Environmental Noise Monitoring

the living wall

an ecological sound barrier solution inc.

In Partnership with Mother Nature

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Environmental Noise Monitoring

For The

91 Street Earth Berm Removal in Edmonton, Alberta

Prepared for the

City of Edmonton
Drainage Services Branch

the living wall
an ecological sound barrier solution inc.

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Executive Summary

aci Acoustical Consultants Inc., of Edmonton AB, was retained by the City of Edmonton, Drainage Services Branch (the City) to conduct an environmental noise study in the area east of 91 Street, between Millwoods Road and Whitemud Drive (Millbourne area). The purpose of the study was to measure the noise impact of the replacement of a portion of the existing earth berm with a Vegetative style noise and visual barrier. As part of the study, long-term noise monitorings were conducted at two residential locations, including: 8855 - 40 Avenue (adjacent to the 'test' replacement section of noise barrier) and 4132 - 89 Street (adjacent to the section of earth berm which will remain intact for the duration of the study, for use as a 'control'). The noise monitorings were conducted in early Fall, 2014 (prior to the start of construction), in Winter, 2015 (after construction, during winter-time conditions), and in Summer, 2015 (after construction in summer-time conditions). The site work for the *Fall, 2014* noise monitoring was conducted between September 14 and 20, 2014. The site work for the *Winter, 2015* noise monitoring was conducted between January 14 and 19, 2015. The site work for the *Summer, 2015* noise monitoring was conducted between July 20 and 30, 2015. All field work was conducted by S. Bilawchuk, M.Sc., P.Eng.

The *Fall, 2014* noise monitoring results at both locations indicated very consistent noise levels for the two separate 24-hour time periods within the same week. As anticipated, during the *Fall, 2014* and *Winter, 2015* and *Summer, 2015* noise monitoring periods, the highest sustained noise levels occurred during the morning peak traffic periods. The resultant 1/3 octave band L_{eq} sound levels have 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. Subjective observations indicated that 91 Street was the dominant noise source for both locations during all of the noise monitoring periods. In addition, the subjective observations, the review of the recorded audio, and the frequency data indicate a higher than normal low frequency component to the noise (near 63 - 80 Hz) during the *Fall, 2014* noise monitoring period, relative to *Winter, 2015*. Although the exact source of this elevated low frequency noise is undetermined, it is likely emanating from the industrial area to the west of 91 Street. This elevated low frequency noise was not present in the *Winter, 2015* noise monitoring results but returned in *Summer, 2015*.

When comparing the *Fall, 2014* noise monitoring data to the *Winter, 2015* noise monitoring data at both locations, there is a notable difference. At the control location of 4132 - 89 Street, the $L_{eq}24$ noise levels increased by 1.6 dBA. If all other conditions had remained the same at the test location of 8855 - 40 Avenue location, a similar increase in noise levels would be expected. However, the noise levels at 8855 - 40 Avenue remained essentially unchanged between the *Fall, 2014* and *Winter, 2015* noise monitoring periods. Based on these results, the eastward-shifted and slightly taller Vegetative Barrier would appear to be performing better than the earth berm by approximately 1.6 dBA.

When comparing the *Summer, 2015* noise monitoring data to the *Fall, 2015* noise monitoring data, there is a reduction in noise levels at both locations. At the control location of 4132 - 89 Street, the $L_{eq}24$ noise levels decreased by 0.3 dBA while at the test location of 8855 - 40 Avenue, the $L_{eq}24$ noise levels decreased by 0.8 dBA. All other factors being equal, this would indicate that the Vegetative Barrier is performing better than the earth berm by approximately 0.5 dBA. However, given that the daily fluctuations in noise levels can easily be 1 - 3 dBA due to varying weather conditions, in terms of comparing noise levels from one year to the next, these changes are relatively small and it is difficult to draw any specific noise level reduction conclusions.

As an overall conclusion, the data indicate that replacing the earth berm with the Vegetative Barrier, with the specific tested geometry, did not adversely affect the noise levels at the adjacent residential receptor. Rather, the data indicate a slight noise level reduction with the Vegetative Barrier which matches the theory based on the fact that the Vegetative Barrier is slightly taller and closer to the residential receptor location, relative to the geometry of the earth berm that it replaced. Thus, based on the noise measurement data, in terms of noise reduction associated with a road noise barrier, the Vegetative Barrier essentially performs as well as other common road noise barrier materials such as masonry walls.

Noise Monitoring Results

	$L_{eq}24$ (dBA)	$L_{eq}Day$ (dBA)	$L_{eq}Night$ (dBA)
8855 - 40 Avenue			
08:00 September 16 - 08:00 September 17, 2014	54.1	55.0	52.3
16:00 September 18 - 16:00 September 19, 2014	54.1	55.3	50.9
Fall, 2014 Logarithmic Average	**54.1**	**55.1**	**51.6**
11:00 January 14 - 11:00 January 15, 2015	53.8	55.0	50.6
Data from 11:00 January 14 - 02:00 January 15 & 02:00 - 11:00 January 16, 2015	54.2	55.5	50.2
Winter, 2015 Logarithmic Average	**54.0**	**55.3**	**50.4**
Difference Between Winter 2015 and Fall 2014	**-0.1**	**0.1**	**-1.2**
09:00 July 27 - 09:00 July 28, 2015	**53.3**	**54.4**	**50.8**
Difference Between Summer 2015 and Winter 2015	**-0.7**	**-0.9**	**0.4**
Difference Between Summer 2015 and Fall 2014	**-0.8**	**-0.8**	**-0.8**
4132 - 89 Street (Control Location)			
08:00 September 16 - 08:00 September 17, 2014	52.6	53.2	51.2
16:00 September 18 - 16:00 September 19, 2014	52.8	53.9	49.9
Fall, 2014 Logarithmic Average	**52.7**	**53.6**	**50.6**
11:00 January 14 - 11:00 January 15, 2015	53.9	55.0	51.2
Data from 11:00 January 14 - 02:00 January 15 & 02:00 - 11:00 January 16, 2015	54.6	55.8	51.2
Winter, 2015 Logarithmic Average	**54.3**	**55.4**	**51.2**
Difference Between Winter 2015 and Fall 2014	**1.6**	**1.9**	**0.7**
09:00 July 27 - 09:00 July 28, 2015	**52.4**	**53.2**	**50.7**
Difference Between Summer 2015 and Winter 2015	**-1.9**	**-2.3**	**-0.5**
Difference Between Summer 2015 and Fall 2014	**-0.3**	**-0.4**	**0.1**

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1.0 Introduction

aci Acoustical Consultants Inc., of Edmonton AB, was retained by the City of Edmonton, Drainage Services Branch (the City) to conduct an environmental noise study in the area east of 91 Street, between Millwoods Road and Whitemud Drive (Millbourne area). The purpose of the study was to measure the noise impact of the replacement of a portion of the existing earth berm with a Vegetative style noise and visual barrier. As part of the study, long-term noise monitorings were conducted at two residential locations, including: 8855 - 40 Avenue (adjacent to the 'test' replacement section of noise barrier) and 4132 - 89 Street (adjacent to the section of earth berm which will remain intact for the duration of the study, for use as a 'control'). The noise monitorings were conducted in early Fall, 2014 (prior to the start of construction), in Winter, 2015 (after construction, during winter-time conditions), and in Summer, 2015 (after construction in summer-time conditions). The site work for the *Fall, 2014* noise monitoring was conducted between September 14 and 20, 2014. The site work for the *Winter, 2015* noise monitoring was conducted between January 14 and 19, 2015. The site work for the *Summer, 2015* noise monitoring was conducted between July 20 and 30, 2015. All field work was conducted by S. Bilawchuk, M.Sc., P.Eng.

2.0 Description

2.1. Location Description

The study area is located in the north Millbourne area of Edmonton, as shown in Figure 1. The City of Edmonton Drainage Services is proposing to remove the existing earth berm located east of 91 Street to the north of Millwoods Road for the purposes of expanding the existing storm water management pond. The initial stage of the Project involved a test section with a portion of the earth berm removed and replaced with the vegetative style noise and visual barrier. As indicated in Figure 2, the test section started at the south end from the alleyway to the south of 40 Avenue and spanned approximately 137 m to the north. This was directly behind the three houses in the cul-de-sac on 40 Avenue and 88 Street which back onto 91 Street.

Within the study area, all of the residences backing onto 91 Street consist of single family detached houses or low-rise multi-family units with backyard outdoor amenity spaces to the west of the house (i.e. the outdoor amenity spaces back directly onto 91 Street). Further to the east are also single family detached houses. There are also some schools and churches and minimal commercial development east of 91 Street. West of 91 Street is commercial and light industrial development. Relative to the area road noise, there are no significant constant noise sources within the commercial/industrial development to the west of 91 Street.

Topographically, the area is generally flat with only minor changes in elevation throughout. As mentioned above, Whitemud Drive drops down approximately 8 m below 91 Street. The only significant topographical features are the earth berms located east of 91 Street (between 91 Street and the adjacent residential lots to the east). Starting from the south, there is an earth berm starting approximately 80 m north of Millwoods Road which continues, uninterrupted to the north and wraps around to the east immediately south of Whitemud Drive. Relative to the elevation of 91 Street, the current earth berm is approximately 3.0 - 4.0 m high (depending on the specific location). Relative to the elevation at the rear property line for the adjacent residential lots, the earth berm ranges in height from approximately 2.5 - 3.0 m high. After removal of the earth berm, the elevations for 91 Street and the rear residential property lines will remain as-is with the elevation at the rear property line similar to that of 91 Street. In between, in place of the earth berm, there will be a depression of approximately 3.5 - 5.0 m which will normally be empty and covered in vegetation (it will be filled with water during high rain periods). It is important to note that most of the residential receptors immediately east of 91 Street have either no fence at the rear property line or have chainlink fences or have acoustically insufficient wooden fences. There are small groups of bushes and trees, but the quantity and density is insufficient for significant sound absorption.

2.2. Vegetative Barrier

As a replacement to the earth berm, the City is proposing to install a vegetative style of noise barrier and visual screen, known as "The Living Wall". The Vegetative Barrier comprises a wooden structure frame and geo-textile material that forms a cavity approximately 0.5 wide and the full height of the barrier. The cavity is filled with dirt and vegetative material grows on the outside (planted in the ground) throughout the full height of the barrier. From the outside, in full foliage, the structure appears as a large vegetative 'hedge row'. With regards to the performance as a noise barrier, it is largely the dirt contained within that provides the mass, the vibration damping, and the sound absorption. The exterior vegetation also provides some minor absorption during the summer foliage months. Note that for the *Winter, 2015* noise monitoring, the exterior of the barrier was covered in burlap to contain the newly planted vegetation. This was removed by *Summer, 2015* and will not be used in subsequent years.

3.0 Measurement Methods

3.1. General Description

As part of the study, noise monitorings were conducted at two locations, east of 91 Street in between Millwoods Road and Whitemud Drive, during three different time periods. The first time period was early Fall, 2014, prior to the start of any construction. This provided baseline data with the earth berm intact. The second time period was in Winter, 2015. This provided data on the performance of the Vegetative Barrier during frozen and no-foliage conditions. The third time period was in Summer, 2015. This provided data on the performance of the Vegetative Barrier during warm weather with foliage[1]. The two noise monitoring locations were selected to obtain noise data at the specific Vegetative Barrier test section and at an equivalent area, further away from the test section, where the earth berm will remain intact (for the duration of the noise study) to act as a control for comparison purposes. The traffic flow on 91 Street is the same for both noise monitoring locations because there are no vehicle access points in between Millwoods Road and Whitemud Drive. This is what allows for the useful comparison between the two locations.

It is important to note that the geometries associated with the test section of the Vegetative Barrier were different than those of the earth berm it replaced. As indicated in Figure 2, the centerline of the Vegetative Barrier shifted approximately 10 m to the east, relative to the centerline of the earth berm. This placed the Vegetative Barrier closer to the residential property lines, resulting in theoretically better noise reduction performance than if it were at the centerline of the earth berm. In addition, the height of the Vegetative Barrier was approximately 0.5 m taller than the earth berm at approximately mid-span and approximately 2.4 m taller than the earth berm at the north and south ends[2]. Thus, assuming that the Vegetative Barrier sufficiently reduces the noise transmitting through itself, the "barrier" effect of the noise propagating over the top and around the sides should be slightly better than that of the berm which it replaced due to the geometry. This is important when comparing the *Fall, 2014* baseline data to the *Winter, 2015* and *Summer, 2015* data since the geometries do not offer a direct comparison. However, one of the main purposes for the study was to determine if the proposed Vegetative Barrier installation, with the proposed height and eastward shifted geometry, will provide at least as much traffic noise

[1] The foliage on the wall was minimal, relative to the design due to issues with watering the wall earlier in the spring. However, since the vegetation on the barrier has minimal impact on the sound attenuation of the barrier itself, the results are still valid, and even slightly conservative.

[2] The increased Vegetative Barrier height at the north and south ends was a safety feature to prevent easy access for pedestrians to the top of the test section of Vegetative Barrier. This increased height will be modified/removed as part of the full Vegetative Barrier installation.

reduction (relative to 91 Street) as the existing earth berm. The methods and results of the study are sufficient to determine this performance.

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 monitorings were conducted on 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 significantly affect the normal traffic on the road. For all 3 noise monitoring time periods, several weekdays worth of data were obtained in an attempt to obtain appropriate weather conditions. Specifically, a light west wind (in the direction of 91 Street towards the noise monitors) was sought. Each of the noise monitorings was accompanied by a digital audio recording for more detailed post process analysis. Finally, a portable weather monitor was used within the area[1] 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.

3.2. 8855 - 40 Avenue

The noise monitor directly adjacent to the Vegetative Barrier test section was located in the backyard at 8855 - 40 Avenue, as shown in Figure 1, and Figures 3 - 6. This placed the noise monitor 1.0 m east of the rear property line, and approximately 2.5 m north of the south property line, with the microphone at a height of 1.5 m above ground. The noise monitor was approximately 23 m east of the earth berm centerline and approximately 13 m east of the Vegetative Barrier. Relative to 91 Street, the noise monitor was approximately 83 m east of the center of the north-bound lanes and approximately 116 m east of the middle of the center of the southbound lanes. At this location, there was no line-of-sight to 91 Street because of the earth berm and the Vegetative Barrier. The *Fall, 2014* noise monitor was started at 12:00 on Sunday September 14, 2014 and ran for 6-days until 13:40 on Saturday September 20, 2014. The *Winter, 2015* noise monitor was started at 10:00 on Wednesday January 14, 2015 and ran for 5 days until 10:00 on Monday January 19, 2015. The noise monitor was shut down early due to

[1] The weather monitor was located beside the noise monitor at 8855 - 40 Avenue

pending poor weather conditions and because appropriate data has already been obtained on January 14 - 16. The *Summer, 2015* noise monitor was started at 11:00 on Monday July 20, 2015 and ran for 10 days until 10:00 on Thursday July 30, 2015.

3.3. 4132 - 89 Street (Control Location)

The noise monitor at the control location was located in the backyard at 4132 - 89 Street, as shown in Figure 1, and Figures 7 - 10. This location was approximately 250 m north of the north edge of the Vegetative Barrier test section. This placed the noise monitor approximately 9.0 m east of the rear property line, and approximately 3.0 m south of the north property line, with the microphone at a height of 1.5 m above ground. The noise monitor was approximately 39 m east of the earth berm centerline. At this location, there was no line-of-sight to 91 Street because of the earth berm. Relative to 91 Street, the noise monitor was approximately 96 m east of the center of the north-bound lanes and approximately 129 m east of the middle of the center of the southbound lanes. Relative to the location at 8855 - 40 Avenue, this placed the noise monitor approximately 13 m further east of 91 Street and 16 m further east of the earth berm. Due to this increased relative distance from 91 Street, the *baseline* noise levels at 4132 - 89 Avenue are slightly lower than those at 8855 - 40 Avenue. However, for the purposes of using this location as a control, these differences are not an issue since the important comparisons are before/after for each location. The *Fall, 2014* noise monitor was started at 11:15 on Sunday September 14, 2014 and ran for 6-days until 13:15 on Saturday September 20, 2014. The *Winter, 2015* noise monitor was started at 10:45 on Wednesday January 14, 2015 and ran for 5 days until 10:45 on Monday January 19, 2015. The noise monitor was shut down early due to pending poor weather conditions and because appropriate data has already been obtained on January 14 - 16. The *Summer, 2015* noise monitor was started at 11:00 on Monday July 20, 2015 and ran for 10 days until 10:00 on Thursday July 30, 2015.

4.0 Results and Discussion

The results obtained from the environmental noise monitorings are shown in Table 1 and Figures 11 - 24 (broadband A-weighted L_{eq} sound levels and 1/3 octave band 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, human activity nearby, dogs barking, abnormally loud vehicle passages on the adjacent residential streets, etc. A detailed list of the data removed along with the duration of the removed data and the reason for removing the data is provided in Appendix IV.

Table 1. Noise Monitoring Results

	L_{eq}24 (dBA)	L_{eq}Day (dBA)	L_{eq}Night (dBA)
8855 - 40 Avenue			
08:00 September 16 - 08:00 September 17, 2014	54.1	55.0	52.3
16:00 September 18 - 16:00 September 19, 2014	54.1	55.3	50.9
Fall, 2014 Logarithmic Average	**54.1**	**55.1**	**51.6**
11:00 January 14 - 11:00 January 15, 2015	53.8	55.0	50.6
Data from 11:00 January 14 - 02:00 January 15 & 02:00 - 11:00 January 16, 2015	54.2	55.5	50.2
Winter, 2015 Logarithmic Average	**54.0**	**55.3**	**50.4**
Difference Between Winter 2015 and Fall 2014	**-0.1**	**0.1**	**-1.2**
09:00 July 27 - 09:00 July 28, 2015	**53.3**	**54.4**	**50.8**
Difference Between Summer 2015 and Winter 2015	**-0.7**	**-0.9**	**0.4**
Difference Between Summer 2015 and Fall 2014	**-0.8**	**-0.8**	**-0.8**
4132 - 89 Street (Control Location)			
08:00 September 16 - 08:00 September 17, 2014	52.6	53.2	51.2
16:00 September 18 - 16:00 September 19, 2014	52.8	53.9	49.9
Fall, 2014 Logarithmic Average	**52.7**	**53.6**	**50.6**
11:00 January 14 - 11:00 January 15, 2015	53.9	55.0	51.2
Data from 11:00 January 14 - 02:00 January 15 & 02:00 - 11:00 January 16, 2015	54.6	55.8	51.2
Winter, 2015 Logarithmic Average	**54.3**	**55.4**	**51.2**
Difference Between Winter 2015 and Fall 2014	**1.6**	**1.9**	**0.7**
09:00 July 27 - 09:00 July 28, 2015	**52.4**	**53.2**	**50.7**
Difference Between Summer 2015 and Winter 2015	**-1.9**	**-2.3**	**-0.5**
Difference Between Summer 2015 and Fall 2014	**-0.3**	**-0.4**	**0.1**

During the *Fall, 2014* noise monitoring period, there were two separate 24-hour time periods within the same week with good weather conditions (i.e. light wind generally in the direction from 91 Street towards the noise monitors and no precipitation). The first time period was from 08:00 September 16 to 08:00 September 17, 2014. During this time, the wind was approximately 5 - 10 km/hr from the S/SW from 08:00 - 15:00. The wind then shifted from the W/NW from 15:00 - 20:00 and then was essentially calm overnight from 20:00 - 08:00. The second time period was from 16:00 September 18 to 16:00 September 19, 2014. During this time, the wind was westerly at approximately 5 - 10 km/hr from 16:00 - 20:00 and then near calm from 20:00 - 00:30. The wind then increased to approximately 5 - 10 km/hr from the SW from 00:30 - 12:00 and then turned westerly at 10 - 15 km/hr from 12:00 - 16:00. The data from both time periods has been used to derive the average $L_{eq}24$, $L_{eq}Day$, and $L_{eq}Night$, as indicated in Table 1. The detailed weather data obtained from the weather monitor during the time period discussed above is presented in Appendix V.

During the *Winter, 2015* noise monitoring period, there was a full 24-hour time period with good weather conditions (i.e. generally light wind generally in the direction from 91 Street towards the noise monitors and no precipitation). The time period from 11:00 January 14 - 11:00 January 15 had a wind of approximately 5 - 10 km/hr from the W/NW from 11:00 - 18:00 on January 14, and then near calm conditions for the remainder. In addition, there was a time period from 02:00 - 11:00 on January 16 with wind approximately 3 - 10 km/hr from the S/SW. The data from both time periods has been used to derive the average $L_{eq}24$, $L_{eq}Day$, and $L_{eq}Night$, as indicated in Table 1. The detailed weather data obtained from the weather monitor during the time period discussed above is presented in Appendix V.

During the *Summer, 2015* noise monitoring period, there was a full 24-hour time period with good weather conditions (i.e. generally light wind in the direction from 91 Street towards the noise monitors and no precipitation). The specific time period used was from 09:00 July 27 - 09:00 July 28. The detailed weather data obtained from the weather monitor during the time period discussed above is presented in Appendix V.

4.1. 8855 - 40 Avenue

The results of the *Fall, 2014* noise monitoring at 8855 - 40 Avenue were very consistent over the two separate 24-hour periods. The two separate 24-hour broadband dBA results are provided in Figures 11 & 12. As anticipated, the highest sustained noise levels occurred during the morning peak traffic period. The resultant 1/3 octave band L_{eq} sound levels are also very consistent and have low frequency noise (near 63 – 80 Hz) typically resulting from engines and exhaust, as well as mid-high frequency noise (near 1,000 Hz) resulting from tire noise, as indicated in Figure 13. Subjective observations indicated that 91 Street was the dominant noise source. In addition, the subjective observations, the review of the recorded audio, and the frequency data indicated a higher than normal low frequency component to the noise (near 63 - 80 Hz). Although the exact source of this elevated low frequency noise is undetermined, it is likely emanating from the industrial area to the west of 91 Street. As will be indicated below, this elevated low frequency noise was not present in the *Winter, 2015* noise monitoring results but returned in the *Summer, 2015* noise monitoring results.

The results of the *Winter, 2015* noise monitoring at 8855 - 40 Avenue on January 14 - 15 are provided in Figure 14. As anticipated, the highest sustained noise levels occurred during the morning peak traffic period. Relative to the *Fall, 2014* noise monitoring period, the noise levels were essentially the same, with a reduction in the $L_{eq}24$ of only 0.1 dBA. The resultant 1/3 octave band L_{eq} sound levels have the typical vehicle traffic 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, as indicated in Figure 15. Also indicated in Figure 15 are the average results from the *Fall, 2014* noise monitoring. It can be seen that the data at the mid-upper frequencies are very similar, with the exception of the elevated low frequency noise in the *Fall, 2014*.

The results of the *Summer, 2015* noise monitoring at 8855 - 40 Avenue on July 27 - 28 are provided in Figure 16. Similar to the previous two noise monitoring periods, the highest sustained noise levels occurred during the morning peak traffic period. Relative to both the *Winter, 2015* and *Fall, 2014* noise monitoring periods, the noise levels were down by 0.7 - 0.8 dBA. The resultant 1/3 octave band L_{eq} sound levels are also very consistent with the *Fall, 2014* noise monitoring period and have low frequency noise (near 63 – 80 Hz) typically resulting from engines and exhaust, as well as mid-high frequency noise (near 1,000 Hz) resulting from tire noise, as indicated in Figure 17. Subjective observations indicated that 91 Street was the dominant noise source. In addition, the subjective observations, the review of the recorded audio, and the frequency data indicated a higher than normal low frequency component to the noise (near 63 - 80 Hz), as was observed during the *Fall, 2014* noise monitoring period. It should also be noted that there was some elevated high frequency noise during the *Summer, 2015* noise monitoring period that was not observed during the previous two noise monitoring periods. This was caused by a yard trimmer operating in the distance for approximately 1-hour on the afternoon of July 27. Although the noise from the yard trimmer had an impact on the highest frequencies, it did not adversely affect the broadband dBA sound level. As such, the data during this time period was not removed from the data set.

4.2. 4132 - 89 Street (Control Location)

The results of the *Fall, 2014* noise monitoring at 4132 - 89 Street were very consistent over the two separate 24-hour periods. The two separate 24-hour broadband dBA results are provided in Figure 18 & 19. As anticipated, the highest sustained noise levels occurred during the morning peak traffic period. The resultant 1/3 octave band L_{eq} sound levels are also very consistent and have low frequency noise (near 63 – 80 Hz) typically resulting from engines and exhaust, as well as mid-high frequency noise (near 1,000 Hz) resulting from tire noise, as indicated in Figure 20. Subjective observations indicated that 91 Street was the dominant noise source. In addition, the subjective observations, the review of the recorded audio, and the frequency data indicate a higher than normal low frequency component to the noise (near 63 - 80 Hz). Although the exact source of this elevated low frequency noise is undetermined, it is likely emanating from the industrial area to the west of 91 Street. As will be indicated below, this elevated low frequency noise was not present in the *Winter, 2015* noise monitoring results but returned in the *Summer, 2015* noise monitoring results.

The results of the *Winter, 2015* noise monitoring at 4132 - 89 Street on January 14 - 15 are provided in Figure 21. As anticipated, the highest sustained noise levels occurred during the morning peak traffic period. Relative to the *Fall, 2014* noise monitoring period, the $L_{eq}24$ noise levels increased by 1.6 dBA. The resultant 1/3 octave band L_{eq} sound levels have the typical vehicle traffic 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, as indicated in Figure 22. Also indicated in Figure 22 are the average results from the *Fall, 2014* noise monitoring. It can be seen that the *Winter, 2015* data at the mid-upper frequencies are elevated by approximately 1 - 2 dBA relative to the *Fall, 2014* data. In addition, there is the elevated low frequency noise in the *Fall, 2014*.

The results of the *Summer, 2015* noise monitoring at 4132 - 89 Street on July 27 - 28 are provided in Figure 23. Similar to the previous two noise monitoring periods, the highest sustained noise levels occurred during the morning peak traffic period. Relative to the *Winter, 2015* and *Fall, 2014* noise monitoring periods, the noise levels were down by 1.9 dBA and 0.3 dBA, respectively. The resultant 1/3 octave band L_{eq} sound levels are also very consistent with the *Fall, 2014* noise monitoring period and have low frequency noise (near 63 – 80 Hz) typically resulting from engines and exhaust, as well as mid-high frequency noise (near 1,000 Hz) resulting from tire noise, as indicated in Figure 24. Subjective observations indicated that 91 Street was the dominant noise source. In addition, the subjective observations, the review of the recorded audio, and the frequency data indicated a higher than normal low frequency component to the noise (near 63 - 80 Hz), as was observed during the *Fall, 2014* noise monitoring period.

4.3. Comparison Between Study Locations

When comparing the *Fall, 2014* noise monitoring data to the *Winter, 2015* noise monitoring data at both locations, it can be seen that there is a notable difference. At the control location of 4132 - 89 Street, the $L_{eq}24$ noise levels increased by 1.6 dBA. If all other conditions had remained the same at the test location of 8855 - 40 Avenue, a similar increase in noise levels would be expected. However, the noise levels at 8855 - 40 Avenue remained essentially unchanged between the *Fall, 2014* and the *Winter, 2015* noise monitoring periods. Based on these results, the eastward-shifted and slightly taller Vegetative Barrier would appear to be performing better than the earth berm by approximately 1.6 dBA.

When comparing the *Summer, 2015* noise monitoring data to the *Fall, 2015* noise monitoring data, there is a reduction in noise levels at both locations. At the control location of 4132 - 89 Street, the $L_{eq}24$ noise levels decreased by 0.3 dBA while at the test location of 8855 - 40 Avenue, the $L_{eq}24$ noise levels decreased by 0.8 dBA. All other factors being equal, this would indicate that the Vegetative Barrier is performing better than the earth berm by approximately 0.5 dBA. However, in terms of comparing noise levels from one year to the next, these changes are relatively small and it is difficult to draw any specific noise level reduction conclusions.

As an overall conclusion, the data indicate that replacing the earth berm with the Vegetative Barrier, with the specific tested geometry, did not adversely affect the noise levels at the adjacent residential receptor. Rather, the data indicate a slight noise level reduction with the Vegetative Barrier which matches the theory based on the fact that the Vegetative Barrier is slightly taller and closer to the residential receptor location, relative to the geometry of the earth berm that it replaced. Thus, based on the noise measurement data, in terms of noise reduction associated with a road noise barrier, the Vegetative Barrier essentially performs as well as other common road noise barrier materials such as masonry walls.

5.0 Conclusion

The *Fall, 2014* noise monitoring results at both locations indicated very consistent noise levels for the two separate 24-hour time periods within the same week. As anticipated, during the *Fall, 2014* and *Winter, 2015* and *Summer, 2015* noise monitoring periods, the highest sustained noise levels occurred during the morning peak traffic periods. The resultant 1/3 octave band L_{eq} sound levels have 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. Subjective observations indicated that 91 Street was the dominant noise source for both locations during all of the noise monitoring periods. In addition, the subjective observations, the review of the recorded audio, and the frequency data indicate a higher than normal low frequency component to the noise (near 63 - 80 Hz) during the *Fall, 2014* noise monitoring period, relative to *Winter, 2015*. Although the exact source of this elevated low frequency noise is undetermined, it is likely emanating from the industrial area to the west of 91 Street. This elevated low frequency noise was not present in the *Winter, 2015* noise monitoring results but returned in *Summer, 2015*.

When comparing the *Fall, 2014* noise monitoring data to the *Winter, 2015* noise monitoring data at both locations, there is a notable difference. At the control location of 4132 - 89 Street, the L_{eq}24 noise levels increased by 1.6 dBA. If all other conditions had remained the same at the test location of 8855 - 40 Avenue location, a similar increase in noise levels would be expected. However, the noise levels at 8855 - 40 Avenue remained essentially unchanged between the *Fall, 2014* and *Winter, 2015* noise monitoring periods. Based on these results, the eastward-shifted and slightly taller Vegetative Barrier would appear to be performing better than the earth berm by approximately 1.6 dBA.

When comparing the *Summer, 2015* noise monitoring data to the *Fall, 2015* noise monitoring data, there is a reduction in noise levels at both locations. At the control location of 4132 - 89 Street, the L_{eq}24 noise levels decreased by 0.3 dBA while at the test location of 8855 - 40 Avenue, the L_{eq}24 noise levels decreased by 0.8 dBA. All other factors being equal, this would indicate that the Vegetative Barrier is performing better than the earth berm by approximately 0.5 dBA. However, given that the daily fluctuations in noise levels can easily be 1 - 3 dBA due to varying weather conditions, in terms of comparing noise levels from one year to the next, these changes are relatively small and it is difficult to draw any specific noise level reduction conclusions.

As an overall conclusion, the data indicate that replacing the earth berm with the Vegetative Barrier, with the specific tested geometry, did not adversely affect the noise levels at the adjacent residential receptor. Rather, the data indicate a slight noise level reduction with the Vegetative Barrier which matches the theory based on the fact that the Vegetative Barrier is slightly taller and closer to the residential receptor location, relative to the geometry of the earth berm that it replaced. Thus, based on the noise measurement data, in terms of noise reduction associated with a road noise barrier, the Vegetative Barrier essentially performs as well as other common road noise barrier materials such as masonry walls.

6.0 References

- 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

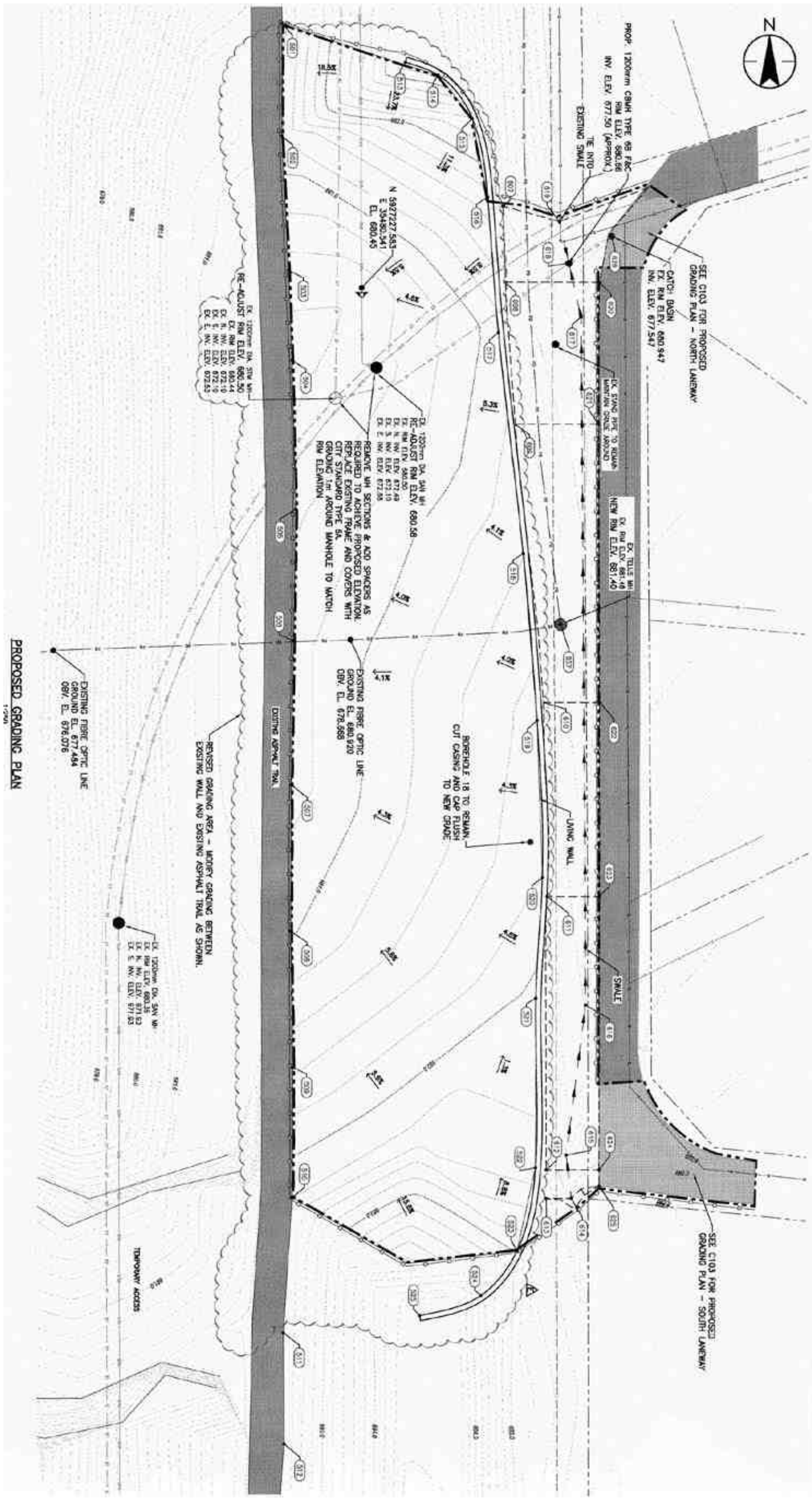

Figure 2. Test Section of Wall

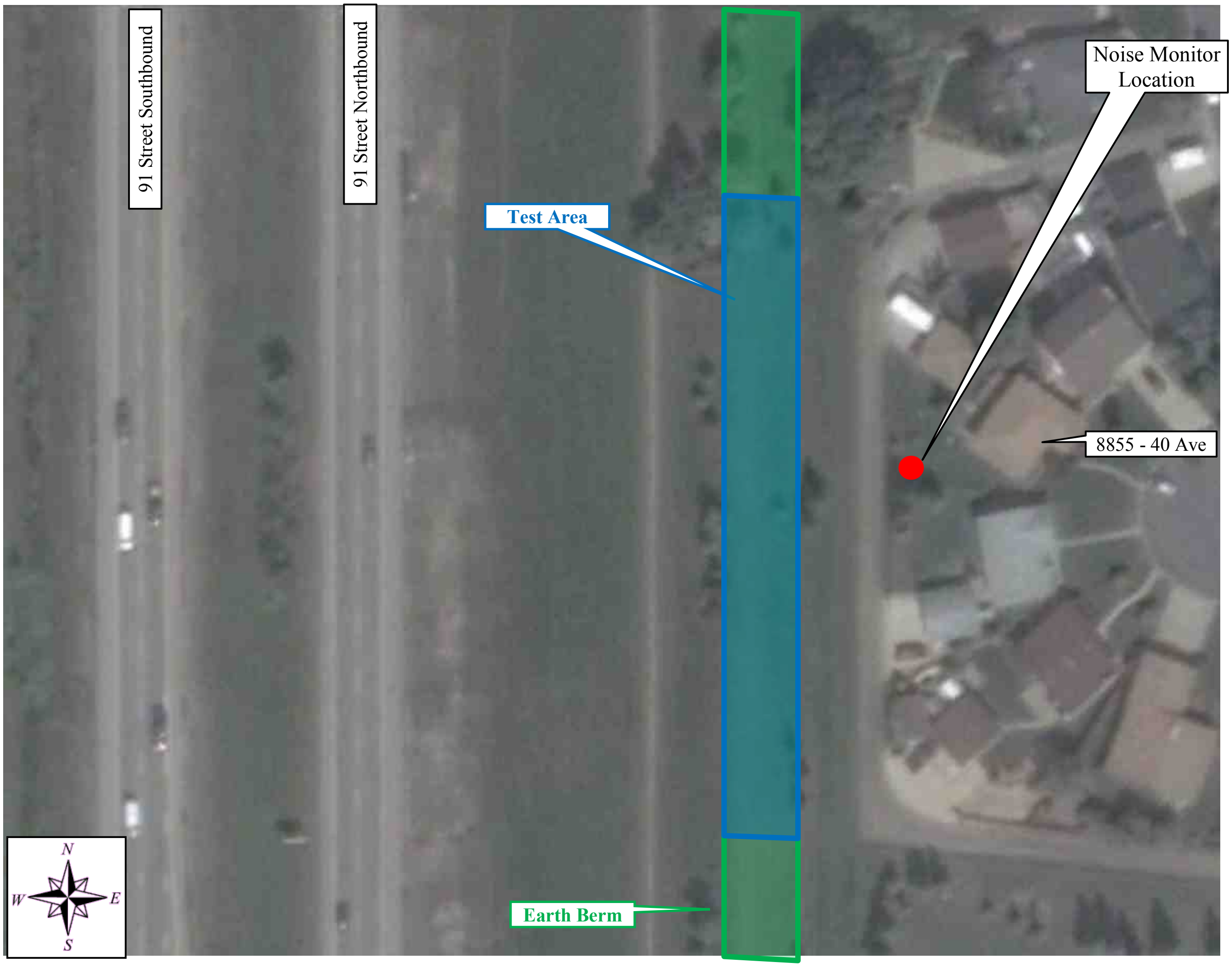

Figure 3. Noise Monitor Location at 8855 - 40 Avenue

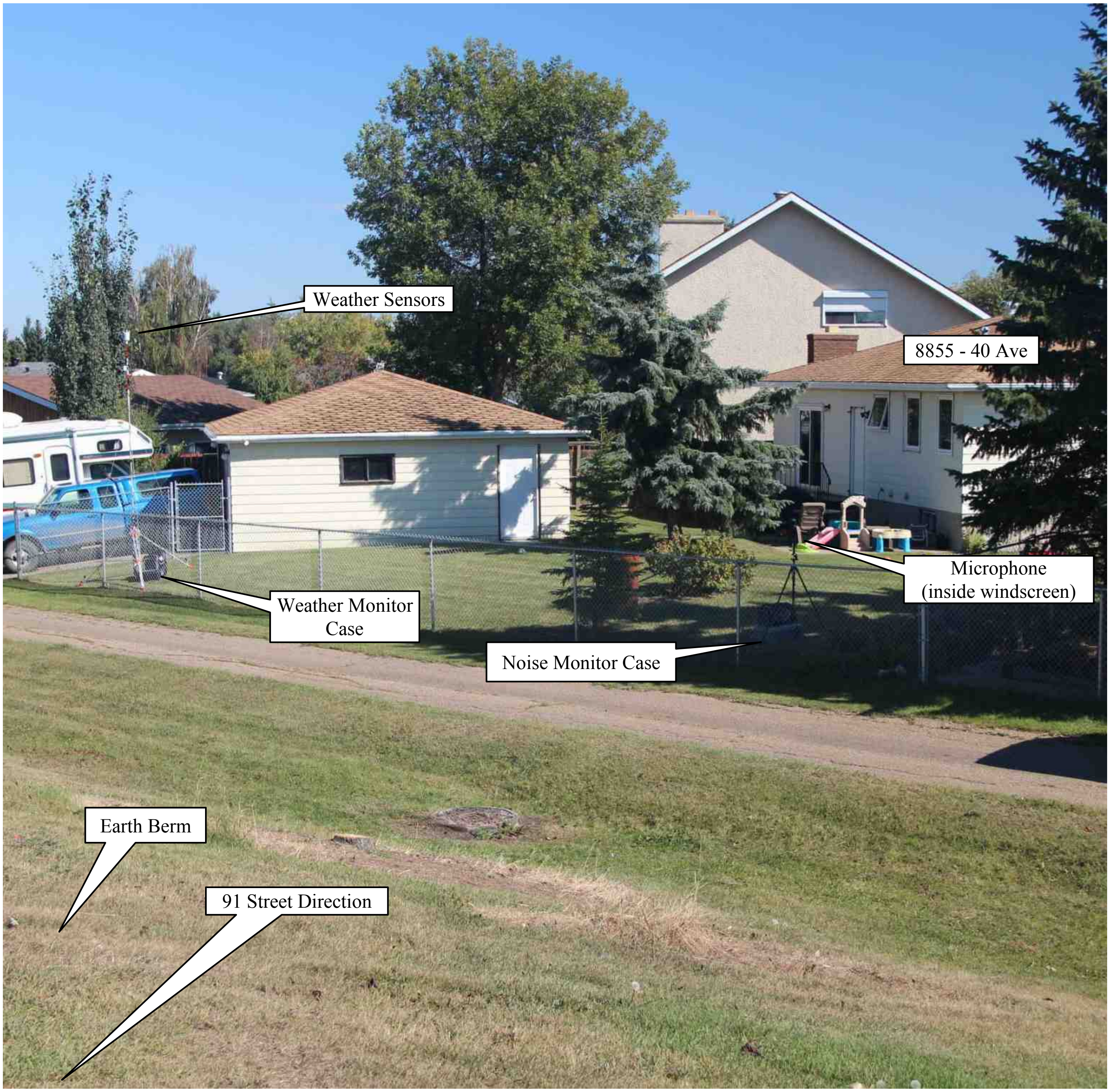

Figure 4. Picture of Noise Monitor at 8855 - 40 Avenue (*Fall, 2014*)

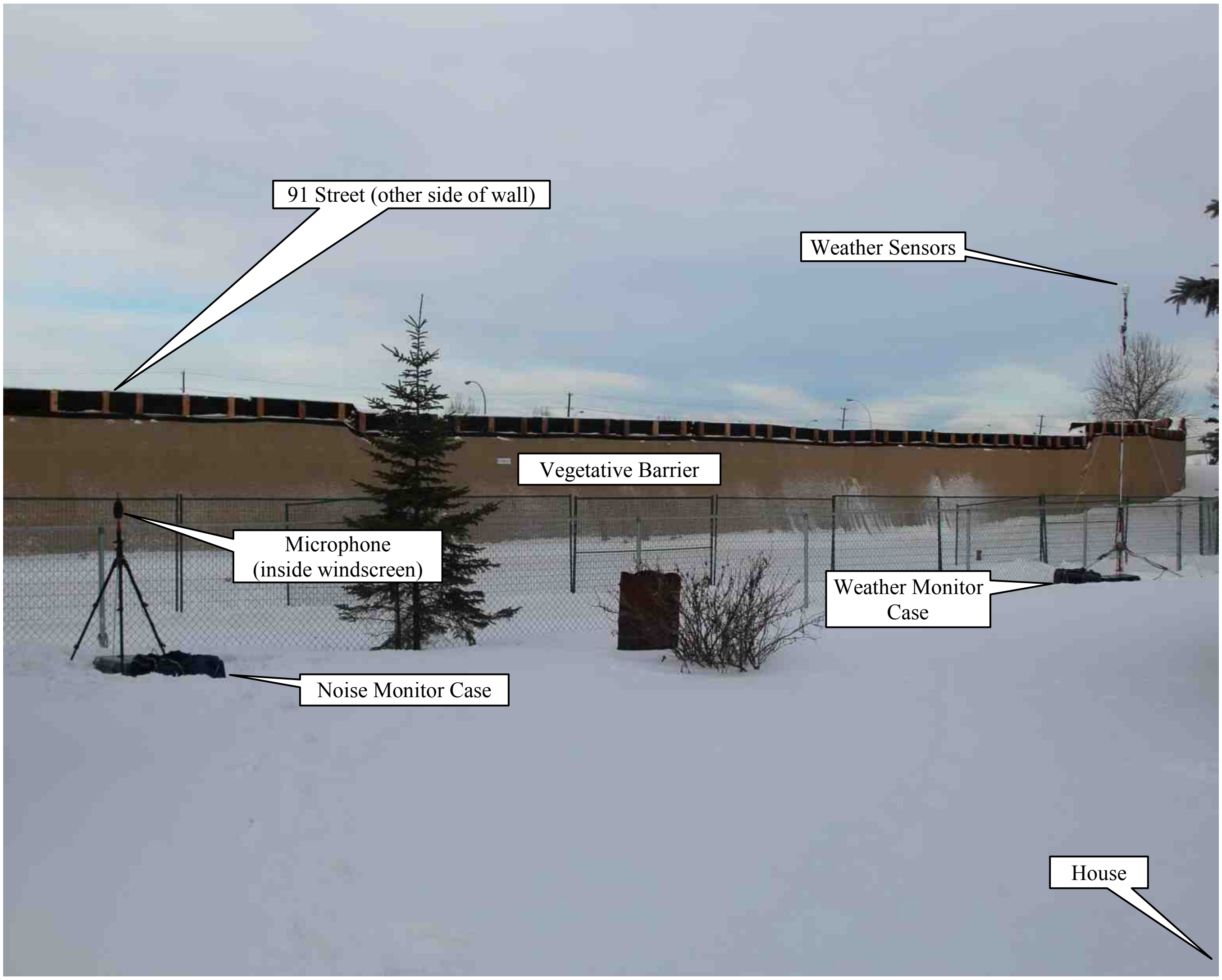

Figure 5. Picture of Noise Monitor at 8855 - 40 Avenue (*Winter, 2015*)

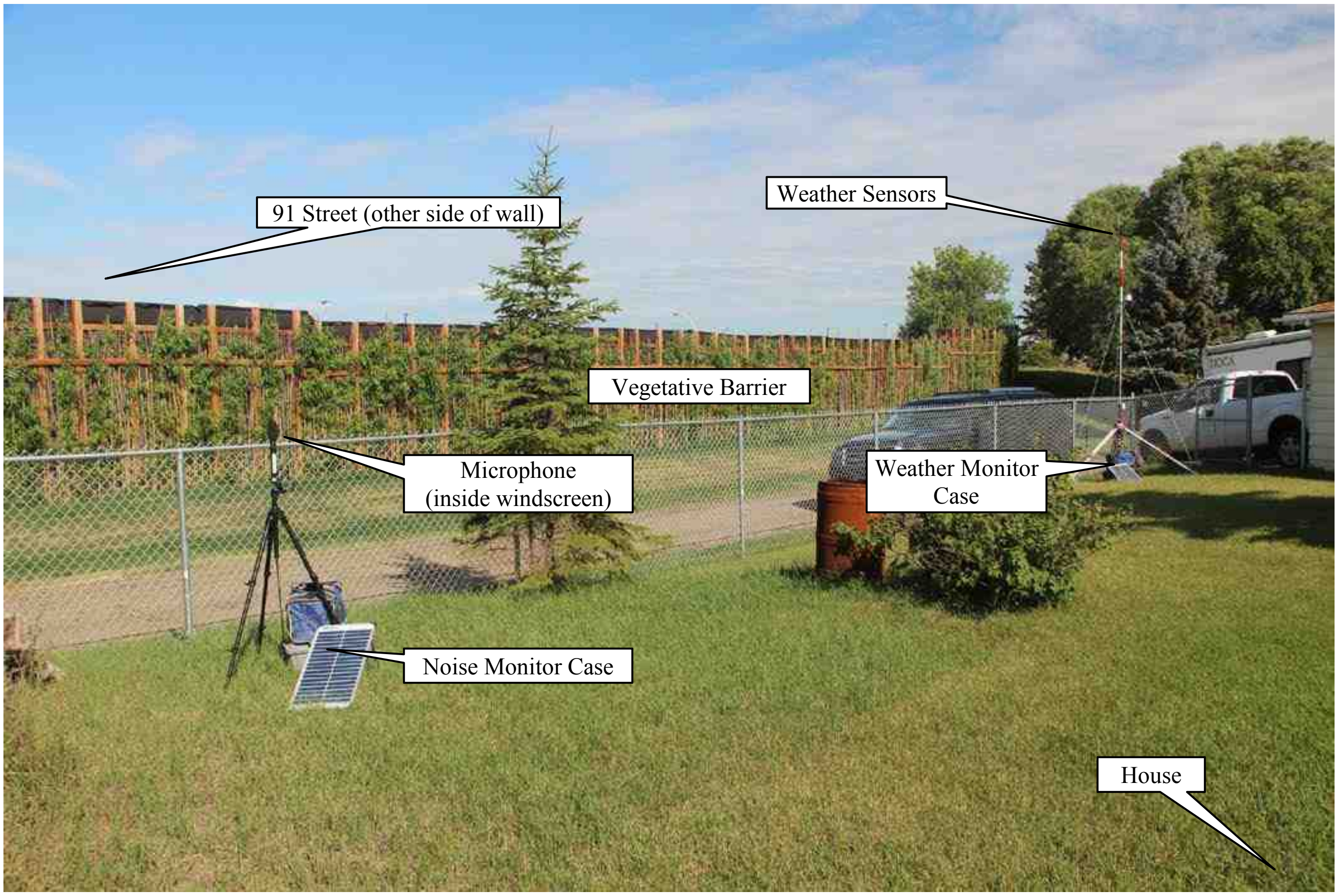

Figure 6. Picture of Noise Monitor at 8855 - 40 Avenue (*Summer, 2015*)

Figure 7. Noise Monitor Location at 4132 - 89 Street

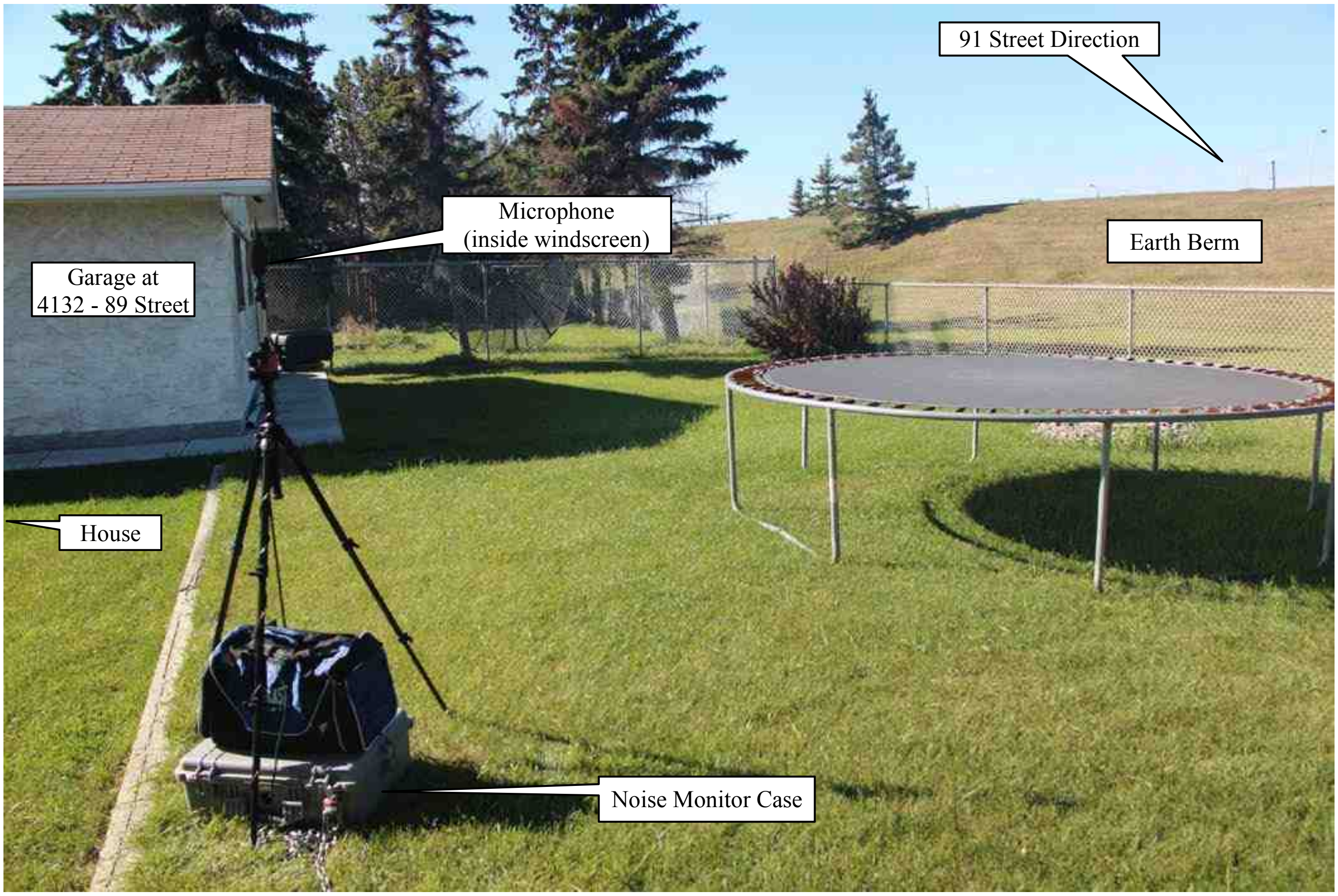

Figure 8. Picture of Noise Monitor at 4132 - 89 Street (*Fall, 2014*)

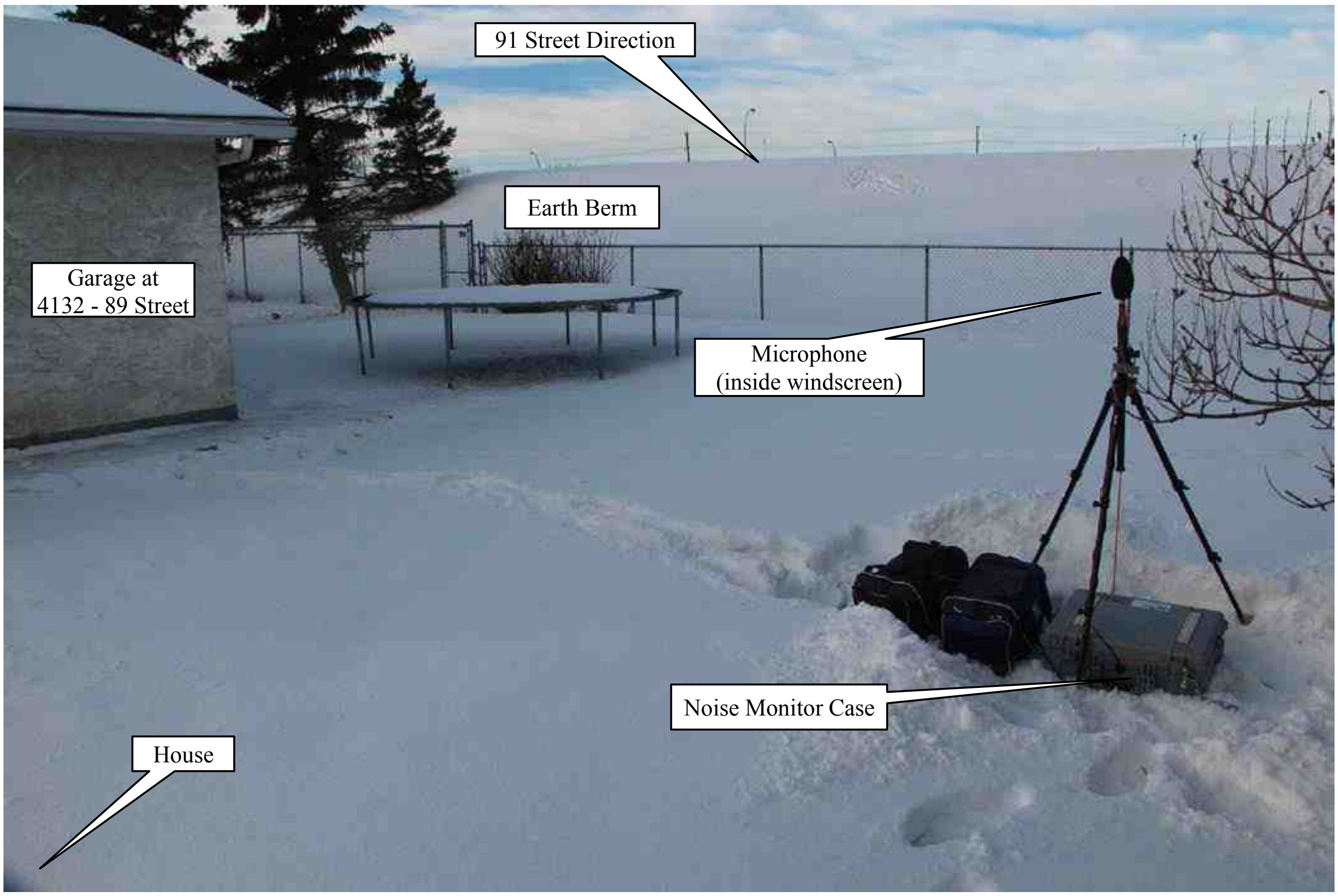

Figure 9. Picture of Noise Monitor at 4132 - 89 Street (*Winter, 2015*)

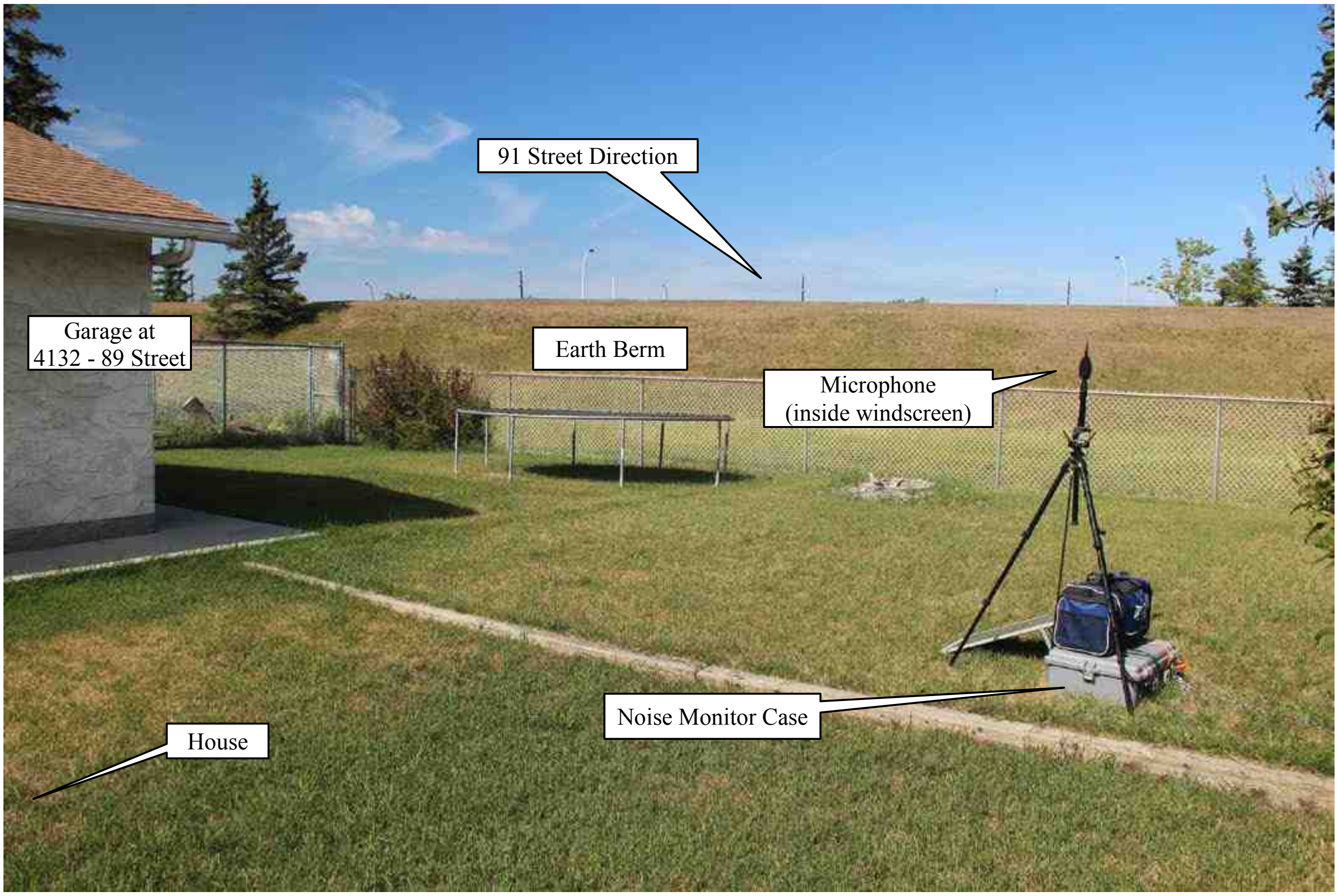

Figure 10. Picture of Noise Monitor at 4132 - 89 Street (*Summer, 2015*)

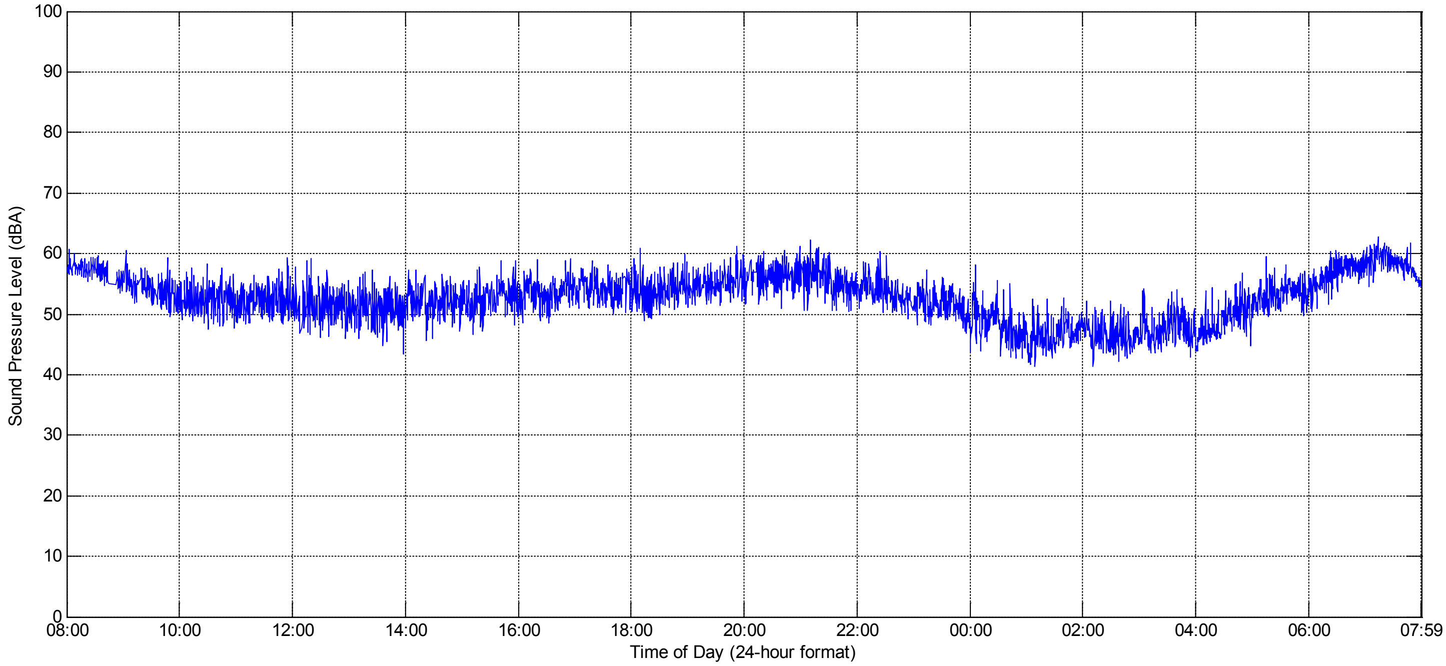

Figure 11. 24-Hour Broadband A-Weighted L_{eq} Sound Levels at 8855 - 40 Avenue (Sept. 16 - 17, 2014)

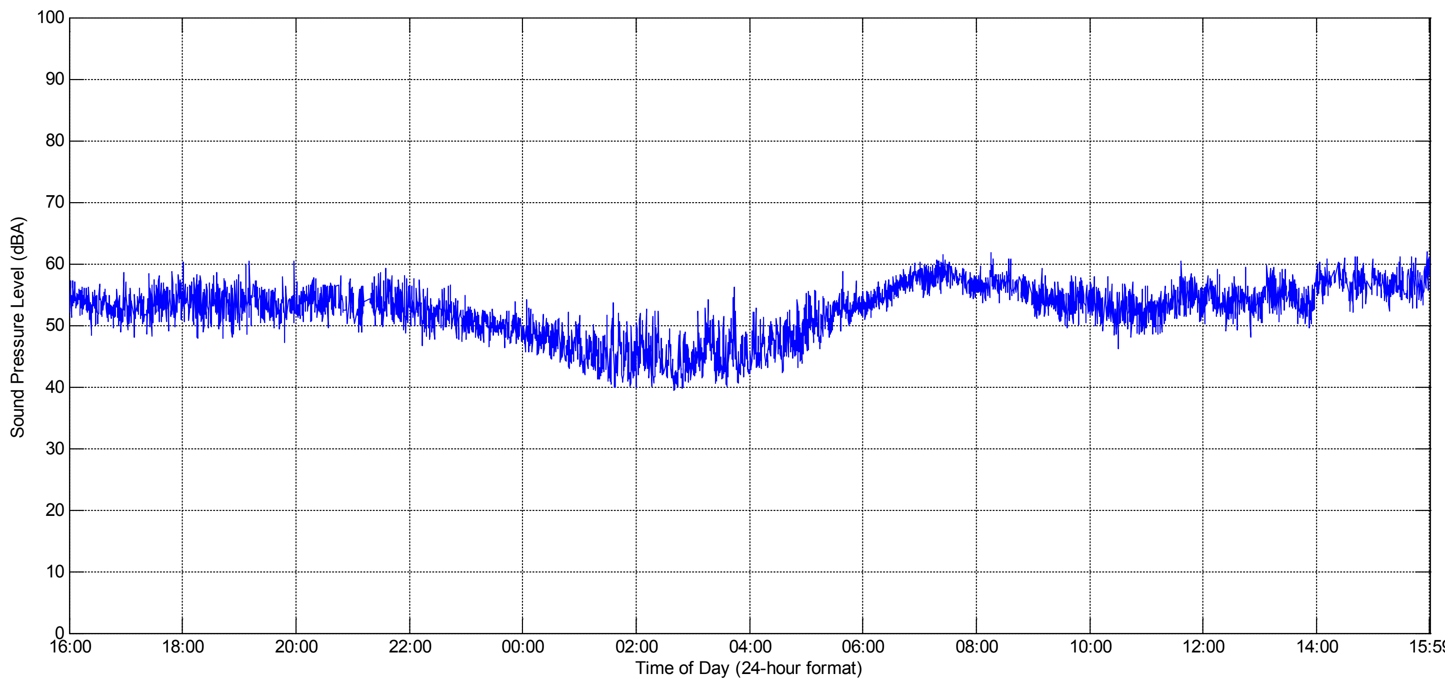

Figure 12. 24-Hour Broadband A-Weighted L_{eq} Sound Levels at 8855 - 40 Avenue (Sept. 18 - 19, 2014)

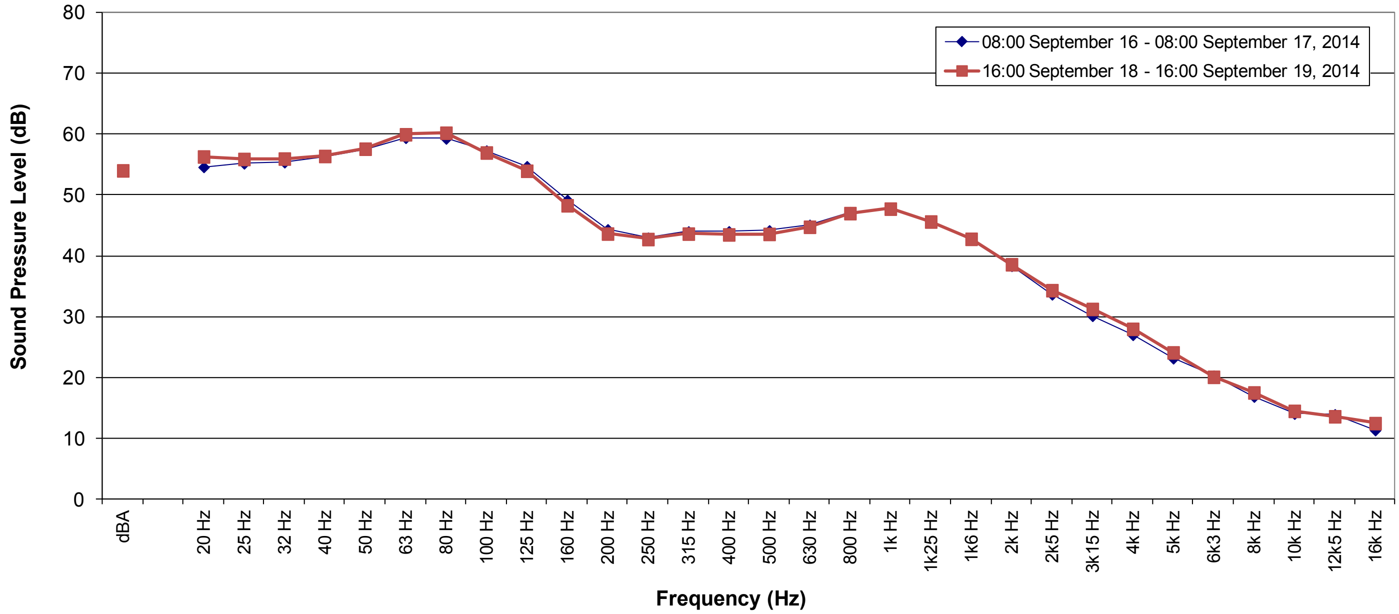

Figure 13. 24-Hour 1/3 Octave Band L_{eq} Sound Levels at 8855 - 40 Avenue (*Fall, 2014*)

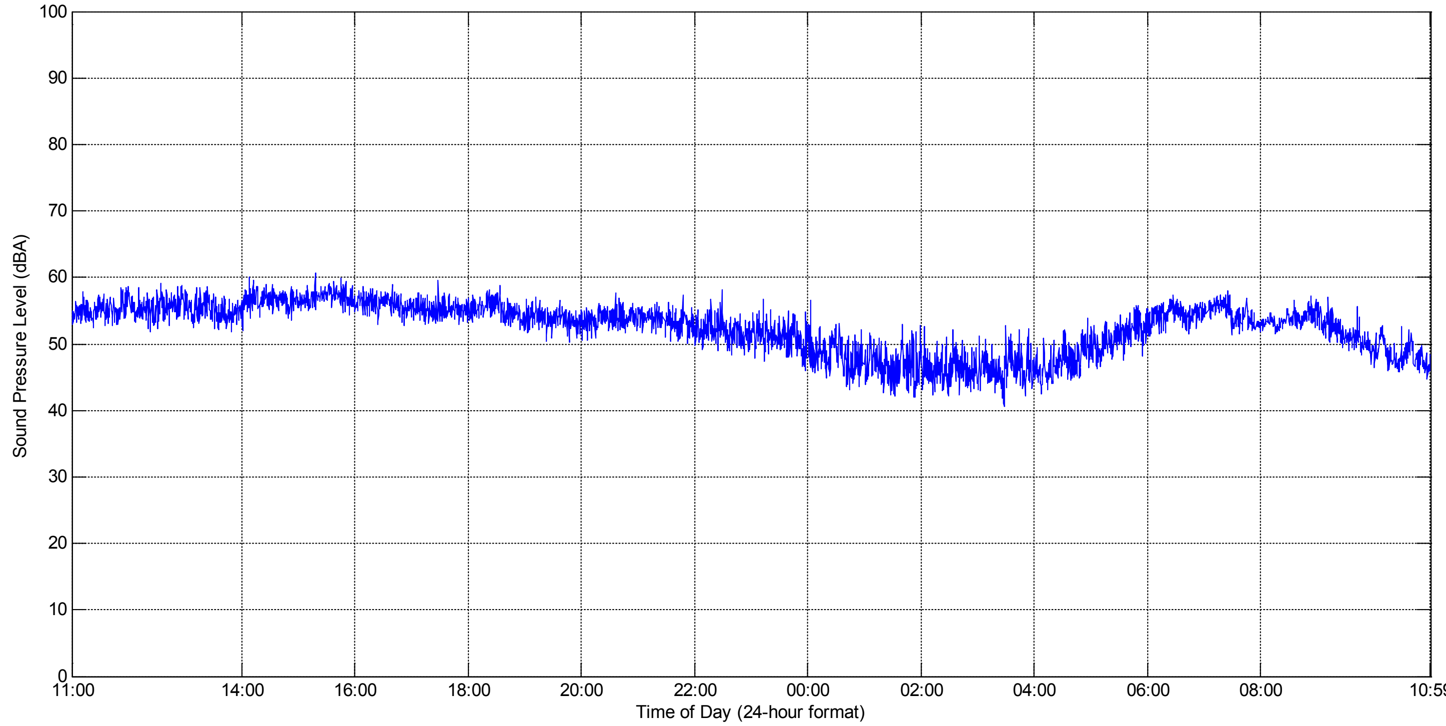

Figure 14. 24-Hour Broadband A-Weighted L_{eq} Sound Levels at 8855 - 40 Avenue (Jan. 14 - 15, 2015)

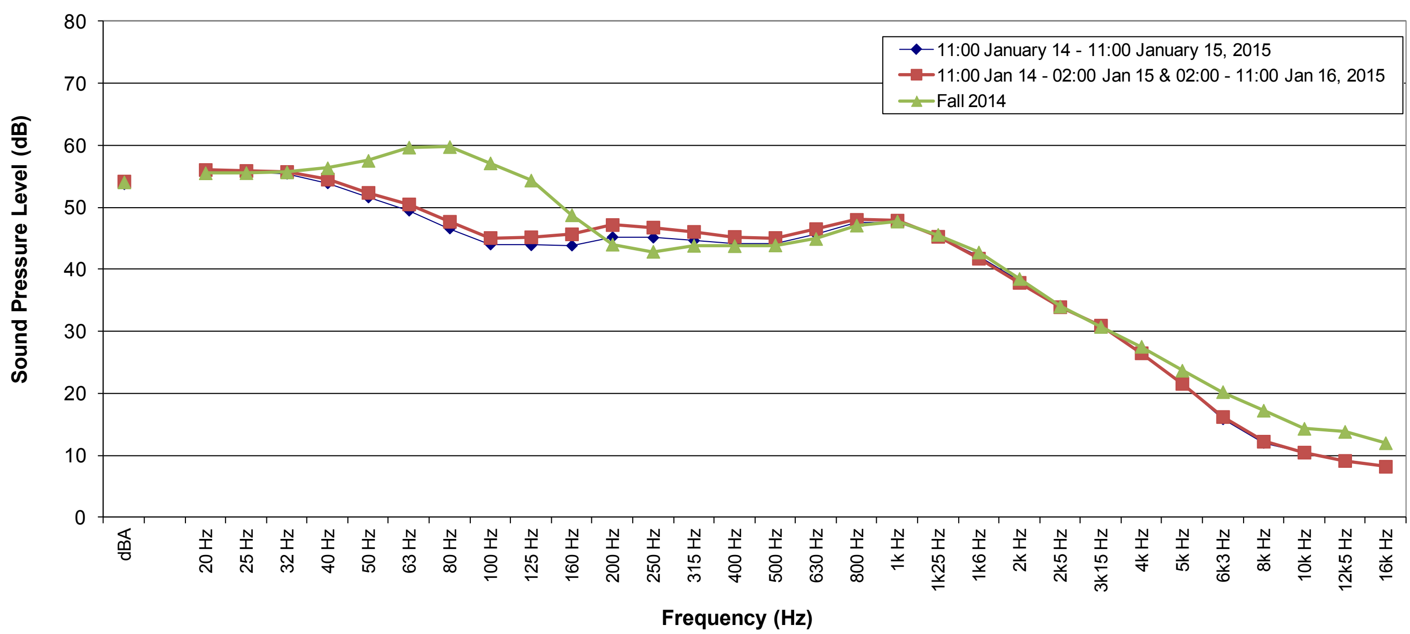

Figure 15. 24-Hour 1/3 Octave Band L_{eq} Sound Levels at 8855 - 40 Avenue (*Winter, 2015*)

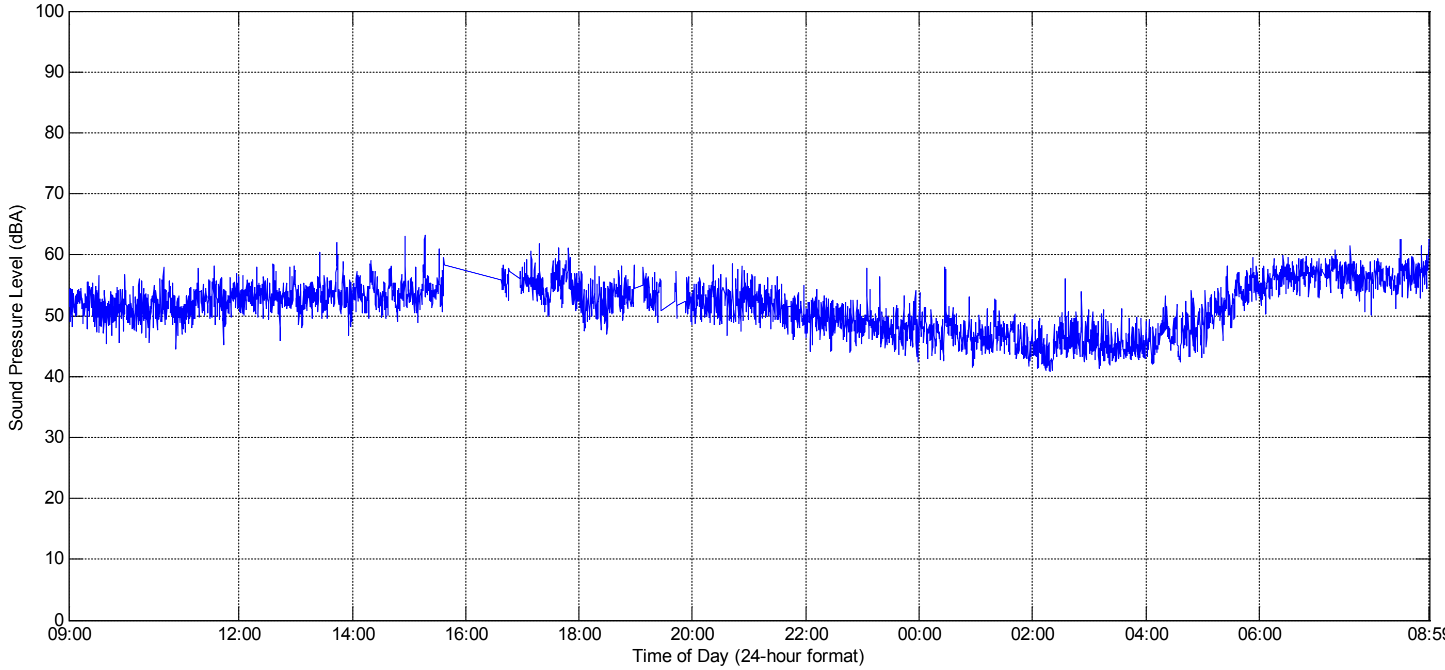

Figure 16. 24-Hour Broadband A-Weighted L_{eq} Sound Levels at 8855 - 40 Avenue (July 27 - 28, 2015)

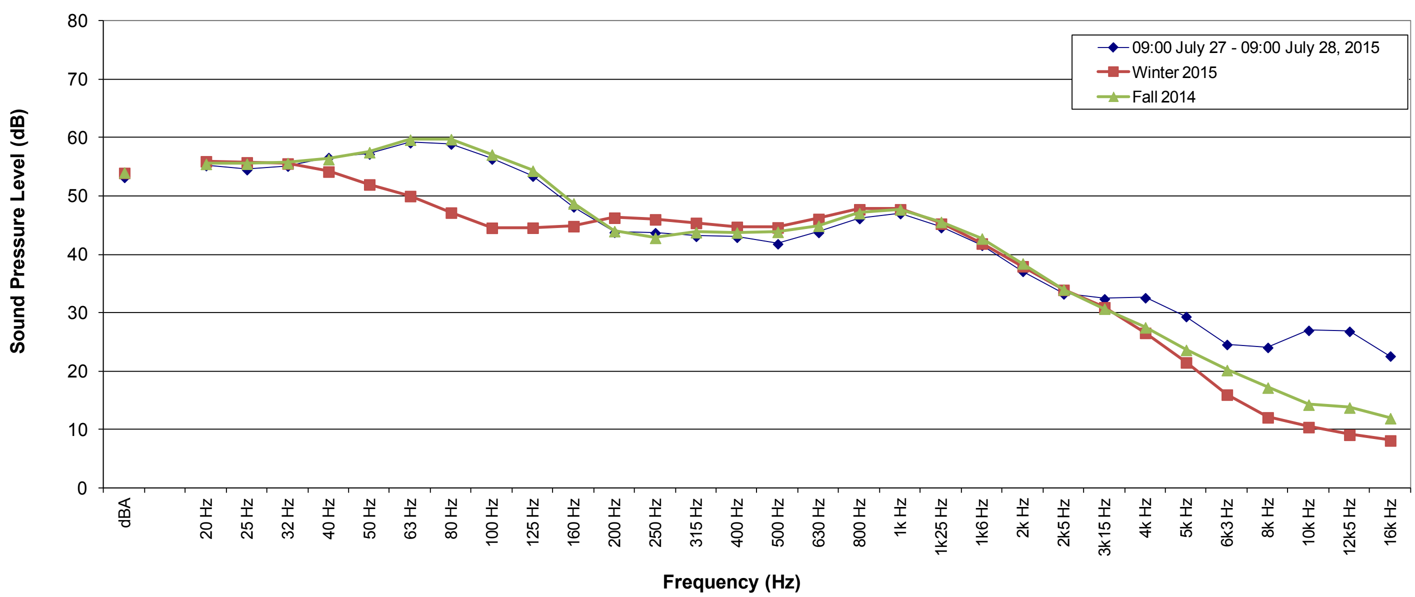

Figure 17. 24-Hour 1/3 Octave Band L_{eq} Sound Levels at 8855 - 40 Avenue (*Summer, 2015*)

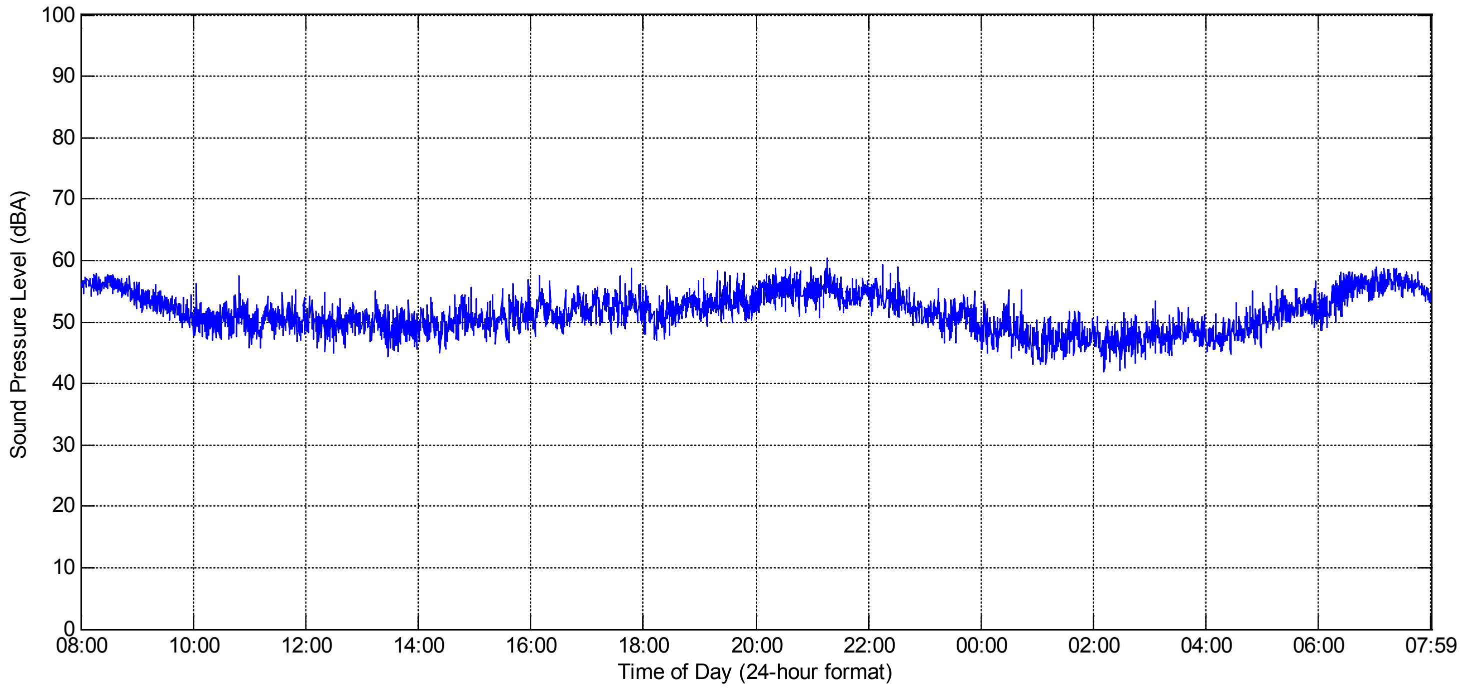

Figure 18. 24-Hour Broadband A-Weighted L_{eq} Sound Levels at 4132 - 89 Street (Sept. 16 - 17, 2014)

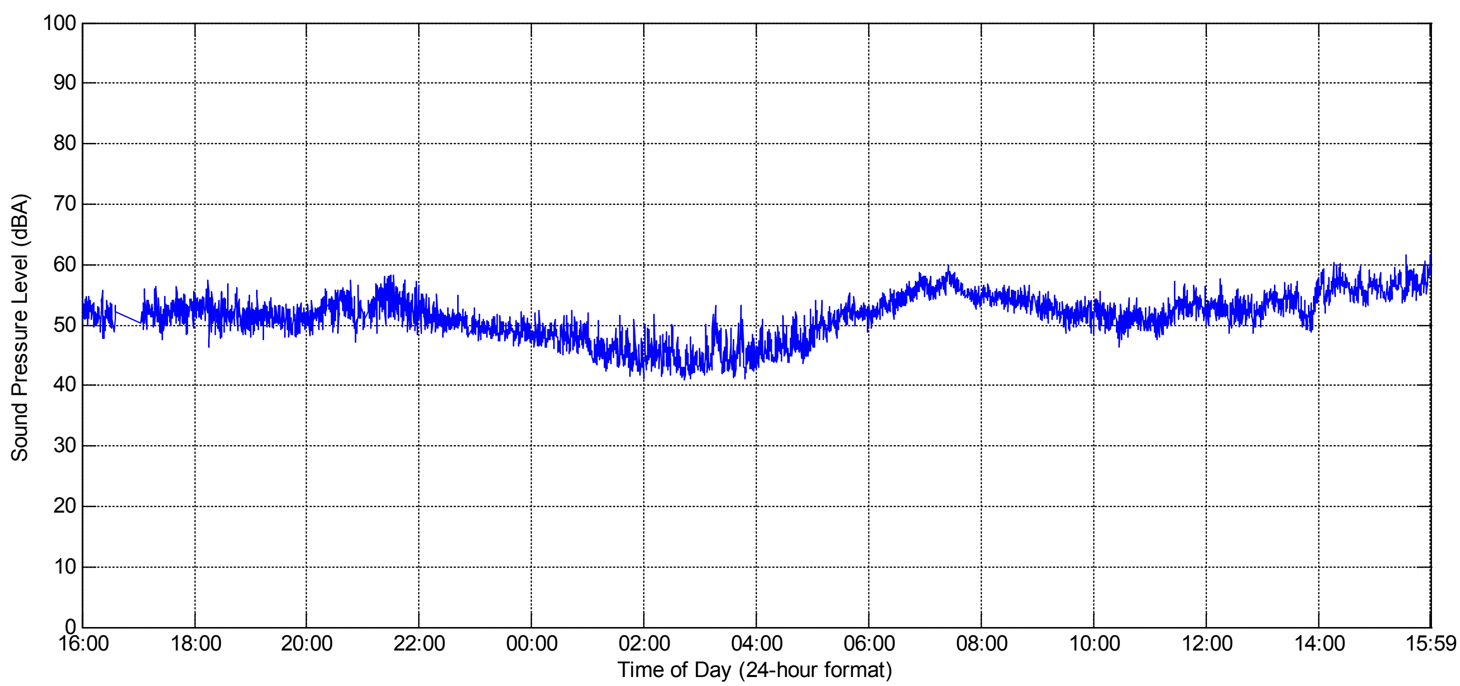

Figure 19. 24-Hour Broadband A-Weighted L_{eq} Sound Levels at 4132 - 89 Street (Sept. 18 - 19, 2014)

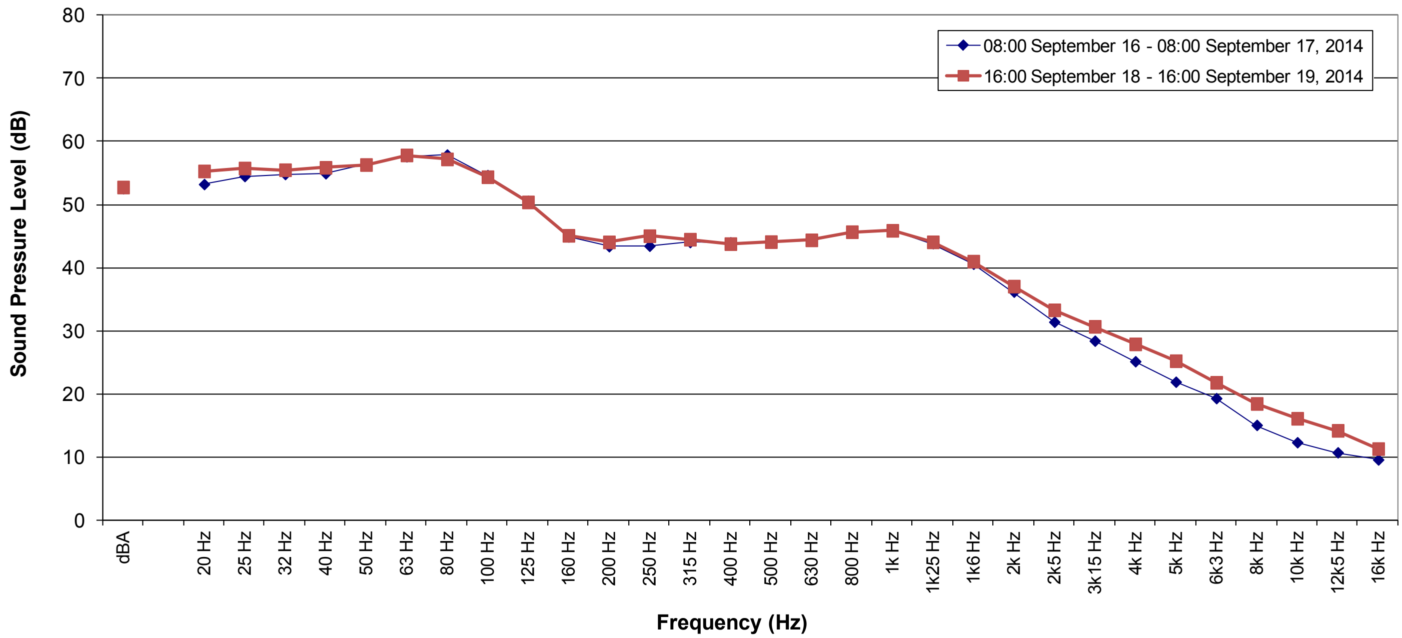

Figure 20. 24-Hour 1/3 Octave Band L_{eq} Sound Levels at 4132 - 89 Street (*Fall, 2014*)

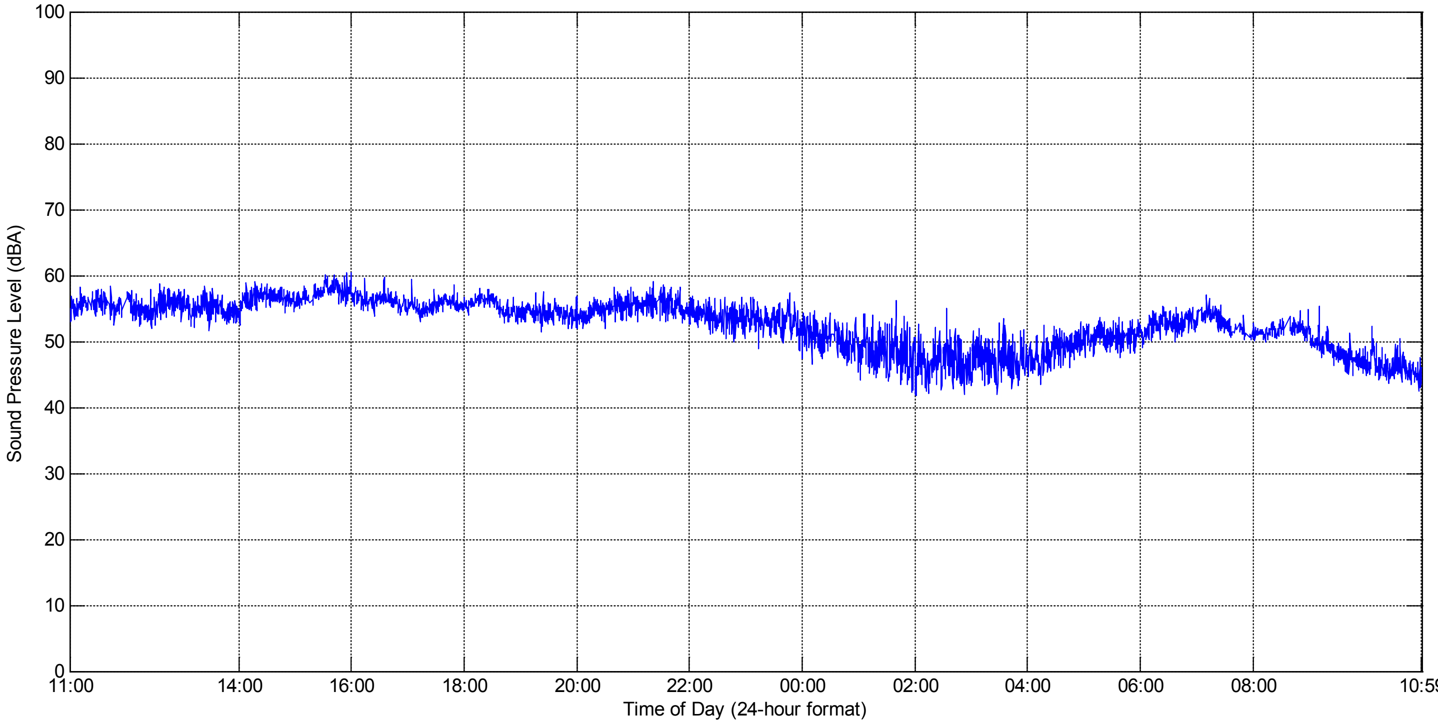

Figure 21. 24-Hour Broadband A-Weighted L_{eq} Sound Levels at 4132 - 89 Street (Jan. 14 - 15, 2015)

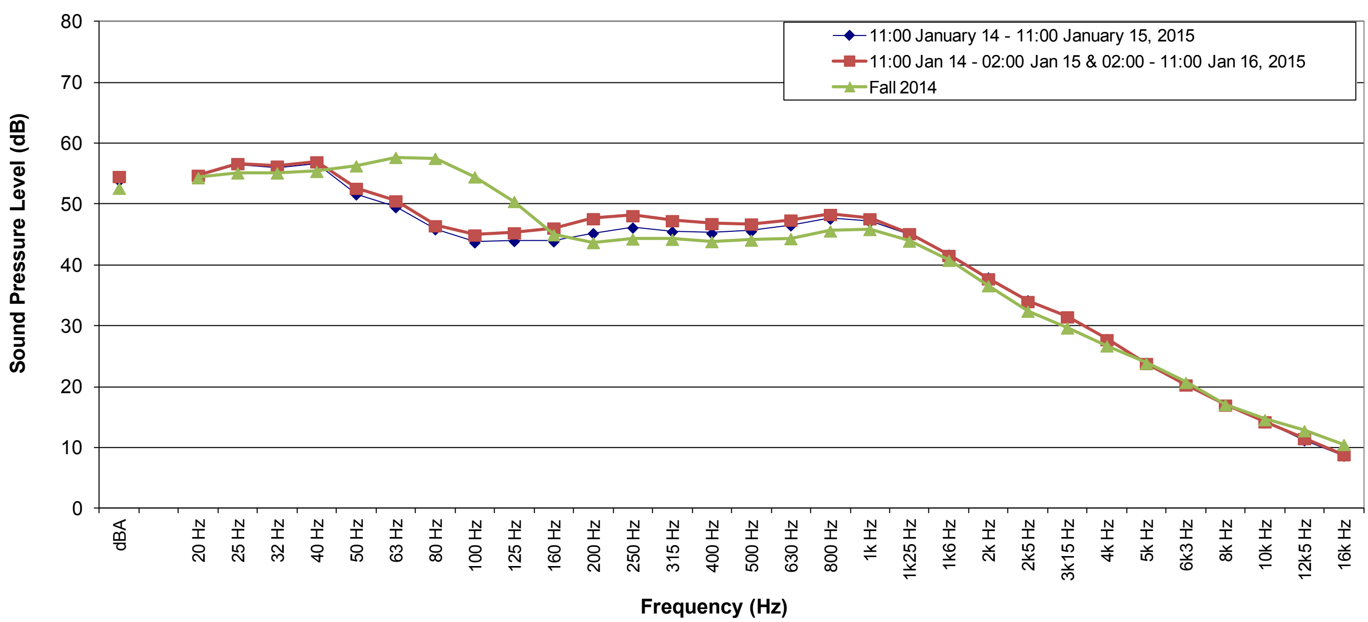

Figure 22. 24-Hour 1/3 Octave Band L_{eq} Sound Levels at 4132 - 89 Street (*Winter, 2015*)

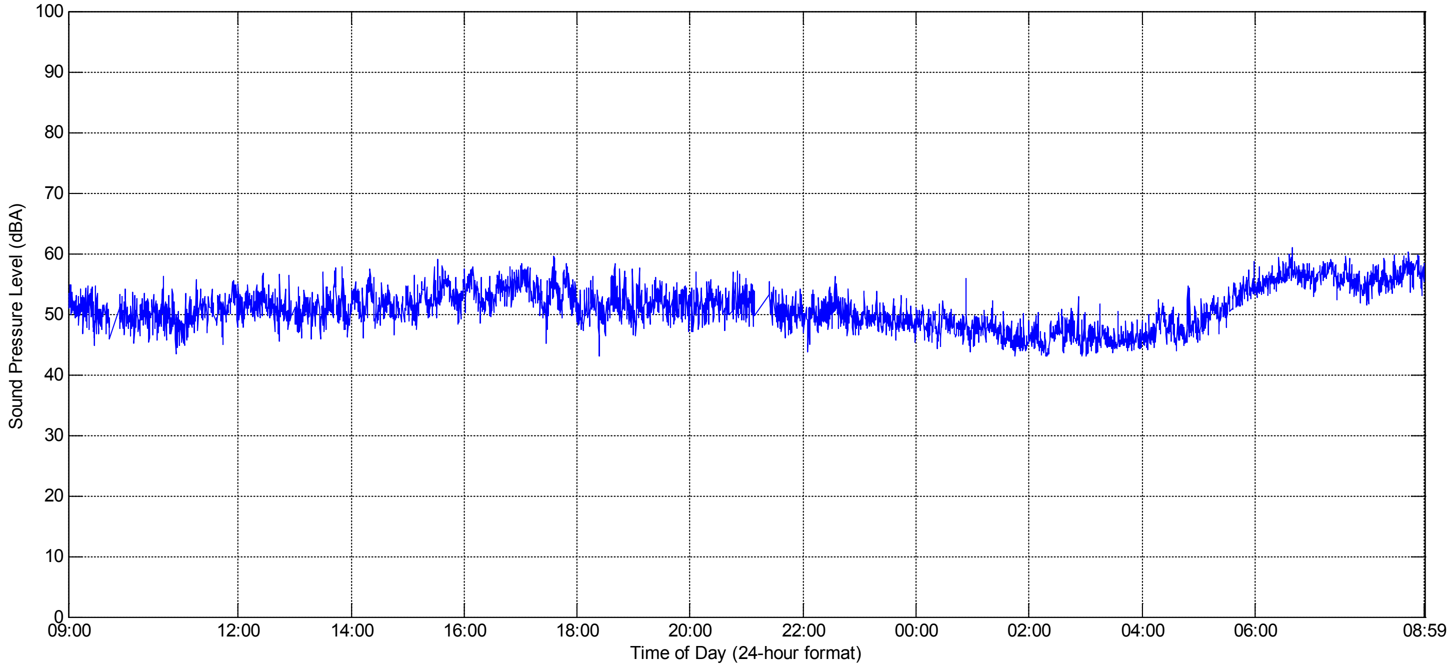

Figure 23. 24-Hour Broadband A-Weighted L_{eq} Sound Levels at 4132 - 89 Street (July 27 - 28, 2015)

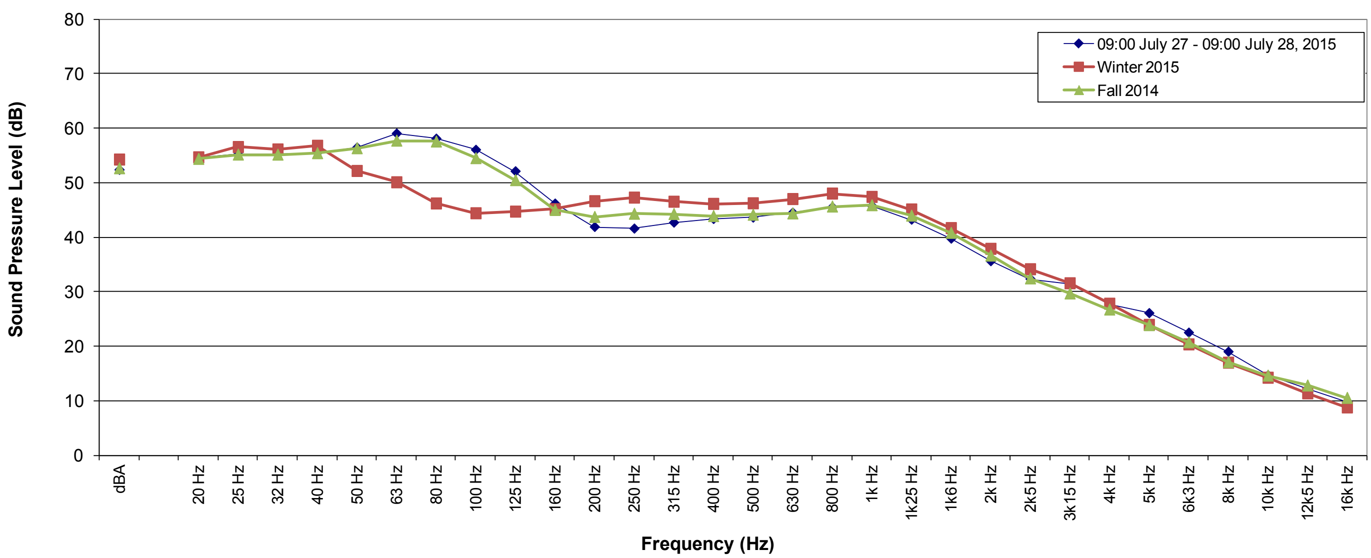

Figure 24. 24-Hour 1/3 Octave Band L_{eq} Sound Levels at 4132 - 89 Street (*Summer, 2015*)

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. For the *Fall, 2014* noise monitoring period, the sound level meters, pre-amplifiers and microphones that were used were certified on October 02, 2012 / October 1, 2012 and the calibrator (type B&K 4231) that was used was certified on November 07, 2013 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. For the *Winter, 2015* noise monitoring period, the sound level meters, pre-amplifiers and microphones that were used were certified on April 30, 2014 and the calibrator was certified on October 06, 2014. For the *Summer, 2015* noise monitoring period, the sound level meters, pre-amplifiers and microphones that were used were certified on October 8/9, 2014 and the calibrator was certified on October 06, 2014. 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 with a WXT520 Self-Aspirating Radiation Shield Sensor Unit, a Weather MicroServer 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 temperature, relative humidity, rain rate and total rain accumulation.

Record of Calibration Results

Description	Date	Time	Pre / Post	Calibration Level	Calibrator Model	Serial Number
September, 2014						
8855 - 40 Avenue	September 14 2014	12:00	Pre	93.9 dBA	B&K 4231	2594693
8855 - 40 Avenue	September 20 2014	13:30	Post	93.9 dBA	B&K 4231	2594693
4132 - 89 Street	September 14 2014	11:15	Pre	93.9 dBA	B&K 4231	2594693
4132 - 89 Street	September 20 2014	13:15	Post	93.8 dBA	B&K 4231	2594693
January, 2015						
8855 - 40 Avenue	January 14 2015	10:00	Pre	93.9 dBA	B&K 4231	2594693
8855 - 40 Avenue	January 19 2015	10:00	Post	93.8 dBA	B&K 4231	2594693
4132 - 89 Street	January 14 2015	10:45	Pre	93.9 dBA	B&K 4231	2594693
4132 - 89 Street	January 19 2015	10:45	Post	93.8 dBA	B&K 4231	2594693
Summer, 2015						
8855 - 40 Avenue	July 20 2015	10:00	Pre	93.9 dBA	B&K 4231	2594693
8855 - 40 Avenue	July 30 2015	12:50	Post	93.8 dBA	B&K 4231	2594693
4132 - 89 Street	July 20 2015	10:45	Pre	93.9 dBA	B&K 4231	2594693
4132 - 89 Street	July 30 2015	12:05	Post	93.9 dBA	B&K 4231	2594693

(*Fall, 2014*) B&K 2250 Unit #6 SLM Calibration Certificate

Scantek, Inc.
CALIBRATION LABORATORY

ISO 17025: 2005, ANSI/NCSL Z540:1994 Part 1
ACCREDITED by NVLAP (an ILAC and APLAC signatory)

NVLAP®
NVLAP Lab Code: 200625-0

Calibration Certificate No.27286

Instrument:	**Sound Level Meter**	*Date Calibrated:* **10/2/2012**	*Cal Due:*
Model:	**2250**	*Status:*	
Manufacturer:	**Brüel and Kjær**		
Serial number:	**2661161**		
Tested with:	**Microphone 4189 s/n 2650730** **Preamplifier ZC0032 s/n 9935**		
Type (class):	**1**		
Customer:	**ACI Acoustical Consultants Inc.**	*Address:*	**5031 - 210 Street, Edmonton**
Tel/Fax:	**780-414-6373 / -6376**		**Alberta, CANADA T6M 0A8**

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

Contains non-accredited tests: __Yes _X_ No
Calibration service: __ Basic _X_ Standard

Tested in accordance with the following procedures and standards:
Calibration of Sound Level Meters, Scantek Inc., Rev. 6/22/2012
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	25747	Jul 2, 2012	Scantek, Inc./ NVLAP	Jul 2, 2013
DS-360-SRS	Function Generator	61646	Nov 16, 2011	ACR Env./ A2LA	Nov 16, 2013
34401A-Agilent Technologies	Digital Voltmeter	MY41022043	Dec 9, 2011	ACR Env. / A2LA	Dec 9, 2012
DPI 141-Druck	Pressure Indicator	790/00-04	Dec 13, 2010	ACR Env./ A2LA	Dec 13, 2012
HMP233-Vaisala Oyj	Humidity & Temp.	V3820001	Sep 6, 2012	ACR Env./ A2LA	Mar 6, 2014
PC Program 1019 Norsonic	Calibration software	v.5.2	Validated Mar 2011	Scantek, Inc.	-
1251-Norsonic	Calibrator	30878	Dec 13, 2011	Scantek, Inc./ NVLAP	Dec 13, 2012

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 (%)
23.2 °C	99.991 kPa	51.9 %RH

Calibrated by:	Valentin Buzduga	**Authorized signatory:**	Mariana Buzduga
Signature		Signature	
Date	10/02/2012	Date	10/2/2012

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(*Fall, 2014*) B&K 2250 Unit #6 Microphone Calibration Certificate

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

NVLAP®
NVLAP Lab Code: 200625-0

Calibration Certificate No.27287

Instrument: **Microphone**
Model: **4189**
Manufacturer: **Brüel & Kjær**
Serial number: **2650730**
Composed of:

Date Calibrated: **10/1/2012** *Cal Due:*

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

Contains non-accredited tests: __Yes _X_ No

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 Measurement Microphones, Scantek, Inc., Rev. 11/30/2010

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	25747	Jul 2, 2012	Scantek, Inc./ NVLAP	Jul 2, 2013
DS-360-SRS	Function Generator	61646	Nov 16, 2011	ACR Env./ A2LA	Nov 16, 2013
34401A-Agilent Technologies	Digital Voltmeter	MY41022043	Dec 9, 2011	ACR Env. / A2LA	Dec 9, 2012
DPI 141-Druck	Pressure Indicator	790/00-04	Dec 13, 2010	ACR Env./ A2LA	Dec 13, 2012
HMP233-Vaisala Oyj	Humidity & Temp. Transmitter	V3820001	Sep 6, 2012	ACR Env./ A2LA	Mar 6, 2014
PC Program 1017 Norsonic	Calibration software	v.5.2	Validated Mar 2011	Scantek, Inc.	-
1253-Norsonic	Calibrator	28326	Dec 13, 2011	Scantek, Inc./ NVLAP	Dec 13, 2012
1203-Norsonic	Preamplifier	14059	Jan 3, 2012	Scantek, Inc./ NVLAP	Jan 3, 2013
4180-Brüel&Kjær	Microphone	2246115	Nov 21, 2011	NPL-UK / UKAS	Nov 21, 2013

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

Calibrated by:	Valentin Buzduga	**Authorized signatory:**	Mariana Buzduga
Signature		Signature	
Date	10/01/2012	Date	10/2/2012

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(*Fall, 2014*) B&K 2250 Unit #7 SLM Calibration Certificate

Scantek, Inc.
CALIBRATION LABORATORY

ISO 17025: 2005, ANSI/NCSL Z540:1994 Part 1
ACCREDITED by NVLAP (an ILAC and APLAC signatory)

NVLAP®
NVLAP Lab Code: 200625-0

Calibration Certificate No.27288

Instrument: **Sound Level Meter**
Model: **2250**
Manufacturer: **Brüel and Kjær**
Serial number: **2722859**
Tested with: **Microphone 4189 s/n 2710791**
Preamplifier ZC0032 s/n 13398
Type (class): **1**
Customer: **ACI Acoustical Consultants Inc.**
Tel/Fax: **780-414-6373 / -6376**

Date Calibrated: **10/1/2012** *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. 6/22/2012
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	25747	Jul 2, 2012	Scantek, Inc./ NVLAP	Jul 2, 2013
DS-360-SRS	Function Generator	61646	Nov 16, 2011	ACR Env./ A2LA	Nov 16, 2013
34401A-Agilent Technologies	Digital Voltmeter	MY41022043	Dec 9, 2011	ACR Env. / A2LA	Dec 9, 2012
DPI 141-Druck	Pressure Indicator	790/00-04	Dec 13, 2010	ACR Env./ A2LA	Dec 13, 2012
HMP233-Vaisala Oyj	Humidity & Temp.	V3820001	Sep 6, 2012	ACR Env./ A2LA	Mar 6, 2014
PC Program 1019 Norsonic	Calibration software	v.5.2	Validated Mar 2011	Scantek, Inc.	-
1251-Norsonic	Calibrator	30878	Dec 13, 2011	Scantek, Inc./ NVLAP	Dec 13, 2012

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 (%)
22.7 °C	100.02 kPa	47.4 %RH

Calibrated by:	Valentin Buzduga	**Authorized signatory:**	Mariana Buzduga
Signature		Signature	
Date	10/01/2012	Date	10/2/2012

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.
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(*Fall, 2014*) B&K 2250 Unit #7 Microphone Calibration Certificate

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

NVLAP®
NVLAP Lab Code: 200625-0

Calibration Certificate No.27289

Instrument: **Microphone**
Model: **4189**
Manufacturer: **Brüel & Kjær**
Serial number: **2710791**
Composed of:

Date Calibrated: **10/1/2012** *Cal Due:*

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

Contains non-accredited tests: __Yes _X_ No

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 Measurement Microphones, Scantek, Inc., Rev. 11/30/2010

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	25747	Jul 2, 2012	Scantek, Inc./ NVLAP	Jul 2, 2013
DS-360-SRS	Function Generator	61646	Nov 16, 2011	ACR Env./ A2LA	Nov 16, 2013
34401A-Agilent Technologies	Digital Voltmeter	MY41022043	Dec 9, 2011	ACR Env. / A2LA	Dec 9, 2012
DPI 141-Druck	Pressure Indicator	790/00-04	Dec 13, 2010	ACR Env./ A2LA	Dec 13, 2012
HMP233-Vaisala Oyj	Humidity & Temp. Transmitter	V3820001	Sep 6, 2012	ACR Env./ A2LA	Mar 6, 2014
PC Program 1017 Norsonic	Calibration software	v.5.2	Validated Mar 2011	Scantek, Inc.	-
1253-Norsonic	Calibrator	28326	Dec 13, 2011	Scantek, Inc./ NVLAP	Dec 13, 2012
1203-Norsonic	Preamplifier	14059	Jan 3, 2012	Scantek, Inc./ NVLAP	Jan 3, 2013
4180-Brüel&Kjær	Microphone	2246115	Nov 21, 2011	NPL-UK / UKAS	Nov 21, 2013

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

Calibrated by:	Valentin Buzduga	Authorized signatory:	Mariana Buzduga
Signature		Signature	
Date	10/01/2012	Date	10/2/2012

Document stored as: Z:\Calibration Lab\Mic 2012\B&K4189_2710791_M1.doc Page 1 of 2

(*Fall, 2014*) 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.30003

Instrument:	**Acoustical Calibrator**	*Date Calibrated:* **11/7/2013** *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. 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	25747	Jul 2, 2013	Scantek, Inc./ NVLAP	Jul 2, 2014
DS-360-SRS	Function Generator	61646	Nov 20, 2012	ACR Env./ A2LA	Nov 20, 2014
34401A-Agilent Technologies	Digital Voltmeter	MY41022043	Nov 20, 2012	ACR Env. / A2LA	Nov 20, 2013
DPI 141-Druck	Pressure Indicator	790/00-04	Nov 21, 2012	ACR Env./ A2LA	Nov 21, 2014
HMP233-Vaisala Oyj	Humidity & Temp. Transmitter	V3820001	Sep 6, 2012	ACR Env./ A2LA	Mar 6, 2014
8903A-HP	Audio Analyzer	2514A05691	Dec 1, 2010	ACR Env./ A2LA	Dec 1, 2013
PC Program 1018 Norsonic	Calibration software	v.5.2	Validated March 2011	Scantek, Inc.	-
4134-Brüel&Kjær	Microphone	906763	Nov 23, 2011	NPL-UK / UKAS	Nov 23, 2013
1203-Norsonic	Preamplifier	14059	Jan 4, 2013	Scantek, Inc./ NVLAP	Jan 4, 2014

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	
Date	11/07/2013	Date	11/07/2013

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(*Winter, 2015*) B&K 2250 Unit #8 SLM Calibration Certificate

MANUFACTURER'S CERTIFICATE OF CONFORMANCE

We certify that Brüel & Kjær **-2250--D00-** Serial No. **3005978** 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-2014

Torben Bjørn
Vice President, Operations

Please note that this document is not a calibration certificate.
For information on our calibration services please contact your nearest Brüel & Kjær office.

HEADQUARTERS: Brüel & Kjær Sound & Vibration Measurement A/S · DK-2850 Nærum · Denmark
Telephone: +45 7741 2000 · Fax: +45 4580 1405 · www.bksv.com · info@bksv.com
Local representatives and service organisations worldwide

Brüel & Kjær

Prepolarized Free-field 1/2" Microphone Type 4189

Bruel & Kjær

Calibration Chart

Serial No: 2851039

Open-circuit Sensitivity*, S_0:	*-25.8*	dB re 1V/Pa
Equivalent to:	*51.6*	mV/Pa
Uncertainty, 95 % confidence level	0.2	dB
Capacitance:	*13.7*	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:
102.5 kPa 23 °C 46 % RH

Procedure: 704215 **Date:** 10. Dec. 2013 **Signature:** BLt

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

(*Winter, 2015*) B&K 2250 Unit #9 SLM Calibration Certificate

MANUFACTURER'S CERTIFICATE OF CONFORMANCE

We certify that Brüel & Kjær **-2250--D00-** Serial No. **3006198** 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-2014

Torben Bjørn
Vice President, Operations

Please note that this document is not a calibration certificate.
For information on our calibration services please contact your nearest Brüel & Kjær office.

HEADQUARTERS: Brüel & Kjær Sound & Vibration Measurement A/S · DK-2850 Nærum · Denmark
Telephone: +45 77412000 · Fax: +45 4580 1405 · www.bksv.com · info@bksv.com
Local representatives and service organisations worldwide

Brüel & Kjær

Prepolarized Free-field 1/2" Microphone Type 4189

Bruel & Kjær — Calibration Chart

Serial No:	2906926	
Open-circuit Sensitivity*, S_0:	-25.7	dB re 1V/Pa
Equivalent to:	52.0	mV/Pa
Uncertainty, 95 % confidence level	0.2	dB
Capacitance:	12.7	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:
99.2 kPa 23 °C 50 % RH

Procedure: 704215 **Date:** 10. Feb. 2014 **Signature:** BLC

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

(*Summer, 2015*) B&K 2250 Unit #5 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.32428

Instrument: Sound Level Meter
Model: 2250
Manufacturer: Brüel and Kjær
Serial number: 2722894
Tested with: Microphone 4189 s/n 2719777
Preamplifier ZC0032 s/n 13895
Type (class): 1
Customer: ACI Acoustical Consultants Inc.
Tel/Fax: 780-414-6373 / -6376

Date Calibrated: 10/8/2014 *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. 6/22/2012
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	25747	Jul 2, 2014	Scantek, Inc./ NVLAP	Jul 2, 2015
DS-360-SRS	Function Generator	61646	Nov 20, 2012	ACR Env./ A2LA	Nov 20, 2014
34401A-Agilent Technologies	Digital Voltmeter	MY41022043	Nov 22, 2013	ACR Env. / A2LA	Nov 22, 2014
DPI 141-Druck	Pressure Indicator	790/00-04	Nov 21, 2012	ACR Env./ A2LA	Nov 21, 2014
HMP233-Vaisala Oyj	Humidity & Temp. Transmitter	V3820001	Mar 17, 2014	ACR Env./ A2LA	Sep 17, 2015
PC Program 1019 Norsonic	Calibration software	v.5.2	Validated Mar 2011	Scantek, Inc.	-
1251-Norsonic	Calibrator	30878	Nov 8, 2013	Scantek, Inc./ NVLAP	Nov 8, 2014

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 (%)
23.3 °C	99.964 kPa	45.0 %RH

Calibrated by:	Valentin Buzduga	**Authorized signatory:**	Mariana Buzduga
Signature		Signature	
Date	10/08/2014	Date	10/9/2014

Calibration Certificates or Test Reports shall not be reproduced, except in full, without written approval of the laboratory.
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(*Summer, 2015*) B&K 2250 Unit #5 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.32429

Instrument:	Microphone	*Date Calibrated:*	10/3/2014	*Cal Due:*
Model:	4189	*Status:*	Received	Sent
Manufacturer:	Brüel & Kjær	*In tolerance:*	X	X
Serial number:	2719777	*Out of tolerance:*		
Composed of:		*See comments:*		

Contains non-accredited tests: __Yes _X_ No

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 Measurement Microphones, Scantek, Inc., Rev. 11/30/2010

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	25747	Jul 2, 2014	Scantek, Inc./ NVLAP	Jul 2, 2015
DS-360-SRS	Function Generator	61646	Nov 20, 2012	ACR Env./ A2LA	Nov 20, 2014
34401A-Agilent Technologies	Digital Voltmeter	MY41022043	Nov 22, 2013	ACR Env. / A2LA	Nov 22, 2014
DPI 141-Druck	Pressure Indicator	790/00-04	Nov 21, 2012	ACR Env./ A2LA	Nov 21, 2014
HMP233-Vaisala Oyj	Humidity & Temp. Transmitter	V3820001	Mar 17, 2014	ACR Env./ A2LA	Sep 17, 2015
PC Program 1017 Norsonic	Calibration software	v.6.1m	Validated July 2014	Scantek, Inc.	-
1253-Norsonic	Calibrator	28326	Nov 8, 2013	Scantek, Inc./ NVLAP	Nov 8, 2014
1203-Norsonic	Preamplifier	14059	Jan 2, 2014	Scantek, Inc./ NVLAP	Jan 2, 2015
4180-Brüel&Kjær	Microphone	2246115	Oct 15, 2013	NPL-UK / UKAS	Oct 15, 2015

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

Calibrated by:	Valentin Buzduga	**Authorized signatory:**	Mariana Buzduga
Signature		Signature	
Date	10/03/2014	Date	10/9/2014

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(*Summer, 2015*) B&K 2250 Unit #7 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.32432

Instrument:	**Sound Level Meter**	*Date Calibrated:* **10/9/2014**	*Cal Due:*	
Model:	**2250**	*Status:*	**Received**	**Sent**
Manufacturer:	**Brüel and Kjær**	*In tolerance:*	X	X
Serial number:	**2722859**	*Out of tolerance:*		
Tested with:	**Microphone 4189 s/n 2710791** **Preamplifier ZC0032 s/n 13398**	*See comments:*		
		Contains non-accredited tests: __Yes **X** No		
Type (class):	**1**	*Calibration service:* __ Basic **X** Standard		
Customer:	**ACI Acoustical Consultants Inc.**	*Address:* **5031 - 210 Street, Edmonton Alberta, CANADA T6M 0A8**		
Tel/Fax:	**780-414-6373 / -6376**			

Tested in accordance with the following procedures and standards:
Calibration of Sound Level Meters, Scantek Inc., Rev. 6/22/2012
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	25747	Jul 2, 2014	Scantek, Inc./ NVLAP	Jul 2, 2015
DS-360-SRS	Function Generator	61646	Nov 20, 2012	ACR Env./ A2LA	Nov 20, 2014
34401A-Agilent Technologies	Digital Voltmeter	MY41022043	Nov 22, 2013	ACR Env. / A2LA	Nov 22, 2014
DPI 141-Druck	Pressure Indicator	790/00-04	Nov 21, 2012	ACR Env./ A2LA	Nov 21, 2014
HMP233-Vaisala Oyj	Humidity & Temp. Transmitter	V3820001	Mar 17, 2014	ACR Env./ A2LA	Sep 17, 2015
PC Program 1019 Norsonic	Calibration software	v.5.2	Validated Mar 2011	Scantek, Inc.	-
1251-Norsonic	Calibrator	30878	Nov 8, 2013	Scantek, Inc./ NVLAP	Nov 8, 2014

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 (%)
24.0 °C	100.630 kPa	42.7 %RH

Calibrated by:	Valentin Buzduga	**Authorized signatory:**	Mariana Buzduga
Signature		Signature	
Date	10/09/2014	Date	10/9/2014

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(*Summer, 2015*) B&K 2250 Unit #7 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.32433

Instrument:	**Microphone**	*Date Calibrated:* **10/3/2014** *Cal Due:*		
Model:	**4189**	*Status:*	**Received**	**Sent**
Manufacturer:	**Brüel & Kjær**	*In tolerance:*	X	X
Serial number:	**2710791**	*Out of tolerance:*		
Composed of:		*See comments:*		
		Contains non-accredited tests: __Yes _X_ No		
Customer:	**ACI Acoustical Consultants Inc.**	*Address:*	**5031 - 210 Street, Edmonton Alberta, CANADA T6M 0A8**	
Tel/Fax:	**780-414-6373 / -6376**			

Tested in accordance with the following procedures and standards:
Calibration of Measurement Microphones, Scantek, Inc., Rev. 11/30/2010

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	25747	Jul 2, 2014	Scantek, Inc./ NVLAP	Jul 2, 2015
DS-360-SRS	Function Generator	61646	Nov 20, 2012	ACR Env./ A2LA	Nov 20, 2014
34401A-Agilent Technologies	Digital Voltmeter	MY41022043	Nov 22, 2013	ACR Env. / A2LA	Nov 22, 2014
DPI 141-Druck	Pressure Indicator	790/00-04	Nov 21, 2012	ACR Env./ A2LA	Nov 21, 2014
HMP233-Vaisala Oyj	Humidity & Temp. Transmitter	V3820001	Mar 17, 2014	ACR Env./ A2LA	Sep 17, 2015
PC Program 1017 Norsonic	Calibration software	v.6.1m	Validated July 2014	Scantek, Inc.	-
1253-Norsonic	Calibrator	28326	Nov 8, 2013	Scantek, Inc./ NVLAP	Nov 8, 2014
1203-Norsonic	Preamplifier	14059	Jan 2, 2014	Scantek, Inc./ NVLAP	Jan 2, 2015
4180-Brüel&Kjær	Microphone	2246115	Oct 15, 2013	NPL-UK / UKAS	Oct 15, 2015

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

Calibrated by:	Valentin Buzduga	Authorized signatory:	Mariana Buzduga
Signature		Signature	
Date	10/03/2014	Date	10/3/2014

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(*Winter & Summer, 2015*) 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 Lab Code: 200625-0

Calibration Certificate No.32434

Instrument:	**Acoustical Calibrator**	*Date Calibrated:* **10/6/2014** *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. 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	25747	Jul 2, 2014	Scantek, Inc./ NVLAP	Jul 2, 2015
DS-360-SRS	Function Generator	61646	Nov 20, 2012	ACR Env./ A2LA	Nov 20, 2014
34401A-Agilent Technologies	Digital Voltmeter	MY41022043	Nov 22, 2013	ACR Env. / A2LA	Nov 22, 2014
DPI 141-Druck	Pressure Indicator	790/00-04	Nov 21, 2012	ACR Env./ A2LA	Nov 21, 2014
HMP233-Vaisala Oyj	Humidity & Temp. Transmitter	V3820001	Mar 17, 2014	ACR Env./ A2LA	Sep 17, 2015
8903A-HP	Audio Analyzer	2514A05691	Dec 12, 2013	ACR Env./ A2LA	Dec 12, 2016
PC Program 1018 Norsonic	Calibration software	v.6.1c	Validated July 2014	Scantek, Inc.	-
4134-Brüel&Kjær	Microphone	906763	Oct 15, 2013	NPL-UK / UKAS	Oct 15, 2015
1203-Norsonic	Preamplifier	14059	Jan 2, 2014	Scantek, Inc./ NVLAP	Jan 2, 2015

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	
Date	10/06/2014	Date	10/9/2014

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Appendix II. THE ASSESSMENT OF ENVIRONMENTAL NOISE (GENERAL)

Sound Pressure Level

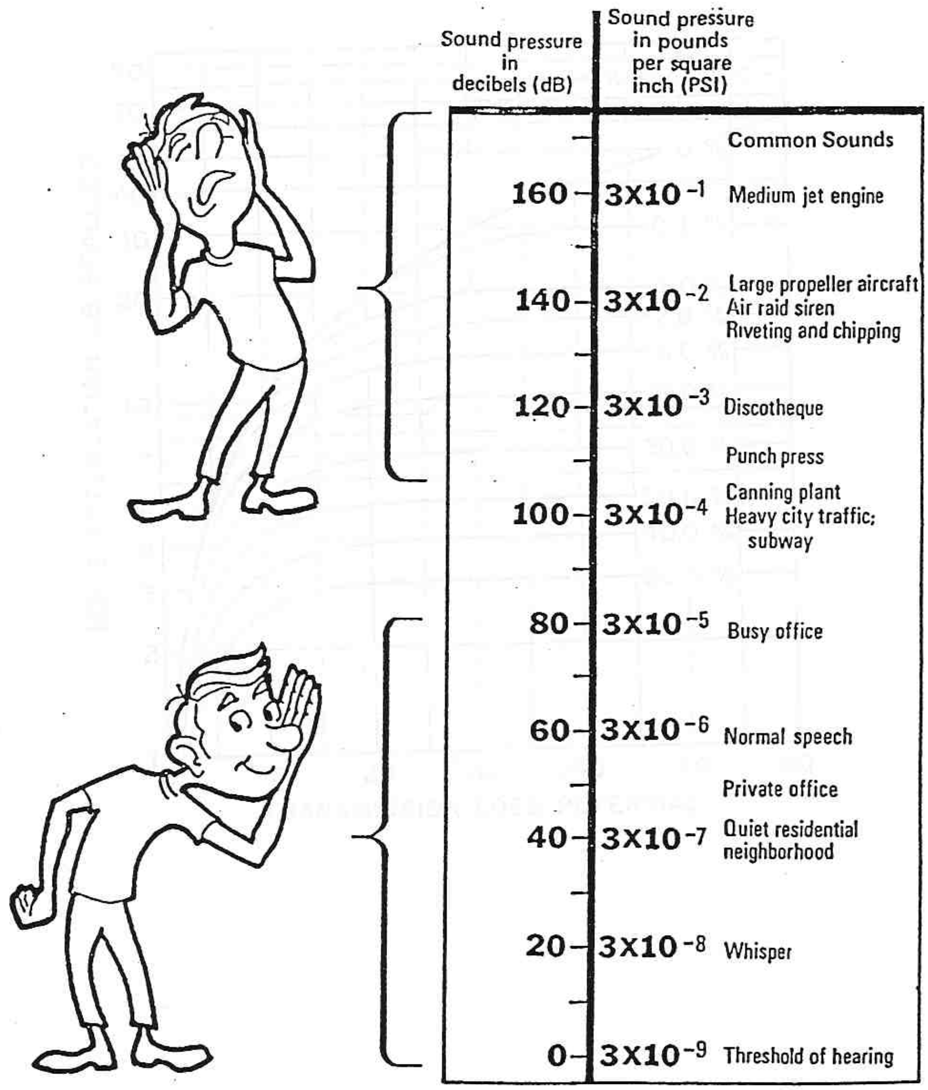
Sound pressure is initially measured in Pascal's (Pa). Humans can hear several orders of magnitude in sound pressure levels, so a more convenient scale is used. This scale is known as the decibel (dB) scale, named after Alexander Graham Bell (telephone guy). It is a base 10 logarithmic scale. When we 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
Canning plant
100 3X10-4 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

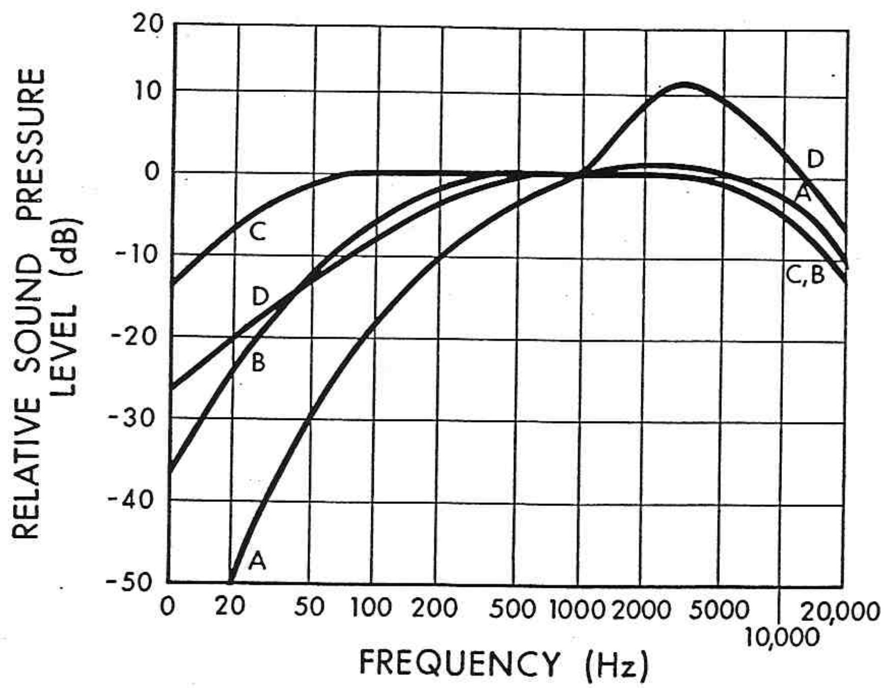
The range of frequencies audible to the human ear ranges from approximately 20 Hz to 20 kHz. Within this range, the human ear does not hear equally at all frequencies. It is not very sensitive to low frequency sounds, is very sensitive to mid frequency sounds and is slightly less sensitive to high frequency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

Whole Octave Lower Band Limit	Whole Octave Center Frequency	Whole Octave 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

1/3 Octave Lower Band Limit	1/3 Octave Center Frequency	1/3 Octave 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.

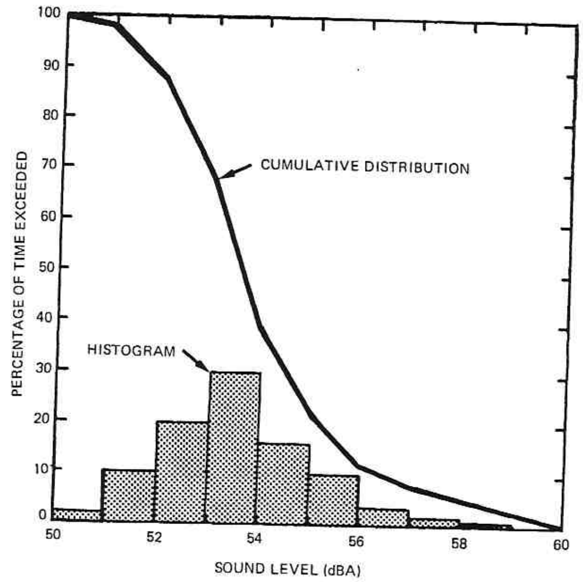


Figure 16.6 Statistically processed community noise showing histogram and cumulative distribution of A weighted sound levels.

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

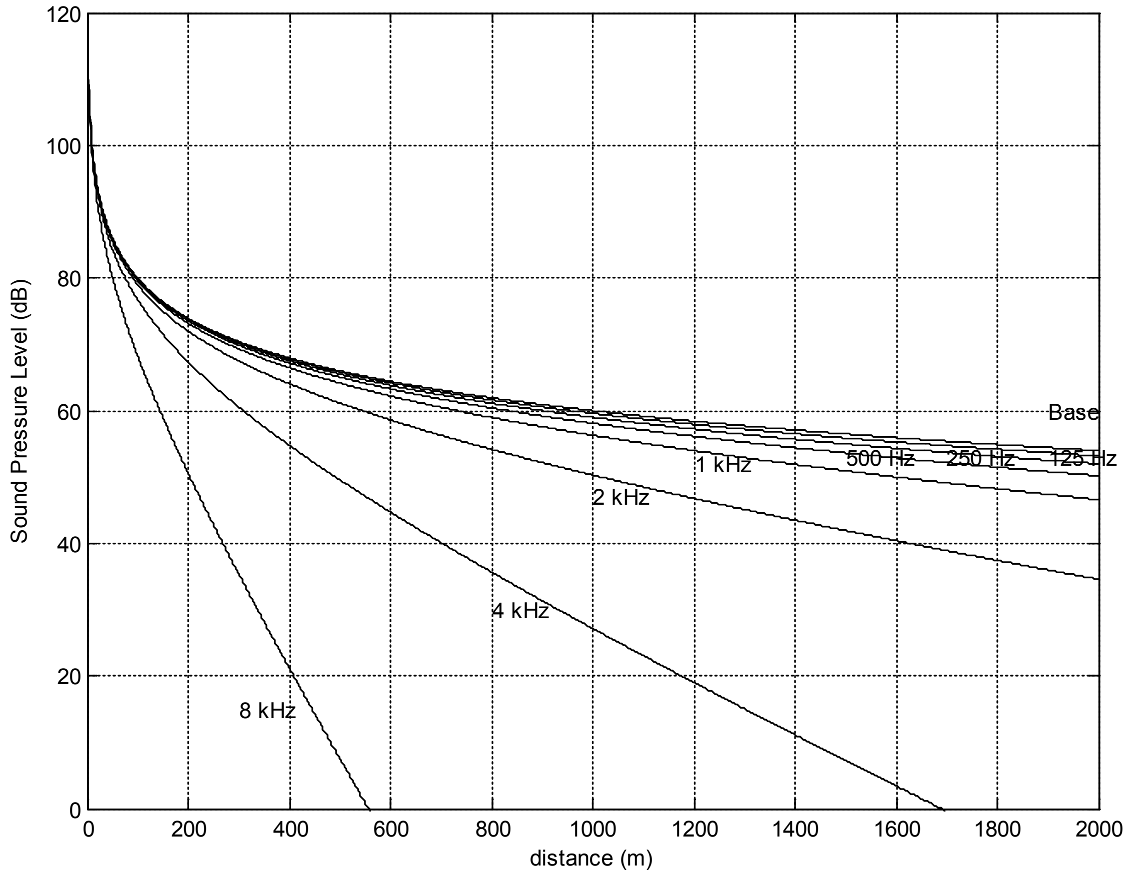
As sound transmits through a medium, there is an attenuation (or dissipation of acoustic energy) which can be attributed to three mechanisms:

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 ^{o}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 10°C 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

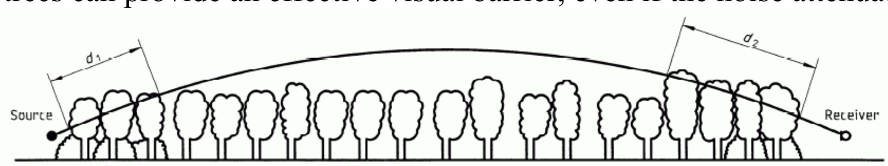
- Can be an effective absorber due to large area covered
- Only effective at low height above ground. Does not affect sound transmitted direct from source to receiver if there is line of sight.
- Typically less absorption than atmospheric absorption when there is line of sight.
- Approximate rule of 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	Nominal midband frequency							
	Hz							
m	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 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. REMOVED DATA

8855 - 40 Avenue (September 16 - 17, 2014)

Start Time	End Time	Duration (min)	Reason
9/16/14 8:04	9/16/14 8:05	1.25	Dog Barking
9/16/14 8:06	9/16/14 8:07	1.50	Aircraft Flyover
9/16/14 8:44	9/16/14 8:52	8.25	Dog Barking
9/16/14 9:00	9/16/14 9:03	2.25	Dog Barking
9/16/14 9:16	9/16/14 9:18	2.75	Dog Barking
9/16/14 9:34	9/16/14 9:36	1.75	Dog Barking
9/16/14 10:02	9/16/14 10:04	1.25	Loud Vehicle Passby
9/16/14 10:48	9/16/14 10:49	1.25	Aircraft Flyover
9/16/14 11:40	9/16/14 11:41	1.25	Dog Barking
9/16/14 12:04	9/16/14 12:06	1.75	Siren
9/16/14 12:08	9/16/14 12:10	2.00	Aircraft Flyover
9/16/14 14:03	9/16/14 14:04	1.25	Aircraft Flyover
9/16/14 14:18	9/16/14 14:20	2.25	Dog Barking
9/16/14 14:55	9/16/14 14:56	1.00	Loud Vehicle Passby
9/16/14 15:31	9/16/14 15:33	1.75	Sirens
9/16/14 17:19	9/16/14 17:19	0.50	Dog Barking
9/16/14 17:30	9/16/14 17:31	1.50	Loud Vehicle Passby
9/16/14 17:51	9/16/14 17:53	2.00	Aircraft Flyover
9/16/14 17:56	9/16/14 17:57	1.50	Dog Barking
9/16/14 17:58	9/16/14 18:00	1.50	Dog Barking
9/16/14 19:14	9/16/14 19:15	1.50	Loud Vehicle Passby
9/16/14 19:26	9/16/14 19:27	0.75	Loud Vehicle Passby
9/16/14 19:49	9/16/14 19:50	1.50	Dog Barking
9/16/14 19:54	9/16/14 19:56	2.00	People
9/16/14 20:04	9/16/14 20:06	2.50	Dog Barking
9/16/14 20:10	9/16/14 20:12	2.25	Dog Barking
9/16/14 20:46	9/16/14 20:47	1.00	Loud Vehicle Passby
9/16/14 20:48	9/16/14 20:50	1.25	Aircraft Flyover
9/16/14 21:01	9/16/14 21:02	1.75	Dog Barking
9/16/14 22:15	9/16/14 22:16	1.00	Loud Vehicle Passby
9/16/14 22:58	9/16/14 22:59	1.50	Aircraft Flyover
9/17/14 2:25	9/17/14 2:27	1.50	Aircraft Flyover
9/17/14 6:09	9/17/14 6:11	1.75	Aircraft Flyover
	Total	**58.75**	

8855 - 40 Avenue (September 18 - 19, 2014)

Start Time	End Time	Duration (min)	Reason
9/18/14 17:06	9/18/14 17:08	1.75	Aircraft Flyover
9/18/14 17:10	9/18/14 17:12	1.50	Dog Barking
9/18/14 17:19	9/18/14 17:21	2.00	Dog Barking
9/18/14 19:13	9/18/14 19:15	1.50	Loud Vehicle Passby
9/18/14 19:50	9/18/14 19:52	2.25	Dog Barking
9/18/14 19:58	9/18/14 20:00	1.25	Dog Barking
9/18/14 20:42	9/18/14 20:44	2.50	Dog Barking
9/18/14 20:50	9/18/14 20:52	2.50	Dog Barking
9/18/14 20:54	9/18/14 20:56	2.00	Siren
9/18/14 21:01	9/18/14 21:04	3.00	Aircraft Flyover
9/18/14 21:12	9/18/14 21:18	6.00	Dog Barking
9/18/14 22:53	9/18/14 22:54	1.75	Loud Vehicle Passby
9/19/14 2:28	9/19/14 2:31	2.75	Aircraft Flyover
9/19/14 5:20	9/19/14 5:21	1.50	Loud Vehicle Passby
9/19/14 7:36	9/19/14 7:38	1.75	Aircraft Flyover
9/19/14 7:43	9/19/14 7:44	1.50	Aircraft Flyover
9/19/14 8:12	9/19/14 8:14	1.50	Dog Barking
9/19/14 8:45	9/19/14 8:47	2.00	Dog Barking
9/19/14 8:56	9/19/14 8:58	2.25	Dog Barking
9/19/14 9:54	9/19/14 9:55	1.75	Aircraft Flyover
9/19/14 10:14	9/19/14 10:17	2.25	Dog Barking
9/19/14 13:28	9/19/14 13:30	1.75	Dog Barking
9/19/14 14:16	9/19/14 14:19	3.00	Dog Barking
9/19/14 14:20	9/19/14 14:23	3.00	Dog Barking
9/19/14 14:32	9/19/14 14:34	1.75	Dog Barking
9/19/14 14:53	9/19/14 14:58	4.75	Dog Barking
9/19/14 15:09	9/19/14 15:12	2.25	Dog Barking
9/19/14 15:33	9/19/14 15:35	2.25	Dog Barking
	Total	**64.00**	

8855 - 40 Avenue (January 14 - 15, 2015)

Start Time	End Time	Duration (min)	Reason
1/14/15 11:21	1/14/15 11:22	1.00	Aircraft Flyover
1/14/15 11:40	1/14/15 11:41	1.00	Aircraft Flyover
1/14/15 12:00	1/14/15 12:02	1.75	Aircraft Flyover
1/14/15 14:17	1/14/15 14:18	1.50	Aircraft Flyover
1/14/15 18:16	1/14/15 18:18	2.25	Human Activity Near Monitor
1/14/15 21:26	1/14/15 21:28	2.25	Aircraft Flyover
1/14/15 21:48	1/14/15 21:51	2.50	Siren
1/15/15 0:32	1/15/15 0:33	1.50	Loud Vehicle Passby
1/15/15 0:58	1/15/15 1:00	2.25	Sirens
1/15/15 5:43	1/15/15 5:45	1.75	Siren
1/15/15 7:02	1/15/15 7:04	2.50	Aircraft Flyover
1/15/15 7:38	1/15/15 7:40	1.75	Aircraft Flyover
1/15/15 7:43	1/15/15 7:45	2.00	Aircraft Flyover
1/15/15 7:54	1/15/15 7:56	2.50	Aircraft Flyover
1/15/15 8:26	1/15/15 8:27	1.25	Loud Vehicle Passby
1/15/15 10:42	1/15/15 10:43	1.25	Dog Barking
	Total	**29.00**	

8855 - 40 Avenue (January 16, 2015)

Start Time	End Time	Duration (min)	Reason
1/16/15 2:46	1/16/15 2:48	1.50	Loud Vehicle Passby
1/16/15 4:12	1/16/15 4:13	1.50	Loud Vehicle Passby
1/16/15 4:35	1/16/15 4:37	2.00	Loud Vehicle Passby
1/16/15 4:38	1/16/15 4:47	9.00	Unknown Machine Noise
1/16/15 7:30	1/16/15 7:33	3.25	Aircraft Flyover
1/16/15 8:37	1/16/15 8:39	1.50	Aircraft Flyover
1/16/15 9:01	1/16/15 9:03	2.00	Aircraft Flyover
1/16/15 9:49	1/16/15 9:52	2.50	Excessive Bird Noise
1/16/15 9:54	1/16/15 9:56	1.75	Excessive Bird Noise
1/16/15 10:16	1/16/15 10:17	1.00	Excessive Bird Noise
	Total	**26.00**	

8855 - 40 Avenue (July 27 - 28, 2015)

Start Time	End Time	Duration (min)	Reason
7/27/15 11:18	7/27/15 11:20	1.50	Aircraft Flyover
7/27/15 15:37	7/27/15 16:38	60.50	Heavy Machinery Nearby
7/27/15 16:46	7/27/15 16:57	11.50	Lawn Mower
7/27/15 18:59	7/27/15 19:07	8.50	Yard Trimmer
7/27/15 19:27	7/27/15 19:41	14.00	Lawn Mower
7/27/15 19:43	7/27/15 19:52	9.00	Lawn Mower
7/27/15 20:32	7/27/15 20:34	1.75	Loud Vehicle Passby
7/27/15 20:43	7/27/15 20:45	1.75	Sirens
7/27/15 21:41	7/27/15 21:44	2.25	Dog Barking
7/28/15 7:06	7/28/15 7:09	2.50	Aircraft Flyover
	Total	**113.25**	

4132 - 89 Street (September 16 - 17, 2014)

Start Time	End Time	Duration (min)	Reason
9/16/14 8:05	9/16/14 8:08	2.50	Aircraft Flyover
9/16/14 12:04	9/16/14 12:06	1.75	Siren
9/16/14 12:08	9/16/14 12:09	1.25	Aircraft Flyover
9/16/14 12:31	9/16/14 12:31	0.75	Dog Barking
9/16/14 12:59	9/16/14 13:00	1.75	Aircraft Flyover
9/16/14 14:03	9/16/14 14:04	1.25	Aircraft Flyover
9/16/14 15:32	9/16/14 15:32	0.50	Siren
9/16/14 17:51	9/16/14 17:54	2.75	Aircraft Flyover
9/16/14 18:09	9/16/14 18:11	2.00	Aircraft Flyover
9/16/14 18:12	9/16/14 18:13	1.25	Dog Barking
9/16/14 20:48	9/16/14 20:50	2.50	Aircraft Flyover
9/16/14 21:10	9/16/14 21:11	1.25	Loud Vehicle Passby
9/16/14 21:24	9/16/14 21:25	1.00	Loud Vehicle Passby
9/16/14 22:24	9/16/14 22:25	1.00	Loud Vehicle Passby
9/16/14 22:58	9/16/14 22:59	1.25	Aircraft Flyover
9/17/14 2:25	9/17/14 2:27	1.50	Aircraft Flyover
9/17/14 6:09	9/17/14 6:12	2.25	Aircraft Flyover
9/17/14 7:48	9/17/14 7:49	1.00	Aircraft Flyover
	Total	**27.50**	

4132 - 89 Street (September 18 - 19, 2014)

Start Time	End Time	Duration (min)	Reason
9/18/14 16:32	9/18/14 16:34	2.50	Dog Barking
9/18/14 16:35	9/18/14 17:03	27.25	Lawn Mower
9/18/14 20:21	9/18/14 20:23	1.25	People Nearby
9/18/14 21:02	9/18/14 21:05	2.75	Aircraft Flyover
9/18/14 22:53	9/18/14 22:55	2.75	Loud Vehicle Passby
9/19/14 5:20	9/19/14 5:21	1.50	Loud Vehicle Passby
9/19/14 7:37	9/19/14 7:38	1.25	Aircraft Flyover
9/19/14 7:43	9/19/14 7:45	1.75	Aircraft Flyover
9/19/14 8:56	9/19/14 8:59	2.75	Aircraft Flyover
9/19/14 9:54	9/19/14 9:55	1.25	Aircraft Flyover
9/19/14 14:30	9/19/14 14:32	2.00	Dog Barking
	Total	**47.00**	

4132 - 89 Street (January 14 - 15, 2015)

Start Time	End Time	Duration (min)	Reason
1/14/15 11:20	1/14/15 11:22	2.25	Aircraft Flyover
1/14/15 11:40	1/14/15 11:42	2.50	Aircraft Flyover
1/14/15 11:56	1/14/15 12:01	5.25	Aircraft Flyover
1/14/15 15:15	1/14/15 15:18	3.50	Dog Barking
1/14/15 21:25	1/14/15 21:27	2.00	Aircraft Flyover
1/15/15 0:31	1/15/15 0:34	2.25	Loud Vehicle Passby
1/15/15 0:57	1/15/15 0:59	1.75	Sirens
1/15/15 2:16	1/15/15 2:17	1.75	Siren
1/15/15 5:44	1/15/15 5:46	2.00	Siren
1/15/15 7:02	1/15/15 7:05	3.25	Aircraft Flyover
1/15/15 7:38	1/15/15 7:40	2.25	Aircraft Flyover
1/15/15 7:42	1/15/15 7:46	3.75	Aircraft Flyover
1/15/15 7:53	1/15/15 7:57	4.25	Aircraft Flyover
1/15/15 8:33	1/15/15 8:39	6.25	Dog Barking
	Total	**43.00**	

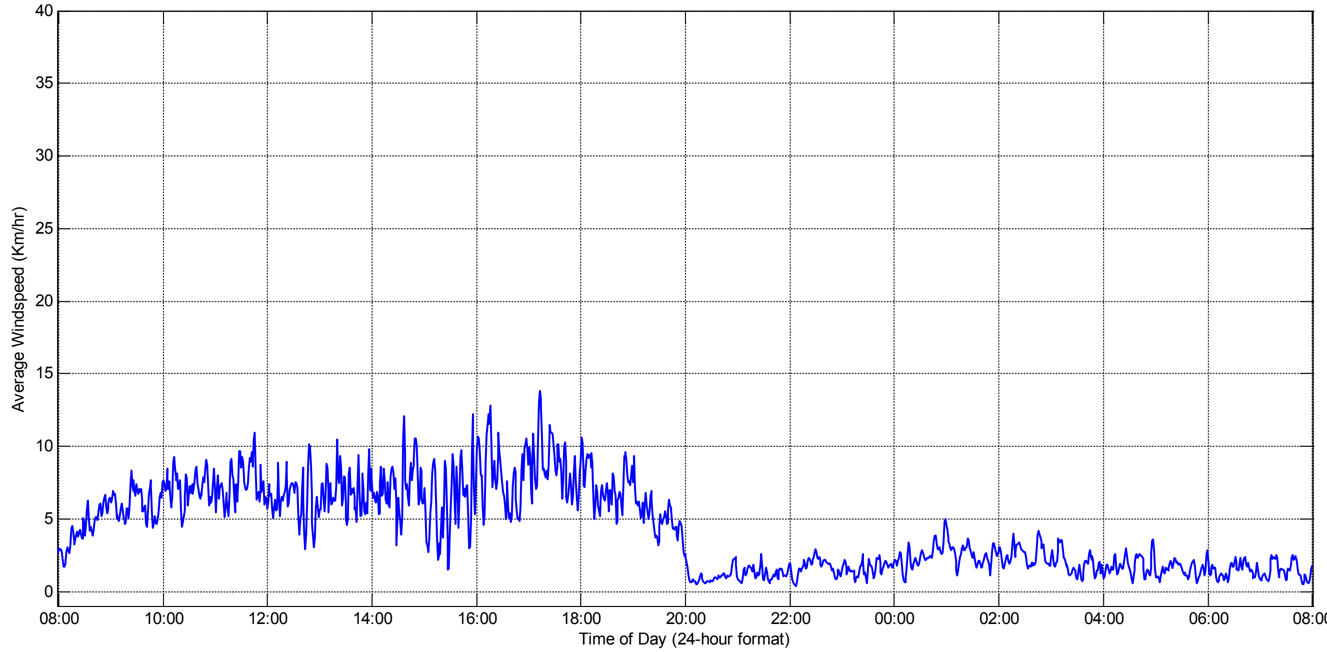
4132 - 89 Street (January 16, 2015)

Start Time	End Time	Duration (min)	Reason
1/16/15 4:36	1/16/15 4:51	15.00	Unknown Machine Noise
1/16/15 7:28	1/16/15 7:36	7.50	Aircraft Flyover
1/16/15 7:38	1/16/15 7:40	1.75	Aircraft Flyover
1/16/15 7:48	1/16/15 7:50	2.50	Aircraft Flyover
1/16/15 7:58	1/16/15 8:00	1.50	Siren
1/16/15 8:31	1/16/15 8:34	2.75	Aircraft Flyover
1/16/15 8:37	1/16/15 8:39	1.75	Aircraft Flyover
1/16/15 9:01	1/16/15 9:04	2.50	Aircraft Flyover
1/16/15 10:28	1/16/15 10:29	1.00	Dog Barking
1/16/15 10:30	1/16/15 10:31	1.25	Dog Barking
	Total	**37.50**	

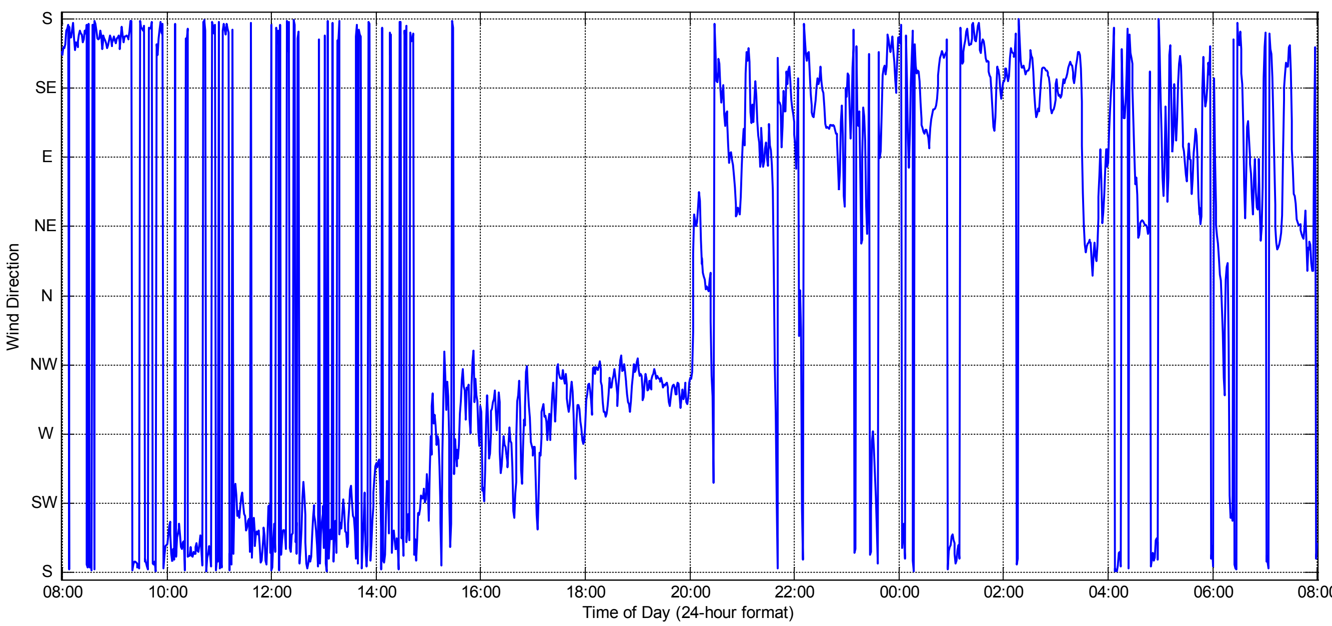
4132 - 89 Street (July 27 - 28, 2015)

Start Time	End Time	Duration (min)	Reason
7/27/15 9:37	7/27/15 9:39	1.75	Excessive Bird Noise
7/27/15 9:43	7/27/15 9:53	10.00	Excessive Bird Noise
7/27/15 10:13	7/27/15 10:15	1.25	Loud Vehicle Passby
7/27/15 11:18	7/27/15 11:20	2.00	Aircraft Flyover
7/27/15 11:23	7/27/15 11:24	1.00	Dog Barking
7/27/15 11:25	7/27/15 11:27	1.25	Dog Barking
7/27/15 11:29	7/27/15 11:31	2.00	Dog Barking
7/27/15 11:33	7/27/15 11:36	3.00	Dog Barking
7/27/15 11:53	7/27/15 11:54	1.50	Excessive Bird Noise
7/27/15 12:57	7/27/15 13:00	2.75	Dog Barking
7/27/15 13:24	7/27/15 13:26	1.75	Aircraft Flyover
7/27/15 14:51	7/27/15 14:53	1.25	Aircraft Flyover
7/27/15 14:55	7/27/15 14:57	1.75	Aircraft Flyover
7/27/15 15:15	7/27/15 15:17	2.00	Aircraft Flyover
7/27/15 19:39	7/27/15 19:41	1.25	Dog Barking
7/27/15 20:32	7/27/15 20:34	1.25	Loud Vehicle Passby
7/27/15 20:34	7/27/15 20:36	1.50	Dog Barking
7/27/15 20:41	7/27/15 20:43	1.25	Loud Vehicle Passby
7/27/15 20:43	7/27/15 20:44	1.75	Sirens
7/27/15 21:08	7/27/15 21:23	15.00	Truck Idling Nearby
7/27/15 21:29	7/27/15 21:30	1.50	Dog Barking
7/27/15 22:02	7/27/15 22:03	1.75	Equipment Nearby
7/28/15 0:27	7/28/15 0:28	1.25	Loud Vehicle Passby
7/28/15 4:19	7/28/15 4:21	1.75	Train Passby
7/28/15 5:33	7/28/15 5:35	2.25	Excessive Bird Noise
7/28/15 5:47	7/28/15 5:48	1.25	Excessive Bird Noise
7/28/15 7:06	7/28/15 7:08	2.00	Aircraft Flyover
7/28/15 8:29	7/28/15 8:30	0.75	Aircraft Flyover
7/28/15 8:49	7/28/15 8:52	3.00	Excessive Bird Noise
	Total	**70.75**	

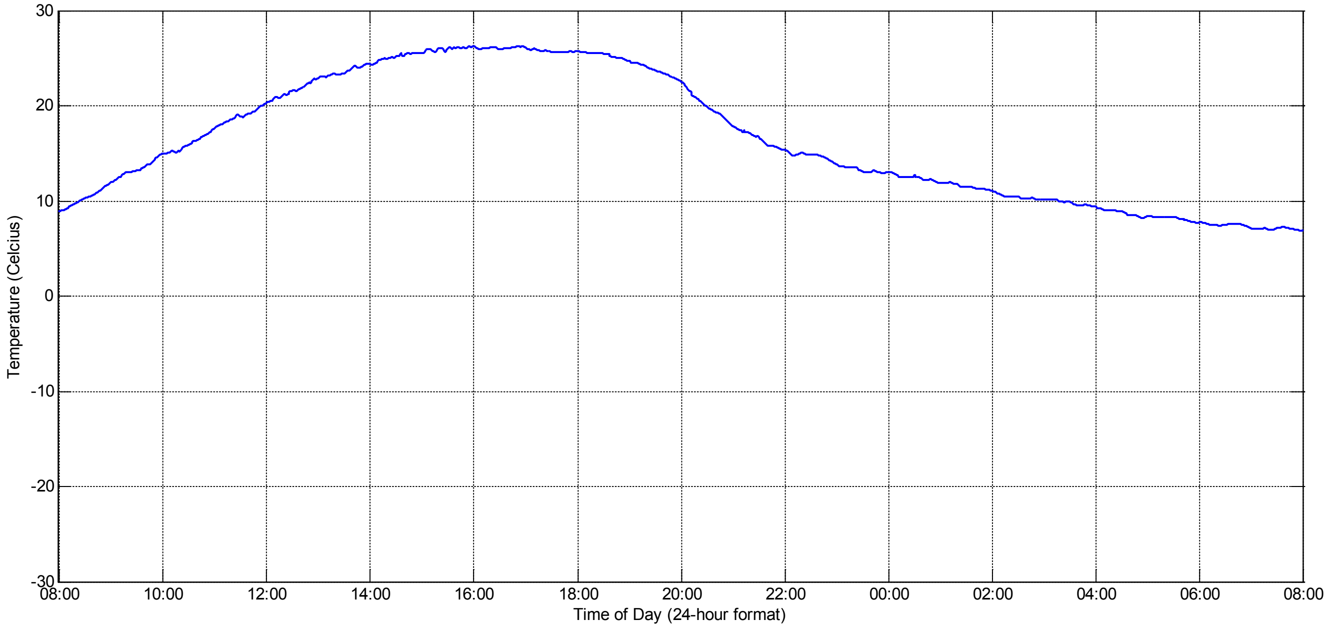
Appendix V. WEATHER DATA



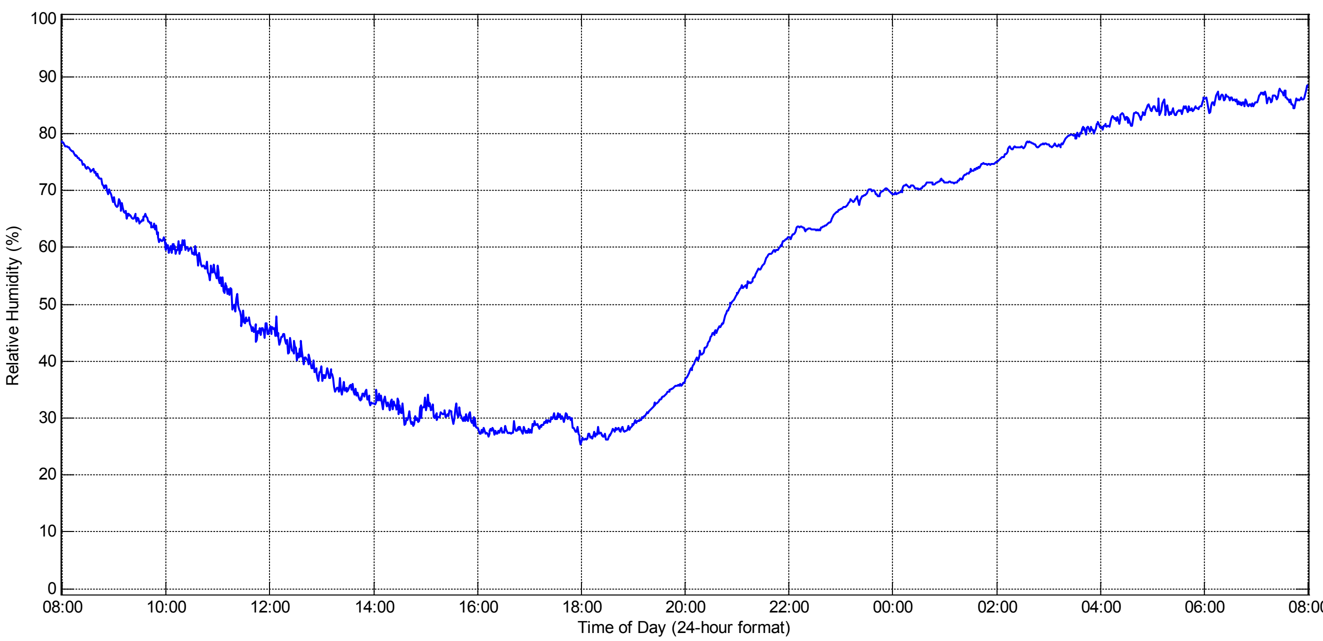
September 16 - 17, 2014 Monitored Wind Speed



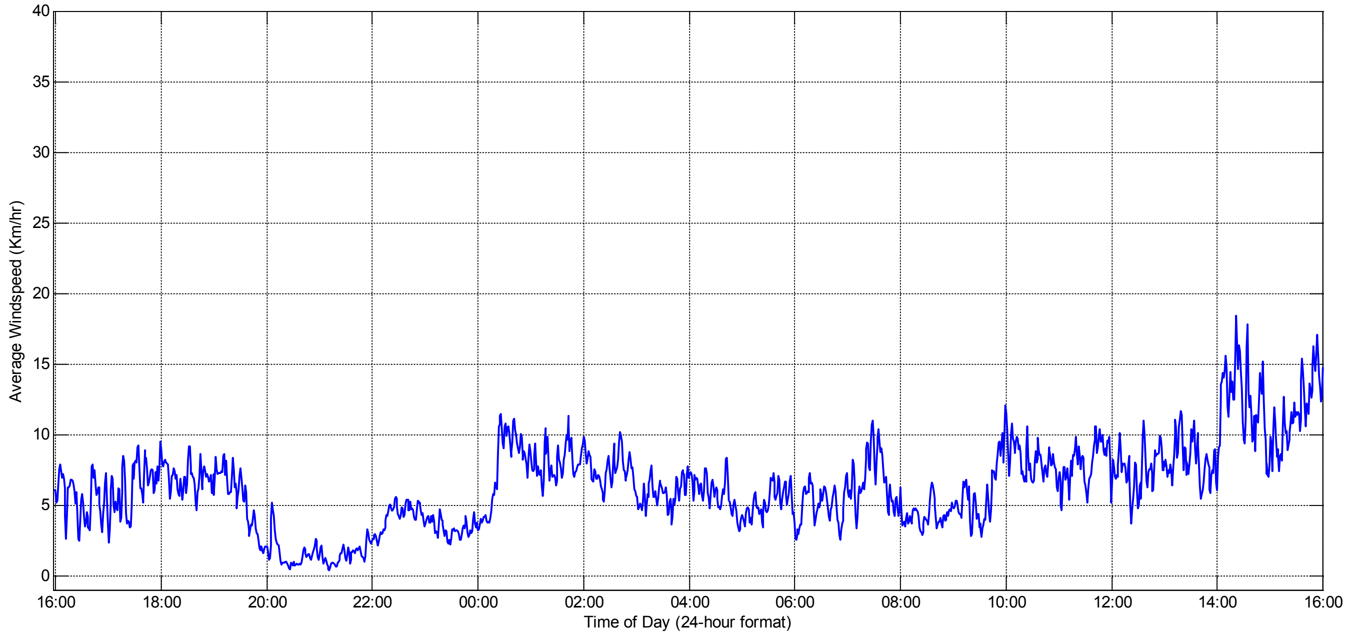
September 16 - 17, 2014 Monitored Wind Direction



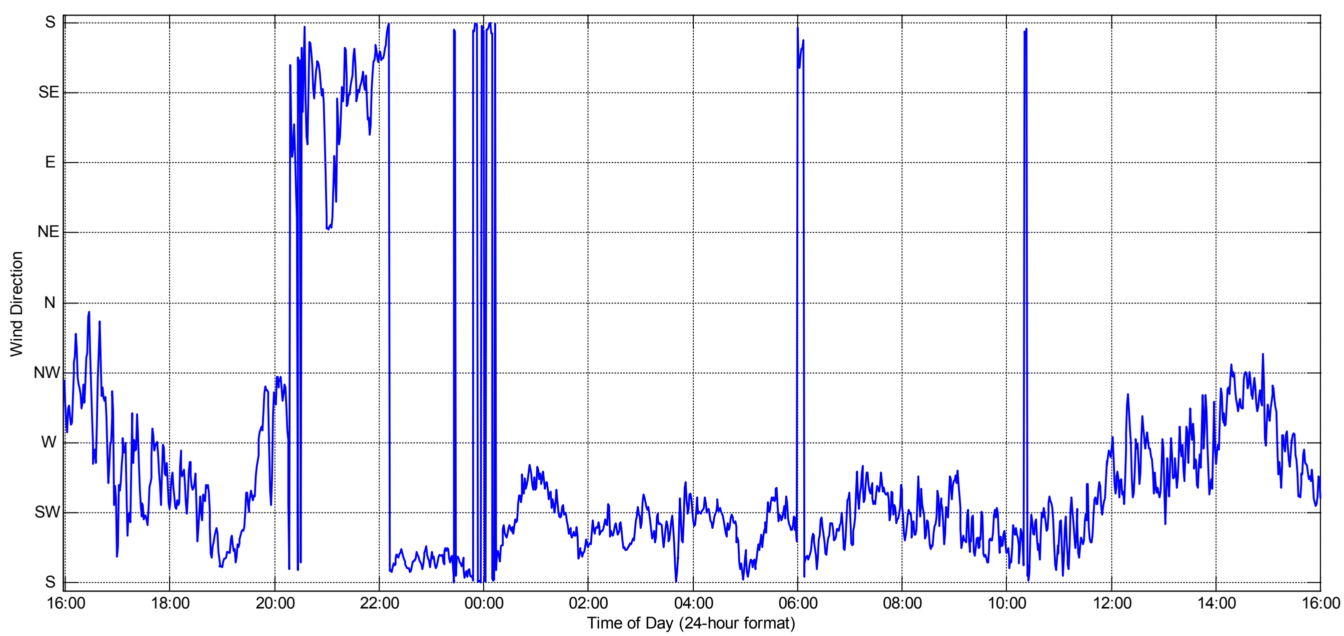
September 16 - 17, 2014 Monitored Temperature



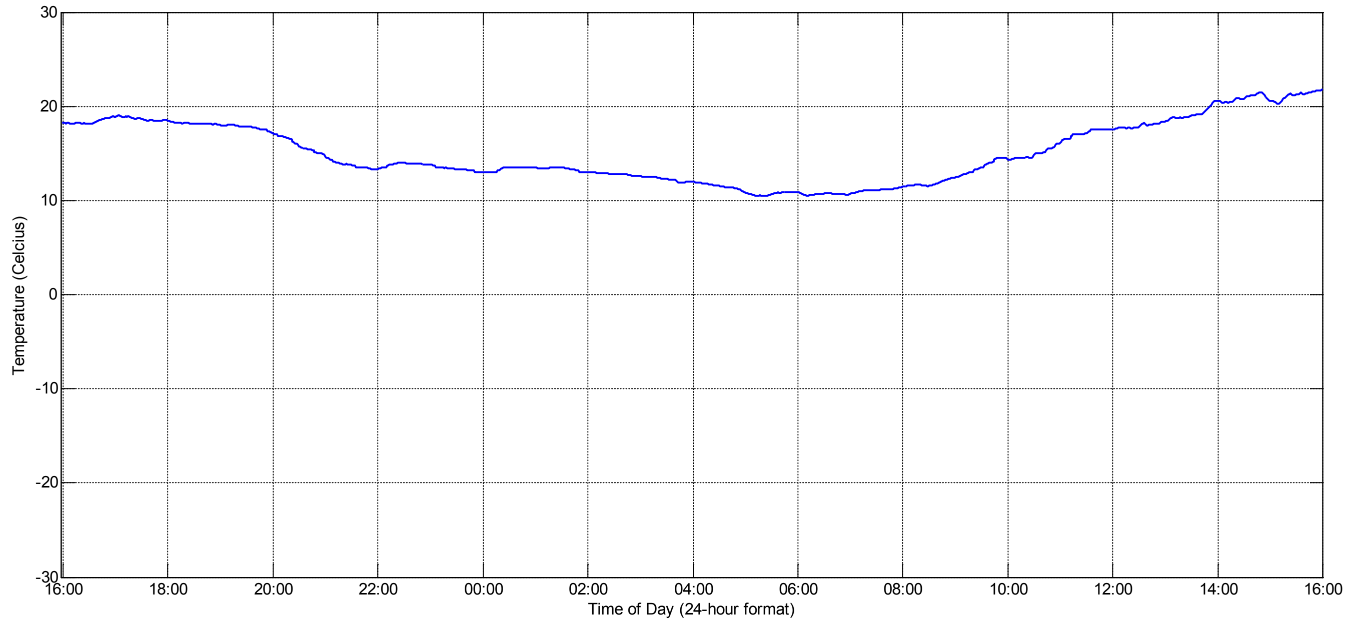
September 16 - 17, 2014 Monitored Relative Humidity



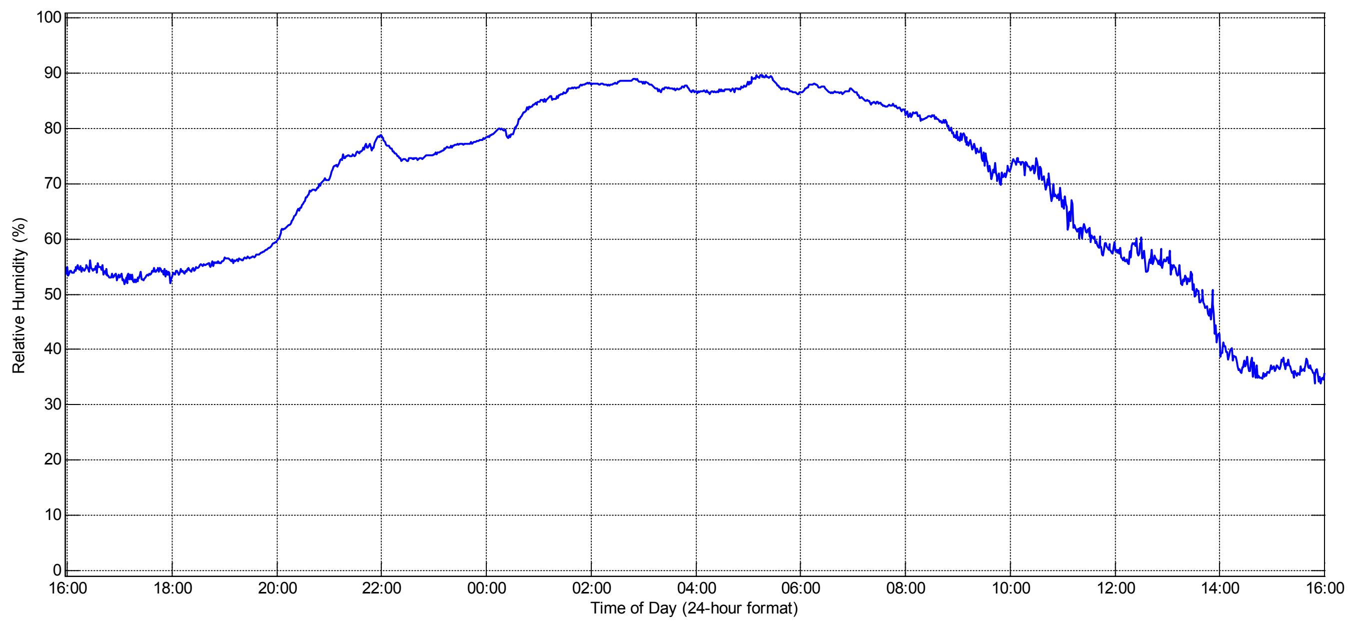
September 18 - 19, 2014 Monitored Wind Speed



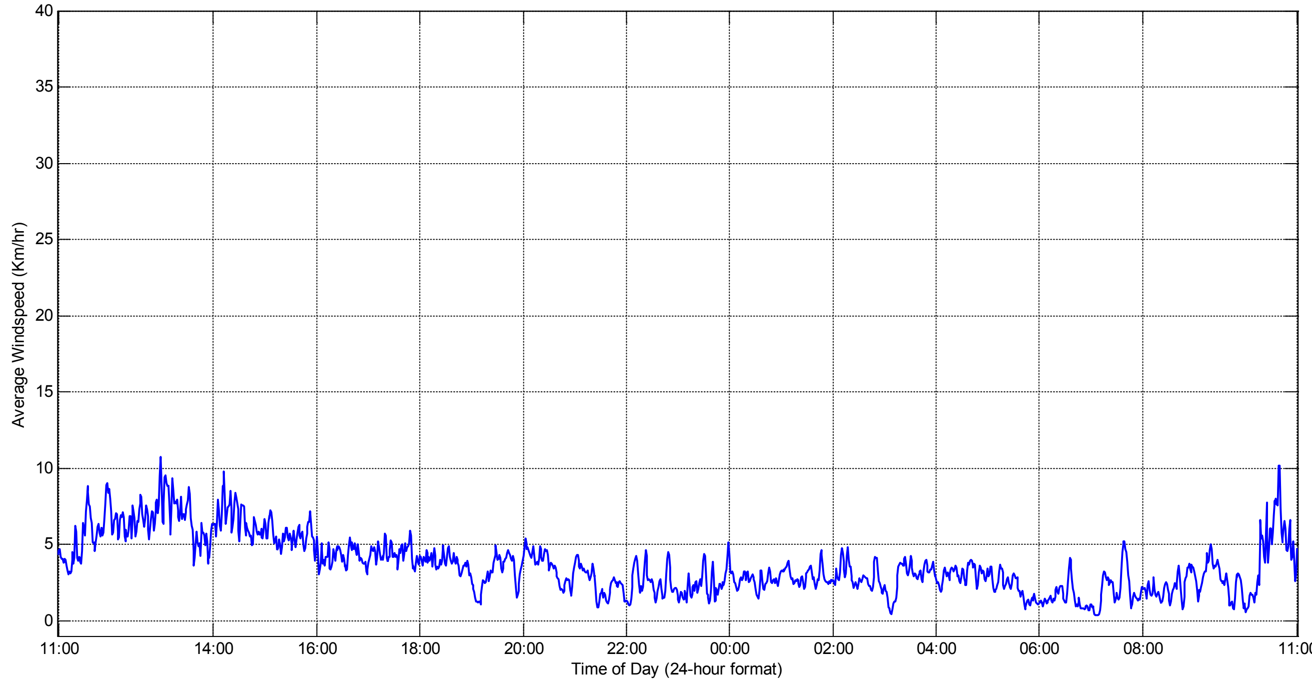
September 18 - 19, 2014 Monitored Wind Direction



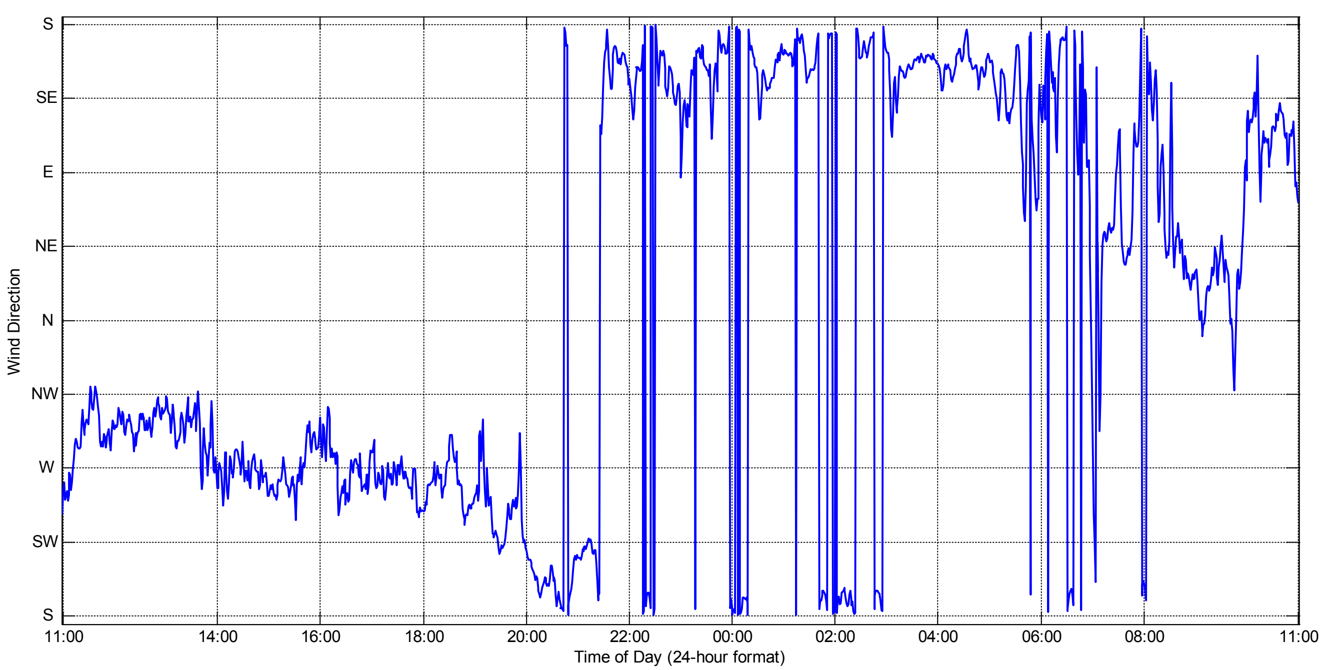
September 18 - 19, 2014 Monitored Temperature



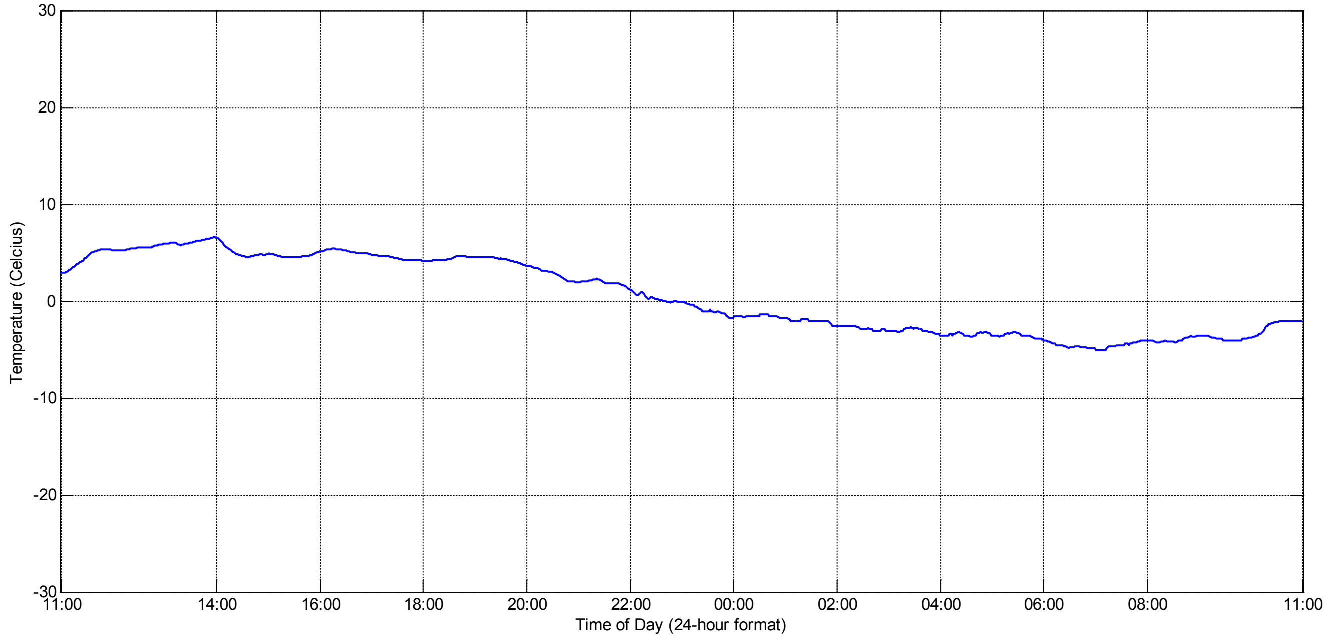
September 18 - 19, 2014 Monitored Relative Humidity



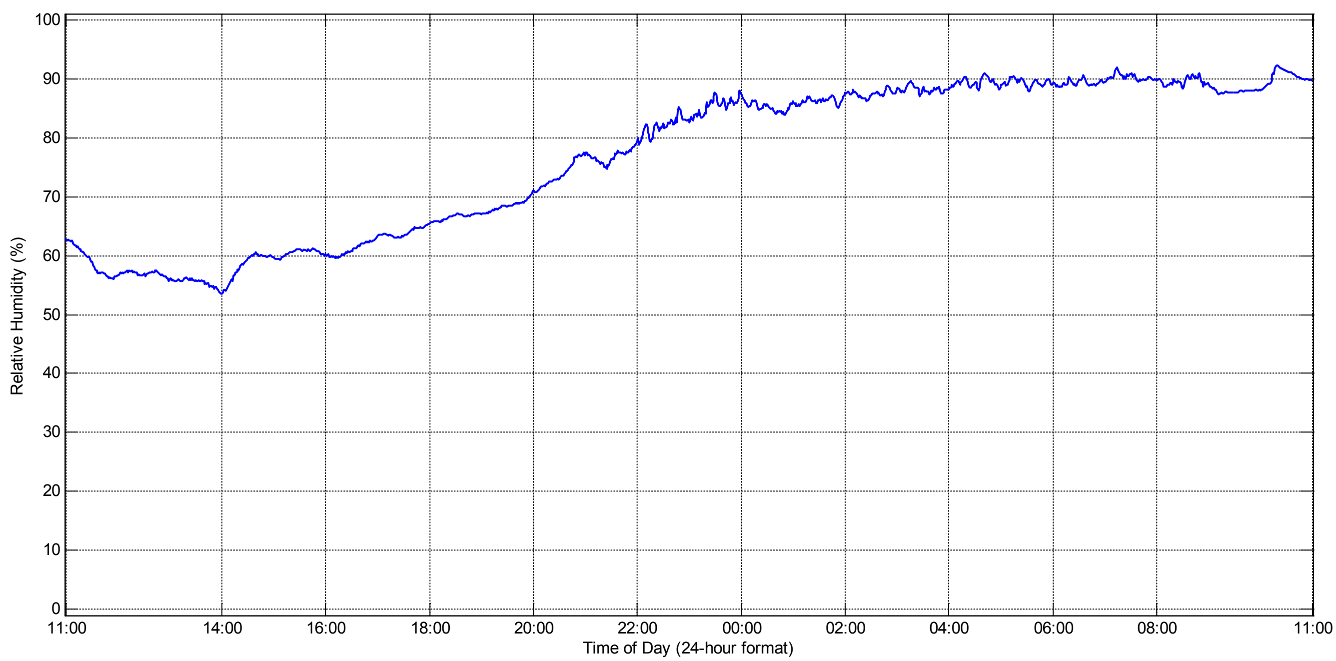
January 14 - 15, 2015 Monitored Wind Speed



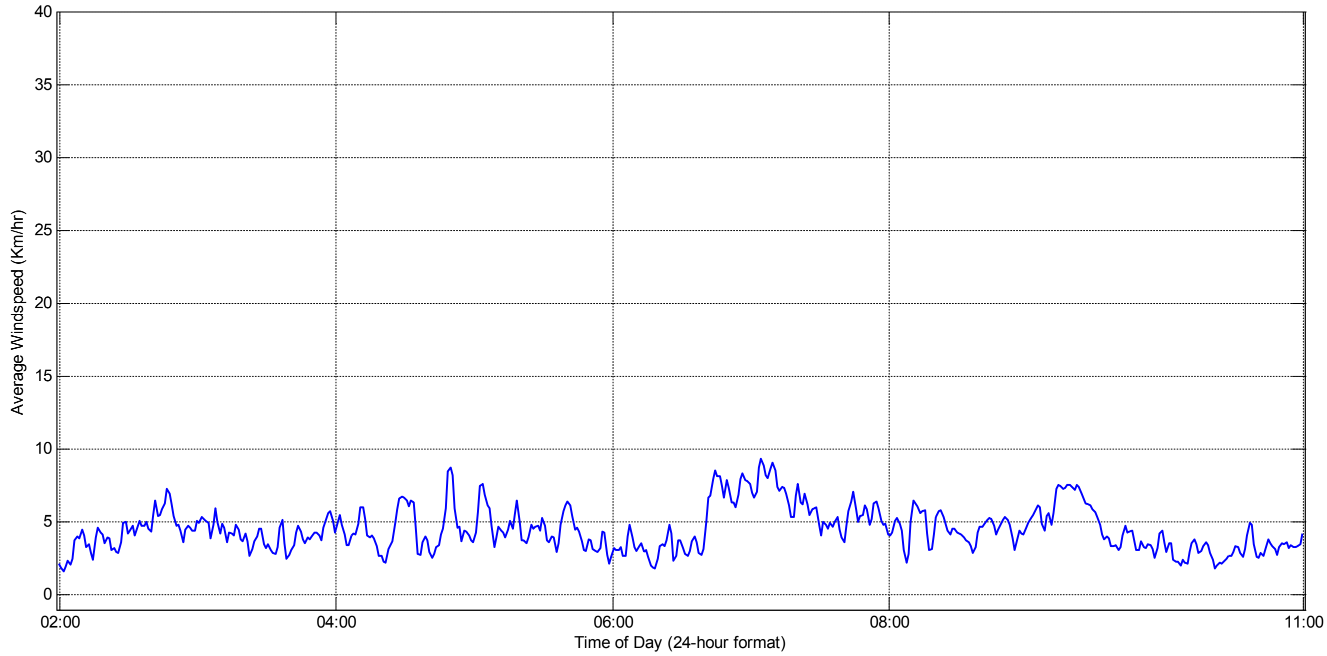
January 14 - 15, 2015 Monitored Wind Direction



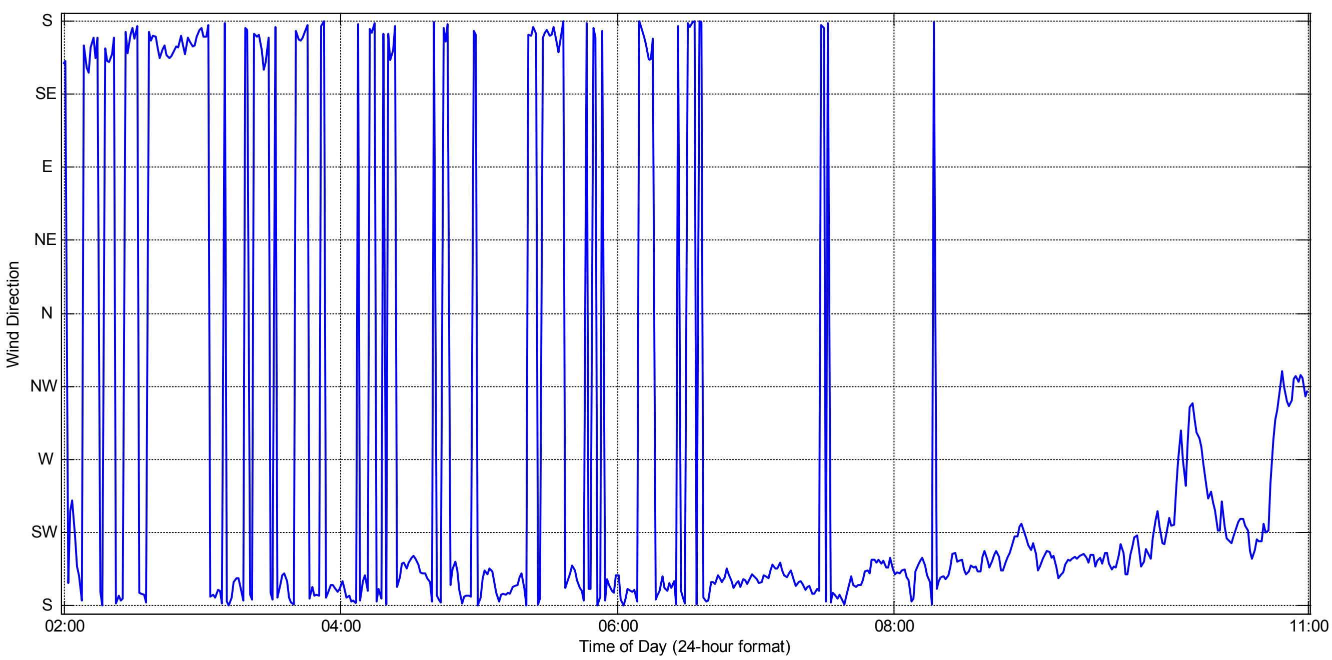
January 14 - 15, 2015 Monitored Temperature



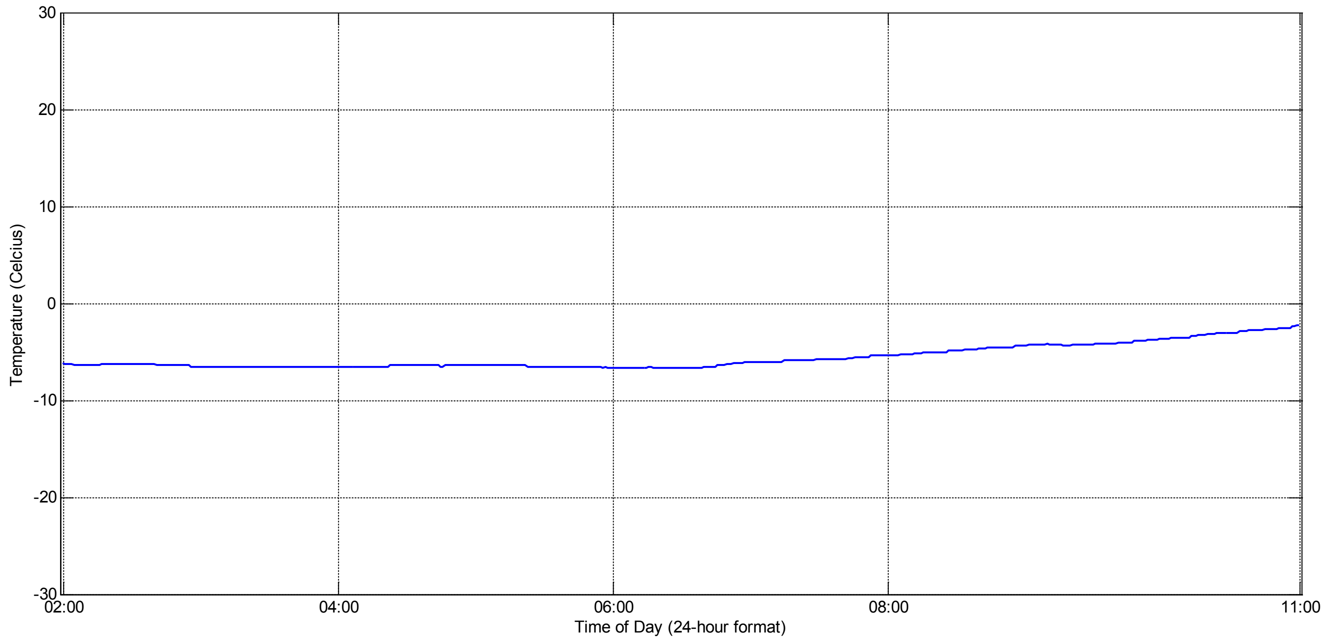
January 14 - 15, 2015 Monitored Relative Humidity



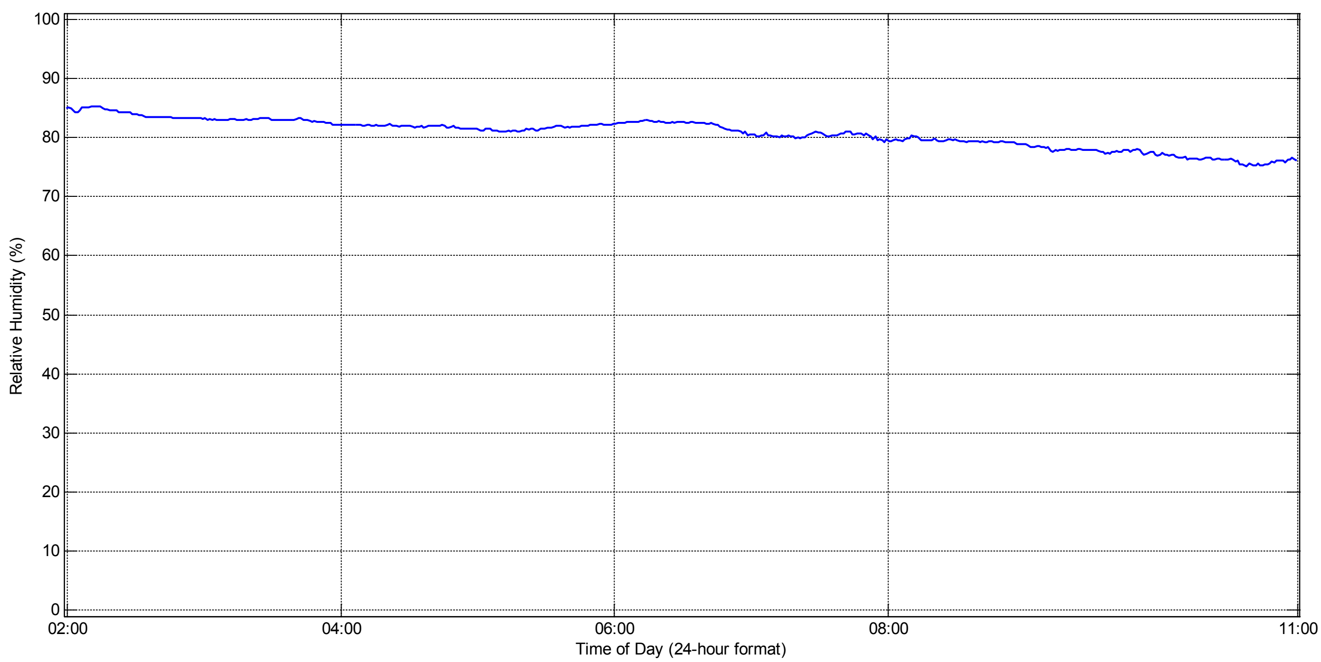
January 16, 2015 Monitored Wind Speed



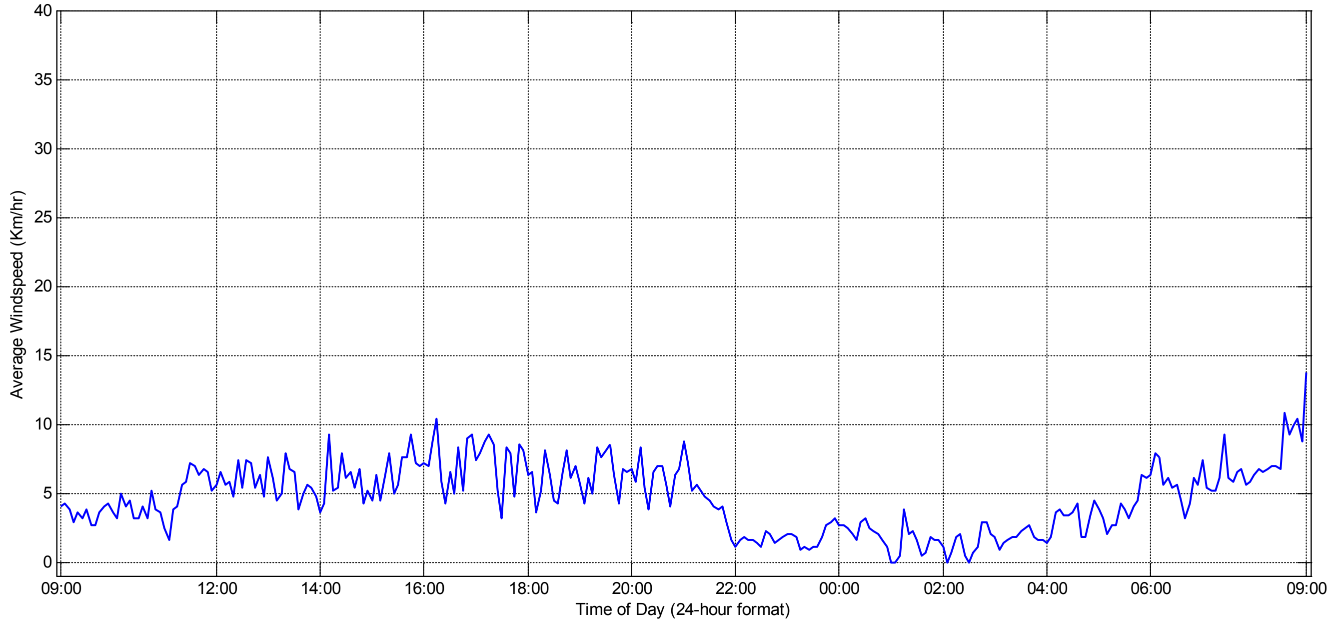
January 16, 2015 Monitored Wind Direction



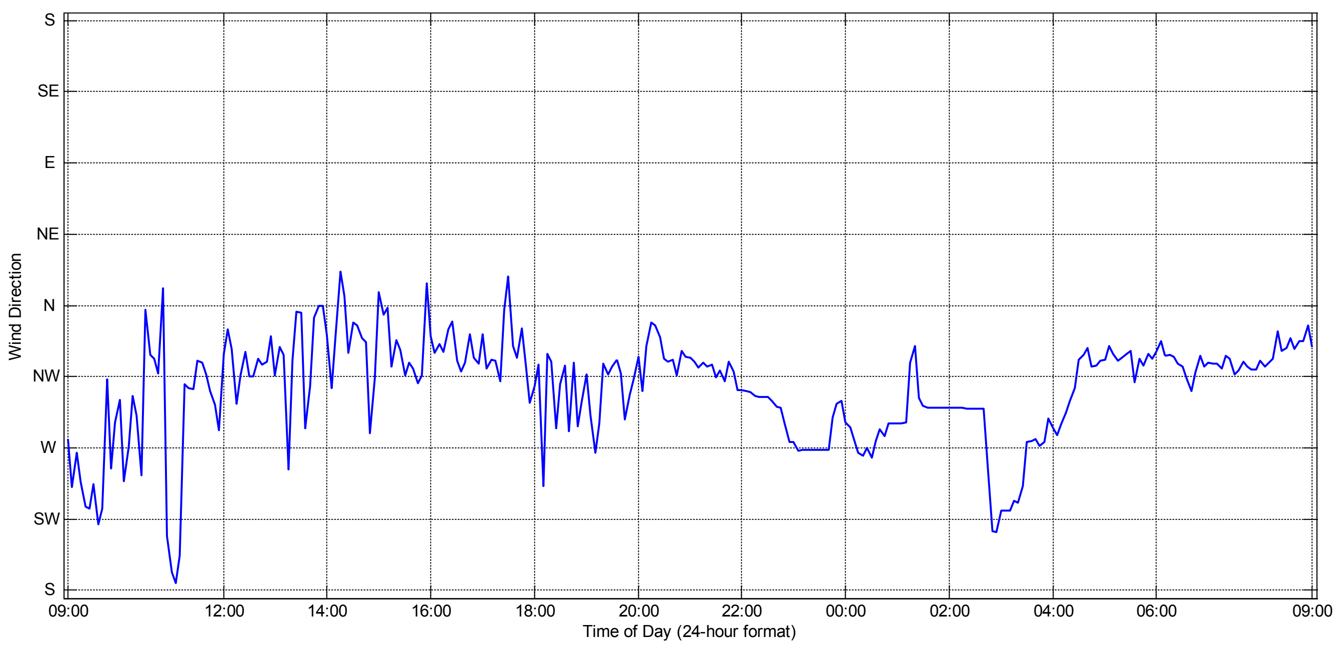
January 16, 2015 Monitored Temperature



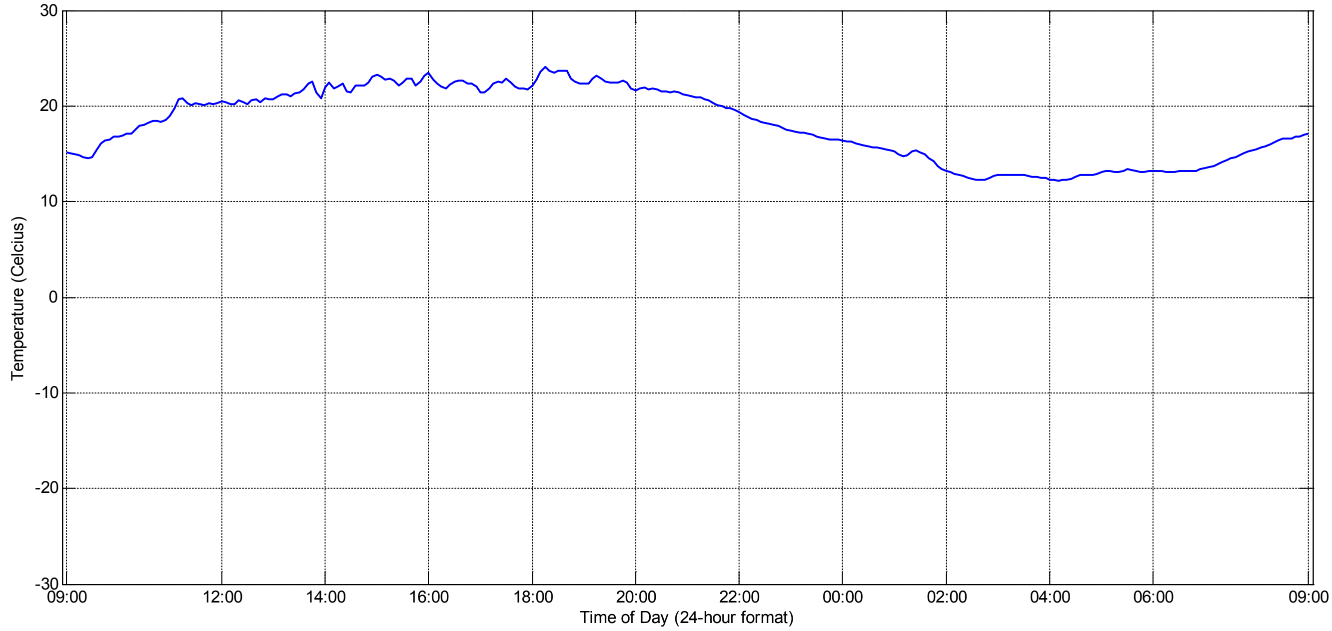
January 16, 2015 Monitored Relative Humidity



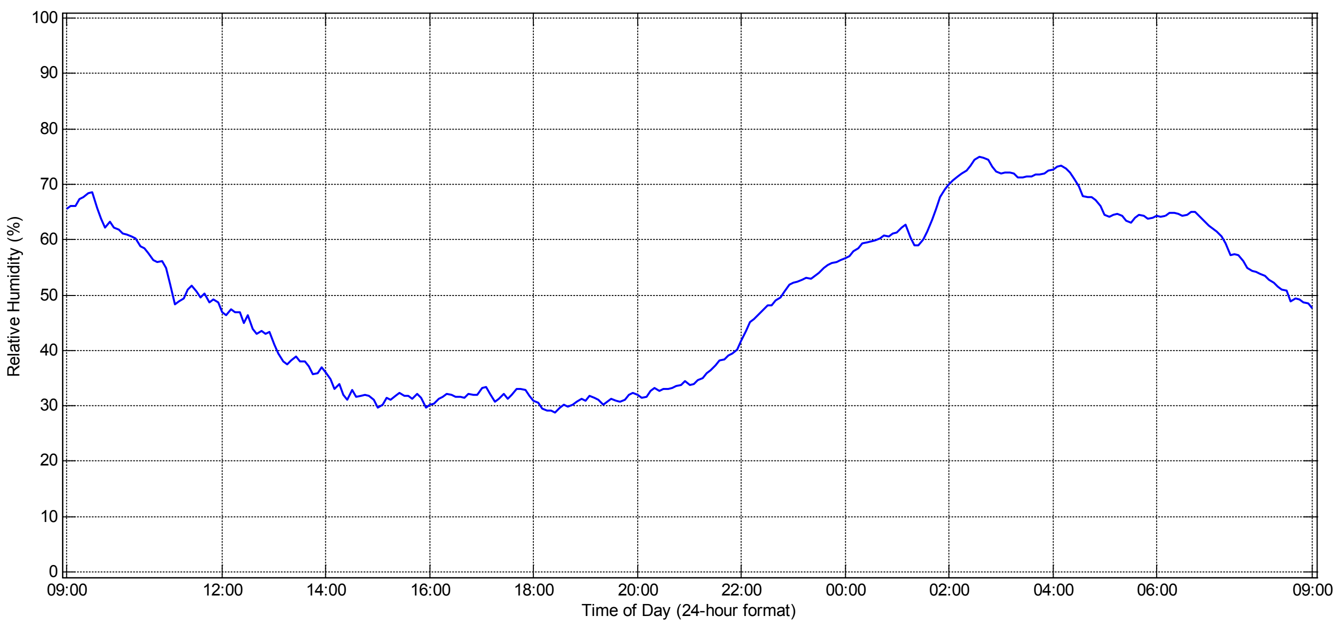
July 27 - 28, 2015 Monitored Wind Speed



July 27 - 28, 2015 Monitored Wind Direction



July 27 - 28, 2015 Monitored Temperature



July 27 - 28, 2015 Monitored Relative Humidity