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Noise Impact Assessment for a Dimensional Stone Quarry:

Halifax Quarry

Prepared for:

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1. INTRODUCTION

C.A. Denison Lumber Co. Inc. (C.A. Denison) is planning to develop a dimension stone quarry in Halifax, Vermont (Halifax Quarry) which will be operated by Ashfield Stone, LLC. RSG was retained to perform a noise impact assessment of the proposed project.

Included in this report are:

- A project description,
- A primer on the science of sound,
- An overview of standards and precedents that apply to the project,
- Sound monitoring results.
- Sound propagation modeling results,
- Conclusions

2. PROJECT DESCRIPTION

Halifax Quarry, if approved, would be located approximately 2.5 miles (4 kilometers) northeast of Halifax village on a large track of land owned by Russell Denison. The proposed extraction site is approximately half a mile due east of Deer Park Pond in a large forested area approximately halfway between Deer Park Road and Josh Road. The access road to the site runs north-northwest from the Class 4 section of Town Highway 52 (TH 52) which intersects Jacksonville Stage Road approximately one mile southeast of the extraction site. A map of the proposed site is shown in Figure 1.

The proposed project involves the extraction of large sections of rock which will be loaded on flatbed trucks and hauled away from the site for processing at another facility. No blasting or processing of material will be conducted at the site. Typical equipment that has the potential to produce noise emissions include a rock drill, a hand drill powered by a generator, a bucket loader, an excavator, and the haul truck. The operator plans to make final equipment selections after permits are obtained. The project expects to generate up to ten one-way truck trips (five trucks loads) per week which will access the site via the previously described access road.

The nearest residence is to the west-northwest of the site, approximately 2,320 feet (710 meters) from the western edge of the extraction area. Other nearby residences are between 2,600 and 3,500 feet (790 and 1,065 meters) to the northwest, between 3,200 and 3,500 feet (975 and 1,065 meters) to the northeast, and around 5,400 feet (1,645 meters) to the southeast. At the southern terminus of the access road where it intersections TH 52, there is a residence approximately 1,160 feet (355 meters) to the east-southeast. The surrounding forest blocks the line-of-sight from the extraction area and access road to all neighboring residences.

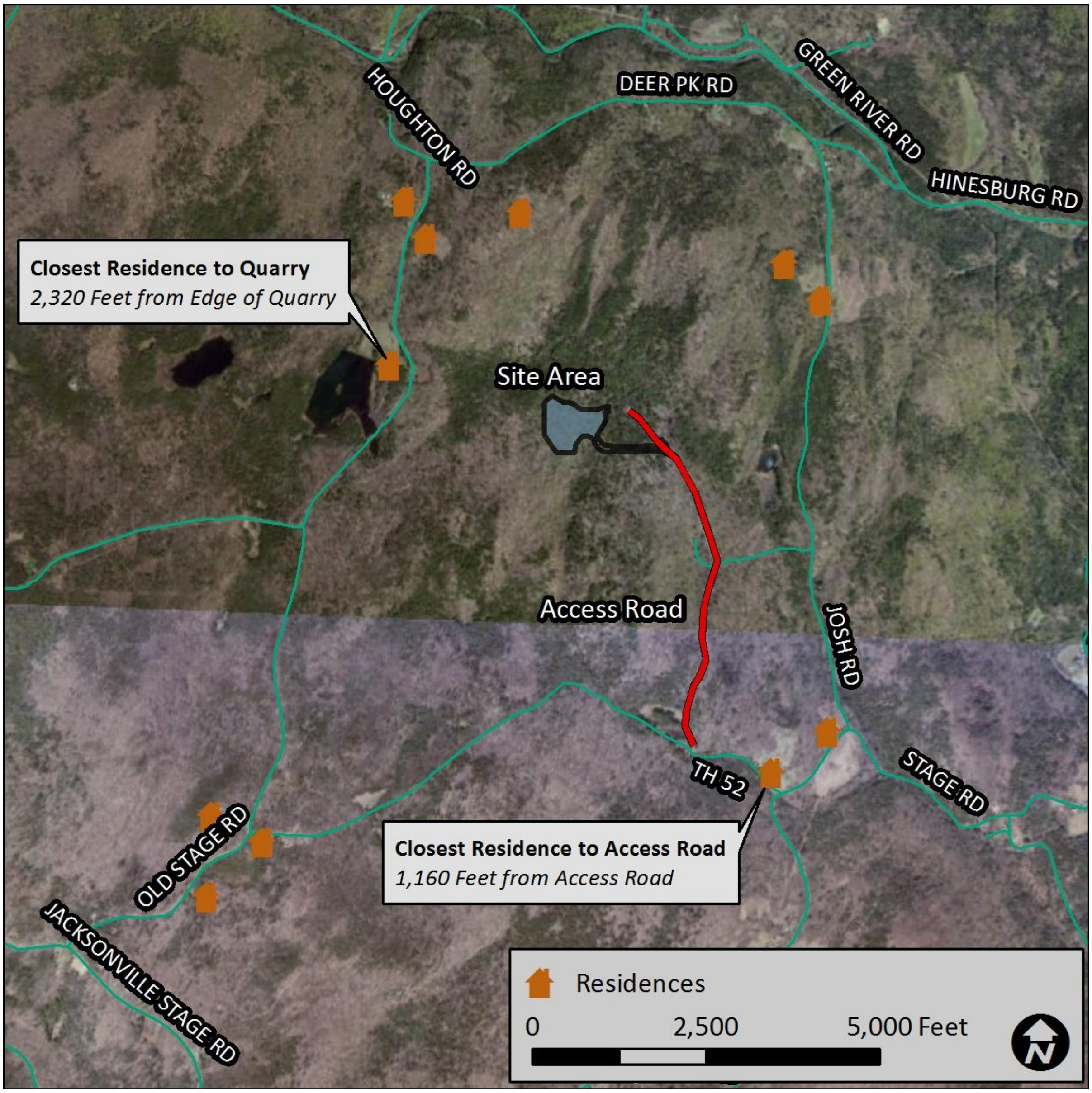

Figure 1: Halifax Quarry - Site Overview

3. NOISE PRIMER

3.1 How is Sound Described?

Sound is caused by variations in air pressure at a range of frequencies. Sound levels that are detectable by human hearing are defined in the decibel (dB) scale, with 0 dB being the approximate threshold of human hearing, and 135 dB causing pain and permanent damage to the ear. Figure 2 shows the sound levels of typical activities that generate noise.

The decibel scale can be weighted to mimic the human perception of certain frequencies. The most common of these weighting scales is the "A" weighting. It is used most frequently in environmental noise analyses. Sound levels that are weighted by the "A" scale have units of dBA or dB(A).

3.2 What is the Difference between Sound Pressure Levels and Sound Power Levels?

Both sound power and sound pressure levels are described in terms of decibels, but they are not the same thing. Sound power is a measure of the acoustic power emitted or radiated by a source. The sound power level of a source does not change with its surrounding conditions.

Sound pressure level is observed at a specific location and is related to the difference in air pressure above or below atmospheric pressure. This fluctuation in air pressure is a result of the sound power of a source, the distance at which the sound pressure level is being observed, and the characteristics of the path and environment around the source and receiver. When one refers to sound level, they are generally speaking of the perceived level, or sound pressure level.

For example, a coffee grinder will have the same sound power whether or not it is grinding indoors or outdoors. The amount of sound the coffee grinder generates is always the same. However, if you are standing six meters away from the coffee grinder indoors, you would experience a higher sound pressure level than you would if you were six meters away from the coffee grinder outdoors in an open field. The reason for this is that the sound being emitted from the coffee grinder would bounce off walls and other surfaces indoors which would cause sound to build up and raise the sound pressure level.

Sound power cannot be directly measured. However, since sound pressure and sound power are related, sound power can be calculated by measurements of sound pressure and sound intensity. It can be helpful to note that over soft ground outside, the sound pressure level of a small source observed 50 meters away is roughly 33 dB lower than its sound power level.

Figure 2: Common Sounds in A-weighted Decibels

3.3 How is Sound Modeled?

The decibel sound level is described on a logarithmic scale. One manifestation of this is that sound power increases by a factor of 10 for every 10 dB increase. However, for every 10 dB increase in sound pressure, we perceive an approximate doubling of loudness. Small changes in sound level, below 3 dB, are generally not perceptible.

For a point source, sound level diminishes or attenuates by 6 dB for every doubling of distance due to geometrical divergence. For example, if an idling truck is measured at 50 meters as 66 dBA, at 100 meters the level will decline to 60 dBA, and at 200 meters, 54 dBA, assuming no other influences.

Other factors, such as intervening vegetation, terrain, walls, berms, buildings, and atmospheric absorption will also further reduce the sound level reaching the listener. In each of these, higher frequencies will attenuate faster than lower frequencies. Finally, the ground can also have an impact on sound levels. Harder ground generally increases and softer ground generally decreases the sound level at a receiver. Reflections off of buildings and walls can increase broadband sound levels by as much as 3 dB.

If we add two equal sources together, the resulting sound level will be 3 dB higher. For example, if one machine registers 76 dBA at 50 meters, two co-located machines would register 3 dB more, or 79 dBA at that distance. In a similar manner, at a distance of 50 meters, four machines, all operating at the same place and time, would register 82 dBA and eight machines would register 85 dBA. If the two sources differ in sound level then 0 to 3 dB will be added to the higher level as shown in Table 1.

Table 1: Decibel Addition

If Two Sources Differ By	Add
0-1 dB	3 dB
2-4 dB	2 dB
5-9 dB	1 dB
>9 dB	0 dB

Subtracting sound levels follow the same principles as addition. If there are two co-located machines of equal sound power level and one is turned off, sound levels will decrease by 3 dB. Similarly, if there are two co-located machines that differ in sound power level by between 5 and 9 dB, and the quieter machine is turned off, the overall sound level will decrease by 1 dB.

3.4 Description of Terms

Sound can be measured in many different ways. Perhaps the simplest way is to take an instantaneous measurement, which gives the sound pressure level at an exact moment in time. The level reading could be 62 dB, but a second later it could 57 dB. Sound pressure levels are constantly changing. It is for this reason noise control professionals and most noise regulations typically to describe noise and sound in terms of time.

The most common ways of describing noise over time is in terms of various levels. Take as an example, the sound levels measured over time shown in Figure 3. Instantaneous measurements are shown as a ragged grey line. The sound levels that occur over this time can be described verbally, but it is much easier to describe the recorded levels statistically. This is done using a variety of "levels" which are described below.

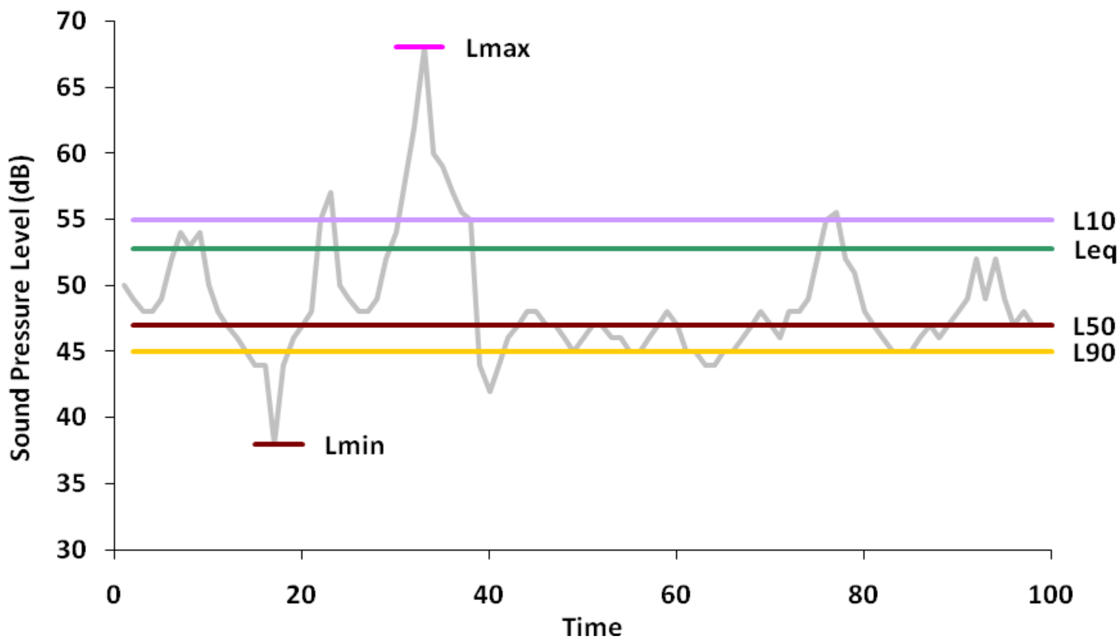

Figure 3: Example of Descriptive Terms of Sound Measurement over Time

3.4.1 Equivalent Average Sound Level - Leq

One of the most common ways of describing noise levels is in terms of the continuous equivalent sound level (Leq). The Leq is the average of the sound pressure over an entire monitoring period and expressed as a decibel. The monitoring period could be for any amount of time. It could be one second ($Leq_{1\text{-sec}}$), one hour ($Leq_{(1)}$), or 24 hours ($Leq_{(24)}$). Because Leq describes the average pressure, loud and infrequent noises have a greater effect on the resulting level than quieter and more frequent noises. For example, in Figure 3, the median sound level is about 47 dBA, but the equivalent average sound level (Leq) is 53 dBA. Because it tends to weight the higher sound levels and is representative of sound that takes place over time, the Leq is the most commonly used descriptor in noise standards and regulations.

3.4.2 Percentile Sound Level - Ln

Ln is the sound level exceeded n percent of the time. This type of statistical sound level, also shown in Figure 3, gives us information about the distribution of sound levels over time. For example, the L10 is the sound level that is exceeded 10 percent of the time, while the L90 is the sound level exceeded 90% of the time. The L50 is exceeded half the time.

3.4.3 Lmin and Lmax

Lmin and Lmax are simply the minimum and maximum sound level, respectively, monitored over a period of time.

4. Noise Standard

The Town of Halifax has a quantitative noise standard that is applicable to this project. Section 405 of the Zoning Bylaws limits property line sound levels to 70 dBA. The General Performance Standards in this section state the following about noise:

> *The following conditions must not exist at the individual property lines:*
>
> 1. *Noise in excess of seventy (70) decibels.*

This bylaw does not specify the averaging time or metric used to evaluate the 70 dBA standard. For the purposes of this analysis, we will conservatively assume that it is the maximum one-second A-weighted equivalent average sound level (max $LAeq_{1\text{-sec}}$).

The State of Vermont does not have a quantitative noise standard through regulation or policy. There is a noise limit that has been set through Act 250 precedent, though, which is a daytime limit of 55 dBA Lmax[1] at homes and areas of frequent human use. This precedent limit is used to help determine if a project causes unduly adverse impacts on aesthetics with regard to noise (Criterion 8). In some cases a 70 dBA Lmax limit has been applied to residential property lines which is similar to the Zoning Bylaw limits for Halifax. In addition, some projects were permitted with a 50 dBA Lmax standard where the town plan has specific language related to the control of noise for specific development types.

We have evaluated the project to meet the most common Act 250 precedent of 55 dBA Lmax at the residence and the Town standard of 70 dBA at the property line.

[1] Lmax as applied in Act 250 refers to the maximum 1-second Leq in the absence of background sound.

5. Sound Level Monitoring of Typical Equipment

As noted in Section 2 of this report, the quarry will include noise emissions from a hydraulic or pneumatic rock drill, a hand drill powered by a generator, a bucket loader, an excavator and a haul truck.

On September 4, 2013, RSG visited the proposed site to become more familiar with the area and to measure sound emissions from a rock drill and hand drill powered by a generator, similar to the type of equipment proposed to be used at this site. During the site visit, Thomas Drilling and Blasting, Inc. drilled holes into exposed rock sections in the vicinity of the proposed extraction area (Figure 4). After measurements of the rock drill were completed, Ashfield Stone, LLC operated a hand drill powered by a generator (Figure 5).

The sound level data that was gathered at the site visit was converted into sound power data for use in the sound propagation model which is discussed in the next section. The spectral sound power data of the monitored sources is provided in Table 2. Note, these are sound *power* levels and not sound *pressure* levels. The distinction is described in Section 3.2 of this report.

Figure 4: Rock Drill Operating near the Proposed Extraction Area

Figure 5: Hand Drill Powered by a Generator

Table 2: Spectral Sound Power Level (dB) of Proposed Sound Sources

Source	Octave Band Frequency (Hz)									Overall Sound Power Level	
	31.5	*63*	*125*	*250*	*500*	*1000*	*2000*	*4000*	*8000*	dBA	dB
Hydraulic Rock Drill - TEREX REEDDRILL R20	98	100	109	101	111	111	118	123	123	127	127
Hand Rock Drill with Generator	90	116	120	116	114	113	117	115	116	122	125

6. Sound Propagation Modeling

6.1 Modeling Methodology

Modeling for the project was completed using the International Standards Organization ISO 9613-2 standard, "Acoustics – Attenuation of sound during propagation outdoors, Part 2: General Method of Calculation." The ISO standard states,

> "This part of ISO 9613 specifies an engineering method for calculating the attenuation of sound during propagation outdoors in order to predict the levels of environmental noise at a distance from a variety of sources. The method predicts the equivalent continuous A-weighted sound pressure level … under meteorological conditions favorable to propagation from sources of known sound emissions. These conditions are for downwind propagation … or, equivalently, propagation under a well-developed moderate ground-based temperature inversion, such as commonly occurs at night."

The model takes into account source sound power levels, surface reflection and absorption, atmospheric absorption, geometric divergence, meteorological conditions, walls, barriers, berms, and terrain. The ISO standard was implemented in the Cadna A acoustical modeling software made by Datakustik GmbH. Cadna A is an internationally accepted acoustical model, used by many other noise control professionals in the United States and abroad. It has also been accepted for many years as a reliable noise modeling methodology by Act 250 commissions, the former Environmental Board, and the Vermont Superior Court Environmental Division.

Standard modeling methodology takes into account moderate nighttime inversions or moderate downwind conditions. For this study, we modeled the sound propagation in accordance with ISO 9613-2 with spectral ground attenuation and porous ground (G=1.0) except for within the operational area where we modeled reflective ground (G=0).

A 33-foot (10-meter) by 33 foot (10-meter) grid of receivers was set up in the model covering approximately 7 square miles (18 square kilometers) around the site at a height of approximately 5 feet (1.5 meters). In addition, 11 discrete receivers were modeled at nearby residences at a height of approximately 13 feet (4 meters). A receiver is a point above the ground at which the computer model calculates a sound level.

To evaluate the project against the local property line limit and Act 250 precedents, we modeled a worst-case scenario which involves the rock drill, hand drill with generator, an excavator and loader operating simultaneously within the extraction area at their maximum sound emissions and a haul truck exiting the site at the southern end of the access road. This scenario is unlikely to occur and could only occur when the contracted rock drill is on site. Nonetheless, it demonstrates a worst-case scenario. This scenario was run for both existing and final grading within the extraction area to account for the difference in terrain.

Model input data including equipment noise emissions for the sources and source and receiver locations are provided in Appendix A.

6.2 Modeling Results

The highest modeled sound level at a neighboring residence is 48 dBA which results from the existing grading model run. This occurs at the residence directly north of the extraction area which is approximately 2,670 feet (815 meters) from the extraction area. As the grading at the site decreases in elevation, sound levels from the proposed project will generally decrease. Under the final grading model run the highest modeled sound level occurs at the same residence and is 42 dBA. At this worst-case residence, the modeled sound levels of the individual sources when they operate by themselves are:

- Rock Drill – Existing: 43 dBA, Final: 40 dBA
- Hand Drill with Generator – Existing: 44 dBA, Final: 35 dBA
- Loader – Existing: 37 dBA, Final: 26 dBA
- Haul Truck – Existing & Final: 25 dBA
- Excavator – Existing: 39 dBA, Final: 31 dBA

The next highest modeled sound levels at neighboring residences with all four sources operating simultaneously are 35 dBA or less for the existing and final grading scenarios.

The highest modeled sound level at the approximate property line location is 67 dBA for the existing grade model run and 52 dBA for the future grade model run both of which occur on the property line just south of the extraction area.

Maps showing the maximum simultaneous sound pressure levels from the rock drill, hand drill with generator, loader, excavator and haul truck under the existing grading and final grading scenarios are provided in Figure 6 and Figure 7, respectively. Model results for all modeled residences are provided in Appendix A. These model results indicate that the project will meet the Act 250 residential noise precedent limits discussed in Section 4 by 8 dB or more at all residences under the worst-case conditions. The model results also indicate that the project will meet the Act 250 and local zoning property line noise limit by 3 dB or more at the forested property line surrounding the extraction area.

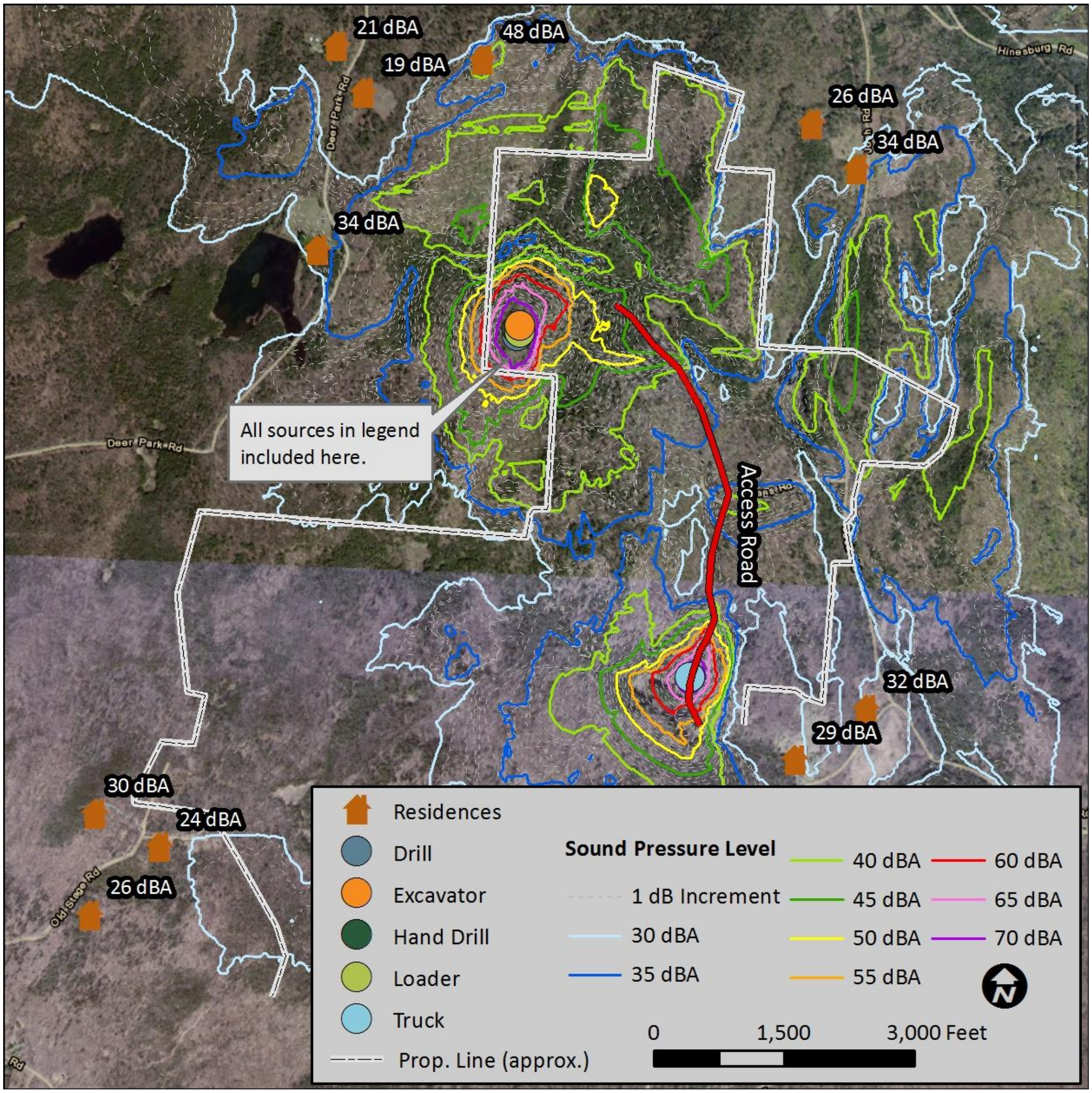

Figure 6: Map of Sound Propagation Model Results with Existing Grading (dBA)

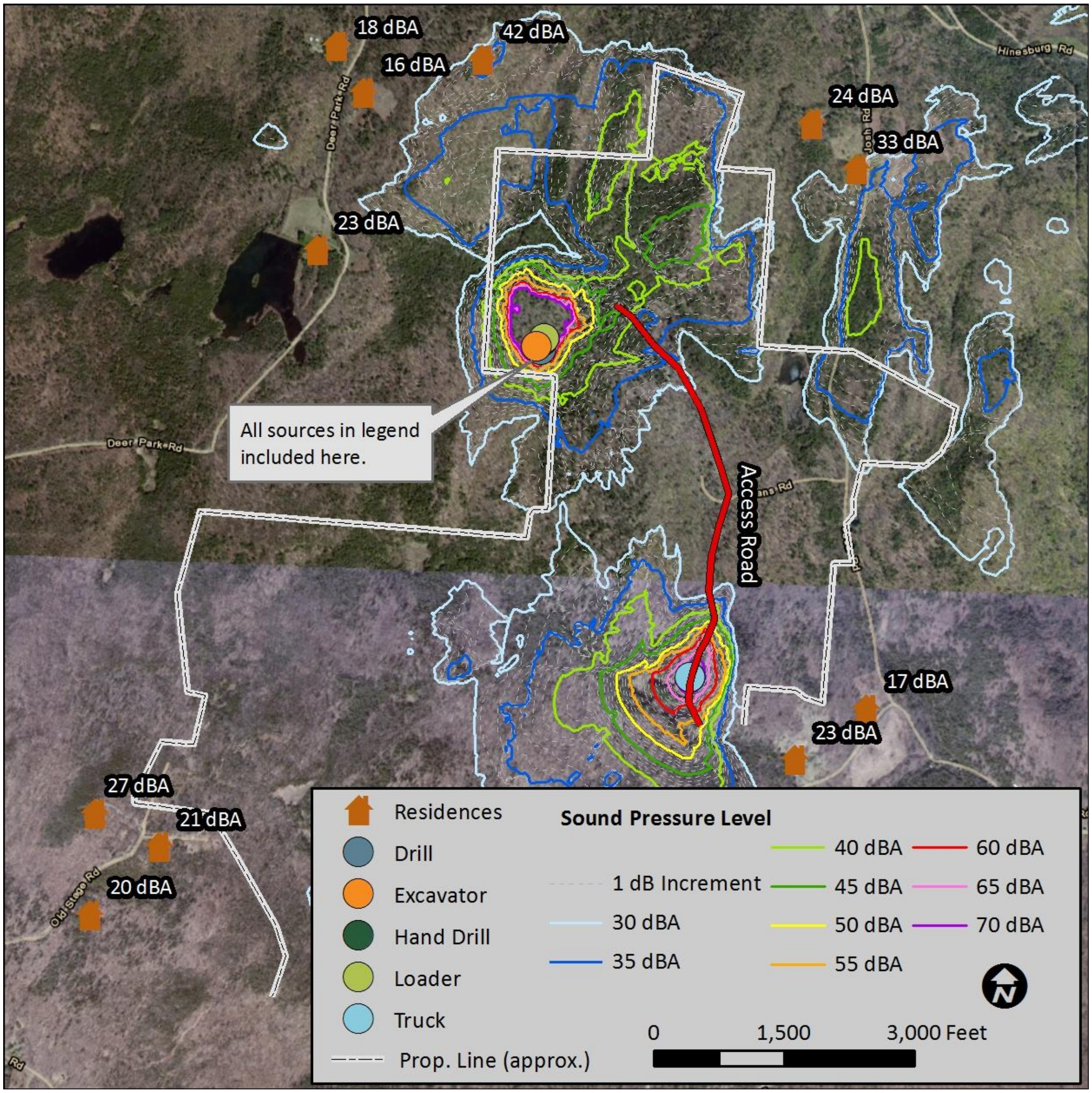

Figure 7: Map of Sound Propagation Model Results with Final Grading (dBA)

7. RECOMMENDATIONS

The model results presented in the previous section include the attenuation of the substantial forest around the project area and as such, we recommend the forest adjacent to the quarry area be maintained such that the line-of-sight between the proposed operation and neighboring residences remains blocked during the life of the project.

While not required to meet the Act 250 noise precedent, we also recommend as a good practice and reasonable mitigation measure to utilize a broadband, variable loudness, or radar-type backup alarm on the loader if a backup alarm is required. Broadband backup alarms are often found to be less annoying because they do not have the pure tonal qualities of regular backup alarms. They are also more directional and attenuate more quickly over distances. Broadband backup alarms emit a sound that is often described as being similar to static.

8. CONCLUSIONS

C.A. Denison Lumber Co., Inc. plans to establish a dimensional stone quarry to be operated by Ashfield Stone in Halifax, Vermont. The operation involves a rock drill, a hand drill powered by a generator, a bucket loader, an excavator, and the haul truck. The nearest residence to the proposed extraction site is approximately 2,390 feet west-northwest of the site. The nearest residence to the access road, which intersects with TH 52 approximately one mile southeast of the extraction site, is approximately 1,160 feet to the east-southeast of the southern terminus of the access road.

Sound propagation modeling was conducted to project the maximum sound levels from the proposed project at neighboring residences and project property lines. The highest modeled sound level at a neighboring residence was 48 dBA (max $LAeq_{1\ 1\text{-sec}}$) which occurred at a residence at a higher elevation approximately 2,670 feet north of the extraction area. When sources are not operating simultaneously, maximum sound levels at the nearest residence will be 44 dBA or less. The highest modeled sound level at a project property line was 67 dBA.

We recommend that the forest on the site be maintained to block line-of-sight between the operation and neighboring residences, and that the loader utilize an alternative low-impact backup alarm if a backup alarm is required.

With sound levels at neighboring residences and areas of frequent human use less than 55 dBA and below 70 dBA at the project property line, this proposed project will not cause an undue adverse impact on aesthetics with regard to noise and will comply with the noise limit in the Halifax zoning regulations.

APPENDIX A – MODELING INFORMATION

Table A 1: Modeled Receiver Input Data and Receiver Model Results

Receiver ID	Sound Pressure Levels (dBA)		Relative Height (m)	NAD 83, VT State Plane Coordinates		
	Existing	Final		X (m)	Y (m)	Absolute Height (m)
1	29	23	4	484427.74	30554.38	351.65
2	32	17	4	484675.75	30733.04	326.53
3	35	23	4	482749.55	32344.17	469.32
4	19	17	4	482912.24	32897.08	469.92
5	21	18	4	482816.13	33061.70	454.20
6	48	42	4	483328.43	33012.22	492.85
7	34	33	4	484643.98	32627.01	383.88
8	26	24	4	484484.08	32786.91	385.99
9	30	27	4	481969.27	30366.58	601.65
10	24	21	4	482194.58	30250.29	562.09
11	25.6	20	4	481951.10	30010.44	555.65

Table A 2: Modeled Source Input Data

Type	Model	Sound Power Level (dBA)	Phase	Relative Height (m)	NAD 83, VT State Plane Coordinates		
					X (m)	Y (m)	Absolute Height (m)
Drill	TEREX R-20	127	Existing	0.3	483449.91	32042.22	430.2
			Final		483533.72	31995.57	401.67
Hand Drill	Generic Rock Hand Drill	122	Existing	0.5	483450.43	32067.08	429.14
			Final		483538.82	32023.21	395.51
Excavator	FHWA RCNM	110	Existing	1.5	483460.17	32080.38	428.37
			Final		483517.25	32006.51	397.51
Loader	CAT966G	109	Existing	2.0	483460.35	32053.85	430.17
			Final		483544.64	32033.59	396.77
Truck Low	Heavy Truck Accelerating to 20mph	114	Both Cases	0.5	484061.14	30841.81	383.46
Truck High		109		3.6	484057.13	30844.38	386.42

Table A 3: Model Settings and Assumptions

Parameter	Settings
Atmospheric Conditions	Temperature: 10˚C & Relative Humidity: 70%
Reflection	No Reflections
Grid Receiver Height	1.5 meters
Ground Absorption	0.0 in the Quarry, 1 All Other Ground Cover
Maximum Search Radius	3,000 meters
Foliage Attenuation	18 meter high forest