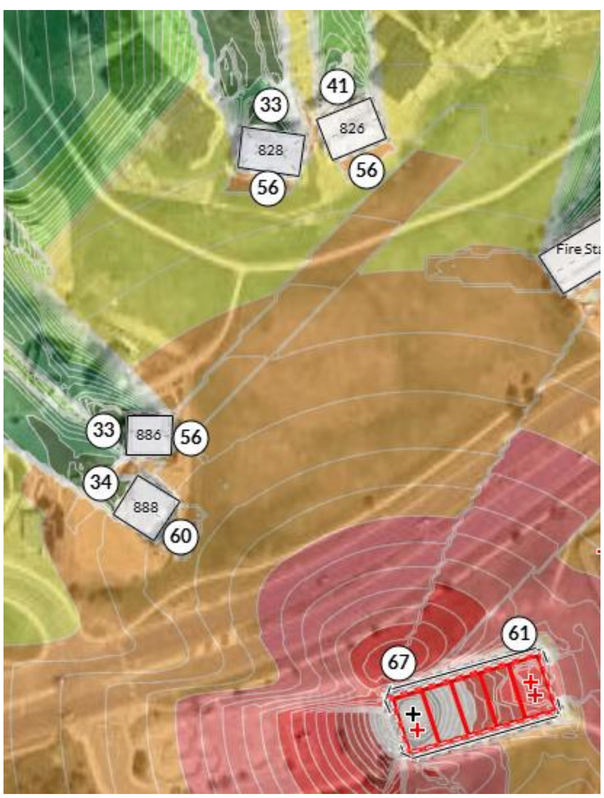


Figure 13a – Source 1, 8 foot sound barrier

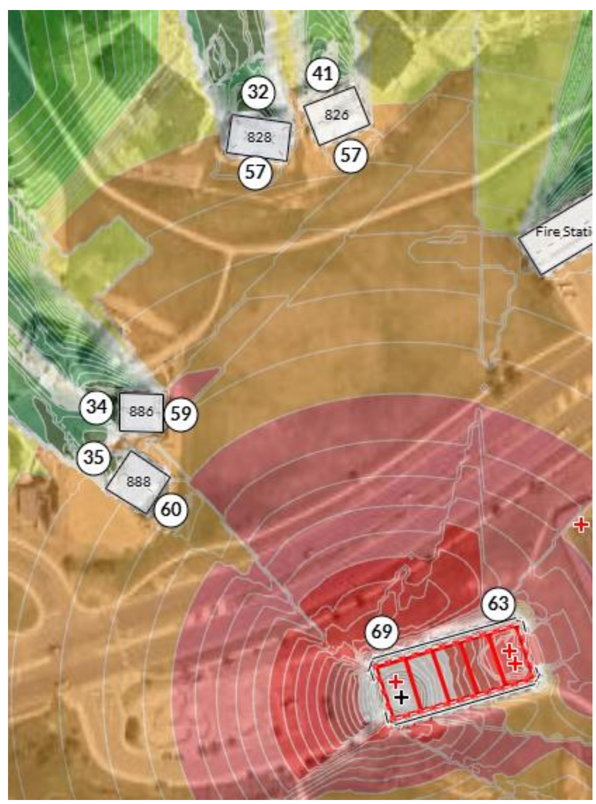


Figure 13b – Source 2, 8 foot sound barrier

Figures 13c and 13d compare sound to the south from source positions 1 and 2, respectively. Slightly higher sound levels are seen at the same receiver positions with the source farther from the sound barrier. Comparing 13C with an 8 foot barrier to Figure 12a with no barrier, a 1 dB increase in sound levels is seen at Trail Ridge Drive. The barrier is not high enough to provide nose reduction at higher elevations above the court. Also, sound is reflected from the south barrier and redirected in the opposite direction.

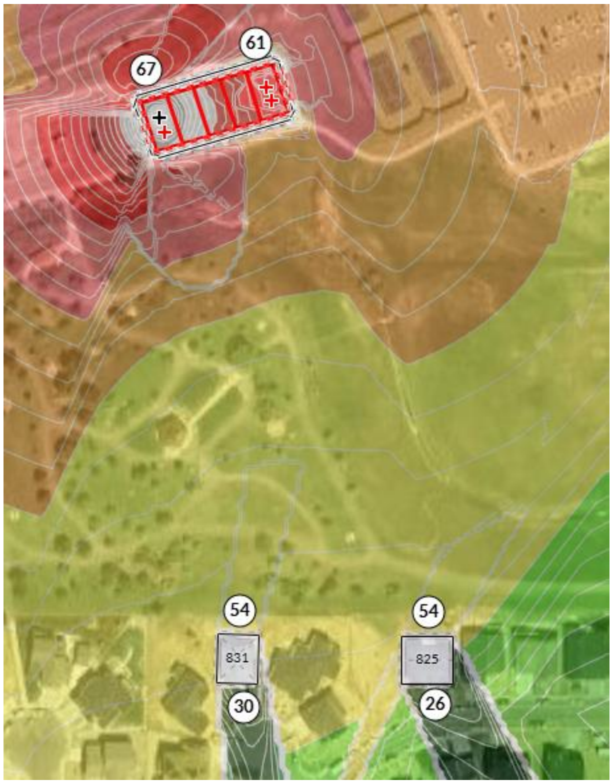


Figure 13c – Source 1, 8 foot sound barrier

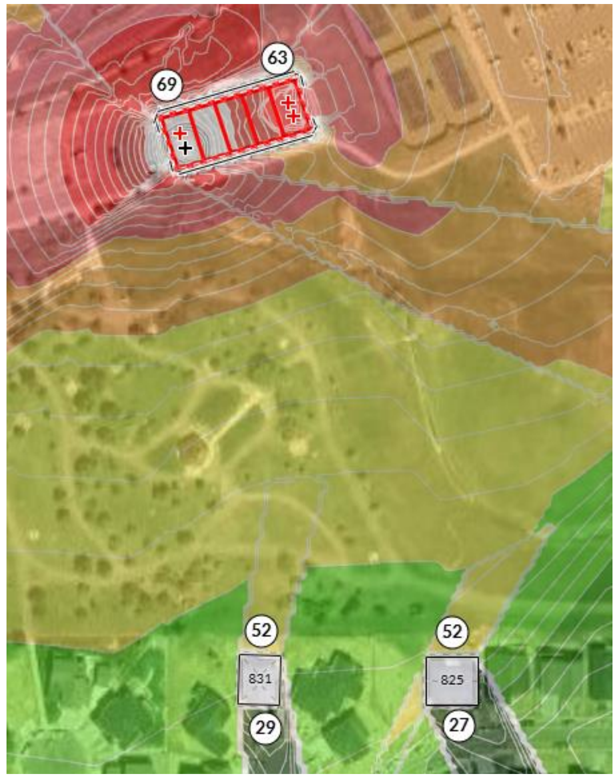


Figure 13d – Source 2, 8 foot sound barrier

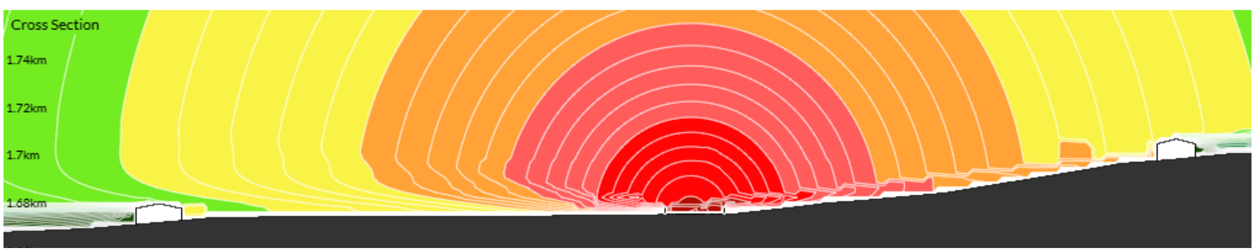


Figure 13e – Source 2, 8 foot sound barrier, cross section

Figure 13f shows the impact of the rise in elevation from the court to Trails Edge Drive. The angle of the slope is approximately 7 degrees. The black dots represent a source at 5 feet above ground level at the center of the court and a receiver at 5 above ground level at Trails Edge Drive. The dotted line shows the line of sight into the center of the court. The black square is a 10 foot barrier wall that just touches this line of sight. If a line of sight exists between the source and the receiver, sound will easily travel along this path. The only sound reduction will be sound reduction with distance as shown in Figures 3 and 4.

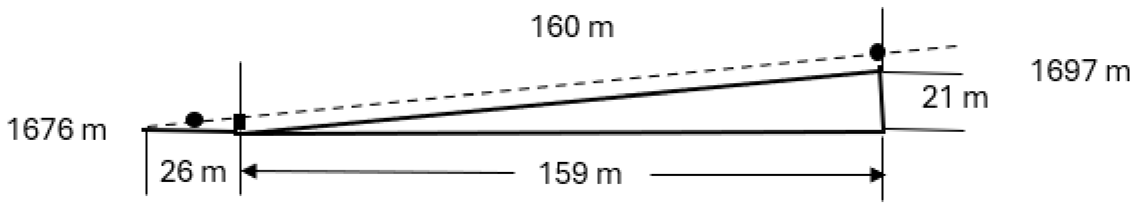


Figure 13f – Elevation between court and Trails Edge Drive (not to scale)

This shows that the effectiveness of sound barriers depends on height, placement, and reflecting surfaces. Also, the most critical source location is position 2, farthest from the sound barrier. For effective noise mitigation at these courts, these 3 points must be considered:

1. The sound barrier must be high enough to limit the sound spilling over the top.
2. The sound barrier becomes more effective the closer it can be placed to the court (the source)
3. The sound barrier on the opposite wall can reflect sound in the opposite direction.

The highest sound levels on Larkspur Court and Trail Ridge Drive show that attention must be focused on a sound mitigation design that addresses these receivers.

Next, a 12 foot mass loaded vinyl barrier was evaluated in the same position as the hockey fence boundary. This reduced sound levels to 57 dB LAFmax at Larkspur Court and Trail Ridge Drive and 51 dB LAFmax at West Mulberry. These are still above the design objective. Additional sound estimates were made with 14, 16, and 18 foot sound barriers, but none were able to achieve favorable sound levels at or near the design objective at all homes.

To reduce reflected sound, a 12 foot barrier with a sound absorbing inner liner was evaluated. Figures 14a and 14b show the sound levels to the north and south respectively from source position 2. The sound level to the north is still above the design objective, indicating that a higher barrier is needed. The sound level to the south meets the design objective, indicating that a lower barrier is possible. Figure 14c shows the cross section to the north and south which indicates how sound still spills over the top of the barrier.

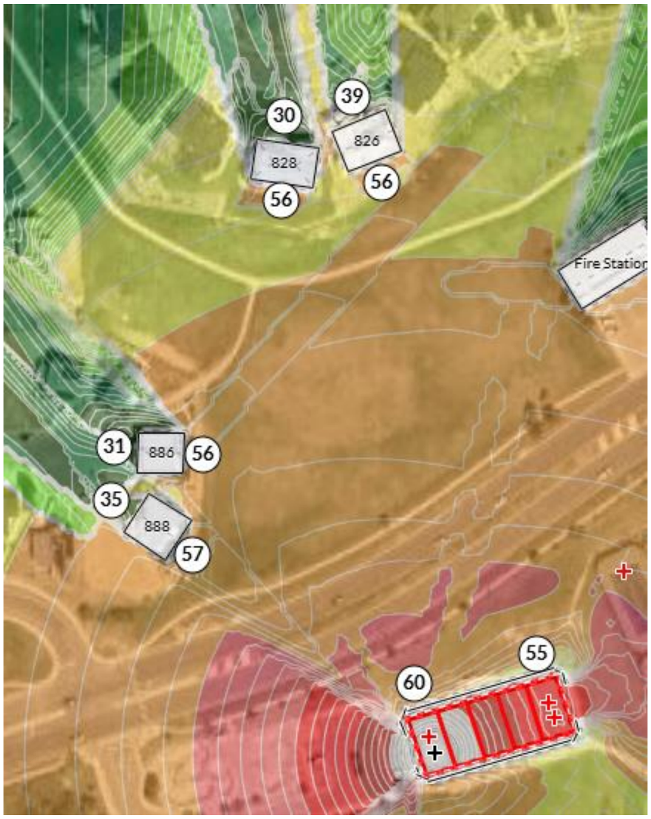


Figure 14a – Source 2, 12 foot absorbing barrier

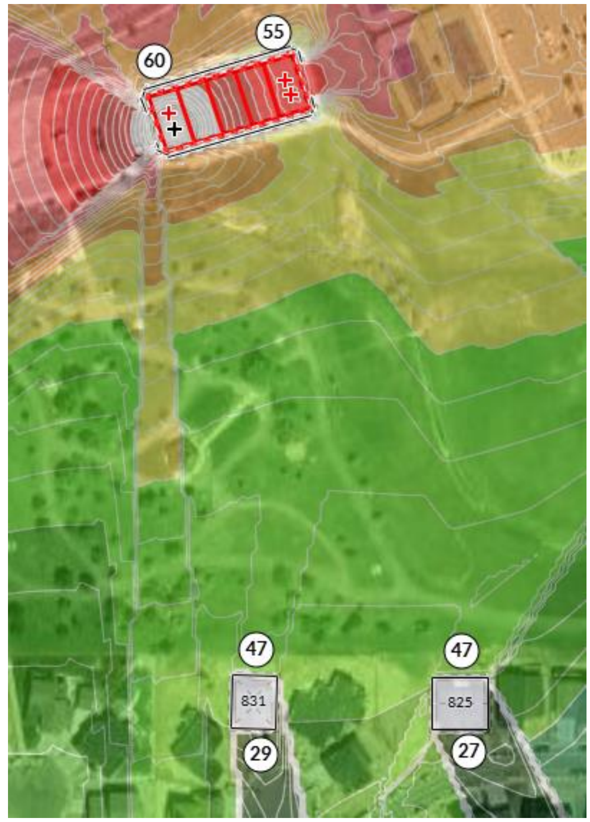


Figure 14b – Source 2, 12 foot absorbing barrier

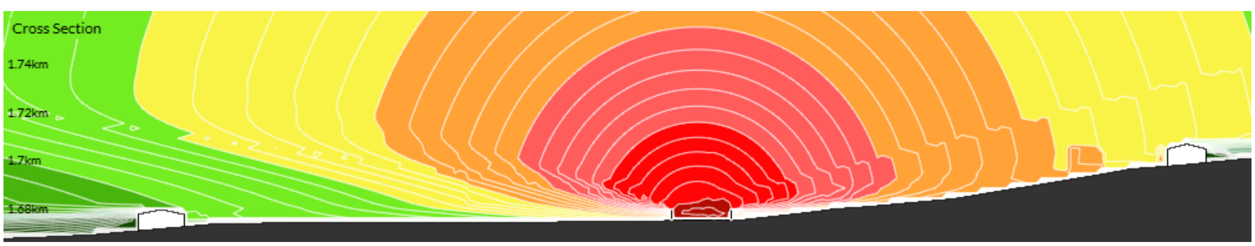


Figure 14c – Source 2, 12 foot absorbing barrier, cross section

The sound barrier was raised in 2 foot increments on the north side until the design objective was met. This required a barrier at 18 feet on the north side. The south side barrier was lowered to 10 feet. Figures 15a and 15b show that the sound levels to the north for this source position are within 1 to 2 dB of the design objective. This is considered acceptable.

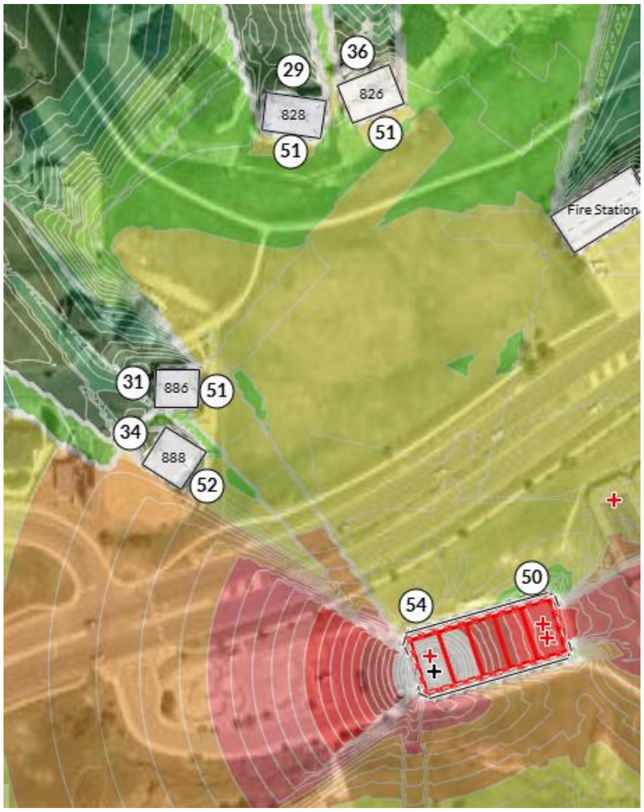


Figure 15a – Source 2, 18 ft absorbing barrier on N wall and 10 ft absorbing barrier on S wall

Figure 15b – Source 2, 18 ft absorbing barrier on N wall and 10 ft absorbing barrier on S wall

The 3 other source positions were next evaluated for the same 18 foot/10 foot sound barrier design. The sound levels are shown in Figures 16a, 16b, 16c, and 16d.

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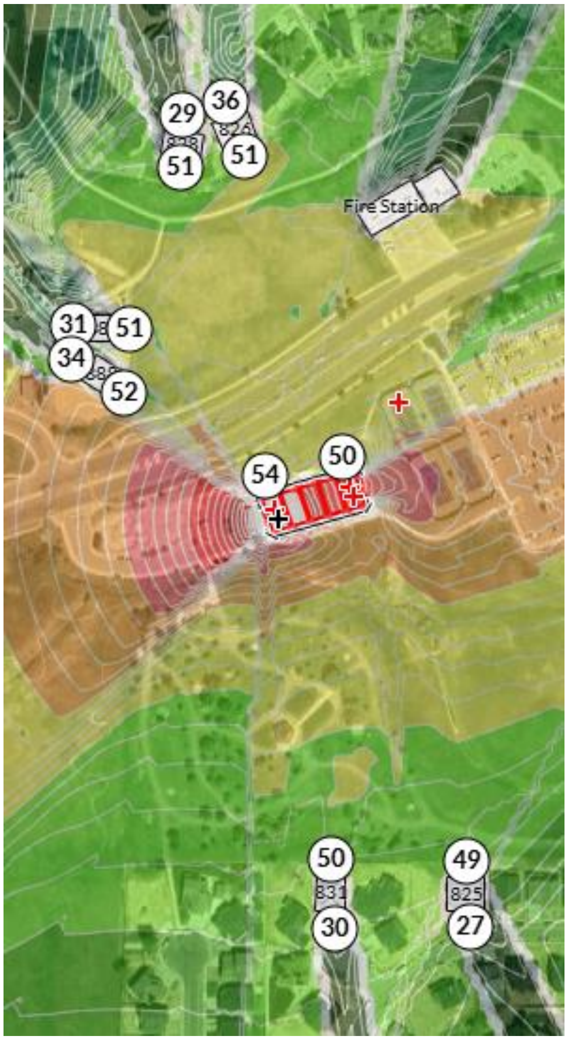

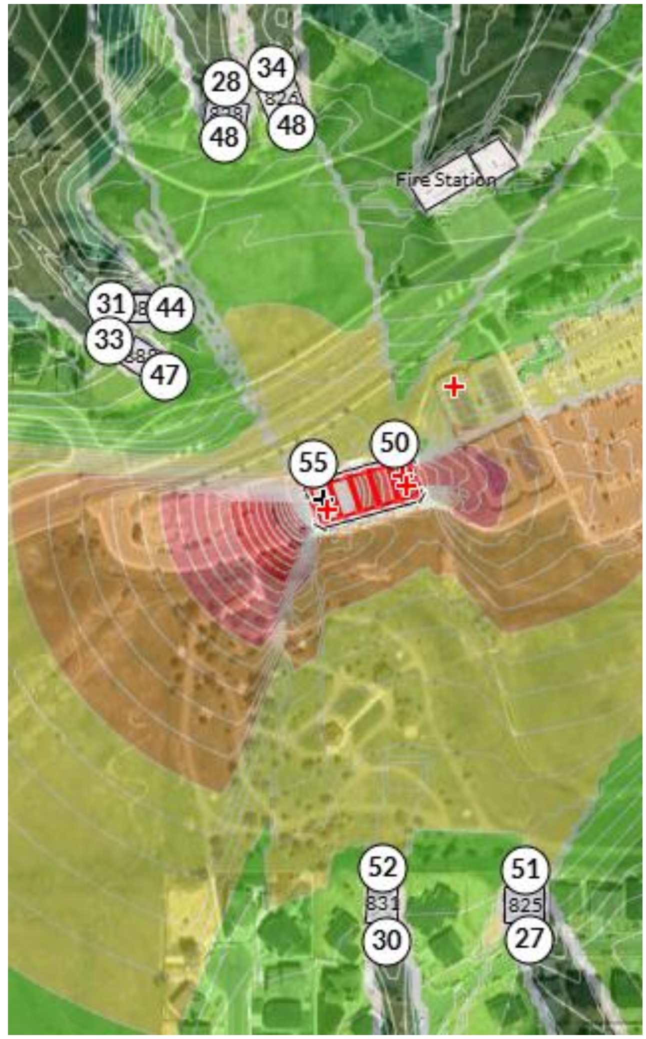

Figure 16a – Source 2, 18 ft/10 ft absorbing barrier   Figure 16b – Source 1, 18 ft/10 ft absorbing barrier

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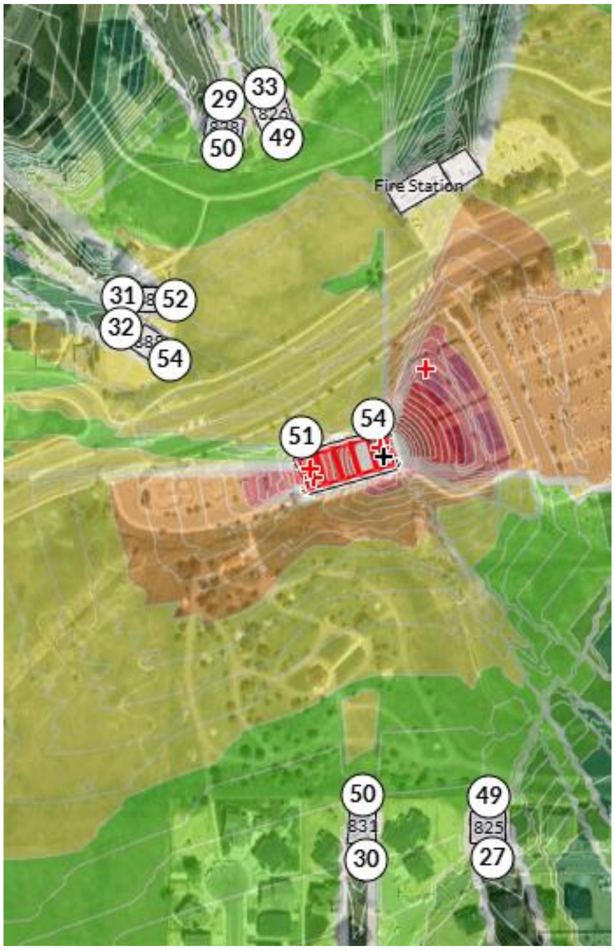

Figure 16c – Source 3, 18 ft/10 ft absorbing barrier

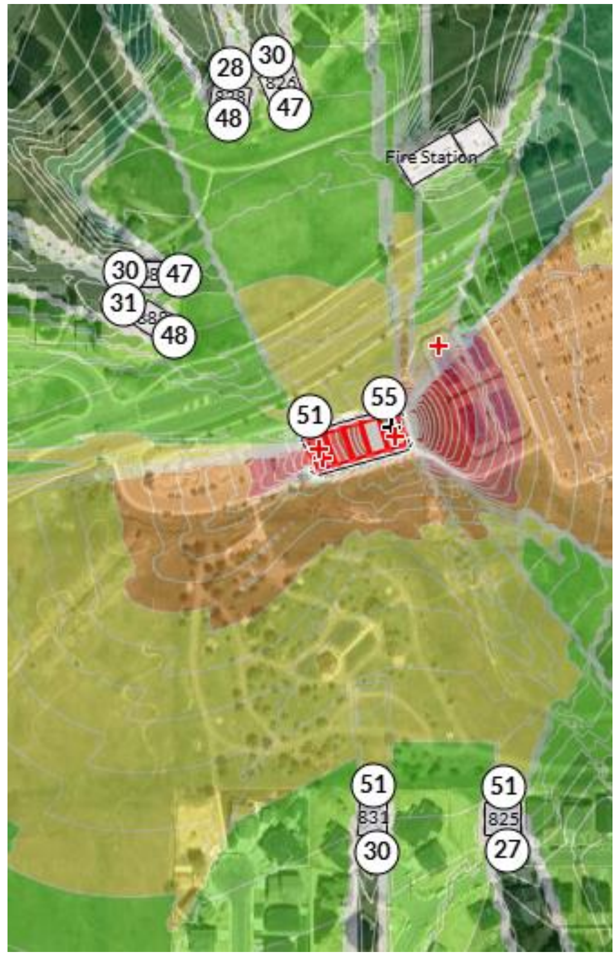

Figure 16d – Source 4, 18 ft/10 ft absorbing barrier

Figure 16e is a cross section of the sound field and shows how the higher barrier to the north directs the sound upward. This is much different than Figure 13e with an 8 foot barrier and Figure 14c with a 12 foot barrier where sound spills over the top of the barrier and continues to travel uphill.

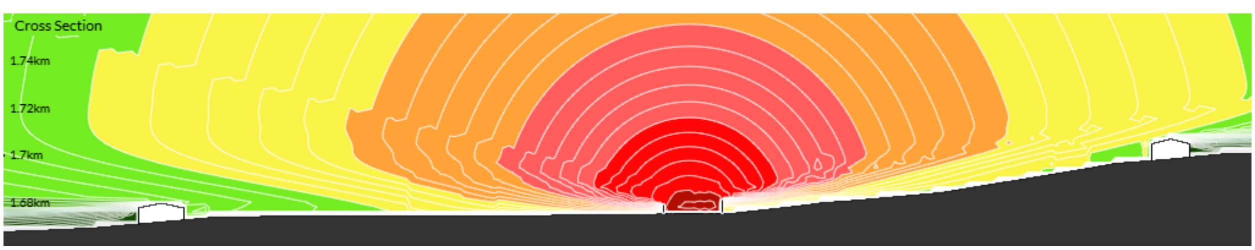

Figure 16e – Source 2, 18 ft/10 ft absorbing barrier, cross section

Sound levels to the east and west would not be above the design objective since the "no sound mitigation" baseline in Figure 12c showed levels below 50 dB on West Pinyon Way.

The previous sound maps showed sound from three individual courts. If all 5 courts were active at the same time, the sound levels would not be 5 times louder. This is because the individual pickleball impacts from each court are separate events that occur randomly in time. With simultaneous activity on 5 courts, the number of impacts per hour would be 5 times the number of impacts from one court. The goal of sound mitigation is to reduce the sound from the loudest pickleball impacts so that a listener is unbothered by activity from the loudest sound from one court or from all 5 courts. With proper sound mitigation, sound levels below the loudest levels will then be even less noticeable.

All the previous models placed the sound barrier on the perimeter of the hockey rink. An option was considered with the sound barrier placed on the perimeter of the pickleball courts. This moves the barrier closer to the sound source and makes the barrier more effective in reducing sound. Figure 17a shows the sound levels with a 16 foot sound absorbing barrier on the north side, a 16 foot reflecting barrier on the west side of the court, and a 10 foot sound absorbing barrier on the south side. The west side of the court could also be a sound absorbing barrier. If an open viewing area to the west is required, then transparent sound barriers in mass loaded vinyl or impact glass (Pickleglass) could be used – see Appendix A. Sound levels with this design meet the design objective. The tradeoff is a 16 foot high barrier on the north and west sides of the courts against an 18 foot barrier on the north side (and the north corners of the hockey rink) with an open west wall.

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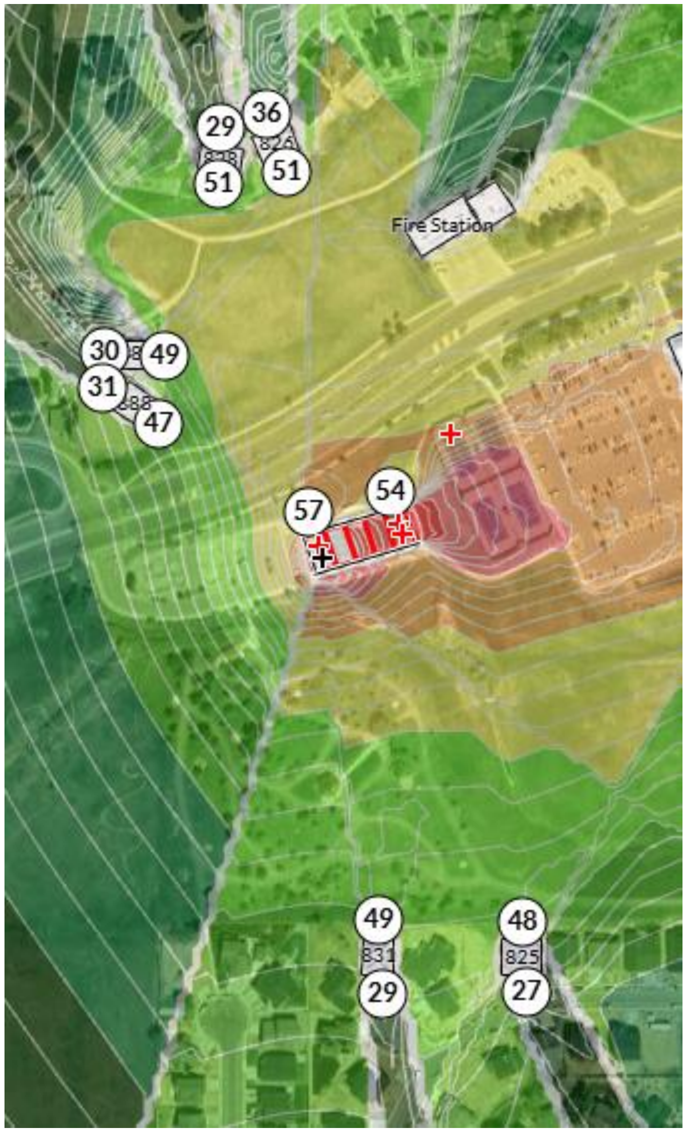

Figure 17a – Source 2, 16 ft absorbing barrier on north court side, 16 foot reflecting barrier on west court side (transparent), 10 ft sound absorbing barrier on south court side

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Figure 17b shows the cross section of the sound traveling to the north and to the south. The sound is contained by the walls surrounding the court and blocked at higher elevations.

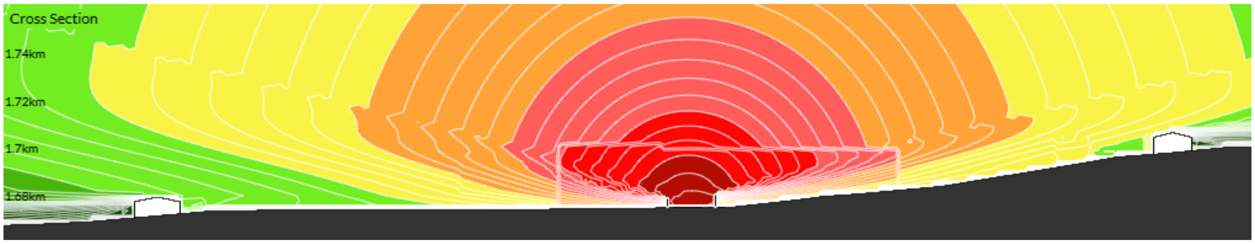

Figure 17b – Source 2, 16 ft absorbing barrier on north court side, 16 foot reflecting barrier on west court side, 10 ft sound absorbing barrier on south court side

The client requested an analysis of a design with a 15 foot barrier at the hockey rink elevation of 5505 feet and a 5 foot barrier near the road at an elevation of 5515 feet (7). The top of both walls would be 5520 feet. Figure 18a shows that the sound levels are higher than either Figure 16a with an 18 foot barrier or in Figure 17a with a 16 foot barrier. This is because the added 5 foot wall adds no sound blocking as shown in the cross section on Figure 18b. A barrier above 5 feet and preferably closer to 10 feet is needed for this additional wall farther from the court.

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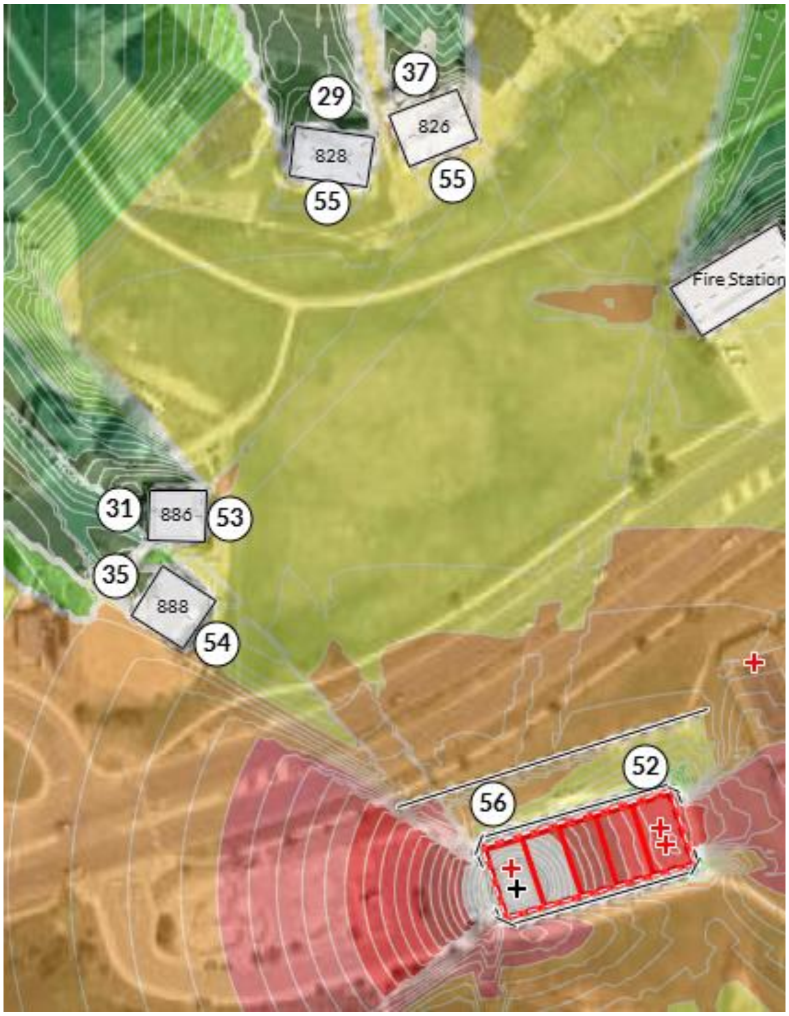

Figure 18a – Source 2, 15 ft absorbing barrier on north side, 10 ft sound absorbing barrier on south side, 5 foot barrier near road

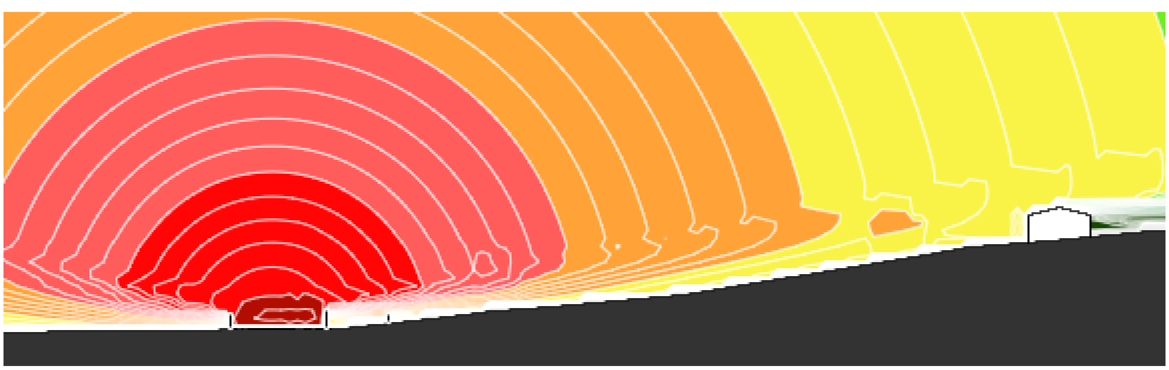

Figure 18a – Source 2, 15 ft absorbing barrier on north. 10 ft sound absorbing barrier on south court side, 5 foot barrier near road

An alternative option for pickleball would be to orient the courts in the east west direction. This layout directs the highest sound in the east west direction of play. Figure 19 shows a proposed court layout for 4 courts. (A 6 court east west layout is possible, but this requires elimination of the rounded corners of the hockey rink.) The closest homes to the east are farther from the courts than homes to the north. These homes to the east also are at an elevation near or below the court elevation where sound barriers more effectively block sound than they do for receivers at higher elevations. A lower level of sound is now directed to the nearest homes at higher elevations on Larkspur Court and Trails Edge Drive.

Figure 19 - 4 court layout in east west direction with sound sources

Starting with the 8 foot fence of the hockey rink, Figures 20a and 20b show the sound levels in the north south direction with an 8 foot barrier on the north side, south side, and all 4 corners. Sound levels at Larkspur Court and Trails Edge Drive are above the design objective.

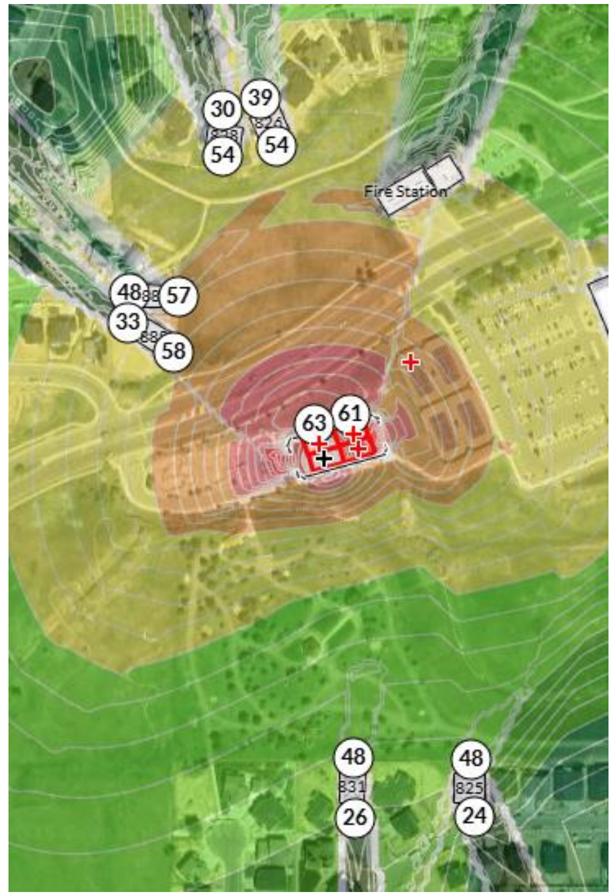

Figure 20a – Source 1, 8 foot barrier

Figure 20b – Source 2, 8 foot barrier

Several sound barrier designs were evaluated considering barrier height and sound absorbing liners to arrive at an optimized design for this east west layout. This design included a 16 foot high sound absorbing barrier for the north side of the hockey rink and 10 foot sound absorbing barrier for the south side of the hockey rink. The north corners must extend to the centerline of the north courts. The barrier on the south side must extend 12 feet beyond the baseline but no corners are needed. Figures 21a, 21b, 21c, and 21d show the sound levels to the north and south for each source position. Figures 21a and 21d show that all sound levels meet the design objective with the sound source closest to the north barrier. Figures 21b and 21c show sound levels above the design objective when the ball is struck from positions farther from the barrier. The levels are considered just above the design objective. They are considered acceptable since the design objective is not exceeded at other positions. Also, the minimum change in sound detectable by the human ear is a 3 dB change.

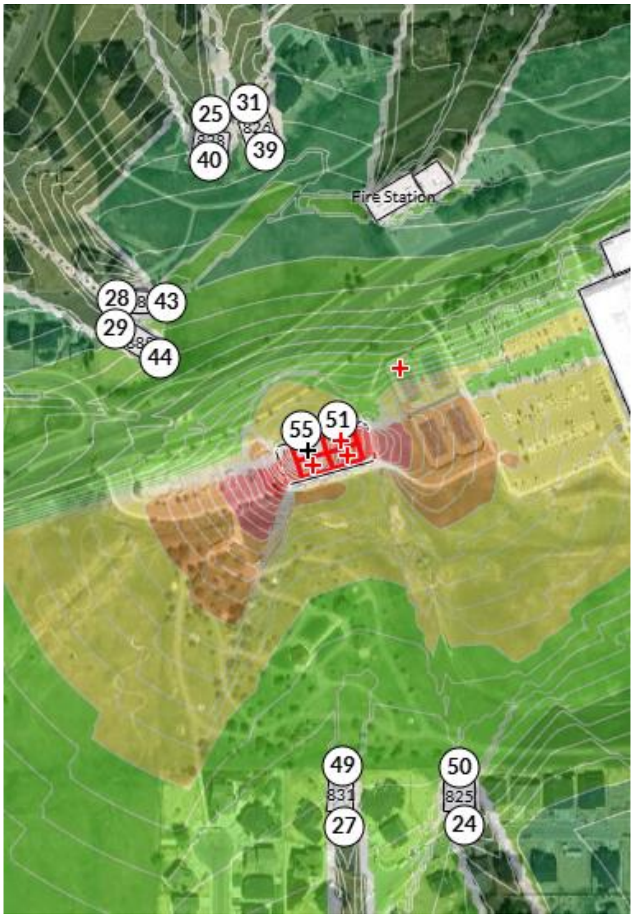

Figure 21a – Source 1, 16 ft/10 ft absorbing barrier

Figure 21b – Source 2, 16 ft/10 ft absorbing barrier

Figure 21e shows sound levels to the east and west. These sound levels are well below the design objective. Figure 21f shows the sound barriers in place.

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Figure 21c – Source 3, 16 ft/10 ft absorbing barrier

Figure 21d – Source 4, 16 ft/10 ft absorbing barrier

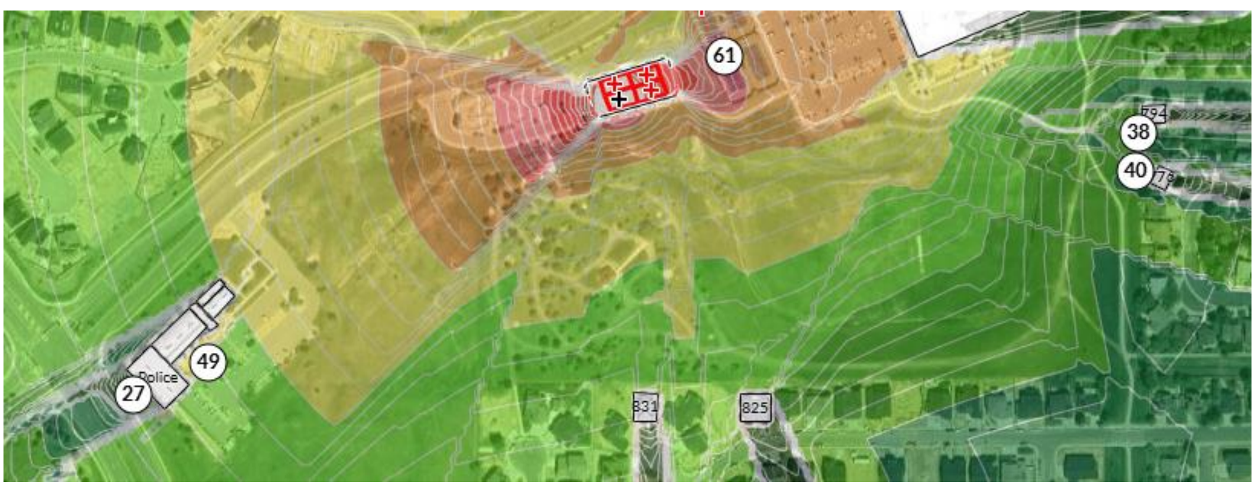

Figure 21e – Source 2, 16 ft/10 ft absorbing barrier

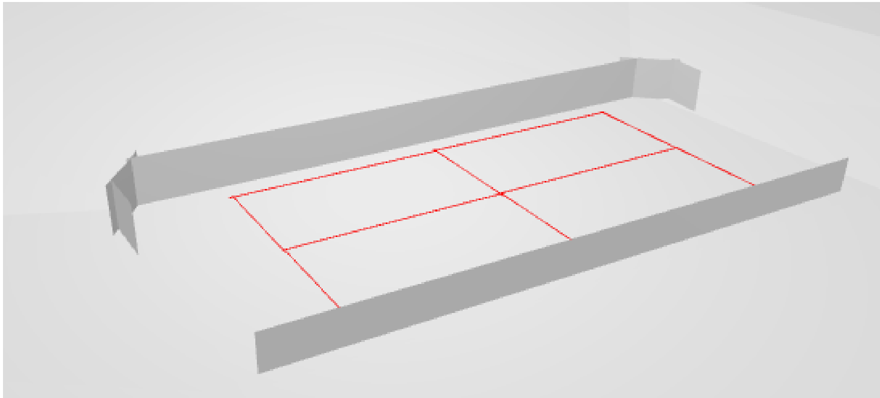

Figure 21f –16 ft absorbing barrier on north side and 10 ft absorbing barrier on south side

Recognizing that a 16 foot wall is above the common 12 foot chain link fence height, a comparison was made with a reduction in height on the north to a 12 foot barrier. Figure 22 shows the sound levels with the 12 foot north and 10 foot south sound absorbing walls.

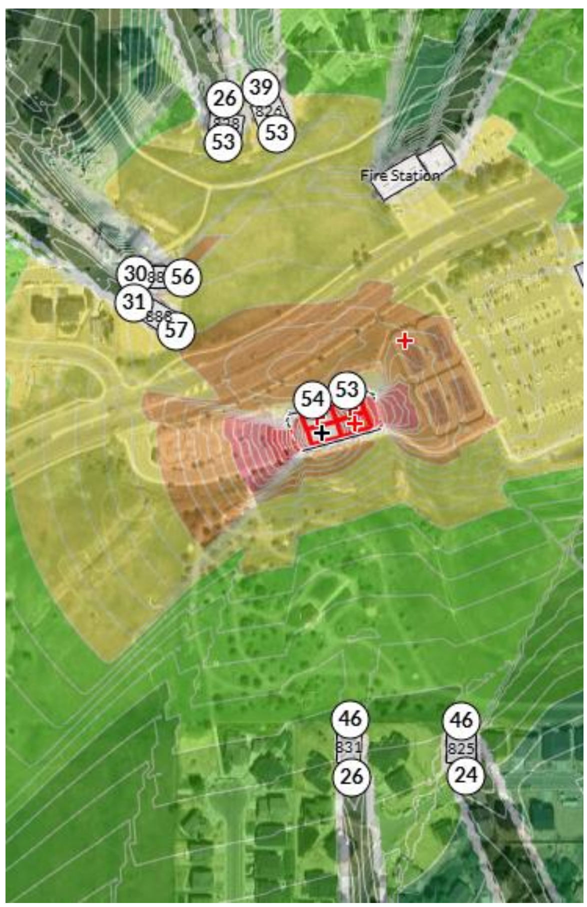

Figure 22 – Source 2, 12 ft/10 ft absorbing barrier

Next, the 16 foot and 10 foot barriers were moved to the perimeter of the pickleball fence to evaluate sound levels. A closer placement to the source allowed a north fence height of 14 feet. With the elimination of the extended barrier on the northwest hockey corner, a sound barrier was needed on the west wall to block sound to the northwest (like in Figure 17a). Comparing Figure 23 (court perimeter barrier with west barrier) to Figure 21b (hockey perimeter barrier), lower sound levels are achieved at homes to the north. To permit spectator viewing from the west, the west wall could be a transparent mass loaded vinyl or high impact glass. Figure 24 shows the barriers placed on the court perimeter.

Figure 23 – Source 2, 14 ft absorbing barrier N, 10 ft absorbing barrier S, 14 foot reflecting barrier (transparent) W – on court perimeter

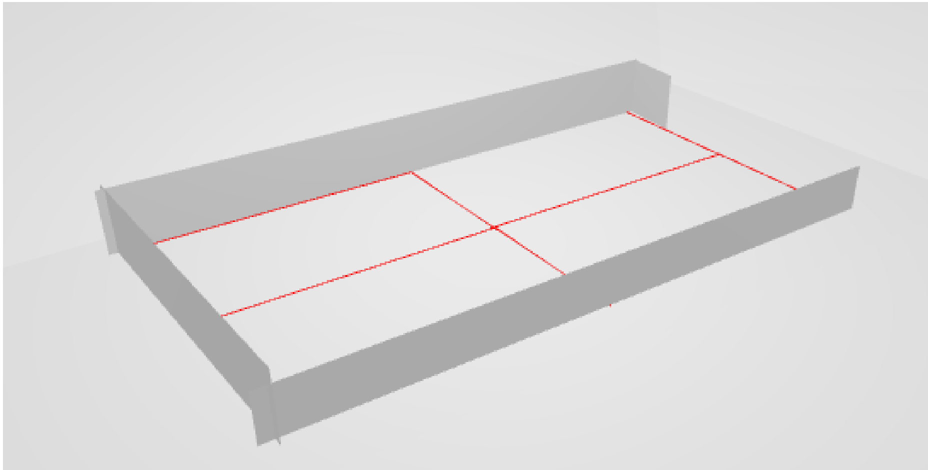

Figure 24 –14 ft absorbing barrier N, 10 ft absorbing barrier S, 14 foot reflecting barrier (transparent) W

The court layout in Figure 19 could be separated to create a north south spectator area between the courts with no change in sound levels. This provides a viewing area if sound barriers are placed on the court perimeter.

The prior figures show the sound reduction that can be achieved with barriers. If additional sound reduction is needed or if the height of the barriers is limited by local zoning, then additional sound reduction can be achieved with a select group of quieter paddles and balls. The paddles in Appendix B have been tested to be quieter than the loudest paddles in use. Louisville Recreation Center (7) did not wish to consider this option for noise mitigation, but it is mentioned for completeness or if barrier heights are not permitted per zoning requirements.

Noise reduced paddles and balls are being developed and promoted. However, these special paddles and balls are not silent – they are a few dB quieter than the loudest paddles and balls sold at the big box sporting goods stores and commonly used by recreational players. A description of quiet balls and paddles is in Appendix B. These Blue List paddles will reduce any sound level by 3 dB or more. This means that a sound level of 53 dB LAFmax will now be 50 dB LAFmax, or less depending on paddle type. It also means that barrier heights can be reduced by about 3 feet or more. It should be noted that a mandate to only use approved special equipment often requires players to purchase new equipment. A policy to use preferred equipment is difficult to enforce and requires either a method to assure compliance or an on-site court monitor.

A few pickleballs on the Blue List will provide an additional 3 dB of noise sound when used with any paddle. This means that a Blue list paddle (-3 dB) and a quieter ball (-3dB) can provide an additional 6 dB sound reduction in addition to the sound reduction by the barrier. Again, these balls are not used for tournament play, not favored by skilled players, and require a court monitor to assure their use.

One nonstandard ball does provide noticeable noise reduction of 18 dB when used with any paddle. This is the Gamma Librarian foam pickleball. This ball is quieter than any plastic pickleball but has several drawbacks compared to the standard pickleball. It has a different bounce; it has a different response from the paddle; and it is easily affected by wind. Most players only favor this ball for indoor practice. This approach also requires a control system or court monitor during all hours of play to check that no plastic pickleballs are in use. This ball is not recommended as it will not find favor among recreational or skilled players because of its different response compared to the traditional plastic ball.

Restricted court times can reduce the exposure to pickleball sounds to certain hours of the day. This has the disadvantage of limiting court availability and creating longer waiting times for the players when the courts are available. This is more of an on-off noise strategy.

Table 1, which follows, is a summary of noise levels for different barrier designs. Sound levels at each receiver (or home) will vary based on source position. For some barrier designs, sound levels are shown for all 4 source positions. This table should be compared to the sound maps for each figure which show green zones where sound would not be objectionable. The goal would be to have all homes in a green zone. The minimum sound change detectable by the human ear is 3 dB.

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Table 1 – Sound Levels and Sound Reduction Options

						dB LAFmax per source position					Sound reduction vs no barrier - dB LAFmax				
	Sound Barrier Height	**Barrier position**	**Barrier type**	**Source Position**	**Figure**	**Fence perimeter**	**888 Larkspur**	**828 Trail Ridge**	**831 W Mulberry**	**794 W Pinyon**	**Fence perimeter**	**888 Larkspur**	**828 Trail Ridge**	**831 W Mulberry**	**794 W Pinyon**
Tennis															
	no barrier			Tennis	10	49	47	45	43	38					
Pickleball - 5 courts north south															
	no barrier		no barrier	1	11a,11b	73	61	56	56						
	no barrier		no barrier	2	12a, 12b, 12c	71	60	56	56	40					
	8 feet	Hockey rink	Reflecting	2	13b, 13d	69	60	57	52		-2	0	1	-4	
	12 feet	Hockey rink	Reflecting	2	None	62	57	57	51		-9	-3	1	-5	
	16 feet	Hockey rink	Reflecting	2	None	58	53	55	46		-13	-7	-1	-10	
	18 feet	Hockey rink	Reflecting	2	None	56	52	54	44		-15	-8	-2	-12	
	12 feet	Hockey rink	Absorbing	2	14a,14b	60	57	56	47		-11	-3	0	-9	
	18 ft N/10 ft S	Hockey rink	Absorbing	2	15a,15b,16a	54	52	51	50		-17	-8	-5	-6	
	18 ft N/10 ft S	Hockey rink	Absorbing	1	16b	55	47	48	52		-18	-14	-8	-4	
	18 ft N/10 ft S	Hockey rink	Absorbing	3	16c	51	54	50	51						
	18 ft N/10 ft S	Hockey rink	Absorbing	4	16d	51	48	47	51						
	16 ft N/10 ft S/16 ft W	PB court	Absorb/Refl	2	17a	57	47	51	49		-14	-13	-5	-7	
	15 ft N/10 ft S/5 ft road	Hockey rink	Absorbing	2	18a	56	54	55			-15	-6	-1		
Pickleball - 4 courts east west															
	8 feet	Hockey rink	Reflecting	2	20b	63	58	54	48		-8	-2	-2	-8	
	14 ft N/10 ft S	Hockey rink	Absorbing	2	None	52	55	53	46	38	-19	-5	-3	-10	-2
	14 ft N/10 ft S	Hockey rink	Absorbing	1	None	56	47	42	46		-17	-14	-14	-10	
	14 ft N/10 ft S	Hockey rink	Absorbing	3	None	51	55	53	49						
	14 ft N/10 ft S	Hockey rink	Absorbing	4	None	53	46	42	49						
	16 ft N/10 ft S	Hockey rink	Absorbing	2	21b	51	53	51	46	38	-20	-7	-5	-10	-2
	16 ft N/10 ft S	Hockey rink	Absorbing	1	21a	55	44	40	49		-18	-17	-16	-7	
	16 ft N/10 ft S	Hockey rink	Absorbing	3	21c	49	53	51	46						
	16 ft N/10 ft S	Hockey rink	Absorbing	4	21d	51	44	40	49						
	12 ft N/10 ft S	Hockey rink	Absorbing	2	22	54	57	53	46		-17	-3	-3	-10	
	14 ft N/10 ft S/14 ft W	PB court	Absorb/Refl	2	23	55	50	52	45		-16	-10	-4	-11	
					50 or less										
					51 to 54 dB										
					55 dB or more										

Conclusions

The following conclusions are made from the results of this study.

1. Without sound mitigation, pickleball play on the proposed 5 courts at the hockey rink at Louisville Recreation Center would create sound levels of 56 dB to 60 dB LAFmax at the closest residences to the north on Larkspur Court and Trails Edge Drive and to the south on West Mulberry Street. These levels are above the design objective of 50 dB LAFmax and would lead to complaints.
2. Without sound mitigation, the pickleball sound level to the east on West Pinyon Way is 40 dB LAFmax, which is below the design objective.
3. The closest homes north of the courts are at a higher elevation than the courts, have the highest sound levels from pickleball, and are the primary focus for noise mitigation. These homes have a direct line of sight into the courts which is also a direct path of sound travel.
4. When an 8 foot sound barrier was placed on the north and south sides of the existing 8 foot high fence of the hockey rink, the sound levels to the north were not noticeably reduced. Pickleball sound is spilling over the top of an 8 foot sound barrier to receivers at a higher elevation.
5. Several design options with higher barriers and sound absorbing liners were evaluated until the sound levels at the closest homes to the north and south were at or just above the design objective. These 2 options are:
    a. Using the hockey rink perimeter - 18 foot sound barrier with sound absorbing barrier on the north fence and north corners; 10 foot sound barrier with sound absorbing barrier on the south fence and south corners; open east and west walls.
    b. Using the pickleball court perimeter - 16 foot sound barrier with sound absorbing barrier on north fence and north corners; 10 foot sound barrier with sound absorbing barrier on south fence and south corners; 16 foot sound barrier on west wall, east wall open
6. With the courts oriented in an east west direction, the sound level is reduced in the critical north to south direction but still requires sound barriers. This orientation allows 4 courts without removing the rounded hockey corners.
7. With an east west court orientation, several design options with higher barriers and sound absorbing liners were evaluated until the sound levels at the closest homes to the north and south were at or just above the design objective. These 2 options are:
    a. Using the hockey rink perimeter - 16 foot sound barrier with sound absorbing barrier on north fence and north corners; 10 foot sound barrier with sound absorbing barrier on south fence; open east and west sides.
    b. Using the pickleball court perimeter - 14 foot sound barrier with sound absorbing barrier on north fence and north corners; 10 foot sound barrier with sound absorbing barrier on south fence and south corners; 14 foot reflecting (transparent) barrier on west fence; open east side.
8. No single sound barrier design will provide the same sound levels everywhere unless even higher sound barriers are used, or an enclosure is placed around the courts. Any reduction in the height

of any sound barrier will increase the sound level by approximately 1 dB per foot in the direction of sound over the barrier.

9. Options to further reduce sound levels or to reduce barrier height are described using quieter paddles and balls than the loudest equipment in use but this requires purchase of select equipment and a court monitor to assure use of this select equipment.

Recommendations

Due to the challenge of noise reduction for the closest homes at elevations above the courts that have a direct line of sight into the courts, the following recommendations are made for pickleball courts at the Louisville Recreation Center hockey rink.

1. The structural capabilities of the existing hockey fence foundation should be evaluated and compared to sound barrier height and weight for sound mitigation.
2. Of the 2 court layouts - 5 courts in north south direction or 4 courts in east west direction – the east west court layout allows lower fence heights.
3. While Table 1 provides a summary of sound levels under different sound mitigation scenarios for source position 2, the selected option should be based on the greatest area of green zones closest to the courts. All 4 options described in the conclusions are similar in terms of sound level results.
4. A sound barrier should be chosen from the supplier list in Appendix A or from any comparable vendor. A visit to nearby pickleball facilities with barriers in place will give an idea of design options which are simple to execute.
5. If the fence or foundation cannot support the weight of the barrier (1 pound per square foot or TL greater than 20 dB at 1000 Hz), then a structural wall as used on highway systems can be considered.
6. If pickleball courts are to be viewed by spectators, then the west sound barrier wall can be a transparent barrier as supplied by Hushtec, USA or a high impact glass material such as Pickleglass - when this wall is included in the chosen option.
7. The height of any sound barrier should not be reduced as this will increase the sound level by approximately 1 dB per foot of height reduction in the direction of sound over the barrier.

PSM Consulting LLC has provided these conclusions and recommendations on pickleball sound at Louisville Recreation Center to balance the growth and popularity of pickleball with acceptable sound levels for quality of life for the residents living near the courts. The goal is to develop pickleball recreational facilities at Louisville Recreation Center and to perform due diligence on sound mitigation for nearby residents. PSM Consulting LLC is available to answer any questions related to this work.

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Disclaimer

The results, conclusions, and recommendations presented here are based on information provided to PSMC LLC by the client and on measurements made using calibrated equipment and standard acoustical practices. These results are intended to address maximum sound levels from play. Pickleball sound assessment is a random process where the sound from each impact and from each game can vary based on player skill, force of impact, and equipment in use. Sound levels from pickleball are random impulsive events, meaning that it is predictable over a range and has averages and other statistical characteristics, but it has no exact single level. Actual sound levels will vary over time. In addition, it is not possible to determine what any particular person believes is an acceptable sound level. Because additional variables may be associated with the site, the players, or the equipment in use, PSMC LLC assumes no liability for work undertaken by the client based on these recommendations, or for results that do not conform to the client's expectations.

Barry R Wyerman, PhD, PE
Principal Acoustical Consultant
PSM Consulting LLC

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4. https://noisetools.net/dbmap/ - Sound Mapping Tool
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6. Louisville Recreation Center https://earth.google.com/web/@39.97354702,-105.15775937,1667.29934572a,1318.08671257d,35y,-0.00140005h,0t,0r/data=CgRCAggBOgMKATBCAggASg0I_____________ARAA
7. Private communication – email on May 2, 2025, Bryon Weber

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PSMC LLC Information

PSM Consulting LLC

PSMC LLC was created in 2022 after 8 years of pickleball sound studies and advice on pickleball sound mitigation. This work included field measurements of pickleball play at multiple sites, analysis of the sound from different pickleball paddles and balls, consultation with USA Pickleball on equipment standards, and evaluation of suppliers of sound barrier systems. PSMC has designed successful sound reduction systems for pickleball courts and has evaluated multiple paddles and balls to create lists of “quieter” paddles and balls. It has also completed field studies of pickleball sound to provide guidance to homeowners regarding local sound ordinances. In total, PSMC has completed or has been involved in sound surveys and recommended sound mitigations measures for 100 pickleball sites. PSMC is at the forefront of pickleball technology and is working directly with USA Pickleball to develop acoustical test methods for paddles, to identify quieter gear, and to create improved community standards for pickleball sound. It is also working with paddle manufacturers to help bring improved, quieter paddles to the market. PSMC LLC has developed the industry’s first anechoic chamber for testing both pickleball paddles and balls under controlled speed conditions. This provides baseline data on paddles without the variables of background sound and player skill in hitting the ball.

The mission of PSMC is to support pickleball clubs, pickleball players, communities, parks and recreation departments, country clubs, and homeowner associations with an understanding of pickleball sound and of strategies and measures to control pickleball sound.

Barry Wyerman, PhD, PE

Barry Wyerman, PhD, is the Principal Acoustical Consultant for PSMC LLC. He is a pickleball player and a USA Pickleball Level 2 Referee. His professional background includes over 45 years of acoustical experience in creating innovative acoustical products, solving industrial sound control and vibration problems, and designing solutions for automotive noise and vibration control. He is the owner of Acoustical Design and Consulting, LLC, which provides engineering and consulting support in all areas of acoustics and noise control. He has a BS degree in physics from Ohio University and MS and PhD degrees in engineering acoustics from Penn State University. He became involved in pickleball sound mitigation when he provided initial recommendations on pickleball sound control from his work experience and acoustical training. His professional associations include:

- The Acoustical Society of America
- Society of Automotive Engineers, Noise and Vibration Committee
- Society of Automotive Engineers, Acoustical Materials Committee
- Professional Engineer, registered in Ohio

Appendix A - Sound Barriers

Sound barriers block the direct path of sound as it travels from a source to a receiver. A barrier must be massive enough to block sound that could pass through it. The recommended weight for a barrier is one pound per square foot or a transmission loss of 20 dB at 1000 Hz. A small amount of sound still passes over the top or around the edges of a barrier. This is called “diffracted sound.” With this weight barrier, the sound reduction is limited only by the height and width of the barrier.

The barrier must be solid with no holes, no gaps at the bottom, and no gaps between adjoining panels. Any holes or openings will allow sound to leak to the other side. Earth mounds and buildings can function as barriers if they are high enough and wide enough to disrupt a direct path of sound.

Shrubs, bushes, and trees are NOT barriers even though they block a line of sight. They are not massive enough and not solid enough to block sound. A small amount of sound attenuation may be achieved with a dense planting of hedges, but this would not provide more than 1 dB sound reduction even if the hedges were 3 or 4 feet in depth and 12 feet high. These are primarily a visual barrier.

The effectiveness of a high mass barrier is controlled primarily by its height and then by its width. The barrier must be tall enough and wide enough so that it minimizes the sound that is diffracted or bent over the top and around the edge. The amount of sound diffracted over the top and around the edge can be minimized as the barrier becomes higher and longer. As the height of a sound barrier increases, a point of diminishing returns is reached. This means that a percentage increase in height (and cost) will result in a lower percentage improvement (or return on benefits) in sound reduction. In some cases, it may be best to enclose all four sides of a pickleball court with the highest barrier possible. If there are no homes exposed to pickleball sounds from one side of the court, then a barrier can be eliminated on that side.

Common vendors for sound barriers are:

- Acoustiblok, Tampa, FL, 813-980-1400, https://acoustiblok.com/acoustiblok-soundproofing-product-lines/acoustifence-noise-reducing-fences/ (printed barriers)
- Insul-Quilts USA, South El Monte, CA, 833-853-6444, https://www.insulquilt.com/
- eNoise Control, Noblesville, IN, 866-481-2024, https://www.enoisecontrol.com/
- DDS Acoustical Specialties, Westfield, MA 413-248-8118, https://ddsacoustical.com/
- Hushtec USA, Connecticut, 860-289-8033, https://hushtecusa.com/ (clear barriers)
- Putterman Athletics LLC, DeLand, FL, 800-621-0146, https://www.puttermanathletics.com/
- FenceScreen, Grand Prairie, TX, 888-313-6613, https://www.fencescreen.com/
- Pickletile, Austin, TX, 561-342-0038, https://pickletile.com/pickleglass/ (Pickleglass)

All barriers of the same weight would perform the same. None of these products are noticeably different other than by the color or by printing. Any differences in product sheets can be due to lab differences in testing. Sound barriers should weigh one pound per square foot to block any sound that could pass through the barrier. The effectiveness of this high weight barrier can still be compromised by the sound that is diffracted over the top or around an edge. A contractor must be consulted to assure that an existing fence or a new fence can support the added weight of a barrier. Wind loads on the barrier are also to be considered.

Some barriers are available with a sound absorbing lining material on the side facing the sound source – if this is needed. This sound absorbing lining can reduce the sound level on the court by reducing the reflected sound as it bounces between the side walls. It can also be effective in reducing reflected sound in the opposite direction away from a barrier if only one side of a court has a barrier. The sound absorbing lining can also reduce a reflected sound wave that can travel over the opposite wall. However, the sound absorbing lining has no impact on the direct sound passing over the top of the barrier. This direct path of sound is not influenced by anything on the side walls. The sound absorbing liner can also help with sound reduction for the players.

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Appendix B – PSMC Blue List of Pickleball Paddles

The Pickleball Paddle Blue List

List updated: January 12, 2025

Introduction: The following paddles have been selected and qualified for 'Blue List' status through a testing procedure that uses a combination of metrics in addition to loudness (sound pressure). This includes measuring the 'pitch' and duration of the sound produced when a pickleball is struck by a paddle (the "decay time").

This latest version of the Blue List categorizes paddles as "Reduced Sound," which means quieter than ordinary paddles and "Extra Quiet," and it includes paddle covers that can be added to any paddle to reduce the sound level produced.

The metrics and criteria were selected after reviewing with players and non-players the sound characteristics of a typical pickleball hit. The categories were established by PSM LLC as a means of recommending paddles to communities and pickleball clubs that are attempting to mitigate the sound of pickleball to an acceptable level without overly restricting a player's paddle preferences.

Test Procedure: PSM LLC is a pickleball acoustics consulting firm. We have assembled a tall (16 feet) echo free (or anechoic) ball drop chamber for testing pickleballs and paddles. An ordinary tournament approved pickleball is dropped from the top of the chamber and it reaches a speed of about 19 mph just before it strikes a rigidly mounted paddle at a slight angle to cause the bouncing ball to travel away from the paddle face after the hit.

A calibrated microphone is mounted in this chamber and a computer outside of the chamber analyzes the microphone output using REW and Audacity software.

Criteria: The paddles on this list are in two categories, "Reduced Sound" and "Extra Quiet." "Reduced Sound" paddles have a measured sound level of at least 3 decibels below typical ½ inch thick honeycomb poly-core fiberglass face models and a prime "pitch" below 900 Hz. "Extra Quiet" paddles are quieter still, with a sound level of 6 decibels, or more, below ordinary models and a main pitch below 700 Hz. In addition, all of these paddles have vibration decay times of the primary vibration mode (to less than 10% of its initial peak value) of under 6 milliseconds. This ensures that there is no well-defined "pitch" to the sound produced.

Using this list: PSM LLC updates this list as it tests and identifies additional paddles that meet the criteria and as suppliers release new models.

Updating this list: To arrange additional paddle or pickleball testing, contact PSM LLC via email at bob@pickleballsound.com.

For an updated version of The Blue List, see the Pickleball Sound Labs web page at pickleballsoundlabs.com as well as the Pickleball Sound Mitigation Facebook group page. The Pickleball Paddle Blue List is copyright free.

Reduced Sound Paddles (paddles are listed alphabetically by vendor name)

Paddle Vendor	Paddle Model Name	Notes
CRBN	1 & 2	
CRBN Pickleball Rocks Edition	Marked "Recreational Play Only"	1
Diadem	Warrior	
E6	16s	
Electrum	E Pro II	
Focus	Silencer	
Gearbox	CX11, CX14, GX5 and GX6	
Joola	Ben Johns 16 mm, Radius	
Joola	Simone Jardim 16 mm	
One More	Vibe	
One More	Pro Custom	
One Shot	Stealth	
PIKKL	VANTAGE Pro 16mm	
Pro Drive	DRIVE	
Pro Kennex	Pro Speed	
Pro Pickleball	Infinity Widebody 16 MM	
TMPR	Tantrum and TC-16	
Versix	Pro XL	
Wild Monkeys	Grizzly	
Wowlly	Surge XL	
Wolfe	Bite	

Note 1: Not USA Pickleball Approved for Tournament Play

Reduced Sound Paddle Guidance: Tests have shown that many paddles that are at least 16 mm thick with carbon fiber surfaces and deemed to be "Control" models by paddle suppliers are generally quieter and have a lower main pitch sound and are likely to qualify for the "Reduced Sound" list but they may not have been tested by Pickleball Sound Labs.

Extra Quiet Paddles and Paddle Attachments

The following products are several decibels quieter than the Reduced Sound Models listed above and they have an audio pitch about an octave lower than ordinary fiberglass face paddles.

Paddle Vendor	Paddle Model Name	Notes
Diadem	Vice and Hush	1
Master Athletics	Q1	1
NINEFOUR	Apex Series 3K	2
Owl Sports	Founders Edition, Owl CX,	2
	CXE and the Silent Storm	2
Pro XR	Quiet Luxury	1
Stafford	Blackbird	2

Note 1: Not USA Pickleball Approved for Tournament Play
Note 2: The Quietest Tournament Approved Paddles

Aftermarket options – attachments/covers that reduce the sound level produced by any paddle

The Pickleball Muffler (may be used with any paddle)	This is a paddle attachment/cover	1
Quiet Strike	Removable attachment Pads	1
QuietSSHOT	Removable attachment Pads	1

Note 1: Not USA Pickleball Approved for Tournament Play

Paddles (or pad attachments) that qualify as "Quiet" generally have additional design features on the face or internally that substantially reduce both sound level and pitch. These paddles are specifically designed to achieve a low sound level.

Pickleballs

Somewhat Popular Quieter Balls: The Onix Fuse and Onix Pure 2 (higher bounce) outdoor models

The quietest USA P tournament approved ball: Monarch Outdoor ball by Dicks Sporting Goods

Other Quiet Balls

The Gamma Librarian: this is a foam ball that is the very quietest ball tested.

The Diadem Quiet Ball

The Accel Digital 3D printed ball (available in several colors and firmness variations)

The LOUDEST tournament approved ball tested by PSM LLC was the Dura Fast 40 although we have measured even louder sound levels from some less expensive discount store models.