aci Acoustical Consultants Inc.
5031 – 210 Street
Edmonton, Alberta, Canada T6M 0A8
Phone: (780) 499-1591
www.aciacoustical.com

Environmental Noise Impact Assessment
For The

Noise Attenuation City Wide Data Collection Phase 2

Boudreau Road & Bellerose Drive

Prepared for:
The City of St. Albert

PERMIT TO PRACTICE
ACI ACOUSTICAL CONSULTANTS INC.
Signature
Date 03/01/2023
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The Association of Professional Engineers, Geologists and Geophysicists of Alberta

PROFESSIONAL LICENSEE (ENGINEERING) ALBERTA
PATRICK FROMENT
Member ID :196923
3/01/2023

Prepared by:
P. Froment, B.Sc., B.Ed., P.L.(Eng.)
aci Acoustical Consultants Inc.
Edmonton, Alberta
APEGA Permit to Practice #P7735

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Executive Summary

aci Acoustical Consultants Inc., of Edmonton AB, was retained by the City of St. Albert (the City) AB, to complete their Noise Attenuation City Wide Data Collection Phase 2 Study (the Project). As part of the Project aci conducted 24-hour environmental noise monitoring at various residential locations throughout the City in 2021. From the monitoring data, specific locations within the City were categorized as high priority for future investigations for noise mitigation. This report is specific to the residents within Evergreen Place, with backyards adjacent to Boudreau Road and Bellerose Drive. Site work was conducted for aci during the spring, summer and fall months of 2021 by P. Froment, B.Sc., B.Ed., P.L.(Eng.).

As part of the study a total of two (2) 24-hour environmental noise monitorings were conducted within the study area. The locations of the monitors were selected to represent the varying noise climate within the study area. The results of the baseline noise monitoring indicated sound levels of 53.7 and 59.3 dBA L_{eq}24, respectively. At both locations, the noise climate was dominated by Boudreau Road and Bellerose Drive.

The results of the Baseline Case noise modeling resulted in similar values to the monitoring results. The current projected noise levels range from 56.6 – 59.9 dBA which is below the City of St. Albert's limit of 65 dBA L_{eq}24.

The Future Case noise model without mitigation but with projected traffic volumes that cause an exceedance indicated noise level ranging from 61.7 dBA to 65.0 dBA L_{eq}24 for all locations. To achieve this, 2019 traffic volumes were multiplied by 3.2.

The Baseline Case noise modeling with mitigation (in the form of a 1.83 m noise barrier) resulted in L_{eq}24 noise levels ranging from 53.5 – 57.5 dBA which is below the City of St. Albert's limit of 65 dBA L_{eq}24. Relative to the Baseline case modeling scenario without mitigation, the decrease in noise levels ranged from (-)2.4 dBA to (-)3.1 dBA.

The Future Case noise modeling with mitigation (in the form of a 1.83 m noise barrier) resulted in L_{eq}24 noise levels ranging from 58.7 – 62.8 dBA which is below the City of St. Albert's limit of 65 dBA L_{eq}24. Relative to the Future case modeling scenario without mitigation, the decrease in noise levels ranged from (-)2.2 dBA to (-)3.1 dBA.

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1.0 Introduction

aci Acoustical Consultants Inc., of Edmonton AB, was retained by the City of St. Albert (the City) AB, to complete their Noise Attenuation City Wide Data Collection Phase 2 Study (the Project). As part of the Project aci conducted 24-hour environmental noise monitoring at various residential locations throughout the City in 2021. From the monitoring data, specific locations within the City were categorized as high priority for future investigations for noise mitigation. This report is specific to the residents within Evergreen Place with backyards adjacent to Boudreau Road and Bellerose Drive. Site work was conducted for aci during the spring, summer and fall months of 2021 by P. Froment, B.Sc., B.Ed., P.L.(Eng.).

2.0 Location Description

The residential receptor locations that will be investigated in this report are for residents along Evergreen Close who back onto Boudreau Road and Bellerose Drive (1 – 17 Evergreen Close), as shown in Figure 1. Currently, the residential fences within this area vary from well-built wooden fences that will provide a certain level of noise attenuation to fences with large gaps that are currently providing little to negligible amounts of acoustic mitigation. Dwellings within this area are composed entirely of single-family homes with their own private outdoor amenity spaces. The rear property line for residents ranges from 20 m (in the north) to 8 m for residents at 9 Evergreen Close.

Boudreau Road and Bellerose Drive are both four-lane roads that are separated by a centre median throughout. The intersection between Boudreau Road and Bellerose Drive was upgraded during the summer of 2021. Apart from these two roads there are no other major noise sources within the study area.

Topographically, there are moderate changes in elevation throughout. Starting in the northwest portion of the study area, Boudreau Road drops by approximately 8 m – 9 m before intersecting Bellerose Drive. In addition, the rear property line relative to the road also varies throughout the study area. As such, elevation contours have been implemented into the model.

Lastly, the vegetation between the roads and the residents consists primarily of thin vegetation. Given the relative distance between the roads and the residents, the vegetative sound absorption is considered minimal.

3.0 Measurement Methods

As part of the Project, a 24-hour environmental noise monitoring was conducted at two (2) residential receptor locations within the study area. The noise monitoring locations, as indicated in Figure 1, were selected to best calibrate the existing noise climate for residents. A detailed description of each location is provided below. The noise monitoring was conducted collecting broadband A-weighted and C-weighted as well as 1/3 octave band sound levels. In addition, the noise monitoring was accompanied by a digital audio recording for more detailed post process analysis. A local weather monitoring station was used throughout the entire noise monitoring period to obtain the wind speed, wind direction, temperature, and relative humidity.

Refer to Appendix I for a detailed description of the measurement equipment used in addition to calibration records, Appendix II for a description of the acoustical terminology, and Appendix III for a list of common noise sources. All noise measurement instrumentation was calibrated at the start of the measurements and then checked afterwards to ensure that there had been negligible calibration drift over the duration of the measurements.

Noise Monitor 1 (9 Evergreen Close)

Noise Monitor 1 was located approximately 10 m northwest of the intersection of Boudreau Road and Bellerose Drive as shown in Figure 1 and Figure 2. This placed the noise monitor approximately 5 m northwest of the back-property line at 9 Evergreen Close. The noise monitor had direct line-of-sight to through the fence but also over top of the fence to both roadways. It should be noted that the backyard space for this property was above the roadways. The noise monitoring data for this location was taken from 00:00 on Tuesday October 5 to 00:00 on Wednesday October 6, 2021 (entire 24-hour period).

Noise Monitor 2 (10 Inverness Crescent)[1]

Noise Monitor 13 was located approximately 20 m southwest of the intersection of Boudreau Road and Bellerose Drive as shown in Figure 1 and Figure 3. This placed the noise monitor approximately 13 m southwest of the back-property line at 10 Inverness Crescent. The noise monitor did not have line-of-sight either roadway due to the masonry wall along the rear property line. The noise monitoring data for this location was taken from 00:00 on Tuesday October 5 to 00:00 on Wednesday October 6, 2021 (entire 24-hour period).

[1] It should be noted that this location is outside of the study area, however, the results were still be utilized to calibrate the noise model.

4.0 Computer Noise Modeling

4.1. Computer Noise Modeling Software

The computer noise modeling was conducted using the CADNA/A (Version 2022 MR2, build: 193.5260) software package. CADNA/A allows for the modeling of various noise sources such as road, rail, and various stationary sources. In addition, topographical features such as land contours, vegetation, and bodies of water can be included. Finally, meteorological conditions such as temperature, relative humidity, wind-speed and wind-direction can be included in the calculations.

The calculation method used for noise propagation follows the ISO standard 9613-2. All receiver locations were assumed as being downwind from the source(s). In particular, as stated in Section 5 of the ISO document:

> *"Downwind propagation conditions for the method specified in this part of IS0 9613 are as specified in 5.4.3.3 of IS0 1996-2:1987, namely*
>
> - *wind direction within an angle of ± 45^0 of the direction connecting the centre of the dominant sound source and the centre of the specified receiver region, with the wind blowing from source to receiver, and*
> - *wind speed between approximately 1 m/s and 5 m/s, measured at a height of 3 m to 11 m above the ground.*
>
> *The equations for calculating the average downwind sound pressure level LAT(DW) in this part of IS0 9613, including the equations for attenuation given in clause 7, are the average for meteorological conditions within these limits. The term average here means the average over a short time interval, as defined in 3.1.*
>
> *These equations also hold, equivalently, for average propagation under a well-developed moderate ground-based temperature inversion, such as commonly occurs on clear, calm nights".*

Due to the small amount of vegetation, and thus relative ineffectiveness to mitigate the noise climate, no vegetation was included in the model. Similarly, no snow cover was included since there can be variation in absorption/reflection caused by different snow conditions. As a result, all sound level propagation calculations are considered representative of summertime conditions for all surrounding residents.

4.2. Noise Modeling Scenarios

As part of the study, four (4) scenarios were modeled including:

1) **Baseline Case**: This included existing buildings, elevation contours and noise sources (including current traffic volumes and road alignments). The results from the baseline noise monitoring were used a calibration tool for the noise model.
2) **Future Case**: This included components of the Current Case Scenario with the projected future traffic volumes required to exceed the City of St. Albert's permissible sound levels (discussed in later sections).
3) **Baseline Case with Noise Mitigation**: This included components of the Current Case Scenario with the addition of a 1.83 m noise barrier.
4) **Future Case with Noise Mitigation**: This included components of the Future Case Scenario with the addition of a 1.83 m noise barrier.

4.3. Noise Modeling Parameters

Due to the relatively short distances from the roads to the nearest residential structures and the minimal amount of vegetation, vegetative sound absorption was not included in the model. In addition, snow cover was not included since there can be variation in absorption/reflection caused by different snow conditions. As a result, all projected future sound level propagation calculations are considered representative of summertime conditions for all residents.

Buildings were included in the model, however, receptors were only placed in the first rows of perimeter development. In general, these houses have the highest potential for providing shielding for the remainder of the houses further in. The exact dimensions and locations of existing structures were not known, so approximate dimensions were used.

Digital topographical information (in the form of elevation contours) representing existing conditions were included in the noise model.

Existing traffic volumes on Boudreau Road and Bellerose Drive were provided from the City of St. Albert.

The computer noise modeling results were calculated in two ways. First, sound levels were calculated at specific receptor locations (i.e. typical residential outdoor amenity spaces). This was done at a height of 1.5 m (from the ground) and at a 5 m offset from the back/side property line of for all locations. The projected noise levels at the receptor locations provide a more representative indication of the typical noise levels experienced by residents in their private backyard space (i.e. not directly adjacent to the rear property line). In addition, the use of specific receptor locations allows for a better comparative evaluation of noise levels (e.g. anticipated performance of any noise mitigation measures).

Secondly, color noise contours were calculated using a 2 m x 2 m grid over the entire study area at a height of 1.5 m. The color noise contours are used to determine if and where noise mitigation is required as they illustrate the projected noise levels within the entire residential private back yard spaces. They are then used once mitigation is in place in order to ensure that all areas within the residential private back yard spaces are below the applicable criteria.

Refer to Appendix IV for a list of all noise modeling parameters including vehicle traffic volumes.

4.4. Modeling Confidence

The algorithms used for the noise modeling follow the ISO 9613 standard. The published accuracy for this standard is ±3 dBA between 100 m – 1,000 m. Accuracy levels beyond 1,000 m are not published. Experience based on similar noise models conducted over large distances shows that, as expected, as the distance increases, the associated accuracy in prediction decreases. Experience has shown that environmental factors such as wind, temperature inversions, topography and ground cover all have increasing effects over distances larger than approximately 1,500 m.

5.0 Permissible Sound Levels

Environmental noise levels from roads are commonly described in terms of equivalent sound levels or L_{eq}. This is the level of a steady sound having the same acoustic energy, over a given time period, as the fluctuating sound. In addition, this energy averaged level is A–weighted to account for the reduced sensitivity of average human hearing to low frequency sounds. These L_{eq} in dBA, which are the most common environmental noise measure, are often given for day-time (07:00 to 22:00) L_{eq}Day and night-time (22:00 to 07:00) L_{eq}Night while other criteria use the entire 24-hour period as L_{eq}24.

The criteria used to evaluate the road noise in the study area include the City of St. Albert Municipal Engineering Standards, Section 3.9 on Noise Attenuation. The following is taken directly from the document:

> "*A Noise Impact Assessment, signed and sealed by a professional engineer, must be provided in cases where a major arterial roadway and/or railway runs through or adjacent to a proposed residential development. The assessment must list the current noise levels, estimate future noise levels, and identify and implement noise attenuation measures required to achieve a* ***maximum noise level of 65 dBA Leq over a 24-hour period****, and in accordance with the City's Noise Bylaw, Bylaw 31/2006.*"

As such, the permissible sound level (PSL) is **65 dBA L_{eq}24.**

6.0 Results and Discussion

6.1. Environmental Monitoring

The results obtained from the baseline environmental noise monitoring are provided in Table 1 and Figures 4 – 7 (broadband A-weighted L_{eq} sound levels and 1/3 octave band L_{eq} sound levels provided). It should be noted that the data has been adjusted by the removal of non-transportation related or otherwise abnormal noise events (such as loud aircraft flyovers, loud vehicle passages, dogs barking, etc.). Thus, the remaining data more accurately reflects the noise levels associated with the adjacent transportation corridors. A list of all non-typical noise events removed from each monitoring location can be found in Appendix V.

Table 1. Leq 24-hour results

Monitor	Location	Date	L_{eq}24 (dBA)	L_{eq}Day (dBA)	L_{eq}Night (dBA)
Monitor 1	9 Evergreen Close	10/5/2021 – 10/6/2021	59.3	61.0	53.1
Monitor 2	10 Inverness Crescent	10/5/2021 – 10/6/2021	53.8	55.3	48.0

The measured L_{eq}24 values for both locations were below 65 dBA and, as anticipated, the dominant noise source was traffic from the intersection of Bellerose Drive and Boudreau Road. The resultant 1/3 octave band L_{eq} sound levels for both monitors are very similar. They both show the typical trend of low frequency noise (near 63 – 80 Hz) resulting from engines and exhaust, mid-high frequency noise (near 1,000 Hz) resulting from tire noise. These results confirm that the noise levels being measured by the noise monitors were largely attributed to the nearby roadways.

Weather Conditions

The weather was relatively moderate (between 5 - 10 km/hr), apart from a few short duration of high wind speeds, for the entire noise monitoring period. The wind direction was primarily from the west-northwest, which resulted in either downwind or crosswind conditions for all noise monitoring locations. The temperature ranged from 2°C - 11°C and the relative humidity ranged from 42% - 73%. In addition, there was no precipitation. Weather data obtained by the weather station are presented in Appendix VI.

6.2. Computer Noise Modelling

6.2.1. Scenarios without Mitigation

6.2.1.1. Baseline Case Scenario

The projected $L_{eq}24$ results of the Baseline Case noise modeling at the monitoring locations is provided in Table 2. As mentioned previously, the $L_{eq}24$ noise monitoring data was used as a calibration tool for the noise model. The relative difference between the modeling and monitoring results is also provided. As indicated in Table 2, the modeling data matches very well with the measured values and tend to be slightly conservative (higher than measured).

Table 2. Baseline Case Noise Modeling Results at Noise Monitor Location

Location	Monitor LeqDay (dBA)	Model LeqDay (dBA)	Relative Difference (dBA)
M1	59.3	59.9	0.5
M2	53.7	54.2	0.5

The results of the Baseline Case noise modeling at the various residential receptor locations within the study area are presented in Table 3 and illustrated in Figure 8. The projected noise levels are all below 60 dBA and range from 56.6 to 59.9 dBA. The highest $L_{eq}24$ noise level is for receptor R-06, which was anticipated due to its proximity to both Boudreau Road and Bellerose Drive. The noise contributions from the nearby roads would need to increase by 5.1 dBA before they exceed the City of St. Albert's PSL of 65 dBA $L_{eq}24$.

Table 3. Baseline Case Noise Modeling Results

Receptor	Baseline $L_{eq}24$ (dBA)
R-01	56.7
R-02	57.7
R-03	58.3
R-04	58.4
R-05	58.6
R-06	59.9
R-07	57.0
R-08	56.7
R-09	56.6
R-10	56.6
R-11	56.7
Min	56.6
Max	59.9

6.2.1.2. Future Case Scenario

The results of the Future Case noise modeling scenario are provided in Table 4 and illustrated in Figure 9. As previously mentioned, the maximum existing $L_{eq}24$ noise level of 59.9 dBA was for the residential location within closest proximity to Boudreau Road and Bellerose Drive. For the noise levels at this location to exceed the City of St. Albert's PSL of 65 dBA $L_{eq}24$, the noise levels will need to increase by 5.1 dBA. For this to occur, the 2019 traffic volumes[1] would need to be increased by a factor of 3.2 (i.e. existing traffic volumes X 3.5). As such, for this scenario the 2019 AADT values were multiplied by 3.2.

Table 4. Future Case Noise Modeling Results

Receptor	Future $L_{eq}24$ (dBA)	Difference Relative to Baseline Case Leq24 (dBA)
R-01	62.0	5.3
R-02	62.9	5.2
R-03	63.6	5.3
R-04	63.7	5.3
R-05	63.9	5.3
R-06	65.0	5.1
R-07	62.2	5.2
R-08	62.0	5.3
R-09	61.8	5.2
R-10	61.9	5.3
R-11	61.7	5.0
Min	61.7	5.0
Max	65.0	5.3

As indicated in Table 4, there is now an exceedance of 65 dBA $L_{eq}24$ within the study area with noise levels ranging from 61.7 – 65.0 dBA. The relative difference in noise levels when comparing to the Baseline Case scenario ranges from 5.0 – 5.3 dBA.

[1] 2019 values were utilized for the calibration as they were most reflective of the 2021 traffic conditions.

6.2.2. Scenarios with Mitigation

6.2.2.1. Baseline Case Scenario with 1.83 m Barrier

The results of the Baseline Case Scenario with mitigation (1.83 m Tall Barrier) noise modeling scenario at the various residential outdoor amenity spaces are presented in Table 5 and illustrated in Figure 10. The relative difference between the Baseline Case $L_{eq}24$ with and without mitigation is also included. As indicated in Table 5, all $L_{eq}24$ noise levels are below 60 dBA $L_{eq}24$ and range from 53.5 – 57.5 dBA. The relative difference in noise levels with and without noise mitigation ranges from (-)2.4 to (-)3.1 dBA for all locations.

Table 5. Baseline Case with Mitigation (1.83 m Tall Barrier) Noise Modeling Results

Receptor	$L_{eq}24$ (dBA)	Difference Relative to Baseline Case Leq24 (dBA)
R-01	54.0	-2.7
R-02	54.8	-2.9
R-03	55.3	-3.0
R-04	55.8	-2.6
R-05	56.0	-2.6
R-06	57.5	-2.4
R-07	54.3	-2.7
R-08	53.9	-2.8
R-09	53.5	-3.1
R-10	53.6	-3.0
R-11	54.0	-2.7
Min	53.5	-3.1
Max	57.5	-2.4

6.2.2.2. Future Case Scenario with 1.83 m Barrier

The results of the Future Case Scenario with mitigation (1.83 m Tall Barrier) noise modeling scenario at the various residential outdoor amenity spaces are presented in Table 6 and illustrated in Figure 11. The relative difference between the Future Case $L_{eq}24$ with and without mitigation is also included. As indicated in Table 6, all $L_{eq}24$ noise levels are below 65 dBA $L_{eq}24$ and range from 58.7 – 62.8 dBA. The relative difference in noise levels with and without noise mitigation ranges from (-)2.2 to (-)3.1 dBA for all locations.

Table 6. Future Case with Mitigation (1.83 m Tall Barrier) Noise Modeling Results

Receptor	$L_{eq}24$ (dBA)	Difference Relative to Future Case Leq24 (dBA)
R-01	59.3	-2.7
R-02	60.1	-2.8
R-03	60.6	-3.0
R-04	61.0	-2.7
R-05	61.3	-2.6
R-06	62.8	-2.2
R-07	59.5	-2.7
R-08	59.1	-2.9
R-09	58.7	-3.1
R-10	58.8	-3.1
R-11	59.0	-2.7
Min	58.7	-3.1
Max	62.8	-2.2

7.0 Conclusion

As part of the study a total of two (2) 24-hour environmental noise monitorings were conducted within the study area. The locations of the monitors were selected to represent the varying noise climate within the study area. The results of the baseline noise monitoring indicated sound levels of 53.7 and 59.3 dBA L_{eq}24, respectively. At both locations, the noise climate was dominated by Boudreau Road and Bellerose Drive.

The results of the Baseline Case noise modeling resulted in similar values to the monitoring results. The current projected noise levels range from 56.6 – 59.9 dBA which is below the City of St. Albert's limit of 65 dBA L_{eq}24.

The Future Case noise model without mitigation but with projected traffic volumes that cause an exceedance indicated noise level ranging from 61.7 dBA to 65.0 dBA L_{eq}24 for all locations. To achieve this, 2019 traffic volumes were multiplied by 3.2.

The Baseline Case noise modeling with mitigation (in the form of a 1.83 m noise barrier) resulted in L_{eq}24 noise levels ranging from 53.5 – 57.5 dBA which is below the City of St. Albert's limit of 65 dBA L_{eq}24. Relative to the Baseline case modeling scenario without mitigation, the decrease in noise levels ranged from (-)2.4 dBA to (-)3.1 dBA.

The Future Case noise modeling with mitigation (in the form of a 1.83 m noise barrier) resulted in L_{eq}24 noise levels ranging from 58.7 – 62.8 dBA which is below the City of St. Albert's limit of 65 dBA L_{eq}24. Relative to the Future case modeling scenario without mitigation, the decrease in noise levels ranged from (-)2.2 dBA to (-)3.1 dBA.

8.0 References

- City of St. Albert Municipal Engineering Standards, Section 3.9 on Noise Attenuation, 2013
- International Organization for Standardization (ISO), *Standard 1996-1, Acoustics – Description, measurement and assessment of environmental noise – Part 1: Basic quantities and assessment procedures, 2003*, Geneva Switzerland.
- International Organization for Standardization (ISO), *Standard 9613-1, Acoustics – Attenuation of sound during propagation outdoors – Part 1: Calculation of absorption of sound by the atmosphere, 1993*, Geneva Switzerland.
- International Organization for Standardization (ISO), *Standard 9613-2, Acoustics – Attenuation of sound during propagation outdoors – Part 2: General method of calculation, 1996*, Geneva Switzerland.

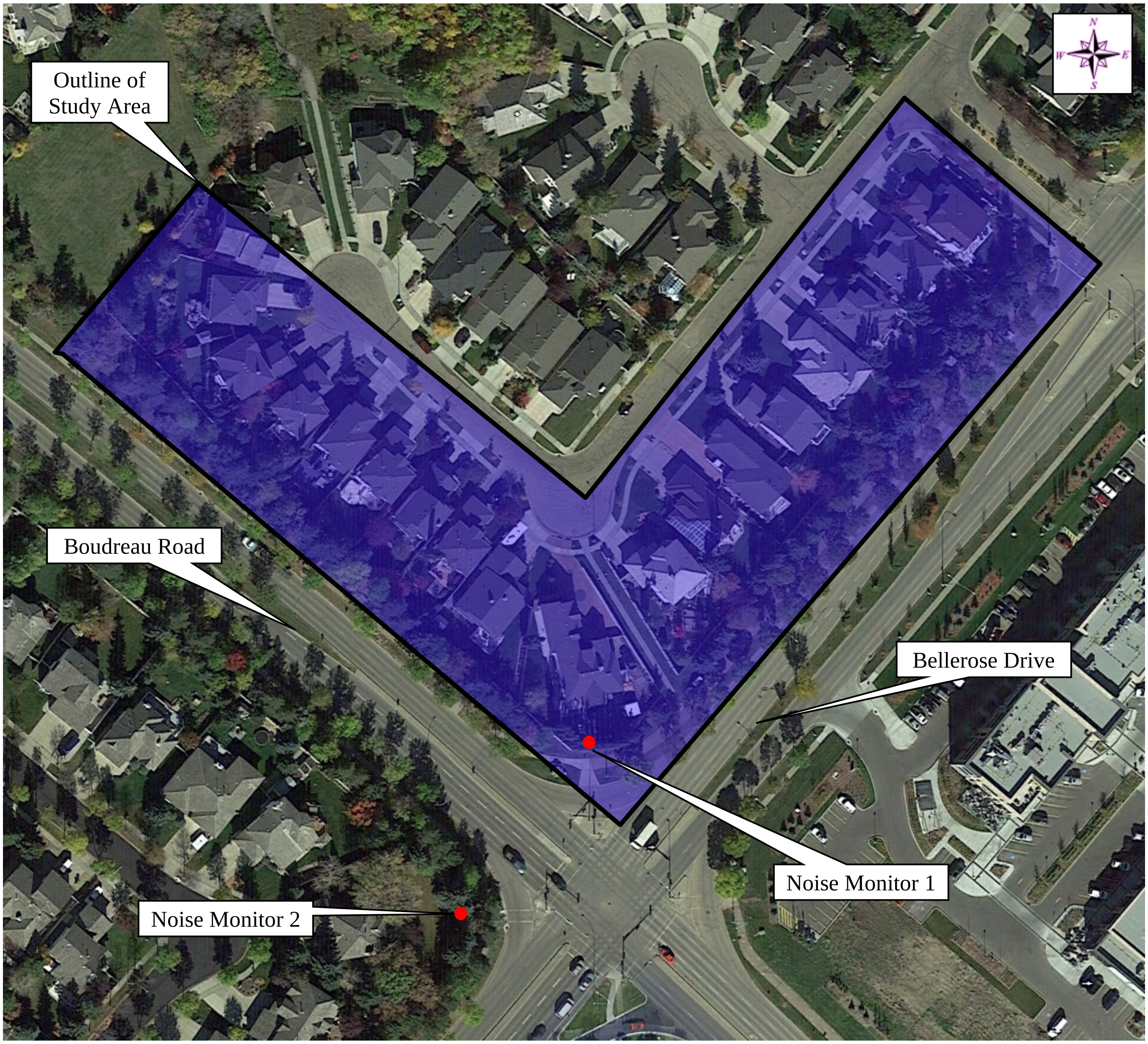

Figure 1. Study Area

Figure 2. Noise Monitor #1 (9 Evergreen Close)

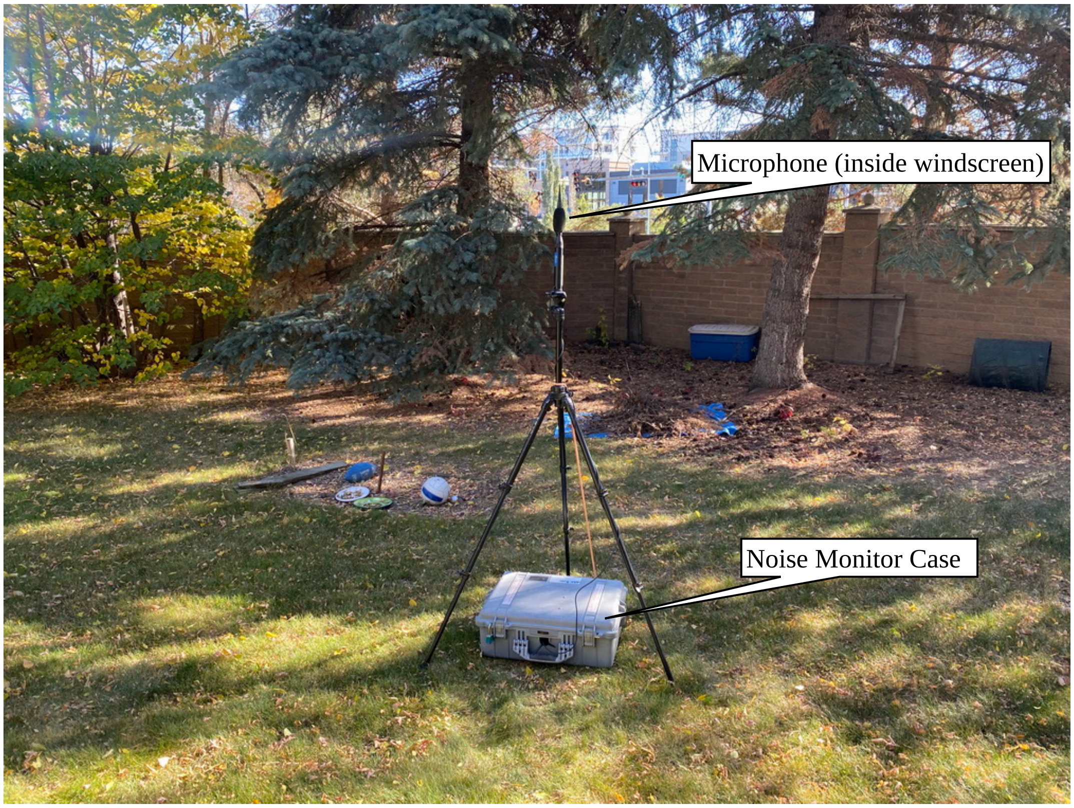

Figure 3. Noise Monitor #2 (10 Inverness Crescent)

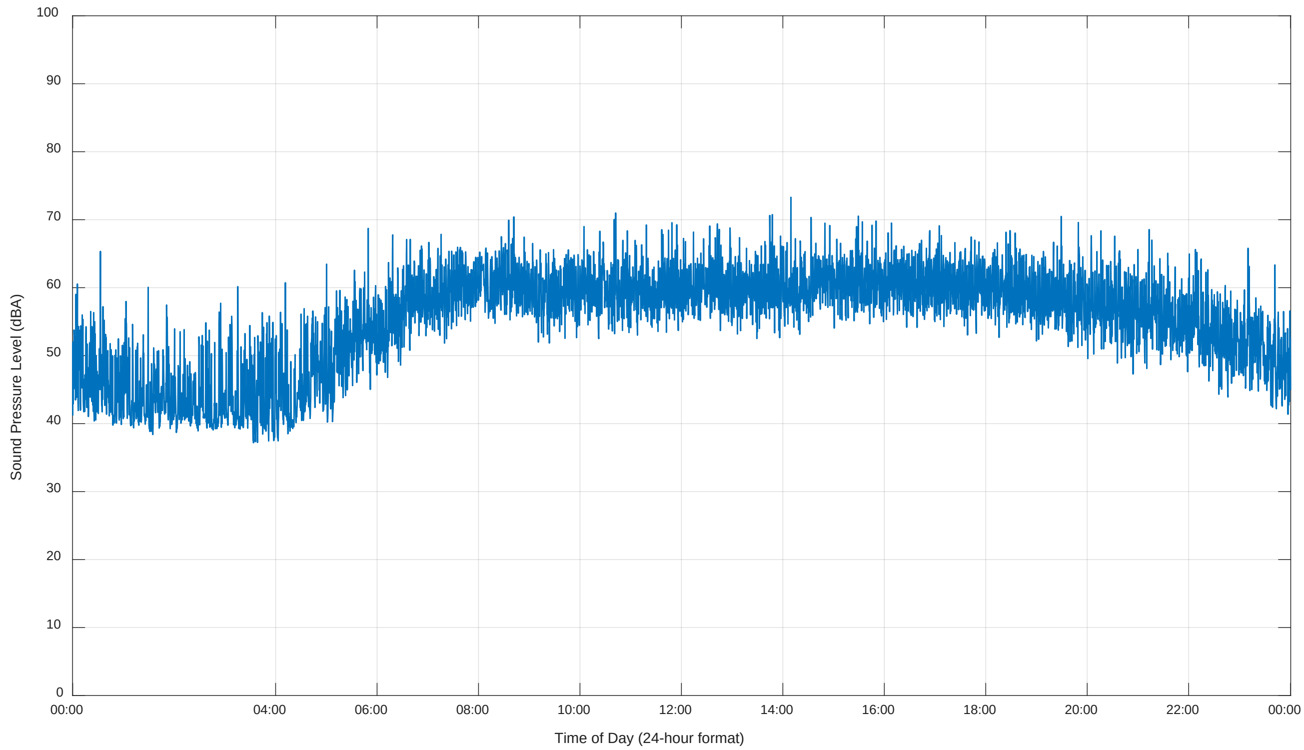

Figure 4. Noise Monitor #1 – 15-Second L_{eq}24 Sound Levels (October 5 - 6, 2021)

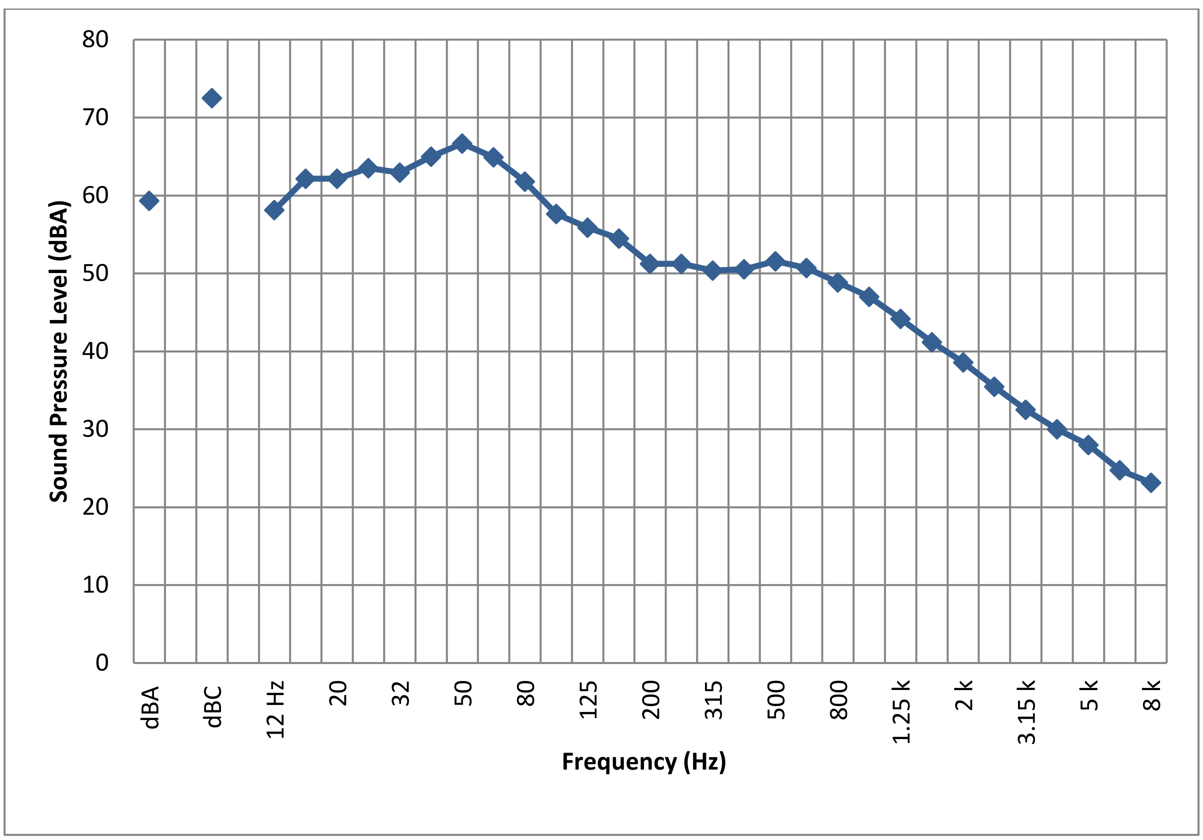

Figure 5. Noise Monitor #1 – 24-Hour 1/3 Octave Band L_{eq} Sound Levels (October 5 - 6, 2021)

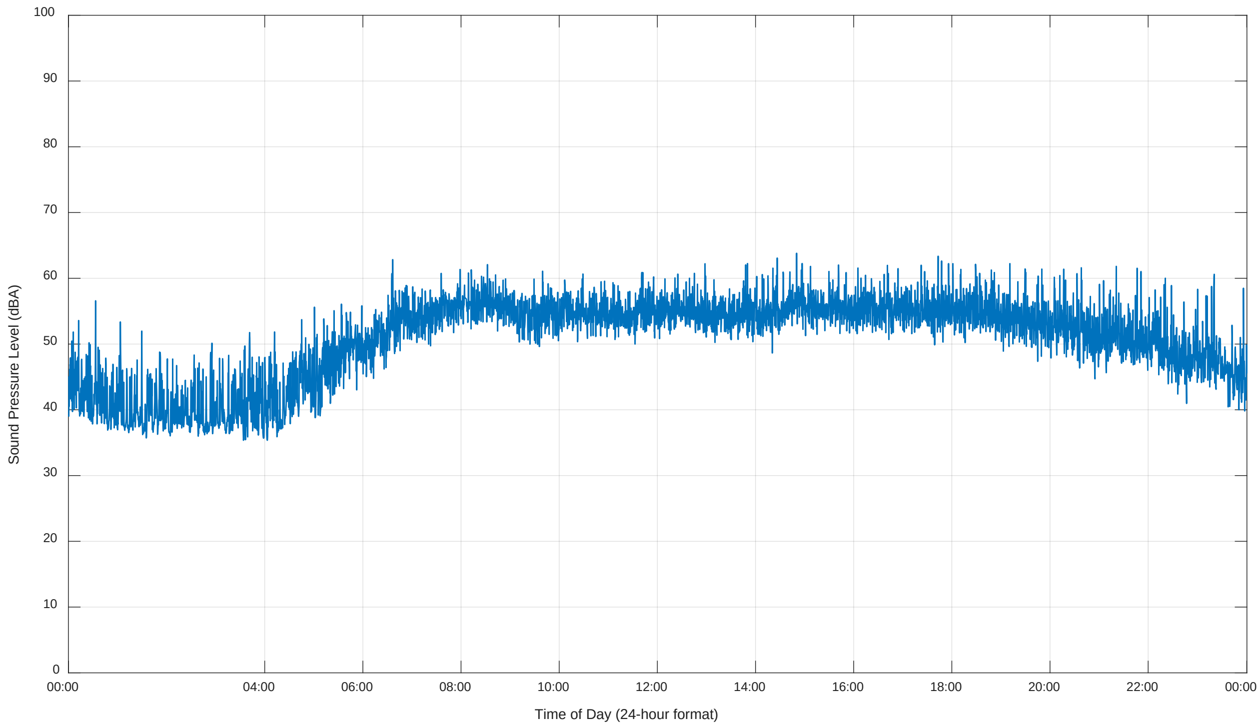

Figure 6. Noise Monitor #2 – 15-Second L_{eq}24 Sound Levels (October 5 - 6, 2021)

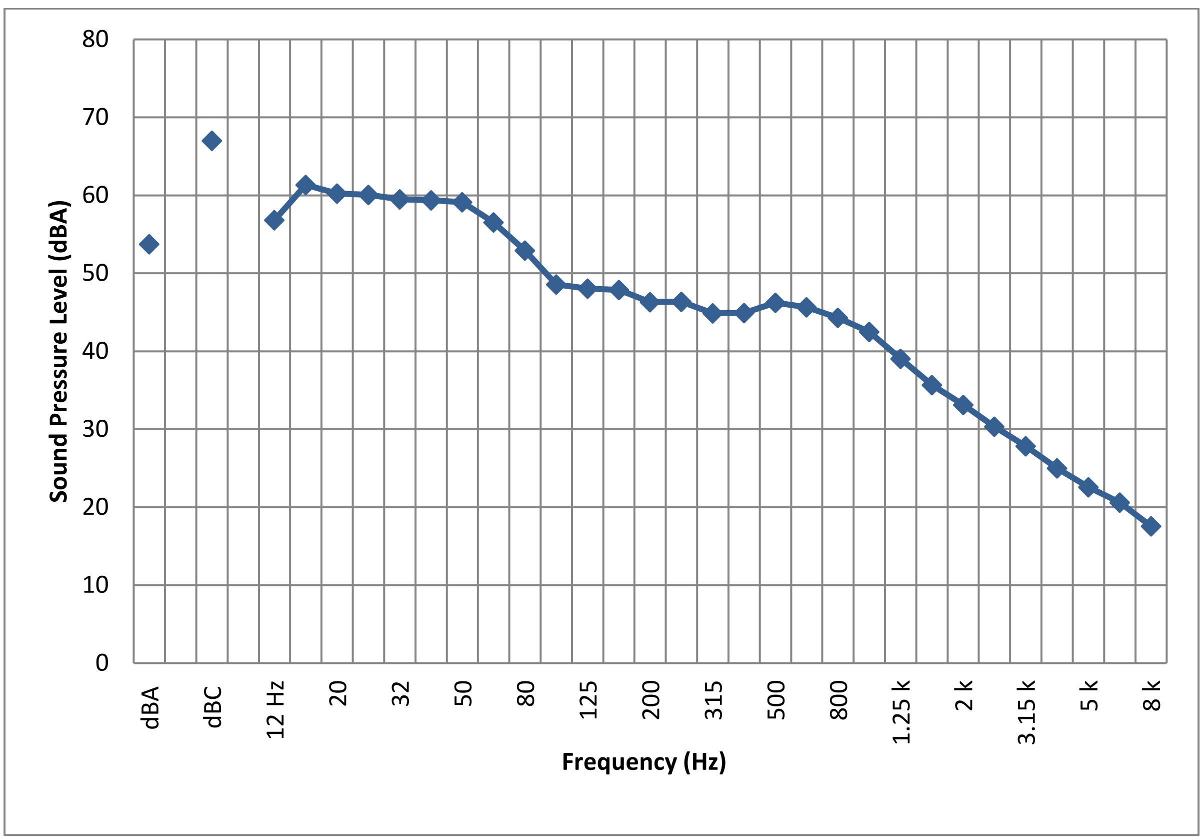

Figure 7. Noise Monitor #2 – 24-Hour 1/3 Octave Band L_{eq} Sound Levels (October 5 - 6, 2021)

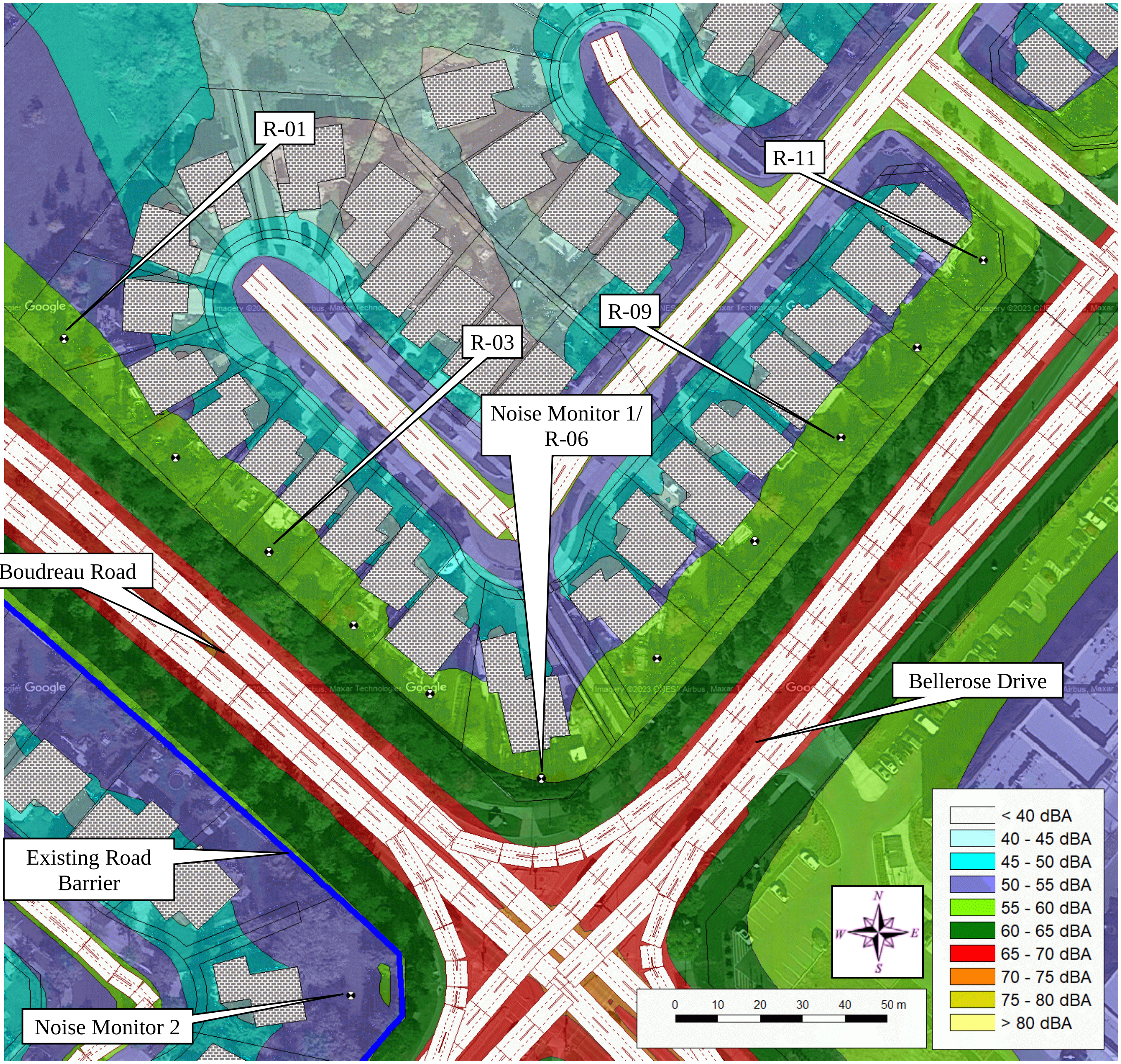

Figure 8. Baseline Case L_{eq}24 Noise Levels

Figure 9. Future Case L_{eq}24 Noise Levels

Figure 10. Baseline Case with Mitigation (1.83 m Tall Barrier) Case L_{eq}24 Noise Levels

Figure 11. Future Case with Mitigation (1.83 m Tall Barrier) Case L_{eq}24 Noise Levels

Appendix I MEASUREMENT EQUIPMENT USED

Brüel and Kjær 2250/2270 (Unit 2/ Unit 3/)

The environmental noise monitoring equipment used consisted of a Brüel and Kjær Type 2250/2270 Precision Integrating Sound Level Meter enclosed in an environmental case, a tripod, a weather protective microphone hood. The system acquired data in 15-second L_{eq} samples using 1/3 octave band frequency analysis and overall A-weighted and C-weighted sound levels. The sound level meter conforms to Type 1, ANSI S1.4, ANSI S1.43, IEC 61672-1, IEC 60651, IEC 60804 and DIN 45657. The 1/3 octave filters conform to S1.11 – Type 0-C, and IEC 61260 – Class 0. The calibrator conforms to IEC 942 and ANSI S1.40. The sound level meter, pre-amplifier and microphone were certified on April 07, 2021 / April 07, 2021 and the calibrator (type B&K 4231) was certified on March 03, 2021 by a NIST NVLAP Accredited Calibration Laboratory for all requirements of ISO 17025: 1999 and relevant requirements of ISO 9002:1994, ISO 9001:2000 and ANSI/NCSL Z540: 1994 Part 1. Simultaneous digital audio was recorded directly on the sound level meter using a 8 kHz sample rate for more detailed post-processing analysis. Refer to the next section in the Appendix for a detailed description of the various acoustical descriptive terms used.

Weather Monitor

The weather monitoring equipment used for the study consisted of an Orion Weather Station 9510-A-1 with a WXT520 Self-Aspirating Radiation Shield Sensor Unit, a Weather MicroServer 9590 Data-logger, and a Lightning Arrestor. The Data-logger and batteries were located in a grounded, weather protective case. The Sensor Unit was mounted on a sturdy survey tripod (with supporting guy-wires) at approximately 5.0 m above ground. The system was set up to record data in 1-minute samples obtaining the wind-speed, peak wind-speed, and wind-direction in a rolling 2-minute average as well as the 1-minute temperature, relative humidity, barometric pressure, rain rate and total rain accumulation.

Record of Calibration Results

Description	Date	Time	Pre / Post	Calibration Level	Calibrator Model	Serial Number
Monitor #5	04-Oct-21	11:20	Pre	93.9 dBA	B&K 4231	2642956
Monitor #5	06-Oct-21	11:40	Post	93.9 dBA	B&K 4231	2642956
Monitor #13	04-Oct-21	11:45	Pre	93.9 dBA	B&K 4231	2575493
Monitor #13	06-Oct-21	11:55	Post	93.9 dBA	B&K 4231	2575493

B&K 2270 Unit #2 SLM Calibration Certificate

CALIBRATED BY TRANSCAT

CERTIFICATE OF CALIBRATION

Customer: ACI ACCOUSTICAL CONSULTANTS IN
5031-210 STREET NW
EDMONTON, AB T6M 0A8

PO Number: BILAWCHUK

ANAB ACCREDITED ISO/IEC 17025 CALIBRATION LABORATORY
ANAB AC-2489.07
ilac-MRA

Certificate/SO Number: 17-Q1X3X-100-1 Revision 0

Manufacturer: Bruel & Kjaer
Model Number: 2270
Description: Sound Level Meter
Serial Number: 3002718/2850742
ID: UNIT 2

As-Found: In Tolerance
As-Left: In Tolerance

Issue Date: Apr 07, 2021
Calibration Date: Apr 07, 2021

Calibrated To: Manufacturer Specification
Calibration Procedure: 1-AC28548-3

Transcat Calibration Laboratories have been audited and found in compliance with ISO/IEC 17025:2017. Accredited calibrations performed within the Lab?s Scope of Accreditation are indicated by the presence of the Accrediting Body?s Logo and Certificate Number. Any measurements on an accredited calibration not covered by that Lab?s Scope of Accreditation are listed in the notes section of the certificate. SCC, NRC, CLAS or ANAB do not guarantee the accuracy of an individual calibration by accredited laboratories.

Transcat calibrations, as applicable, are performed in compliance with the requirements of the Transcat Quality Manual QAC-P01-000, the customer?s Purchase Order and/or Quality Agreement requirements, ISO 9001:2015, ANSI/NCSL Z540.1-1994 (R2002) or NQA-1, as applicable. Complete records of work performed are maintained by Transcat and are available for inspection. Laboratory standards used in the performance of this calibration are listed on this certificate.

Transcat documents the traceability of measurements to the SI units through the National Institute of Standards and Technology(NIST), or the National Research Council of Canada (NRC), or other national measurement institutes (NMI) that are signatories to the CIPM Mutual Recognition Arrangement, or accepted fundamental and/or natural physical constants, or by the use of specified methods, consensus standards or ratio type measurements. Documentation supporting traceability information is available for review upon written request at a Transcat facility. The measured quantity and the measurement uncertainty are required for further dissemination of traceability.

A binary decision rule, utilizing simple acceptance, and simple rejection criteria is used for the determination of compliance, unless otherwise superseded by the client?s Decision Rule. When Calibration Tolerance compliance statements are present, they are reported without factoring in the effects of uncertainty and comply with the guidelines established by ASME B89.7.3.1-2001(R2019) as follows:
-The acceptance zone is defined as: less than or equal to the high calibration tolerance limit, and/or greater than or equal to the low calibration tolerance limit. The rejection zones are defined as greater than the high calibration tolerance limit and/or less than the low calibration tolerance limit.
-Single measurement results in the acceptance zone are be identified as in-tolerance. Single measurement results in the rejection zone are identified as out-of-tolerance (OOT).
-When all measurement results are in the acceptance zone for repeated measurements, for the same characteristic, the test is identified as in-tolerance. For repeated characteristic measurements, a single measurement result in the rejection zone, will cause the test to be identified as out-of-tolerance (OOT).

Uncertainties are reported with a coverage factor k=2, providing a level of confidence of approximately 95%. All calibrations have been performed using processes having a TUR of 4:1 or better (3:1 for mass calibrations), unless otherwise noted. The Test Uncertainty Ratio (TUR) is calculated in accordance with NCSL International RP-18. For mass calibrations: Conventional mass referenced to 8.0 g/cm³.

The results in this report relate only to the item calibrated or tested. Recorded calibration data is valid at the time of calibration within the stated uncertainties at the environmental conditions noted. The determination of compliance to the specification is specific to the model/serial no./ID no. referenced above based on the tolerances shown; these tolerances are either the original equipment manufacturers(OEM?s) warranted specifications or the client?s requested specifications. This certificate may not be reproduced except in full, without the written approval of Transcat. Additional information, if applicable may be included on separate report(s).

Date Received: March 19, 2021
Service Level : R9

Certificate - Page 1 of 7

Customer Number: 9-330269-000
OPS-F20-014R8 04/01/21 FP014R0 4/2/2021

B&K 2270 Unit #3 SLM Calibration Certificates

CALIBRATED BY TRANSCAT

CERTIFICATE OF CALIBRATION

Customer: ACI ACCOUSTICAL CONSULTANTS IN
5031-210 STREET NW
EDMONTON, AB T6M 0A8

PO Number: BILAWCHUK

ANAB ACCREDITED ISO/IEC 17025 CALIBRATION LABORATORY
ANAB AC-2489.07

ilac-MRA

Certificate/SO Number: 17-Q1X3X-80-1 Revision 0

Manufacturer: Bruel & Kjaer
Model Number: 2270
Description: Sound Level Meter
Serial Number: 3002730/2850741
ID: UNIT 3

As-Found: In Tolerance
As-Left: In Tolerance

Issue Date: Apr 07, 2021
Calibration Date: Apr 07, 2021

Calibrated To: Manufacturer Specification
Calibration Procedure: 1-AC28548-3

Transcat Calibration Laboratories have been audited and found in compliance with ISO/IEC 17025:2017. Accredited calibrations performed within the Lab?s Scope of Accreditation are indicated by the presence of the Accrediting Body?s Logo and Certificate Number. Any measurements on an accredited calibration not covered by that Lab?s Scope of Accreditation are listed in the notes section of the certificate. SCC, NRC, CLAS or ANAB do not guarantee the accuracy of an individual calibration by accredited laboratories.

Transcat calibrations, as applicable, are performed in compliance with the requirements of the Transcat Quality Manual QAC-P01-000, the customer?s Purchase Order and/or Quality Agreement requirements, ISO 9001:2015, ANSI/NCSL Z540.1-1994 (R2002) or NQA-1, as applicable. Complete records of work performed are maintained by Transcat and are available for inspection. Laboratory standards used in the performance of this calibration are listed on this certificate.

Transcat documents the traceability of measurements to the SI units through the National Institute of Standards and Technology(NIST), or the National Research Council of Canada (NRC), or other national measurement institutes (NMI) that are signatories to the CIPM Mutual Recognition Arrangement, or accepted fundamental and/or natural physical constants, or by the use of specified methods, consensus standards or ratio type measurements. Documentation supporting traceability information is available for review upon written request at a Transcat facility. The measured quantity and the measurement uncertainty are required for further dissemination of traceability.

A binary decision rule, utilizing simple acceptance, and simple rejection criteria is used for the determination of compliance, unless otherwise superseded by the client?s Decision Rule. When Calibration Tolerance compliance statements are present, they are reported without factoring in the effects of uncertainty and comply with the guidelines established by ASME B89.7.3.1-2001 (R2019) as follows:
-The acceptance zone is defined as: less than or equal to the high calibration tolerance limit, and/or greater than or equal to the low calibration tolerance limit. The rejection zones are defined as greater than the high calibration tolerance limit and/or less than the low calibration tolerance limit.
-Single measurement results in the acceptance zone are be identified as in-tolerance. Single measurement results in the rejection zone are identified as out-of-tolerance (OOT).
-When all measurement results are in the acceptance zone for repeated measurements, for the same characteristic, the test is identified as in-tolerance. For repeated characteristic measurements, a single measurement result in the rejection zone, will cause the test to be identified as out-of-tolerance (OOT).

Uncertainties are reported with a coverage factor k=2, providing a level of confidence of approximately 95%. All calibrations have been performed using processes having a TUR of 4:1 or better (3:1 for mass calibrations), unless otherwise noted. The Test Uncertainty Ratio (TUR) is calculated in accordance with NCSL International RP-18. For mass calibrations: Conventional mass referenced to 8.0 g/cm^3.

The results in this report relate only to the item calibrated or tested. Recorded calibration data is valid at the time of calibration within the stated uncertainties at the environmental conditions noted. The determination of compliance to the specification is specific to the model/serial no./ID no. referenced above based on the tolerances shown; these tolerances are either the original equipment manufacturers (OEM?s) warranted specifications or the client?s requested specifications. This certificate may not be reproduced except in full, without the written approval of Transcat. Additional information, if applicable may be included on separate report(s).

Date Received: March 19, 2021
Service Level : R9

Certificate - Page 1 of 7

Customer Number: 9-330269-000
OPS-F20-014R8 04/01/21 FP014R0 4/2/2021

B&K 4231 Calibrator Calibration Certificate

Scantek, Inc.
CALIBRATION LABORATORY
ISO 17025: 2017, ANSI/NCSL Z540:1994 Part 1
ACCREDITED by NVLAP (an ILAC MRA signatory)

NVLAP®
CALIBRATION
NVLAP Lab Code: 200625-0

Calibration Certificate No.46832

Instrument: **Acoustical Calibrator**
Model: **4231**
Manufacturer: **Brüel and Kjær**
Serial number: **2642956**
Class (IEC 60942): **1**
Barometer type:
Barometer s/n:
Customer: **ACI Acoustical Consultants Inc.**
Tel/Fax: **780-414-6373 / 780-414-6376**

Date Calibrated: **8/26/2021** *Cal Due:*

Status:	Received	Sent
In tolerance:	X	X
Out of tolerance:		
See comments:		

Contains non-accredited tests: __Yes _X_ No

Address: **5031 - 210 Street, Edmonton, Alberta, CANADA T6M 0A8**

Tested in accordance with the following procedures and standards:
Calibration of Acoustical Calibrators, Scantek Inc., Rev. 10/1/2010

Instrumentation used for calibration: Nor-1504 Norsonic Test System:

Instrument - Manufacturer	Description	S/N	Cal. Date	Traceability evidence Cal. Lab / Accreditation	Cal. Due
483B-Norsonic	SME Cal Unit	31052	Oct 31, 2020	Scantek, Inc./ NVLAP	Oct 31, 2021
DS-360-SRS	Function Generator	33584	Oct 23, 2019	ACR Env./ A2LA	Oct 23, 2021
34401A-Agilent Technologies	Digital Voltmeter	MY47011118	Feb 4, 2021	ACR Env. / A2LA	Feb 4, 2022
HM30-Thommen	Meteo Station	1040170/39633	Dec 7, 2020	ACR Env./ A2LA	Dec 7, 2021
140-Norsonic	Real Time Analyzer	1406423	Nov 3, 2020	Scantek / NVLAP	Nov 3, 2021
PC Program 1018 Norsonic	Calibration software	v.6.1T	Validated Nov 2014	Scantek, Inc.	-
4134-Brüel&Kjær	Microphone	173368	Oct 26, 2020	Scantek, Inc. / NVLAP	Oct 26, 2021
1203-Norsonic	Preamplifier	14059	March 3, 2021	Scantek, Inc./ NVLAP	March 3, 2022

Instrumentation and test results are traceable to SI (International System of Units) through standards maintained by NIST (USA) and NPL (UK)

Calibrated by:	Lydon Dawkins	Authorized signatory:	William Gallagher
Signature	Lydon Dawkins	Signature	William Gallagher
Date	8/26/2021	Date	8/27/2021

Calibration Certificates or Test Reports shall not be reproduced, except in full, without written approval of the laboratory.
This Calibration Certificate or Test Reports shall not be used to claim product certification, approval or endorsement by NVLAP, NIST, or any agency of the federal government.
Document stored as: Y:\Calibration Lab\Cal 2021\BNK4231_2642956_M1.doc

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Appendix II THE ASSESSMENT OF ENVIRONMENTAL NOISE (GENERAL)

Sound Pressure Level

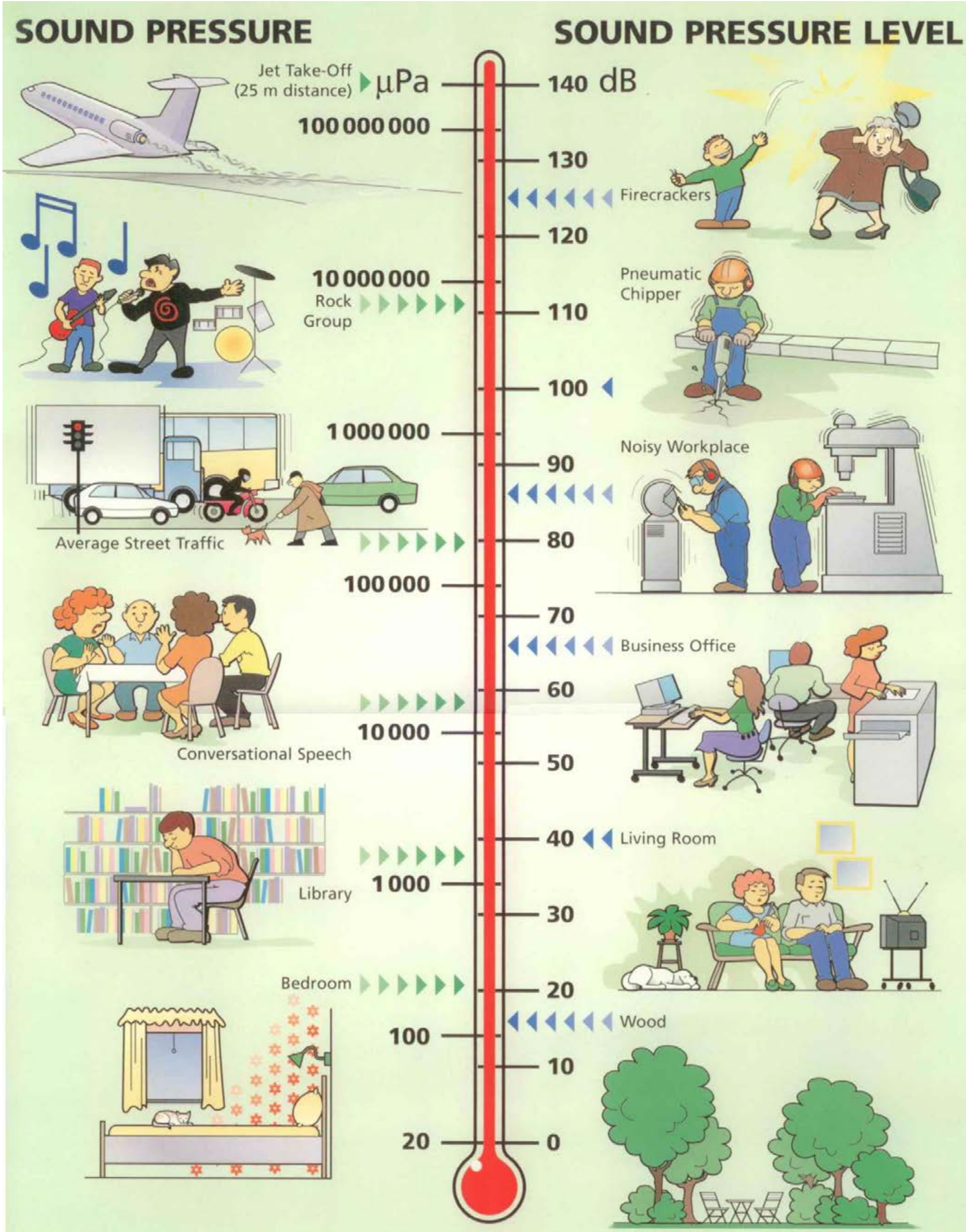
Sound pressure is initially measured in Pascal's (Pa). Humans can hear several orders of magnitude in sound pressure levels, so a more convenient scale is used. This scale is known as the decibel (dB) scale, named after Alexander Graham Bell (telephone guy). It is a base 10 logarithmic scale. When we measure pressure we typically measure the RMS sound pressure.

$$SPL = 10\log_{10}\left[\frac{P_{RMS}^2}{P_{ref}^2}\right] = 20\log_{10}\left[\frac{P_{RMS}}{P_{ref}}\right]$$

Where: SPL = Sound Pressure Level in dB
P_{RMS} = Root Mean Square measured pressure (Pa)
P_{ref} = Reference sound pressure level (P_{ref} = 2x10^{-5} Pa = 20 μPa)

This reference sound pressure level is an internationally agreed upon value. It represents the threshold of human hearing for "typical" people based on numerous testing. It is possible to have a threshold which is lower than 20 μPa which will result in negative dB levels. As such, zero dB does not mean there is no sound!

In general, a difference of 1 – 2 dB is the threshold for humans to notice that there has been a change in sound level. A difference of 3 dB (factor of 2 in acoustical energy) is perceptible and a change of 5 dB is strongly perceptible. A change of 10 dB is typically considered a factor of 2. This is quite remarkable when considering that 10 dB is 10-times the acoustical energy!


SOUND PRESSURE
SOUND PRESSURE LEVEL
Jet Take-Off (25 m distance)
µPa
140 dB
100 000 000
130
Firecrackers
120
10 000 000
Rock Group
Pneumatic Chipper
110
100
1 000 000
Noisy Workplace
90
Average Street Traffic
80
100 000
70
Business Office
60
10 000
Conversational Speech
50
40
Living Room
Library
1000
30
Bedroom
20
Wood
100
10
20
0

Frequency

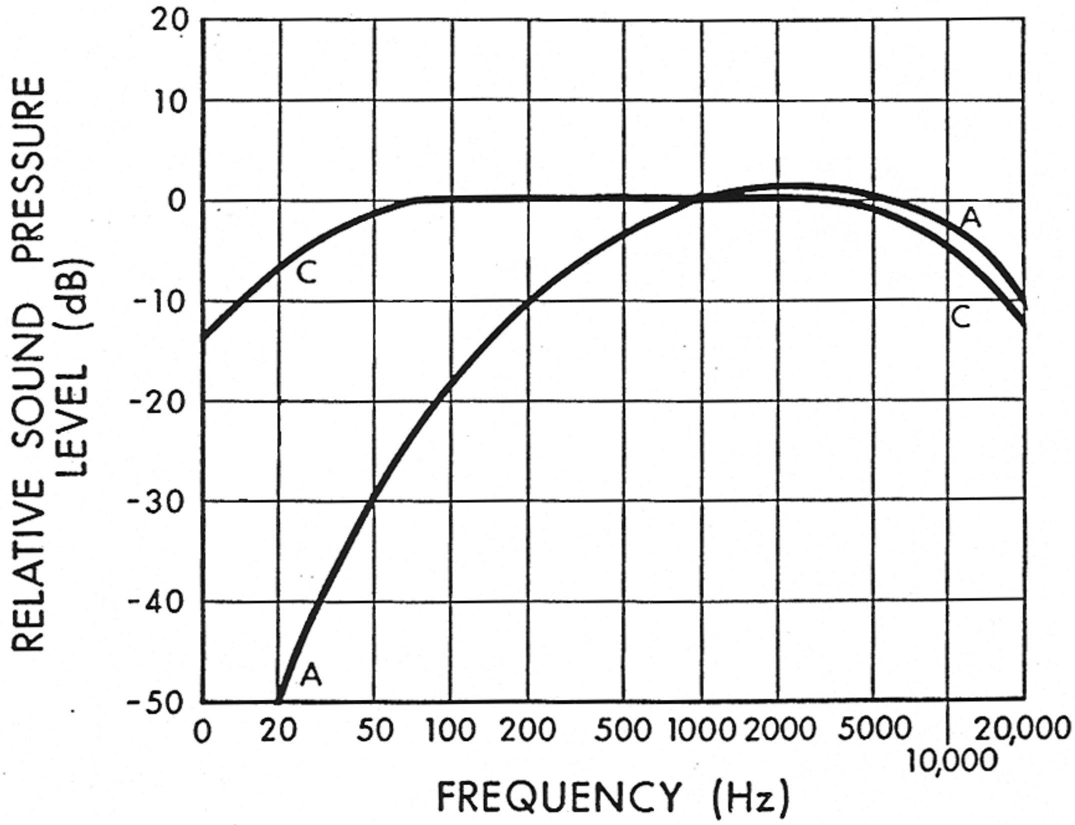
The range of frequencies audible to the human ear ranges from approximately 20 Hz to 20 kHz. Within this range, the human ear does not hear equally at all frequencies. It is not very sensitive to low frequency sounds, is very sensitive to mid frequency sounds and is slightly less sensitive to high frequency sounds. Due to the large frequency range of human hearing, the entire spectrum is often divided into 31 bands, each known as a 1/3 octave band.

The internationally agreed upon center frequencies and upper and lower band limits for the 1/1 (whole octave) and 1/3 octave bands are as follows:

Lower Band Limit	Whole Octave Center Frequency	Upper Band Limit
11	**16**	22
22	**31.5**	44
44	**63**	88
88	**125**	177
177	**250**	355
355	**500**	710
710	**1000**	1420
1420	**2000**	2840
2840	**4000**	5680
5680	**8000**	11360
11360	**16000**	22720

Lower Band Limit	1/3 Octave Center Frequency	Upper Band Limit
14.1	**16**	17.8
17.8	**20**	22.4
22.4	**25**	28.2
28.2	**31.5**	35.5
35.5	**40**	44.7
44.7	**50**	56.2
56.2	**63**	70.8
70.8	**80**	89.1
89.1	**100**	112
112	**125**	141
141	**160**	178
178	**200**	224
224	**250**	282
282	**315**	355
355	**400**	447
447	**500**	562
562	**630**	708
708	**800**	891
891	**1000**	1122
1122	**1250**	1413
1413	**1600**	1778
1778	**2000**	2239
2239	**2500**	2818
2818	**3150**	3548
3548	**4000**	4467
4467	**5000**	5623
5623	**6300**	7079
7079	**8000**	8913
8913	**10000**	11220
11220	**12500**	14130
14130	**16000**	17780
17780	**20000**	22390

Human hearing is most sensitive at approximately 3500 Hz which corresponds to the ¼ wavelength of the ear canal (approximately 2.5 cm). Because of this range of sensitivity to various frequencies, we typically apply various weighting networks to the broadband measured sound to more appropriately account for the way humans hear. By default, the most common weighting network used is the so-called “A-weighting”. It can be seen in the figure that the low frequency sounds are reduced significantly with the A-weighting.



Combination of Sounds

When combining multiple sound sources the general equation is:

$$\Sigma SPL_n = 10\log_{10}\left[\sum_{i=1}^{n} 10^{\frac{SPL_i}{10}}\right]$$

Examples:

- Two sources of 50 dB each add together to result in 53 dB.
- Three sources of 50 dB each add together to result in 55 dB.
- Ten sources of 50 dB each add together to result in 60 dB.
- One source of 50 dB added to another source of 40 dB results in 50.4 dB

It can be seen that, if multiple similar sources exist, removing or reducing only one source will have little effect.

Sound Level Measurements

Over the years a number of methods for measuring and describing environmental noise have been developed. The most widely used and accepted is the concept of the Energy Equivalent Sound Level (L_{eq}) which was developed in the US (1970's) to characterize noise levels near US Air-force bases. This is the level of a steady state sound which, for a given period of time, would contain the same energy as the time varying sound. The concept is that the same amount of annoyance occurs from a sound having a high level for a short period of time as from a sound at a lower level for a longer period of time.
The L_{eq} is defined as:

$$L_{eq} = 10\log_{10}\left[\frac{1}{T}\int_0^T 10^{\frac{dB}{10}}\, dT\right] = 10\log_{10}\left[\frac{1}{T}\int_0^T \frac{P^2}{P_{ref}^2}\, dT\right]$$

We must specify the time period over which to measure the sound. i.e. 1-second, 10-seconds, 15-seconds, 1-minute, 1-day, etc**. An L_{eq} is meaningless if there is no time period associated**.

In general there a few very common L_{eq} sample durations which are used in describing environmental noise measurements. These include:

- $L_{eq}24$ - Measured over a 24-hour period
- $L_{eq}Night$ - Measured over the night-time (typically 22:00 – 07:00)
- $L_{eq}Day$ - Measured over the day-time (typically 07:00 – 22:00)
- L_{DN} - Same as $L_{eq}24$ with a 10 dB penalty added to the night-time

Statistical Descriptor

Another method of conveying long term noise levels utilizes statistical descriptors. These are calculated from a cumulative distribution of the sound levels over the entire measurement duration and then determining the sound level at xx % of the time.

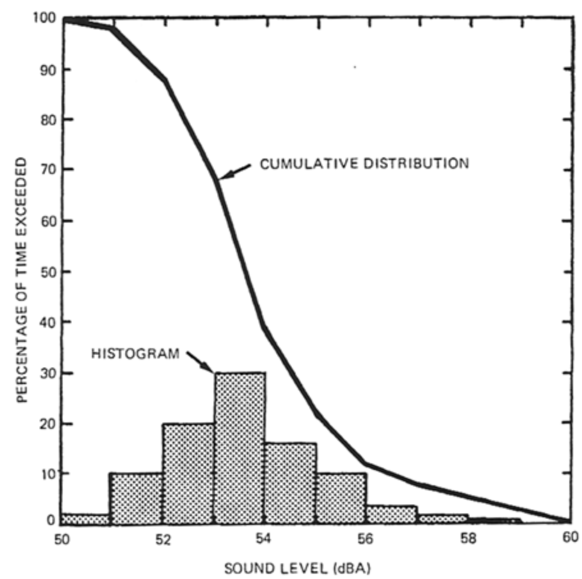


Figure 16.6 Statistically processed community noise showing histogram and cumulative distribution of A weighted sound levels.

Industrial Noise Control, Lewis Bell, Marcel Dekker, Inc. 1994

The most common statistical descriptors are:

L_{min} - minimum sound level measured
L_{01} - sound level that was exceeded only 1% of the time
L_{10} - sound level that was exceeded only 10% of the time.
- Good measure of intermittent or intrusive noise
- Good measure of Traffic Noise

L_{50} - sound level that was exceeded 50% of the time (arithmetic average)
- Good to compare to L_{eq} to determine steadiness of noise

L_{90} - sound level that was exceeded 90% of the time
- Good indicator of typical “ambient” noise levels

L_{99} - sound level that was exceeded 99% of the time
L_{max} - maximum sound level measured

These descriptors can be used to provide a more detailed analysis of the varying noise climate:

- If there is a large difference between the L_{eq} and the L_{50} (L_{eq} can never be any lower than the L_{50}) then it can be surmised that one or more short duration, high level sound(s) occurred during the time period.
- If the gap between the L_{10} and L_{90} is relatively small (less than 15 – 20 dBA) then it can be surmised that the noise climate was relatively steady.

Sound Propagation

In order to understand sound propagation, the nature of the source must first be discussed. In general, there are three types of sources. These are known as 'point', 'line', and 'area'. This discussion will concentrate on point and line sources since area sources are much more complex and can usually be approximated by point sources at large distances.

Point Source

As sound radiates from a point source, it dissipates through geometric spreading. The basic relationship between the sound levels at two distances from a point source is:

$$\therefore SPL_1 - SPL_2 = 20\log_{10}\left(\frac{r_2}{r_1}\right)$$

Where: SPL_1 = sound pressure level at location 1, SPL_2 = sound pressure level at location 2
r_1 = distance from source to location 1, r_2 = distance from source to location 2

Thus, the reduction in sound pressure level for a point source radiating in a free field is **6 dB per doubling of distance**. This relationship is independent of reflectivity factors provided they are always present. Note that this only considers geometric spreading and does not take into account atmospheric effects. Point sources still have some physical dimension associated with them, and typically do not radiate sound equally in all directions in all frequencies. The directionality of a source is also highly dependent on frequency. As frequency increases, directionality increases.

Examples (note no atmospheric absorption):

- A point source measuring 50 dB at 100m will be 44 dB at 200m.
- A point source measuring 50 dB at 100m will be 40.5 dB at 300m.
- A point source measuring 50 dB at 100m will be 38 dB at 400m.
- A point source measuring 50 dB at 100m will be 30 dB at 1000m.

Line Source

A line source is similar to a point source in that it dissipates through geometric spreading. The difference is that a line source is equivalent to a long line of many point sources. The basic relationship between the sound levels at two distances from a line source is:

$$SPL_1 - SPL_2 = 10\log_{10}\left(\frac{r_2}{r_1}\right)$$

The difference from the point source is that the '20' term in front of the 'log' is now only 10. Thus, the reduction in sound pressure level for a line source radiating in a free field is **3 dB per doubling of distance**.

Examples (note no atmospheric absorption):

- A line source measuring 50 dB at 100m will be 47 dB at 200m.
- A line source measuring 50 dB at 100m will be 45 dB at 300m.
- A line source measuring 50 dB at 100m will be 44 dB at 400m.
- A line source measuring 50 dB at 100m will be 40 dB at 1000m.

Atmospheric Absorption

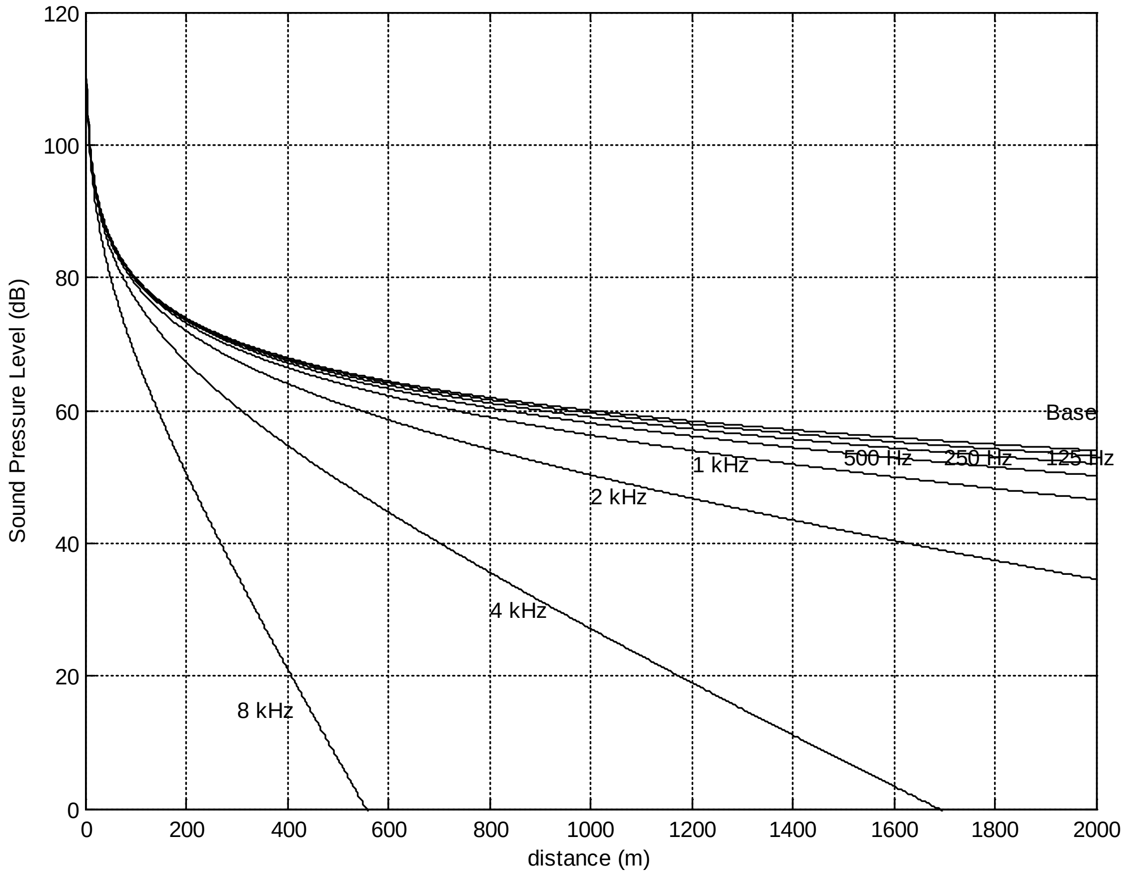
As sound transmits through a medium, there is an attenuation (or dissipation of acoustic energy) which can be attributed to three mechanisms:

1) **Viscous Effects** - Dissipation of acoustic energy due to fluid friction which results in thermodynamically irreversible propagation of sound.
2) **Heat Conduction Effects** - Heat transfer between high and low temperature regions in the wave which result in non-adiabatic propagation of the sound.
3) **Inter Molecular Energy Interchanges** - Molecular energy relaxation effects which result in a time lag between changes in translational kinetic energy and the energy associated with rotation and vibration of the molecules.

The following table illustrates the attenuation coefficient of sound at standard pressure (101.325 kPa) in units of dB/100m.

Temperature °C	Relative Humidity (%)	Frequency (Hz) 125	250	500	1000	2000	4000
30	20	0.06	0.18	0.37	0.64	1.40	4.40
	50	0.03	0.10	0.33	0.75	1.30	2.50
	90	0.02	0.06	0.24	0.70	1.50	2.60
20	20	0.07	0.15	0.27	0.62	1.90	6.70
	50	0.04	0.12	0.28	0.50	1.00	2.80
	90	0.02	0.08	0.26	0.56	0.99	2.10
10	20	0.06	0.11	0.29	0.94	3.20	9.00
	50	0.04	0.11	0.20	0.41	1.20	4.20
	90	0.03	0.10	0.21	0.38	0.81	2.50
0	20	0.05	0.15	0.50	1.60	3.70	5.70
	50	0.04	0.08	0.19	0.60	2.10	6.70
	90	0.03	0.08	0.15	0.36	1.10	4.10

- As frequency increases, absorption tends to increase
- As Relative Humidity increases, absorption tends to decrease
- There is no direct relationship between absorption and temperature
- **The net result of atmospheric absorption is to modify the sound propagation of a point source from 6 dB/doubling-of-distance to approximately 7 – 8 dB/doubling-of-distance (based on anecdotal experience)**



Atmospheric Absorption at 10ºC and 70% RH

Meteorological Effects

There are many meteorological factors which can affect how sound propagates over large distances. These various phenomena must be considered when trying to determine the relative impact of a noise source either after installation or during the design stage.

Wind

- Can greatly alter the noise climate away from a source depending on direction
- Sound levels downwind from a source can be increased due to refraction of sound back down towards the surface. This is due to the generally higher velocities as altitude increases.
- Sound levels upwind from a source can be decreased due to a “bending” of the sound away from the earth’s surface.
- Sound level differences of ±10dB are possible depending on severity of wind and distance from source.
- Sound levels crosswind are generally not disturbed by an appreciable amount
- Wind tends to generate its own noise, however, and can provide a high degree of masking relative to a noise source of particular interest.

Temperature

- Temperature effects can be similar to wind effects
- Typically, the temperature is warmer at ground level than it is at higher elevations.
- If there is a very large difference between the ground temperature (very warm) and the air aloft (only a few hundred meters) then the transmitted sound refracts upward due to the changing speed of sound.
- If the air aloft is warmer than the ground temperature (known as an *inversion*) the resulting higher speed of sound aloft tends to refract the transmitted sound back down towards the ground. This essentially works on Snell’s law of reflection and refraction.
- Temperature inversions typically happen early in the morning and are most common over large bodies of water or across river valleys.
- Sound level differences of ±10dB are possible depending on gradient of temperature and distance from source.

Rain

- Rain does not affect sound propagation by an appreciable amount unless it is very heavy
- The larger concern is the noise generated by the rain itself. A heavy rain striking the ground can cause a significant amount of highly broadband noise. The amount of noise generated is difficult to predict.
- Rain can also affect the output of various noise sources such as vehicle traffic.

Summary

- In general, these wind and temperature effects are difficult to predict
- Empirical models (based on measured data) have been generated to attempt to account for these effects.
- Environmental noise measurements must be conducted with these effects in mind. Sometimes it is desired to have completely calm conditions, other times a “worst case” of downwind noise levels are desired.

Topographical Effects

Similar to the various atmospheric effects outlined in the previous section, the effect of various geographical and vegetative factors must also be considered when examining the propagation of noise over large distances.

Topography

- One of the most important factors in sound propagation.
- Can provide a natural barrier between source and receiver (i.e. if berm or hill in between).
- Can provide a natural amplifier between source and receiver (i.e. large valley in between or hard reflective surface in between).
- Must look at location of topographical features relative to source and receiver to determine importance (i.e. small berm 1km away from source and 1km away from receiver will make negligible impact).

Grass

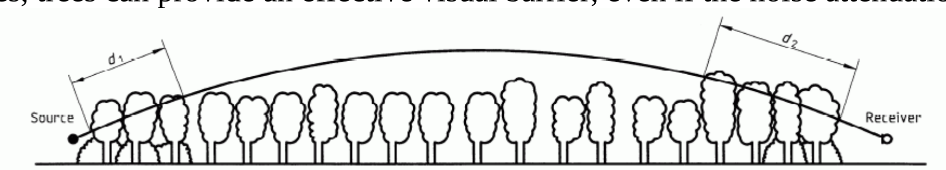
- Can be an effective absorber due to large area covered
- Only effective at low height above ground. Does not affect sound transmitted direct from source to receiver if there is line of sight.
- Typically less absorption than atmospheric absorption when there is line of sight.
- Approximate rule of thumb based on empirical data is:

$$A_g = 18\log_{10}(f) - 31 \qquad (dB/100m)$$

Where: A_g is the absorption amount

Trees

- Provide absorption due to foliage
- Deciduous trees are essentially ineffective in the winter
- Absorption depends heavily on density and height of trees
- No data found on absorption of various kinds of trees
- Large spans of trees are required to obtain even minor amounts of sound reduction
- In many cases, trees can provide an effective visual barrier, even if the noise attenuation is negligible.



NOTE — $d_f = d_1 + d_2$

For calculating d_1 and d_2, the curved path radius may be assumed to be 5 km.

Figure A.1 — Attenuation due to propagation through foliage increases linearly with propagation distance d_f through the foliage

Table A.1 — Attenuation of an octave band of noise due to propagation a distance d_f through dense foliage

Propagation distance d_f m	Nominal midband frequency Hz							
	63	125	250	500	1 000	2 000	4 000	8 000
$10 \leq d_f \leq 20$	Attenuation, dB: 0	0	1	1	1	1	2	3
$20 \leq d_f \leq 200$	Attenuation, dB/m: 0,02	0,03	0,04	0,05	0,06	0,08	0,09	0,12

Tree/Foliage attenuation from ISO 9613-2:1996

Bodies of Water

- Large bodies of water can provide the opposite effect to grass and trees.
- Reflections caused by small incidence angles (grazing) can result in larger sound levels at great distances (increased reflectivity, Q).
- Typically air temperatures are warmer high aloft since air temperatures near water surface tend to be more constant. Result is a high probability of temperature inversion.
- Sound levels can "carry" much further.

Snow

- Covers the ground for approximately 1/2 of the year in northern climates.
- Can act as an absorber or reflector (and varying degrees in between).
- Freshly fallen snow can be quite absorptive.
- Snow which has been sitting for a while and hard packed due to wind can be quite reflective.
- Falling snow can be more absorptive than rain, but does not tend to produce its own noise.
- Snow can cover grass which might have provided some means of absorption.
- Typically sound propagates with less impedance in winter due to hard snow on ground and no foliage on trees/shrubs.

Appendix III SOUND LEVELS OF FAMILIAR NOISE SOURCES

Used with Permission Obtained from the Alberta Energy Regulator Directive 038 (February, 2007)

Source[1]	Sound Level (dBA)
Bedroom of a country home	30
Soft whisper at 1.5 m	30
Quiet office or living room	40
Moderate rainfall	50
Inside average urban home	50
Quiet street	50
Normal conversation at 1 m	60
Noisy office	60
Noisy restaurant	70
Highway traffic at 15 m	75
Loud singing at 1 m	75
Tractor at 15 m	78-95
Busy traffic intersection	80
Electric typewriter	80
Bus or heavy truck at 15 m	88-94
Jackhammer	88-98
Loud shout	90
Freight train at 15 m	95
Modified motorcycle	95
Jet taking off at 600 m	100
Amplified rock music	110
Jet taking off at 60 m	120
Air-raid siren	130

[1] Cottrell, Tom, 1980, *Noise in Alberta*, Table 1, p.8, ECA80 - 16/1B4 (Edmonton: Environment Council of Alberta).

SOUND LEVELS GENERATED BY COMMON APPLIANCES

Used with Permission Obtained from the Alberta Energy Regulator Directive 038 (February, 2007)

Source[1]	**Sound level at 3 feet (dBA)**
Freezer	38-45
Refrigerator	34-53
Electric heater	47
Hair clipper	50
Electric toothbrush	48-57
Humidifier	41-54
Clothes dryer	51-65
Air conditioner	50-67
Electric shaver	47-68
Water faucet	62
Hair dryer	58-64
Clothes washer	48-73
Dishwasher	59-71
Electric can opener	60-70
Food mixer	59-75
Electric knife	65-75
Electric knife sharpener	72
Sewing machine	70-74
Vacuum cleaner	65-80
Food blender	65-85
Coffee mill	75-79
Food waste disposer	69-90
Edger and trimmer	81
Home shop tools	64-95
Hedge clippers	85
Electric lawn mower	80-90

[1] Reif, Z. F., and Vermeulen, P. J., 1979, "Noise from domestic appliances, construction, and industry," Table 1, p.166, in Jones, H. W., ed., *Noise in the Human Environment*, vol. 2, ECA79-SP/1 (Edmonton: Environment Council of Alberta).

Appendix IV NOISE MODELING PARAMETERS

Baseline Case Volumes

Road	Day (Vehicles Per Hour)	Day % Heavy Vehicles	Night (Vehicles Per Hour)	Night % Heavy Vehicles	Speed (km/hr)	Total Volume (AADT)
Boudreau WB (West of Bellerose Drive)	588	2.8	109	2.8	60	9805
Boudreau EB (West of Bellerose Drive)	539	2.8	100	2.8	60	8985
Boudreau WB (East of Bellerose Drive)	870	2.8	161	2.8	60	14505
Boudreau EB (East of Bellerose Drive)	857	2.8	159	2.8	60	14280
Bellerose Drive SB (South of Boudreau Road)	390	2.8	72	2.8	50	6493
Bellerose Drive NB (South of Boudreau Road)	358	2.8	66	2.8	50	5973
Bellerose Drive SB (North of Boudreau Road)	433	2.8	80	2.8	50	7213
Bellerose Drive NB (North of Boudreau Road)	437	2.8	81	2.8	50	7288
Internal Collector	12	2.0	2	2.0	40	200

Future Case Volumes

Road	Day (Vehicles Per Hour)	Day % Heavy Vehicles	Night (Vehicles Per Hour)	Night % Heavy Vehicles	Speed (km/hr)	Total Volume (AADT)
Boudreau WB (West of Bellerose Drive)	1941	2.8	360	2.8	60	32357
Boudreau EB (West of Bellerose Drive)	1779	2.8	329	2.8	60	29651
Boudreau WB (East of Bellerose Drive)	2872	2.8	532	2.8	60	47867
Boudreau EB (East of Bellerose Drive)	2827	2.8	524	2.8	60	47124
Bellerose Drive SB (South of Boudreau Road)	1286	2.8	238	2.8	50	21427
Bellerose Drive NB (South of Boudreau Road)	1183	2.8	219	2.8	50	19711
Bellerose Drive SB (North of Boudreau Road)	1428	2.8	264	2.8	50	23803
Bellerose Drive NB (North of Boudreau Road)	1443	2.8	267	2.8	50	24050
Internal Collector	12	2.0	2	2.0	40	200

Noise Modeling Parameters

Parameter	Value
Modeling Software	CADNA/A (Version 2022 MR2, build: 193.5260)
Standard Followed	ISO 9613-2
Ground Sound Absorption Coefficient	0.7
Wind Speed	1 - 5 m/s (3.6 - 18 km/hr)
Wind Direction	Downwind from all sources to all receptors
Temperature	10 °C
Humidity	70%
Topography	Digital Terrain Model Contours provided by Client

Appendix V DATA REMOVAL

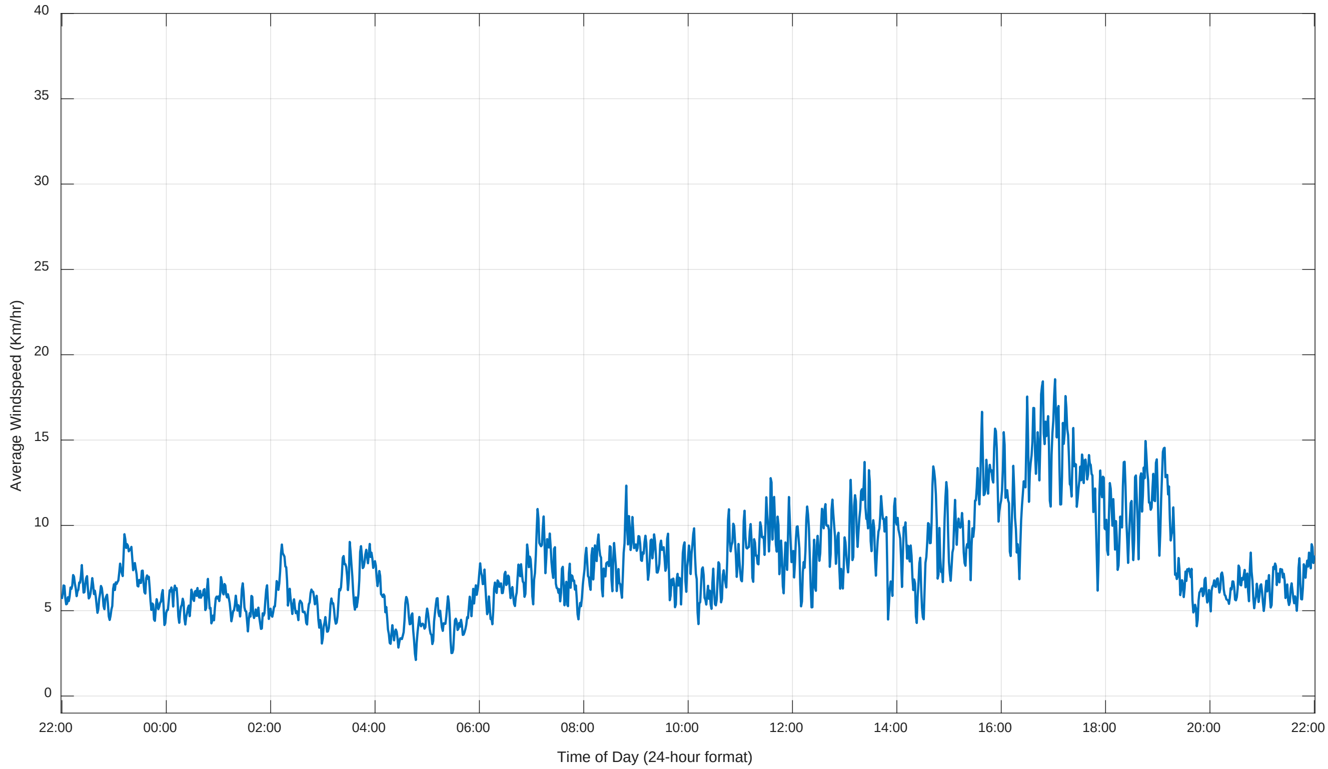
Data Removal Noise Monitoring Location #1

Start Time	End Time	Leq (dBA)	Duration (min)	Reason
10/05/21 1:47	10/05/21 1:48	64.7	0.75	Loud Vehicle Pass-by
10/05/21 3:06	10/05/21 3:06	60.6	0.50	Aircraft Flyover
10/05/21 5:03	10/05/21 5:04	78.0	0.25	Loud Vehicle Pass-by
10/05/21 6:20	10/05/21 6:20	69.6	0.50	Loud Vehicle Pass-by
10/05/21 6:21	10/05/21 6:22	83.4	0.25	Loud Vehicle Pass-by
10/05/21 6:36	10/05/21 6:36	85.4	0.25	Loud Vehicle Pass-by
10/05/21 7:58	10/05/21 7:59	69.6	1.00	Loud Vehicle Pass-by
10/05/21 8:04	10/05/21 8:06	75.7	1.75	Emergency Sirens
10/05/21 8:10	10/05/21 8:11	75.9	1.00	Emergency Sirens
10/05/21 8:12	10/05/21 8:13	77.9	1.25	Emergency Sirens
10/05/21 8:16	10/05/21 8:16	84.7	0.25	Loud Vehicle Pass-by
10/05/21 9:39	10/05/21 9:40	69.0	0.75	Loud Vehicle Pass-by
10/05/21 9:51	10/05/21 9:51	82.3	0.25	Loud Vehicle Pass-by
10/05/21 10:06	10/05/21 10:08	74.5	1.25	Emergency Sirens
10/05/21 12:18	10/05/21 12:18	80.8	0.25	Loud Vehicle Pass-by
10/05/21 13:24	10/05/21 13:24	82.9	0.25	Loud Vehicle Pass-by
10/05/21 13:51	10/05/21 13:52	80.3	0.50	Emergency Sirens
10/05/21 14:06	10/05/21 14:07	70.6	0.50	Loud Vehicle Pass-by
10/05/21 14:07	10/05/21 14:08	84.5	0.25	Loud Vehicle Pass-by
10/05/21 14:19	10/05/21 14:19	72.5	0.50	Loud Vehicle Pass-by
10/05/21 14:41	10/05/21 14:41	85.7	0.25	Loud Vehicle Pass-by
10/05/21 15:02	10/05/21 15:02	77.3	0.75	Emergency Sirens
10/05/21 15:36	10/05/21 15:36	74.0	0.50	Loud Vehicle Pass-by
10/05/21 15:52	10/05/21 15:52	85.4	0.25	Loud Vehicle Pass-by
10/05/21 16:32	10/05/21 16:33	72.2	0.75	Loud Vehicle Pass-by
10/05/21 17:12	10/05/21 17:12	72.2	0.50	Loud Vehicle Pass-by
10/05/21 17:20	10/05/21 17:20	91.2	0.25	Loud Vehicle Pass-by
10/05/21 17:37	10/05/21 17:38	68.0	0.50	Loud Vehicle Pass-by
10/05/21 17:55	10/05/21 17:55	91.2	0.25	Loud Vehicle Pass-by
10/05/21 18:00	10/05/21 18:01	69.9	0.50	Loud Vehicle Pass-by
10/05/21 18:21	10/05/21 18:22	68.9	1.00	Loud Vehicle Pass-by
10/05/21 18:28	10/05/21 18:28	87.3	0.25	Loud Vehicle Pass-by
10/05/21 18:42	10/05/21 18:43	69.8	0.50	Loud Vehicle Pass-by
10/05/21 18:49	10/05/21 18:50	70.1	0.50	Loud Vehicle Pass-by
10/05/21 21:20	10/05/21 21:20	69.0	0.50	Loud Vehicle Pass-by
10/05/21 21:23	10/05/21 21:23	85.7	0.25	Loud Vehicle Pass-by
10/05/21 21:46	10/05/21 21:46	77.6	0.25	Loud Vehicle Pass-by
10/05/21 21:50	10/05/21 21:51	80.3	0.25	Loud Vehicle Pass-by
10/05/21 22:13	10/05/21 22:14	80.5	1.00	Loud Vehicle Pass-by
10/05/21 22:18	10/05/21 22:19	69.0	0.50	Loud Vehicle Pass-by
10/05/21 22:58	10/05/21 22:58	67.8	0.50	Loud Vehicle Pass-by
10/05/21 23:00	10/05/21 23:00	68.0	0.50	Loud Vehicle Pass-by
10/05/21 23:17	10/05/21 23:17	83.6	0.25	Loud Vehicle Pass-by
10/05/21 23:19	10/05/21 23:20	66.7	0.75	Aircraft Flyover
10/05/21 23:35	10/05/21 23:35	70.1	0.50	Loud Vehicle Pass-by
10/05/21 23:55	10/05/21 23:56	64.8	0.50	Loud Vehicle Pass-by
	Total Time of Data Removed		**24.75**	

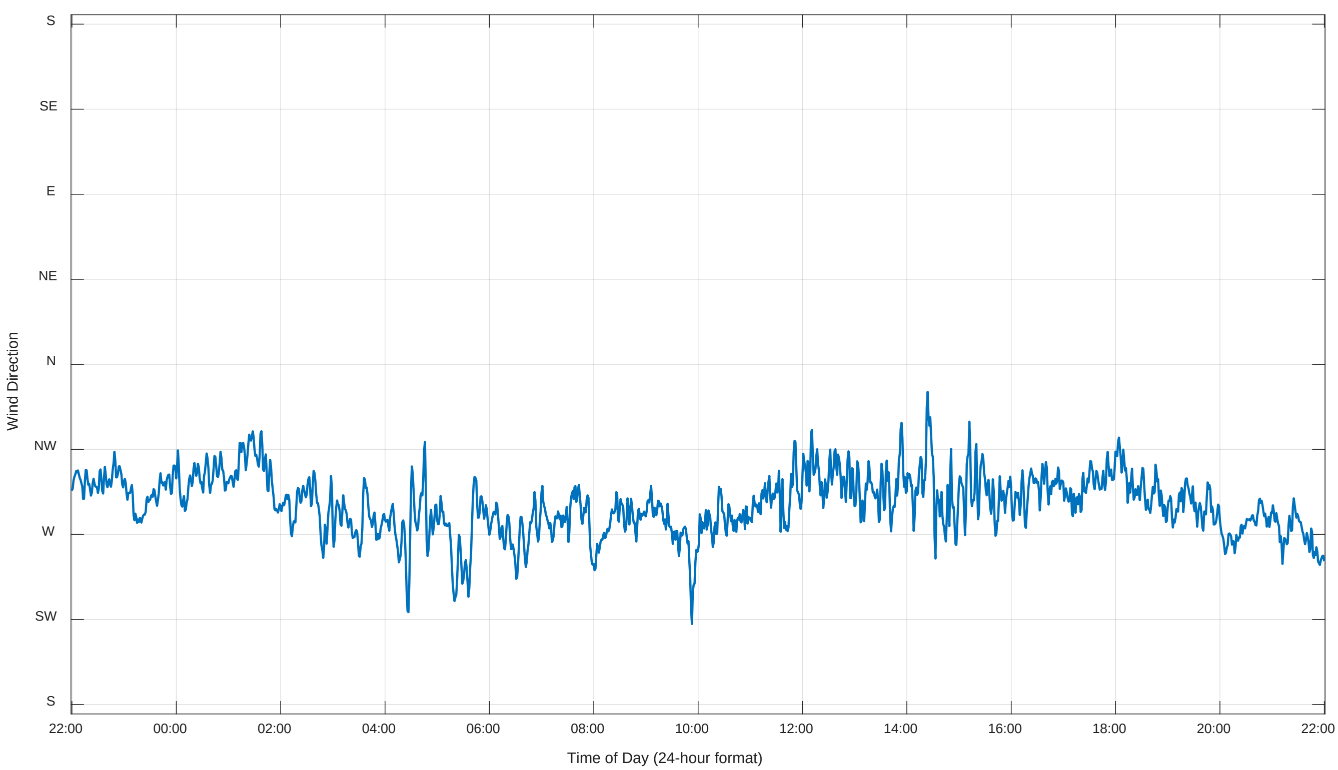
Data Removal Noise Monitoring Location #2

Start Time	End Time	Leq (dBA)	Duration (min)	Reason
10/05/21 1:47	10/05/21 1:48	55.6	1.00	Loud Vehicle Pass-by
10/05/21 3:06	10/05/21 3:08	54.9	1.50	Aircraft Flyover
10/05/21 5:04	10/05/21 5:04	55.7	0.50	Loud Vehicle Pass-by
10/05/21 5:49	10/05/21 5:51	54.8	1.50	Loud Vehicle Pass-by
10/05/21 6:19	10/05/21 6:19	75.8	0.25	Loud Vehicle Pass-by
10/05/21 6:20	10/05/21 6:21	57.8	1.00	Loud Vehicle Pass-by
10/05/21 6:22	10/05/21 6:22	79.3	0.25	Loud Vehicle Pass-by
10/05/21 6:36	10/05/21 6:36	0.0	0.00	Loud Vehicle Pass-by
10/05/21 8:04	10/05/21 8:06	70.3	1.75	Emergency Sirens
10/05/21 8:11	10/05/21 8:12	71.2	1.00	Emergency Sirens
10/05/21 8:12	10/05/21 8:13	73.7	0.75	Loud Vehicle Pass-by
10/05/21 8:40	10/05/21 8:41	61.4	1.25	Loud Vehicle Pass-by
10/05/21 9:19	10/05/21 9:21	62.6	1.25	Aircraft Flyover
10/05/21 9:49	10/05/21 9:50	77.2	0.25	Loud Vehicle Pass-by
10/05/21 9:52	10/05/21 9:52	73.0	0.25	Loud Vehicle Pass-by
10/05/21 9:58	10/05/21 9:59	59.0	0.50	Loud Vehicle Pass-by
10/05/21 10:07	10/05/21 10:08	69.3	1.75	Emergency Sirens
10/05/21 10:24	10/05/21 10:24	61.1	0.50	Loud Vehicle Pass-by
10/05/21 11:19	10/05/21 11:19	59.5	0.50	Loud Vehicle Pass-by
10/05/21 11:35	10/05/21 11:35	77.8	0.25	Loud Vehicle Pass-by
10/05/21 11:37	10/05/21 11:37	82.7	0.25	Loud Vehicle Pass-by
10/05/21 11:45	10/05/21 11:45	61.3	0.50	Loud Vehicle Pass-by
10/05/21 12:18	10/05/21 12:19	62.8	0.75	Loud Vehicle Pass-by
10/05/21 12:33	10/05/21 12:34	60.3	1.25	Loud Vehicle Pass-by
10/05/21 12:47	10/05/21 12:47	76.2	0.25	Loud Vehicle Pass-by
10/05/21 13:25	10/05/21 13:25	60.3	0.75	Loud Vehicle Pass-by
10/05/21 13:35	10/05/21 13:35	59.8	0.50	Loud Vehicle Pass-by
10/05/21 13:52	10/05/21 13:52	74.8	0.50	Emergency Sirens
10/05/21 14:07	10/05/21 14:07	79.0	0.25	Loud Vehicle Pass-by
10/05/21 14:19	10/05/21 14:20	63.4	0.50	Loud Vehicle Pass-by
10/05/21 15:02	10/05/21 15:03	74.1	0.75	Emergency Sirens
10/05/21 15:27	10/05/21 15:28	62.0	0.50	Loud Vehicle Pass-by
10/05/21 15:36	10/05/21 15:36	65.3	0.50	Loud Vehicle Pass-by
10/05/21 15:52	10/05/21 15:53	62.3	0.50	Loud Vehicle Pass-by
10/05/21 16:27	10/05/21 16:27	76.6	0.25	Loud Vehicle Pass-by
10/05/21 16:33	10/05/21 16:33	79.6	0.25	Loud Vehicle Pass-by
10/05/21 17:08	10/05/21 17:08	75.7	0.25	Loud Vehicle Pass-by
10/05/21 17:12	10/05/21 17:13	62.1	1.00	Loud Vehicle Pass-by
10/05/21 17:20	10/05/21 17:21	67.6	0.50	Loud Vehicle Pass-by
10/05/21 18:24	10/05/21 18:25	66.0	0.75	Loud Vehicle Pass-by
10/05/21 18:43	10/05/21 18:43	62.8	0.50	Loud Vehicle Pass-by
10/05/21 22:14	10/05/21 22:14	71.2	0.50	Loud Vehicle Pass-by
10/05/21 22:59	10/05/21 22:59	78.2	0.25	Loud Vehicle Pass-by
10/05/21 23:35	10/05/21 23:36	63.5	0.50	Loud Vehicle Pass-by
	Total Time of Data Removed		**28.50**	

Appendix VI WEATHER DATA

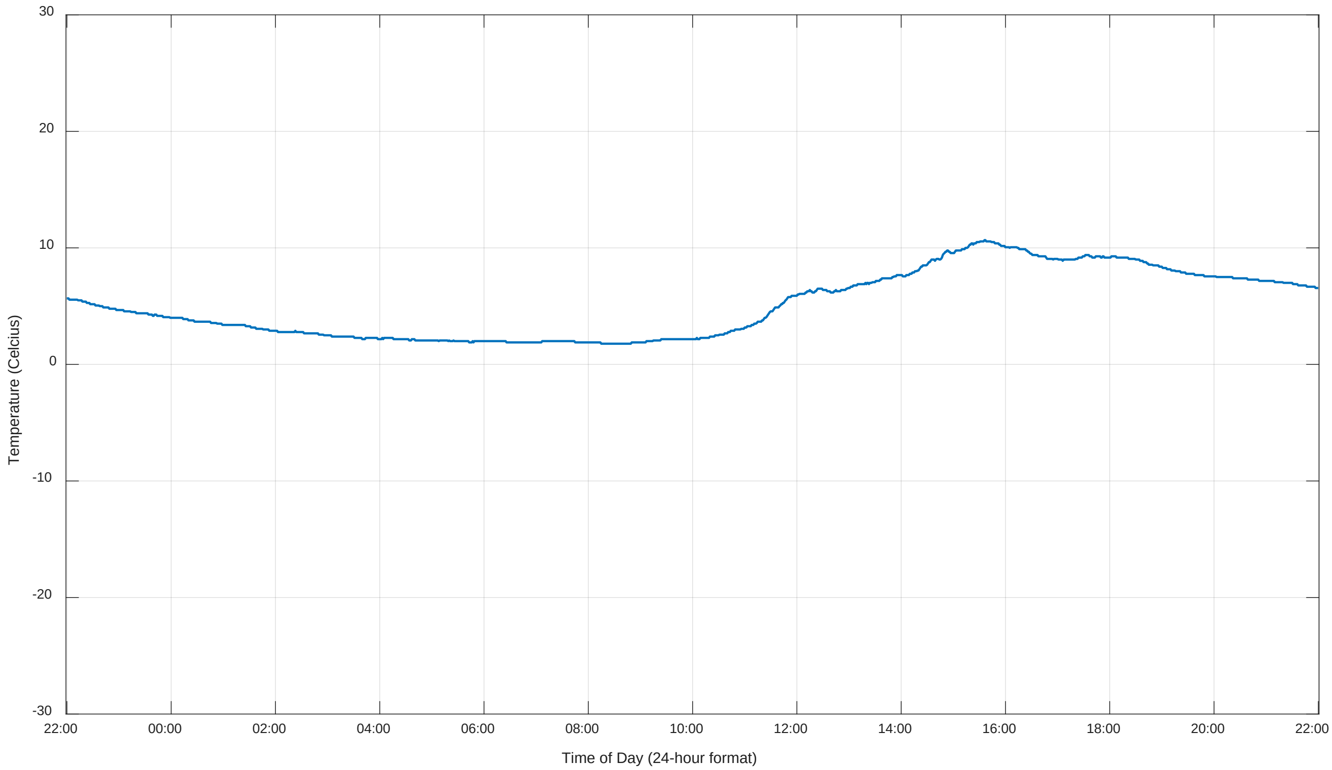


Monitored Wind Speed (October 5 – 6, 2021)

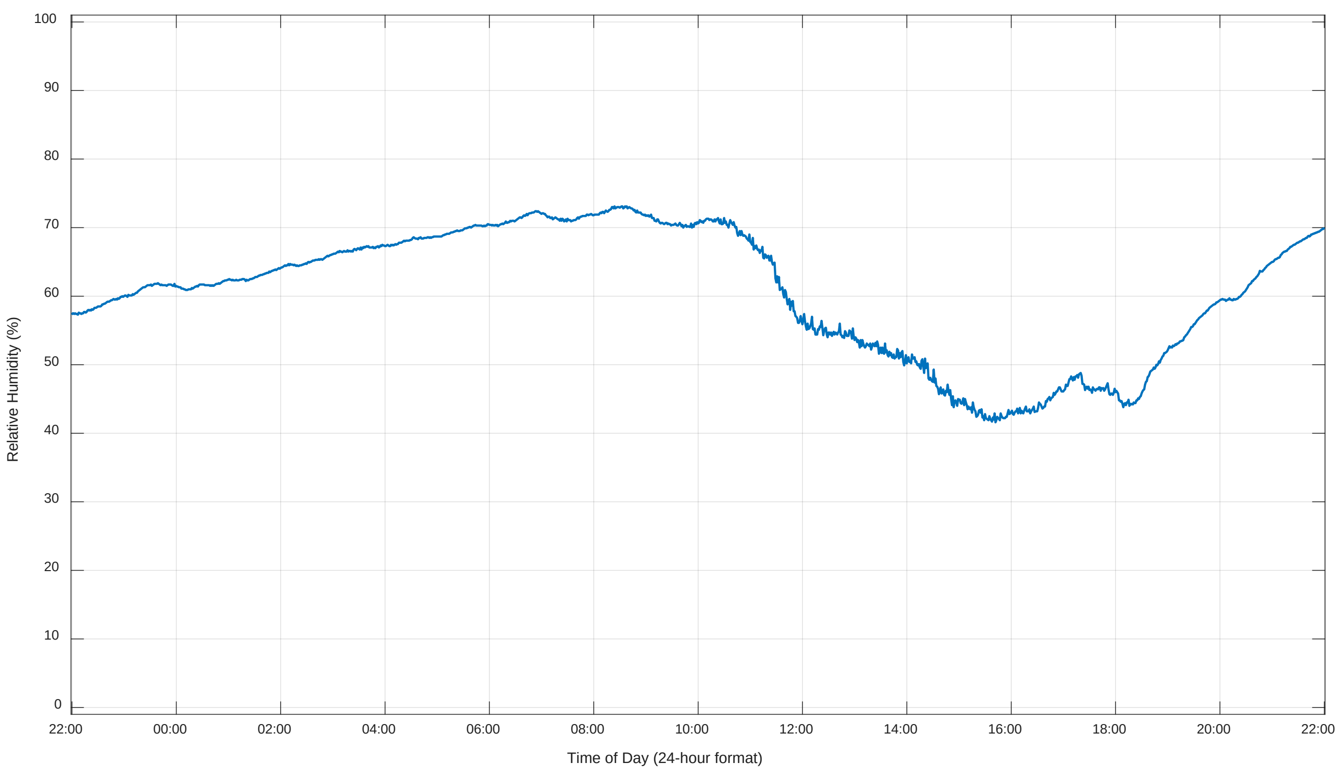


Monitored Wind Direction (October 5 – 6, 2021)

acoustical consultants inc



Monitored Temperature (October 5 – 6, 2021)



Monitored Humidity (October 5 – 6, 2021)