aci Acoustical Consultants Inc.
5031-210 Street
Edmonton, Alberta, Canada T6M 0A8
Phone: (780) 414-6373
www.aciacoustical.com

Environmental Noise Study

For

Southwest Anthony Henday Drive
At
Wedgewood Heights Residential Neighborhood
in
Edmonton, AB

Prepared for:
ISL Engineering and Land Services Ltd.

Prepared by:
S. Bilawchuk, M.Sc., P.Eng.
aci Acoustical Consultants Inc.
Edmonton, Alberta
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Executive Summary

aci Acoustical Consultants Inc., of Edmonton AB, was retained by ISL Engineering and Land Services Ltd. (ISL) to conduct an environmental noise assessment for the Southwest section of Anthony Henday Drive (SWAHD) within the residential neighborhood of Wedgewood Heights, in Edmonton, Alberta. The purpose of the work was to conduct long-term environmental noise monitorings at 2 locations adjacent to the roadway and generate a computer noise model with current and future traffic conditions and compare the results to the Alberta Transportation noise guidelines. In addition, the results are compared to those obtained in 2007[1] and in 2013[2] for the same study area.

The noise monitoring results indicate an increase in the L_{eq}24 noise levels from 2007 to 2013 of 3.3 dBA. This change was the result of the following:

- Increase in traffic volumes (AADT of 30,020 in 2007 and 63,130 in 2013)
- Increased posted speed limit from 90 km/hr (with 70 km/hr zones) to 100 km/hr throughout;
- The addition of the interchange at SWAHD and Lessard Road between 2007 and 2013 (this generally lowers noise levels because it promotes steady traffic flow without start/stop at light controlled intersections).

The noise monitoring results indicate an increase in the L_{eq}24 noise levels from 2013 to 2016 of 3.1 dBA. This change was the result of the following:

- Increase in traffic volumes (AADT of 63,130 in 2007 and approximately 87,300 in 2016)
- Lack of foliage on the trees (relative to the 2013 noise monitoring period)
- Wear and degradation of the road surface

The 1/3 octave band frequency data show the typical trend of low frequency noise (near 63 – 80 Hz) resulting from engines and exhaust, as well as mid-high frequency noise (near 1,000 Hz) resulting from tire noise.

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[1] Data available in the report entitled *"Environmental Noise Survey and Computer Modeling for Southwest Anthony Henday Drive in Edmonton, Alberta"*, prepared for UMA Engineering Ltd., by aci Acoustical Consultants Inc., October, 2007.
[2] Data available in the report entitled *"Environmental Noise Study for Southwest Anthony Henday Drive in Edmonton, Alberta"*, prepared for AECOM, by aci Acoustical Consultants Inc., December, 2013.

The noise modeling results for *Current Conditions* matched well with the noise measurement results with slightly conservative results. The *Current Conditions* modeled noise levels were below the limit of 65 dBA L_{eq}24 at all of the residential receptor locations. The noise modeling results for the *Future Conditions* (with projected traffic volumes for the Year 2027) indicated noise levels which were still below the limit of 65 dBA L_{eq}24 at all residential receptor locations. Finally, a sensitivity analysis of the future traffic volumes, traffic speeds, and % heavy trucks on SWAHD indicated that individual increases to each parameter or increases to all three combined, would still result in noise levels below 65 dBA L_{eq}24 at all locations.

Table of Contents

List of Tables

List of Figures

1.0 Introduction

aci Acoustical Consultants Inc., of Edmonton AB, was retained by ISL Engineering and Land Services Ltd. (ISL) to conduct an environmental noise assessment for the Southwest section of Anthony Henday Drive (SWAHD) within the residential neighborhood of Wedgewood Heights, in Edmonton, Alberta. The purpose of the work was to conduct long-term environmental noise monitorings at 2 locations adjacent to the roadway and generate a computer noise model with current and future traffic conditions and compare the results to the Alberta Transportation noise guidelines. In addition, the results are compared to those obtained in 2007[1] and in 2013[2] for the same study area.

2.0 Location Description

2.1. Roadways

SWAHD spans from Yellowhead Trail in the northwest end of the City to Calgary Trail / Gateway Boulevard in the southeast end of the City. Throughout the entire span (approximately 20 km), SWAHD is a twinned road with at least 2-lanes in each direction. North of Lessard Road, the road surface is comprised of conventional asphalt pavement (ACP). Starting at Lessard Road and continuing southeast, the material used is Portland Cement Concrete Pavement (PCCP) with the exception of the bridges (with asphalt surfaces). This concrete has a screeded surface with the grooves oriented parallel to the direction of traffic flow. The posted speed limit throughout is 100 km/hr. Near the study area, there are currently grade separated interchanges at the following locations:

- Callingwood Road / 62 Avenue (grade separated interchange, new since 2007)
- Lessard Road (grade separated interchange, new since 2007)
- Cameron Heights Drive (grade separated interchange, new since 2007)

2.2. Adjacent Development

The study area is specific to the Wedgewood Heights residential neighborhood (Wedgewood Heights), as indicated in Figure 1. The adjacent roads include SWAHD to the west and south, Lessard Road to the north, and the interchange between SWAHD and Lessard Road to the west and northwest. Relative to SWAHD, the nearest residents are approximately 135 m away. The residential development within

[1] Data available in the report entitled *"Environmental Noise Survey and Computer Modeling for Southwest Anthony Henday Drive in Edmonton, Alberta"*, prepared for UMA Engineering Ltd., by aci Acoustical Consultants Inc., October, 2007.
[2] Data available in the report entitled *"Environmental Noise Study for Southwest Anthony Henday Drive in Edmonton, Alberta"*, prepared for AECOM, by aci Acoustical Consultants Inc., December, 2013.

Wedgewood Heights is comprised of single family detached houses. On the western and southwest portion of Wedgewood Heights, the residential lots back directly onto the Transportation and Utility Corridor (TUC) and SWAHD. Starting from the northwest, there is a 1.83 m (6 ft) wood fence at the rear property line for the residential lots backing onto the TUC. This extends along the western property line until approximately 1634 Welbourn Cove. Further south of this point, the lots have chainlink fences at the rear property line.

2.3. Topography

Topographically, for the northern portion of Wedgewood Heights, the ground is relatively flat in between the western-most residents and SWAHD and Lessard Road. The land is generally covered in tall field grasses. There is a narrow row of trees which extends north-south approximately 42 m west of the residential property lines. During the summer foliage months, this row of trees blocks the line-of-sight to SWAHD. Approximately midway north-south, there is a gap in the trees (approximately 180 m in length) where there is direct line-of-sight to SWAHD. Moving further south, Wedgewood Heights curves to the southeast such that the residential lots back to the southwest. For these areas, there is a berm (approximately 3 m tall) that runs parallel with SWAHD in between SWAHD and the residential lots. Near the south end, there is also the start of a small gully that leads in to the Wedgewood Ravine to the south. There is also a wider area of trees and bushes, blocking the line-of-sight. At the south end of Wedgewood Heights is the Wedgewood Ravine which is approximately 30 m deep and filled with tall trees and bushes.

3.0 Measurement & Modeling Methods

3.1. Environmental Noise Monitoring

As part of the study, two (2) long-term environmental noise monitorings were conducted within the study area, as indicated in Figure 1. The western noise monitor (Location M6) was identical to the location used for the 2007 and 2013 noise studies. The eastern nose monitor (Location M6b) was selected based on consultation with the Wedgewood Heights residential community. A detailed description of each location is provided below. The measurements were conducted collecting broadband A-weighted as well as 1/3-octave band sound levels. This enabled a detailed analysis of the noise climate. The noise monitors collected data for approximately 2-weeks and then the data during appropriate weather and traffic conditions was used to derive the 24-hour noise monitoring results. The noise monitoring data was assessed for weekdays under "typical" traffic conditions. In particular, measurements avoided any holidays, major construction activity that would re-route traffic nearby, and other occurrences which would affect the normal traffic on the road. In addition, the monitorings were conducted in Fall conditions with no foliage on the trees and a very light snow covering that was starting to melt. The road surfaces were dry and there was no precipitation during the period for which the data were assessed. The monitorings were each accompanied by a digital audio recording for more detailed post process analysis. Finally, a portable weather monitor was used within the area to obtain local weather conditions. Refer to Appendix I for a detailed description of the measurement equipment used, 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 each measurement and then checked afterwards to ensure that there had been negligible calibration drift over the duration of the measurement period.

Noise Monitor M6

Noise Monitor M6 was located approximately 810 m south of Lessard Road and 100 m northeast of (perpendicular to) SWAHD (northbound lanes) as shown in Figure 1 and Figure 2. This put the noise monitor approximately 40 m west of the rear fence of the residence at 1644 Welbourn Cove. At this location, there was partial line-of-sight to SWAHD through a row of trees. The 2007 noise monitor was started at 11:00 on Tuesday May 15, 2007 and ran for 24-hours until 11:00 on Wednesday May 16, 2007. The 2013 noise monitor was started at 06:00 on Tuesday August 13, 2013 and ran for 24-hours until 06:00 on Wednesday August 14, 2013. The 2016 noise monitor was started at 12:30 on Thursday September 29, 2016 and ran for approximately 2-weeks until 09:20 on Thursday, October 13, 2016. The assessment data used was from 12:00 on October 11, 2016 until 12:00 on October 12, 2016.

Noise Monitor M6b

Noise Monitor M6b was placed in the backyard at the residence at 1664 Welbourn Cove. The noise monitor was located approximately mid-yard (north-south) at 2 m from the rear property line and with the microphone at a height of 1.2 m as per the Alberta Transportation noise criteria. This placed the noise monitor approximately 890 m south of Lessard Road and 150 m from SWAHD (northbound lanes) as shown in Figure 1 and Figure 3. At this location, there was no line-of-sight to SWAHD due to the trees and topography. The noise monitor was started at 13:30 on Thursday September 29, 2016 and ran for approximately 2-weeks until 10:45 on Thursday, October 13, 2016. The assessment data used was from 12:00 on October 11, 2016 until 12:00 on October 12, 2016.

3.2. Computer Noise Modeling

The computer noise modeling was conducted using the CADNA/A (version 4.6.153) 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 default calculation method for traffic noise in CADNA/A follows the German Standard RLS-90. It is aci's experience that this calculation method is accurate under the conditions present for this study, with a tendency to slightly over-predict potential noise levels (i.e. resulting in conservative values). 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".*

Throughout the study area, the ground was given an absorption coefficient of 0.5. Field grasses and trees were added where appropriate to match existing conditions in addition to providing a calibration of the modeled results compared to the measured results at the various noise monitoring locations. Therefore, all sound level propagation calculations are considered conservatively representative of summertime conditions for all surrounding residents.

Note that not every house in the area was modeled. Only the first row of buildings (in relation to the major roadways) were included, since these are the ones which will have the highest sound levels and will result in the greatest impact and level of shielding for structures further in.

As part of the study, various scenarios were modeled including:

1) *Current Conditions*: This included existing road configurations and traffic volumes present during the noise monitoring (2016). The noise monitoring data was used as a calibration method for the model.
2) *Future Conditions*: This included road configurations and interchanges with projected traffic volumes for the year 2027.
3) *Future Conditions* (as in Item #2) with a sensitivity analysis: This involved modification of various traffic parameters (listed below) to determine their effect on noise levels.
    a. Traffic counts
    b. Traffic speeds
    c. Traffic composition (i.e. % heavy vehicles)
    d. All of (a), (b), and (c) combined

The computer noise modeling results were calculated in two ways. First, sound levels were calculated at specific receiver locations. This included the noise monitor locations as well as numerous representative residential locations. Next, the sound levels were calculated using a 5 m x 5 m grid over the entire study area for the *Current Conditions* and *Future Conditions*. This provided color noise contours for easier visualization of the results.

Refer to Appendix IV for a list of the computer noise modeling parameters.

4.0 Permissible Sound Levels

Environmental noise levels from road traffic 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 criterion used to evaluate the road noise in the study area is based on the document entitled *"Noise Attenuation Guidelines for Provincial Highways Under Provincial Jurisdiction Within Cities and Urban Areas"* by Alberta Transportation. The document specifies:

> *"For construction or improvements of highways through cities and other urban areas, Alberta Transportation will adopt a noise level of 65 dBA L_{eq}24 measured 1.2 m above ground level and 2 meters inside the property line (outside the highway right-of-way). The measurements should be adjusted to the 10-year planning horizon, as a threshold to consider noise mitigation measures"*

As such, the criterion used to assess the noise levels in the computer noise model will be **65 dBA L_{eq}24** for all current dwellings at a height of 1.2 m above grade. All of the residential lots adjacent to the TUC back onto the provincial roadway. Thus, the assessment will be taken at 2 m inside the residential property line in the back-yard amenity space.

5.0 Noise Monitoring Results

5.1. Location M6

Within the 2-week noise monitoring duration, the 24-hour time period which resulted in the most favorable sound propagation conditions (from SWAHD towards the noise monitors) and which resulted in the highest monitored noise levels was from 12:00 on October 11 until 12:00 October 12, 2016. During this time period, the wind was light from the west/southwest/south, there was no precipitation, the road surface was dry, and traffic was flowing continuously with no traffic accidents or other events that would affect the normal flow of traffic. Further, there was no foliage on the trees/bushes and there was partial melting snow cover on the ground. This represents essentially ideal conditions for sound transmission from SWAHD towards the noise monitors.

The results obtained at Location M6 during the 2007, 2013, and 2016 noise monitoring periods are shown in Table 1 and Figures 4a – 4c (broadband A-weighted L_{eq} sound levels provided). It should be noted that the data have been adjusted by the removal of non-typical noise events such as loud aircraft flyovers (the noise modeling and assessment criteria does not account for aircraft), emergency sirens, etc. Refer to Appendix V for a detailed list of the isolated data from the 2016 results.

Table 1. Location M6 Noise Monitoring Results

	L_{eq}24 (dBA)	L_{eq}Day (dBA)	L_{eq}Night (dBA)
May 2007	57.2	58.1	55.1
August 2013	60.5	61.5	58.0
Relative Difference (2013 - 2007)	3.3	3.4	2.9
September 2016	63.6	64.6	61.2
Relative Difference (2016 - 2013)	3.1	3.1	3.3

The noise monitoring results indicate an increase in the L_{eq}24 noise levels from 2007 to 2013 of 3.3 dBA. This change was the result of the following:

- Increase in traffic volumes (AADT of 30,020 in 2007 and 63,130 in 2013)
- Increased posted speed limit from 90 km/hr (with 70 km/hr zones) to 100 km/hr throughout;
- The addition of the interchange at SWAHD and Lessard Road between 2007 and 2013 (this generally lowers noise levels because it promotes steady traffic flow without start/stop at light controlled intersections).

The noise monitoring results indicate an increase in the L_{eq}24 noise levels from 2013 to 2016 of 3.1 dBA. This change was the result of the following:

- Increase in traffic volumes (AADT of 63,130 in 2007 and approximately 87,300 in 2016)
- Lack of foliage on the trees (relative to the 2013 noise monitoring period)
- Wear and degradation of the road surface

In addition to the broadband A-weighted L_{eq} sound levels, the 24-hour 1/3 octave band L_{eq} sound levels are provided in Figure 5. The results show the typical trend of low frequency noise (near 63 – 80 Hz) resulting from engines and exhaust, as well as mid-high frequency noise (near 1,000 Hz) resulting from tire noise. The frequency results confirm the subjective observations that the noise levels being measured by the noise monitorings were largely attributed to SWAHD in addition to the other major roadways (i.e. not from other non-transportation related noise sources). The May 2007 results also show elevated peaks near 5 - 8 kHz which are related to bird chirping nearby (these higher frequency noises did not impact the broadband dBA results within 0.1 dBA). In comparing all three assessment time periods, the largest differences are in the range near 1,000 Hz. As noted previously, from 2007 to 2013, this difference is largely related to the increase in traffic volumes between the two periods. From 2013 to 2016, this difference is related to the increased traffic volumes as well as the lack of foliage on the trees in between SWAHD and the noise monitor location.

5.2. Location M6b

As mentioned previously, within the 2-week noise monitoring duration, the 24-hour time period which resulted in the most favorable sound propagation conditions (from SWAHD towards the noise monitors) and which resulted in the highest monitored noise levels was from 12:00 on October 11 until 12:00 October 12, 2016. The results obtained at Location M6b are shown in Table 2 and Figure 6 (broadband A-weighted L_{eq} sound levels provided). As with Location M6, the data have been adjusted by the removal of non-typical noise events such as loud aircraft flyovers (the noise modeling and assessment criteria does not account for aircraft), emergency sirens, abnormally loud vehicle passages, etc. Refer to Appendix V for a detailed list of the isolated data from the results.

Table 2. Location M6b Noise Monitoring Results

	L_{eq}24 (dBA)	L_{eq}Day (dBA)	L_{eq}Night (dBA)
September 2016	58.4	59.4	55.8

In addition to the broadband A-weighted L_{eq} sound levels, the 24-hour 1/3 octave band L_{eq} sound levels are provided in Figure 7. The results show the typical trend of low frequency noise (near 63 – 80 Hz) resulting from engines and exhaust, as well as mid-high frequency noise (near 1,000 Hz) resulting from tire noise. The frequency results confirm the subjective observations that the noise levels being measured by the noise monitoring were largely attributed to SWAHD in addition to the other major roadways (i.e. not from other non-transportation related noise sources).

5.3. Weather Conditions

The weather conditions during the 2016 noise monitoring assessment period had a light wind from the west/southwest/south throughout. The wind conditions were favourable for the adjacent section of SWAHD towards the noise monitors. The detailed weather data is presented in Appendix VI.

6.0 Noise Modelling Results

6.1. Current Conditions

The results of the noise modeling under *Current Conditions* at the noise monitoring locations are presented in Table 2. The $L_{eq}24$ sound levels are presented as well as the difference in the $L_{eq}24$ sound levels relative to the monitor results at both locations. It can be seen that the modeled sound levels compare very well with the monitored results at both locations with a slightly higher $L_{eq}24$ result in the noise model relative to the measured data, which is conservative.

Table 2. Noise Modeling Results Under *Current Conditions* at Monitor Locations

Monitor	Noise Monitor Results $L_{eq}24$ (dBA)	Noise Model Results $L_{eq}24$ (dBA)	Difference Relative to Monitor Results $L_{eq}24$ (dBA)
M6	63.6	63.7	0.1
M6b	58.4	58.8	0.4

The results of the *Current Conditions* noise modeling at the various residential property locations are presented in Table 3. In addition to the information presented in Table 3, the $L_{eq}24$ color noise contours for the entire study area are shown in Figure 8. The color contours provide a representation of where the "hot" spots are (in terms of elevated noise levels) and the relative contribution from each of the nearby roadways for the various receptor locations. In the event of a discrepancy between the results indicated in the color contours and the Table, the Table will be considered as correct because the calculation locations in the Table are at exact coordinates while the color contours are calculated on a 5m x 5m grid and the results elsewhere are interpolated. Note also that only the first row of houses (relative to SWAHD) were included in the model. Thus, the modeled noise levels further into the neighborhood are a conservative representation because of the lack of additional shielding that would otherwise be provided by the houses further within the neighborhood.

The current noise levels at the adjacent residential property locations ranged from 55.1 dBA to 61.8 dBA and all residential locations within the entire neighbourhood are under the limit of 65 dBA $L_{eq}24$.

Table 3. Noise Modeling Results With *Current* Conditions

Receptor	L_{eq}24 (dBA)		Receptor	L_{eq}24 (dBA)
W-01	58.1		W-35	56.5
W-02	58.1		W-36	56.4
W-03	56.9		W-37	56.6
W-04	57.2		W-38	56.9
W-05	57.0		W-39	57.0
W-06	57.0		W-40	57.0
W-07	57.8		W-41	57.6
W-08	57.1		W-42	57.9
W-09	57.7		W-43	58.5
W-10	58.2		W-44	57.9
W-11	58.4		W-45	58.0
W-12	58.2		W-46	58.1
W-13	56.7		W-47	58.5
W-14	56.1		W-48	61.8
W-15	55.9		W-49	61.7
W-16	55.7		W-50	61.5
W-17	55.5		W-51	61.3
W-18	55.6		W-52	61.1
W-19	55.1		W-53	61.0
W-20	55.3		W-54	60.8
W-21	55.4		W-55	60.4
W-22	55.4		W-56	60.1
W-23	55.4		W-57	60.0
W-24	55.5		W-58	59.8
W-25	55.6		W-59	59.6
W-26	55.6		W-60	59.4
W-27	55.6		W-61	59.2
W-28	55.7		W-62	59.0
W-29	55.9		W-63	58.8
W-30	56.1		W-64	58.7
W-31	56.1		W-65	58.6
W-32	56.0		W-66	58.4
W-33	56.1		W-67	58.5
W-34	56.5		W-68	58.4

6.2. *Future Conditions*

The results of the noise modeling under *Future Conditions* (Year 2027) at the residential receptor locations are presented in Table 4 and shown in Figure 9. The $L_{eq}24$, sound levels are presented along with the relative increase compared to the *Current Conditions*. As with the *Current Conditions*, in the event of a discrepancy between the results indicated in the color contours and the Table, the Table will be considered as correct. The *Future Conditions* noise modeling indicates noise levels below 65 dBA $L_{eq}24$ at all locations. The increases relative to the *Current Conditions* ranged from +0.3 to +0.8 dBA which were due to the projected increases in traffic volumes on SWAHD and adjacent City Roads.

Table 4. Noise Modeling Results With *Future Conditions*

Receptor	$L_{eq}24$ (dBA)	$L_{eq}24$ Increase Relative to Current Conditions (dBA)		Receptor	$L_{eq}24$ (dBA)	$L_{eq}24$ Increase Relative to Current Conditions (dBA)
W-01	58.9	0.8		W-35	56.8	0.3
W-02	58.9	0.8		W-36	56.8	0.4
W-03	57.7	0.8		W-37	56.9	0.3
W-04	58.0	0.8		W-38	57.3	0.4
W-05	57.8	0.8		W-39	57.4	0.4
W-06	57.7	0.7		W-40	57.4	0.4
W-07	58.5	0.7		W-41	57.9	0.3
W-08	57.8	0.7		W-42	58.2	0.3
W-09	58.4	0.7		W-43	58.9	0.4
W-10	58.9	0.7		W-44	58.2	0.3
W-11	59.1	0.7		W-45	58.4	0.4
W-12	58.9	0.7		W-46	58.4	0.3
W-13	57.3	0.6		W-47	58.8	0.3
W-14	56.5	0.4		W-48	62.2	0.4
W-15	56.3	0.4		W-49	62.1	0.4
W-16	56.1	0.4		W-50	61.9	0.4
W-17	55.9	0.4		W-51	61.7	0.4
W-18	56.0	0.4		W-52	61.5	0.4
W-19	55.4	0.3		W-53	61.3	0.3
W-20	55.7	0.4		W-54	61.2	0.4
W-21	55.7	0.3		W-55	60.8	0.4
W-22	55.7	0.3		W-56	60.4	0.3
W-23	55.8	0.4		W-57	60.3	0.3
W-24	55.9	0.4		W-58	60.1	0.3
W-25	55.9	0.3		W-59	59.9	0.3
W-26	55.9	0.3		W-60	59.7	0.3
W-27	56.0	0.4		W-61	59.5	0.3
W-28	56.1	0.4		W-62	59.4	0.4
W-29	56.3	0.4		W-63	59.2	0.4
W-30	56.4	0.3		W-64	59.0	0.3
W-31	56.4	0.3		W-65	58.9	0.3
W-32	56.3	0.3		W-66	58.7	0.3
W-33	56.5	0.4		W-67	58.8	0.3
W-34	56.9	0.4		W-68	58.7	0.3

6.3. *Future Conditions* Sensitivity Analysis

As part of the study, a sensitivity analysis was performed for the main future (2027) traffic parameters associated with SWAHD. These included the overall traffic volumes, the traffic speeds, and the % heavy trucks. Each was evaluated with an increase and a decrease relative to the *Future Conditions* modeled. In addition, the cumulative impact of an increase and a decrease in all three variables was assessed.

6.3.1. Traffic Volume Analysis

As with any noise source, the relative change in noise level with changing quantity is a simple logarithmic function as indicated below:

$$\Delta SPL = 10\log_{10}\left(relative\ change\right)$$

This means that if the traffic volumes, for example, are doubled, there will be a 3.0 dBA increase. **If there is a relative increase in traffic volumes of 25%, there will be a relative maximum 1.0 dBA increase for locations in which the noise climate is entirely dominated by SWAHD (i.e. relative to other City Roadways). Conversely, there is a maximum relative decrease of -1.3 dBA for a relative reduction in traffic volumes of 25%.** At locations in which the noise climate has a greater influence by City Roadways, changes in traffic volumes on SWAHD will have less of an impact. Table 5 shows the $L_{eq}24$ results for the ± 25% vehicles per day conditions as well as the relative change in noise levels at all modeled receptor locations. <u>The relative increase in noise levels from a relative increase of 25% in traffic volumes on SWAHD would still result in noise levels below 65 dBA $L_{eq}24$ at all locations.</u>

As an aside, typical traffic volumes on typical urban roads only vary a few percent from day-to-day. This means that changes in noise levels from day-to-day are almost entirely dictated by environmental and meteorological conditions, and not by varying traffic volumes.

Table 5. Effects of Changing AHD Traffic Volumes

Receptor	L_{eq}24 with +25% Vehicles Per Day (dBA)	Increase Relative to *Future* Vehicles Per Day (dBA)	L_{eq}24 with -25% Vehicles Per Day (dBA)	Decrease Relative to *Future* Vehicles Per Day (dBA)	Receptor	L_{eq}24 with +25% Vehicles Per Day (dBA)	Increase Relative to *Future* Vehicles Per Day (dBA)	L_{eq}24 with -25% Vehicles Per Day (dBA)	Decrease Relative to *Future* Vehicles Per Day (dBA)
W-01	59.1	0.2	58.7	-0.2	W-35	57.7	0.9	55.7	-1.1
W-02	59.2	0.3	58.7	-0.2	W-36	57.7	0.9	55.7	-1.1
W-03	57.9	0.2	57.5	-0.2	W-37	57.8	0.9	55.8	-1.1
W-04	58.2	0.2	57.7	-0.3	W-38	58.2	0.9	56.1	-1.2
W-05	58.0	0.2	57.5	-0.3	W-39	58.3	0.9	56.2	-1.2
W-06	58.0	0.3	57.4	-0.3	W-40	58.3	0.9	56.3	-1.1
W-07	58.8	0.3	58.1	-0.4	W-41	58.8	0.9	56.7	-1.2
W-08	58.1	0.3	57.5	-0.3	W-42	59.1	0.9	57.1	-1.1
W-09	58.8	0.4	58.0	-0.4	W-43	59.8	0.9	57.7	-1.2
W-10	59.2	0.3	58.5	-0.4	W-44	59.1	0.9	57.0	-1.2
W-11	59.5	0.4	58.6	-0.5	W-45	59.3	0.9	57.2	-1.2
W-12	59.3	0.4	58.5	-0.4	W-46	59.4	1.0	57.3	-1.1
W-13	57.8	0.5	56.6	-0.7	W-47	59.8	1.0	57.7	-1.1
W-14	57.2	0.7	55.7	-0.8	W-48	63.1	0.9	61.0	-1.2
W-15	57.0	0.7	55.4	-0.9	W-49	63.0	0.9	60.9	-1.2
W-16	56.8	0.7	55.2	-0.9	W-50	62.8	0.9	60.7	-1.2
W-17	56.7	0.8	55.0	-0.9	W-51	62.6	0.9	60.5	-1.2
W-18	56.8	0.8	55.1	-0.9	W-52	62.4	0.9	60.3	-1.2
W-19	56.2	0.8	54.5	-0.9	W-53	62.3	1.0	60.1	-1.2
W-20	56.5	0.8	54.7	-1.0	W-54	62.1	0.9	60.0	-1.2
W-21	56.5	0.8	54.7	-1.0	W-55	61.7	0.9	59.6	-1.2
W-22	56.5	0.8	54.7	-1.0	W-56	61.4	1.0	59.2	-1.2
W-23	56.6	0.8	54.8	-1.0	W-57	61.2	0.9	59.1	-1.2
W-24	56.7	0.8	54.8	-1.1	W-58	61.1	1.0	58.9	-1.2
W-25	56.7	0.8	54.9	-1.0	W-59	60.9	1.0	58.7	-1.2
W-26	56.8	0.9	54.9	-1.0	W-60	60.7	1.0	58.5	-1.2
W-27	56.8	0.8	54.9	-1.1	W-61	60.5	1.0	58.3	-1.2
W-28	56.9	0.8	55.0	-1.1	W-62	60.3	0.9	58.1	-1.3
W-29	57.1	0.8	55.2	-1.1	W-63	60.1	0.9	58.0	-1.2
W-30	57.3	0.9	55.3	-1.1	W-64	60.0	1.0	57.8	-1.2
W-31	57.3	0.9	55.3	-1.1	W-65	59.9	1.0	57.7	-1.2
W-32	57.2	0.9	55.3	-1.0	W-66	59.7	1.0	57.5	-1.2
W-33	57.3	0.8	55.4	-1.1	W-67	59.8	1.0	57.6	-1.2
W-34	57.8	0.9	55.7	-1.2	W-68	59.7	1.0	57.5	-1.2

6.3.2. Traffic Speed Analysis

In order to determine the effect of different traffic speeds, two scenarios were modeled. The *Future Conditions* case included a speed of 100 km/hr on SWAHD throughout the entire study area. This speed was increased to 110 km/hr and then decreased to 90 km/hr to determine the relative change compared to 100 km/hr. It is unlikely that the posted traffic speeds will fall outside of this range. Table 6 shows the L_{eq}24 results for both the 110 km/hr and 90 km/hr conditions as well as the change in noise levels (relative to 100 km/hr) at all modeled receptor locations. **When increasing the speed to 110 km/hr, the noise levels increased by 0.1 to 0.6 dBA. When reducing the speed to 90 km/hr, the noise levels decreased by 0.1 to 0.6 dBA.** As with the traffic volumes assessment, the largest changes were at locations where the noise climate was completely dominated by the noise from SWAHD. The locations with the lowest changes were those where the noise climate was dominated by City Roads. The relative increase in noise levels from a speed increase to 110 km/hr on SWAHD would still result in noise levels below 65 dBA L_{eq}24 at all locations.

Table 6. Effects of Changing AHD Traffic Speed

Receptor	L_{eq}24 with 110 km/hr on AHD (dBA)	Increase Compared to 100 km/hr (dBA)	L_{eq}24 with 90 km/hr on AHD (dBA)	Decrease Compared to 100 km/hr (dBA)	Receptor	L_{eq}24 with 110 km/hr on AHD (dBA)	Increase Compared to 100 km/hr (dBA)	L_{eq}24 with 90 km/hr on AHD (dBA)	Decrease Compared to 100 km/hr (dBA)
W-01	59.0	0.1	58.8	-0.1	W-35	57.4	0.6	56.3	-0.5
W-02	59.1	0.2	58.8	-0.1	W-36	57.3	0.5	56.3	-0.5
W-03	57.8	0.1	57.6	-0.1	W-37	57.5	0.6	56.5	-0.4
W-04	58.1	0.1	57.9	-0.1	W-38	57.8	0.5	56.8	-0.5
W-05	57.9	0.1	57.6	-0.2	W-39	57.9	0.5	56.8	-0.6
W-06	57.9	0.2	57.6	-0.1	W-40	57.9	0.5	56.9	-0.5
W-07	58.7	0.2	58.3	-0.2	W-41	58.5	0.6	57.4	-0.5
W-08	58.0	0.2	57.6	-0.2	W-42	58.8	0.6	57.7	-0.5
W-09	58.6	0.2	58.2	-0.2	W-43	59.4	0.5	58.4	-0.5
W-10	59.1	0.2	58.7	-0.2	W-44	58.8	0.6	57.7	-0.5
W-11	59.3	0.2	58.9	-0.2	W-45	58.9	0.5	57.9	-0.5
W-12	59.2	0.3	58.7	-0.2	W-46	59.0	0.6	57.9	-0.5
W-13	57.6	0.3	57.0	-0.3	W-47	59.4	0.6	58.3	-0.5
W-14	56.9	0.4	56.2	-0.3	W-48	62.7	0.5	61.6	-0.6
W-15	56.7	0.4	55.9	-0.4	W-49	62.6	0.5	61.5	-0.6
W-16	56.6	0.5	55.7	-0.4	W-50	62.4	0.5	61.3	-0.6
W-17	56.4	0.5	55.5	-0.4	W-51	62.3	0.6	61.2	-0.5
W-18	56.5	0.5	55.6	-0.4	W-52	62.1	0.6	61.0	-0.5
W-19	55.9	0.5	55.0	-0.4	W-53	61.9	0.6	60.8	-0.5
W-20	56.2	0.5	55.3	-0.4	W-54	61.8	0.6	60.6	-0.6
W-21	56.2	0.5	55.3	-0.4	W-55	61.4	0.6	60.3	-0.5
W-22	56.2	0.5	55.3	-0.4	W-56	61.0	0.6	59.9	-0.5
W-23	56.3	0.5	55.3	-0.5	W-57	60.9	0.6	59.8	-0.5
W-24	56.4	0.5	55.4	-0.5	W-58	60.7	0.6	59.6	-0.5
W-25	56.4	0.5	55.4	-0.5	W-59	60.5	0.6	59.4	-0.5
W-26	56.4	0.5	55.5	-0.4	W-60	60.3	0.6	59.2	-0.5
W-27	56.5	0.5	55.5	-0.5	W-61	60.1	0.6	59.0	-0.5
W-28	56.6	0.5	55.6	-0.5	W-62	59.9	0.5	58.8	-0.6
W-29	56.8	0.5	55.8	-0.5	W-63	59.8	0.6	58.6	-0.6
W-30	57.0	0.6	55.9	-0.5	W-64	59.6	0.6	58.5	-0.5
W-31	56.9	0.5	55.9	-0.5	W-65	59.5	0.6	58.4	-0.5
W-32	56.9	0.6	55.9	-0.4	W-66	59.3	0.6	58.2	-0.5
W-33	57.0	0.5	56.0	-0.5	W-67	59.4	0.6	58.3	-0.5
W-34	57.4	0.5	56.4	-0.5	W-68	59.3	0.6	58.2	-0.5

6.3.3. % Heavy Trucks Analysis

In order to determine the effect of varying % heavy trucks, two scenarios were modeled. The *future conditions* were increased by 5% and then decreased by 5% to determine a relative range of values. It is unlikely that the % heavy trucks will fall outside of this range. The results are shown in Table 7. It can be seen that **the relative sound level increase with a relative increase of 5% heavy trucks is approximately 0.2 to 0.9 dBA. The relative sound level decrease with a relative decrease of 5% heavy trucks is approximately 0.2 to 1.1 dBA.** As with the traffic volumes and traffic speeds assessments, the largest changes were at locations where the noise climate was completely dominated by the noise from SWAHD. The locations with the lowest changes were those where the noise climate was dominated by City Roads. The relative increase in noise levels with a relative increase of 5% heavy trucks on SWAHD would still result in noise levels below 65 dBA L_{eq}24 at all locations.

In general, the effect of changing the % heavy trucks is inversely logarithmic. For example, the difference between 0% and 1% is significant (approximately 0.7 dBA) while the difference between 10% and 11% is much less (approximately 0.2 dBA). Since the % heavy trucks is at least 9% along the entire SWAHD, small % changes in heavy trucks will not have a significant impact.

Table 7. Effects of Changing AHD % Heavy Trucks

Receptor	L_{eq}24 with 5% Greater Heavy Trucks on AHD (dBA)	Increase Compared to *Future Conditions* (dBA)		L_{eq}24 with 5% Fewer Heavy Trucks on AHD (dBA)	Decrease Compared to *Future Conditions* (dBA)		Receptor	L_{eq}24 with 5% Greater Heavy Trucks on AHD (dBA)	Increase Compared to *Future Conditions* (dBA)		L_{eq}24 with 5% Fewer Heavy Trucks on AHD (dBA)	Decrease Compared to *Future Conditions* (dBA)
W-01	59.1	0.2		58.7	-0.2		W-35	57.6	0.8		55.9	-0.9
W-02	59.1	0.2		58.7	-0.2		W-36	57.6	0.8		55.8	-1.0
W-03	57.9	0.2		57.5	-0.2		W-37	57.8	0.9		55.9	-1.0
W-04	58.2	0.2		57.7	-0.3		W-38	58.1	0.8		56.3	-1.0
W-05	58.0	0.2		57.5	-0.3		W-39	58.2	0.8		56.3	-1.1
W-06	58.0	0.3		57.4	-0.3		W-40	58.2	0.8		56.4	-1.0
W-07	58.8	0.3		58.1	-0.4		W-41	58.7	0.8		56.9	-1.0
W-08	58.1	0.3		57.5	-0.3		W-42	59.0	0.8		57.2	-1.0
W-09	58.8	0.4		58.1	-0.3		W-43	59.7	0.8		57.9	-1.0
W-10	59.2	0.3		58.6	-0.3		W-44	59.0	0.8		57.2	-1.0
W-11	59.4	0.3		58.7	-0.4		W-45	59.2	0.8		57.3	-1.1
W-12	59.3	0.4		58.6	-0.3		W-46	59.3	0.9		57.4	-1.0
W-13	57.8	0.5		56.7	-0.6		W-47	59.7	0.9		57.8	-1.0
W-14	57.1	0.6		55.8	-0.7		W-48	63.0	0.8		61.1	-1.1
W-15	56.9	0.6		55.5	-0.8		W-49	62.9	0.8		61.0	-1.1
W-16	56.8	0.7		55.3	-0.8		W-50	62.7	0.8		60.8	-1.1
W-17	56.6	0.7		55.1	-0.8		W-51	62.5	0.8		60.6	-1.1
W-18	56.7	0.7		55.2	-0.8		W-52	62.3	0.8		60.4	-1.1
W-19	56.1	0.7		54.6	-0.8		W-53	62.2	0.9		60.2	-1.1
W-20	56.4	0.7		54.8	-0.9		W-54	62.0	0.8		60.1	-1.1
W-21	56.5	0.8		54.8	-0.9		W-55	61.7	0.9		59.7	-1.1
W-22	56.5	0.8		54.8	-0.9		W-56	61.3	0.9		59.4	-1.0
W-23	56.5	0.7		54.9	-0.9		W-57	61.2	0.9		59.2	-1.1
W-24	56.6	0.7		55.0	-0.9		W-58	61.0	0.9		59.1	-1.0
W-25	56.7	0.8		55.0	-0.9		W-59	60.8	0.9		58.9	-1.0
W-26	56.7	0.8		55.0	-0.9		W-60	60.6	0.9		58.6	-1.1
W-27	56.8	0.8		55.1	-0.9		W-61	60.4	0.9		58.4	-1.1
W-28	56.8	0.7		55.1	-1.0		W-62	60.2	0.8		58.3	-1.1
W-29	57.0	0.7		55.3	-1.0		W-63	60.0	0.8		58.1	-1.1
W-30	57.2	0.8		55.5	-0.9		W-64	59.9	0.9		58.0	-1.0
W-31	57.2	0.8		55.4	-1.0		W-65	59.8	0.9		57.8	-1.1
W-32	57.1	0.8		55.4	-0.9		W-66	59.6	0.9		57.6	-1.1
W-33	57.3	0.8		55.5	-1.0		W-67	59.7	0.9		57.7	-1.1
W-34	57.7	0.8		55.9	-1.0		W-68	59.6	0.9		57.7	-1.0

6.3.4. Cumulative Sensitivity Analysis

With the information provided by the sensitivity analysis for each of the three main traffic parameters, it is possible to determine a cumulative effect if all three are taken into account simultaneously. The results are presented in Table 8. It can be seen that **the relative sound level increase with 25% more traffic on SWAHD, a speed of 110 km/hr, and a relative increase of 5% heavy trucks is approximately 0.6 to 2.3 dBA. The relative sound level decrease with 25% less traffic, a speed of 90 km/hr, and a relative decrease of 5% heavy trucks is approximately 0.5 to 3.1 dBA.** At locations in which the noise climate is most directly impacted by City roadways, the increases are as low as 0.6 dBA. The relative increase in noise levels associated with a relative increase of 25% traffic volumes, 5% heavy trucks and a speed of 110 km/hr on SWAHD would still result in noise levels below 65 dBA L_{eq}24 at all locations.

Table 8. Effects of Cumulative Effects on Noise Levels

Receptor	L_{eq}24 with 25% Additional Vehicles, Speed of 110 km/hr, 5% Greater Heavy Trucks on AHD (dBA)	Increase Compared to *Future Conditions* (dBA)		L_{eq}24 with 25% Fewer Vehicles, Speed of 90 km/hr, 5% Fewer Heavy Trucks on AHD (dBA)	Decrease Compared to *Future Conditions* (dBA)		Receptor	L_{eq}24 with 25% Additional Vehicles, Speed of 110 km/hr, 5% Greater Heavy Trucks on AHD (dBA)	Increase Compared to *Future Conditions* (dBA)		L_{eq}24 with 25% Fewer Vehicles, Speed of 90 km/hr, 5% Fewer Heavy Trucks on AHD (dBA)	Decrease Compared to *Future Conditions* (dBA)
W-01	59.5	0.6		58.4	-0.5		W-35	59.0	2.2		54.1	-2.7
W-02	59.5	0.6		58.4	-0.5		W-36	58.9	2.1		54.1	-2.7
W-03	58.3	0.6		57.2	-0.5		W-37	59.1	2.2		54.2	-2.7
W-04	58.7	0.7		57.4	-0.6		W-38	59.4	2.1		54.5	-2.8
W-05	58.5	0.7		57.1	-0.7		W-39	59.5	2.1		54.6	-2.8
W-06	58.5	0.8		57.1	-0.6		W-40	59.5	2.1		54.6	-2.8
W-07	59.4	0.9		57.6	-0.9		W-41	60.1	2.2		55.1	-2.8
W-08	58.6	0.8		57.1	-0.7		W-42	60.4	2.2		55.4	-2.8
W-09	59.4	1.0		57.6	-0.8		W-43	61.0	2.1		56.0	-2.9
W-10	59.8	0.9		58.1	-0.8		W-44	60.4	2.2		55.4	-2.8
W-11	60.1	1.0		58.1	-1.0		W-45	60.6	2.2		55.5	-2.9
W-12	59.9	1.0		58.0	-0.9		W-46	60.7	2.3		55.6	-2.8
W-13	58.7	1.4		55.8	-1.5		W-47	61.1	2.3		55.9	-2.9
W-14	58.2	1.7		54.7	-1.8		W-48	64.4	2.2		59.2	-3.0
W-15	58.0	1.7		54.3	-2.0		W-49	64.3	2.2		59.1	-3.0
W-16	57.9	1.8		54.0	-2.1		W-50	64.1	2.2		58.9	-3.0
W-17	57.8	1.9		53.8	-2.1		W-51	63.9	2.2		58.7	-3.0
W-18	57.9	1.9		53.8	-2.2		W-52	63.7	2.2		58.5	-3.0
W-19	57.3	1.9		53.2	-2.2		W-53	63.6	2.3		58.3	-3.0
W-20	57.7	2.0		53.3	-2.4		W-54	63.4	2.2		58.2	-3.0
W-21	57.7	2.0		53.3	-2.4		W-55	63.1	2.3		57.8	-3.0
W-22	57.7	2.0		53.3	-2.4		W-56	62.7	2.3		57.4	-3.0
W-23	57.8	2.0		53.3	-2.5		W-57	62.6	2.3		57.3	-3.0
W-24	57.9	2.0		53.4	-2.5		W-58	62.4	2.3		57.1	-3.0
W-25	57.9	2.0		53.4	-2.5		W-59	62.2	2.3		56.9	-3.0
W-26	58.0	2.1		53.4	-2.5		W-60	62.0	2.3		56.7	-3.0
W-27	58.0	2.0		53.5	-2.5		W-61	61.8	2.3		56.5	-3.0
W-28	58.1	2.0		53.5	-2.6		W-62	61.6	2.2		56.3	-3.1
W-29	58.3	2.0		53.7	-2.6		W-63	61.5	2.3		56.1	-3.1
W-30	58.5	2.1		53.8	-2.6		W-64	61.3	2.3		56.0	-3.0
W-31	58.5	2.1		53.8	-2.6		W-65	61.2	2.3		55.9	-3.0
W-32	58.4	2.1		53.7	-2.6		W-66	61.0	2.3		55.7	-3.0
W-33	58.6	2.1		53.8	-2.7		W-67	61.1	2.3		55.8	-3.0
W-34	59.0	2.1		54.1	-2.8		W-68	61.0	2.3		55.7	-3.0

7.0 Conclusion

Noise Monitoring

The noise monitoring results indicate an increase in the L_{eq}24 noise levels from 2007 to 2013 of 3.3 dBA. This change was the result of the following:

- Increase in traffic volumes (AADT of 30,020 in 2007 and 63,130 in 2013)
- Increased posted speed limit from 90 km/hr (with 70 km/hr zones) to 100 km/hr throughout;
- The addition of the interchange at SWAHD and Lessard Road between 2007 and 2013 (this generally lowers noise levels because it promotes steady traffic flow without start/stop at light controlled intersections).

The noise monitoring results indicate an increase in the L_{eq}24 noise levels from 2013 to 2016 of 3.1 dBA. This change was the result of the following:

- Increase in traffic volumes (AADT of 63,130 in 2007 and approximately 87,300 in 2016)
- Lack of foliage on the trees (relative to the 2013 noise monitoring period)
- Wear and degradation of the road surface

The 1/3 octave band frequency data show the typical trend of low frequency noise (near 63 – 80 Hz) resulting from engines and exhaust, as well as mid-high frequency noise (near 1,000 Hz) resulting from tire noise.

Noise Modeling

The noise modeling results for *Current Conditions* matched well with the noise measurement results with a slightly conservative result. The *Current Conditions* modeled noise levels were below the limit of 65 dBA L_{eq}24 at all of the residential receptor locations. The noise modeling results for the *Future Conditions* (with projected traffic volumes for the Year 2027) indicated noise levels which were still below the limit of 65 dBA L_{eq}24 at all residential receptor locations. Finally, a sensitivity analysis of the future traffic volumes, traffic speeds, and % heavy trucks on SWAHD indicated that individual increases to each parameter or increases to all three combined, would still result in noise levels below 65 dBA L_{eq}24 at all locations.

8.0 References

- *"Noise Attenuation Guidelines for Provincial Highways Under Provincial Jurisdiction Within Cities and Urban Areas"*, by Alberta Transportation. October, 2002.
- *Environmental Noise Survey and Computer Modeling for Southwest Anthony Henday Drive in Edmonton, Alberta*, prepared for UMA Engineering Ltd., by aci Acoustical Consultants Inc., October, 2007.
- *Environmental Noise Study for Southwest Anthony Henday Drive in Edmonton, Alberta*, prepared for AECOM, by aci Acoustical Consultants Inc., December, 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

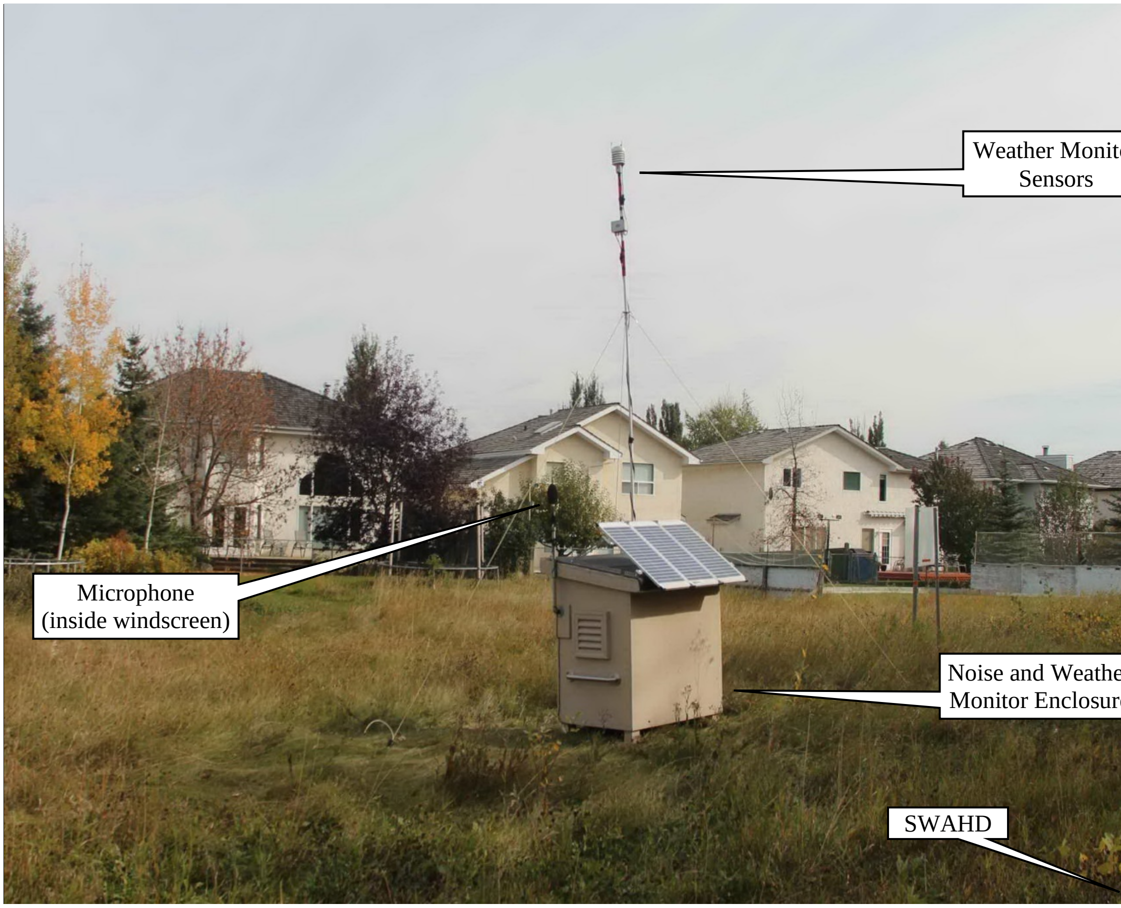

Figure 2. Noise Monitor at Location M6

Figure 3. Noise Monitor at Location M6b

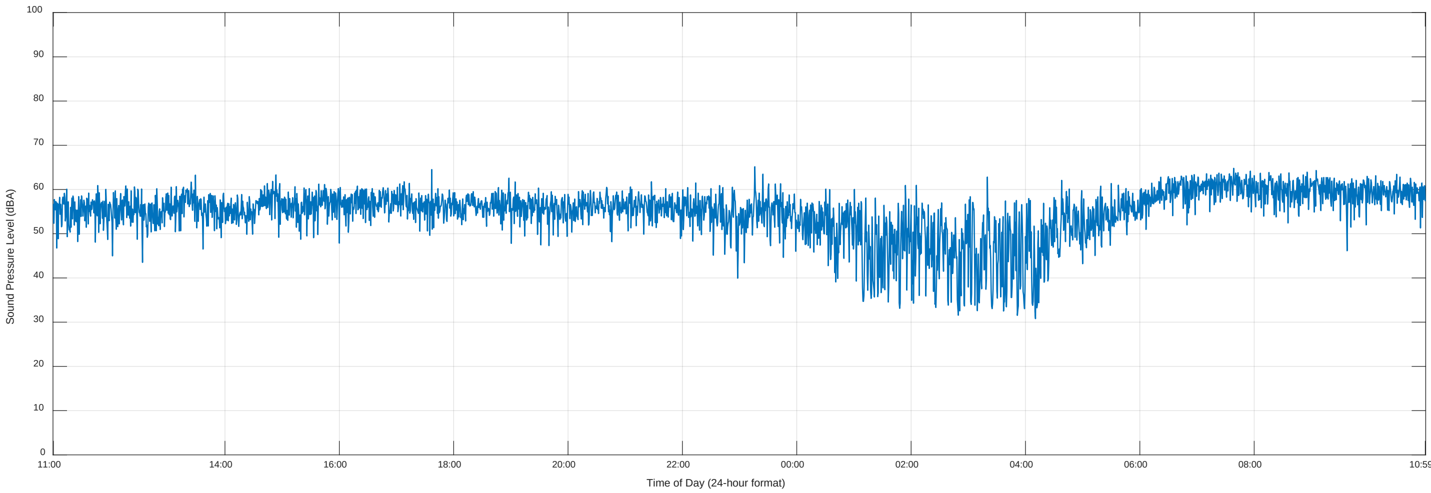

Figure 4a. 24-Hour Broadband A-Weighted L_{eq} Sound Levels at Monitor Location M6 (2007)

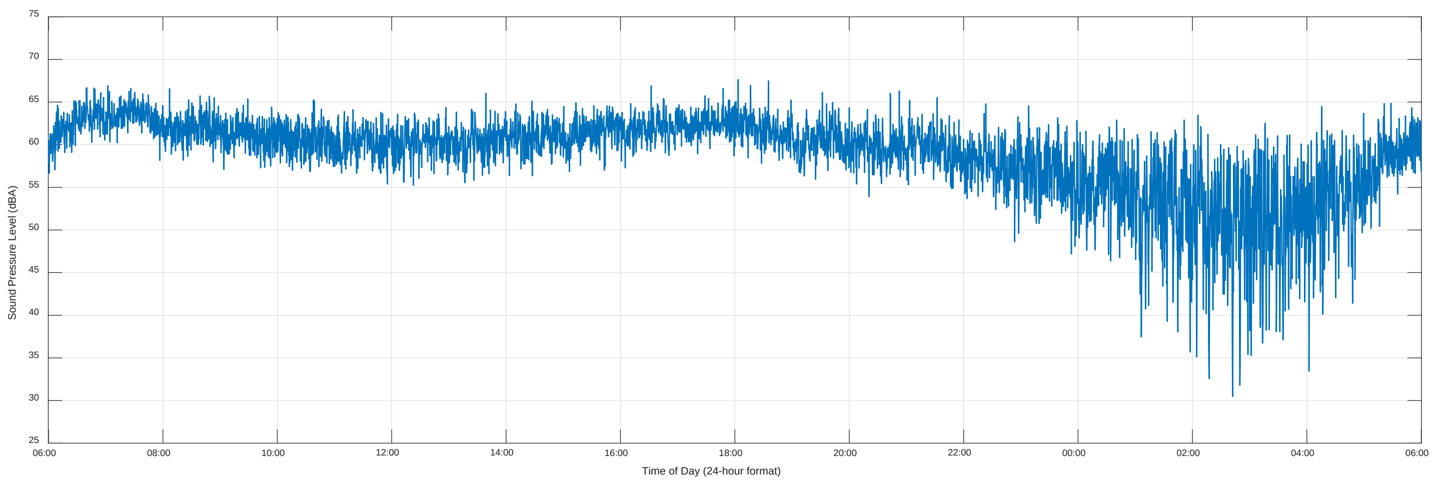

Figure 4b. 24-Hour Broadband A-Weighted L_{eq} Sound Levels at Monitor Location M6 (2013)

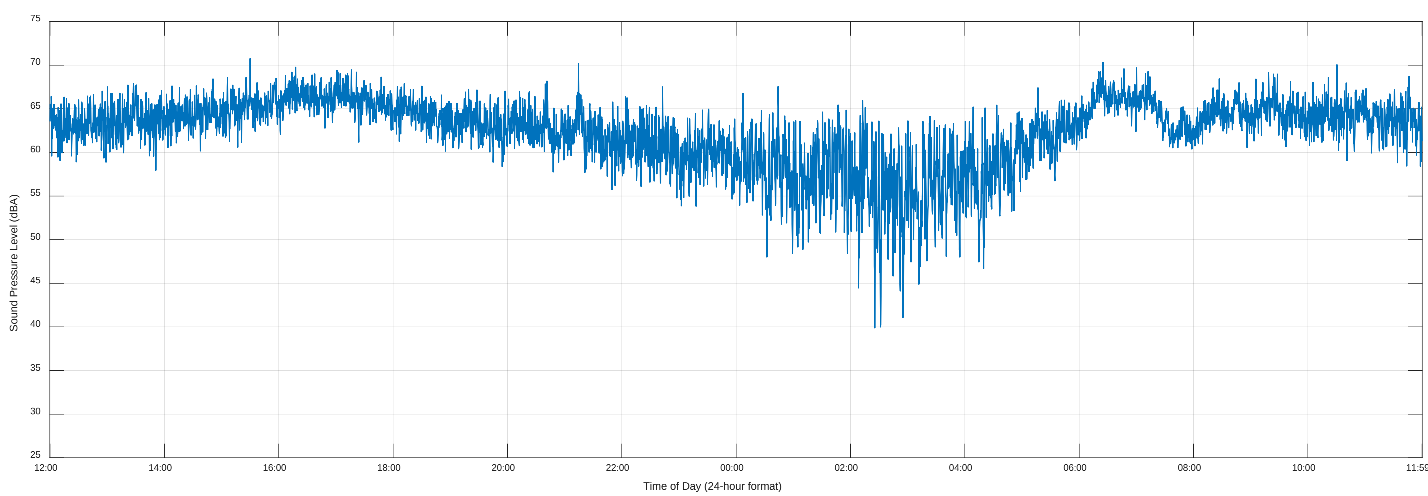

Figure 4c. 24-Hour Broadband A-Weighted L_{eq} Sound Levels at Monitor Location M6 (2016)

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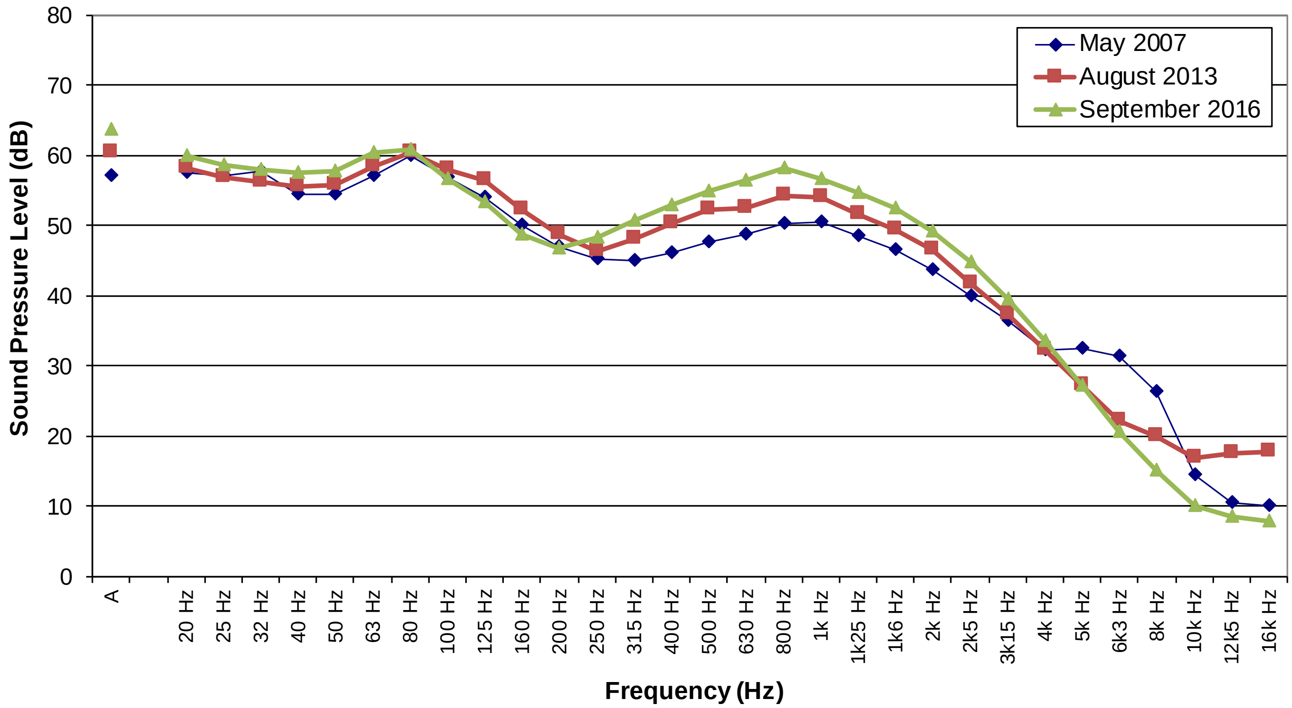

Figure 5. 24-Hour 1/3 Octave Band L_{eq} Sound Levels at Monitor Location M6 (2007, 2013, 2016)

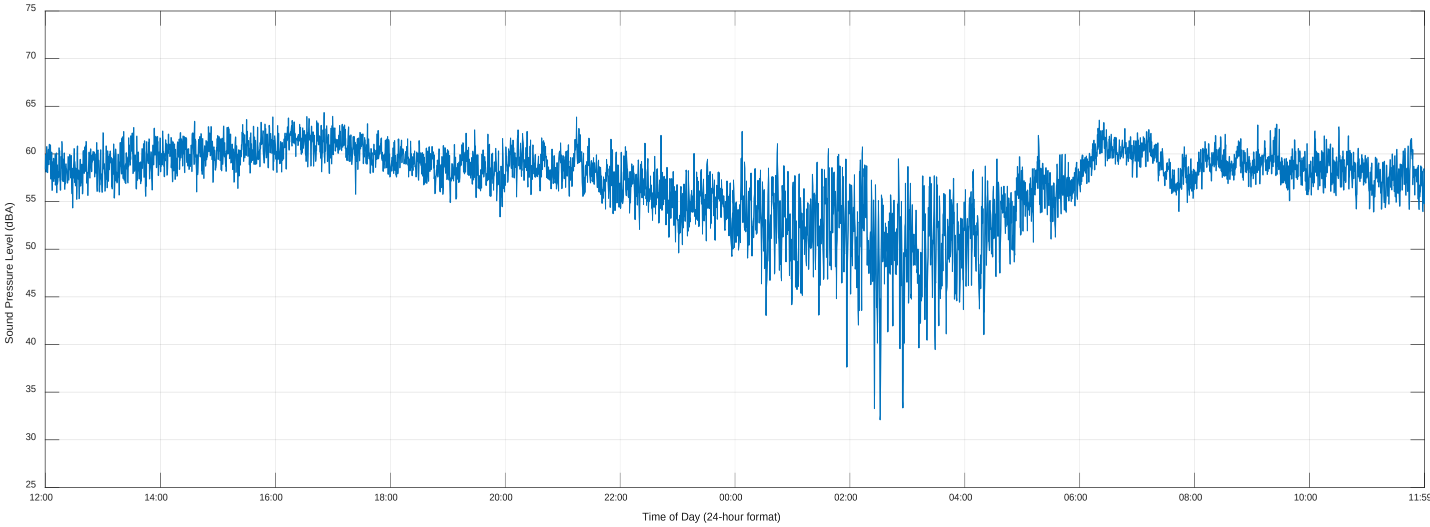

Figure 6. 24-Hour Broadband A-Weighted L_{eq} Sound Levels at Monitor Location M6b

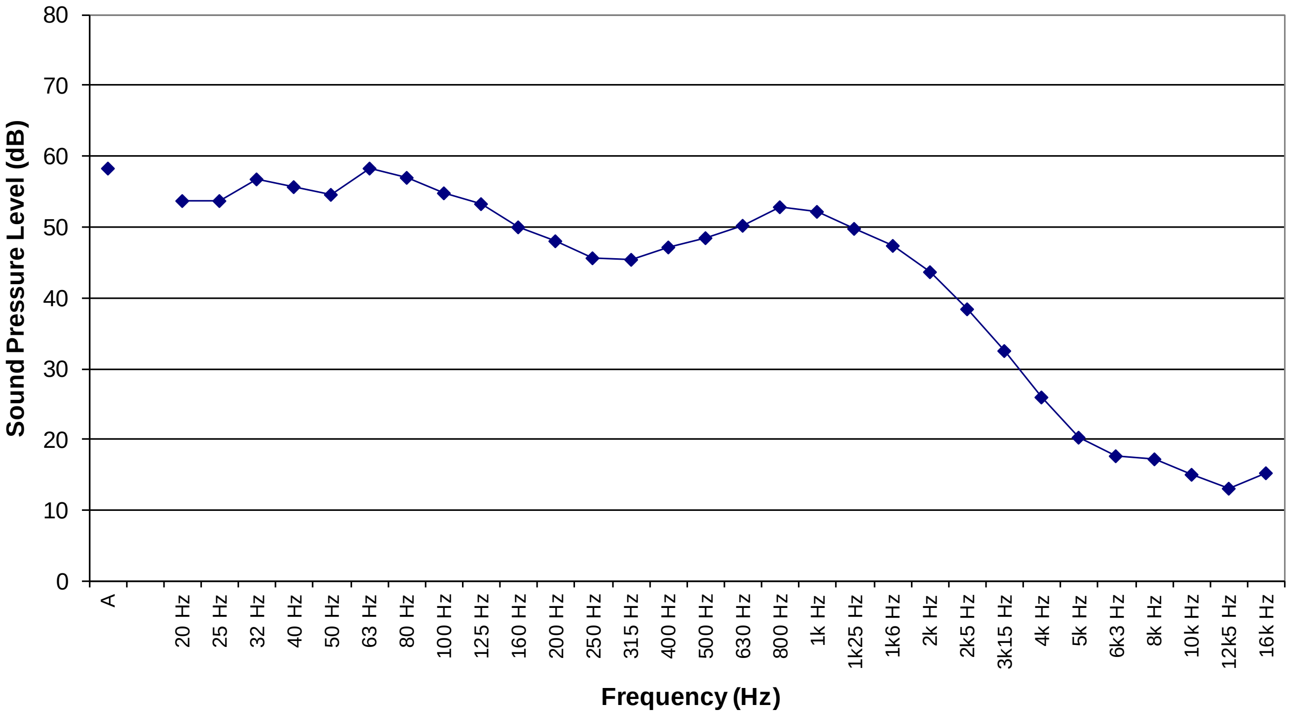

Figure 7. 24-Hour 1/3 Octave Band L_{eq} Sound Levels at Monitor Location M6b

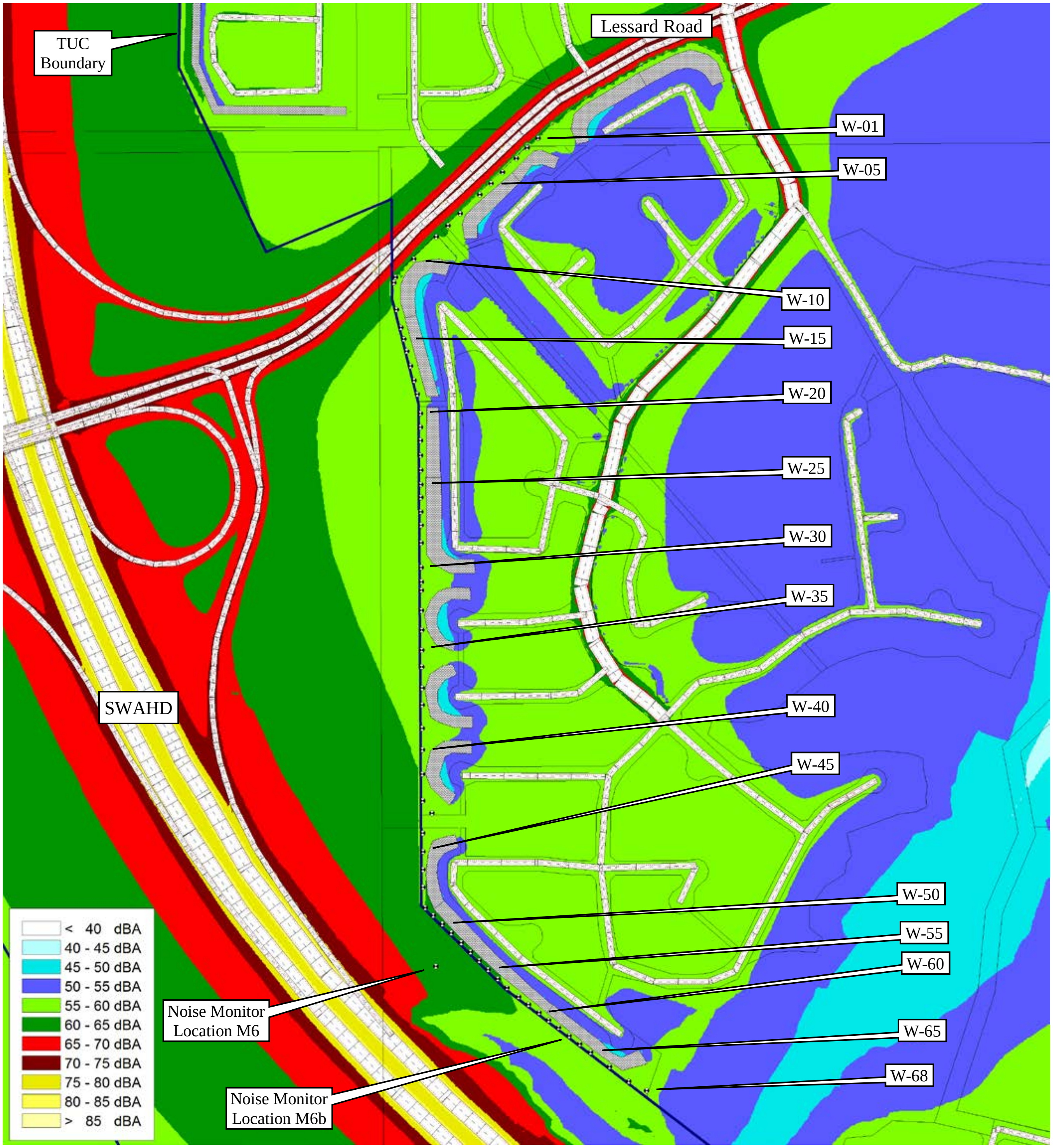

Figure 8. *Current Conditions* L_{eq}24 Sound Levels

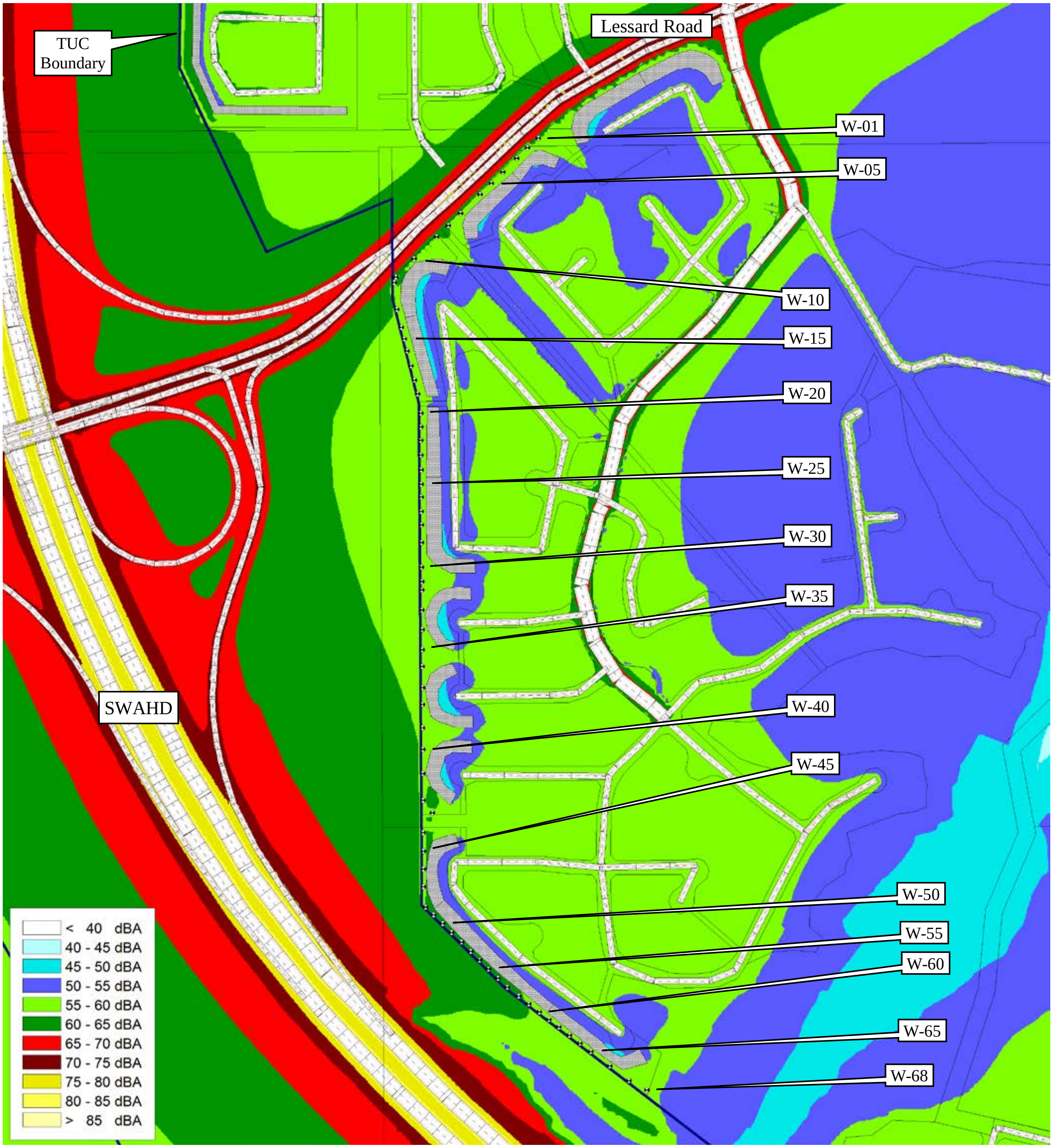

Figure 9. *Future Conditions* L_{eq}24 Sound Levels

Appendix I. MEASUREMENT EQUIPMENT USED

Noise Monitors

The environmental noise monitoring equipment used consisted of Brüel and Kjær Type 2250 Precision Integrating Sound Level Meters enclosed in environmental cases, with tripods, and weather protective microphone hoods. The systems 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 meters conform 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 meters, pre-amplifiers and microphones were certified on April 29, 2016 & April 30, 2015 and the calibrator (type B&K 4231) was certified on November 23, 2015 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
M6	September 29 2016	12:30	Pre	93.9 dBA	B&K 4231	2594693
M6	October 13 2016	9:20	Post	93.8 dBA	B&K 4231	2594693
M6b	September 29 2016	13:30	Pre	93.9 dBA	B&K 4231	2594693
M6b	October 13 2016	10:45	Post	93.9 dBA	B&K 4231	2594693

B&K 4231 Calibrator Calibration Certificate

Scantek, Inc.
CALIBRATION LABORATORY
ISO 17025: 2005, ANSI/NCSL Z540:1994 Part 1
ACCREDITED by NVLAP (an ILAC MRA signatory)

NVLAP®
NVLAP Lab Code: 200625-0

Calibration Certificate No.35026

Instrument:	**Acoustical Calibrator**	*Date Calibrated:* **11/23/2015** *Cal Due:*		
Model:	**4231**	*Status:*	**Received**	**Sent**
Manufacturer:	**Brüel and Kjær**	*In tolerance:*	X	X
Serial number:	**2594693**	*Out of tolerance:*		
Class (IEC 60942):	**1**	*See comments:*		
Barometer type:		*Contains non-accredited tests:* __Yes _X_ No		
Barometer s/n:				

Customer: **ACI Acoustical Consultants Inc.**
Tel/Fax: **780-414-6373 / -6376**
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. 1/16/2015

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	25747	Jul 2, 2015	Scantek, Inc./ NVLAP	Jul 2, 2016
DS-360-SRS	Function Generator	61646	Aug 12, 2015	ACR Env./ A2LA	Aug 12, 2017
34401A-Agilent Technologies	Digital Voltmeter	MY41022043	Aug 13, 2015	ACR Env. / A2LA	Aug 13, 2016
DPI 141-Druck	Pressure Indicator	790/00-04	Nov 18, 2014	ACR Env./ A2LA	Nov 18, 2016
HMP233-Vaisala Oyj	Humidity & Temp. Transmitter	V3820001	Oct 1, 2015	ACR Env./ A2LA	Apr 1, 2017
8903A-HP	Audio Analyzer	2514A05691	Dec 12, 2013	ACR Env./ A2LA	Dec 12, 2016
PC Program 1018 Norsonic	Calibration software	v.6.1T	Validated Nov 2014	Scantek, Inc.	-
4134-Brüel&Kjær	Microphone	950698	Nov 11, 2015	Scantek, Inc. / NVLAP	Nov 11, 2016
1203-Norsonic	Preamplifier	14059	Jan 5, 2015	Scantek, Inc./ NVLAP	Jan 5, 2016

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

Calibrated by:	Valentin Buzduga	**Authorized signatory:**	Mariana Buzduga
Signature	[signature]	Signature	[signature]
Date	11/23/2015	Date	11/23/2015

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B&K 2250 Unit #8 SLM Calibration Certificate

Scantek, Inc.
CALIBRATION LABORATORY
ISO 17025: 2005, ANSI/NCSL Z540:1994 Part 1
ACCREDITED by NVLAP (an ILAC MRA signatory)

NVLAP®
NVLAP Lab Code: 200625-0

Calibration Certificate No.36136

Instrument: **Sound Level Meter**
Model: **2250**
Manufacturer: **Brüel and Kjær**
Serial number: **3005978**
Tested with: **Microphone 4189 s/n 2851039**
Preamplifier ZC0032 s/n 20742
Type (class): **1**
Customer: **Acoustical Consultants Inc.**
Tel/Fax: **780-414-6373 /**

Date Calibrated: **4/29/2016** *Cal Due:*

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

Contains non-accredited tests: __Yes _X_ No
Calibration service: __ Basic _X_ Standard
Address: **5031 210 Street, Edmonton, Alberta, Canada T6M 0A8**

Tested in accordance with the following procedures and standards:
Calibration of Sound Level Meters, Scantek Inc., Rev. 6/26/2015
SLM & Dosimeters – Acoustical Tests, Scantek Inc., Rev. 7/6/2011

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	31061	Jul 20, 2015	Scantek, Inc./ NVLAP	Jul 20, 2016
DS-360-SRS	Function Generator	88077	Sep 9, 2014	ACR Env./ A2LA	Sep 9, 2016
34401A-Agilent Technologies	Digital Voltmeter	MY47011118	Sep 24, 2015	ACR Env./ A2LA	Sep 24, 2016
HM30-Thommen	Meteo Station	1040170/39633	Oct 23, 2015	ACR Env./ A2LA	Oct 23, 2016
PC Program 1019 Norsonic	Calibration software	v.6.1T	Validated Nov 2014	Scantek, Inc.	-
1251-Norsonic	Calibrator	30878	Nov 10, 2015	Scantek, Inc./ NVLAP	Nov 10, 2016

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

Environmental conditions:

Temperature (°C)	Barometric pressure (kPa)	Relative Humidity (%)
23.1	100.26	38.9

Calibrated by:	Jeremy Gotwalt	**Authorized signatory:**	Valentin Buzduga
Signature	[signature]	Signature	[signature]
Date	4/29/16	Date	5/04/2016

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B&K 2250 Unit #8 Microphone Calibration Certificate

Scantek, Inc.
CALIBRATION LABORATORY
ISO 17025: 2005, ANSI/NCSL Z540:1994 Part 1
ACCREDITED by NVLAP (an ILAC MRA signatory)

NVLAP®
NVLAP Lab Code: 200625-0

Calibration Certificate No.36137

Instrument:	**Microphone**	*Date Calibrated:* **4/29/2016**	*Cal Due:*		
Model:	**4189**	*Status:*	**Received**	**Sent**	
Manufacturer:	**Brüel & Kjær**	*In tolerance:*	**X**	**X**	
Serial number:	**2851039**	*Out of tolerance:*			
Composed of:		*See comments:*			
		Contains non-accredited tests: __Yes _X_ No			

Customer: **Acoustical Consultants Inc.**
Tel/Fax: **780-414-6373/**
Address: **5031 210 Street, Edmonton, Alberta, Canada T6M 0A8**

Tested in accordance with the following procedures and standards:
Calibration of Measurement Microphones, Scantek, Inc., Rev. 2/25/2015

Instrumentation used for calibration: N-1504 Norsonic Test System:

Instrument - Manufacturer	Description	S/N	Cal. Date	Traceability evidence Cal. Lab / Accreditation	Cal. Due
483B-Norsonic	SME Cal Unit	31061	Jul 20, 2015	Scantek, Inc./ NVLAP	Jul 20, 2016
DS-360-SRS	Function Generator	88077	Sep 9, 2014	ACR Env./ A2LA	Sep 9, 2016
34401A-Agilent Technologies	Digital Voltmeter	MY47011118	Sep 24, 2015	ACR Env./ A2LA	Sep 24, 2016
HM30-Thommen	Meteo Station	1040170/39633	Oct 23, 2015	ACR Env./ A2LA	Oct 23, 2016
PC Program 1017 Norsonic	Calibration software	v.6.1T	Validated Nov 2014	Scantek, Inc.	-
1253-Norsonic	Calibrator	22909	Nov 10, 2015	Scantek, Inc./ NVLAP	Nov 10, 2016
1203-Norsonic	Preamplifier	92268	Oct 14, 2015	Scantek, Inc./ NVLAP	Oct 14, 2016
4180-Brüel&Kjær	Microphone	2246115	Oct 26, 2015	NPL-UK / UKAS	Oct 26, 2017

Instrumentation and test results are traceable to SI - BIPM through standards maintained by NPL (UK) and NIST (USA)

Calibrated by:	Jeremy Gotwalt	**Authorized signatory:**	Valentin Buzduga
Signature	[signature]	Signature	[signature]
Date	4/29/16	Date	5/04/2016

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B&K 2250 Unit #10 SLM Calibration Certificate

Brüel & Kjær

MANUFACTURER'S CERTIFICATE OF CONFORMANCE

We certify that Brüel & Kjær **-2250--D00-** Serial No. **3007542** has been tested and passed all production tests, confirming compliance with the manufacturer's published specification at the date of the test.

The final test has been performed using calibrated equipment, traceable to national or international standards or by ratio measurements.

Brüel & Kjær is certified under ISO 9001:2008 assuring that all test data is retained on file and is available for inspection upon request.

Nærum 30-apr-2015

Torben Bjørn
Vice President, Operations

Please note that this document is not a calibration certificate.
For information on our calibration services please go to www.bksv.com/service.

Bruel & Kjær

Prepolarized Free-field 1/2" Microphone Type 4189

Calibration Chart

Serial No:	**2978664**	
Open-circuit Sensitivity*, S_0:	*-27.1*	dB re 1V/Pa
Equivalent to:	*44.2*	mV/Pa
Uncertainty, 95 % confidence level	0.2	dB
Capacitance:	*13.3*	pF
Valid At:		
Temperature:	23	°C
Ambient Static Pressure:	101.3	kPa
Relative Humidity:	50	%
Frequency:	251.2	Hz
Polarization Voltage, external:	0	V

Sensitivity Traceable To:
DPLA: Danish Primary Laboratory of Acoustics
NIST: National Institute of Standards and Technology, USA

IEC 61094-4: Type WS 2 F

Environmental Calibration Conditions:
100.7 kPa 22 °C 52 % RH

Procedure: 704215 **Date:** 27. Feb. 2015 **Signature:** H.P.

$^*K_0 = -26 - S_0$ Example: $K_0 = -26 - (-26.2) = +0.2$ dB

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Appendix II. THE ASSESSMENT OF ENVIRONMENTAL NOISE (GENERAL)

Sound Pressure Level

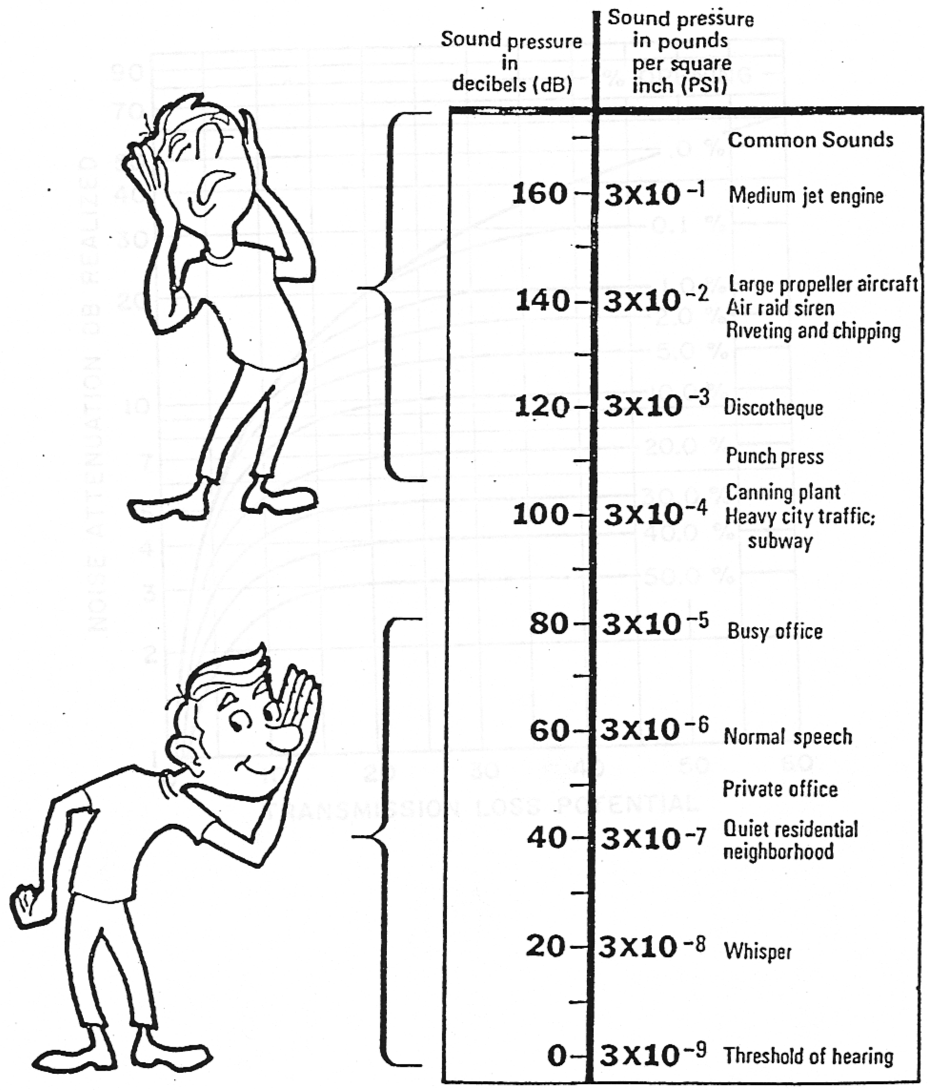
Sound pressure is initially measured in Pascal's (Pa). Humans can hear several orders of magnitude in sound pressure levels, so a more convenient scale is used. This scale is known as the decibel (dB) scale, named after Alexander Graham Bell (telephone guy). It is a base 10 logarithmic scale. When we 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 ($P_{ref} = 2\text{x}10^{-5}$ 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 in decibels (dB)
Sound pressure in pounds per square inch (PSI)
Common Sounds
160 3X10 -1 Medium jet engine
140 3X10 -2 Large propeller aircraft
Air raid siren
Riveting and chipping
120 3X10 -3 Discotheque
Punch press
100 3X10 -4 Canning plant
Heavy city traffic; subway
80 3X10 -5 Busy office
60 3X10 -6 Normal speech
Private office
40 3X10 -7 Quiet residential neighborhood
20 3X10 -8 Whisper
0 3X10 -9 Threshold of hearing

Frequency

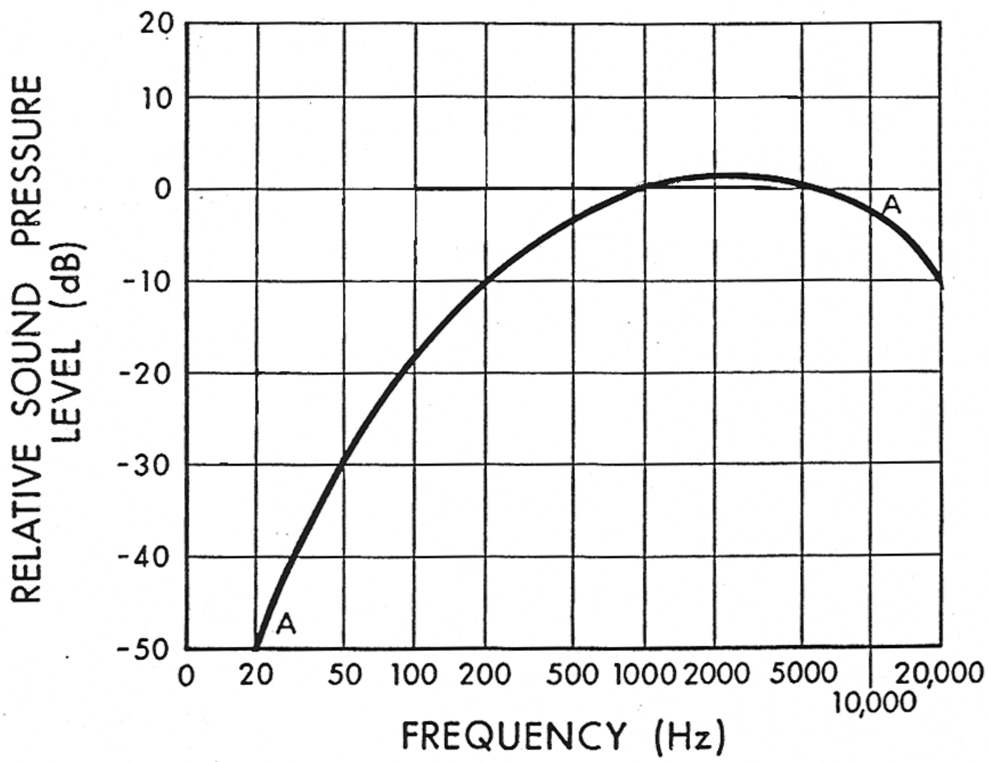
The range of frequencies audible to the human ear ranges from approximately 20 Hz to 20 kHz. Within this range, the human ear does not hear equally at all frequencies. It is not very sensitive to low frequency sounds, is very sensitive to mid frequency sounds and is slightly less sensitive to high frequency 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.

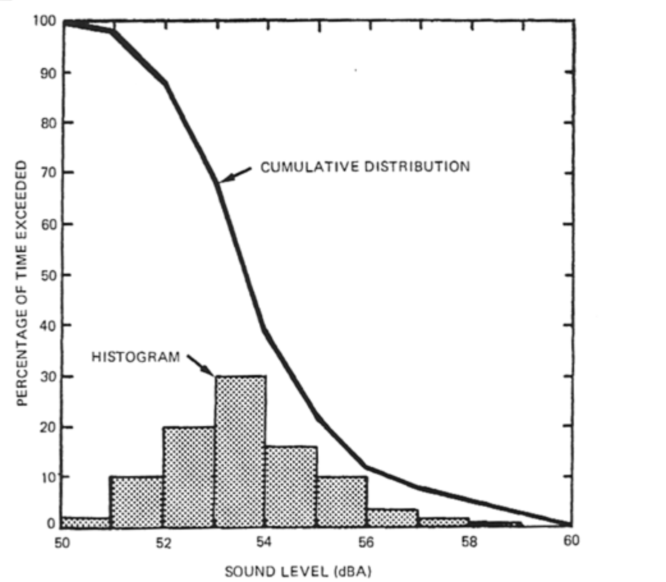


Figure 16.6 Statistically processed community noise showing histogram and cumulative distribution of A weighted sound levels.

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 34 dB at 400m.
- A line source measuring 50 dB at 100m will be 40 dB at 1000m.

Atmospheric Absorption

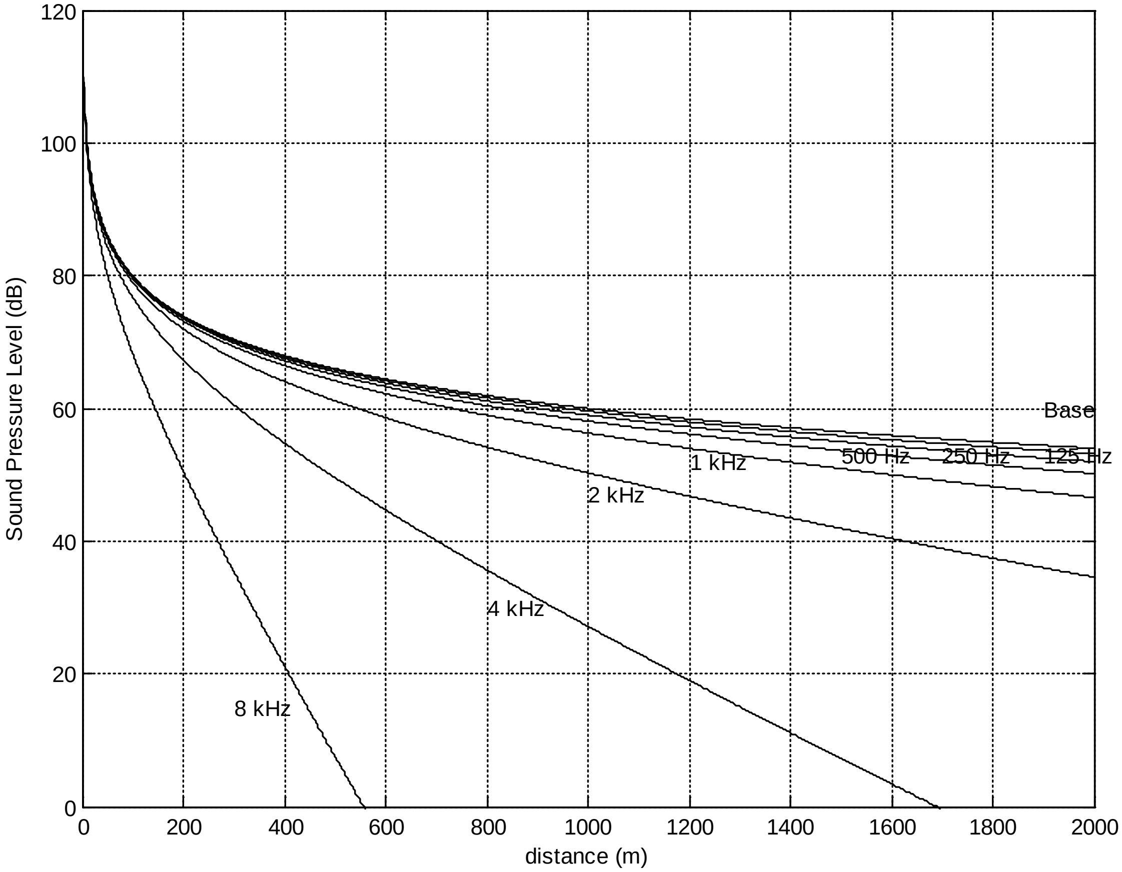
As sound transmits through a medium, there is an attenuation (or dissipation of acoustic energy) which can be attributed to three mechanisms:

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 increases
- As Relative Humidity increases, absorption decreases
- 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

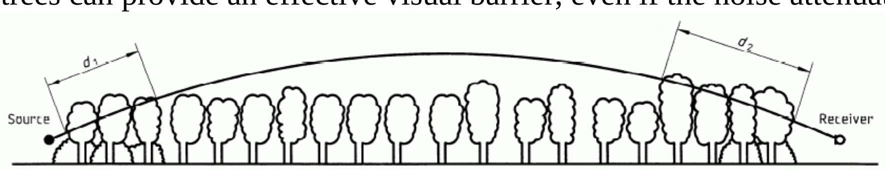
- Can be an effective absorber due to large area covered
- Only effective at low height above ground. Does not affect sound transmitted direct from source to receiver if there is line of sight.
- Typically less absorption than atmospheric absorption when there is line of sight.
- Approximate rule of 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
	Attenuation, dB:							
$10 \leq d_f \leq 20$	0	0	1	1	1	1	2	3
	Attenuation, dB/m:							
$20 \leq d_f \leq 200$	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 (AER) Directive 038 (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 (AER) Directive 038 (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 MODELLING PARAMETERS

Current Conditions (Year 2016)

Road	Day (Vehicles Per Hour)	Day % Heavy Vehicles	Night (Vehicles Per Hour)	Night % Heavy Vehicles	Speed (km/hr)	Total Volume (vehicles per day)
AHD South of Whitemud Drive NB	3006	10.5	795	10.5	100	52242
AHD South of Whitemud Drive SB	3006	10.5	795	10.5	100	52242
AHD South of 62 Avenue NB	2638	11.4	698	11.4	100	45855
AHD South of 62 Avenue SB	2638	11.4	698	11.4	100	45855
AHD South of Lessard Road NB	2638	11.1	698	11.1	100	45849
AHD South of Lessard Road SB	2638	11.1	698	11.1	100	45849
AHD East of Cameron Heights Drive NB	2711	10.6	717	10.6	100	47125
AHD East of Cameron Heights Drive SB	2711	10.6	717	10.6	100	47125
Callingwood Road East of AHD EB	439	3.2	116	3.2	60	7639
Callingwood Road East of AHD WB	439	3.2	116	3.2	60	7639
62 Avenue West of AHD EB	849	3.9	225	3.9	60	14756
62 Avenue West of AHD WB	849	3.9	225	3.9	60	14756
AHD NB to Callingwood Road EB Ramp	92	3.7	24	3.7	70	1596
AHD NB to 62 Avenue WB Ramp	137	5.9	36	5.9	70	2379
Callingwood Road WB to AHD NB Ramp	132	4.1	35	4.1	60	2289
Callingwood Road WB to AHD SB Ramp	91	3.8	24	3.8	60	1585
AHD SB to 62 Avenue WB Ramp	457	4.2	121	4.2	70	7942
AHD SB to Callingwood Road EB Ramp	132	3.8	35	3.8	70	2289
62 Avenue EB to AHD SB Ramp	137	4.4	36	4.4	60	2379
62 Avenue EB to AHD NB Ramp	457	4.4	121	4.4	60	7942
Lessard Road East of AHD EB	438	4.0	116	4.0	60	7618
Lessard Road East of AHD WB	438	4.0	116	4.0	60	7618
Lessard Road West of AHD EB	473	5.4	125	5.4	60	8222
Lessard Road West of AHD WB	473	5.4	125	5.4	60	8222
AHD NB to Lessard Road EB Ramp	143	3.8	38	3.8	70	2478
AHD NB to Lessard Road WB Ramp	126	7.0	33	7.0	70	2194
Lessard Road WB to AHD NB Ramp	106	4.1	28	4.1	70	1837
Lessard Road WB to AHD SB Ramp	143	5.3	38	5.3	60	2478
AHD SB to Lessard Road WB Ramp	133	7.6	35	7.6	70	2310
AHD SB to Lessard Road EB Ramp	106	5.1	28	5.1	70	1837
Lessard Road EB to AHD SB Ramp	126	5.7	33	5.7	70	2194
Lessard Road EB to AHD NB Ramp	133	8.1	35	8.1	60	2310
Cameron Heights Drive South of AHD NB	136	3.2	36	3.2	70	2362
Cameron Heights Drive South of AHD SB	136	3.2	36	3.2	70	2362
Cameron Heights Drive North of AHD NB	120	9.3	32	9.3	60	2079
Cameron Heights Drive North of AHD SB	120	9.3	32	9.3	60	2079
AHD WB to Cameron Heights Drive NB Ramp	54	6.2	14	6.2	60	945
AHD WB to Cameron Heights Drive SB Ramp	101	2.7	27	2.7	60	1764
Cameron Heights Drive SB to AHD WB Ramp	62	9.1	16	9.1	60	1081
Cameron Heights Drive SB to AHD EB Ramp	54	8.6	14	8.6	60	945
AHD EB to Cameron Heights Drive SB Ramp	31	2.9	8	2.9	60	546
AHD EB to Cameron Heights Drive NB Ramp	62	12.0	16	12.0	60	1081
Cameron Heights Drive NB to AHD EB Ramp	101	3.3	27	3.3	60	1764
Cameron Heights Drive NB to AHD WB Ramp	31	2.3	8	2.3	60	546

Future Conditions (Year 2027)

Road	Day (Vehicles Per Hour)	Day % Heavy Vehicles	Night (Vehicles Per Hour)	Night % Heavy Vehicles	Speed (km/hr)	Total Volume (vehicles per day)
AHD South of Whitemud Drive NB	3297	10.0	872	10.0	100	57309
AHD South of Whitemud Drive SB	3270	10.0	865	10.0	100	56837
AHD South of 62 Avenue NB	2974	10.0	787	10.0	100	51694
AHD South of 62 Avenue SB	2919	10.0	772	10.0	100	50728
AHD South of Lessard Road NB	2981	10.0	789	10.0	100	51814
AHD South of Lessard Road SB	2994	10.0	792	10.0	100	52044
AHD East of Cameron Heights Drive NB	3136	10.0	830	10.0	100	54506
AHD East of Cameron Heights Drive SB	3114	10.0	824	10.0	100	54133
Callingwood Road East of AHD EB	561	3.0	149	3.0	60	9758
Callingwood Road East of AHD WB	533	3.0	141	3.0	60	9262
62 Avenue West of AHD EB	939	3.0	248	3.0	60	16315
62 Avenue West of AHD WB	939	3.0	248	3.0	60	16314
AHD NB to Callingwood Road EB Ramp	119	3.0	32	3.0	70	2077
AHD NB to 62 Avenue WB Ramp	196	3.0	52	3.0	70	3405
Callingwood Road WB to AHD NB Ramp	145	3.0	38	3.0	60	2512
Callingwood Road WB to AHD SB Ramp	115	3.0	31	3.0	60	2004
AHD SB to 62 Avenue WB Ramp	470	3.0	124	3.0	70	8163
AHD SB to Callingwood Road EB Ramp	176	3.0	47	3.0	70	3055
62 Avenue EB to AHD SB Ramp	179	3.0	47	3.0	60	3104
62 Avenue EB to AHD NB Ramp	494	3.0	131	3.0	60	8586
Lessard Road East of AHD EB	567	4.0	150	4.0	60	9854
Lessard Road East of AHD WB	545	4.0	144	4.0	60	9479
Lessard Road West of AHD EB	565	4.0	149	4.0	60	9817
Lessard Road West of AHD WB	569	4.0	151	4.0	60	9897
AHD NB to Lessard Road EB Ramp	199	4.0	53	4.0	70	3453
AHD NB to Lessard Road WB Ramp	151	4.0	40	4.0	70	2625
Lessard Road WB to AHD NB Ramp	128	4.0	34	4.0	70	2222
Lessard Road WB to AHD SB Ramp	192	4.0	51	4.0	60	3333
AHD SB to Lessard Road WB Ramp	160	4.0	42	4.0	70	2777
AHD SB to Lessard Road EB Ramp	122	4.0	32	4.0	70	2114
Lessard Road EB to AHD SB Ramp	165	4.0	44	4.0	70	2874
Lessard Road EB to AHD NB Ramp	153	4.0	40	4.0	60	2656
Cameron Heights Drive South of AHD NB	240	13.0	63	13.0	70	4166
Cameron Heights Drive South of AHD SB	274	13.0	73	13.0	70	4770
Cameron Heights Drive North of AHD NB	214	6.0	57	6.0	60	3720
Cameron Heights Drive North of AHD SB	214	6.0	57	6.0	60	3720
AHD WB to Cameron Heights Drive NB Ramp	132	6.0	35	6.0	60	2294
AHD WB to Cameron Heights Drive SB Ramp	186	13.0	49	13.0	60	3236
Cameron Heights Drive SB to AHD WB Ramp	85	6.0	23	6.0	60	1486
Cameron Heights Drive SB to AHD EB Ramp	111	6.0	29	6.0	60	1932
AHD EB to Cameron Heights Drive SB Ramp	71	13.0	19	13.0	60	1232
AHD EB to Cameron Heights Drive NB Ramp	79	6.0	21	6.0	60	1365
Cameron Heights Drive NB to AHD EB Ramp	158	13.0	42	13.0	60	2753
Cameron Heights Drive NB to AHD WB Ramp	78	13.0	21	13.0	60	1352

Appendix V NOISE MONITORING ISOLATED DATA

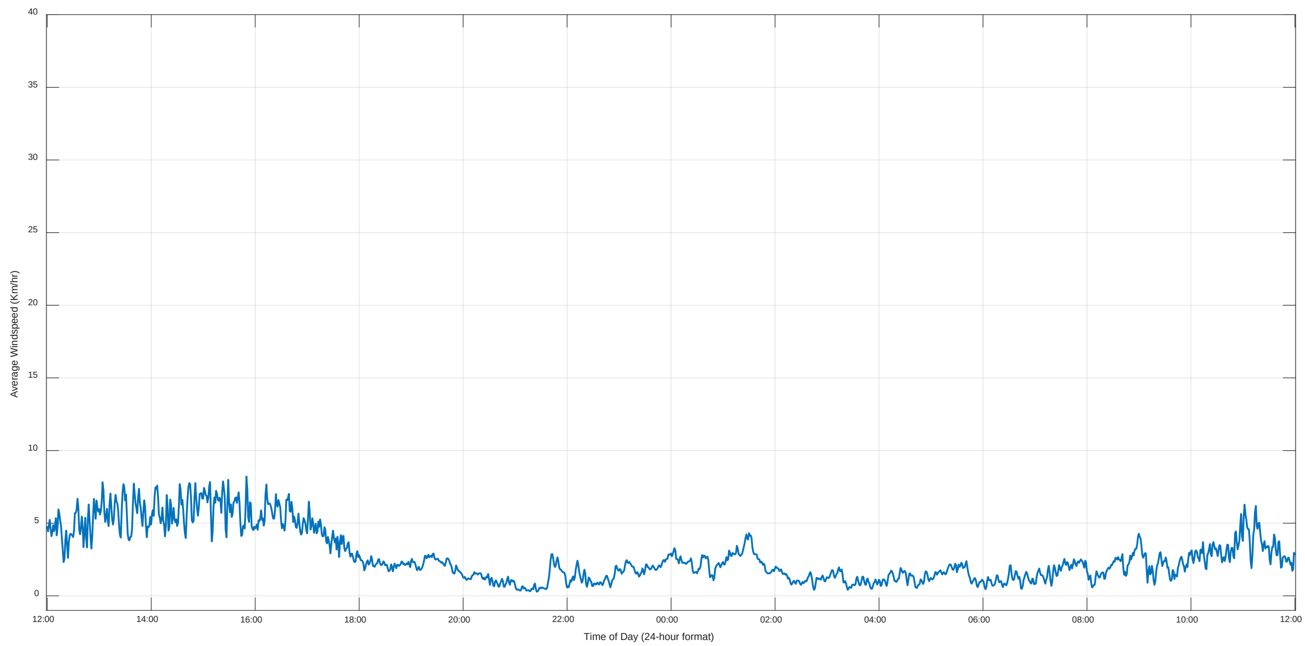
Noise Monitor Location M6

Start Time	End Time	Duration (min)	Reason
10/11/2016 18:00	10/11/2016 18:01	0.75	Emergency Sirens
10/11/2016 21:34	10/11/2016 21:34	0.75	Loud Vehicle Passby
	TOTAL	1.5	

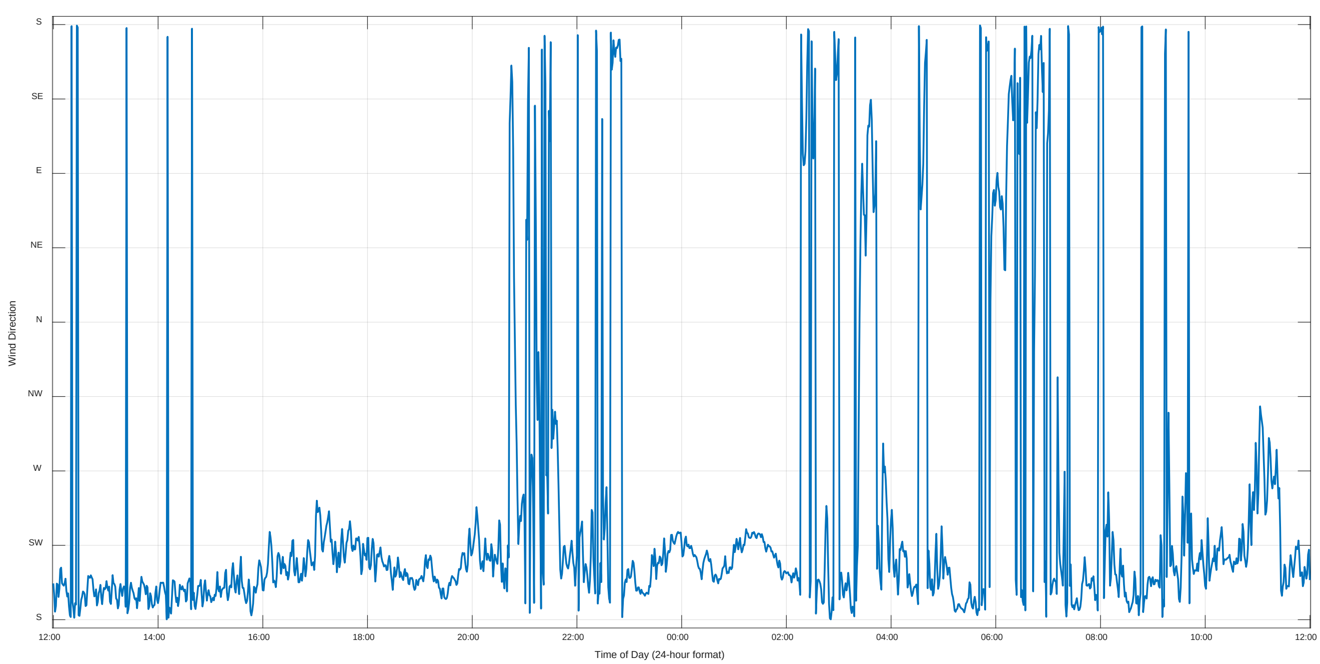
Noise Monitor Location M6b

Start Time	End Time	Duration (min)	Reason
10/11/2016 18:00	10/11/2016 18:01	1.5	Emergency Sirens
10/11/2016 21:34	10/11/2016 21:35	1	Loud Vehicle Passby
	TOTAL	2.5	

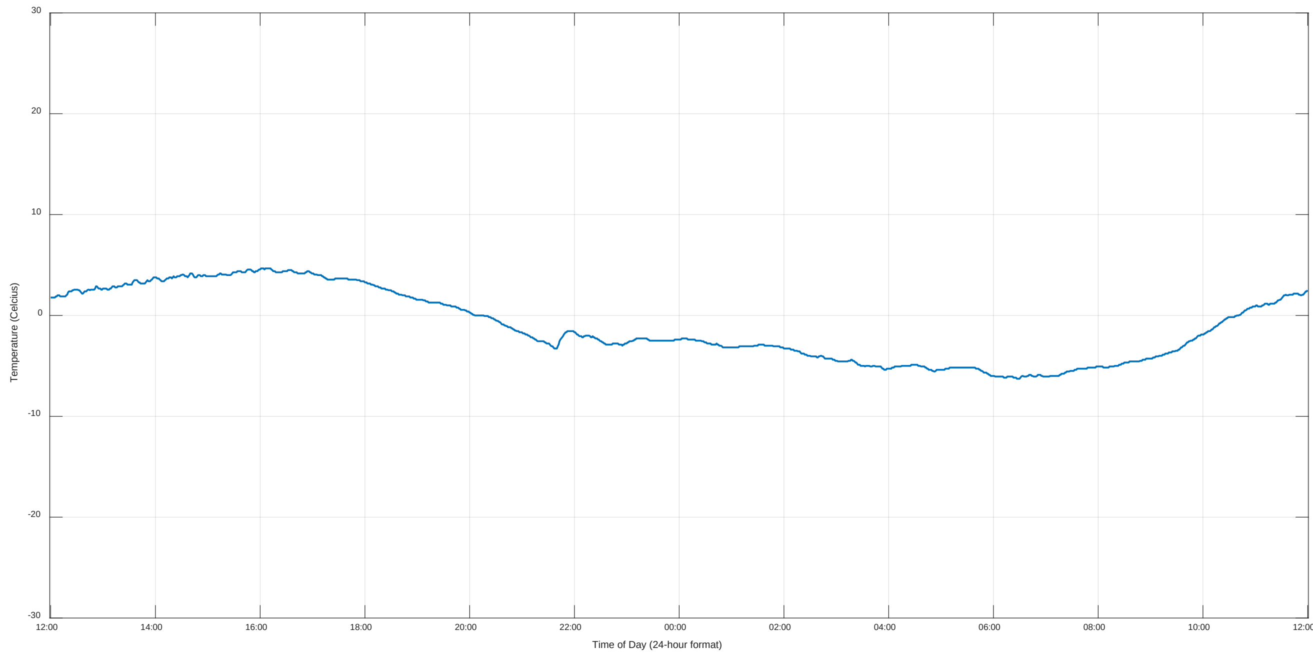
Appendix VI. NOISE MONITORING WEATHER DATA



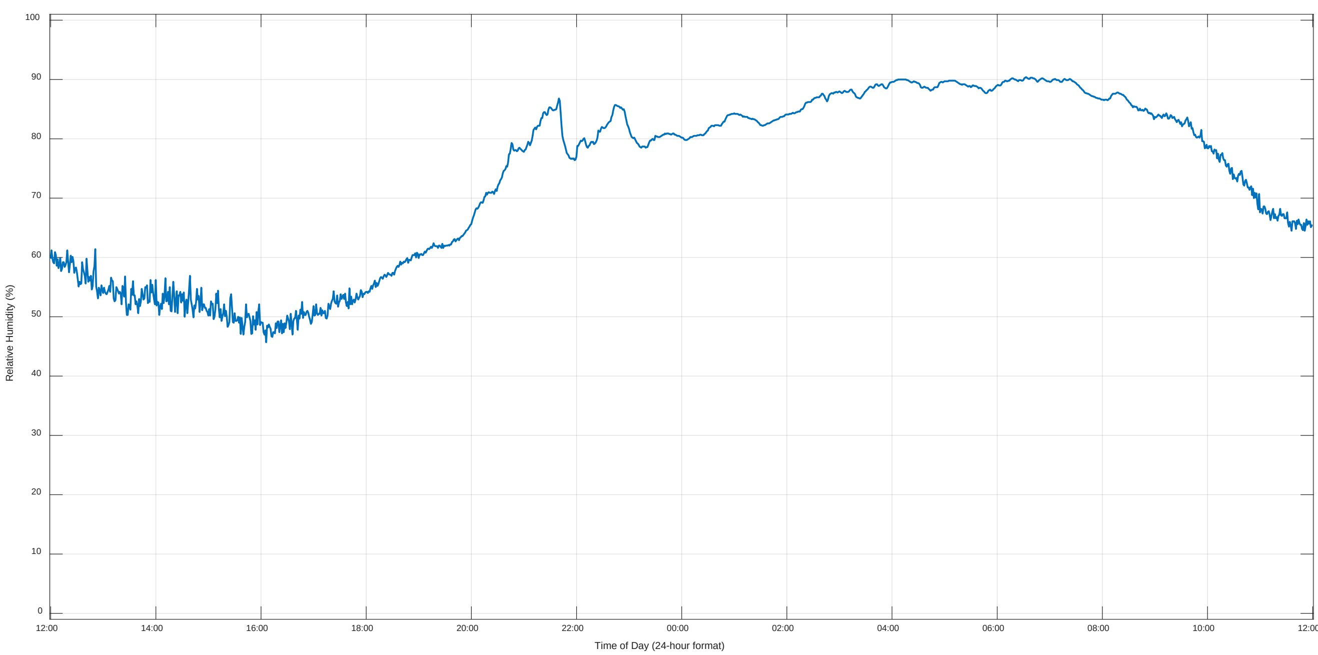
October 11 – 12, 2016 Monitored Wind Speed



October 11 – 12, 2016 Monitored Wind Direction



October 11 – 12, 2016 Monitored Temperature



October 11 – 12, 2016 Monitored Relative Humidity