1. Agenda

   Documents:

   2022.09.13_BOH_AGENDA.PDF

2. Meeting Materials

   Documents:

   2022.09.13_BOARD_OF_HEALTH_DRAFT_MINUTES.PDF
   2022.09.13_BOH_KENS_FOOD_SOUTHBOOUGH_NOISE_BARRIER_STUDY.PDF
   KENS_FOOD_SOUTHBOROUGH_NOISE_BARRIER_STUDY.PDF

RECEIVED
By Town Clerk/jfh at 4:46 pm, Sep 07, 2022

Town of Southborough, MA
Meeting of the Board of Health

Tuesday, September 13, 2022 at 9:30 AM
Virtual Meeting Room

Agenda

Pursuant to Chapter 20 of the Acts of 2021, An Act Relative to Extending Certain COVID-19 Measures Adopted During the State of Emergency, signed into law on June 16, 2021, this meeting will be conducted via remote participation. No in person attendance by members of the public will be permitted.

This meeting may be watched or residents may participate in the meeting remotely with the meeting link at: https://www.southboroughtown.com/remotemeetings

Business Item (Board may vote):

1. Public Comment
2. Sound Barrier Report - Ken's Warehouse
3. Public Comment

Chelsea Malinowski, Dr. Safdar Medina, Nancy Sacco

RECEIVED
By K Battles at 2:05 pm, Oct 04, 2022

Town of Southborough
Board of Health
9 Cordaville Road, Lower Level
Southborough, MA 01772-1662

Phone: (508) 481-3013

Minutes of the Southborough Board of Health

September 13, 2022 – Board of Health – Virtual – 9:30 AM

Present:
Board Members Chelsea Malinowski, Nancy Sacco, Dr. Safdar Medina; Public Health Director, Dr. Heather Alker; Public Health Nurse, Taylor West; Administrative Assistant, Barbara Spiri

Also in Attendance: Representing Ken's Warehouse, Bill Pezzoni; Sound Engineer, David Coate, Operation Manager, Jim Bourne, Sound Engineer – Tech Environmental, Marc Wallace; Residents, Kevin Farrington, Meme Luttrell

Opening:
The meeting of the Board of Health was called to order at 9:30 AM by Ms. Malinowski.

Topic: **Public Comment**

Discussion: Public comments were not brought before the Board.

Topic: **Ken's Warehouse – Sound Barrier**

Discussion: Both Sound Engineers – David Coate and Marc Wallace – presented the report to the Board. The testing that occurred in July staged 20 refrigerated trucks that were turned on and off. The noise level was measured at 48, 58, 68 Flagg Road and 7 Eastbrook Farm Lane (utilizing actual receivers). The 50 Hz refrigeration unit peak was measurable above ambient sound levels at all locations. Mr. Coate stated he was not sure if 24 or 28 Flagg Road was disturbed with the noise. Mr. Farrington confirmed that the prior owner did hear the noise. CADNA (Computer-aided Noise Abatement) software is used for analysis and evaluation of environmental noise. The model was directionally in line with the actual results of the testing done at the resident locations. The results will help to create a reliable sound barrier. Three design options were included in the report. Each option showed where the barrier would be placed and how it will affect the noise at each address (the report included a grid that showed the reduction in noise for each wall option). Options were a short (in the middle of the parking lot), long (at the perimeter), and long shortened (at the perimeter) barriers along with the cost to build them.

Ms. Malinowski asked if an address could be added to the modeling software for the final report without slowing the process down. Mr. Coate and Mr. Pezzoni said that an address could be added, and the results shouldn't change. Ms. Luttrell wanted to know if the trucks will be on the west side, if the wall was in the middle of the parking lot. (The barrier would be reducing the noise coming from the east side.) Mr. Pezzoni told her he could not say "never" but the refrigerated trucks are normally on the east side. Mr. Farrington did mention the original owner of 24 Flagg Road was one of the original complainers about the noise.

The Board requested Mr. Coate and Mr. Wallace give their recommendation which would be best for the residents. Mr. Pezzoni spoke to the representatives of Ken's and they feel the shortened wall at the perimeter is the best scenario and within the cost. Mr. Wallace feels it is a good solution and protects some homes to the north as well, more so than the other two options. Ms. Malinowski thanked all of the parties involved and requested that a final report reflect the final recommendation as discussed and that Conservation Commission review the proposal for tweaks.

Action: **Ms. Malinowski moved to adopt the recommendations from Mr. Coate and Mr. Wallace to move forward with the short perimeter wall as presented subject to the Conservation Commission review. Ms. Sacco seconded the motion and voted aye. Dr. Medina voted aye. Ms. Malinowski voted aye. All in favor.**

Topic: **Public Comment**

Discussion: Public comments were not brought before the Board

At 10:42 am Ms. Malinowski made a motion to adjourn the meeting. Dr. Medina seconded the motion. Vote to end the meeting: Ms. Malinowski – yes and Dr. Medina – yes. All in favor.

Respectively submitted by Barbara Spiri, Business Administrator and edited by Chelsea Malinowski.

David Coate Consulting

Acoustics • Vibration

Ken's Food Southborough Noise Barrier Study

August, 2022

Table of Contents

1. Introduction

Residents on the west side of Ken's Food facility in Southborough, Massachusetts have complained about noise associated with warehouse trucking activities. David Coate Consulting (DCC) has prepared two previous noise study reports (June 12, 2020[1], and March 9, 2022[2]) leading up to the present study. These previous studies identified and isolated the truck refrigeration units as the primary cause of low frequency sound affecting some residents in the adjacent community. (The reader is referred to the previous studies for background, additional analyses, and information.)

This noise study evaluates the feasibility and design of a noise barrier which would effectively reduce the low frequency refrigeration unit noise.

2. Source Noise Measurements

2.1 Detailed Refrigeration Unit Noise Measurements

DCC's June 12, 2020 noise study included an octave frequency band measurement of a single refrigeration unit in one direction at 25 feet away. To determine possible differences between units as well as directivity effects, on June 28, 2022, DCC performed sound tests on three separate refrigeration units for four radial directions (0, 90, -90, and 180 degrees) at 25 feet and 50 feet distances. Figure 1 shows the results for the 25-foot measurements.

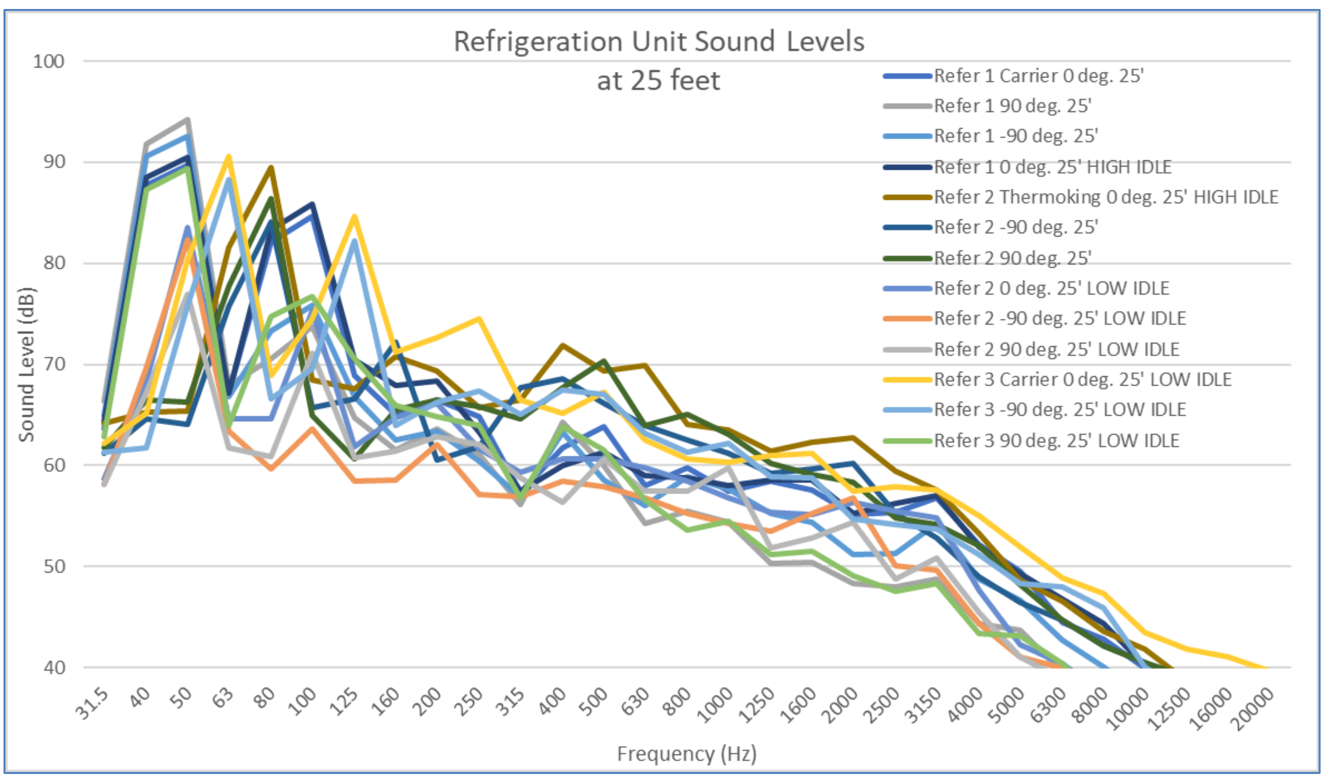

Figure 1. One third Octave Frequency Band Refrigeration Unit Sound Levels at 25'

The predominant low frequency peak is at 50 Hz. During the measurements it was observed that on start up the units were at high idle with peaks corresponding to ones higher than 50 Hz. After around 10 minutes, the units would switch to low idle, and the peaks would drop down to the lower 50 Hz range. Consequently, for units in the parking lot for an hour or more, the 50 Hz peak is more relevant for what the residents are experiencing.

Figure 2 shows the test results for refrigeration units at 50 feet. The 50 Hz and 100 Hz peaks are also in this data, at lower levels as expected due to distance attenuation.

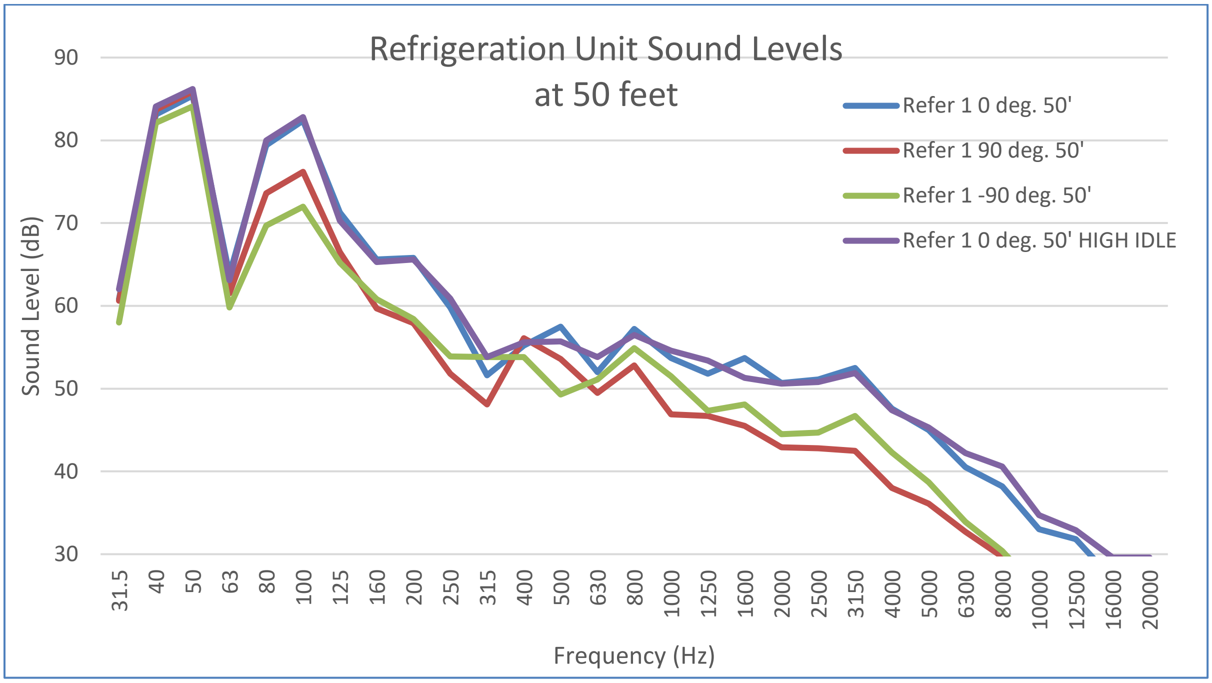

Figure 2. One third Octave Frequency Band Refrigeration Unit Sound Levels at 50'

The data in Figure 1 were averaged and converted from one third octave frequency band to octave frequency band data. This composite average test data was compared with the original data used in the previous CADNA models and shown in Figure 3. This comparison shows that the original data is suitable as well as the overall average. Since the orientation of refrigeration units varies with respect to acoustical paths to specific community receiver locations, an average of the data is appropriate.

Frequency (Hertz, or Hz): Frequency of sound is the pitch or cycles per second of a waveform. Many common sounds contain a range of frequency content.

Decibels (dB) A logarithmic unit to measure sound. This is needed to compress a large range of pressures that humans can hear, from the threshold of hearing (nominally 0 dB) to the threshold of pain (130 dB).

A-weighted decibels (dBA): A measure of noise level used to compare noise from various sources. A-weighting approximates the frequency response of human hearing.

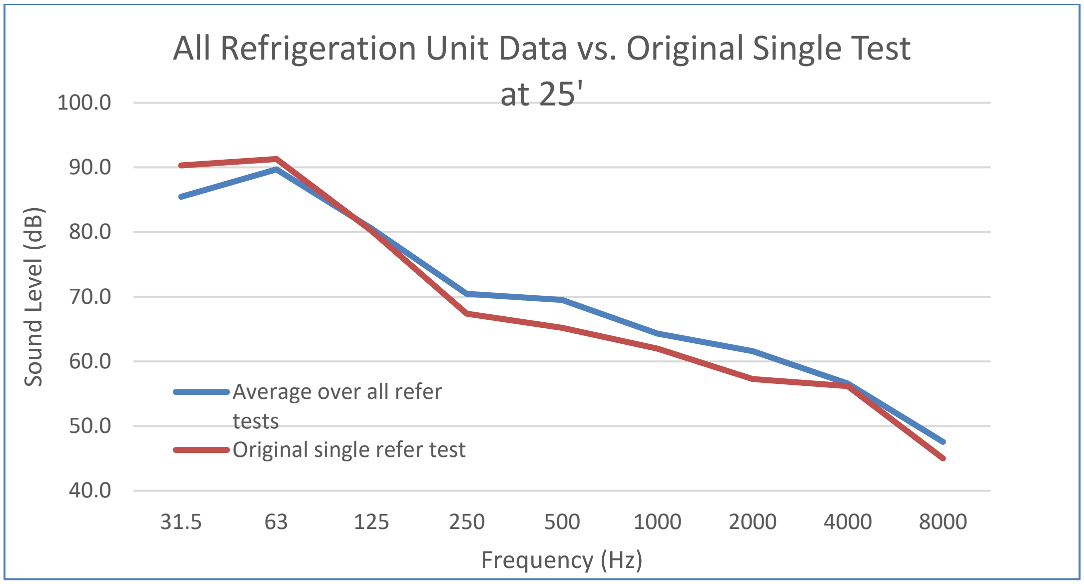

Figure 3. All Refrigeration Unit Data Vs. Original Single Test at 25'

2.2 Idling Truck Noise

To address the concern that idling trucks might be a contributing factor for community noise exposure, DCC measured idling truck noise at 25 feet for four radial directions (0, 90, -90, and 180 degrees). Figure 4 shows these results compared with refrigeration unit noise levels at 25 feet.

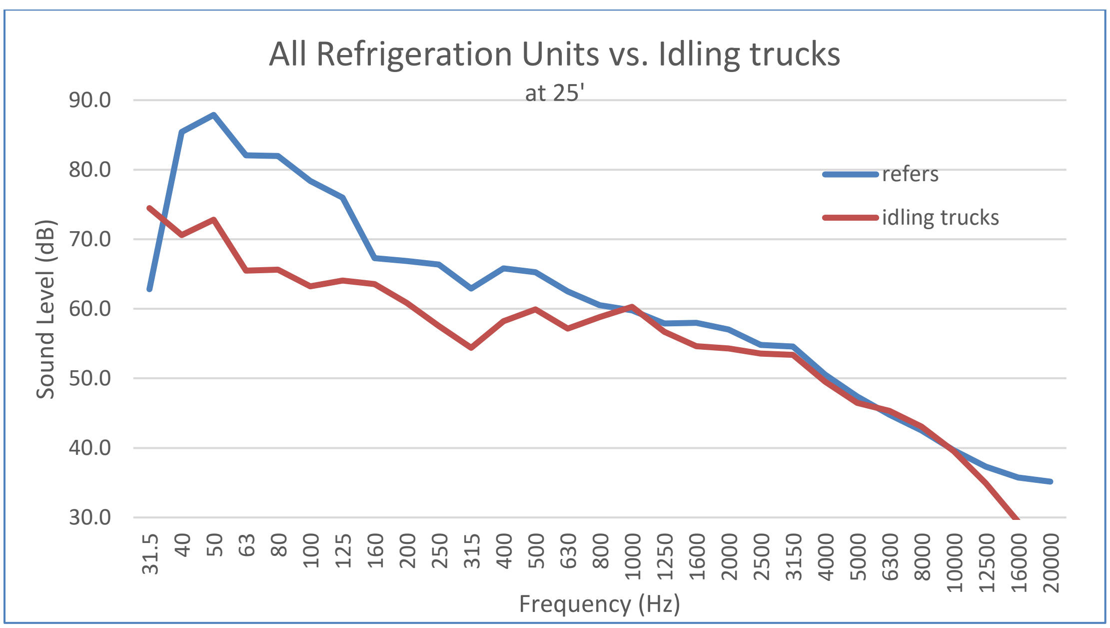

Figure 4. All Refrigeration Unit Sound Data versus Idling Trucks- in One Third Octave Frequency Bands

The data in Figure 3 shows that low frequency sound levels of refrigeration units are at least 15 decibels higher than that of the idling trucks. That coupled with the fact that according to Ken's staff, trucks are not allowed to idle for a length of time shows that idling trucks are not contributing significantly to the community noise issue. Furthermore, brief periods of truck idling during actual operations would be shielded and behind the proposed noise barrier.

2.2.1 Truck Passby Noise

Similar to the idling truck noise issue, truck passbys around the parking lot perimeter as they exit the facility have also been a concern for potential community noise exposure. Sound levels for five truck passbys were measured at 50 feet. Figure 5 shows the results of these tests. As the case with idling trucks, the refrigeration unit low frequency noise is 10 to 20 dB higher than that of the truck passbys. Additionally, according to Kens staff, in the nighttime/early morning hours, trucks exiting the facility is an infrequent occurrence. Therefore, both truck idling and passby noise is not contributing significantly to the community noise issue.

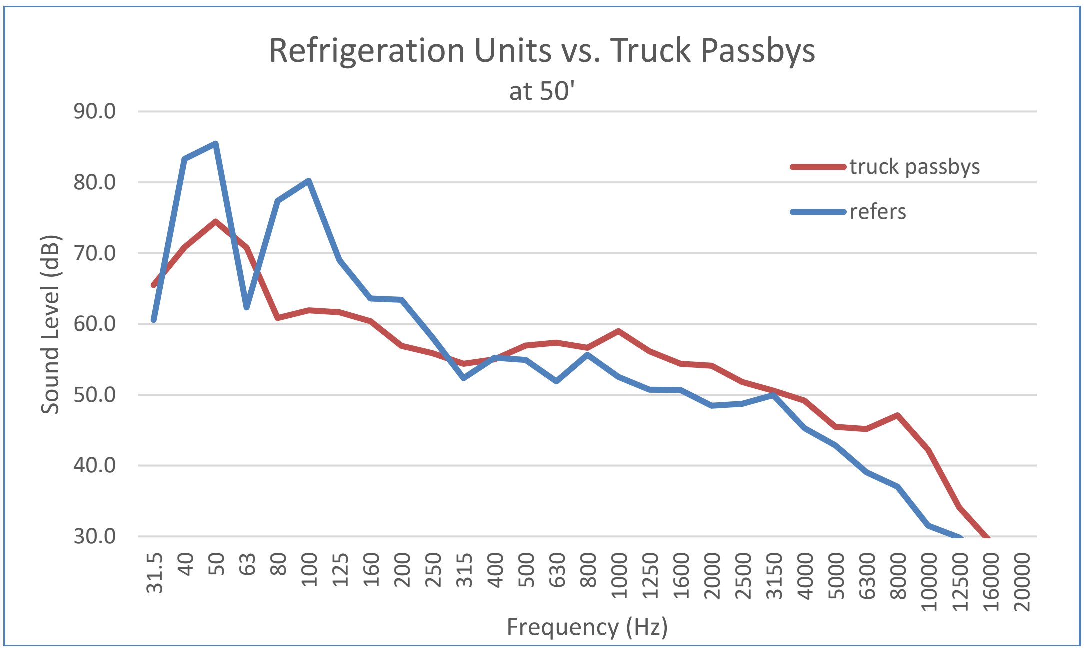

Figure 5. Refrigeration Unit Sound Data versus Idling Trucks- in One Third Octave Frequency Bands

3. Community Sound Tests

3.1 Sound Tests

On July 11, 2022, a series of simple/direct noise tests were performed to determine worst case refrigerator unit sound levels at residential receiver locations. The tests were performed with 20 refrigeration units operating in the loading dock area. Immediately following each measurement of refrigeration unit sound, the units were shut down so a direct comparison to ambient sound levels could be made. Figure 6 shows a location map of the test/receiver locations.

> **Ambient sound:** The sum of all sound (from human and naturally occurring sources) at a specific location over a specific time.

Figure 6. Area Map with Test Receiver Locations

Figures 7 to 10 show the results of the refrigeration units on vs. off sound measurements. The 50 Hz refrigeration unit peak was measurable above ambient sound levels at all locations.

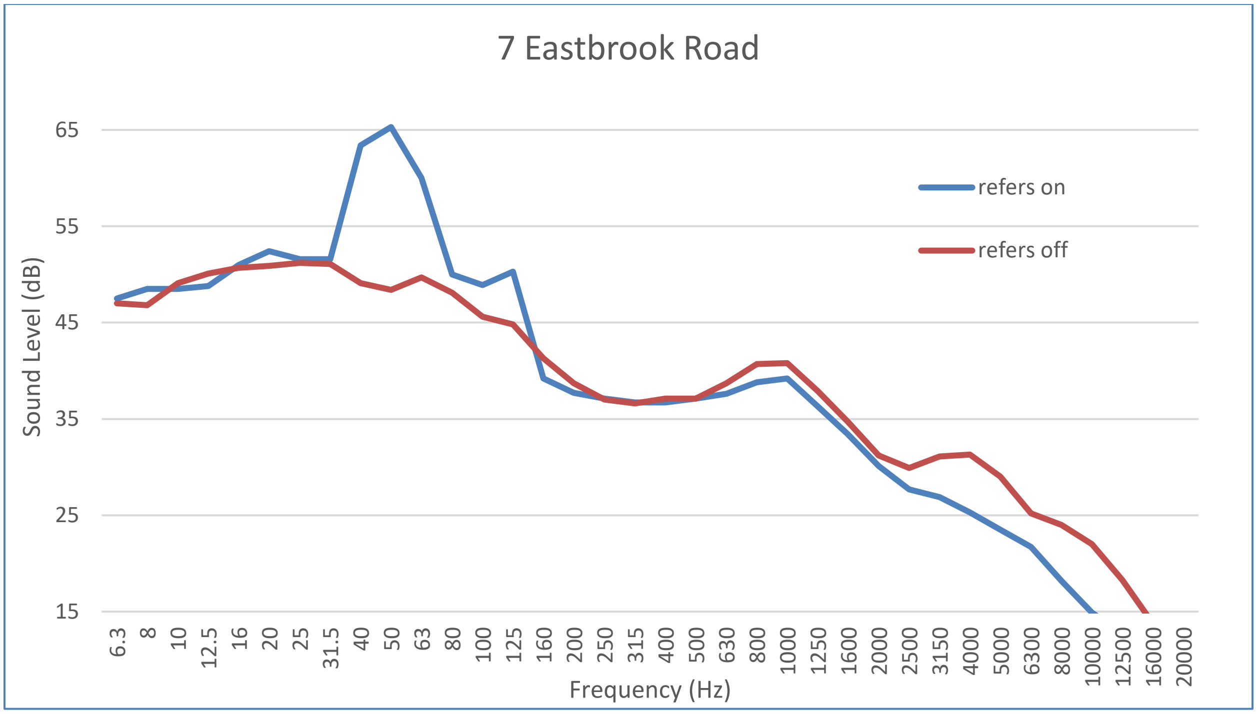

Figure 7. Sound Levels- 7 Eastbrook Road Refrigeration Units On vs. Off

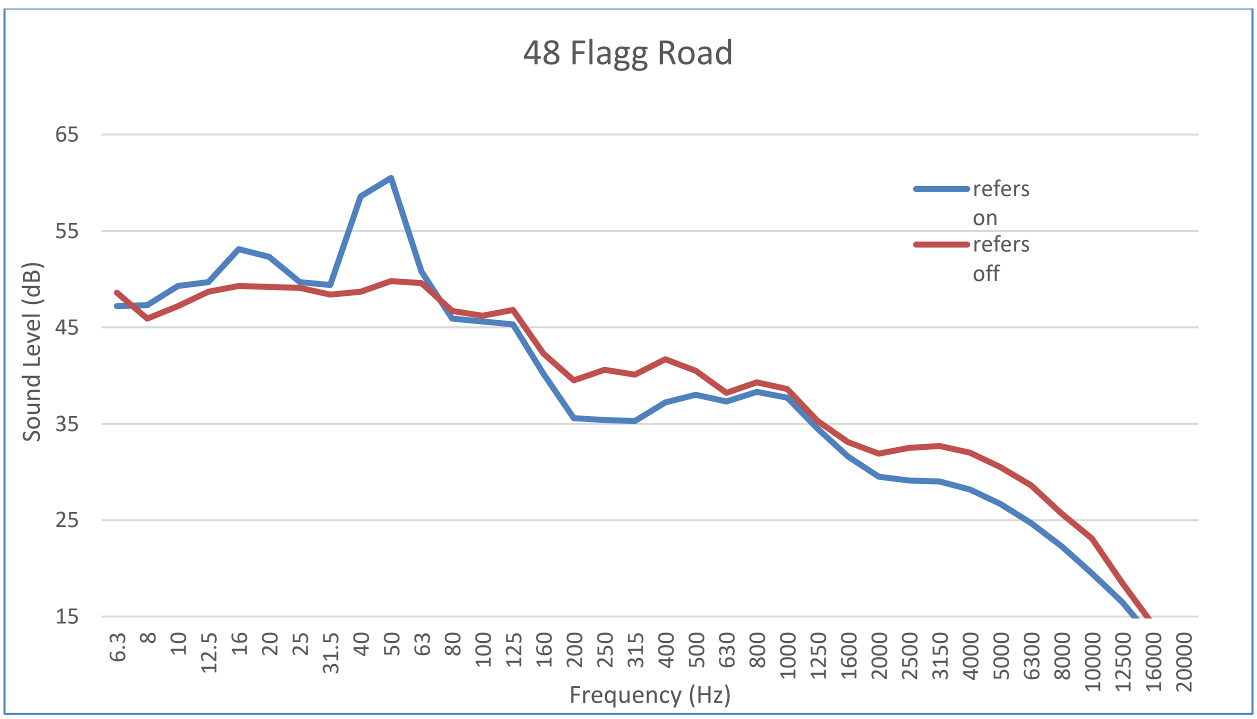

Figure 8. Sound Levels- 48 Flagg Road Refrigeration Units On vs. Off

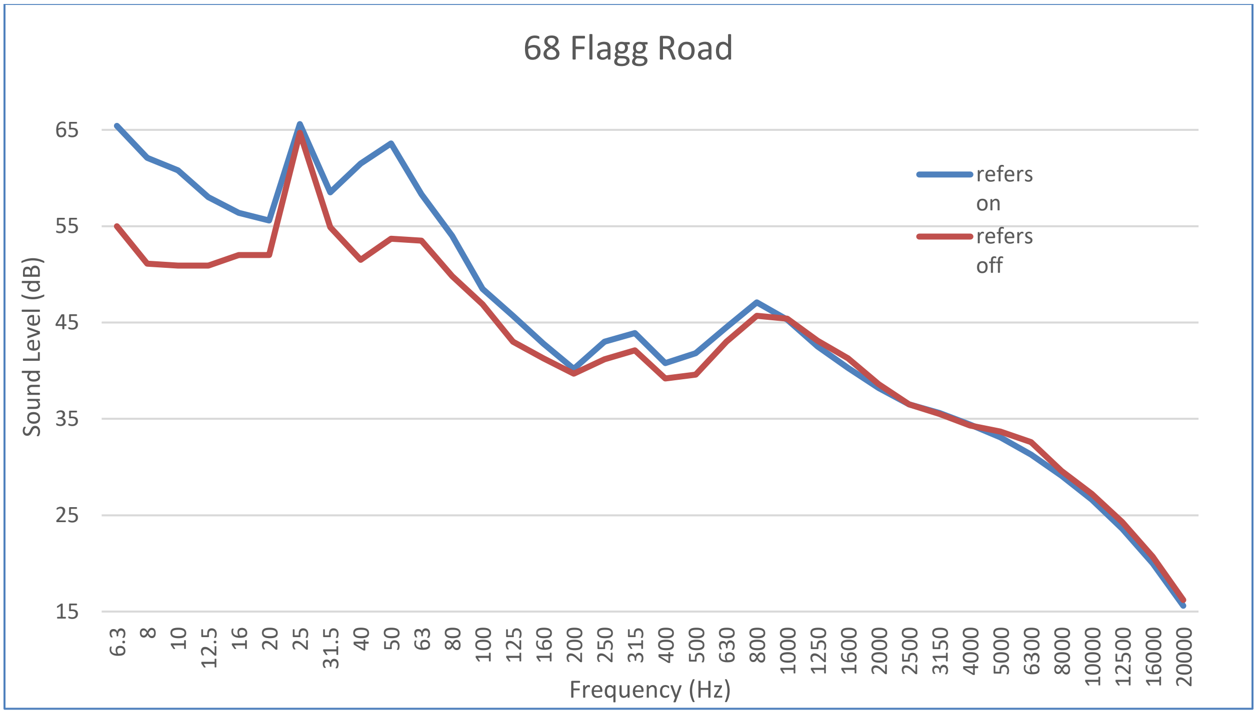

Figure 9. Sound Levels- 68 Flagg Road Refrigeration Units On vs. Off

The peak at 31.5 Hz was present in both the On and Off measurements and was due to very audible traffic noise on nearby Route 9. The reader is referred to DCC's June 12, 2020, report which discusses other low frequency noise sources in the area.

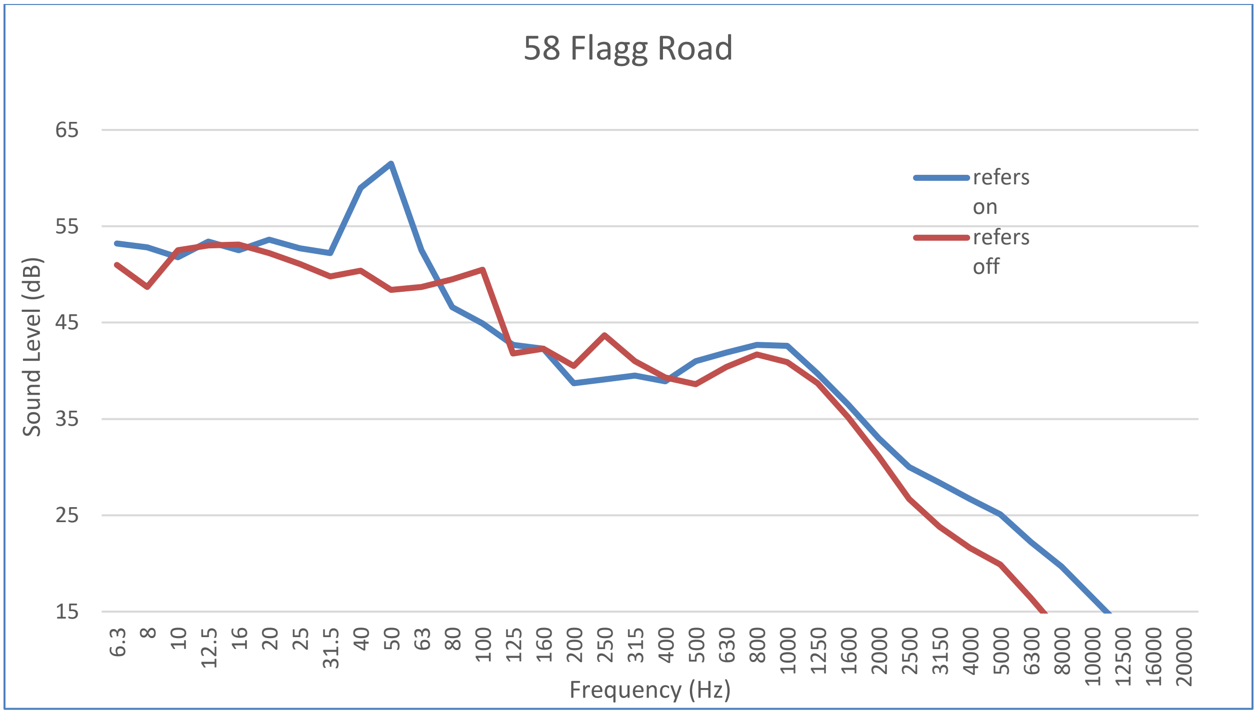

Figure 10. Sound Levels- 58 Flagg Road Refrigeration Units On vs. Off

3.2 CADNA Model of Test Results

The CADNA model for this project was updated with the actual test refrigeration unit positions as well as other data as appropriate. CADNA's octave frequency band predictions of the test conditions at each test location were tabulated. Since CADNA only computes the contribution of the refrigeration units, measured ambient noise levels were logarithmically added to the CADNA results. As typically happens, there were some variations between predictions and measurements, but overall, there is good agreement between them. Table 1 shows the overall average difference between modeled and measured. Given this good agreement, modeling of noise barrier performance can be done with confidence.

CADNA: Cadna-A (Computer-aided Noise Abatement) is the leading software application for the analysis and evaluation of environmental noise which employs International Standards Organization's ISO 9613 outdoor sound propagation standard.

				Frequency (Hz)						
	31.5	63	125	250	500	1000	2000	4000	8000	dBA
TOTAL AVERAGE Modeled-Measured	0.5	0.0	2.7	1.9	3.9	2.4	2.6	1.2	-1.3	2.1

Table 1. Community Receiver Test Conditions, 20 refrigeration units- Difference between Modeled and Measured

4. Noise Barrier Modeling and Design

4.1 CADNA Model- No Noise Barrier

Figure 11 shows the noise contour results of the 20 refrigeration unit test with no noise barrier.

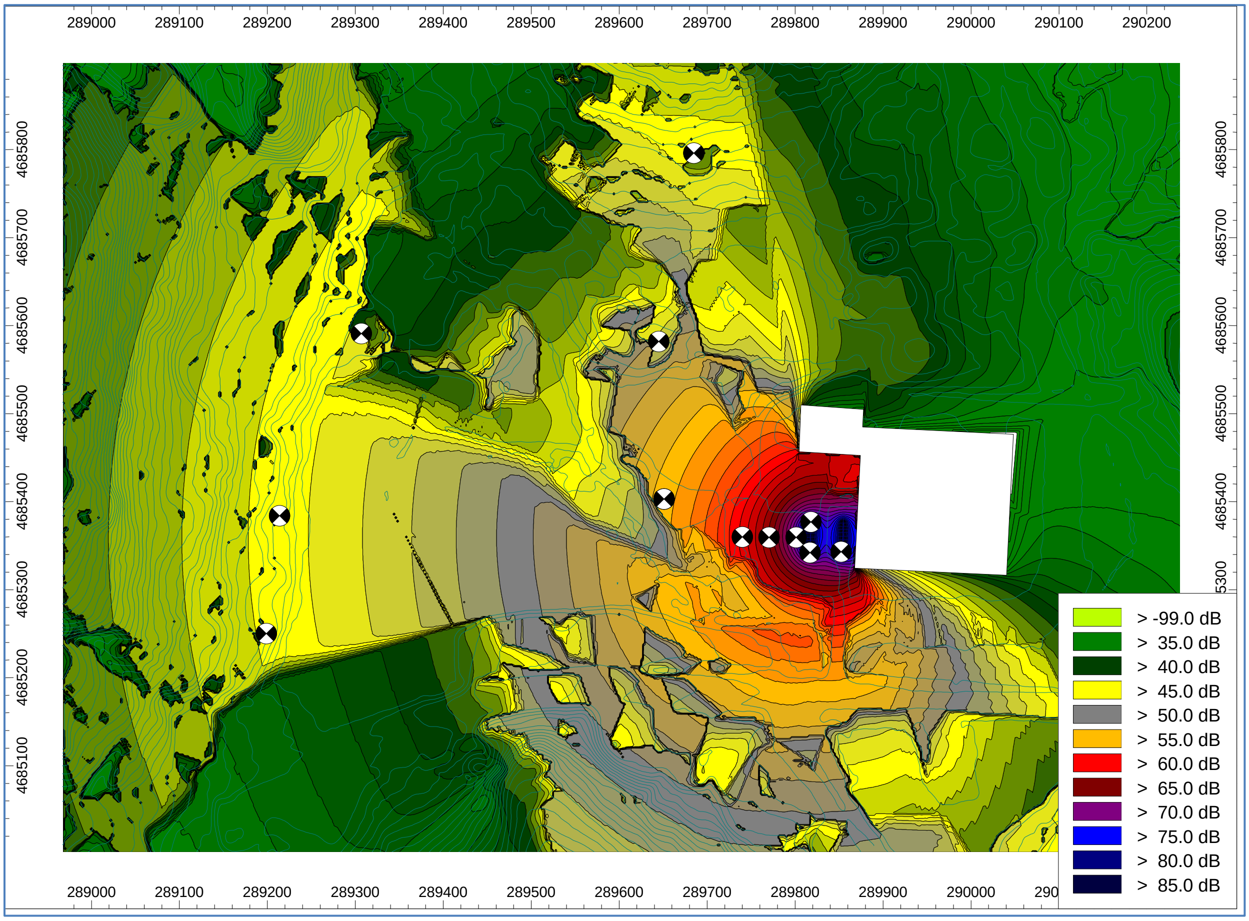

Figure 11. CADNA Noise Contours- No Noise Barrier

4.2 Noise Barrier Design Options

Several noise barrier design options were analyzed including a short barrier situated close to the refrigeration units, a long barrier at the perimeter of the parking lot, and a modified (shortened) parking lot perimeter barrier.

"Short" Noise Barrier Option

Figure 12 shows the noise contour results incorporating a 376' foot long and 20' high noise barrier situated close to the 20 refrigeration units. Comparison of Figure 12 and 11 shows a significant reduction of noise contours which is expected given the fact that noise barriers generally perform best when located close to the noise sources (or close to receivers). In addition, the previous sections of the report detailing truck passby and idling noise show that this barrier option would be effective since those noise sources are not appreciably contributing to community noise. In other words, concentrating the noise mitigation (noise barrier) on the refrigeration units would generally have the best performance/value.

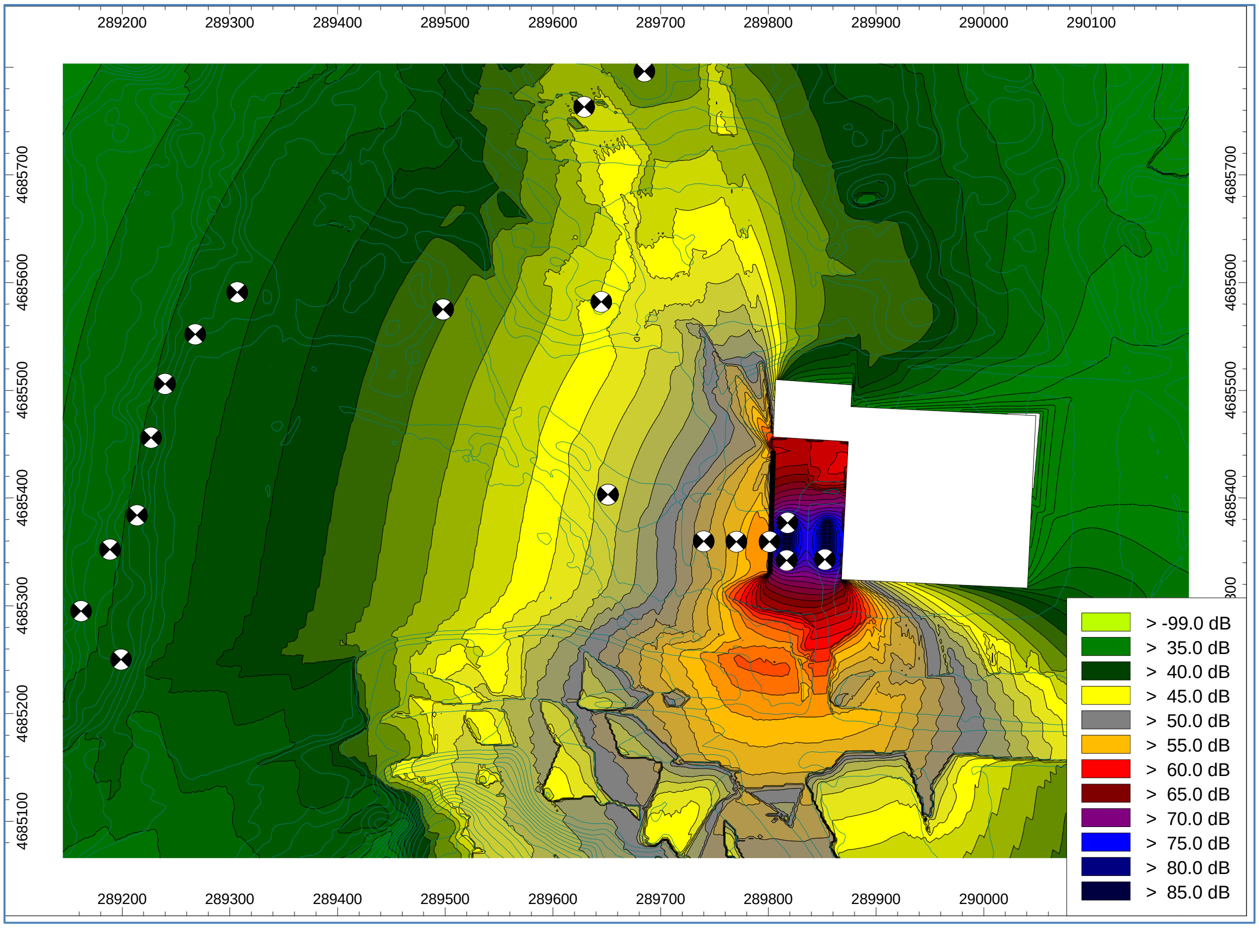

Figure 12. CADNA Noise Contours- With "Short" Noise Barrier

Figure 13 shows a zoomed in view of the "short" noise barrier option.

Figure 13. "Short" Noise Barrier Option

"Long" Noise Barrier Option

Figure 14 shows the noise contour results incorporating a 980 foot long and 16 foot high noise barrier at the perimeter of the parking lot. This noise barrier will have similar acoustic performance to the "short" barrier, but at a higher cost due to the extra length and overall surface area.

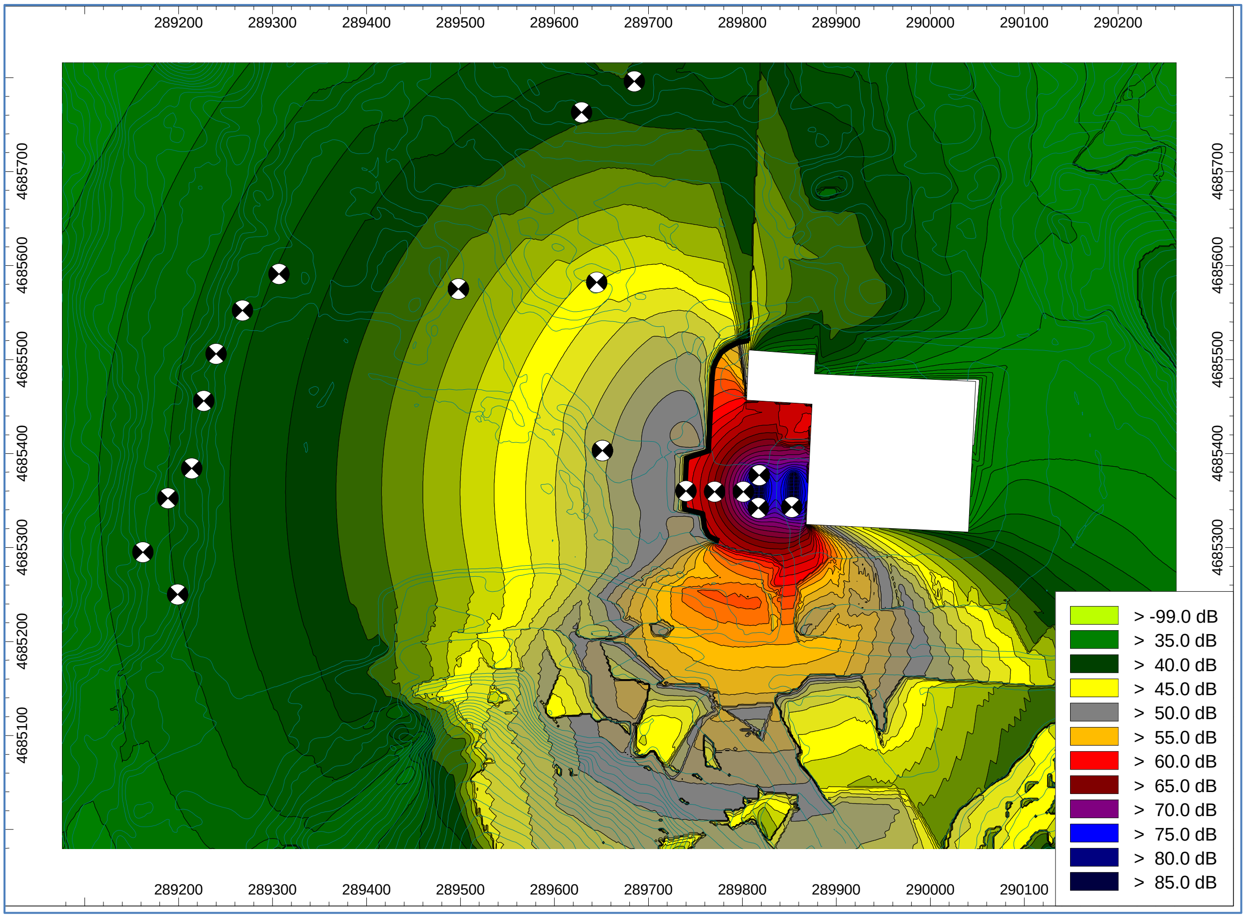

Figure 14. CADNA Noise Contours- With "Long" Noise Barrier

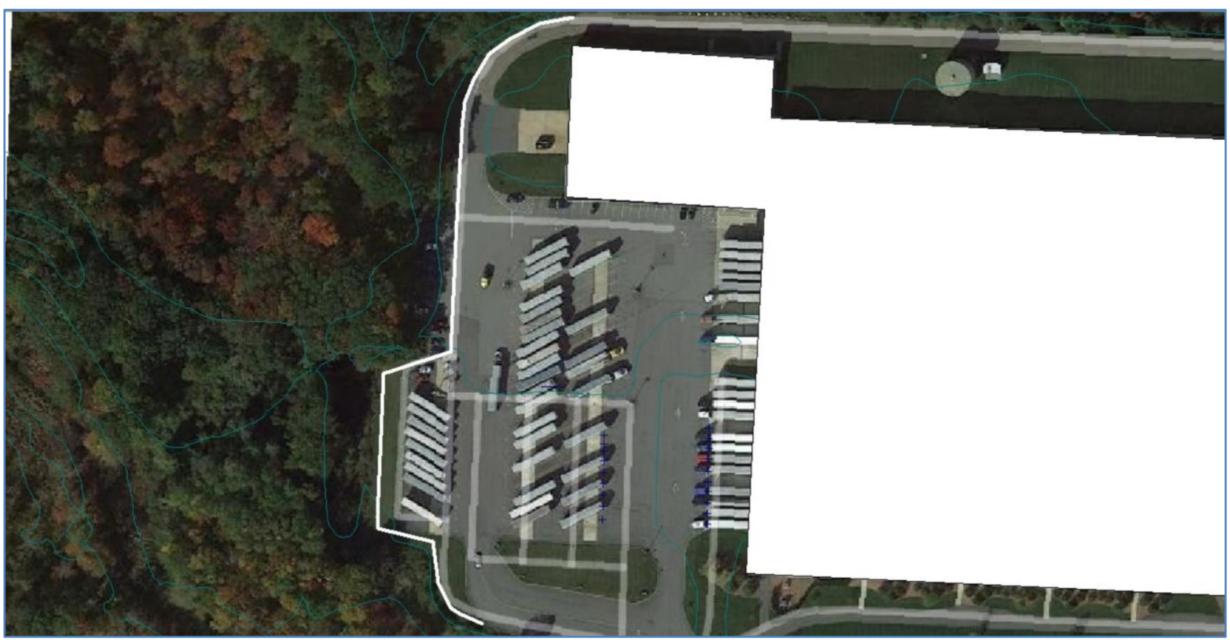

Figure 15. "Long" Noise Barrier Option

Shortened Parking Lot Perimeter Noise Barrier Option

Figure 16 shows the noise contour results incorporating a shortened version of the "long" parking lot perimeter noise barrier option (and moved slightly to the west). As part of the optimization process, both the north and south ends of the barrier were modified slightly to avoid wetland areas. It would have slightly lower acoustic performance, but at a lower cost than the "long" version.

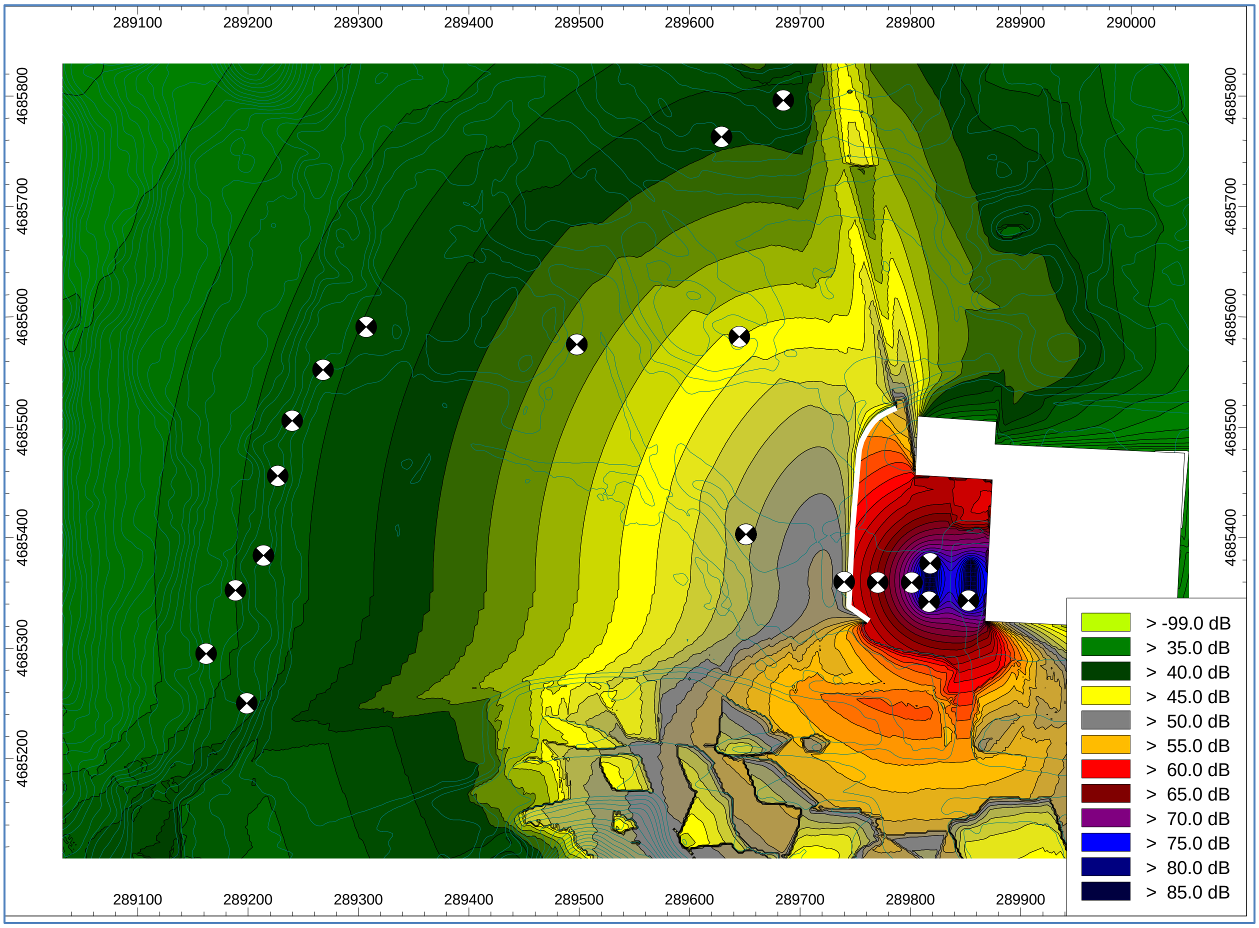

Figure 16. CADNA Noise Contours- With shortened Perimeter Parking Lot Noise Barrier

Figure 17 shows a zoomed in view of this noise barrier option.

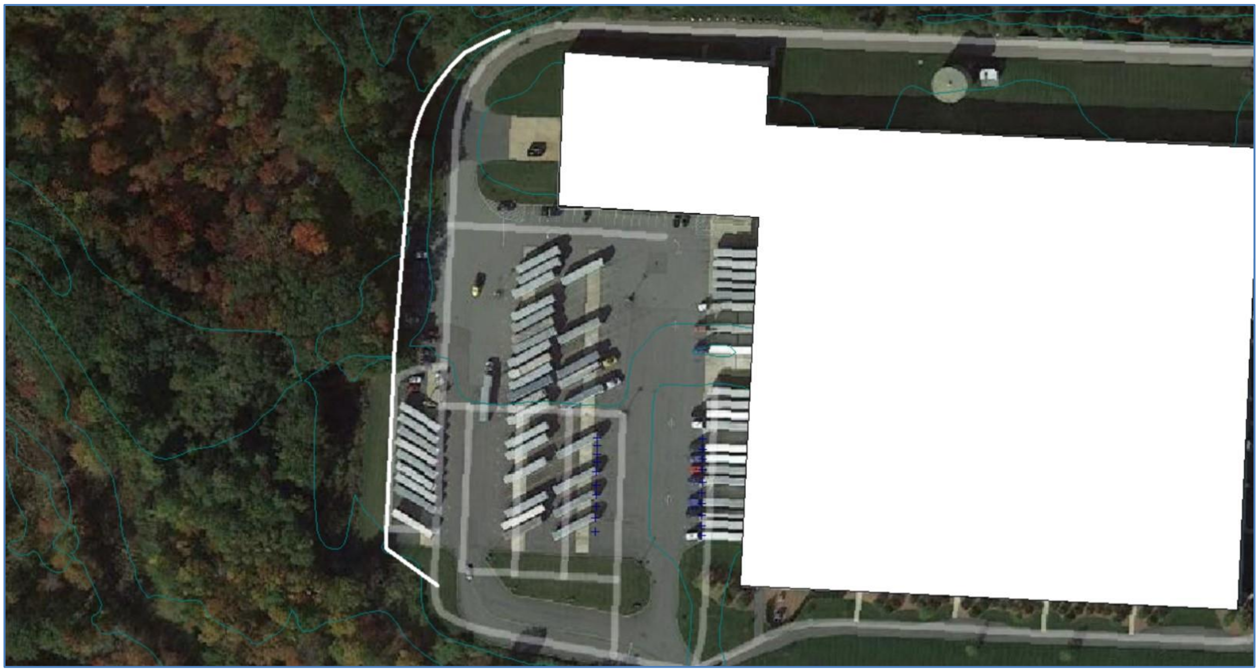

Figure 17. Shortened Perimeter Parking Lot Noise Barrier Option

4.3 Noise Barrier Options Insertion Loss

"Insertion Loss" (in decibels or dB) is defined as the amount of noise reduction achieved when a noise barrier is inserted into the acoustic path between noise source and receiver.

Tables 2 -4 show the CADNA predicted barrier insertion loss values on a frequency and overall dBA basis at each receiver location for the three noise barrier options. All three options have good acoustic performance, particularly at the problematic 63 Hz frequency band[1]. The lower 7 Eastbrook Farm insertion loss is somewhat of an anomaly as the improvements are good in this general area. Possible causes are because of the topography at this receiver which has higher elevations thus causing a shallower break in the noise barrier line-of-sight to refrigeration units.

Second story insertion losses are within approximately one to two decibels of the ground floor level insertion loss values.

[1] Note that the 50 Hz one third octave frequency band peak described in the previous sections is summed in the 63 Hz octave frequency band data.

					Frequency (Hz)					
	31.5	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**	**dBA**
550' location										
With Barrier	28.9	42.6	42.2	36.1	39.2	37.7	31.5	23.1	-10.8	47.4
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	68.3	68.8	58.3	44.7	42.4	37.7	30.3	22.1	-9.7	
No Barrier	37.7	51.8	48.4	39.3	45.7	47.6	43.2	7.7	30.0	55.5
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	69.8	71.7	57.4	47.7	48.0	48.8	43.8	41.3	36.9	
Insertion Loss	1.5	2.9	-0.9	3.0	5.6	11.1	13.5	19.2	46.6	8.1
7 Eastbrook Farm Rd.										
With Barrier	26.4	40	38.1	33.7	37.9	37.2	31.4	22	-19	45.1
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	65.8	66.2	54.2	42.3	41.1	37.2	30.2	21	-17.9	
No Barrier	25.4	39.7	39.0	35.6	41.4	41.9	36.6	28.2	-10.1	47.5
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	64.8	65.9	55.1	44.2	44.6	41.9	35.4	27.2	-9.0	
Insertion Loss	-1.0	-0.3	0.9	1.9	3.5	4.7	5.2	6.2	8.9	2.4
48 Flagg Rd.										
With Barrier	19.4	33.3	33.4	27.6	31	29.7	22.2	6.5	-58	38
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	58.8	59.5	49.5	36.2	34.2	29.7	21	5.5	-56.9	
No Barrier	28.5	42.7	36.8	29.7	35.4	36.8	29.9	15.0	-47.0	45.3
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	67.9	68.9	52.9	38.3	38.6	36.8	28.7	14	-45.9	
Insertion Loss	9.1	9.4	3.4	2.1	4.4	7.1	7.7	8.5	11.0	7.3
68 Flagg Rd.										
With Barrier	20.3	33.9	32.7	26.7	30.5	29.4	21.6	4.1	-66.8	38.4
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	59.7	60.1	48.8	35.3	33.7	29.4	20.4	3.1	-65.7	
No Barrier	28.5	42.6	36.3	29.0	35.4	36.5	29.3	12.6	-55.7	45.2
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	67.9	68.8	52.4	37.6	38.6	36.5	28.1	11.6	-54.6	
Insertion Loss	8.2	8.7	3.6	2.3	4.9	7.1	7.7	8.5	11.1	6.8
58 Flagg Rd.										
With Barrier	19.4	33.2	32.8	26.9	30.3	28.9	21.1	4.3	-64.3	38.2
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	58.8	59.4	48.9	35.5	33.5	28.9	19.9	3.3	-63.2	
No Barrier	28.8	42.9	36.8	29.3	35.7	36.9	29.8	13.7	-52.5	
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	68.2	69.1	52.9	37.9	38.9	36.9	28.6	12.7	-51.4	45.5
Insertion Loss	9.4	9.7	4.0	2.4	5.4	8.0	8.7	9.4	11.8	7.3

Table 2. Short Barrier Option Noise Barrier Insertion Loss (dB)

					Frequency (Hz)					
	31.5	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**	**dBA**
550' location										
With Barrier	28.9	42.8	42.5	36.4	39.5	38.3	32.4	24.5	-9.3	47.8
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	68.3	69	58.6	45	42.7	38.3	31.2	23.5	-8.2	
No Barrier	37.7	51.8	48.4	39.3	45.7	47.6	43.2	7.7	30.0	55.5
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	69.8	71.7	57.4	47.7	48.0	48.8	43.8	41.3	36.9	
Insertion Loss	1.5	2.7	-1.2	2.7	5.3	10.5	12.6	17.8	45.1	7.7
7 Eastbrook Farm Rd.										
With Barrier	25.2	39.4	38.3	34.1	37.8	37.2	31.9	23.3	-15.4	45
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	64.6	65.6	54.4	42.7	41	37.2	30.7	22.3	-14.3	
No Barrier	25.4	39.7	39.0	35.6	41.4	41.9	36.6	28.2	-10.1	47.5
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	64.8	65.9	55.1	44.2	44.6	41.9	35.4	27.2	-9.0	
Insertion Loss	0.2	0.3	0.7	1.5	3.6	4.7	4.7	4.9	5.3	2.5
48 Flagg Rd.										
With Barrier	19.3	33.4	33.7	28	31.6	30.6	23.7	8.7	-54.2	39.1
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	58.7	59.6	49.8	36.6	34.8	30.6	22.5	7.7	-53.1	
No Barrier	28.5	42.7	36.8	29.7	35.4	36.8	29.9	15.0	-47.0	45.3
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	67.9	68.9	52.9	38.3	38.6	36.8	28.7	14	-45.9	
Insertion Loss	9.2	9.3	3.1	1.7	3.8	6.2	6.2	6.3	7.2	6.2
68 Flagg Rd.										
With Barrier	18.3	32.5	32.7	27	30.5	29.6	22.1	5.6	-62.7	38
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	57.7	58.7	48.8	35.6	33.7	29.6	20.9	4.6	-61.6	
No Barrier	28.5	42.6	36.3	29.0	35.4	36.5	29.3	12.6	-55.7	45.2
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	67.9	68.8	52.4	37.6	38.6	36.5	28.1	11.6	-54.6	
Insertion Loss	10.2	10.1	3.6	2.0	4.9	6.9	7.2	7.0	7.0	7.2
58 Flagg Rd.										
With Barrier	18.6	32.8	33	27.3	30.9	29.7	22.5	6.8	-59.9	38.4
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	58	59	49.1	35.9	34.1	29.7	21.3	5.8	-58.8	
No Barrier	28.8	42.9	36.8	29.3	35.7	36.9	29.8	13.7	-52.5	
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	68.2	69.1	52.9	37.9	38.9	36.9	28.6	12.7	-51.4	45.5
Insertion Loss	10.2	10.1	3.8	2.0	4.8	7.2	7.3	6.9	7.4	7.1

Table 3. Long Noise Barrier Option Insertion Loss (dB)

					Frequency (Hz)					
	31.5	63	125	250	500	1000	2000	4000	8000	dBA
550' location										
With Barrier	29.0	43.2	43.1	37.6	41.1	40.3	34.9	27.7	-4.0	48.8
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	68.4	69.4	59.2	46.2	44.3	40.3	33.7	26.7	-2.9	
No Barrier	37.7	51.8	48.4	39.3	45.7	47.6	43.2	7.7	30.0	55.5
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	69.8	71.7	57.4	47.7	48.0	48.8	43.8	41.3	36.9	
Insertion Loss	1.4	2.3	-1.8	1.5	3.7	8.5	10.1	14.6	39.8	6.7
7 Eastbrook Farm Rd.										
With Barrier	25.2	39.4	38.3	34.1	37.8	37.2	31.8	23.4	-14.9	45
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	64.6	65.6	54.4	42.7	41	37.2	30.6	22.4	-13.8	
No Barrier	25.4	39.7	39.0	35.6	41.4	41.9	36.6	28.2	-10.1	47.5
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	64.8	65.9	55.1	44.2	44.6	41.9	35.4	27.2	-9.0	
Insertion Loss	0.2	0.3	0.7	1.5	3.6	4.7	4.8	4.8	4.8	2.5
48 Flagg Rd.										
With Barrier	19.3	33.5	33.7	28	31.6	30.6	23.5	8.4	-54	39.1
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	58.7	59.7	49.8	36.6	34.8	30.6	22.3	7.4	-52.9	
No Barrier	28.5	42.7	36.8	29.7	35.4	36.8	29.9	15.0	-47.0	45.3
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	67.9	68.9	52.9	38.3	38.6	36.8	28.7	14	-45.9	
Insertion Loss	9.2	9.2	3.1	1.7	3.8	6.2	6.4	6.6	7.0	6.2
68 Flagg Rd.										
With Barrier	19.8	33.8	33.1	27.1	31.2	30.4	22.9	6	-62.8	38.8
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	59.2	60	49.2	35.7	34.4	30.4	21.7	5	-61.7	
No Barrier	28.5	42.6	36.3	29.0	35.4	36.5	29.3	12.6	-55.7	45.2
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	67.9	68.8	52.4	37.6	38.6	36.5	28.1	11.6	-54.6	
Insertion Loss	8.7	8.8	3.2	1.9	4.2	6.1	6.4	6.6	7.1	6.4
58 Flagg Rd.										
With Barrier	18.6	32.8	33	27.3	30.9	29.8	22.4	6.2	-60	38.4
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	58	59	49.1	35.9	34.1	29.8	21.2	5.2	-58.9	
No Barrier	28.8	42.9	36.8	29.3	35.7	36.9	29.8	13.7	-52.5	
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	68.2	69.1	52.9	37.9	38.9	36.9	28.6	12.7	-51.4	45.5
Insertion Loss	10.2	10.1	3.8	2.0	4.8	7.1	7.4	7.5	7.5	7.1

Table 4. Shortened Parking Lot Perimeter Noise Barrier Option Insertion Loss (dB)

4.4 Noise Barrier Design Evaluation Criteria

State and federal agencies that manage and regulate noise barrier construction evaluate the feasibility and reasonability of noise barriers. For example, most state Departments of Transportation define feasibility as obtaining at least a 5 dBA insertion loss. This is because human perception is at 3 dBA so a noticeable improvement must be made to justify the noise barrier. Reasonability is defined on the basis of cost per protected receiver.

The Massachusetts Department of Transportation[3] determines whether or not a noise barrier is acceptable if the cost per receiver divided by insertion loss is $8400 or less. Insertion loss is averaged over receivers with 5 dBA or more insertion loss. Table 5 and 6 show a breakdown of this analysis for the three noise barrier options. Table 6 includes residences in addition to the test receivers that could benefit from a barrier.

	Short	**Long**	**Long shortened**
Length (ft)	376	980	712
Height (ft)	20	16	16
Area (sqft)	7520	15680	11391
Cost	$376,000	$784,000	$569,554

Table 5. Barrier Options Dimensions/Cost

Short Barrier		9 receivers			**Long Barrier**		11 receivers			**Long shortened**		11 receivers		
	Barrier	**No Barrier IL**		**Cost/IL/Units**		**Barrier**	**No Barrier IL**		**Cost/IL/Units**		**Barrier**	**No Barrier IL**		**Cost/IL/Units**
58 Flagg	38.2	45.5	7.3	$5,785	58 Flagg	38.4	45.5	7.1	$10,467	58 Flagg	38.4	45.5	7.1	$7,676
60 Flagg	37.9	45.1	7.2		60 Flagg	38	45.1	7.1		60 Flagg	38	45.1	7.1	
64 Flagg	37.6	44.7	7.1		64 Flagg	37.6	44.7	7.1		64 Flagg	37.6	44.7	7.1	
68 Flagg	38.4	45.2	6.8		68 Flagg	38	45.2	7.2		68 Flagg	38.8	45.2	6.4	
56 Flagg	38.1	45.6	7.5		56 Flagg	38.5	45.6	7.1		56 Flagg	38.5	45.6	7.1	
54 Flagg	38.1	45.6	7.5		54 Flagg	38.5	45.6	7.1		54 Flagg	38.5	45.6	7.1	
50 Flagg	38.3	45.9	7.6		50 Flagg	38.7	45.9	7.2		50 Flagg	38.7	45.9	7.2	
24 Flagg	42.4	45.7	3.3		24 Flagg	40.4	45.7	5.3		24 Flagg	40.3	45.7	5.4	
28 Flagg	44	47.5	3.5		28 Flagg	40.8	47.5	6.7		28 Flagg	40.8	47.5	6.7	
48 Flagg	38.7	45.3	6.6		48 Flagg	39.1	45.3	6.2		48 Flagg	39.1	45.3	6.2	
7 Eastbrook	45.1	47.5	2.4		7 Eastbrook	45	47.5	2.5		7 Eastbrook	45	47.5	2.5	
5 Eastbrook	41.9	49.3	7.4		5 Eastbrook	42.5	49.3	6.8		5 Eastbrook	42.5	49.3	6.8	
		Average	7.2				Average	6.8				Average	6.7	

Table 6. Noise Barrier Feasibility and Reasonability

The short barrier option has an average insertion loss of 7.2 dBA and has the best reasonability of $5,785 due to the focused nature of this design. The long barrier option has an average insertion loss of 6.8 dBA but exceeds the state reasonability guideline of $8,400 at $10,467. The third shortened perimeter barrier option has an average insertion loss of 6.7 dBA and meets the state reasonability guideline at $7,676.

4.5 Noise Barrier Design Specifications

Surface Mass Density

Noise barriers must have sufficient mass density in order for the sound going "through" the barrier to not compromise the diffracted component of reduced noise over the top of the barrier. In most noise barrier applications, any solid free-standing wall of these heights would have sufficient mass for this to be a non-issue. Noise barrier mass density is typically specified at 5 lbs. per sqft. In this case however, low frequency sound at 63 Hz is the issue, not mid frequency sound. Consequently, on the order of 10 lb./sqft solid material would be needed in this case to achieve adequate reduction in the 63 Hz band. However, a composite noise barrier material such as with an interior airspace would be able to provide enough attenuation. Table 5 shows the required Transmission Loss of the noise barrier to achieve a 0.5 dB or less degradation of performance at 63 Hz. This particular example works out to be STC 35. The more important value in this case is the 19 dB of transmission loss needed at 63 Hz since STC primarily addresses mid frequency sound.

Transmission Loss is a measurement of the reduction in sound level of a sound source as it passes through an acoustic barrier. It is the number of decibels that are reduced by the acoustical barrier or the wall and is measured at different frequencies.

Sound Transmission Class (STC) is a rating of how well a partition attenuates sound. The STC rating very roughly reflects the decibel reduction of noise that a partition can provide. The STC is useful for evaluating speech sounds, but not music or machinery noise as these sources contain more low frequency energy than speech.

					Frequency (Hz)					
	31.5	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**	**35** STC
Needed Transmission Loss	15	19	23	27	31	35	39	43	47	
subtract from no barrier data	53.2	50.1	29.9	10.9	7.9	1.9	-10.4	-30.3	-98.4	
add with barrier data	59.2	59.5	49.2	35.9	34.1	29.8	21.2	5.2	-58.9	
Degradation	1.2	0.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0	

Table 5. Minimum Transmission Loss for Noise Barrier

Absorptive Noise Barrier Face

For the short barrier option, DCC recommends that both sides of the noise barrier be rated at NRC 0.9. Since the parking lot area is reflective, highly absorptive barrier faces would provide beneficial reduction of reflections between these surfaces. For the parking lot perimeter noise barrier options, only the inside face of the barrier (facing the refrigeration units) would need to be rated at NRC 0.9.

Noise Reduction Coefficient (NRC) is an average rating of how much sound an acoustic product can absorb. NRC varies from 0 to 1 with 1 being 100% absorptive.

Noise Barrier Dimensions/Coordinates

Table 6 shows the north and south UTM coordinates of each barrier option as well as the physical dimensions.

Noise Barrier Option	Length (ft)	Height (ft)	Area (sqft)	North UTM Coordinates (m)	South UTM Coordinates (m)
Long	980	16	15680	289807.07, 4685520.20	289775.14, 4685307.09
Short	376	20	7520	289804.62, 4685443.90	289801.39, 4685329.14
Shortened Perimeter	712	16	11391	289787.53, 4685517.48	289762.66, 4685324.70

Table 6. Noise Barrier Dimensions and Coordinates

6. Summary

Extensive acoustic testing, modeling, and analyses have demonstrated that refrigeration unit noise, specifically at 50 Hz, affects certain residential areas to the west and northwest of the trucking facility. Testing of 20 refrigeration units operating simultaneously showed that this 50 Hz peak was measurable above ambient sound levels at the test residential receiver locations.

The study also analyzed three separate noise barrier design options, each of which would substantially reduce the low frequency refrigeration noise. Finally, all three noise barrier options were compared with Mass DOT feasibility and reasonability guidelines. The Short and Shortened Perimeter barrier design options meet these guidelines.

Bibliography

1. Ken’s Food Facility Noise Analysis (West Side)- Southborough, Massachusetts, DCC, June 2020
2. Ken’s Food Facility Noise Analysis (West Side)- Additional Refrigeration Unit Acoustical Test Results, DCC, March 2022
3. Massachusetts Department of Transportation, Massachusetts Department of Transportation Type I and Type II Noise Abatement Policies and Procedures, 2011

David Coate Consulting

Acoustics • Vibration

Ken's Food Southborough Noise Barrier Study

August, 2022

Table of Contents

1. Introduction

Residents on the west side of Ken's Food facility in Southborough, Massachusetts have complained about noise associated with warehouse trucking activities. David Coate Consulting (DCC) has prepared two previous noise study reports (June 12, 2020[1], and March 9, 2022[2]) leading up to the present study. These previous studies identified and isolated the truck refrigeration units as the primary cause of low frequency sound affecting some residents in the adjacent community. (The reader is referred to the previous studies for background, additional analyses, and information.)

This noise study evaluates the feasibility and design of a noise barrier which would effectively reduce the low frequency refrigeration unit noise.

2. Source Noise Measurements

2.1 Detailed Refrigeration Unit Noise Measurements

DCC's June 12, 2020 noise study included an octave frequency band measurement of a single refrigeration unit in one direction at 25 feet away. To determine possible differences between units as well as directivity effects, on June 28, 2022, DCC performed sound tests on three separate refrigeration units for four radial directions (0, 90, -90, and 180 degrees) at 25 feet and 50 feet distances. Figure 1 shows the results for the 25-foot measurements.

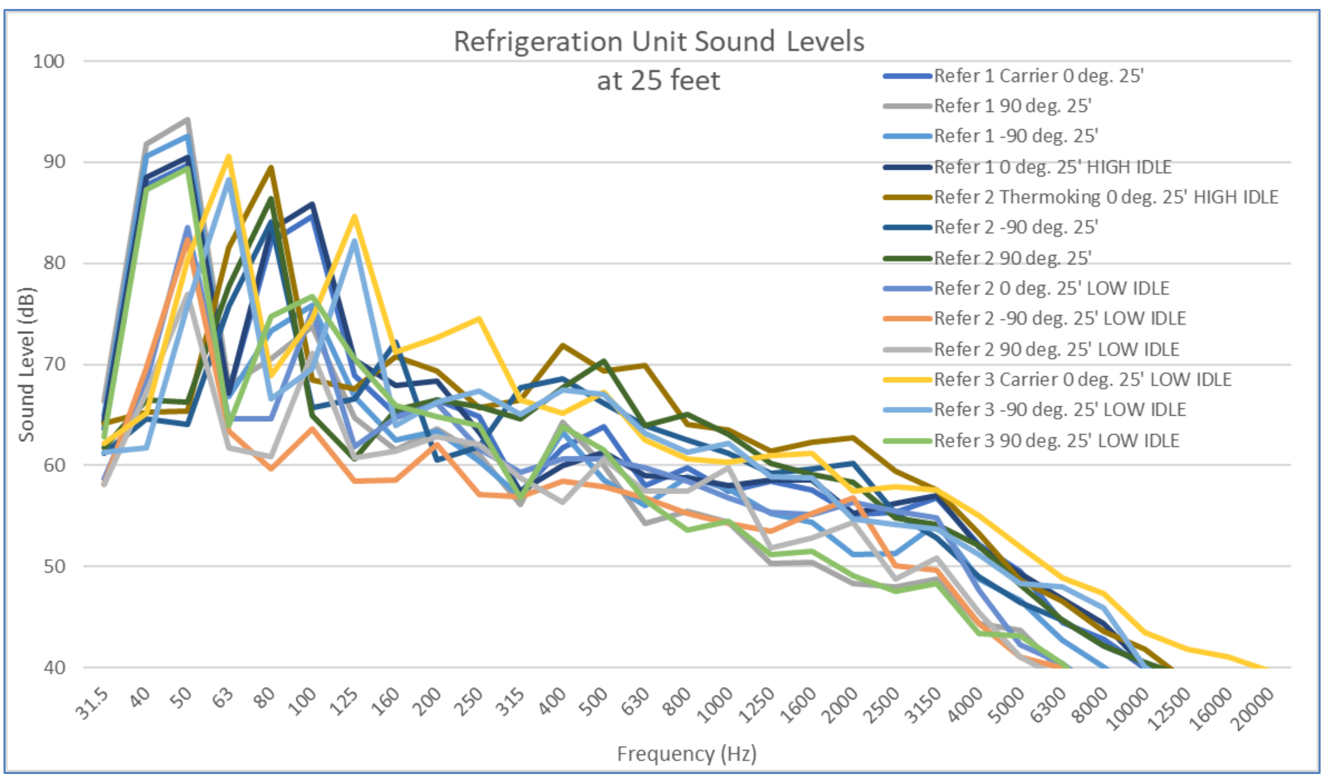

Figure 1. One third Octave Frequency Band Refrigeration Unit Sound Levels at 25'

The predominant low frequency peak is at 50 Hz. During the measurements it was observed that on start up the units were at high idle with peaks corresponding to ones higher than 50 Hz. After around 10 minutes, the units would switch to low idle, and the peaks would drop down to the lower 50 Hz range. Consequently, for units in the parking lot for an hour or more, the 50 Hz peak is more relevant for what the residents are experiencing.

Figure 2 shows the test results for refrigeration units at 50 feet. The 50 Hz and 100 Hz peaks are also in this data, at lower levels as expected due to distance attenuation.

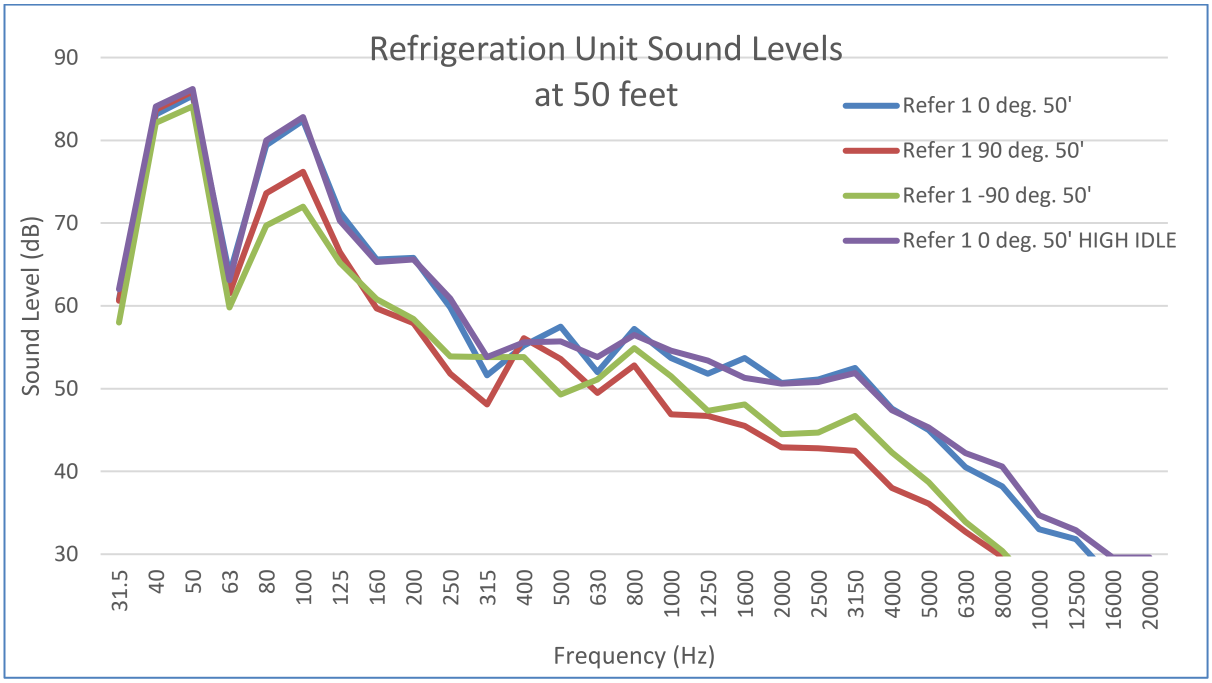

Figure 2. One third Octave Frequency Band Refrigeration Unit Sound Levels at 50'

The data in Figure 1 were averaged and converted from one third octave frequency band to octave frequency band data. This composite average test data was compared with the original data used in the previous CADNA models and shown in Figure 3. This comparison shows that the original data is suitable as well as the overall average. Since the orientation of refrigeration units varies with respect to acoustical paths to specific community receiver locations, an average of the data is appropriate.

Frequency (Hertz, or Hz): Frequency of sound is the pitch or cycles per second of a waveform. Many common sounds contain a range of frequency content.

Decibels (dB) A logarithmic unit to measure sound. This is needed to compress a large range of pressures that humans can hear, from the threshold of hearing (nominally 0 dB) to the threshold of pain (130 dB).

A-weighted decibels (dBA): A measure of noise level used to compare noise from various sources. A-weighting approximates the frequency response of human hearing.

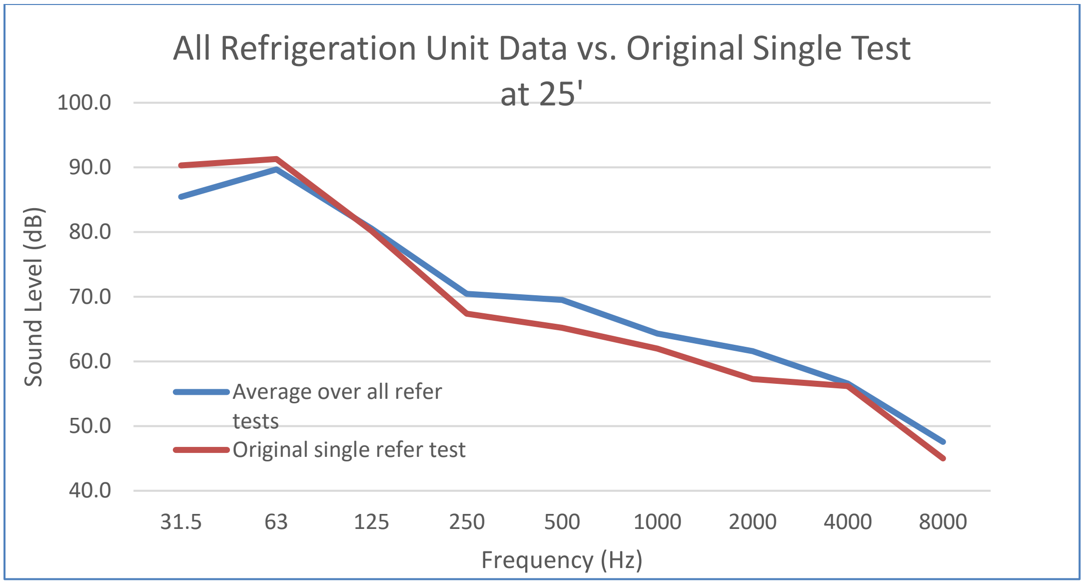

Figure 3. All Refrigeration Unit Data Vs. Original Single Test at 25'

2.2 Idling Truck Noise

To address the concern that idling trucks might be a contributing factor for community noise exposure, DCC measured idling truck noise at 25 feet for four radial directions (0, 90, -90, and 180 degrees). Figure 4 shows these results compared with refrigeration unit noise levels at 25 feet.

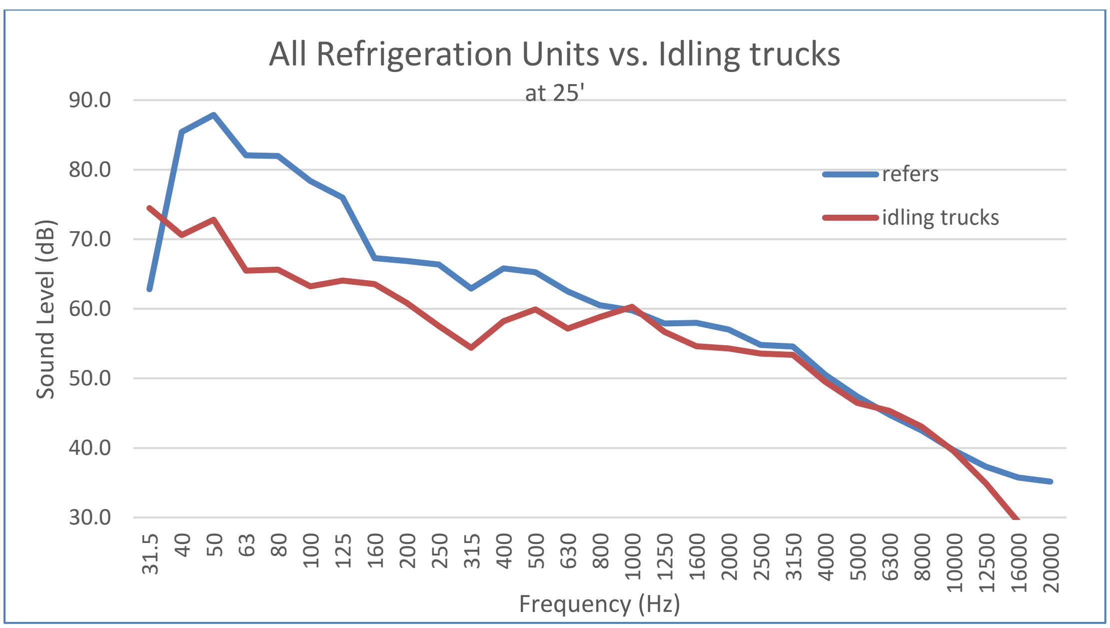

Figure 4. All Refrigeration Unit Sound Data versus Idling Trucks- in One Third Octave Frequency Bands

The data in Figure 3 shows that low frequency sound levels of refrigeration units are at least 15 decibels higher than that of the idling trucks. That coupled with the fact that according to Ken's staff, trucks are not allowed to idle for a length of time shows that idling trucks are not contributing significantly to the community noise issue. Furthermore, brief periods of truck idling during actual operations would be shielded and behind the proposed noise barrier.

2.2.1 Truck Passby Noise

Similar to the idling truck noise issue, truck passbys around the parking lot perimeter as they exit the facility have also been a concern for potential community noise exposure. Sound levels for five truck passbys were measured at 50 feet. Figure 5 shows the results of these tests. As the case with idling trucks, the refrigeration unit low frequency noise is 10 to 20 dB higher than that of the truck passbys. Additionally, according to Kens staff, in the nighttime/early morning hours, trucks exiting the facility is an infrequent occurrence. Therefore, both truck idling and passby noise is not contributing significantly to the community noise issue.

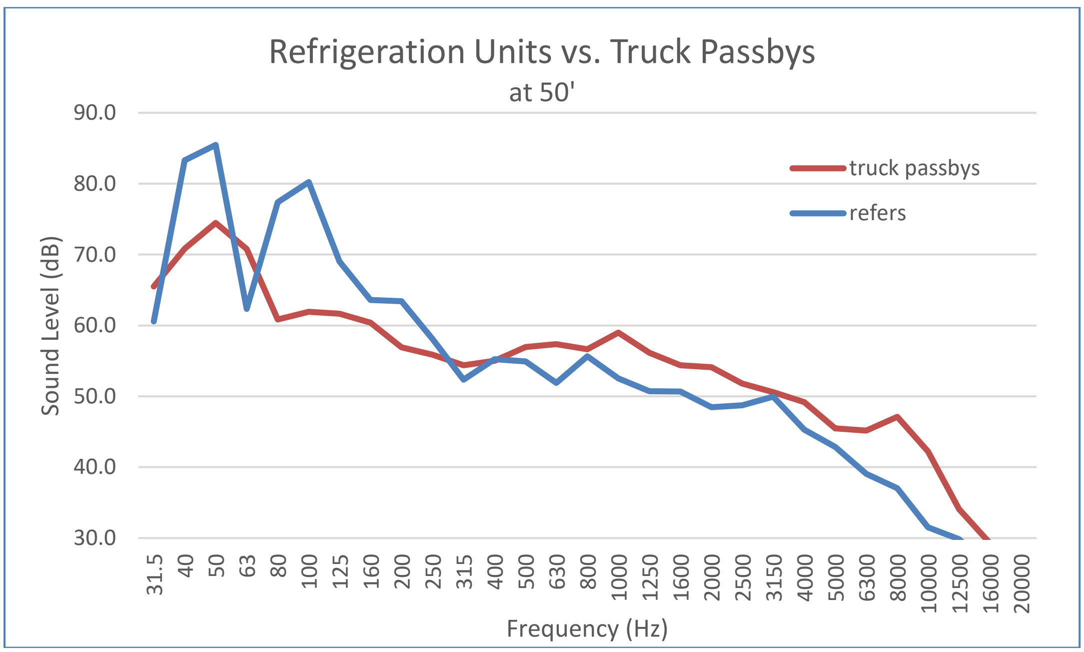

Figure 5. Refrigeration Unit Sound Data versus Idling Trucks- in One Third Octave Frequency Bands

3. Community Sound Tests

3.1 Sound Tests

On July 11, 2022, a series of simple/direct noise tests were performed to determine worst case refrigerator unit sound levels at residential receiver locations. The tests were performed with 20 refrigeration units operating in the loading dock area. Immediately following each measurement of refrigeration unit sound, the units were shut down so a direct comparison to ambient sound levels could be made. Figure 6 shows a location map of the test/receiver locations.

Ambient sound: The sum of all sound (from human and naturally occurring sources) at a specific location over a specific time.

Figure 6. Area Map with Test Receiver Locations

Figures 7 to 10 show the results of the refrigeration units on vs. off sound measurements. The 50 Hz refrigeration unit peak was measurable above ambient sound levels at all locations.

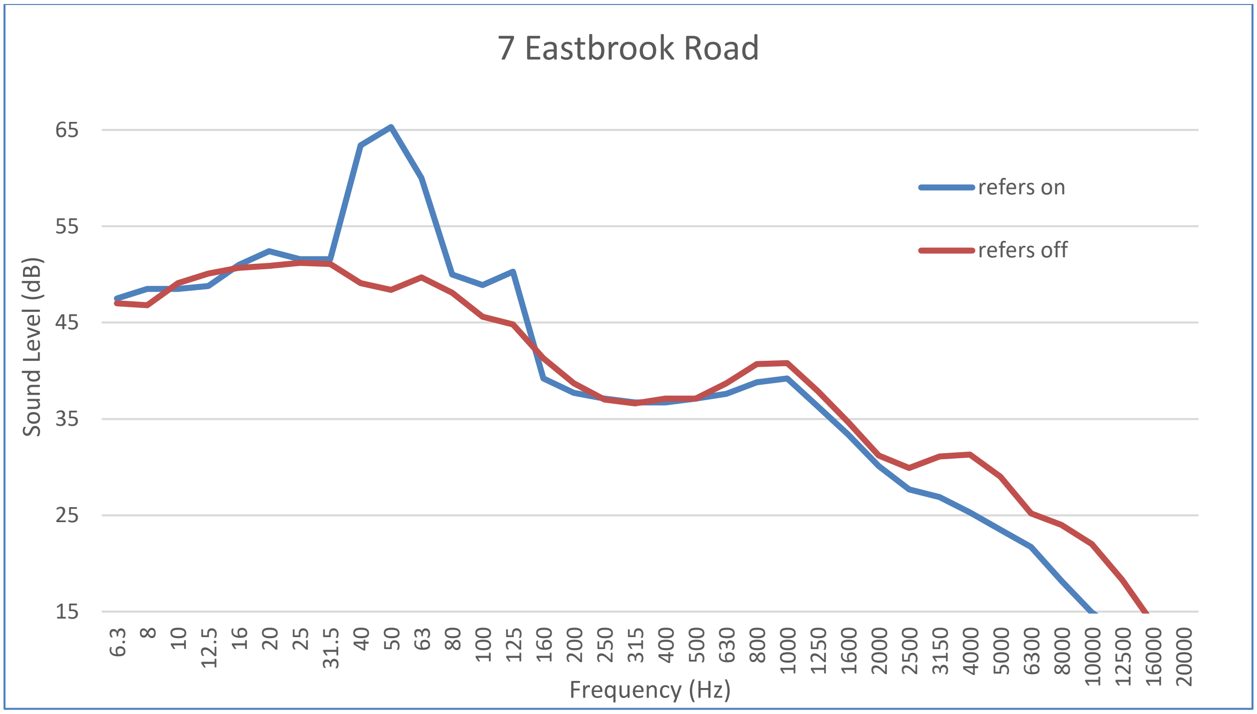

Figure 7. Sound Levels- 7 Eastbrook Road Refrigeration Units On vs. Off

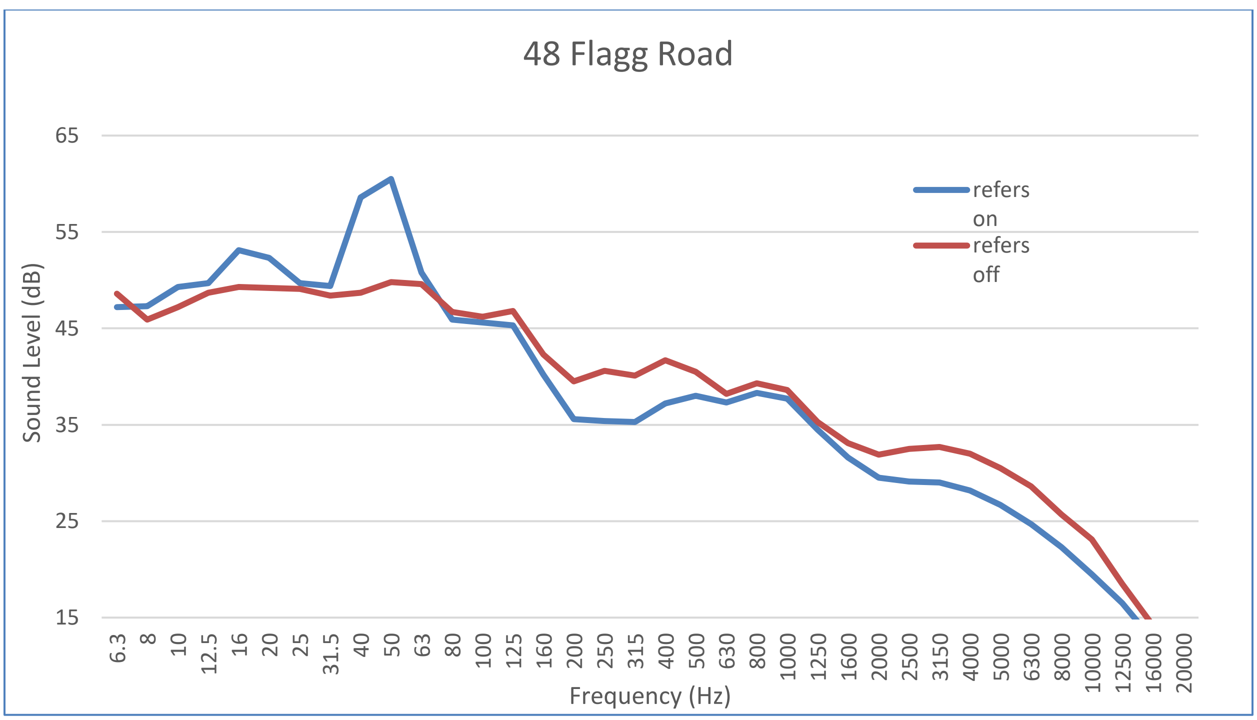

Figure 8. Sound Levels- 48 Flagg Road Refrigeration Units On vs. Off

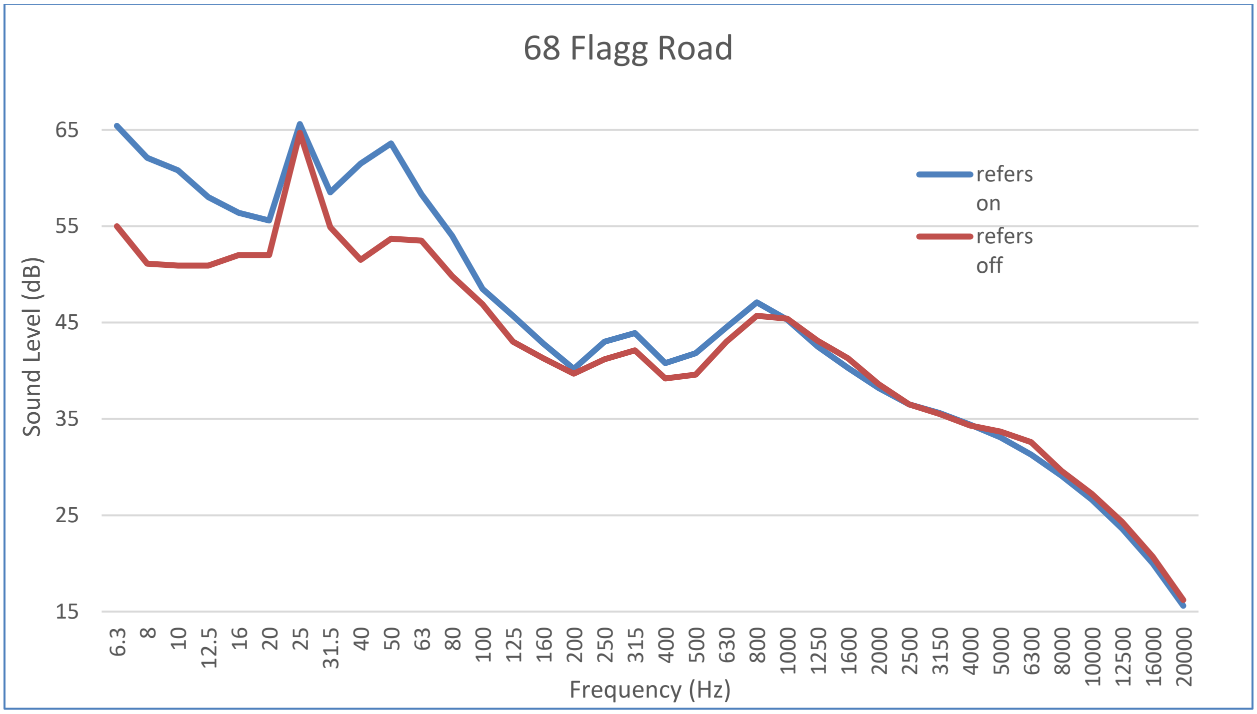

Figure 9. Sound Levels- 68 Flagg Road Refrigeration Units On vs. Off

The peak at 31.5 Hz was present in both the On and Off measurements and was due to very audible traffic noise on nearby Route 9. The reader is referred to DCC's June 12, 2020, report which discusses other low frequency noise sources in the area.

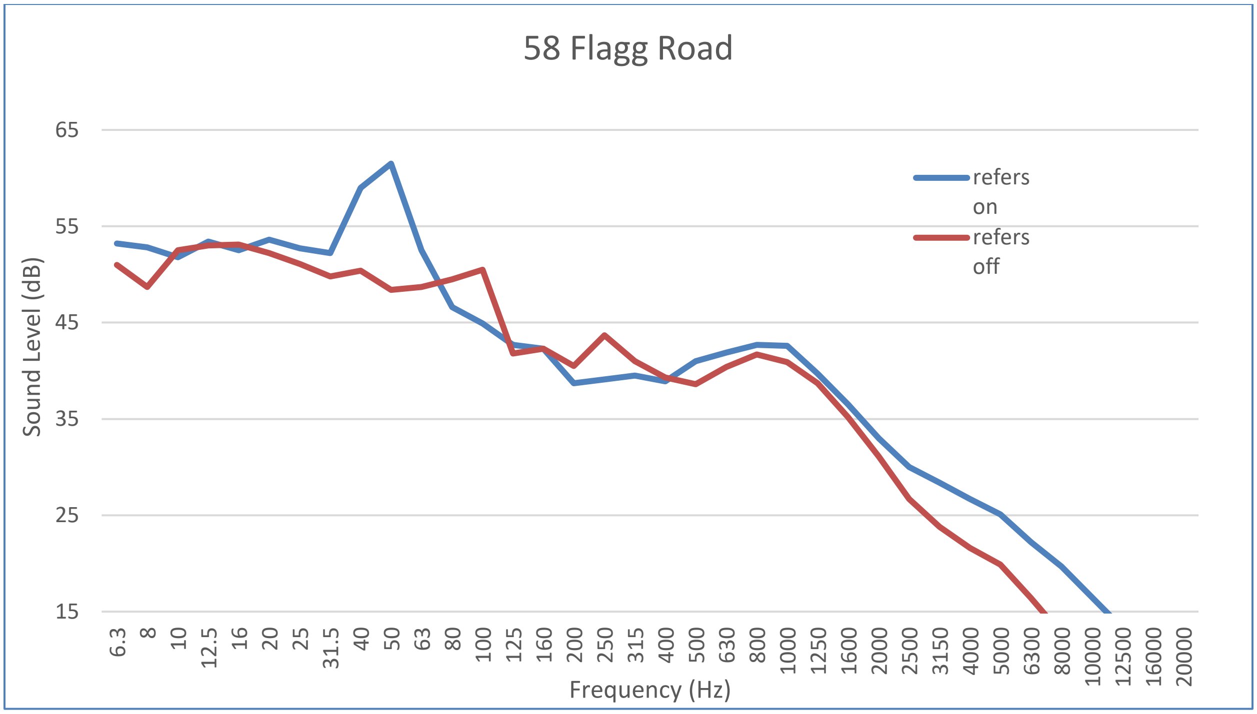

Figure 10. Sound Levels- 58 Flagg Road Refrigeration Units On vs. Off

3.2 CADNA Model of Test Results

The CADNA model for this project was updated with the actual test refrigeration unit positions as well as other data as appropriate. CADNA's octave frequency band predictions of the test conditions at each test location were tabulated. Since CADNA only computes the contribution of the refrigeration units, measured ambient noise levels were logarithmically added to the CADNA results. As typically happens, there were some variations between predictions and measurements, but overall, there is good agreement between them. Table 1 shows the overall average difference between modeled and measured. Given this good agreement, modeling of noise barrier performance can be done with confidence.

CADNA: Cadna-A (Computer-aided Noise Abatement) is the leading software application for the analysis and evaluation of environmental noise which employs International Standards Organization's ISO 9613 outdoor sound propagation standard.

	Frequency (Hz)									
	31.5	63	125	250	500	1000	2000	4000	8000	dBA
TOTAL AVERAGE Modeled-Measured	0.5	0.0	2.7	1.9	3.9	2.4	2.6	1.2	-1.3	2.1

Table 1. Community Receiver Test Conditions, 20 refrigeration units- Difference between Modeled and Measured

4. Noise Barrier Modeling and Design

4.1 CADNA Model- No Noise Barrier

Figure 11 shows the noise contour results of the 20 refrigeration unit test with no noise barrier.

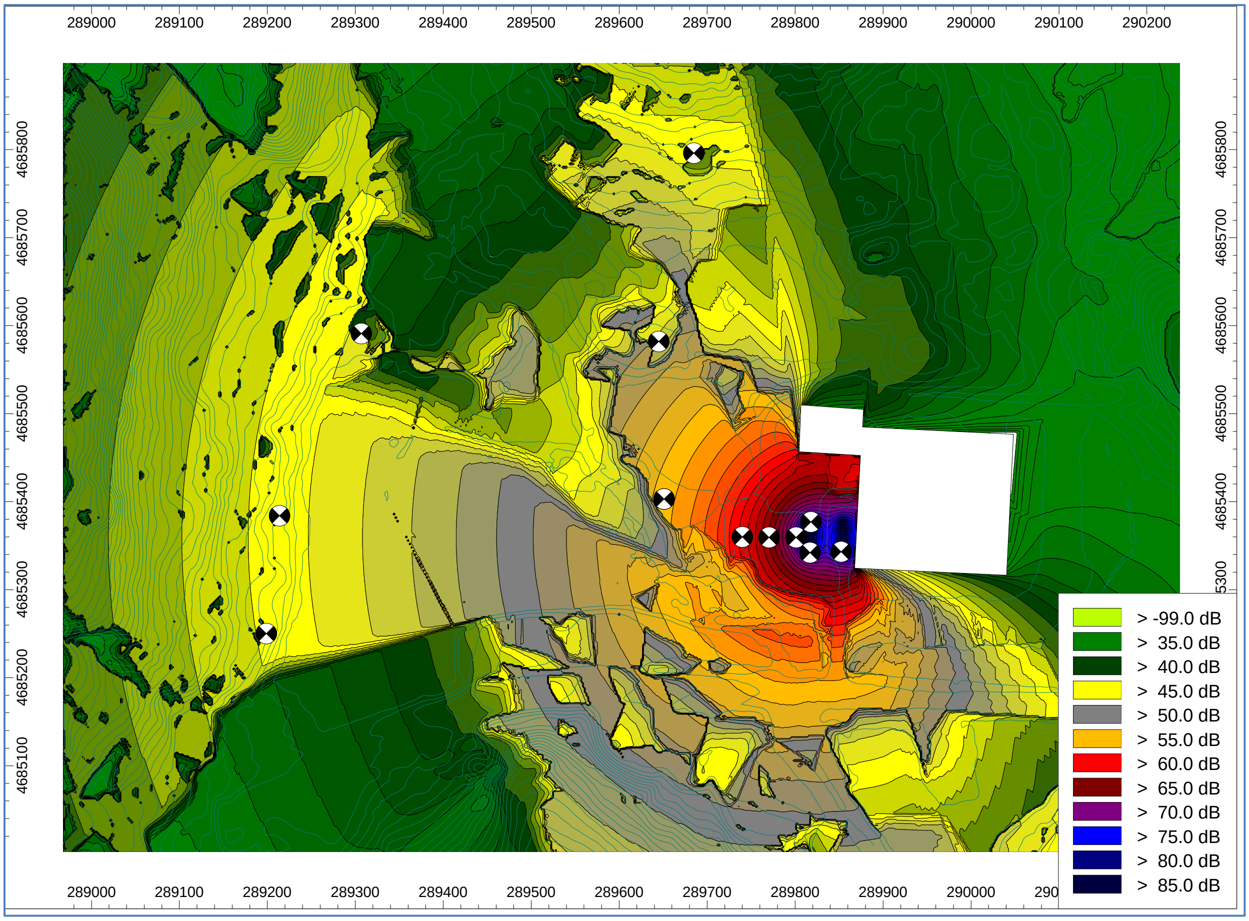

Figure 11. CADNA Noise Contours- No Noise Barrier

4.2 Noise Barrier Design Options

Several noise barrier design options were analyzed including a short barrier situated close to the refrigeration units, a long barrier at the perimeter of the parking lot, and a modified (shortened) parking lot perimeter barrier.

"Short" Noise Barrier Option

Figure 12 shows the noise contour results incorporating a 376' foot long and 20' high noise barrier situated close to the 20 refrigeration units. Comparison of Figure 12 and 11 shows a significant reduction of noise contours which is expected given the fact that noise barriers generally perform best when located close to the noise sources (or close to receivers). In addition, the previous sections of the report detailing truck passby and idling noise show that this barrier option would be effective since those noise sources are not appreciably contributing to community noise. In other words, concentrating the noise mitigation (noise barrier) on the refrigeration units would generally have the best performance/value.

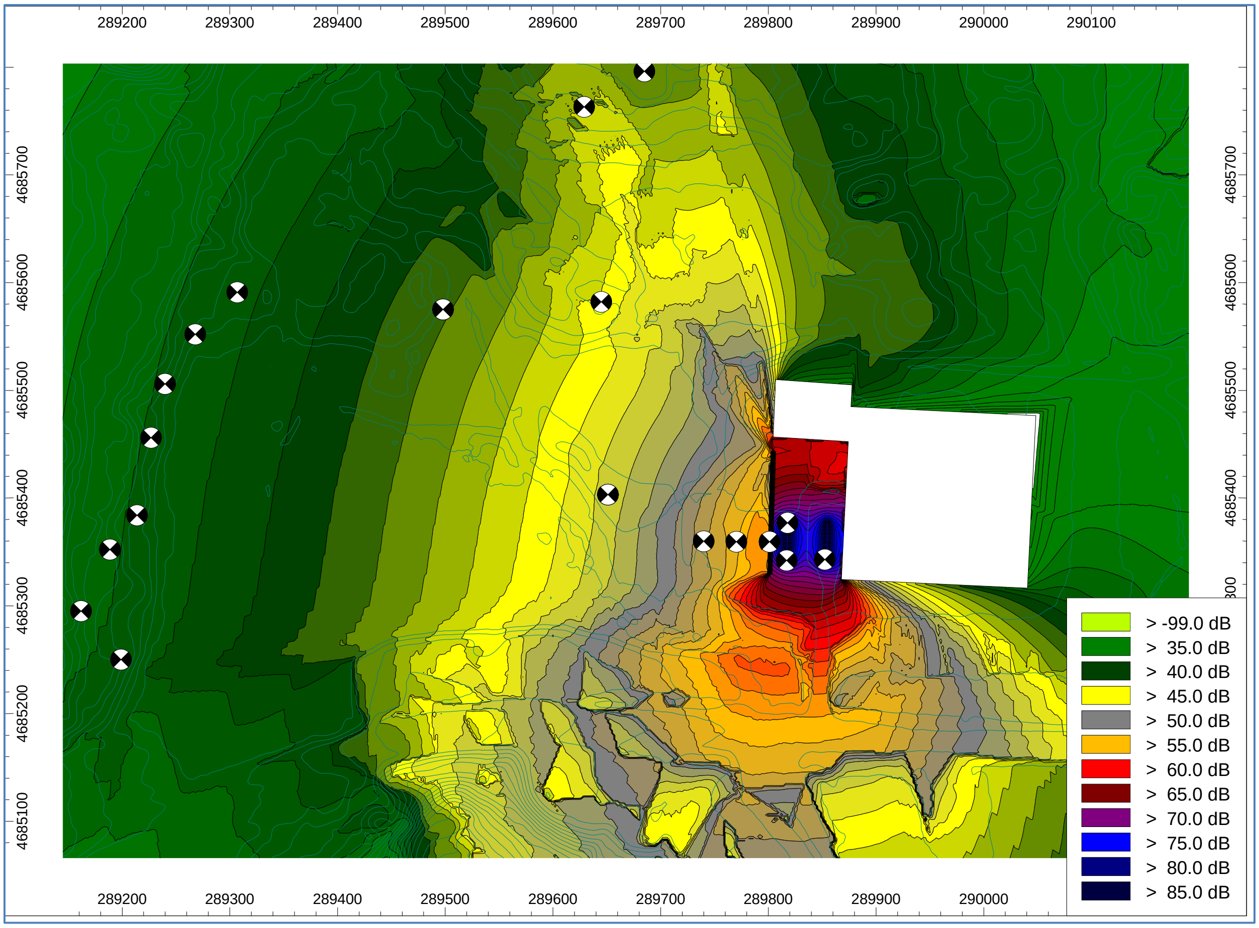

Figure 12. CADNA Noise Contours- With "Short" Noise Barrier

Figure 13 shows a zoomed in view of the "short" noise barrier option.

Figure 13. "Short" Noise Barrier Option

"Long" Noise Barrier Option

Figure 14 shows the noise contour results incorporating a 980 foot long and 16 foot high noise barrier at the perimeter of the parking lot. This noise barrier will have similar acoustic performance to the "short" barrier, but at a higher cost due to the extra length and overall surface area.

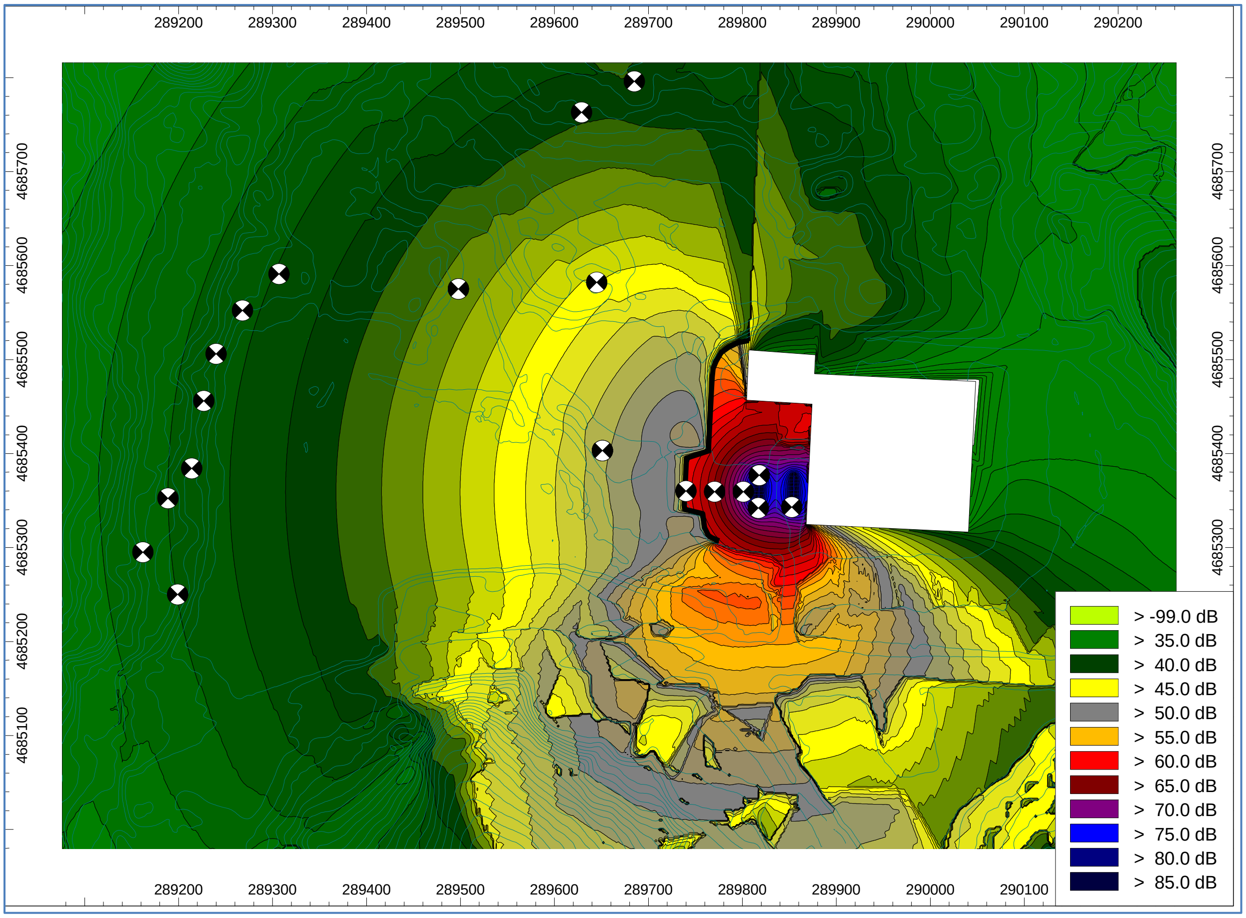

Figure 14. CADNA Noise Contours- With "Long" Noise Barrier

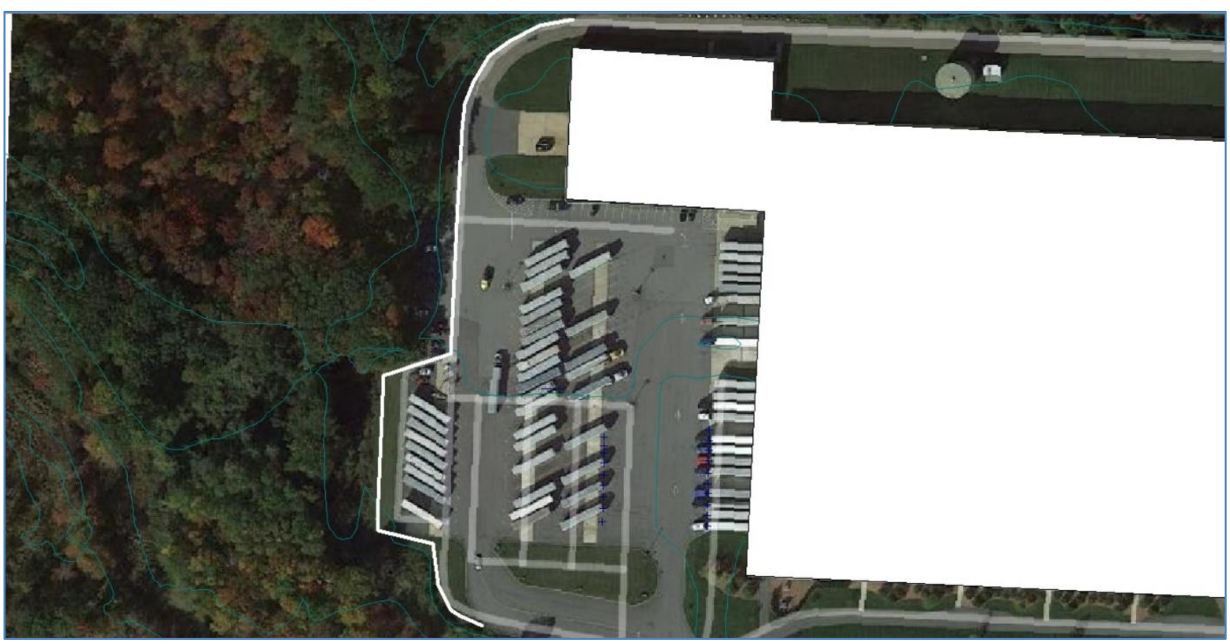

Figure 15. "Long" Noise Barrier Option

Shortened Parking Lot Perimeter Noise Barrier Option

Figure 16 shows the noise contour results incorporating a shortened version of the “long” parking lot perimeter noise barrier option (and moved slightly to the west). As part of the optimization process, both the north and south ends of the barrier were modified slightly to avoid wetland areas. It would have slightly lower acoustic performance, but at a lower cost than the “long” version.

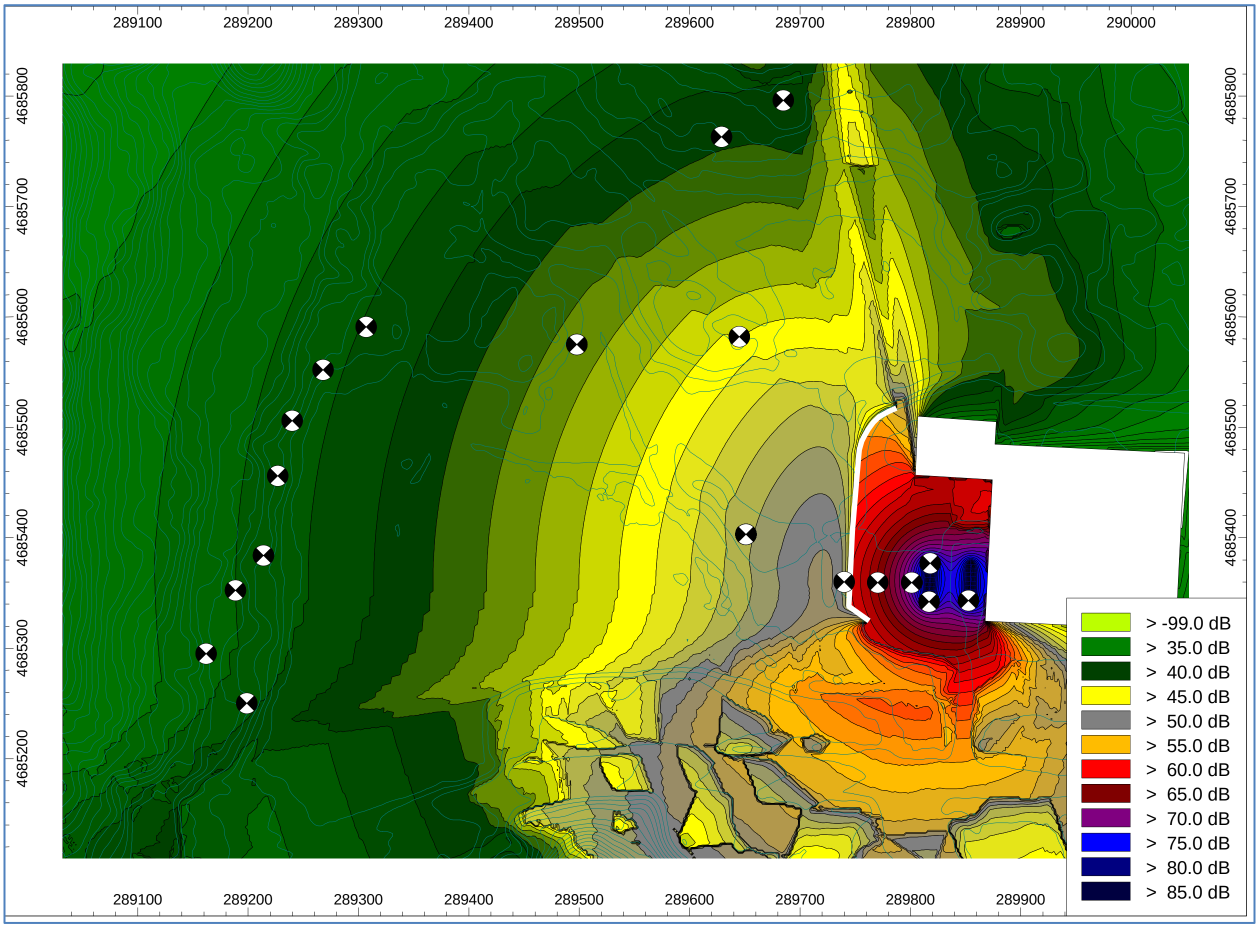

Figure 16. CADNA Noise Contours- With shortened Perimeter Parking Lot Noise Barrier

Figure 17 shows a zoomed in view of this noise barrier option.

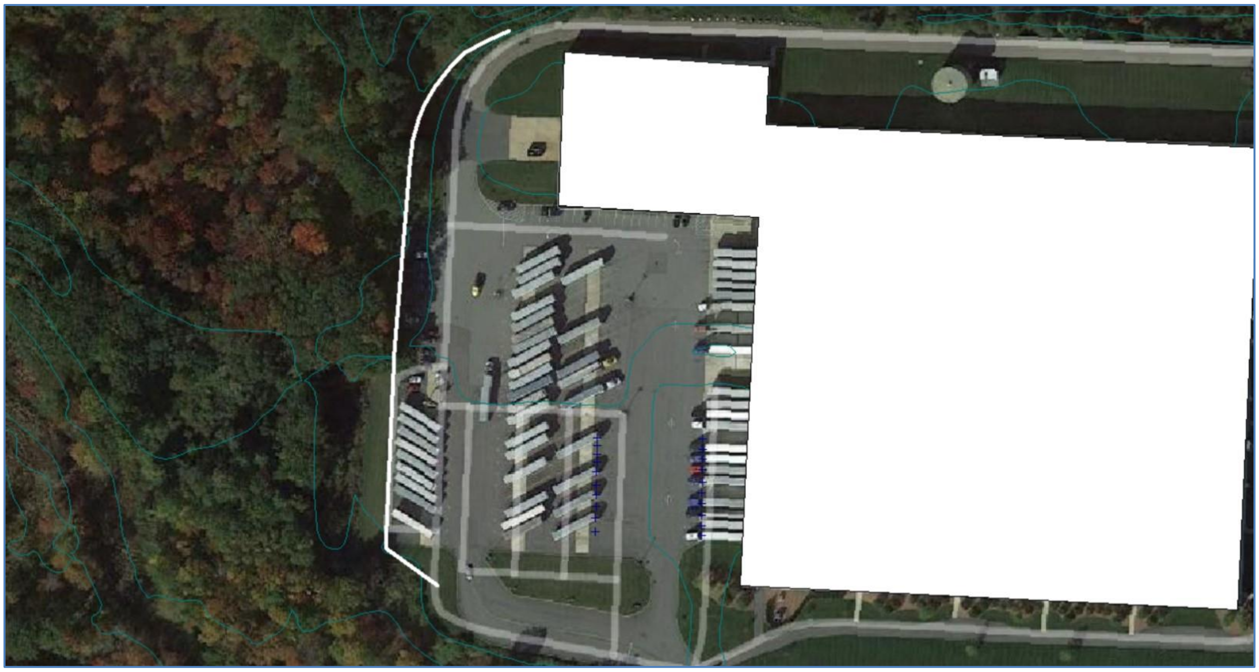

Figure 17. Shortened Perimeter Parking Lot Noise Barrier Option

4.3 Noise Barrier Options Insertion Loss

"Insertion Loss" (in decibels or dB) is defined as the amount of noise reduction achieved when a noise barrier is inserted into the acoustic path between noise source and receiver.

Tables 2 -4 show the CADNA predicted barrier insertion loss values on a frequency and overall dBA basis at each receiver location for the three noise barrier options. All three options have good acoustic performance, particularly at the problematic 63 Hz frequency band[1]. The lower 7 Eastbrook Farm insertion loss is somewhat of an anomaly as the improvements are good in this general area. Possible causes are because of the topography at this receiver which has higher elevations thus causing a shallower break in the noise barrier line-of-sight to refrigeration units.

Second story insertion losses are within approximately one to two decibels of the ground floor level insertion loss values.

[1] Note that the 50 Hz one third octave frequency band peak described in the previous sections is summed in the 63 Hz octave frequency band data.

	Frequency (Hz)									
	31.5	63	125	250	500	1000	2000	4000	8000	dBA
550' location										
With Barrier	28.9	42.6	42.2	36.1	39.2	37.7	31.5	23.1	-10.8	47.4
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	68.3	68.8	58.3	44.7	42.4	37.7	30.3	22.1	-9.7	
No Barrier	37.7	51.8	48.4	39.3	45.7	47.6	43.2	7.7	30.0	55.5
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	69.8	71.7	57.4	47.7	48.0	48.8	43.8	41.3	36.9	
Insertion Loss	1.5	2.9	-0.9	3.0	5.6	11.1	13.5	19.2	46.6	8.1
7 Eastbrook Farm Rd.										
With Barrier	26.4	40	38.1	33.7	37.9	37.2	31.4	22	-19	45.1
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	65.8	66.2	54.2	42.3	41.1	37.2	30.2	21	-17.9	
No Barrier	25.4	39.7	39.0	35.6	41.4	41.9	36.6	28.2	-10.1	47.5
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	64.8	65.9	55.1	44.2	44.6	41.9	35.4	27.2	-9.0	
Insertion Loss	-1.0	-0.3	0.9	1.9	3.5	4.7	5.2	6.2	8.9	2.4
48 Flagg Rd.										
With Barrier	19.4	33.3	33.4	27.6	31	29.7	22.2	6.5	-58	38
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	58.8	59.5	49.5	36.2	34.2	29.7	21	5.5	-56.9	
No Barrier	28.5	42.7	36.8	29.7	35.4	36.8	29.9	15.0	-47.0	45.3
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	67.9	68.9	52.9	38.3	38.6	36.8	28.7	14	-45.9	
Insertion Loss	9.1	9.4	3.4	2.1	4.4	7.1	7.7	8.5	11.0	7.3
68 Flagg Rd.										
With Barrier	20.3	33.9	32.7	26.7	30.5	29.4	21.6	4.1	-66.8	38.4
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	59.7	60.1	48.8	35.3	33.7	29.4	20.4	3.1	-65.7	
No Barrier	28.5	42.6	36.3	29.0	35.4	36.5	29.3	12.6	-55.7	45.2
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	67.9	68.8	52.4	37.6	38.6	36.5	28.1	11.6	-54.6	
Insertion Loss	8.2	8.7	3.6	2.3	4.9	7.1	7.7	8.5	11.1	6.8
58 Flagg Rd.										
With Barrier	19.4	33.2	32.8	26.9	30.3	28.9	21.1	4.3	-64.3	38.2
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	58.8	59.4	48.9	35.5	33.5	28.9	19.9	3.3	-63.2	
No Barrier	28.8	42.9	36.8	29.3	35.7	36.9	29.8	13.7	-52.5	
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	68.2	69.1	52.9	37.9	38.9	36.9	28.6	12.7	-51.4	45.5
Insertion Loss	9.4	9.7	4.0	2.4	5.4	8.0	8.7	9.4	11.8	7.3

Table 2. Short Barrier Option Noise Barrier Insertion Loss (dB)

					Frequency (Hz)					
	31.5	63	125	250	500	1000	2000	4000	8000	dBA
550' location										
With Barrier	28.9	42.8	42.5	36.4	39.5	38.3	32.4	24.5	-9.3	47.8
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	68.3	69	58.6	45	42.7	38.3	31.2	23.5	-8.2	
No Barrier	37.7	51.8	48.4	39.3	45.7	47.6	43.2	7.7	30.0	55.5
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	69.8	71.7	57.4	47.7	48.0	48.8	43.8	41.3	36.9	
Insertion Loss	1.5	2.7	-1.2	2.7	5.3	10.5	12.6	17.8	45.1	7.7
7 Eastbrook Farm Rd.										
With Barrier	25.2	39.4	38.3	34.1	37.8	37.2	31.9	23.3	-15.4	45
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	64.6	65.6	54.4	42.7	41	37.2	30.7	22.3	-14.3	
No Barrier	25.4	39.7	39.0	35.6	41.4	41.9	36.6	28.2	-10.1	47.5
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	64.8	65.9	55.1	44.2	44.6	41.9	35.4	27.2	-9.0	
Insertion Loss	0.2	0.3	0.7	1.5	3.6	4.7	4.7	4.9	5.3	2.5
48 Flagg Rd.										
With Barrier	19.3	33.4	33.7	28	31.6	30.6	23.7	8.7	-54.2	39.1
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	58.7	59.6	49.8	36.6	34.8	30.6	22.5	7.7	-53.1	
No Barrier	28.5	42.7	36.8	29.7	35.4	36.8	29.9	15.0	-47.0	45.3
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	67.9	68.9	52.9	38.3	38.6	36.8	28.7	14	-45.9	
Insertion Loss	9.2	9.3	3.1	1.7	3.8	6.2	6.2	6.3	7.2	6.2
68 Flagg Rd.										
With Barrier	18.3	32.5	32.7	27	30.5	29.6	22.1	5.6	-62.7	38
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	57.7	58.7	48.8	35.6	33.7	29.6	20.9	4.6	-61.6	
No Barrier	28.5	42.6	36.3	29.0	35.4	36.5	29.3	12.6	-55.7	45.2
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	67.9	68.8	52.4	37.6	38.6	36.5	28.1	11.6	-54.6	
Insertion Loss	10.2	10.1	3.6	2.0	4.9	6.9	7.2	7.0	7.0	7.2
58 Flagg Rd.										
With Barrier	18.6	32.8	33	27.3	30.9	29.7	22.5	6.8	-59.9	38.4
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	58	59	49.1	35.9	34.1	29.7	21.3	5.8	-58.8	
No Barrier	28.8	42.9	36.8	29.3	35.7	36.9	29.8	13.7	-52.5	
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	68.2	69.1	52.9	37.9	38.9	36.9	28.6	12.7	-51.4	45.5
Insertion Loss	10.2	10.1	3.8	2.0	4.8	7.2	7.3	6.9	7.4	7.1

Table 3. Long Noise Barrier Option Insertion Loss (dB)

					Frequency (Hz)					
	31.5	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**	**dBA**
550' location										
With Barrier	29.0	43.2	43.1	37.6	41.1	40.3	34.9	27.7	-4.0	48.8
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	68.4	69.4	59.2	46.2	44.3	40.3	33.7	26.7	-2.9	
No Barrier	37.7	51.8	48.4	39.3	45.7	47.6	43.2	7.7	30.0	55.5
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	69.8	71.7	57.4	47.7	48.0	48.8	43.8	41.3	36.9	
Insertion Loss	1.4	2.3	-1.8	1.5	3.7	8.5	10.1	14.6	39.8	6.7
7 Eastbrook Farm Rd.										
With Barrier	25.2	39.4	38.3	34.1	37.8	37.2	31.8	23.4	-14.9	45
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	64.6	65.6	54.4	42.7	41	37.2	30.6	22.4	-13.8	
No Barrier	25.4	39.7	39.0	35.6	41.4	41.9	36.6	28.2	-10.1	47.5
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	64.8	65.9	55.1	44.2	44.6	41.9	35.4	27.2	-9.0	
Insertion Loss	0.2	0.3	0.7	1.5	3.6	4.7	4.8	4.8	4.8	2.5
48 Flagg Rd.										
With Barrier	19.3	33.5	33.7	28	31.6	30.6	23.5	8.4	-54	39.1
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	58.7	59.7	49.8	36.6	34.8	30.6	22.3	7.4	-52.9	
No Barrier	28.5	42.7	36.8	29.7	35.4	36.8	29.9	15.0	-47.0	45.3
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	67.9	68.9	52.9	38.3	38.6	36.8	28.7	14	-45.9	
Insertion Loss	9.2	9.2	3.1	1.7	3.8	6.2	6.4	6.6	7.0	6.2
68 Flagg Rd.										
With Barrier	19.8	33.8	33.1	27.1	31.2	30.4	22.9	6	-62.8	38.8
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	59.2	60	49.2	35.7	34.4	30.4	21.7	5	-61.7	
No Barrier	28.5	42.6	36.3	29.0	35.4	36.5	29.3	12.6	-55.7	45.2
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	67.9	68.8	52.4	37.6	38.6	36.5	28.1	11.6	-54.6	
Insertion Loss	8.7	8.8	3.2	1.9	4.2	6.1	6.4	6.6	7.1	6.4
58 Flagg Rd.										
With Barrier	18.6	32.8	33	27.3	30.9	29.8	22.4	6.2	-60	38.4
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	58	59	49.1	35.9	34.1	29.8	21.2	5.2	-58.9	
No Barrier	28.8	42.9	36.8	29.3	35.7	36.9	29.8	13.7	-52.5	
A weighting	-39.4	-26.2	-16.1	-8.6	-3.2	0	1.2	1	-1.1	
weighted	68.2	69.1	52.9	37.9	38.9	36.9	28.6	12.7	-51.4	45.5
Insertion Loss	10.2	10.1	3.8	2.0	4.8	7.1	7.4	7.5	7.5	7.1

Table 4. Shortened Parking Lot Perimeter Noise Barrier Option Insertion Loss (dB)

4.4 Noise Barrier Design Evaluation Criteria

State and federal agencies that manage and regulate noise barrier construction evaluate the feasibility and reasonability of noise barriers. For example, most state Departments of Transportation define feasibility as obtaining at least a 5 dBA insertion loss. This is because human perception is at 3 dBA so a noticeable improvement must be made to justify the noise barrier. Reasonability is defined on the basis of cost per protected receiver.

The Massachusetts Department of Transportation[3] determines whether or not a noise barrier is acceptable if the cost per receiver divided by insertion loss is $8400 or less. Insertion loss is averaged over receivers with 5 dBA or more insertion loss. Table 5 and 6 show a breakdown of this analysis for the three noise barrier options. Table 6 includes residences in addition to the test receivers that could benefit from a barrier.

	Short	Long	Long shortened
Length (ft)	376	980	712
Height (ft)	20	16	16
Area (sqft)	7520	15680	11391
Cost	$376,000	$784,000	$569,554

Table 5. Barrier Options Dimensions/Cost

Short Barrier		9 receivers			**Long Barrier**		11 receivers			**Long shortened**		11 receivers		
	Barrier	**No Barrier IL**		**Cost/IL/Units**		**Barrier**	**No Barrier IL**		**Cost/IL/Units**		**Barrier**	**No Barrier IL**		**Cost/IL/Units**
58 Flagg	38.2	45.5	7.3	$5,785	58 Flagg	38.4	45.5	7.1	$10,467	58 Flagg	38.4	45.5	7.1	$7,676
60 Flagg	37.9	45.1	7.2		60 Flagg	38	45.1	7.1		60 Flagg	38	45.1	7.1	
64 Flagg	37.6	44.7	7.1		64 Flagg	37.6	44.7	7.1		64 Flagg	37.6	44.7	7.1	
68 Flagg	38.4	45.2	6.8		68 Flagg	38	45.2	7.2		68 Flagg	38.8	45.2	6.4	
56 Flagg	38.1	45.6	7.5		56 Flagg	38.5	45.6	7.1		56 Flagg	38.5	45.6	7.1	
54 Flagg	38.1	45.6	7.5		54 Flagg	38.5	45.6	7.1		54 Flagg	38.5	45.6	7.1	
50 Flagg	38.3	45.9	7.6		50 Flagg	38.7	45.9	7.2		50 Flagg	38.7	45.9	7.2	
24 Flagg	42.4	45.7	3.3		24 Flagg	40.4	45.7	5.3		24 Flagg	40.3	45.7	5.4	
28 Flagg	44	47.5	3.5		28 Flagg	40.8	47.5	6.7		28 Flagg	40.8	47.5	6.7	
48 Flagg	38.7	45.3	6.6		48 Flagg	39.1	45.3	6.2		48 Flagg	39.1	45.3	6.2	
7 Eastbrook	45.1	47.5	2.4		7 Eastbrook	45	47.5	2.5		7 Eastbrook	45	47.5	2.5	
5 Eastbrook	41.9	49.3	7.4		5 Eastbrook	42.5	49.3	6.8		5 Eastbrook	42.5	49.3	6.8	
		Average	7.2				Average	6.8				Average	6.7	

Table 6. Noise Barrier Feasibility and Reasonability

The short barrier option has an average insertion loss of 7.2 dBA and has the best reasonability of $5,785 due to the focused nature of this design. The long barrier option has an average insertion loss of 6.8 dBA but exceeds the state reasonability guideline of $8,400 at $10,467. The third shortened perimeter barrier option has an average insertion loss of 6.7 dBA and meets the state reasonability guideline at $7,676.

4.5 Noise Barrier Design Specifications

Surface Mass Density

Noise barriers must have sufficient mass density in order for the sound going "through" the barrier to not compromise the diffracted component of reduced noise over the top of the barrier. In most noise barrier applications, any solid free-standing wall of these heights would have sufficient mass for this to be a non-issue. Noise barrier mass density is typically specified at 5 lbs. per sqft. In this case however, low frequency sound at 63 Hz is the issue, not mid frequency sound. Consequently, on the order of 10 lb./sqft solid material would be needed in this case to achieve adequate reduction in the 63 Hz band. However, a composite noise barrier material such as with an interior airspace would be able to provide enough attenuation. Table 5 shows the required Transmission Loss of the noise barrier to achieve a 0.5 dB or less degradation of performance at 63 Hz. This particular example works out to be STC 35. The more important value in this case is the 19 dB of transmission loss needed at 63 Hz since STC primarily addresses mid frequency sound.

Transmission Loss is a measurement of the reduction in sound level of a sound source as it passes through an acoustic barrier. It is the number of decibels that are reduced by the acoustical barrier or the wall and is measured at different frequencies.

Sound Transmission Class (STC) is a rating of how well a partition attenuates sound. The STC rating very roughly reflects the decibel reduction of noise that a partition can provide. The STC is useful for evaluating speech sounds, but not music or machinery noise as these sources contain more low frequency energy than speech.

					Frequency (Hz)					
	31.5	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**	**35** STC
Needed Transmission Loss	15	19	23	27	31	35	39	43	47	
subtract from no barrier data	53.2	50.1	29.9	10.9	7.9	1.9	-10.4	-30.3	-98.4	
add with barrier data	59.2	59.5	49.2	35.9	34.1	29.8	21.2	5.2	-58.9	
Degradation	1.2	0.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0	

Table 5. Minimum Transmission Loss for Noise Barrier

Absorptive Noise Barrier Face

For the short barrier option, DCC recommends that both sides of the noise barrier be rated at NRC 0.9. Since the parking lot area is reflective, highly absorptive barrier faces would provide beneficial reduction of reflections between these surfaces. For the parking lot perimeter noise barrier options, only the inside face of the barrier (facing the refrigeration units) would need to be rated at NRC 0.9.

Noise Reduction Coefficient (NRC) is an average rating of how much sound an acoustic product can absorb. NRC varies from 0 to 1 with 1 being 100% absorptive.

Noise Barrier Dimensions/Coordinates

Table 6 shows the north and south UTM coordinates of each barrier option as well as the physical dimensions.

Noise Barrier Option	Length (ft)	Height (ft)	Area (sqft)	North UTM Coordinates (m)	South UTM Coordinates (m)
Long	980	16	15680	289807.07, 4685520.20	289775.14, 4685307.09
Short	376	20	7520	289804.62, 4685443.90	289801.39, 4685329.14
Shortened Perimeter	712	16	11391	289787.53, 4685517.48	289762.66, 4685324.70

Table 6. Noise Barrier Dimensions and Coordinates

6. Summary

Extensive acoustic testing, modeling, and analyses have demonstrated that refrigeration unit noise, specifically at 50 Hz, affects certain residential areas to the west and northwest of the trucking facility. Testing of 20 refrigeration units operating simultaneously showed that this 50 Hz peak was measurable above ambient sound levels at the test residential receiver locations.

The study also analyzed three separate noise barrier design options, each of which would substantially reduce the low frequency refrigeration noise. Finally, all three noise barrier options were compared with Mass DOT feasibility and reasonability guidelines. The Short and Shortened Perimeter barrier design options meet these guidelines.

Bibliography

1. Ken's Food Facility Noise Analysis (West Side)- Southborough, Massachusetts, DCC, June 2020

2. Ken's Food Facility Noise Analysis (West Side)- Additional Refrigeration Unit Acoustical Test Results, DCC, March 2022

3. Massachusetts Department of Transportation, Massachusetts Department of Transportation Type I and Type II Noise Abatement Policies and Procedures, 2011