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

Environmental Noise Impact Assessment
For The

Proposed West Cochrane Gravel Pit (LSD NE 15-26-05-W5M, NW 14-26-05-W5M, NE 14-26-08-W5M)

Prepared for:

BURNCO Rock Products Ltd.

PERMIT TO PRACTICE
ACI ACOUSTICAL CONSULTANTS INC.
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Prepared by:
P. Froment, B.Sc., B.Ed., P.L.(Eng.)
aci Acoustical Consultants Inc.
Edmonton, Alberta
APEGA Permit to Practice #P7735

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Executive Summary

aci Acoustical Consultants Inc., of Edmonton AB, was retained by BURNCO Rock Products Ltd. (BURNCO) of Calgary, AB to conduct an environmental noise impact assessment (NIA) for the proposed West Cochrane Pit (the Project) in Rocky View County, AB. As part of the study, a long-term noise monitoring was conducted at a receptor location within the study area. In addition, detailed on-site measurements were conducted at an existing BURNCO aggregate site. The information from the noise monitoring, the on-site measurements and detailed operational information provided by BURNCO were used to generate a computer noise model of the study area under existing and future conditions (i.e. with the Project operating). The results of the noise model were used to evaluate the noise impact of the Project operations for residential receptors within 2.0 km of the Project boundaries. Site work was conducted for aci on May 9, May 15 & May 24, 2018, by P. Froment, B.Sc., B.Ed., P.L.(Eng.).

A long-term noise monitoring was conducted at a receptor location within the study area to determine the existing noise climate. From this, two (2), 24-hour periods (based on meteorological conditions) indicated that the noise climate of the area was dominated by traffic related noise sources associated with Highway 1A. Results from the long-term noise monitoring were used as a calibration tool to model the projected existing noise climate of the study area.

The results of West Cochrane Gravel Pit #2 Operations noise modeling scenario indicated $L_{eq}24$ sound levels ranging from 36.2 dBA to 49.1 dBA for modeled residential receptor locations within 2.0 km of the Project boundaries. The impact of the Project relative to the existing noise climate ranged from -4.8 to 5.3 dBA. The variance in the impact of the Project was contributed to the relative distance of the receptors to the Project and to Highway 1A, respectively. Therefore, residents that were further from Highway 1A but within proximity to the West Cochrane Gravel Pit #2 operations had the highest impact. Subsequently, the noise climate of receptors further than 600 m from the active site and south of the project were determined to be minimally impacted by the contributions of the Project.

Lastly, additional potential noise mitigation strategies were provided to further reduce the noise impact of the project for the residential receptor locations within the study area. This is consistent with the Municipal District of Rocky View No.44 Bylaw No. C-5772-2003.

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1.0 Introduction

aci Acoustical Consultants Inc., of Edmonton AB, was retained by BURNCO Rock Products Ltd. (BURNCO) of Calgary, AB to conduct an environmental noise impact assessment (NIA) for the proposed West Cochrane Pit (the Project) in Rocky View County, AB. As part of the study, a long-term noise monitoring was conducted at a receptor location within the study area. In addition, detailed on-site measurements were conducted at an existing BURNCO aggregate site. The information from the noise monitoring, the on-site measurements and detailed operational information provided by BURNCO were used to generate a computer noise model of the study area under existing and future conditions (i.e. with the Project operating). The results of the noise model were used to evaluate the noise impact of the Project operations for residential receptors within 2.0 km of the Project boundaries. Site work was conducted for aci on May 9, May 15 & May 24, 2018, by P. Froment, B.Sc., B.Ed., P.L.(Eng.).

2.0 Location Description

As part of the Project, BURNCO is proposing to expand the existing West Cochrane Gravel Pit #1 located at NW 13-26-05-W5M into adjacent land parcels, LSD NE 15-26-05-W5M, NW 14-26-05-W5M, NE 14-26-05-W5M (will be referred to as West Cochrane Gravel Pit #2 or the Project). The existing project site is located approximately 5km northwest of Cochrane's western city limits, as indicated in Figure 1. The Project is bound on the west by a creek that flows to the Bow River, on the north by Highway 1A (which then becomes open fields), on the east by open fields and on the south by open fields and/or the Bow River.

Currently the only industrial noise source within 2.0 km of the Project that has an impact on the noise climate of the study area is the Wildcat Hills Gas Extraction Plant (the Gas Plant) at LSD 05-16-26-05-W5M. Access to this site was limited during the site visit and due to the unpredictable nature of the activities at this site, their noise contributions have not been included in this NIA. Therefore, the future case results of this study will be solely from the contributions of the Project noise sources.

Apart from the Gas Plant, the only other significant noise sources in the area are Highway 1A (Bow Valley Trail) and a CN Rail Line (on the south side of the Bow River). Highway 1A, which is considered a heavily travelled highway[1], is composed of 3.0% heavy vehicles and has a posted speed limit of 100 km/hr.

[1] Based on industry standards, a heavily travelled road is a road in which there are more than 10 vehicles per hour during the night-time period. The 2017 Average Annual Daily Traffic (AADT) volumes for Highway 22 (obtained from the Alberta. Transportation website) are 3620. Assuming 10% of this traffic occurs during the night-time equates to approximately 40 vehicles per hour during the nighttime. This exceeds 10 vehicles per hour for the road to be considered Heavily Traveled.

As such, roadway traffic noise has a significant impact on the noise climate of residents within the study area, particularly for those nearest to the roadway. Information for the CN rail line was not readily available however, it was noted through subjective observations during the setup & takedown of the equipment and through the review of the audio recording, that when present, the noise contributions from the rail are significant to the noise climate of the area.

There are several residents (9 identified during the site visit[1]) within 2.0 km of the Project's boundaries with the nearest being approximately 300 m west of the west border of the Project boundary. Topographically, the Project is found within an area with significant changes in elevation (approximately 240 m change in vertical elevation). Due to the varying terrain, elevation contours[2], provided by BURNCO, for the entire study area have been included in the noise model. The vegetation in the area consists of grain crops and thin vegetation. Given the relative distance between the noise sources and closest impacted residences, the vegetative sound absorption is considered minimal to moderate.

[1] It should be noted that it is possible that a residential location has not been identified or incorrectly placed. This can be attributed to the access during the site and to the resolution of the aerial images. However, the projected noise levels can still be determined through the colour noise contours.
[2] Obtained from LiDAR15 from AltaLIS in 1-meter intervals.

2.1. Environmental Noise Monitoring

As part of the study, a long-term environmental noise monitoring was conducted at a receptor location within the study area. The noise monitoring location, as indicated in Figure 1, was selected to determine the noise impact of the roadway noise on the current noise climate of the study area. The noise monitoring was conducted over a 16-day period from May 9 – 25, 2018. The noise monitoring was conducted collecting broadband A-weighted and C-weighted as well as 1/3 octave band sound levels. In addition, the noise monitoring was accompanied by a digital audio recording for more detailed post process analysis. A local weather monitoring station was used throughout the entire noise monitoring period to obtain the wind speed, wind direction, temperature relative humidity, barometric pressure and rainfall.

The noise monitor was located approximately 460 m north of Highway 1A and 2.7 km west of Grand Valley Road, as shown in Figure 2, at a height of 1.5 m above ground. At this location, there was direct line-of-sight to Highway 1A. The noise monitor was started at 18:00 on Wednesday May 9, 2018 and ran for approximately 16 days until 08:00 on Friday May 25, 2018.

Refer to Appendix I for a detailed description of all measurement equipment used in addition to calibration records, Appendix II for a description of the acoustical terminology, and Appendix III for a list of common noise sources. The noise measurement instrumentation was calibrated at the start of the monitoring and then checked afterwards to ensure that there had been no calibration drift over the duration of the monitoring.

3.0 Operational Description

The Project will be divided into various excavation sites, however for the purposes of this study, the westernmost locations will be investigated as these locations will have the greatest impact on the surrounding residential locations. As indicated in Figure 1, there will be 4 major operations that will be performed throughout the Project (described below).

When operations are closest to residents, the crushing, mining and dirt work will occur in the western portion of the Project. The wash plant, washed stockpile, and scale area will be placed in the northeastern corner of LSD NE-14-26-05-W5M.

Lastly, as prescribed in the Development Permit (DP) for the existing Pit the hours of operation for the Project are as follows (taken directly from the DP):

> *"15. The days and hours of operation, including stripping of overburden, aggregate extraction, operation of the crusher, and stockpiling, is limited to Monday through Saturday inclusive, with hours of operation 24 hours a day, Monday to Friday, and limited from 07:00 a.m. to 05:00p.m. on Saturday, with no activity on Sunday and Statutory Holidays.*
> *16. The days and hours of operation of the gravel pit, including loading and hauling, are Monday to Saturday, from 06:00 a.m. to 07:00 p.m., with no hauling activity on Sunday or Statutory Holidays."*

3.1. Overburden Removal

The overburden removal operations involve the stripping and removal of the vegetation, topsoil, subsoil and overburden. This exposes the aggregate deposit which is mined and hauled to be processed (i.e. screen and/or crushed or washed). The equipment associated with this operation will move throughout the entire site. The specific equipment associated with these operations includes:

- 4 – Scraper (Buggie),
- 1 – Grader
- 1 – Dozer

3.2. Crushing & Mining Operations

The crushing operations involve the excavation of raw material from the gravel deposit. The raw material is then screened, crushed and moved (using conveyors) to various stockpiles around the site. Equipment associated with this operation includes:

- 3 – Dump Trucks
- 1 – Loader
- 1 - Generator Trailer
- 1 - Feeder

- 2 - Screen Decks
- 1 – Jaw Crusher (with screener)
- 1 – Cone Crusher (with aerial cooler)
- 1 – Surge Bin
- Various conveyors

3.3. Wash Plant Operations

The wash plant operations involve the washing and classifying of the product to remove small particles of silt and fines to produce a cleaner product for use in concrete production (at locations separate from this site). It should be noted that the wash plant operations will only occur in the western portion of the Project. Equipment associated with this operation includes:

- 1 - Feeder
- 1 – Oversized Screener
- 1 – Pre-Screener
- 1 – Finishing Screener
- 1 – Sand Screw[1]
- 1 – Log Washer[1]
- 1 – Loader
- Various conveyors

3.4. Hauling Operations

The hauling operations involve the loading of the product (with the use of a wheel-loader) into the tandem dump trucks trailers for delivery off-site. The hauling will occur from the stockpiles at the crushing site and from stockpiles at the wash plant. It is anticipated that during peak operating hours there will be 20 truck loads (one way) per hour. Each truck must enter and leave the site, therefore there will be a total of 40 trips per hour (1 inbound and 1 outbound for each truck). Equipment associated with this operation includes:

- 1 – Loader for Crushing Site[2]
- 1 – Loader for Wash Plant
- 20 – Truck Loads

[1] It should be noted that the noise contributions of the sand screw and the log washer have not been included in the model. The blades for each typically turn at low speeds and relative to the other equipment on-site, their contributions are negligible.
[2] Typically only one Loader is utilized for the hauling/sales operations. However, to be conservative, 1 loader has been modeled at the Crushing site and the Wash Plant site.

4.0 Measurement Methods

4.1. Short Term Sound Level Measurements

Short-term sound level measurements were performed on Tuesday May 15, 2018, at the BURNCO Black Diamond Gravel Pit. The purpose of the measurements was to obtain noise level data of similar equipment, under operation, that is intended to be used use for this Project. This information was then used to determine the sound power levels for the representative Project equipment which was then used in the computer noise model. In addition, the measurements allowed for the observation of specific procedures and operations associated with the BURNCO operations.

While on-site, measurements were conducted on the screening/crushing equipment. All short-term sound level measurements were conducted using approximately 60-second Leq sampling while the equipment was under full load. Therefore, the data obtained is representative of the equipment's maximum noise levels. The information gathered consisted of broadband linear, A-weighted, C-weighted and 1/3 octave band sound levels. The weather during the sound level measurements was sunny with calm wind.

Again, all noise measurement instrumentation was calibrated at the start of the measurements and then checked afterwards to ensure that there had been no calibration drift over the duration of the measurements. Refer to Appendix I for the calibration records.

5.0 Computer Noise Modeling Methods

5.1. Noise Modeling Parameters

The computer noise modeling was conducted using the CADNA/A (Version 2022 MR1, build: 191.5229) software package. CADNA/A allows for the modeling of various noise sources such as road, rail, and various stationary sources. In addition, topographical features such as land contours, vegetation, and bodies of water can be included. Finally, meteorological conditions such as temperature, relative humidity, wind-speed and wind-direction can be included in the calculations.

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

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

A temperature of 10^0C and a relative humidity of 70% were used in the model[1]. Due to the relative distances involved and the type of vegetation that exists in the study area a ground absorption value of 0.5 was used in the model, which is relatively conservative. Vegetation was not included in the model and as a result, all sound level propagation calculations are considered representative of summertime conditions for all surrounding residents[1].

[1] This is consistent with common practices of other regulating bodies. The values chosen are intended to result in projected sound levels for all surrounding residents reflective of summertime conditions.

5.2. Noise Modeling Scenarios

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

1) Baseline Conditions: This scenario was representative of the existing baseline case conditions with the current operations at the Project Site in addition to the existing road configurations and traffic volumes[1]. The baseline noise monitoring data was used as a calibration method for the model.

2) West Cochrane Gravel Pit #2 Operations: This included all 4 major operations of the Project (overburden removal, crushing & mining, wash plant and hauling). It should be noted that this assumes that all operations are occurring simultaneously.

The computer noise modeling results were calculated in two ways. First, sound levels were calculated at specific receiver locations (i.e. residents). Next, the sound levels were calculated using a 5 m x 5 m grid over the entire study area. This provided color noise contours for easier visualization of the results. The model also included residential receptor locations found within 2.0 km of the Project's boundaries.

[1] 2018 AADT Traffic Data for Highway 1A was obtained from the Alberta Transportation website.

5.3. Noise Sources & Site Parameters

All data used in the model representing the Project equipment was obtained from i) on-site[1] short-term sound level measurements as described in Section 4.2 or ii) from measurements conducted for previous projects on similar/equivalent equipment. All measurements were conducted while the equipment was under full load (i.e. not idling). In addition, all noise sources in the model assume that the equipment is operating throughout the entire 24-hour period, therefore there has been no reduction of the noise levels to account for typical breaks that occur during typical work-shifts.

For all noise modeling scenarios, the noise sources associated with the Project have been modeled as traveling or stationary point sources at their appropriate heights that radiate noise equally in all directions (spherically & cylindrically), described in Appendix IV. The only exception is the haul route which was modeled as a road noise source. Directionality has not been applied to any equipment[2] and the equipment was modeled with elevation contours reflective of the Project fully mined. In addition to the noise sources, buildings associated with the site were included in the model, where applicable. The various heights of the buildings associated with crushing were based on observations made at the BURNCO Black Diamond site on May 15, 2018.

Noise from traffic sources is generally not covered by any regulations or guidelines at the municipal, provincial, or federal levels when considering gravel operations. As such, contributions from noises related to vehicle traffic (apart from the haul trucks) were not included in Scenarios 2) to 3). This will more accurately reflect the noise impacts of the Project on the study area, particularly when there are breaks in traffic. However, the Project-Only projected noise levels will still be compared to the Baseline conditions (based on the environmental noise monitoring) to get a sense on the noise impact of the Project relative to the current noise climate of the study area.

All sound power levels (SWLs) used in each of the modeling scenarios are provided in Appendix IV.

[1] It should be noted that field measurements are the preferred method of obtaining sound level data as theoretical data or extrapolation techniques can lead to inaccuracies.
[2] Specifically, genset's are very directional. However, it's exact location and configuration is not known. As result, it's contributions are omni-directional and therefore conservative.

5.4. Modeling Confidence

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

6.0 Noise Descriptors

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

The Municipal District of Rocky View No.44 Bylaw No. C-5772-2003 discusses regulating and controlling noise but does not have specific criteria as it relates to noise as it pertains to aggregates facilities. Therefore, the projected Project noise levels will be compared to the current noise levels of the study area for the Project related scenarios described in Section 5.2.

7.0 Results and Discussion

7.1. Environmental Monitoring

The results obtained from the environmental noise monitoring are presented in Table 1 and Figures 3 – 6, respectively (broadband A-weighted L_{eq} sound levels and 1/3 octave band L_{eq} sound levels provided). For the purposes of the data analysis, two (2) 24-hour periods (May 9 - 10, 2018 and May 12 – 13, 2018) will be reviewed. These 24-periods were selected to represent varying conditions at the site with a primary focus on obtaining data when the wind was either calm (in any direction) or moderate (less than 15 km/hr) coming from the southeast or southeast (downwind/crosswind from the Project & Highway 1A). It should be again be noted that the $L_{eq}24$ results have been adjusted by the isolation (removal) of any abnormal noise events such as birds chirping, abnormally loud vehicle pass-by's (mufflers, tire squealing), etc. Therefore, the results provided in Table 1 are representative of the typical noise climate of the noise monitoring location during "typical" conditions. Refer to Appendix V for a detailed list of the removed data including the start/stop times, the duration of the removed data, and the reason for the removal.

Table 1. Monitored Noise Monitoring L_{eq} Sound Levels

Monitor	$L_{eq}24$ (dBA)
May 09 - 10, 2018 (20:00 - 20:00)	41.0
May 12 - 13, 2018 (22:00 - 22:00)	40.8

The measured results indicated $L_{eq}24$ levels of 41.0 & 40.8 dBA, respectively, which is very consistent. The contributions from traffic were the dominant noise source at this location. Specifically, when reviewing the resultant 1/3 octave band L_{eq} sound levels in Figure 4 & Figure 6, the figures shows the typical trend of low frequency noise (near 63 – 100 Hz) resulting from engines and exhaust noise and mid-high frequency noise (near 1,000 Hz) resulting from tire noise[1]. This was also verified during the setup and takedown of the equipment and in reviewing the simultaneous audio recording.

The weather conditions during the May 9 – 10, 2018 noise monitoring period were moderate (below 15 km/hr) to high (above 15 km/hr) and predominately from the southeast for the monitoring period, thus resulting in downwind/crosswind conditions from Highway 1A. The temperature ranged from 2°C to

[1] This is consistent with aci's previous experience conducting noise monitoring for traffic noise related projects.

12°C. The relative humidity varied between approximately 57% - 91%. The barometric pressure was consistent at 88 kPa and there was no precipitation.

The weather conditions during the May 12 – 13, 2018 noise monitoring period were primarily moderate (below 15 km/hr) with a brief gust's (above 15 km/hr). During the calm conditions, the wind was from the northwest. As the wind speed increased its direction shifted to the east (crosswind from Highway 1A). The temperature ranged from 8°C to 21°C. The relative humidity varied between approximately 23% - 64%. The barometric pressure was consistent at 88 kPa and there was no precipitation.

Weather data obtained from the weather station are presented in Appendix VI.

7.2. Computer Noise Modelling

7.2.1. Baseline Case Scenario

The projected L_{eq}24 results of the Baseline Case noise modeling at the monitoring location is provided in Table 2. As mentioned previously, the noise monitoring data was used as a calibration tool for the noise model. The relative difference between the modeling and monitoring results is also provided. As indicated in Table 2, the modeling data matches very well with the measured values.

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

Date	Monitor L_{eq}24 (dBA)	Model L_{eq}24 (dBA)	Relative Difference (dBA)
May 09 - 10, 2018 (20:00 - 20:00)	41.0	41.2	0.2
May 12 - 13, 2018 (22:00 - 22:00)	40.8	41.2	0.4

The results of the Baseline Case noise modeling at the various residential receptor locations within the study area are presented in Table 3 and in Figure 7. The projected noise levels range from 31.4 to 51.3 dBA and as anticipated, the projected existing noise levels of the residential receptor locations decrease as their relative distance to Highway 1A increases. It should be noted however, that the results only include the noise contributions from Highway 1A. It therefore ignores the ambient noise caused by biological activity (e.g. birds, crickets, etc.), farming, etc. Therefore, it is probable that the existing ambient noise levels found in Table 3[1] are higher for receptors greater than 1 km from Highway 1A.

[1] This is based on hundreds of measured L_{eq}Day noise levels from similar aci conducted, rural noise monitoring's.

Table 3. Baseline Case Noise Modeling Results

Receptor (Distance from Centre of Site)	Calibration Case Leq24 (dBA)
R-01 (550m)	40.3
R-02 (150m)	51.3
R-03 (35m)	44.8
R-04 (415m)	42.8
R-05 (716m)	43.5
R-06 (690m)	46.6
R-07 (980m)	44.0
R-08 (1080m)	36.6
R-09 (1450m)	31.4
Minimum	**31.4**
Maximum	**51.3**

7.2.2. West Cochrane Gravel Pit #2 Operations Scenario

The results of the West Cochrane Gravel Pit #2 noise modeling scenario are presented in Table 4 is illustrated in Figure 8.

Table 4. West Cochrane Gravel Pit #2 Operations Noise Modeling Results

Receptor (Distance from Project Boundary)	Project Site Project Leq24 (dBA)		Baseline Case (Leq24) dBA	Difference Relative to West Site (dBA)		Project Site Project Leq24 (dBC)	dBC - dBA
R-01 (550m)	45.6		40.3	5.3		53.4	7.8
R-02 (150m)	48.3		51.3	-3.0		55.6	7.3
R-03 (35m)	49.1		44.8	4.3		57.3	8.2
R-04 (415m)	46.0		42.8	3.2		53.6	7.6
R-05 (716m)	43.0		43.5	-0.5		51.1	8.1
R-06 (690m)	41.8		46.6	-4.8		50.3	8.5
R-07 (980m)	39.3		44.0	-4.7		48.3	9.0
R-08 (1080m)	38.6		36.6	2.0		47.8	9.2
R-09 (1450m)	36.2		31.4	4.8		46.0	9.8
Minimum	**36.2**		**31.4**	**-4.8**		**46.0**	**7.3**
Maximum	**49.1**		**51.3**	**5.3**		**57.3**	**9.8**

As anticipated and as shown in Table 4 there is a significant variation in the noise levels for the various residents during the western operations. The modeled $L_{eq}24$ noise levels from the West Cochrane Gravel Pit #2 operations for R-01 to R-09 range from 36.2 dBA to 49.1 dBA. As anticipated, the highest projected noise levels during the operations are for receptor location R-02 due to its proximity to the site.

The relative impact of the West Cochrane Gravel Pit #2 operations ranges from -4.8 to 5.3 dBA. The variance in the impact can be attributed to the relative distance of the receptors to the Project and to Highway 1A, respectively. Specifically, Receptor R-01 will have the highest increase in noise levels due to its distance to Highway 1A (+510 m) and its relative proximity to the project site (approx. 550 m north of Project equipment). Subsequently, the noise climate of receptors further than 600 m from the Project site and within 400 m of Highway 1A (R-06 & R-07) will be less impacted by the contributions of the Project.

In addition to the broadband A-weighted (dBA) sound levels, the modeling results at the various receptor locations indicated C-weighted (dBC) sound levels will be less than 20 dB above the dBA sound levels, as shown in Table 4. As per industry standards, if the dBC – dBA sound levels are less than 20 dB, the noise is not considered to have a low frequency tonal component.

Table 5 indicates that the most significant noise contributor to R-02 will be from the scrapers associated with the overburden removal in addition to the crushing equipment (Jaw crusher, screen decks, etc.). This was anticipated and is consistent with previous, similar projects in which equipment associated with the overburden removal crushing is typically the most significant noise source on-site, particularly when under full-load and in proximity to residents.

Table 5. Project Operations –Broadband Sound Level Contributions for Receptor R-02

Noise Source	dBA
Scrapers - Overburden Removal	42.3
Scrapers - Overburden Removal	40.8
Jaw Crusher - Crushing	39.8
Screen Deck #2 - Crushing	39.4
Screen Deck #3 - Crushing	37.6
Loader - Crushing	36.1
Screen Deck #1 - Crushing	36.0
Generator - Crushing	35.8
Loader - Hauling	35.2
Grader - Overburden Removal	35.1
Grader - Overburden Removal	33.8
Dozer - Overburden Removal	32.3
Dozer - Overburden Removal	31.7
Haul Route - Crushing	30.6
Cone Crusher - Crushing	29.3
Dump Truck - Mining	27.9
Dump Truck - Mining	27.1
Dump Truck - Mining	24.7
Dump Truck - Mining	24.6
Cone Crusher Aerial Cooler	23.2
Loader - Wash Plant	23.1
Loader - Hauling	23.1
Oversize Screen - Wash Plant	15.6
Haul Route - Wash Plant	13.0
Pre-Screener- Wash Plant	10.0
Finishing Screener - Wash Plant	6.4

8.0 Potential Noise Mitigation Recommendations

There are certain mitigation strategies that can be employed to reduce the noise impact of the Project on the nearby residents. The following are general noise mitigation approaches that can be used for all stages of the extraction:

- Initially, replace large, loud pieces of equipment with smaller, quieter pieces of equipment[1] provided the same amount of work can be performed.
- Reduce the noise from the loudest noise sources with the use of larger mufflers or noise attenuation enclosures.
- Reduce the number of pieces of equipment operating at a given time, where possible. This can be particularly effective for times in which residents might be more sensitive to noise (e.g. early mornings, weekends, etc.)

In situations where the majority of the equipment is stationary (i.e. crushers, screeners, generators, etc.) the most effective mitigation approaches are as follows:

- Place the Project equipment, as soon as possible, on the pit floor and locate it as close as possible to the pit walls. The pit walls can act as a natural noise barrier and when combined with stockpiles, the noise[2] can be essentially steered in directions away from residential receptors.
- Strategically placing stockpiles or earth berms around the Project equipment. This approach has the most minimal impact on the typical operations of the pit, it is cost effective (because the material to create a stockpile is readily available) and its acoustical performance is very good due to the density and potentially absorptive characteristics of the stockpile.
- Consider the directionality of stationary pieces of equipment (e.g. noise from a generator is significantly louder in front of the aerial cooler in comparison to 90° off-axis) and aim them in directions away from the residential receptors.

It is, however, understood that certain mitigation recommendations may not be practically or economically feasible.

[1] This should be verified with the manufacturer.
[2] It should be noted however that low frequency noise is not as easily "steered" due to its relatively long wavelengths.

9.0 Conclusion

A long-term noise monitoring was conducted at a receptor location within the study area to determine the existing noise climate. From this, two (2), 24-hour periods (based on meteorological conditions) indicated that the noise climate of the area was dominated by traffic related noise sources associated with Highway 1A. Results from the long-term noise monitoring were used as a calibration tool to model the projected existing noise climate of the study area.

The results of West Cochrane Gravel Pit #2 Operations noise modeling scenario indicated $L_{eq}24$ sound levels ranging from 36.2 dBA to 49.1 dBA for modeled residential receptor locations within 2.0 km of the Project boundaries. The impact of the Project relative to the existing noise climate ranged from -4.8 to 5.3 dBA. The variance in the impact of the Project was contributed to the relative distance of the receptors to the Project and to Highway 1A, respectively. Therefore, residents that were further from Highway 1A but within proximity to the West Cochrane Gravel Pit #2 operations had the highest impact. Subsequently, the noise climate of receptors further than 600 m from the active site and south of the project were determined to be minimally impacted by the contributions of the Project.

Lastly, additional potential noise mitigation strategies were provided to further reduce the noise impact of the project for the residential receptor locations within the study area. This is consistent with the Municipal District of Rocky View No.44 Bylaw No. C-5772-2003.

10.0 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.
- *Engineering Noise Control, Theory and Practice*. David A. Bies and Colin H. Hansen, 2003, Spon Press
- *Noise and Vibration Control Engineering, Principles and Applications*. Istvan L. Ver and Leo L. Beranek, 2006, John Wiley & Sons Inc.

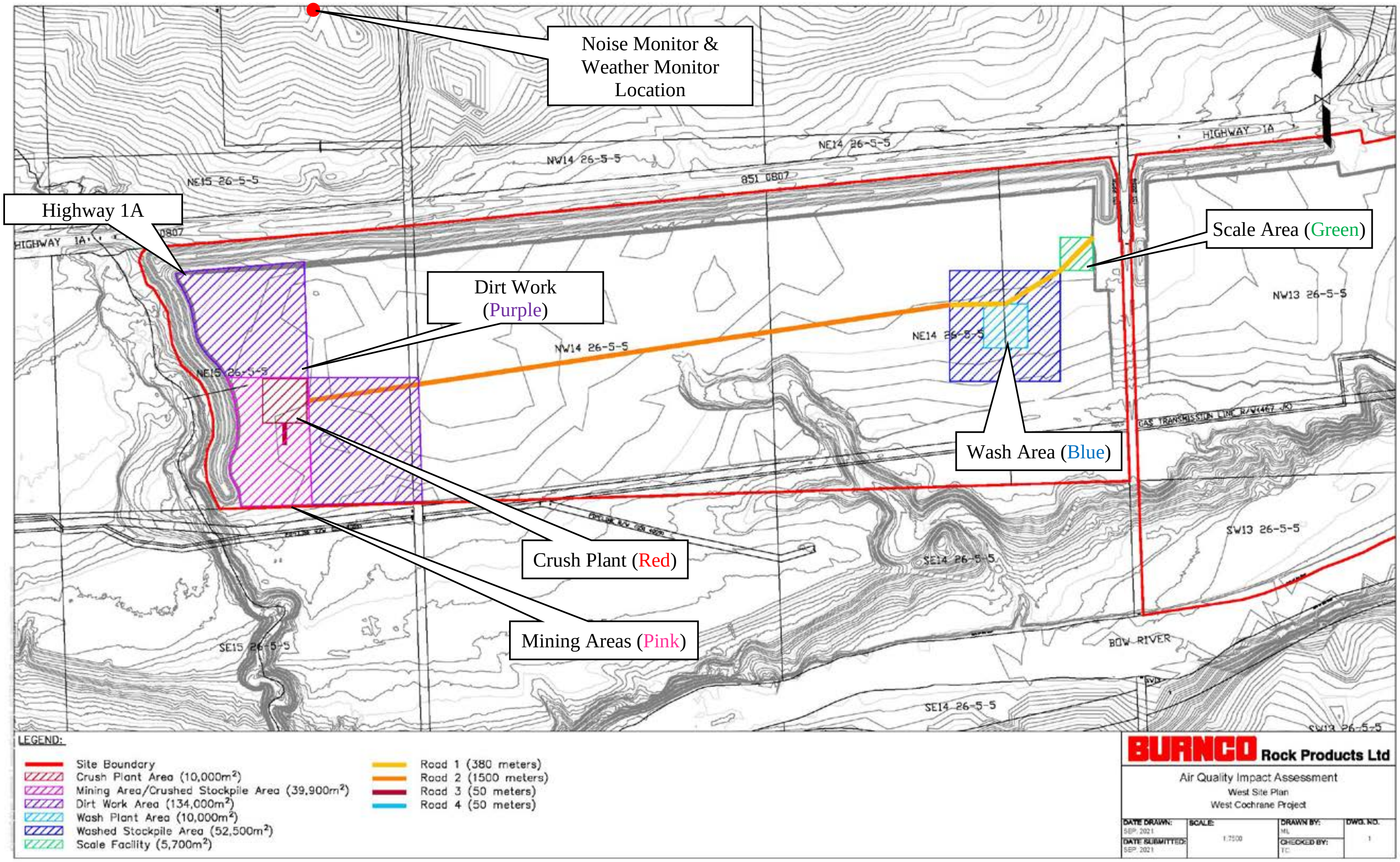

Figure 1. Study Area – West Cochrane Gravel Pit #2 Operations Site Plan

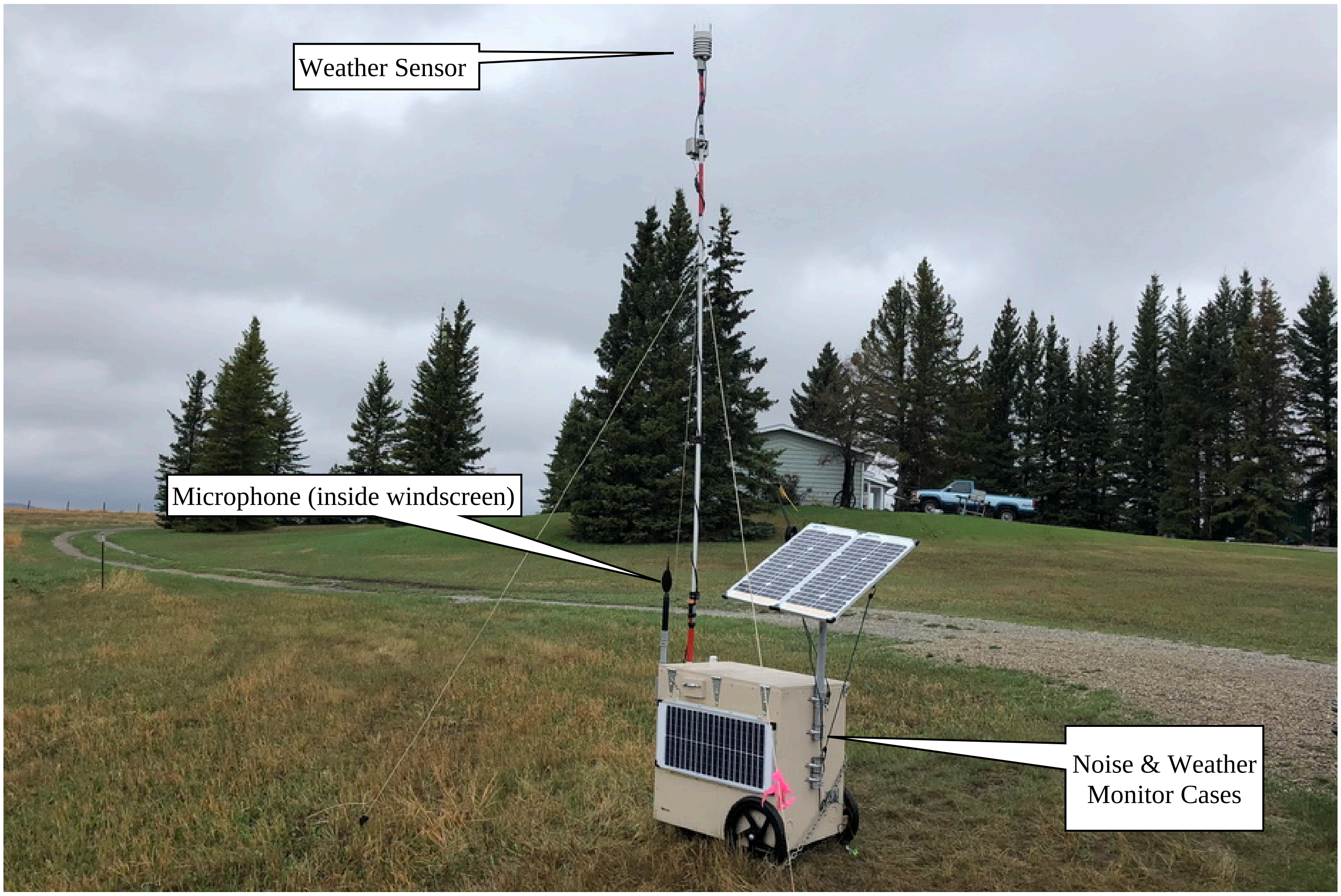

Figure 2. Noise & Weather Monitors Used for Environmental Noise Study

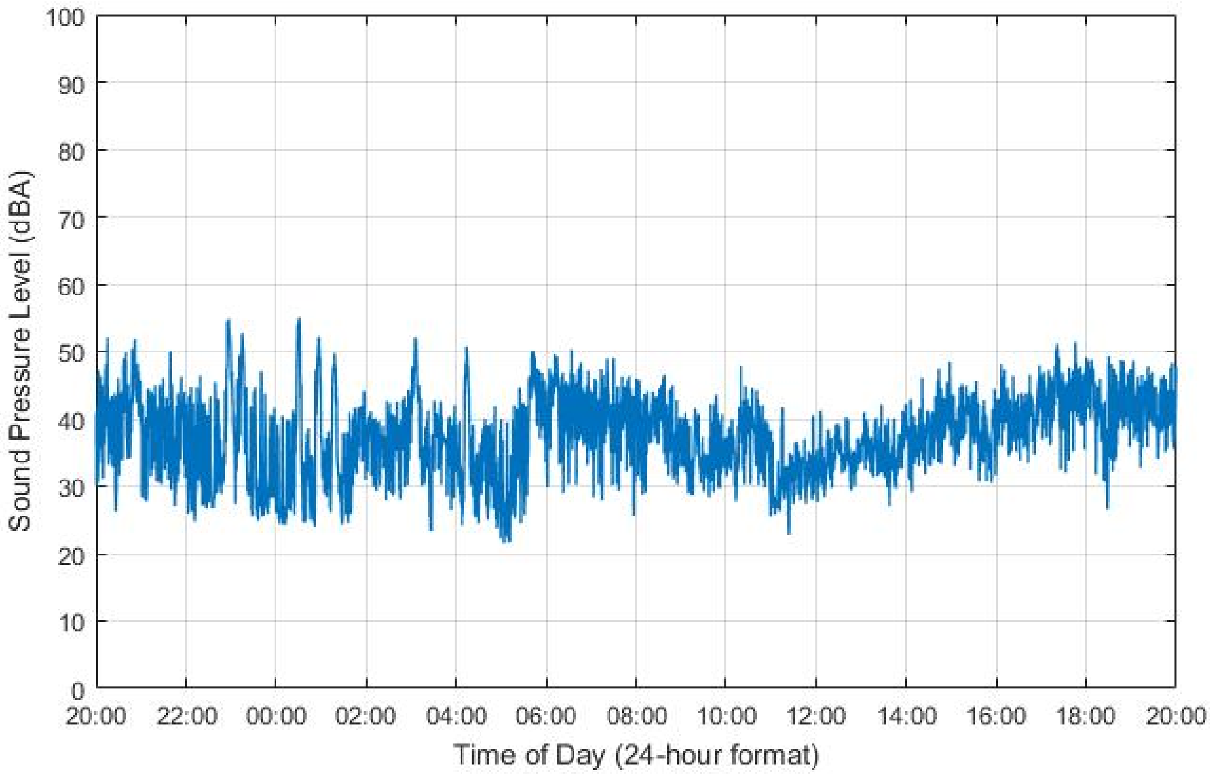

Figure 3. May 9 – 10, 2018 15-Second L_{eq} Sound Levels

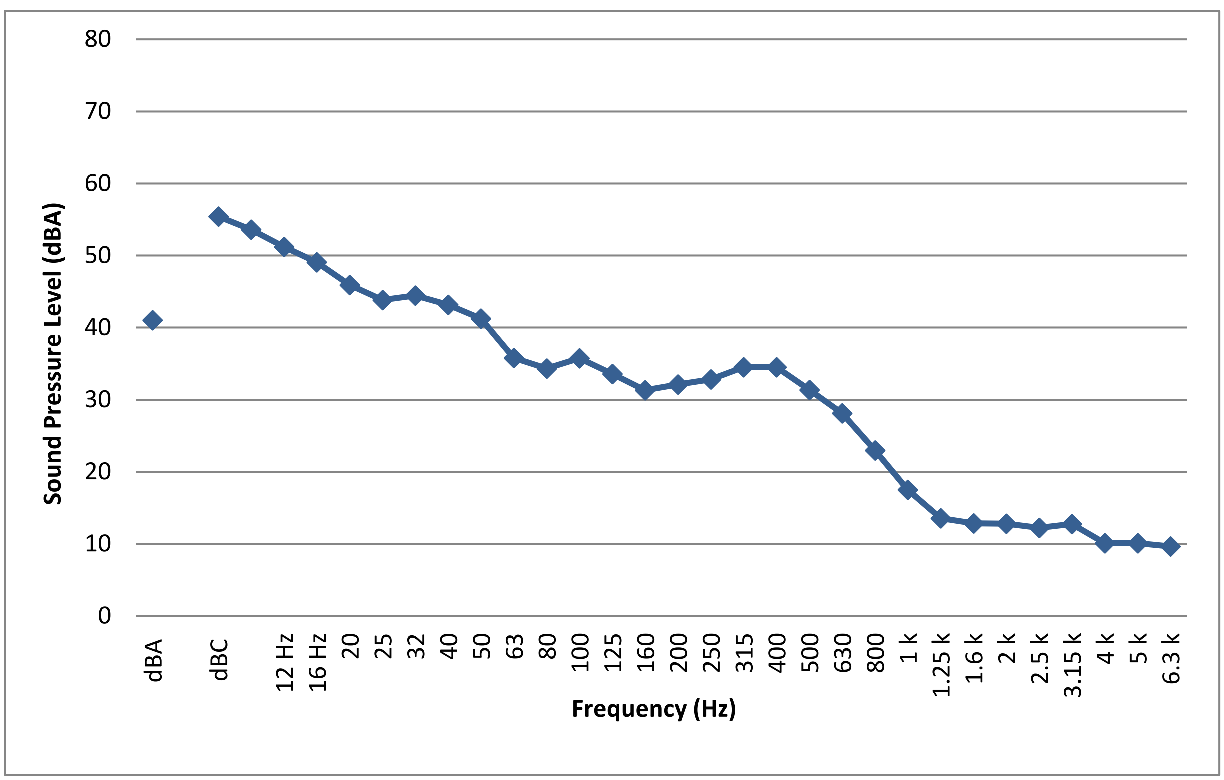

Figure 4. May 9 – 10, 2018 – 1/3 Octave Band Sound Levels

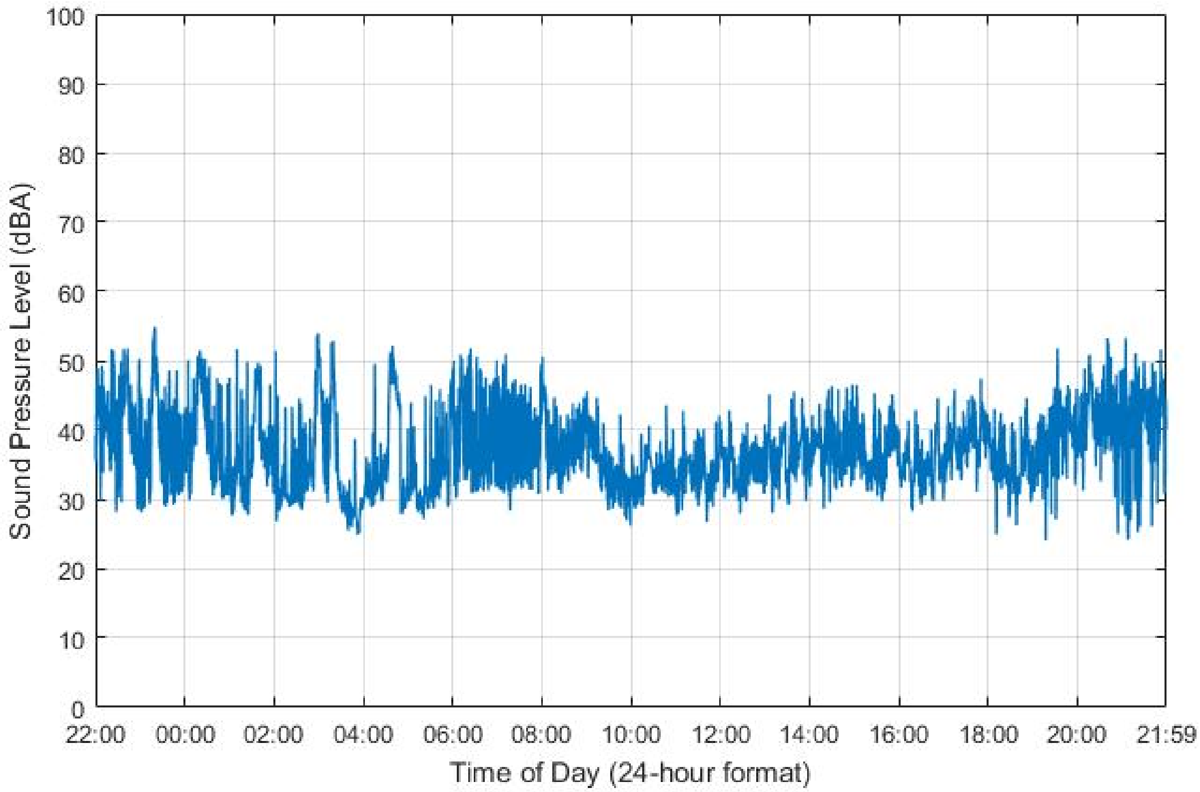

Figure 5. May 12 – 13, 2018 15-Second L_{eq} Sound Levels

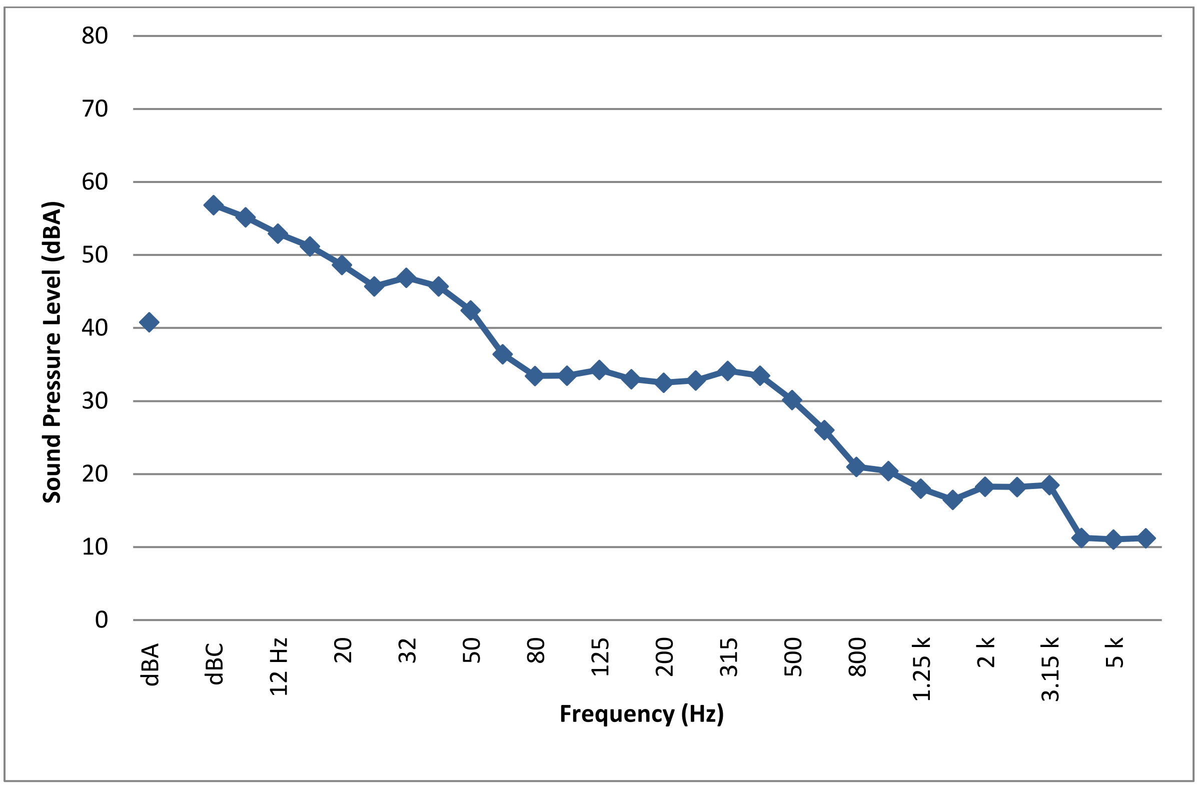

Figure 6. May 12 – 13, 2018 – 1/3 Octave Band Sound Levels

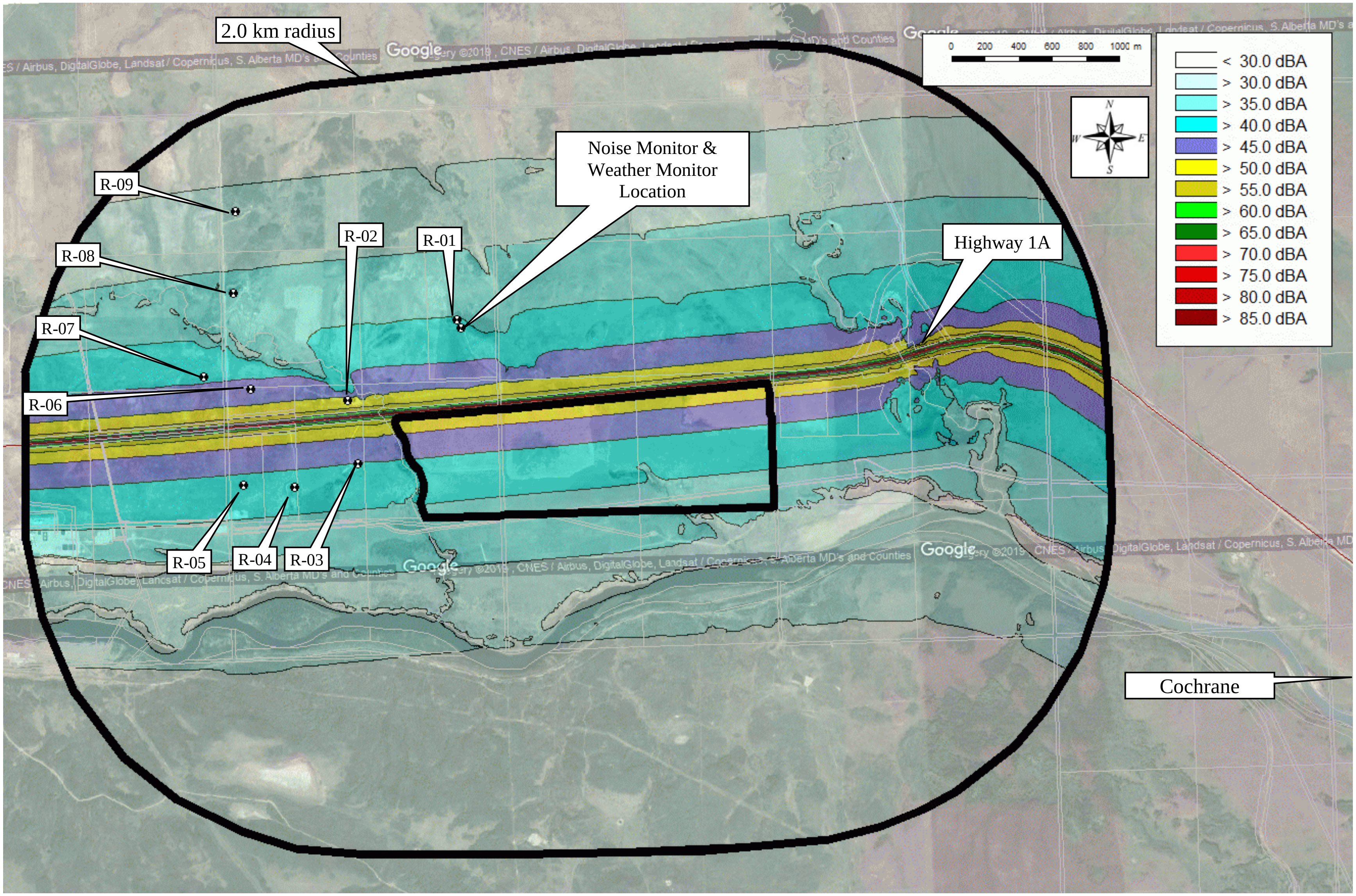

Figure 7. Baseline - L_{eq}24 Sound Levels

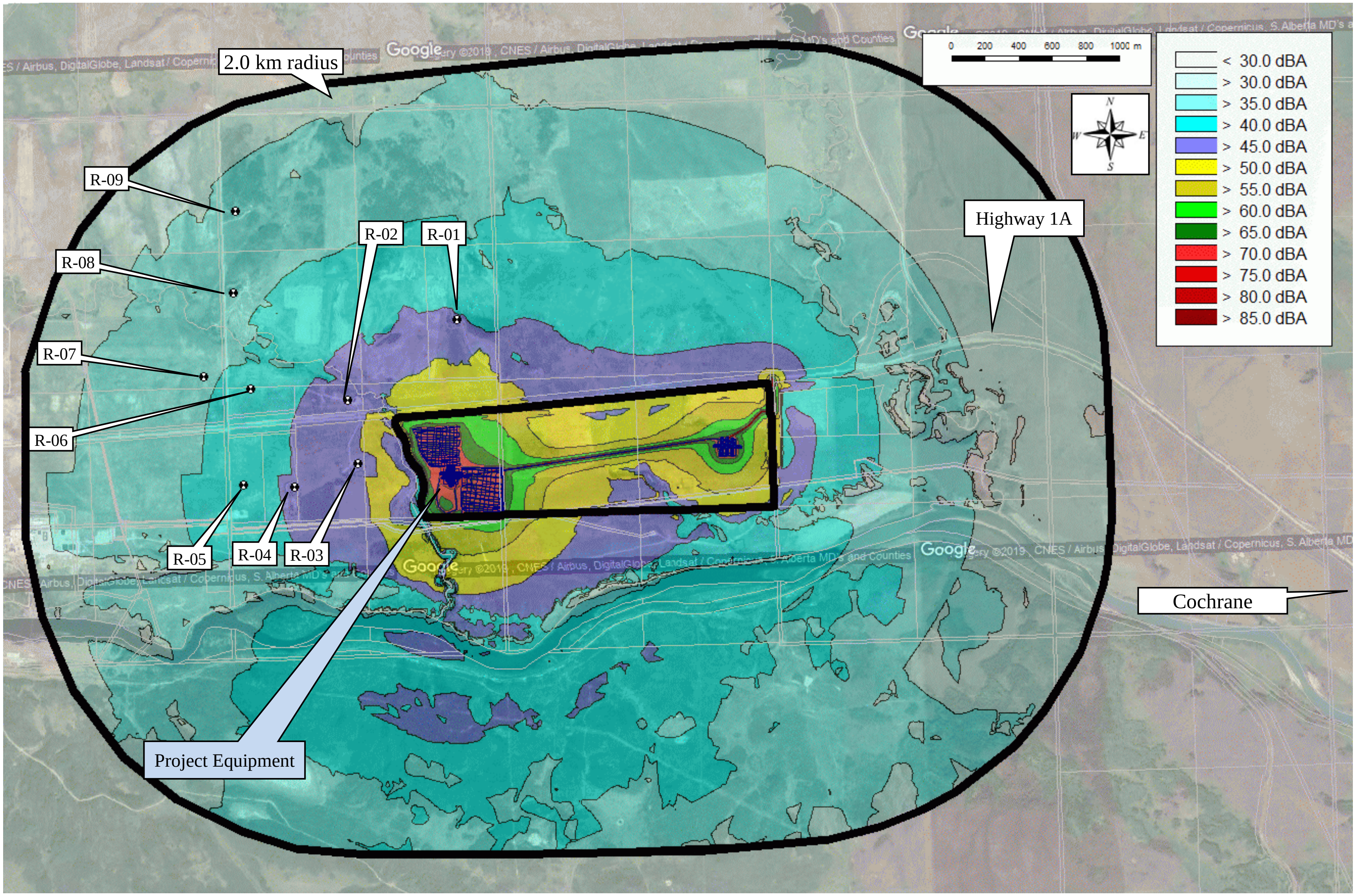

Figure 8. West Cochrane Gravel Pit #2 Site - L_{eq}24 Sound Levels

Appendix I MEASUREMENT EQUIPMENT USED

Noise Monitors

The environmental noise monitoring equipment used consisted of a Brüel and Kjær Type 2250/2270 Precision Integrating Sound Level Meter enclosed in an environmental case, a tripod, a weather protective microphone hood, external battery and solar panels. The system acquired data in 15-second L_{eq} samples using 1/3 octave band frequency analysis and overall A-weighted and C-weighted sound levels. The sound level meter conforms to Type 1, ANSI S1.4, ANSI S1.43, IEC 61672-1, IEC 60651, IEC 60804 and DIN 45657. The 1/3 octave filters conform to S1.11 – Type 0-C, and IEC 61260 – Class 0. The calibrator conforms to IEC 942 and ANSI S1.40. The sound level meter, pre-amplifier and microphone were certified on November 10, 2016 and the calibrator (type B&K 4231) was certified on January 30, 2018 by a NIST NVLAP Accredited Calibration Laboratory for all requirements of ISO 17025: 1999 and relevant requirements of ISO 9002:1994, ISO 9001:2000 and ANSI/NCSL Z540: 1994 Part 1. Simultaneous digital audio was recorded directly on the sound level meter using a 8 kHz sample rate for more detailed post-processing analysis. Refer to the next section in the Appendix for a detailed description of the various acoustical descriptive terms used.

Weather Monitor

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

Record of Calibration Results

Description	Date	Time	Pre / Post	Calibration Level	Calibrator Model	Serial Number
Sound Level Meter (On-site)	May 15, 2018	09:45	Pre	93.9 dBA	B&K 4231	2656414
Sound Level Meter (On-Site)	May 15, 2018	11:00	Post	93.9 dBA	B&K 4231	2656414
South Noise Monitor	May 09, 2018	15:55	Pre	93.9 dBA	B&K 4231	2656414
South Noise Monitor	May 25, 2018	08:05	Post	93.9 dBA	B&K 4231	2656414

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® CALIBRATION
NVLAP Lab Code: 200625-0

Calibration Certificate No.40042

Instrument: **Acoustical Calibrator**
Model: **4231**
Manufacturer: **Brüel and Kjær**
Serial number: **2656414**
Class (IEC 60942): **1**
Barometer type:
Barometer s/n:
Customer: **ACI Acoustical Consultants Inc.**
Tel/Fax: **780-414-6373 / 780-414-6376**

Date Calibrated: **1/30/2018** *Cal Due:*

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

Contains non-accredited tests: __Yes _X_ No

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

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

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

Instrument - Manufacturer	Description	S/N	Cal. Date	Traceability evidence Cal. Lab / Accreditation	Cal. Due
483B-Norsonic	SME Cal Unit	31061	Jul 28, 2017	Scantek, Inc./ NVLAP	Jul 28, 2018
DS-360-SRS	Function Generator	88077	Sep 15, 2016	ACR Env./ A2LA	Sep 15, 2018
34401A-Agilent Technologies	Digital Voltmeter	MY47011118	Sep 20, 2017	ACR Env./ A2LA	Sep 20, 2018
HM30-Thommen	Meteo Station	1040170/39633	Oct 25, 2017	ACR Env./ A2LA	Oct 25, 2018
140-Norsonic	Real Time Analyzer	1403978	Mar 22, 2017	Scantek, Inc. / NVLAP	Mar 22, 2018
PC Program 1018 Norsonic	Calibration software	v.6.1T	Validated Nov 2014	Scantek, Inc.	-
4192-Brüel&Kjær	Microphone	2854675	Nov 11, 2017	Scantek, Inc. / NVLAP	Nov 11, 2018
1203-Norsonic	Preamplifier	92268	Oct 18, 2017	Scantek, Inc./ NVLAP	Oct 18, 2018

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

Calibrated by:	Jeremy Gotwalt	Authorized signatory:	Steven E. Marshall
Signature	*[signature]*	Signature	*[signature]*
Date	1/30/18	Date	1/30/2018

Document stored as: Z:\Calibration Lab\Cal 2018\BNK4231_2656414_M1.doc Page 1 of 2

B&K 2250 SLM Calibration Certificate

Scantek, Inc.
CALIBRATION LABORATORY

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

NVLAP® CALIBRATION
NVLAP Lab Code: 200625-0

Calibration Certificate No.37313

Instrument: **Sound Level Meter**
Model: **2250**
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.**
Tel/Fax: **780-414-6373 / -6376**

Date Calibrated: **11/10/2016** *Cal Due:*

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

Contains non-accredited tests: __ **Yes** X **No**
Calibration service: __ **Basic** X **Standard**
Address: **5031 - 210 Street**
Edmonton, Alberta, CANADA
T6M 0A8

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

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

Instrument - Manufacturer	Description	S/N	Cal. Date	Traceability evidence Cal. Lab / Accreditation	Cal. Due
483B-Norsonic	SME Cal Unit	31061	Jul 27, 2016	Scantek, Inc./ NVLAP	Jul 27, 2017
DS-360-SRS	Function Generator	88077	Sep 15, 2016	ACR Env./ A2LA	Sep 15, 2018
34401A-Agilent Technologies	Digital Voltmeter	MY47011118	Sep 15, 2016	ACR Env./ A2LA	Sep 15, 2017
HM30-Thommen	Meteo Station	1040170/39633	Nov 1, 2016	ACR Env./ A2LA	Nov 1, 2017
PC Program 1019 Norsonic	Calibration software	v.6.1T	Validated Nov 2014	Scantek, Inc.	-
1251-Norsonic	Calibrator	30878	Nov 10, 2016	Scantek, Inc./ NVLAP	Nov 10, 2017

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 (%)
22.1	100.26	38.2

Calibrated by:	Jeremy Gotwalt	**Authorized signatory:**	Valentin Buzduga
Signature		Signature	
Date	11/10/16	Date	11/14/2016

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B&K 2250 Microphone Calibration Certificate

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

NVLAP®
CALIBRATION
NVLAP Lab Code: 200625-0

Calibration Certificate No.37314

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

Date Calibrated: **11/10/2016** *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. 2/25/2015

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

Instrument - Manufacturer	Description	S/N	Cal. Date	Traceability evidence Cal. Lab / Accreditation	Cal. Due
483B-Norsonic	SME Cal Unit	31061	Jul 27, 2016	Scantek, Inc./ NVLAP	Jul 27, 2017
DS-360-SRS	Function Generator	88077	Sep 15, 2016	ACR Env./ A2LA	Sep 15, 2018
34401A-Agilent Technologies	Digital Voltmeter	MY47011118	Sep 15, 2016	ACR Env./ A2LA	Sep 15, 2017
HM30-Thommen	Meteo Station	1040170/39633	Nov 1, 2016	ACR Env./ A2LA	Nov 1, 2017
PC Program 1017 Norsonic	Calibration software	v.6.1T	Validated Nov 2014	Scantek, Inc.	-
1253-Norsonic	Calibrator	28326	Nov 10, 2015	Scantek, Inc./ NVLAP	Nov 10, 2016
1203-Norsonic	Preamplifier	92268	Oct 17, 2016	Scantek, Inc./ NVLAP	Oct 17, 2017
4180-Brüel&Kjær	Microphone	2246115	Oct 26, 2015	NPL-UK / UKAS	Oct 26, 2017

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

Calibrated by:	Jeremy Gotwalt	Authorized signatory:	Valentin Buzduga
Signature		Signature	
Date	11/10/16	Date	11/14/2016

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Page 1 of 2

B&K 4231 Calibrator Calibration Certificate

Scantek, Inc.
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ISO 17025: 2005, ANSI/NCSL Z540:1994 Part 1
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NVLAP® CALIBRATION
NVLAP Lab Code: 200625-0

Calibration Certificate No.40042

Instrument:	**Acoustical Calibrator**	*Date Calibrated:* **1/30/2018** *Cal Due:*		
Model:	**4231**	*Status:*	**Received**	**Sent**
Manufacturer:	**Brüel and Kjær**	*In tolerance:*	X	X
Serial number:	**2656414**	*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.**	*Address:*	**5031 - 210 Street, Edmonton, Alberta, CANADA T6M 0A8**	
Tel/Fax:	**780-414-6373 / 780-414-6376**			

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	31061	Jul 28, 2017	Scantek, Inc./ NVLAP	Jul 28, 2018
DS-360-SRS	Function Generator	88077	Sep 15, 2016	ACR Env./ A2LA	Sep 15, 2018
34401A-Agilent Technologies	Digital Voltmeter	MY47011118	Sep 20, 2017	ACR Env./ A2LA	Sep 20, 2018
HM30-Thommen	Meteo Station	1040170/39633	Oct 25, 2017	ACR Env./ A2LA	Oct 25, 2018
140-Norsonic	Real Time Analyzer	1403978	Mar 22, 2017	Scantek, Inc. / NVLAP	Mar 22, 2018
PC Program 1018 Norsonic	Calibration software	v.6.1T	Validated Nov 2014	Scantek, Inc.	-
4192-Brüel&Kjær	Microphone	2854675	Nov 11, 2017	Scantek, Inc. / NVLAP	Nov 11, 2018
1203-Norsonic	Preamplifier	92268	Oct 18, 2017	Scantek, Inc./ NVLAP	Oct 18, 2018

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

Calibrated by:	Jeremy Gotwalt	**Authorized signatory:**	Steven E. Marshall
Signature	[signature]	Signature	Steven E Marshall
Date	1/30/18	Date	1/30/2018

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Appendix II THE ASSESSMENT OF ENVIRONMENTAL NOISE (GENERAL)

Sound Pressure Level

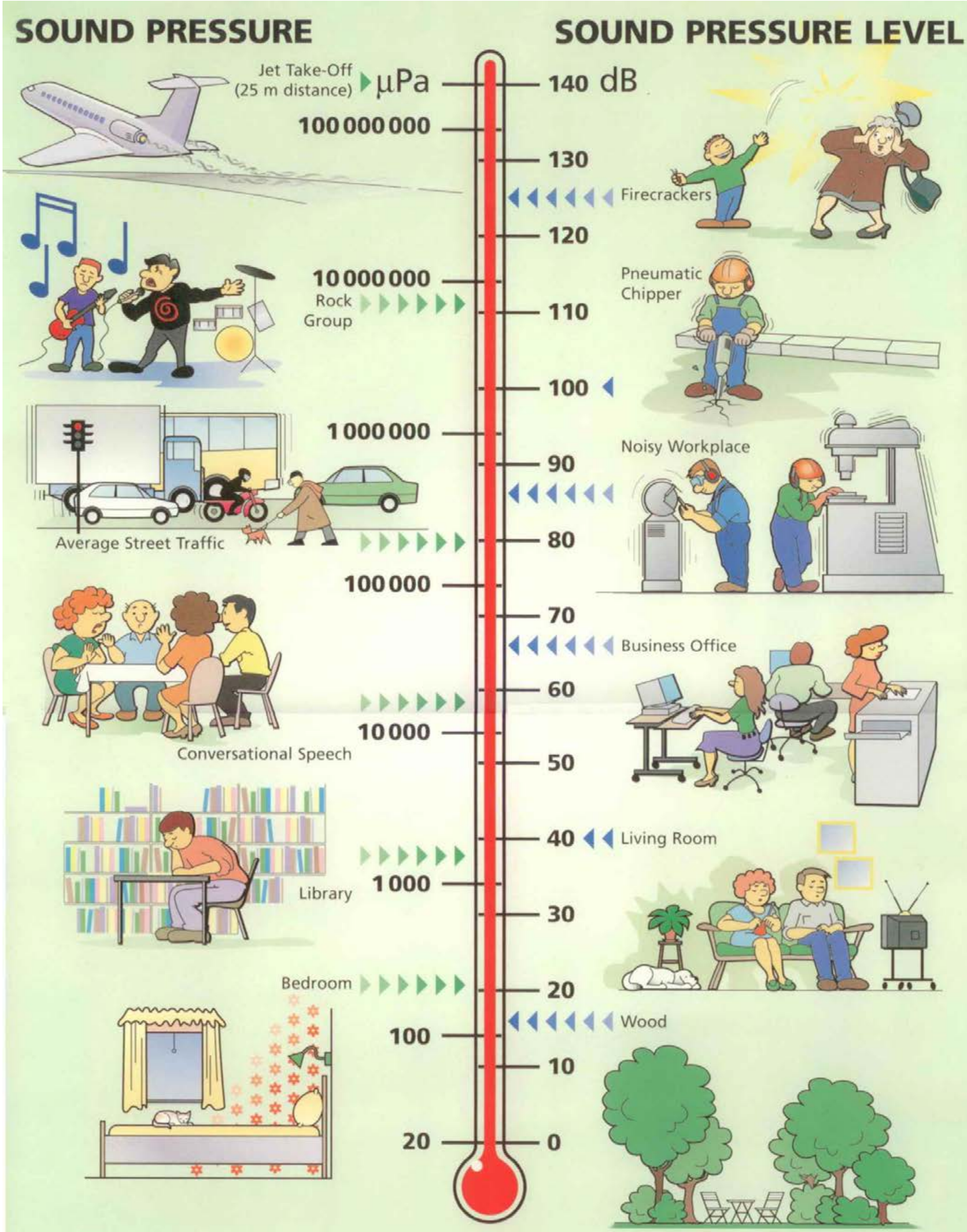
Sound pressure is initially measured in Pascal's (Pa). Humans can hear several orders of magnitude in sound pressure levels, so a more convenient scale is used. This scale is known as the decibel (dB) scale, named after Alexander Graham Bell (telephone guy). It is a base 10 logarithmic scale. When we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



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Frequency

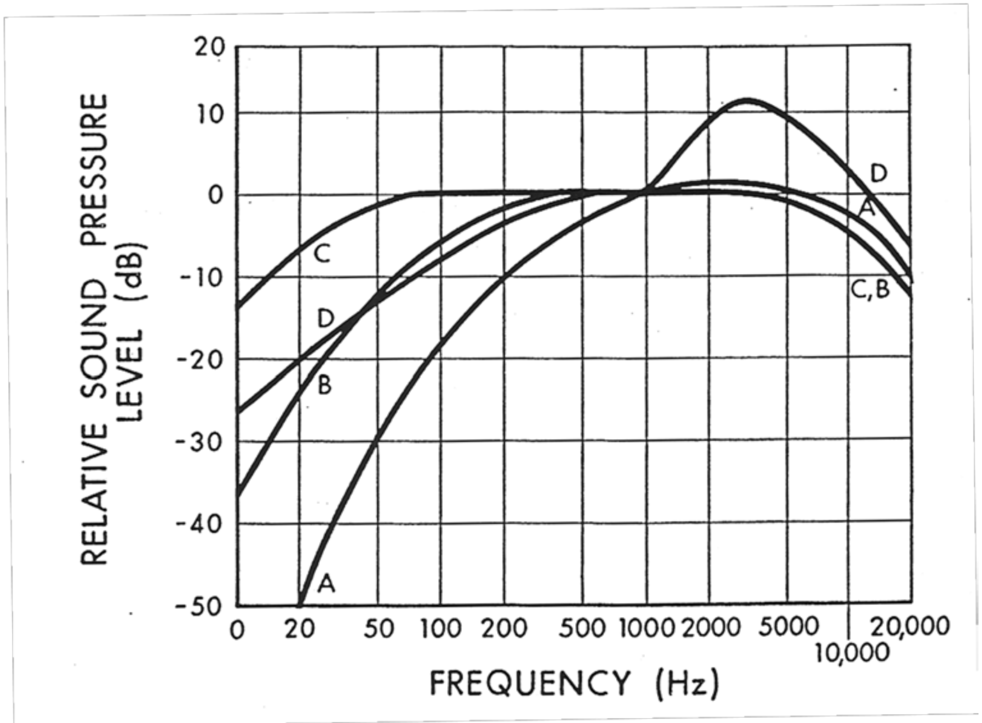
The range of frequencies audible to the human ear ranges from approximately 20 Hz to 20 kHz. Within this range, the human ear does not hear equally at all frequencies. It is not very sensitive to low frequency sounds, is very sensitive to mid frequency sounds and is slightly less sensitive to high frequency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

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

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

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

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



Combination of Sounds

When combining multiple sound sources the general equation is:

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

Examples:

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

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

Sound Level Measurements

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

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

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

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

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

Statistical Descriptor

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

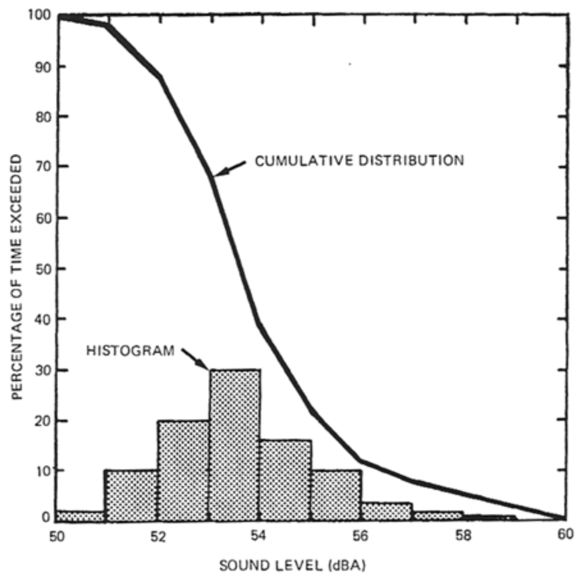


Figure 16.6 Statistically processed community noise showing histogram and cumulative distribution of A weighted sound levels.

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

The most common statistical descriptors are:

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

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

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

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

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

Sound Propagation

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

Point Source

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

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

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

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

Examples (note no atmospheric absorption):

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

Line Source

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

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

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

Examples (note no atmospheric absorption):

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

Atmospheric Absorption

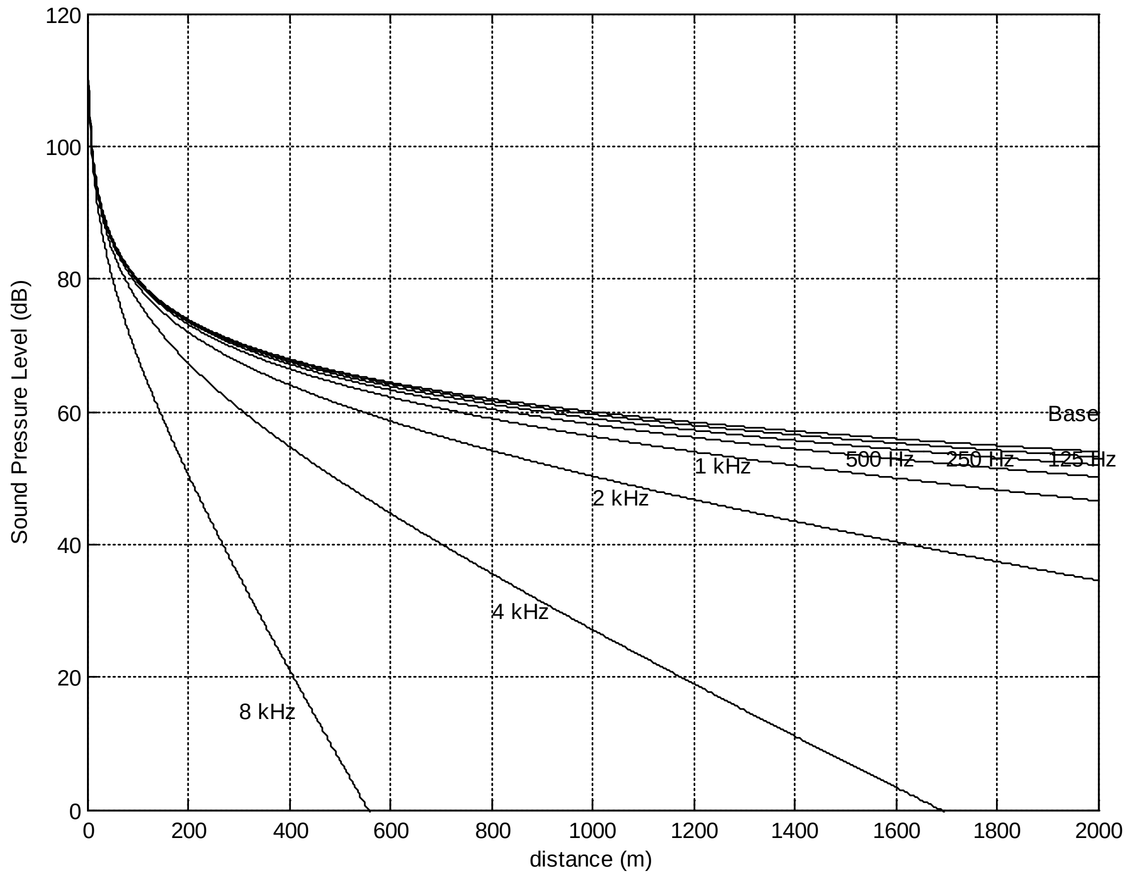
As sound transmits through a medium, there is an attenuation (or dissipation of acoustic energy) which can be attributed to three mechanisms:

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

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

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

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



Atmospheric Absorption at 10ºC and 70% RH

Meteorological Effects

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

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

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

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

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

Topographical Effects

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

Topography

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

Grass

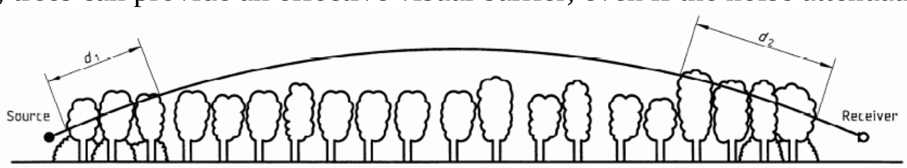
- Can be an effective absorber due to large area covered
- Only effective at low height above ground. Does not affect sound transmitted direct from source to receiver if there is line of sight.
- Typically less absorption than atmospheric absorption when there is line of sight.
- Approximate rule of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

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

Where: A_g is the absorption amount

Trees

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



NOTE — $d_f = d_1 + d_2$

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

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

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

Propagation distance d_f	Nominal midband frequency Hz							
m	63	125	250	500	1 000	2 000	4 000	8 000
	Attenuation, dB:							
$10 \le d_f \le 20$	0	0	1	1	1	1	2	3
	Attenuation, dB/m:							
$20 \le d_f \le 200$	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 NOISE MODELING PARAMETERS

2017 Traffic Data for Highway 22

Road	Day (Vehicles Per Hour)	Day % Heavy Vehicles	Night (Vehicles Per Hour)	Night % Heavy Vehicles	Speed (km/hr)	Total Volume (vehicles per day)
Highway 22	457.8	7.3	83.93	7.3	80	7630

Overburden Removal

Item	Noise Source Type[1]	Qty	Source Height (m)	SWL (dBA)	32 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
CAT 637 - Scraper	TPS	4	2.5	114.2	113.0	104.0	115.0	114.0	111.0	109.0	107.0	100.0	92.0
CAT D8 - Dozer	TPS	1	2.0	112.4	100.4	107.9	107.4	109	108.4	106.5	104.3	105.3	99.4
CAT 14H - Grader	TPS	1	2.0	112.2	102.0	105.4	116.1	115.6	109.2	105.6	102.7	96.2	87.4

Crushing & Mining

Item	Noise Source Type[1]	Qty	Source Height (m)	SWL (dBA)	32 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
CAT 730 Articulated - Rock Truck	TPS	3	2.5	104.9	97.4	107.9	111.2	104.5	102.3	98.8	95.8	92.8	86.9
CAT 980 H - Loader	TPS	1	2.5	110.6	116.0	116.0	113.0	109.0	111.0	103.0	99.0	96.0	91.0
Jaw Crusher	SPS	1	4.0	116.2	98.2	107.3	107.9	111.9	110.6	110.5	110.8	106.8	98.1
Screen (Prior to Jaw)	SPS	1	4.0	114.5	97.5	100.5	104.6	107.0	109.6	108.3	109.3	105.5	96.7
Cone Crusher	SPS	1	3.2	112.8	94.0	100.7	106.0	105.7	107.5	108.2	105.8	104.2	99.5
Aerial Cooler (Crusher)	SPS	1	2.8	103.9	94.9	96.8	103.5	103.9	101.7	98.6	95.3	90.7	82.6
Generator	SPS	1	2.8	118.7	104.0	109.0	115.0	118.0	116.0	112.0	111.0	109.0	106.0
Screen Deck #1	SPS	1	3.2	117.1	96.7	101.4	106.7	108.8	111.3	109.6	111.8	109.9	104.9
Screen Deck #2	SPS	1	3.2	115.6	97.6	98.4	103.7	107.0	106.4	105.9	109.5	110.8	104.8

Wash Plant

Item	Noise Source Type[1]	Qty	Source Height (m)	SWL (dBA)	32 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
Oversize Screener	TPS	1	2.5	109.6	99.4	102.7	101.1	100.7	101.6	101.5	102.2	102.5	104.9
Pre-Screener	TPS	1	2.5	104.2	94.0	97.3	95.7	95.3	96.2	96.1	96.8	97.1	99.5
Finishing Screener	TPS	1	2.5	100.8	90.6	93.9	92.3	91.9	92.8	92.7	93.4	93.7	96.1
CAT 980 H - Loader	TPS	1	2.5	110.6	116	116	113	109	111	103	99	96	91

Hauling

Item	Noise Source Type[1]	Qty	Source Height (m)	SWL (dBA)	32 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
CAT 980 H - Loader	TPS	2	2.5	110.6	116.0	116.0	113.0	109.0	111.0	103.0	99.0	96.0	91.0

Haul Road

Road	Day (Vehicles Per Hour)	Day % Heavy Vehicles	Night (Vehicles Per Hour)	Night % Heavy Vehicles	Speed (km/hr)
Haul Road	40	100	0	0	60

[1] TPS = Travelling Point Source, SPS = Stationary Point Source

General Modeling Parameters

Parameter	Value
Modeling Software	CADNA/A (Version 2022 MR2, Build 191.5229)
Standard Followed	ISO 9613-2
Ground Sound Absorption Coefficient	0.5
Wind Speed	1 - 5 m/s (3.6 - 18 km/hr)
Wind Direction	Downwind from all sources to all receptors
Temperature	10 °C
Humidity	70%
Topography	1.0 m increments From Client

Appendix V NOISE MONITOR ISOLATED DATA

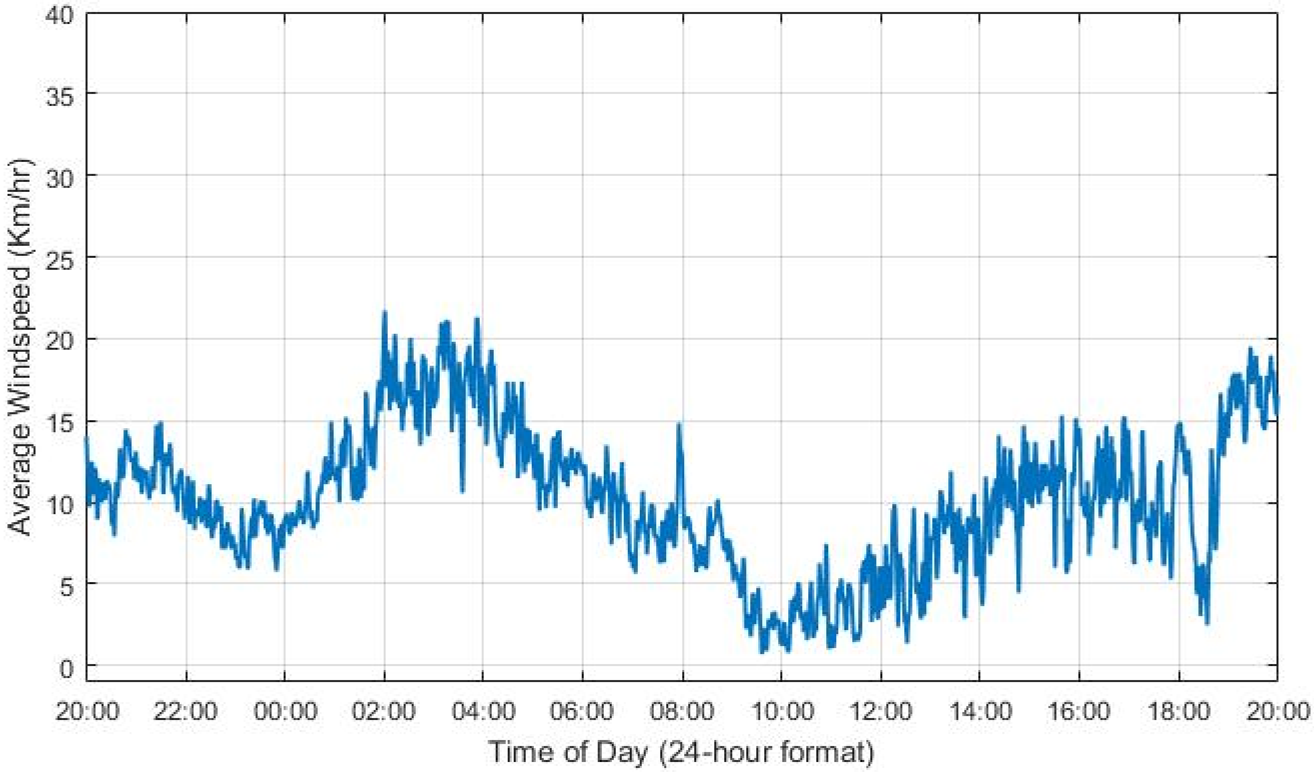
May 9 – 10, 2018 (20:00 – 20:00)

Start Time	End Time	Duration (min)	Reason
5/09/18 20:22	5/09/18 20:23	0.8	Excessive Bird Noise
5/09/18 23:06	5/09/18 23:07	0.8	Aircraft Flyover
5/10/18 01:45	5/10/18 01:46	1.5	Excessive Wind Noise
5/10/18 01:51	5/10/18 01:54	3.3	Excessive Wind Noise
5/10/18 02:00	5/10/18 02:01	1.3	Excessive Wind Noise
5/10/18 02:03	5/10/18 02:04	0.3	Excessive Wind Noise
5/10/18 02:04	5/10/18 02:06	1.5	Excessive Wind Noise
5/10/18 02:19	5/10/18 02:21	2.5	Excessive Wind Noise
5/10/18 02:23	5/10/18 02:25	1.8	Excessive Wind Noise
5/10/18 02:38	5/10/18 02:39	1.0	Excessive Wind Noise
5/10/18 02:39	5/10/18 02:40	0.5	Excessive Wind Noise
5/10/18 02:58	5/10/18 02:58	0.8	Excessive Wind Noise
5/10/18 03:09	5/10/18 03:10	1.3	Excessive Wind Noise
5/10/18 03:15	5/10/18 03:15	0.3	Excessive Wind Noise
5/10/18 03:15	5/10/18 03:17	2.5	Excessive Wind Noise
5/10/18 03:28	5/10/18 03:30	1.8	Excessive Wind Noise
5/10/18 03:32	5/10/18 03:33	0.8	Excessive Wind Noise
5/10/18 03:34	5/10/18 03:35	1.0	Excessive Wind Noise
5/10/18 03:36	5/10/18 03:39	2.5	Excessive Wind Noise
5/10/18 03:41	5/10/18 03:44	2.3	Excessive Wind Noise
5/10/18 03:44	5/10/18 03:47	3.5	Excessive Wind Noise
5/10/18 03:48	5/10/18 03:49	1.0	Excessive Wind Noise
5/10/18 04:00	5/10/18 04:01	1.3	Excessive Wind Noise
5/10/18 04:32	5/10/18 04:33	1.3	Excessive Wind Noise
5/10/18 04:35	5/10/18 04:35	0.3	Excessive Wind Noise
5/10/18 04:36	5/10/18 04:37	0.8	Excessive Wind Noise
5/10/18 06:07	5/10/18 06:08	0.5	Aircraft Flyover
5/10/18 06:37	5/10/18 06:38	1.0	Aircraft Flyover
5/10/18 06:38	5/10/18 06:39	0.3	Aircraft Flyover
5/10/18 06:42	5/10/18 06:43	1.0	Aircraft Flyover
5/10/18 06:52	5/10/18 06:53	1.0	Aircraft Flyover
5/10/18 08:44	5/10/18 08:44	0.3	Excessive Bird Noise
5/10/18 10:33	5/10/18 10:34	1.0	Aircraft Flyover
5/10/18 10:34	5/10/18 10:34	0.3	Aircraft Flyover
5/10/18 10:36	5/10/18 10:37	1.8	Excessive Bird Noise
5/10/18 10:42	5/10/18 10:42	0.8	Excessive Bird Noise
5/10/18 10:53	5/10/18 10:54	1.3	Excessive Bird Noise
5/10/18 10:57	5/10/18 10:58	1.0	Excessive Bird Noise
5/10/18 12:27	5/10/18 12:28	0.8	Excessive Bird Noise
5/10/18 13:00	5/10/18 13:02	2.0	Excessive Bird Noise
5/10/18 13:39	5/10/18 13:40	0.5	Human Activity
5/10/18 14:14	5/10/18 14:16	2.0	Aircraft Flyover
5/10/18 14:53	5/10/18 14:54	1.0	Human Activity
5/10/18 15:19	5/10/18 15:20	1.0	Human Activity
5/10/18 15:21	5/10/18 15:22	1.5	Loud Vehicle Passby
5/10/18 15:50	5/10/18 15:51	0.8	Loud Vehicle Passby
5/10/18 16:14	5/10/18 16:15	1.0	Aircraft Flyover
5/10/18 16:40	5/10/18 16:41	0.8	Human Activity
5/10/18 16:46	5/10/18 16:47	0.8	Human Activity
5/10/18 17:14	5/10/18 17:15	0.8	Human Activity
5/10/18 17:18	5/10/18 17:19	1.0	Aircraft Flyover
5/10/18 19:16	5/10/18 19:17	1.0	Human Activity
Total Isolated Time		**61**	

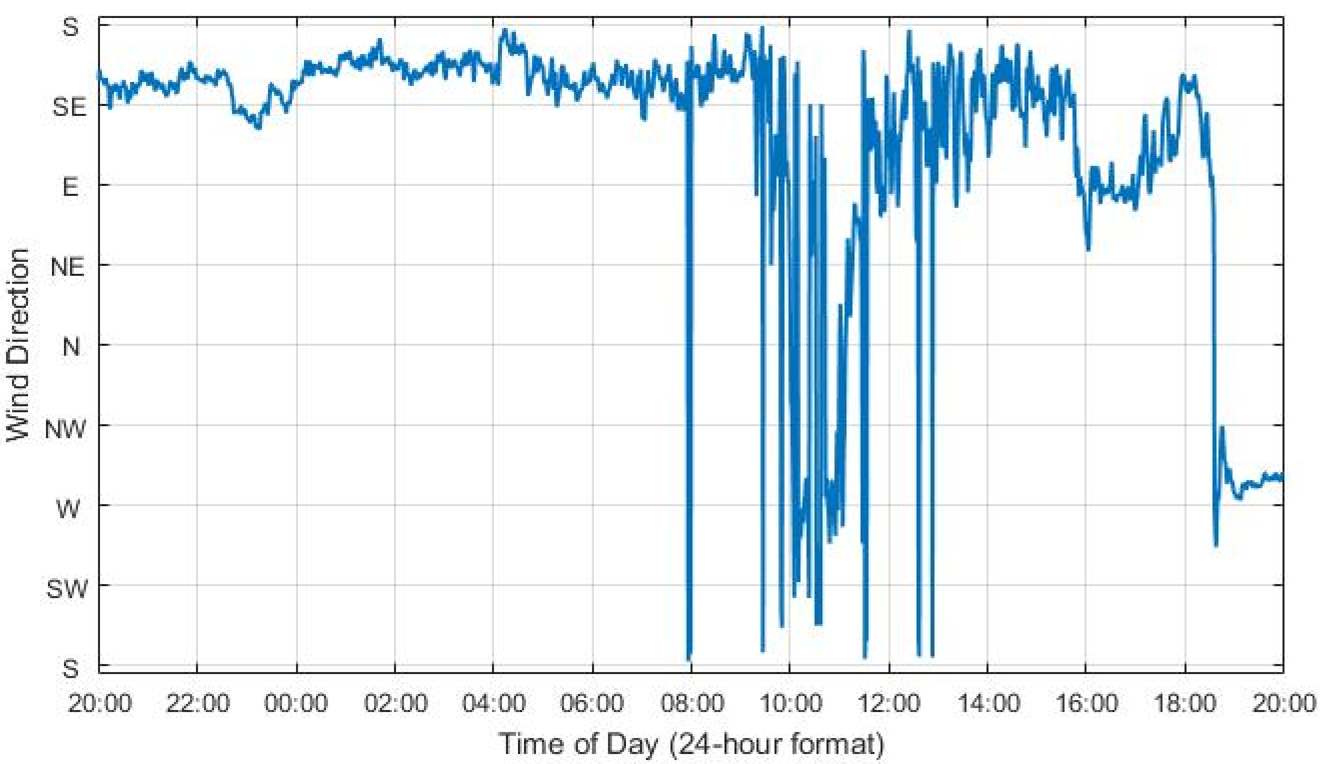
March 12 – 13, 2018 (22:00 – 22:00)

Start Time	End Time	Duration (min)	Reason
5/12/18 22:29	5/12/18 22:29	0.8	Abnormal Event
5/12/18 22:59	5/12/18 23:00	0.5	Aircraft Flyover
5/12/18 23:58	5/13/18 00:00	2.0	Loud Vehicle Passby
5/13/18 06:00	5/13/18 06:01	0.3	Excessive Wind Noise
5/13/18 06:38	5/13/18 06:38	0.3	Loud Vehicle Passby
5/13/18 09:39	5/13/18 09:41	1.3	Human Activity
5/13/18 10:25	5/13/18 10:28	3.0	Aircraft Flyover
5/13/18 10:38	5/13/18 10:39	1.0	Excessive Wind Noise
5/13/18 11:05	5/13/18 11:07	1.5	Aircraft Flyover
5/13/18 11:15	5/13/18 11:18	3.3	Excessive Wind Noise
5/13/18 11:36	5/13/18 11:36	0.5	Insects
5/13/18 13:03	5/13/18 13:05	1.3	Aircraft Flyover
5/13/18 13:22	5/13/18 13:26	3.5	Excessive Wind Noise
5/13/18 13:38	5/13/18 13:39	0.3	Excessive Wind Noise
5/13/18 13:46	5/13/18 13:50	3.3	Excessive Wind Noise
5/13/18 13:55	5/13/18 13:57	1.3	Excessive Wind Noise
5/13/18 14:09	5/13/18 14:11	2.3	Excessive Wind Noise
5/13/18 15:27	5/13/18 15:28	0.3	Aircraft Flyover
5/13/18 17:21	5/13/18 17:22	1.3	Human Activity
5/13/18 18:12	5/13/18 18:13	1.3	Human Activity
	Total Isolated Time	**29**	

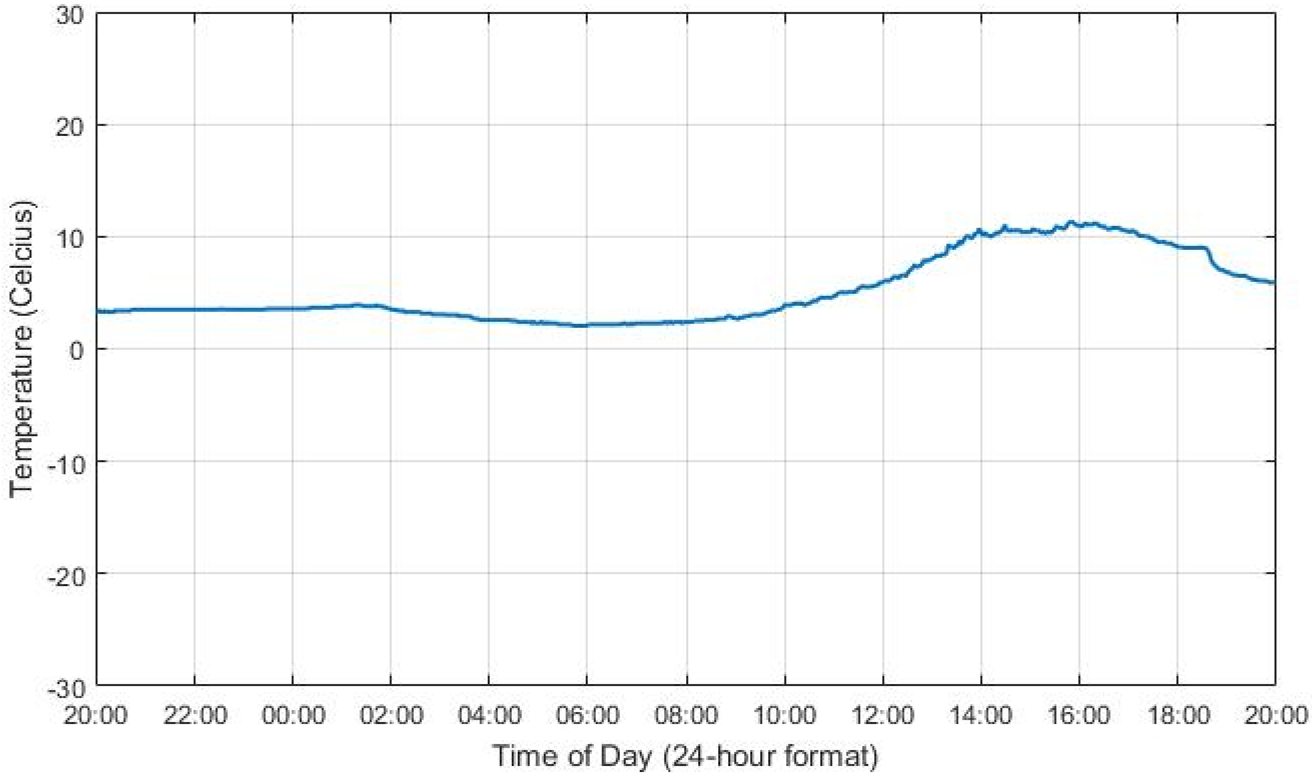
Appendix VI WEATHER DATA



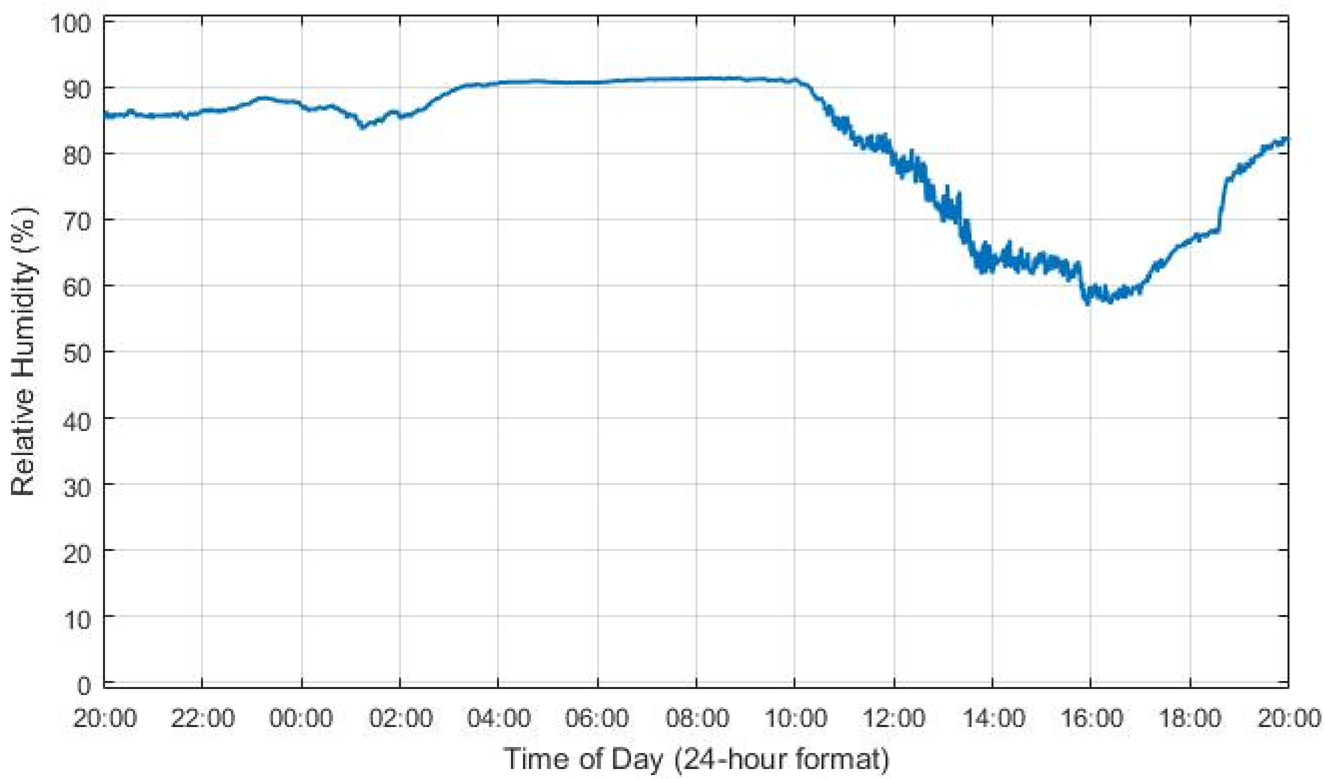
May 9 – 10, 2018 Monitored Wind Speed



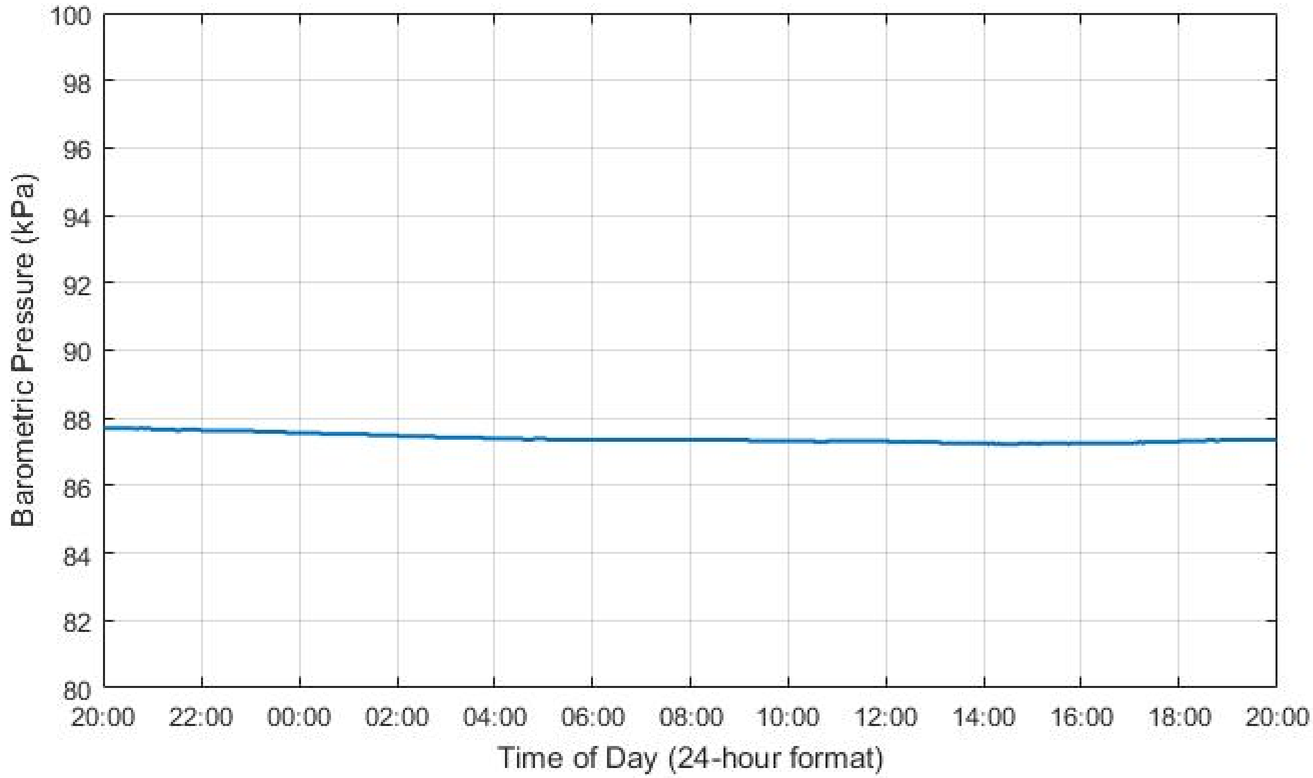
May 9 – 10, 2018 Monitored Wind Direction



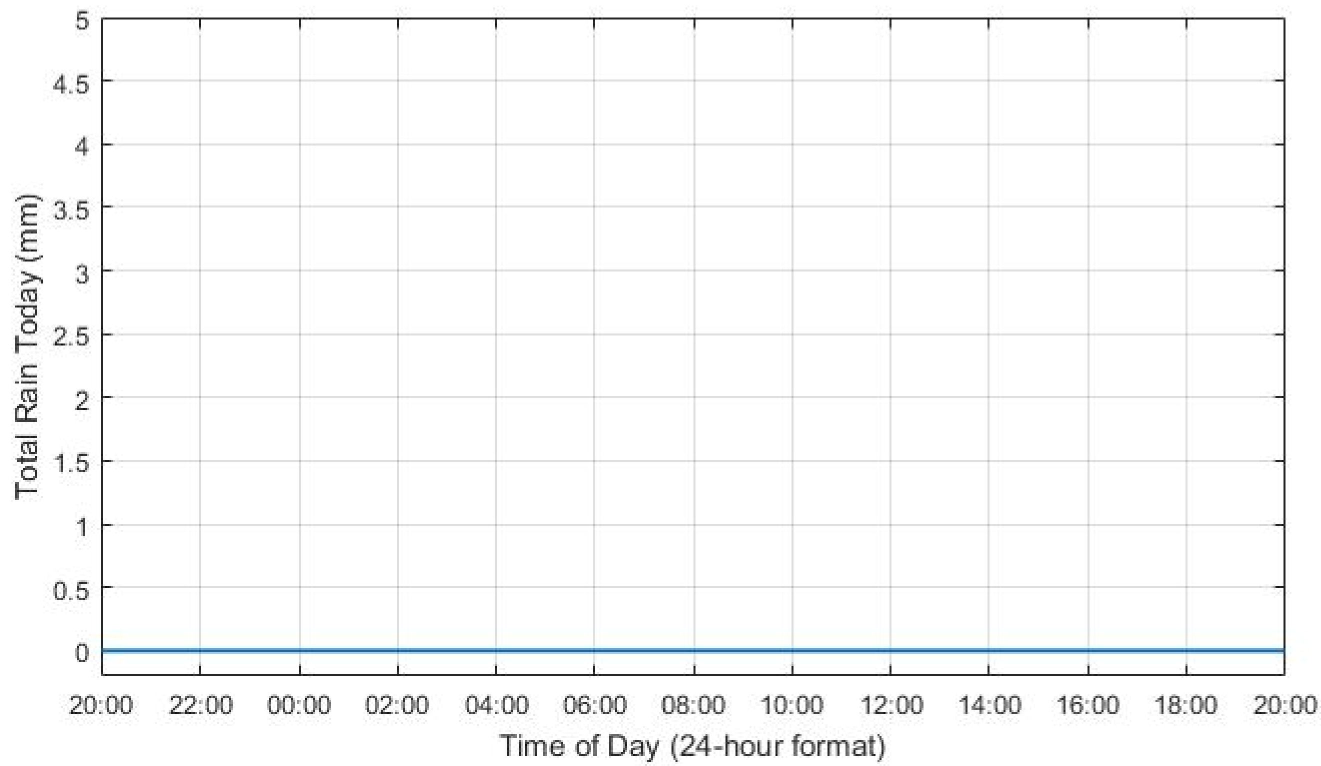
May 9 – 10, 2018 Monitored Temperature



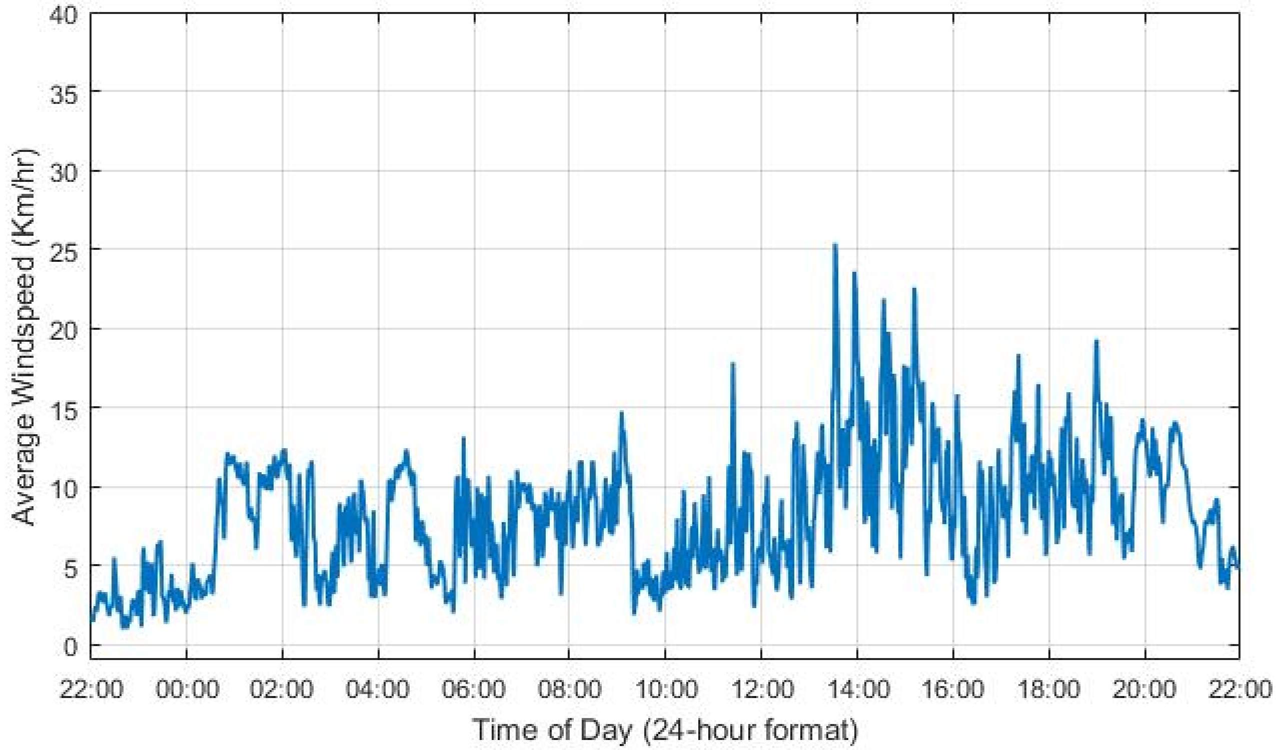
May 9 – 10, 2018 Monitored Relative Humidity



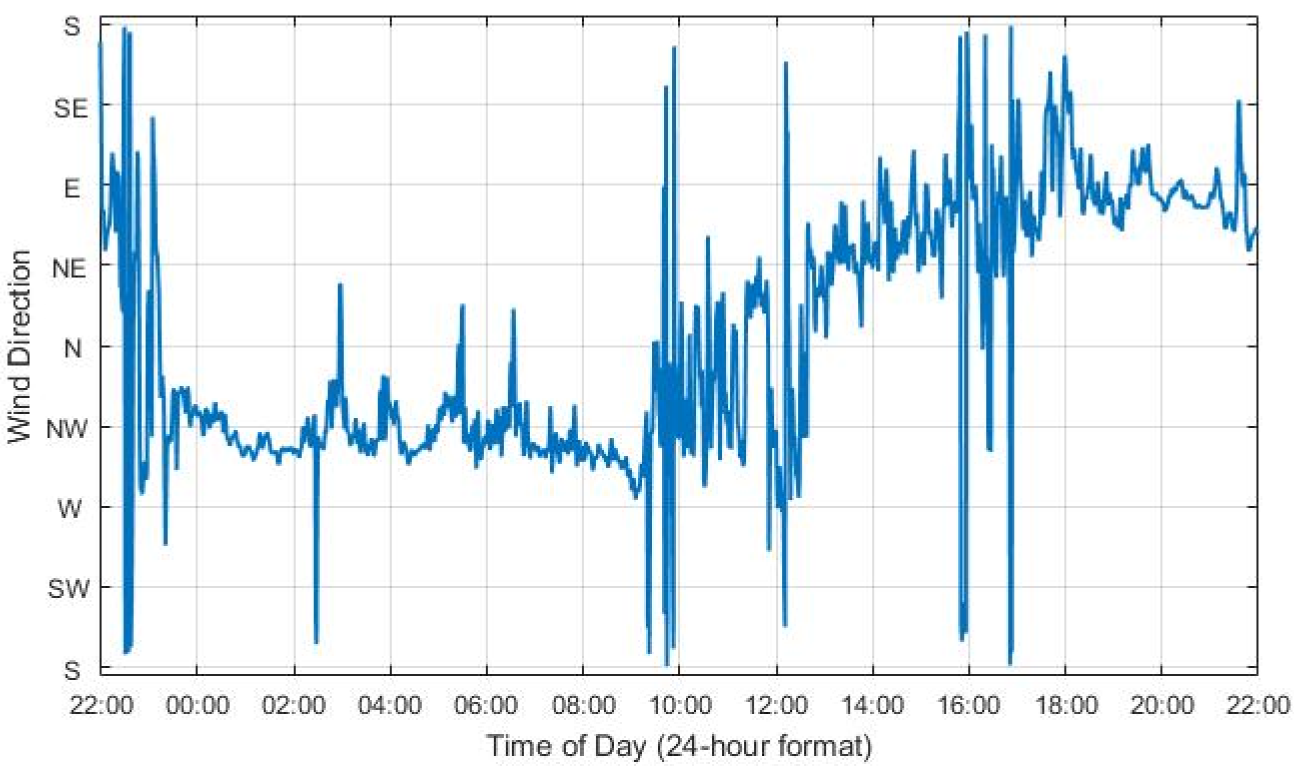
May 9 – 10, 2018 Monitored Barometric Pressure



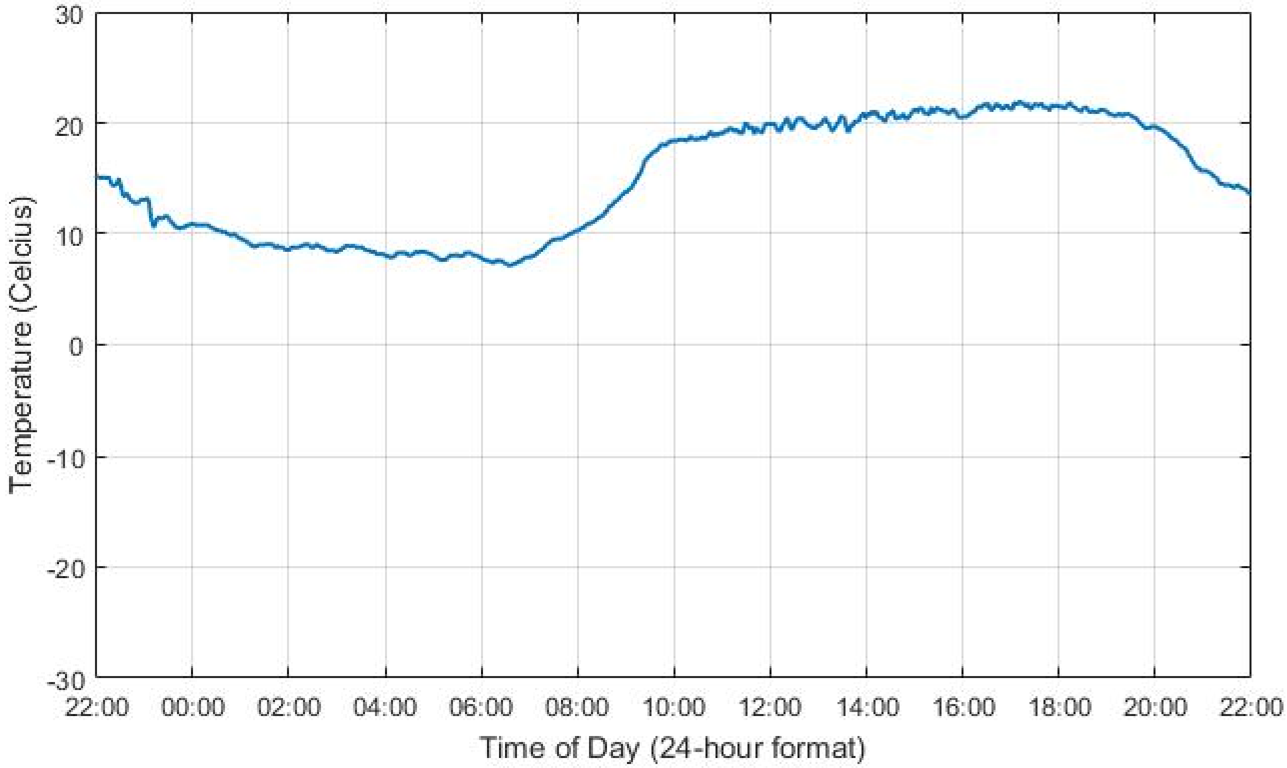
May 9 – 10, 2018 Monitored Rain Fall Rate



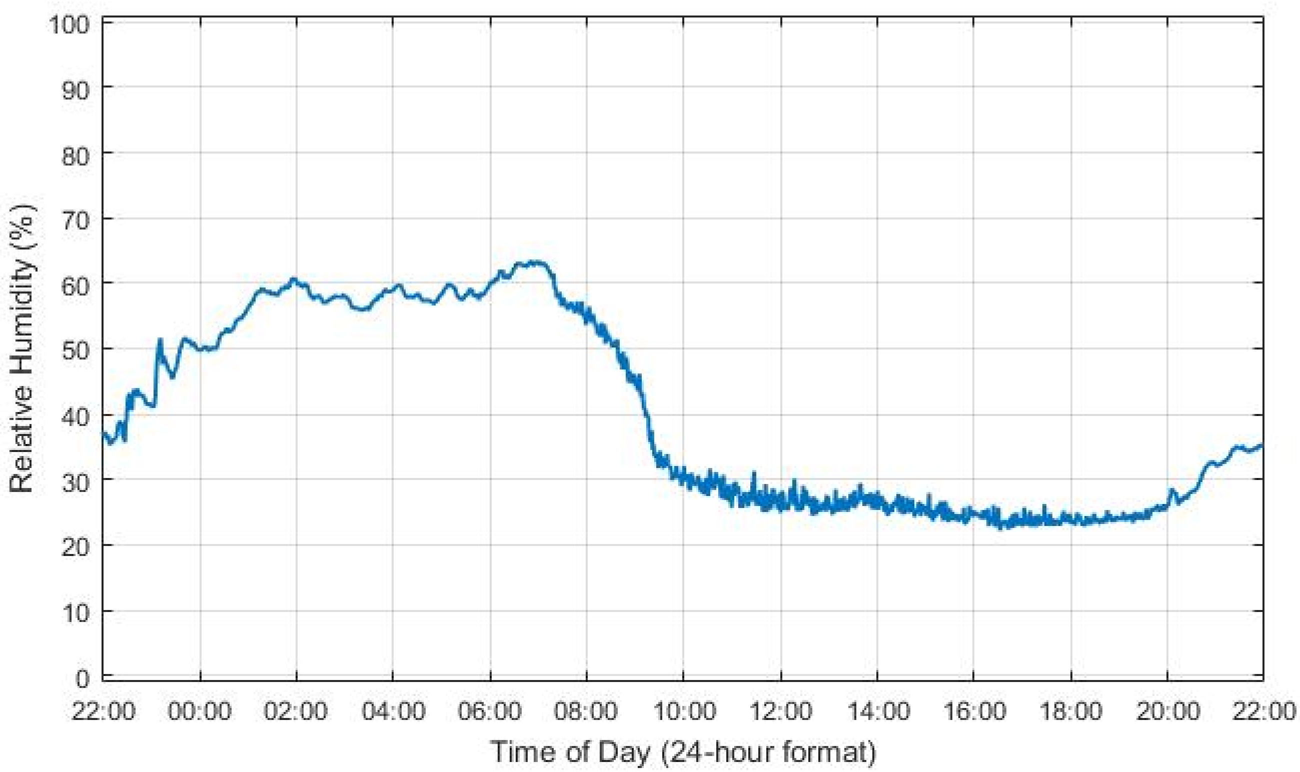
May 12 – 13, 2018 Monitored Wind Speed



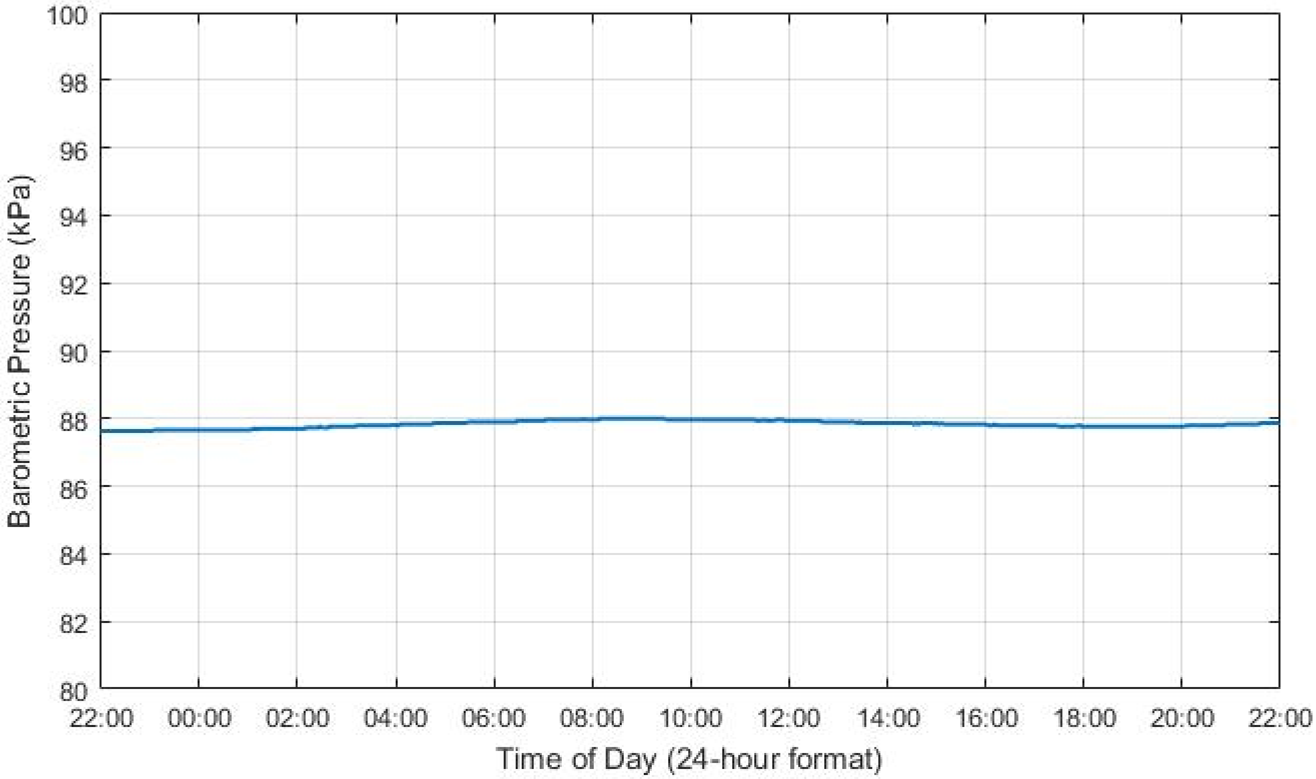
May 12 – 13, 2018 Monitored Wind Direction



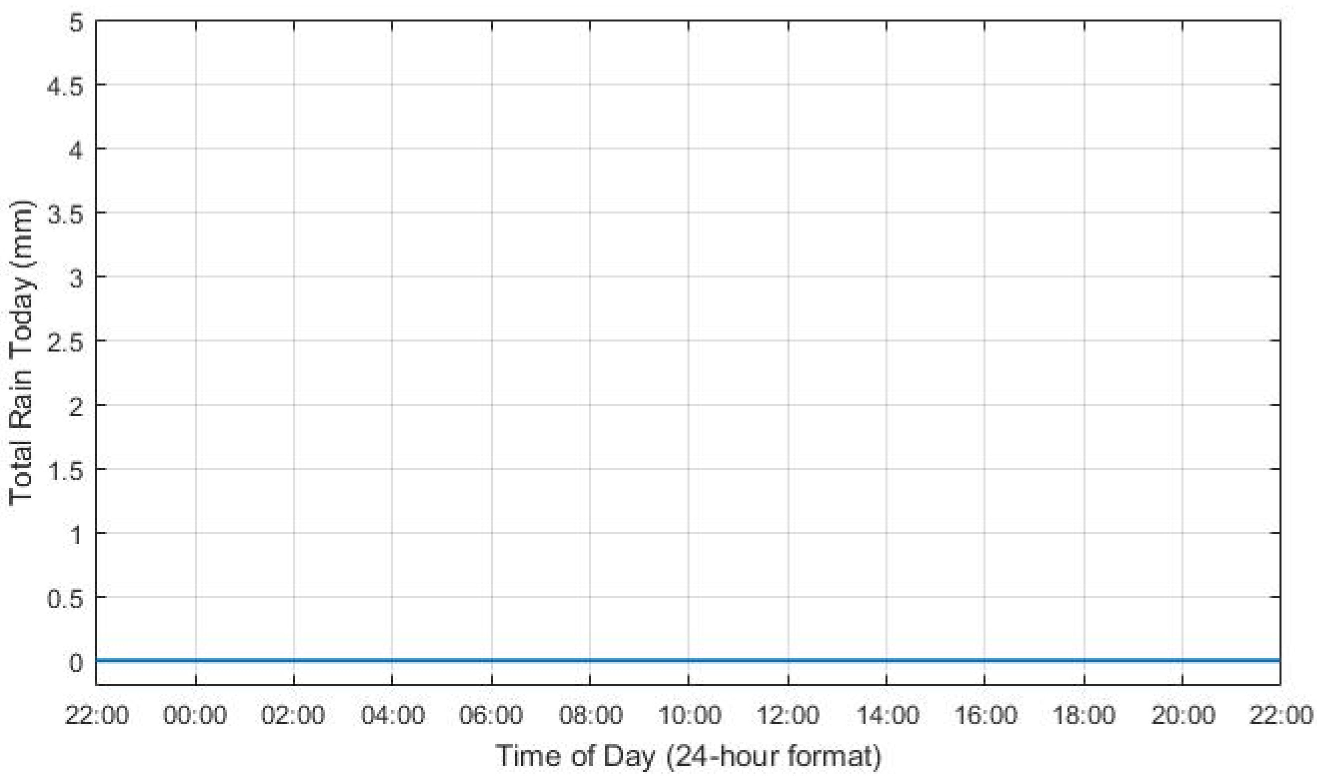
May 12 – 13, 2018 Monitored Temperature



May 12 – 13, 2018 Monitored Relative Humidity



May 12 – 13, 2018 Monitored Barometric Pressure



May 12 – 13, 2018 Monitored Rain Fall Rate