BC Oil and Gas Research and Innovation Society

Low Frequency Noise and Meteorological Condition Validation Study

Prepared for:
BC Oil and Gas Research and Innovation Society
(BC OGRIS)

Prepared by:
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Version Control

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-	Draft Initial Report	SS	April 18, 2023
0	Initial Report	SS	May 22, 2023

Executive Summary

BC Oil and Gas Research and Innovation Society (BC OGRIS, the client) retained Patching Associates Acoustical Engineering Ltd. (PAAE) to conduct a noise validation study for typical oil and gas operations located in northeast British Columbia.

The objectives of the sound study were to:

- Identify and validate new methods for diagnosing and understanding meteorological sound propagation conditions and low frequency noise risk that are not effectively covered off with current guidelines or best practices. This includes investigation of processes for distant noise sources beyond 1500m as well as consideration of variable weather conditions.
- Provide opportunities for local contractors to gain experience in the field of acoustics and to evaluate the applicability of new lower cost sensors technology; both of which will reduce barriers for operators to gather more data on their operations and mitigation efforts.

To achieve the objectives, two comprehensive modeling and monitoring studies, one in summer and one in winter, on two production facilities in northeast BC were conducted. The studies deployed current best practise assessment methodologies with both near-field and far-field monitoring and modeling. This report outlines the results from the study and evaluation of the results relative to the study objectives. The following figures show the study areas with monitoring locations, which also show the predicted facility noise maps following current best practice methodologies.

Figure A: Study Area with Monitoring Locations – Wintertime Facility

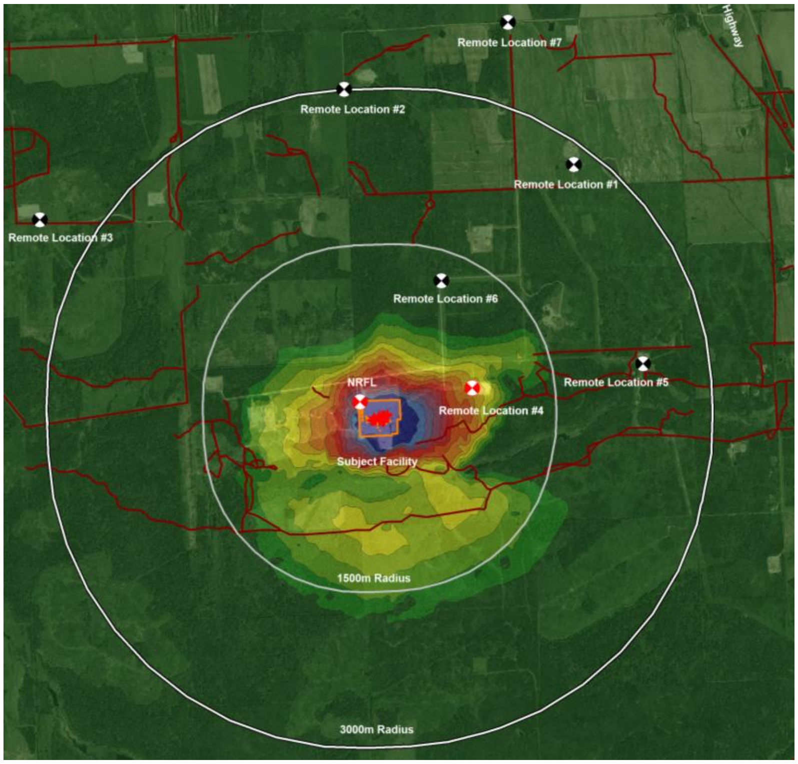
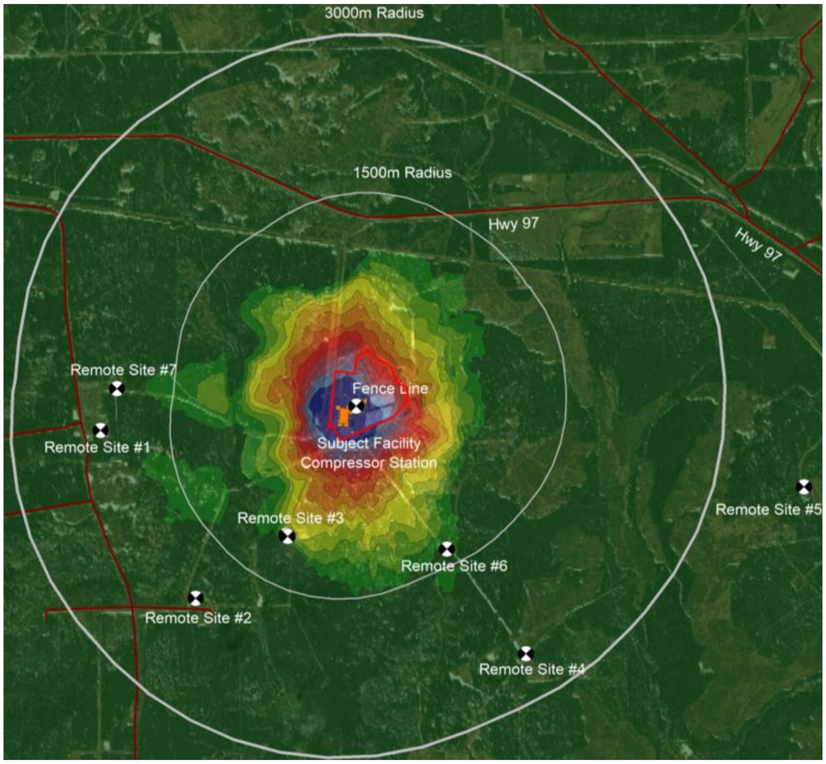


Figure B: Study Area with Monitoring Locations – Summer Facility



The key findings and recommendations of the study results are as follows:

- **Key Finding 1:** The two facilities studied included typical gas processing and compression facilities. The assessment finds that the sound levels beyond 1500 meters are at low risk for exceeding the established PSL of 40 dBA Leq at night. This conclusion is based on analysis of 14 weeks of data using current Class 1 noise monitoring technology. The sound environment beyond 1500m is dominated by sound from the environment (wind, flora, fauna), traffic, human activity, and other nearby facilities.

- **Key Finding 2:** Current best practise noise modeling methods using the Concawe noise modeling algorithm produce reliable results within 1000m for downwind, crosswind and upwind conditions, opening alternatives to ISO downwind conditions when conducting noise modeling. This finding was based on two monitoring locations and should be confirmed with additional study.

- **Key Finding 3:** Modeling accuracy beyond 1500m was not verified as sound measurement results beyond 1500m were contaminated by background contamination. Modeling validated for distances less than 1500m indicates upwind/downwind variability of 2-5 dBA. This forms a hypothesis to test as part of additional study using a higher sound power (louder) source. See recommendation 1.

- **Key Finding 4:** Findings show that Low Frequency Noise (LFN) tones can exist beyond 1500 m and the current methodologies for measuring (LFN) may not be effective for investigating multiple potential LFN noise sources where the source of the noise is not obvious. For these situations additional consideration for fenceline monitoring and narrow band fast Fourier transform (FFT) will reduce false positive attribution error as well as increase confidence when positive attribution is identified. Recommend updating guideline procedure for situations with no obvious source to include simultaneous narrow band noise monitoring at facility fenceline and subject receiver.

- **Key Finding 5:** Weather monitoring results suggest that wind conditions can vary significantly over a 2-3 km study area and represent an area of uncertainty for confidentially establishing the effect of meteorologic conditions. This forms a hypothesis to test as part of an additional study using more weather sensors to establish more detailed insights on weather conditions and the validity of low-cost sensors. See recommendation 1.

- **Key Finding 6:** "Internet of Things (IoT)" low cost off-the-shelf sensors are currently capable of overall broadband dBA assessment. This limits utility to determining the operating status of a facility and the current technology does not support investigation of LFN sound due to technology gaps. As technology advances, the current gaps are likely to be filled, at which time connectivity limitations will need to be solved to support a wide use application to investigate LFN.

- **Key Finding 7:** Prototype IoT sensors allow for frequency analysis; filling a gap present in off-the-shelf sensors. This frequency analysis capability provides a low-cost alternative to Class 1 monitoring equipment for LFN tonal assessment. The technology is not yet reliable for calibrated monitoring to establish compliance. Recommend expanding guideline procedure for LFN investigation to included IoT sensors used for tonal analysis to support source attribution.

- **Key Finding 8:** For locations outside the facility fenceline, environmental sound not related to the oil and gas facility operation dominated, and wind noise dominated the acoustic environment with wind speed above 3 m/s. Investigation of LFN at longer distances require detailed assessment of both local (at microphone) and environmental (overall area wide) wind conditions.

- **Key Finding 9:** Due to high amounts of contamination from ambient non-facility noise, audio recording and post processing as a standard requirement for assessing LFN is required to have meaningful results. At the current state of technology, and without further automation, this will require manual effort to conduct post processing to conduct isolation analysis described in the guidelines. This represents opportunity for application of machine learning (ML) as well as opportunity for local contractors to support creating training datasets.

- **Key Finding 10:** Local Contractors: The wintertime study included training and dedicated staff from local contractors. This supported equipment uptime through weekly battery inspections as well as monitoring for damage from wildlife, this was successful as it reduced air travel and long-distance driving. During the summertime study, local contractors were busier and finding dedicated personnel to train was not possible. This study demonstrates that local contractors can improve data quality and reduce travel costs. Recommend investment in training programs so as to ensure multiple staff members are available, as well as a consistent log term schedule for monitoring.

- **Recommendation 1:** Based on learnings from this assessment conduct focused validation study following similar process to confirm hypothesis from this research, specific features include:
    - Noise source selection 10-15 dBA higher than gas plants selected, suggest drilling or hydraulic fracturing site.
    - Limit study to 2 weeks; and simplify to 4 monitoring locations (including fenceline, nominally fenceline, 500m, 1000m, 2000m, 3500m in one direction).
    - Each monitoring location include Class 1 sound meter, Prototype IoT sensor, and a weather station; do not include off-the-shelf IoT sensors, avoiding need for gateway setup.
    - Include weather monitoring at 10m elevation for at least one location.
    - Conduct detailed isolation analysis and narrow-band FFT analysis at each location to improve insights on tonal assessment as well as meteorological correlation.
    - Use the results of the study above to prepare supplemental guidelines for investigating LFN when the source is not apparent, those that fall outside current guidelines. Include guidance on use of lower-cost non-Class 1 sound monitoring systems as these become available on the market.
    - Use the results of the study above to confirm upwind, crosswind, and downwind modeling method and update guideline to allow for upwind or crosswind as alternative mitigation for planning temporary operations if results are confirmed.

- **Recommendation 2:** Make the dataset from this assessment available to post secondary institutions for establishing use case for machine learning training procedure to automate isolation analysis and increase value from data.

Table of Contents

Acronyms

Acronym	Description
AADT	Average Annual Daily Traffic
AB	Alberta
AER	Alberta Energy Regulator
ASL	Ambient Sound Level
BCOGC	British Columbia Oil and Gas Commission
BC ORGIS	British Columbia Oil and Gas Research and Innovation Society
BSL	Basic Sound Level
CSL	Comprehensive Sound Level
dB	Decibel
dBA	A-Weighted Decibel
dBC	C-Weighted Decibel
dBZ	Z-Weighted Decibel or Linear Decibel
DIL	Dynamic Insertion Loss
FFT	fast Fourier transform
ISO	International Organization for Standardization
L_{eq}	Energy Equivalent Sound Level
LFN	Low Frequency Noise
LSD	Legal Subdivision
NIA	Noise Impact Assessment
NC	Noise Control
NR	Noise Reduction
PSL	Permissible Sound Level
PWL	Sound Power Level
SPL	Sound Pressure Level
TL	Transmission Loss
UTM	Universal Transverse Mercator

Introduction

BC Oil and Gas Research and Innovation Society (BC OGRIS, the client) retained Patching Associates Acoustical Engineering Ltd. (PAAE) to conduct a Low frequency noise and meteorological condition validation study for the typical oil and gas facilities, located in the northeast area of British Columbia.

The objectives of the sound study were to:

- Identify and validate new methods for diagnosing and understanding meteorological sound propagation conditions and low frequency noise risk that are not effectively covered with current guidelines or best practices. This includes investigation processes for distant noise sources beyond 1500m as well as consideration of variable weather conditions.
- Provide opportunities for local contractors to gain experience in the field of acoustics and to evaluate the applicability of new lower cost sensors technology; both of which will reduce barriers for operators to gather more data on their operations and mitigation efforts.

To achieve the objectives, two comprehensive modeling and monitoring studies, one in the summertime and one in the winter, on two production facilities in northeast BC were conducted. The studies deployed current purpose and each facility was studied in detail through noise diagnosis of the noise sources and monitoring at seven remote sites, and detailed noise modeling.

Study Area-Sites Section

In order to investigate the low frequency noise propagation and meteorological conditions impact, two oil and gas facilities were selected, one for the wintertime and one for the summertime study, located northeast of British Columbia.

The selection was based on the consultation with industry. The selection Primary Site Criteria includes the following factors:

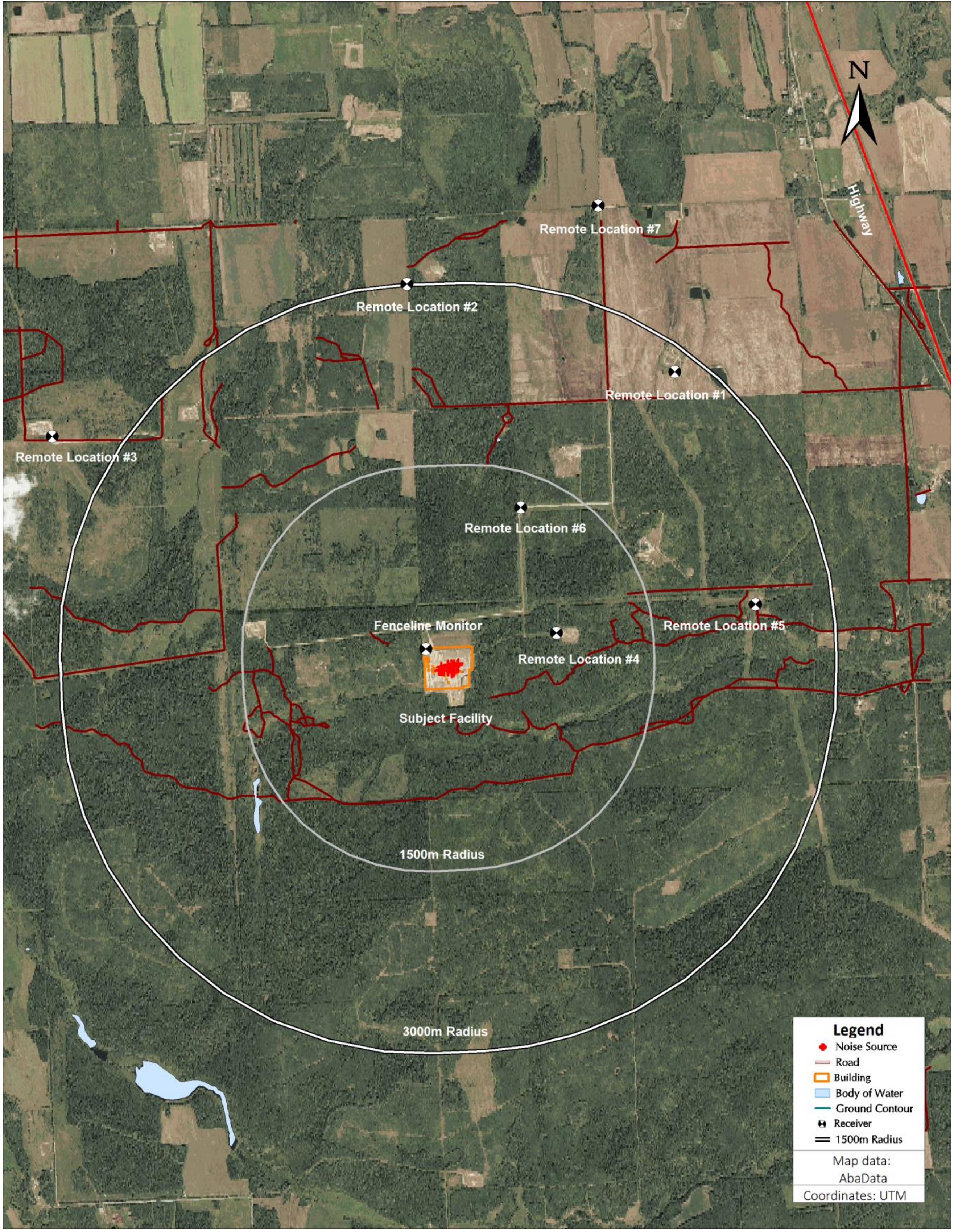
- Potential high noise emission (high facility horsepower).
- Non-complex cumulative impacts to focus on single major sources.
- Remote facility location, which means few residences and/or traffic noise, whilst having road access for far-field sensor installation and access.
- Elevated location for weather station and IoT gateway location.

Two potential sites were assessed based on the criteria. Each facility would be studied in detail through measured diagnostics of the noise sources and monitoring at several remote sites and detailed three-dimensional noise modeling. Noise propagation over distances may extend to more than 1500m for the low frequency noise propagation.

Wintertime Study

The selected oil and gas facility is located in northeast British Columbia. The terrain cover is mainly rolling farmland with patches of trees. The seven monitoring locations and facility fenceline were selected to validate the noise emission the subject facility. Figure 1A shows a map of the study area, which includes the subject facility and selected seven remote sites for noise monitoring. Highway 97 travels through the east side of the study area.

Figure 1A: Study Area Map (Wintertime Study)

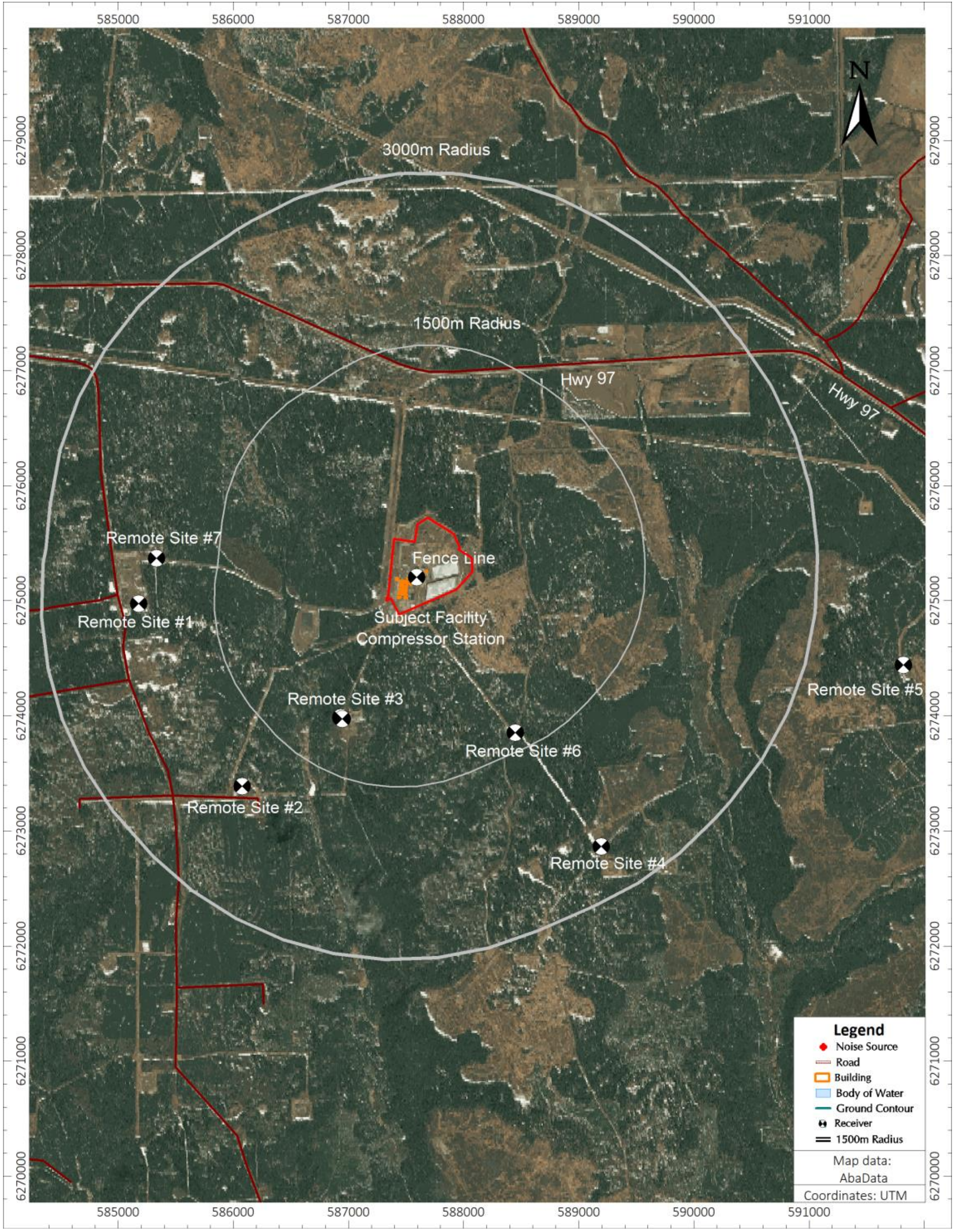


Summertime study

The terrain cover is mainly rolling forest with patches of clearcut. The seven monitoring locations and facility fenceline were selected to validate the noise emission of the subject facility. Highway 97 travels through the north section of the study area.

Figure 1B shows a map of the study area, which includes the subject facility and seven remote sites selected for noise monitoring.

Figure 1B: Study Area Map (Summertime Study)



Noise Criteria-Ambient Discussion

Primary Overall dBA Analysis

Noise from energy related facilities is regulated through the BC OGC Noise Control Guideline (the Guideline). The Guideline sets the Permissible Sound Level (PSL), which is the limit that the Sound Pressure Level (SPL) emanating from the facilities in the study area plus the Ambient Sound Level (ASL) may not exceed over a specified period, as measured at specific locations of interest (the receivers). These allowable limits are dependent on the population density, proximity to heavily traveled transportation routes (motor vehicles, rail and aircraft) and other specified adjustments. The SPL is the sound level received at a specific location. The ASL is the average background sound level not attributable to energy industry facilities. The ASL is assumed to be 5 dBA below the PSL, as prescribed by the Guideline. The receivers assessed are normally located at the residences existing within 1500 m of the subject facility, or else at the 1500m boundary.

The seven survey locations were selected to cover the areas around the subject facility to establish representative conditions in this area and beyond 1500m from the subject facility. see Appendix B for the BSL and PSL calculations based on the Guideline for typical receivers to provide context relative to current methodologies. This study does not specifically evaluate the facilities relative to the PSL.

Secondary Low Frequency Noise Analysis

The BC OGC Guideline suggests consideration of Low Frequency Noise (LFN). LFN considers noise that may be satisfactory on a dBA basis but contains a dominant low frequency that may increase annoyance at nearby dwellings. The Guideline considers LFN analysis a “specialized process” investigation and is only conducted as a specific response to an LFN complaint. According to the Guideline, an LFN component exists when the following two criteria are met;

- the dBC minus dBA sound level is equal to or greater than 20 dB, and
- there is a clear tonal component at a 1/3 octave frequency of 250 Hz or below.

This study was not focused on establishing compliance with any specific criteria. The LFN criteria were considered in the design of this study so that the results can be related to future guideline revisions. This study evaluates potential LFN as per the criteria above to provide context to current methods.

Methodology

- Two production facilities in northeast BC were selected to conduct comprehensive modeling and monitoring studies, one in summer and one in winter based on the selection criteria set up as per consultation with industry. Each facility was studied in detail through detailed best practice near field measurements, detailed noise modeling, and monitoring at remote sites.
- Continuous sound level and weather condition measurements were taken in the study area. The measurements were conducted and analysed from March 24, 2022 to May 15, 2022 for the winter study, and from July 12, 2022 to September 15, 2022 for the summer study. The measurement methodology follows the procedures set forth in the Guideline.
- The sound survey was conducted by setting up Sound Level Meters (applying standard practise) at the seven remote site monitoring locations, as well as at the Facility CSS Monitor location. The sound level meter microphones of the traditional Class 1 meters were mounted with windscreens to reduce the potential for wind-induced noise at the microphone. These sound level meters were calibrated at the beginning and confirmed during the survey period. Sound recording equipment recorded the sound for the whole period. These sound recordings were used to help identify the source of different noises.
- Off-the-shelf acoustic IOT sensors were selected and installed beside the Class 1 sound meter at the monitoring location, which would be used to evaluate the feasibility of long-term monitoring.
- During the sound survey, continuous weather monitoring equipment recorded the weather conditions including the wind speed, wind direction, temperature, and humidity. The weather monitor was installed at the Facility CSS Monitor Location.
- The weather station data and facility fence line sound data were analyzed to determine if the survey was held under representative conditions. The sound level results were analyzed as per wind conditions to validate the noise propagation effects under different weather situations. Detailed isolation for the short-period non-related facility was not conducted, but noise dominated from extreme strong winds and precipitation periods was removed, so the levels may still contain noise from traffic, wind, animals, etc.
- The 1/3 octave band data and dBC-dBA were analyzed to identify the low frequency noise characteristics.
- The noise modeling was conducted using the noise modeling software package CadnaA by Datakustik. CadnaA is an advanced noise propagation model that considers geometric spreading, atmospheric sound absorption, ground impedance effects, site topography and geometry, vegetation and environmental conditions. The calculations performed in CadnaA were conducted in accordance with ISO 9613 and Concawe to determine the facility SPL at the receivers. All calculations were undertaken in linear one-third octave bands. The ground cover was modeled as mixed ground with the consideration of ground covered by grass, trees or other vegetation.
- The Sound Power Levels (PWL) were determined the major facility noise sources through field diagnostics on the subject facilities.
- It is assumed that the facility operating conditions do not change significantly between the daytime and the nighttime period. As such, the assessment focuses solely on the nighttime period, as the Guideline PSL is more stringent during the nighttime than during the daytime.
- The resulting SPLs were investigated as per changes of the meteorological conditions, including temperature, humidity and wind conditions.

Environmental Conditions – Summer and Winter

This study was conducted in the selected two typical seasons for the noised propagation from the energy facilities, which considers the extreme changes of the environmental conditions year-round.

In this study, any wind direction and wind speed is considered as representative, provided that wind noise is not significant, and that there is no precipitation. Non-representative conditions are therefore due either to strong wind resulting in contamination in the microphone or precipitation. In addition, favourable conditions are met during each nighttime period, with up to 10 km/h wind speed limit.

Environmental conditions of the area were recorded with a weather station installed next to the sound monitor by PAAE staff at each of the selected facility fencelines. The weather data from this weather station was used to represent the situation in the study area. Tables 1A and 1B summarize the weather measurement results for the nighttime periods during the survey period at each selected facility.

Table 1A: Weather Summary (Wintertime)

Date (2022)	Average Speed (kph)	Dominant Direction	General Wind Description	Minutes of Regulation Favourable Conditions
Mar 24 - Mar 25	6	ENE	Light wind	346
Mar 25 - Mar 26	3	N	Light wind	524
Mar 26 - Mar 27	3	ESE	Light wind	540
Mar 27 - Mar 28	2	SE	Calm wind	540
Mar 28 - Mar 29	6	SSE	Light wind	540
Mar 29 - Mar 30	3	SE	Light wind	540
Mar 30 - Mar 31	7	SSW	Light wind	530
Mar 31 - Apr 01	4	SSE	Light wind	540
Apr 01 - Apr 02	7	S	Light wind	525
Apr 02 - Apr 03	6	SE	Light wind	540
Apr 03 - Apr 04	5	SSE	Light Wind	540
Apr 04 - Apr 05	3	S	Light Wind	540
Apr 05 - Apr 06	8	SSW	Light Wind	511
Apr 06 - Apr 07	4	SE	Light Wind	536
Apr 07 - Apr 08	2	SE	Calm wind	540
Apr 08 - Apr 09	6	SW	Light Wind	539
Apr 09 - Apr 10	3	W	Calm wind	540
Apr 10 - Apr 11	3	NW	Calm wind	519
Apr 11 - Apr 12	7	NW	Light Wind	524
Apr 12 - Apr 13	4	N	Light Wind	455
Apr 13 - Apr 14	3	WNW	Calm wind	520
Apr 14 - Apr 15	3	WNW	Light Wind	530
Apr 15 - Apr 16	4	NE	Light Wind	366
Apr 16 - Apr 17	3	WNW	Calm wind	540
Apr 17 - Apr 18	6	WNW	Light Wind	540
Apr 18 - Apr 19	5	NW	Light Wind	540
Apr 19 - Apr 20	2	WSW	Calm wind	540
Apr 20 - Apr 21	3	WNW	Calm wind	540
Apr 21 - Apr 22	3	SE	Calm wind	540

Table 1A: Weather Summary (Wintertime)

Date (2022)	Average Speed (kph)	Dominant Direction	General Wind Description	Minutes of Regulation Favourable Conditions
Apr 22 - Apr 23	4	SSE	Light Wind	540
Apr 23 - Apr 24	5	ESE	Light Wind	433
Apr 24 - Apr 25	3	SSE	Calm wind	535
Apr 25 - Apr 26	5	SSE	Light Wind	540
Apr 26 - Apr 27	5	SW	Light Wind	540
Apr 27 - Apr 28	7	WSW	Light Wind	539
Apr 28 - Apr 29	5	WSW	Light Wind	540
Apr 29 - Apr 30	1	NNW	Calm wind	540
Apr 30 - May 01	2	WNW	Calm wind	540
May 01 - May 02	4	NNW	Light Wind	404
May 02 - May 03	6	SE	Light Wind	540
May 03 - May 04	7	SSE	Light Wind	515
May 04 - May 05	3	SSE	Light Wind	536
May 05 - May 06	6	W	Light Wind	473
May 06 - May 07	9	SW	Light Wind	463
May 07 - May 08	5	SW	Light Wind	538
May 08 - May 09	6	WSW	Light Wind	538
May 09 - May 10	3	SW	Calm wind	540
May 10 - May 11	5	SSE	Light Wind	540
May 11 - May 12	3	SSE	Calm wind	510
May 12 - May 13	2	W	Calm wind	540
May 13 - May 14	6	SSE	Light Wind	537
May 14 - May 15	4	SSE	Light Wind	540
May 15 - May 16	3	SSE	Calm wind	530
May 16 - May 17	5	SSE	Light Wind	540

Table 1B: Weather Summary (Summertime)

Date (2022)	Average Speed (kph)	Dominant Direction	General Wind Description	Minutes of Regulation Favourable Conditions
Jul 12 - Jul 13	7	NW	Light Wind	415
Jul 13 - Jul 14	8	WSW	Light Wind	488
Jul 14 - Jul 15	4	SW	Light Wind	518
Jul 15 - Jul 16	5	WSW	Light Wind	540
Jul 16 - Jul 17	4	W	Light Wind	540
Jul 17 - Jul 18	3	WSW	Light Wind	540
Jul 18 - Jul 19	9	WSW	Light Wind	393
Jul 19 - Jul 20	3	W	Light Wind	540
Jul 20 - Jul 21	6	WSW	Light Wind	540
Jul 21 - Jul 22	1	NNW	Calm wind	540
Jul 22 - Jul 23	4	SW	Light Wind	540
Jul 23 - Jul 24	5	NNE	Light Wind	540
Jul 24 - Jul 25	4	WNW	Light Wind	540
Jul 25 - Jul 26	2	NE	Calm wind	540
Jul 26 - Jul 27	3	WNW	Calm wind	540

Table 1B: Weather Summary (Summertime)

Date (2022)	Average Speed (kph)	Dominant Direction	General Wind Description	Minutes of Regulation Favourable Conditions
Jul 27 - Jul 28	4	SSW	Light Wind	540
Jul 28 - Jul 29	8	NE	Light Wind	529
Jul 29 - Jul 30	5	NNE	Light Wind	464
Jul 30 - Jul 31	3	W	Calm wind	540
Jul 31 - Aug 01	4	ENE	Light Wind	466
Aug 01 - Aug 02	5	N	Light Wind	540
Aug 02 - Aug 03	4	SSW	Light Wind	540
Aug 03 - Aug 04	6	NNE	Light Wind	475
Aug 04 - Aug 05	6	W	Light Wind	540
Aug 05 - Aug 06	7	SSW	Light Wind	459
Aug 06 - Aug 07	8	WSW	Light Wind	480
Aug 07 - Aug 08	5	NNE	Light Wind	469
Aug 08 - Aug 09	1	SSE	Calm wind	540
Aug 09 - Aug 10	6	SW	Light Wind	540
Aug 10 - Aug 11	5	WNW	Light Wind	472
Aug 11 - Aug 12	4	NE	Light Wind	540
Aug 12 - Aug 13	2	ESE	Calm wind	538
Aug 13 - Aug 14	4	SW	Light Wind	539
Aug 14 - Aug 15	6	WSW	Light Wind	540
Aug 15 - Aug 16	5	SW	Light Wind	540
Aug 16 - Aug 17	5	SW	Light Wind	540
Aug 17 - Aug 18	4	W	Light Wind	540
Aug 18 - Aug 19	3	SW	Calm wind	540
Aug 19 - Aug 20	7	N	Light Wind	489
Aug 20 - Aug 21	3	ENE	Light Wind	540
Aug 21 - Aug 22	2	SSE	Calm wind	540
Aug 22 - Aug 23	3	NE	Light Wind	540
Aug 23 - Aug 24	3	SW	Light Wind	540
Aug 24 - Aug 25	1	SE	Calm wind	540
Aug 25 - Aug 26	4	W	Light Wind	540
Aug 26 - Aug 27	5	WNW	Light Wind	540
Aug 27 - Aug 28	4	SW	Light Wind	540
Aug 28 - Aug 29	5	SSW	Light Wind	540
Aug 29 - Aug 30	4	SSW	Light Wind	540
Aug 30 - Aug 31	5	SSW	Light Wind	540
Aug 31 - Sep 01	7	W	Light Wind	488
Sep 01 - Sep 02	4	WSW	Light Wind	540
Sep 02 - Sep 03	3	SW	Light Wind	540
Sep 03 - Sep 04	6	WSW	Light Wind	516
Sep 04 - Sep 05	8	WSW	Light Wind	487
Sep 05 - Sep 06	8	WSW	Light Wind	499
Sep 06 - Sep 07	3	SSW	Light Wind	540
Sep 07 - Sep 08	5	W	Light Wind	530
Sep 08 - Sep 09	3	W	Light Wind	540
Sep 09 - Sep 10	8	WSW	Light Wind	415
Sep 10 - Sep 11	7	NE	Light Wind	532

Table 1B: Weather Summary (Summertime)

Date (2022)	Average Speed (kph)	Dominant Direction	General Wind Description	Minutes of Regulation Favourable Conditions
Sep 11 - Sep 12	3	NE	Calm wind	540
Sep 12 - Sep 13	2	NE	Calm wind	540
Sep 13 - Sep 14	3	WSW	Light Wind	523

Regulation Favourable Conditions are defined as per the AER Directive 038 section 4.2, the BC OGC Guideline section 4.3, and the AUC Rule 012 section 4.8.

The results indicate that the nighttime periods from both winter and summer surveys have calm to light wind conditions most of the time, which met the criteria for favourable conditions. Wind data collected during the monitoring period have been used to create the wind roses experienced at the facility area for the total survey period and nighttime periods, which are shown in figures 2A and 2B for the wintertime survey, and Figures 3A and 3B for the summertime survey.

Figure 2A: Wind Rose (Wintertime Total Period)

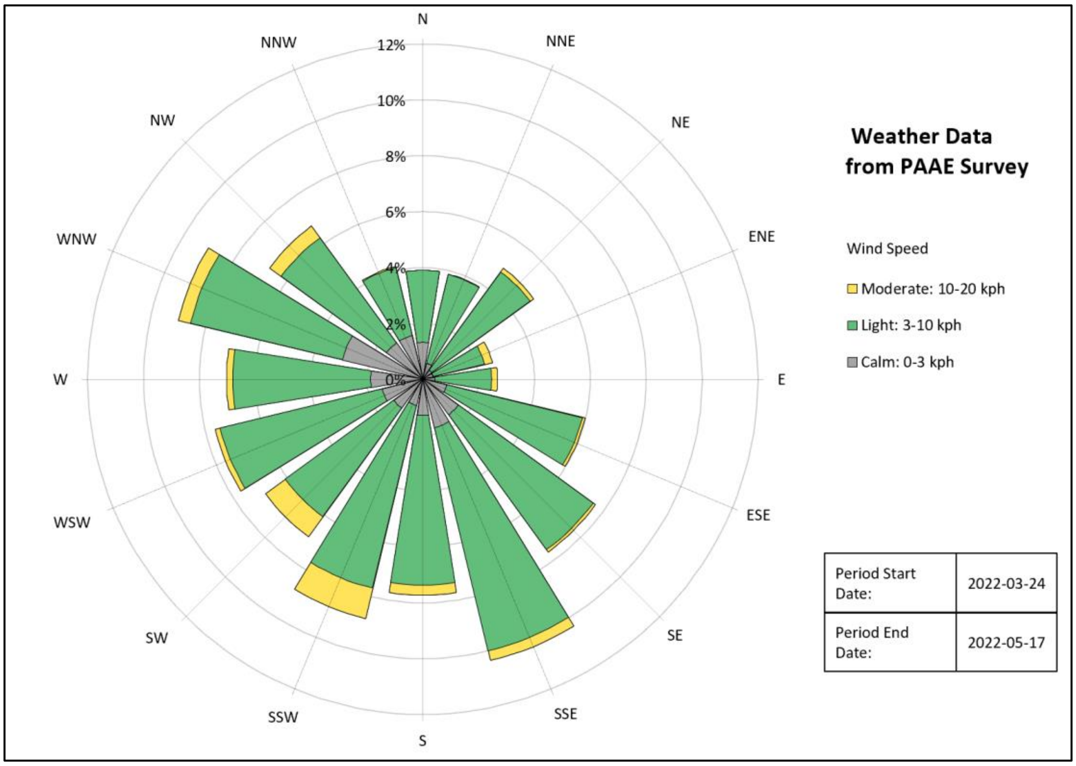


Figure 2B: Wind Rose (Wintertime Nighttime Period)

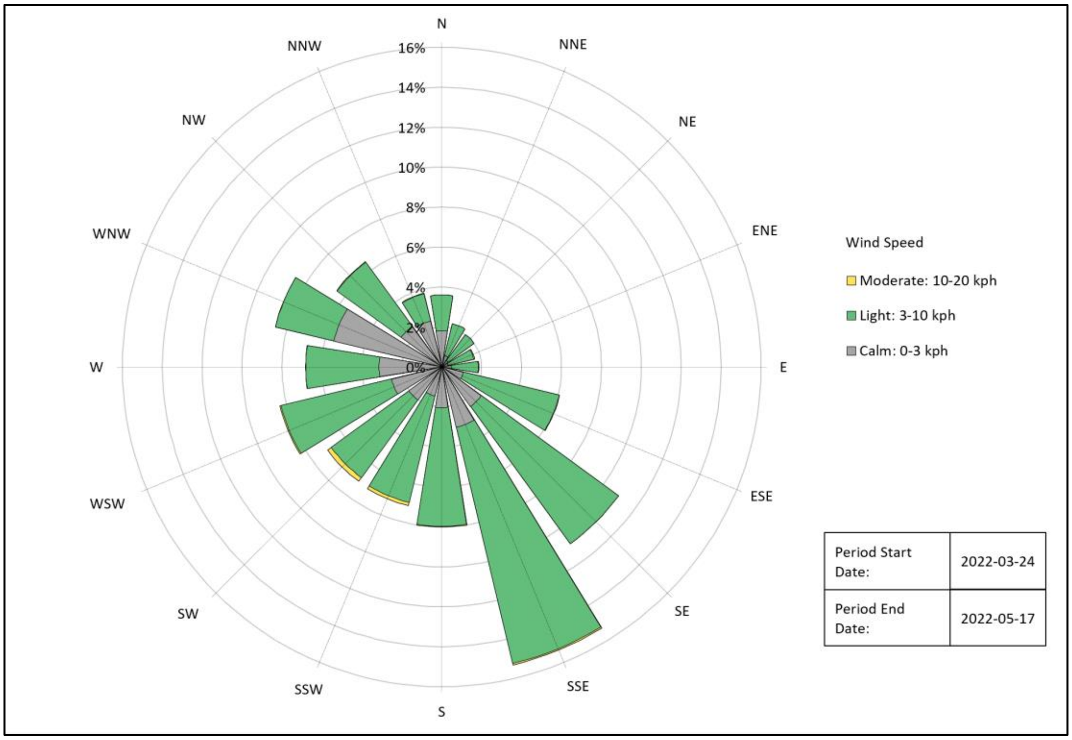
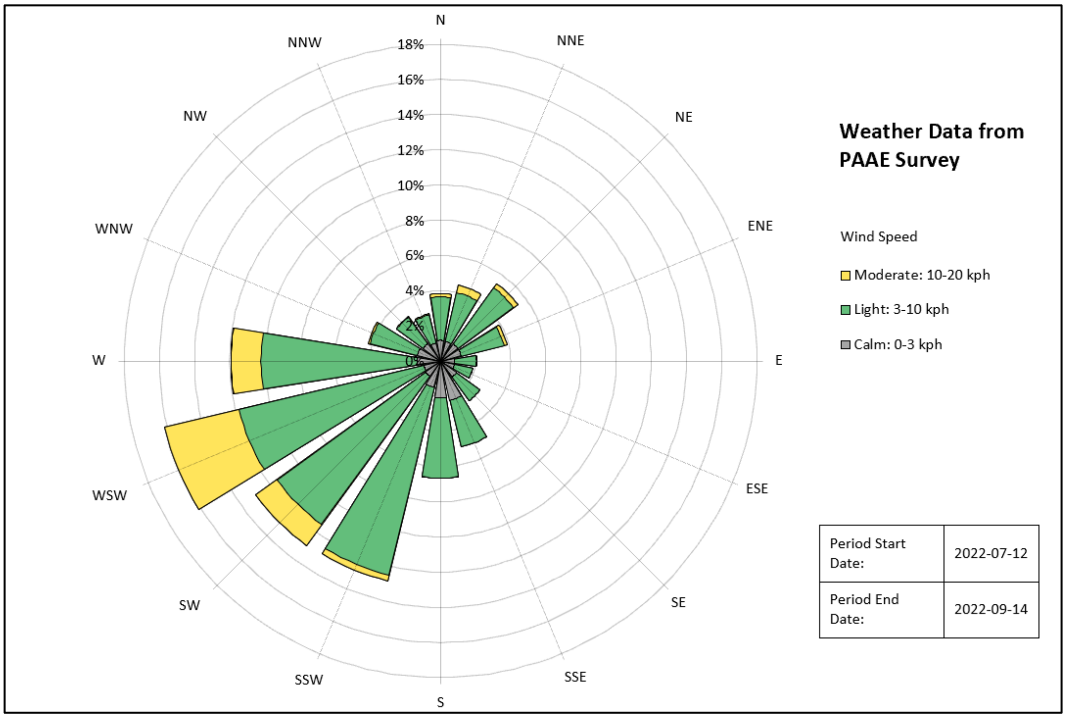
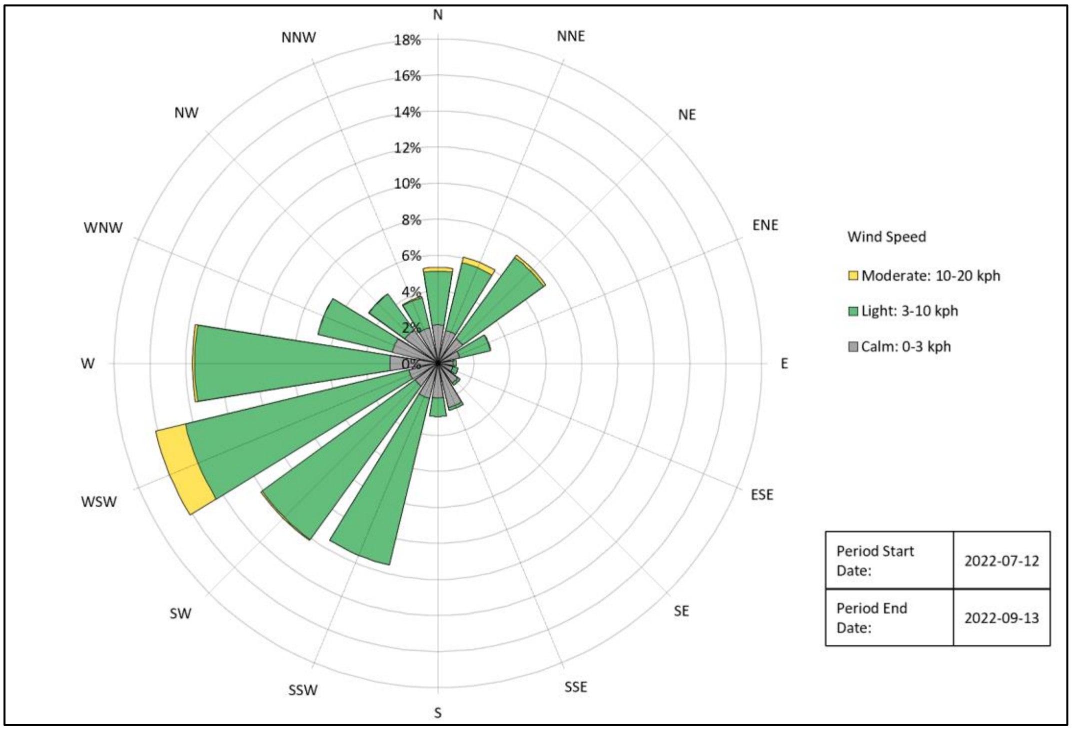


Figure 3A: Wind Rose (Summertime Total Period)



Period Start Date:	2022-07-12
Period End Date:	2022-09-14

Figure 3B: Wind Rose (Summertime Nighttime Period)



Period Start Date:	2022-07-12
Period End Date:	2022-09-13

Results and Discussion

Identification of Facility noise and noise monitoring Results

In order to investigate the noise propagation from the selected oil and gas facilities, detailed diagnostic noise measurements were conducted for the equipment at each selected facility. To determine the validity of the facility operating conditions, a facility representative has confirmed that all equipment was operating normally throughout the survey periods. Tables 2A and 2B list the equipment details for both selected facilities.

Table 2A: Selected Wintertime facility Major Equipment Details

Equipment Name	Equipment Details
Refrigeration Unit 2	• Enclosure: Insulated metal building with Solid Liner • Normal Operation: Doors: Open, Windows: Open, Louvers: Open • Unit: Screw Compressor: Electric driven, 300 HP, 3575 RPM
Cooler 02-EM-3120	• Frequency of operation: Continuous (24 hr)
Amine Unit 1	• Frequency of operation: Continuous (24 hr) • Enclosure: Insulated metal building with Solid Liner • Normal Operation: Doors: Open, Windows: Open, Louvers: Open, Overhead Doors: Closed • Unit: Amine Charge Pumps, 1x unit operating, 1x unit standby, electric driven reciprocating pump, each with 100 HP, 1185 RPM • Unit: Amine Booster Pumps 1x unit operating, 1x unit standby, electric driven reciprocating pump, each with 10 HP, 3510 RPM
Amine Cooler 02-EM-3030/3031	• Frequency of operation: Continuous (24 hr)
Compressor Unit 208	• Frequency of operation: Continuous (24 hr) • Enclosure: Insulated metal building with Perforated Liner • Normal Operation: Doors: Open, Windows: Open, Louvers: Open • Unit: one gas engine driven reciprocating compressor, 3665 HP, 1000 RPM
Compressor 208 Cooler	• Frequency of operation: Continuous (24 hr)
Compressor Unit 212	• Frequency of operation: Continuous (24 hr) • Enclosure: Insulated metal building with Perforated Liner • Normal Operation: Doors: Open, Windows: Open, Louvers: Open • Unit: one gas engine driven reciprocating compressor, 3665 HP, 1000 RPM
Compressor Unit 212 Cooler	• Frequency of operation: Continuous (24 hr)
Utility Heat Unit	• Frequency of operation: Continuous (24 hr) • Normal Operation: Doors: Open, Windows: Open, Louvers: Open Unit: two electric centrifugal Pumps, each with 15 HP, 1765 RPM
Air Compressor Unit 1	• Frequency of operation: Continuous (24 hr) • Enclosure: Insulated metal building with Solid Liner • Normal Operation: Doors: Open, Windows: Open, Louvers: Open

Table 2A: Selected Wintertime facility Major Equipment Details

Equipment Name	Equipment Details
	• Unit: electric driven Sullar Air Compressor
Compressor Unit 108	• Frequency of operation: Continuous (24 hr) • Enclosure: Insulated metal building with Perforated Liner • Normal Operation: Doors: Open, Windows: Open, Louvers: Open • Unit: one gas engine driven reciprocating compressor, 3665 HP, 998 RPM
Compressor 108 Cooler	• Frequency of operation: Continuous (24 hr)
Generator Unit 1	• Frequency of operation: Intermittently • Enclosure: Insulated metal building with Perforated Liner • Normal Operation: Doors: Open, Louvers: Open • Unit: gas driven genset, 565 kW, 1800 RPM
MCC 9300	• Frequency of operation: Continuous (24 hr)
Compressor Unit 112	• Frequency of operation: Continuous (24 hr) • Enclosure: Insulated metal building with Perforated Liner • Normal Operation: Doors: Open, Windows: Open, Louvers: Open ○ Unit: one gas engine driven reciprocating compressor, 3665 HP, 1000 RPM
Compressor Unit 112 Cooler	• Frequency of operation: Continuous (24 hr)
Process Heat Unit 1	• Frequency of operation: Continuous (24 hr) • Enclosure: Insulated metal building with Solid Liner • Normal Operation: Doors: Open, Louvers: Open • One electric process blower, 25 HP, 3600 RPM • One electric centrifugal Pump,: 75 HP, 1800 RPM
Refrigeration Unit 1	• Frequency of operation: Continuous (24 hr) • Enclosure: Insulated metal building with Solid Liner • Normal Operation: Doors: Open, Windows: Open, Louvers: Open • Unit: one electric Screw Compressor, 300 HP, 4575 RPM
Cooler 01-EM-4060	• Frequency of operation: Continuous (24 hr)
Condensate Stabilizer Unit 1	• Frequency of operation: Continuous (24 hr) • Enclosure: Insulated metal building with Solid Liner • Normal Operation: Doors: Open, Windows: Open, Louvers: Open
VRU/ Stabilizer Unit 1	• Frequency of operation: Continuous (24 hr) • Enclosure: Insulated metal building with Solid Liner • Normal Operation: Doors: Open, Louvers: Open • Two electric VRUs operating, each with 7.5 HP, 1800RPM • one electric Reciprocating Pump, 75 HP, 1780 RPM
Water Injection Building	• Frequency of operation: Continuous (24 hr) • Enclosure: Insulated metal building with Solid Liner • Normal Operation: Doors: Open, Windows: Open, Louvers: Open

Table 2A: Selected Wintertime facility Major Equipment Details

Equipment Name	Equipment Details
	• Unit: two electric Reciprocating Pumps, 1x unit operating, 1x unit standby each with 40 HP, 1200RPM • Unit: two electric Booster Pumps, 1x unit operating, 1x unit standby each with 5HP, 1750 RPM
Sulfur Building	• Frequency of operation: Not Operating during the survey • Enclosure: Insulated metal building with Solid Liner • Unit: two electric filtrate Pumps, both standby
Incinerator	• Frequency of operation: Continuous (24 hr)
MCC 9700	• Frequency of operation: Continuous (24 hr) • Enclosure: Insulated metal building with Solid Liner • Normal Operation: Doors: Closed • Unit: 1x HVAC unit standby
MCC 9400	• Frequency of operation: Continuous (24 hr) • Enclosure: Insulated metal building with Solid Liner • Normal Operation: Doors: Closed • Unit: Bard : 1x unit standby
Water Treatment Unit 1	• Frequency of operation: Continuous (24 hr) • Enclosure: Insulated metal building with Solid Liner • Normal Operation: Doors: Open, Windows: Open, Louvers: Open

Table 2B: Selected Summertime Facility Major Equipment Details

Equipment Name	Equipment Details
Compressor #1 K600 Compressor #2 K-610 Compressor #3 K-620 Compressor #4 K630	Four comp units, each with: • Enclosure: Insulated metal building with Perforated Liner • Normal Operation: Doors: Open, Windows: Open, Louvers: Open, Overhead Doors: Open • Unit: one gas engine driven reciprocating compressor, 4735 HP, 1000 RPM Comp #2 and #3: Continuous operation, but Comp #1 and #4 not in operation during the survey
VRU	• Frequency of operation: Continuous (24 hr) • Enclosure: Insulated metal building with Perforated Liner • Normal Operation: Doors: Open, Windows: Open, Louvers: Open • Unit: two VRUs, each with Electric Centrifugal Compressor, 200 HP, 888 RPM
E-House	• Frequency of operation: Continuous (24 hr) • Enclosure: Insulated metal building with Solid Liner • Normal Operation: Doors: Closed • Unit: 1x Bard HVAC Unit operating

Table 2B: Selected Summertime Facility Major Equipment Details

Equipment Name	Equipment Details
Sour Slug Catcher	• Frequency of operation: Continuous (24 hr) • Enclosure: Insulated metal building with Solid Liner • Normal Operation: Doors: Closed, Windows: Open, Louvers: Open
Sweet Slug Catcher	• Frequency of operation: Continuous (24 hr) • Enclosure: Insulated metal building with Solid Liner • Normal Operation: Doors: Closed, Windows: Open, Louvers: Open
Crude Emulsion Treater	• Frequency of operation: Unknown
E-House E-101	• Frequency of operation: Continuous (24 hr) • Enclosure: Insulated metal building with Solid Liner • Normal Operation: Doors: Closed • Unit: 2x HVAC Units
Liquid Storage Building	• Frequency of operation: Continuous (24 hr) • Enclosure: Insulated metal building with Solid Liner • Normal Operation: Doors: Closed, Windows: Open, Louvers: Open
E-House E-100	• Frequency of operation: Continuous (24 hr) • Enclosure: Insulated metal building with Solid Liner • Normal Operation: Doors: Closed • Unit: 1x Bard HVAC Unit
Generator Building	• Frequency of operation: Continuous (24 hr) • Enclosure: Insulated metal building with Perforated Liner • Normal Operation: Doors: Open, Louvers: Open • 2x Gas Caterpillar Engine Generators operating • 1x Diesel Caterpillar Engine Generator standby • 1x Load Bank operating
Utility Building	• Frequency of operation: Continuous (24 hr) • Enclosure: Insulated metal building with Perforated Liner • Normal Operation: Doors: Open, Windows: Open • 2x Heat Medium Reciprocating pumps: 1x unit operating, 1x unit standby, each with 30 HP, 3545RPM • 2x Instrument Air Packages: 1x unit operating, 1x unit standby • 1x Fired Heater operating
Refrigeration Unit	• Frequency of operation: Continuous (24 hr)
Sweet Gas Dehy #2	• Frequency of operation: Continuous (24 hr) • Enclosure: Insulated metal building with Solid Liner • Normal Operation: Doors: Open, Windows: Open, Louvers: Open

Table 2B: Selected Summertime Facility Major Equipment Details

Equipment Name	Equipment Details
	• 2x Reciprocating pumps: 1x unit operating, 1x unit standby, each with 15 HP, 1700RPM • 1x Fired Heater operating
Still Column Vent Tank Cooler	• Frequency of operation: Unknown
Sour Gas Dehyrator #1	• Frequency of operation: Continuous (24 hr) • Enclosure: Insulated metal building with Solid Liner • Normal Operation: Doors: Open, Windows: Open, Louvers: Open • 2x Reciprocating pumps: 1x unit operating, 1x unit standby, each with 10 HP, 1745RPM
Blended Gas Dehyrator #3	• Frequency of operation: Continuous (24 hr) • Enclosure: Insulated metal building with Solid Liner • Normal Operation: Doors: Open, Windows: Open, Louvers: Open • 3x Glycol Rotary pumps: 1x unit operating, 2x units standby, each with 2 HP, 1715RPM
Acid Gas Vapour Recovery Unit	• Frequency of operation: Continuous (24 hr) • Enclosure: Insulated metal building with Perforated Liner • Normal Operation: Doors: Open, Windows: Open, Louvers: Open • Unit: Acid Gas Vapour Recovery Unit: 1x electric driven screw compressor operating
Lean Amine/ Sweet Gas /;Reflux Cooler	• Frequency of operation: Continuous (24 hr)
Lean Amine Cooler #2	• Frequency of operation: Continuous (24 hr)
Amine Heat Medium Building	• Frequency of operation: Continuous (24 hr) • Enclosure: Insulated metal building with Solid Liner • Normal Operation: Doors: Open, Windows: Open, Louvers: Open • 2x Boilers operating • 3x Heat Medium Reciprocating pumps operating, each with 15 HP, 3525 RPM
Amine Building	• Frequency of operation: Continuous (24 hr) • Enclosure: Insulated metal building with Solid Liner • Normal Operation: Doors: Open, Windows: Open • • 2x Amine Circulation Reciprocating pumps: 1x unit operating, 1x unit standby, each with 125 HP, 1190RPM • 2x Amine Booster Reciprocating pumps: 1x unit operating, 1x unit standby, each with 10 HP, 3500RPM

Table 2B: Selected Summertime Facility Major Equipment Details

Equipment Name	Equipment Details
Prod Water / Sales Oil Pump Package	• Frequency of operation: Continuous (24 hr) • Enclosure: Insulated metal building with Perforated Liner • Normal Operation: Doors: Open, Windows: Open, Louvers: Open • 1x Reciprocating pumps, 100 HP, 1185RPM • 2x Rotary pumps standby, each with 15 HP, 3530RPM
Frac Water Transfer Pump Building	• Frequency of operation: 2 weeks per year • Enclosure: Insulated metal building with Perforated Liner • Normal Operation: Doors: Open, Windows: Open, Louvers: Open • 1x Caterpillar Gas Engine gas driven screw compressor operating, 1340 HP, 1400RPM • Only operates 2 weeks a year
E-House E-102/Instrument Air	• Frequency of operation: Unknown • Enclosure: Insulated metal building with Solid Liner • Normal Operation: Doors: Closed, Windows: Open, Louvers: Open • Unit: 1x Instrument air compressor operating, 15 HP, 3525 RPM

Table 3 provides the calibrated overall sound power levels based on the summation of individual noise sources for each of the winter and summer facilities. Figures 4A and 4B show the one third octave band spectrum sound power levels for each facility.

Table 3 Sound Power Levels of the Winter and Summer Facilities

Facility	PWL dB(A/C)	Linear One Third Octave Band Level (dB)													
		25Hz	31.5Hz	40Hz	50Hz	63Hz	80Hz	100Hz	125Hz	160Hz	200Hz	250Hz	315Hz	400Hz	500Hz
Winter	124.2/ 138.2	130.8	130.6	135	125.9	130	125.6	125.6	127.2	128.1	121.8	122.9	120.1	112.6	111
		630Hz	800Hz	1kHz	1.25kHz	1.6kHz	2kHz	2.5kHz	3.15kHz	4kHz	5kHz	6.3kHz	8kHz	10kHz	
		110.2	111.3	112.5	113.6	113.4	111.3	110.7	108	104.4	94.2	73.7	63.5	61.7	
Summer	120.9/ 133.4	25Hz	31.5Hz	40Hz	50Hz	63Hz	80Hz	100Hz	125Hz	160Hz	200Hz	250Hz	315Hz	400Hz	500Hz
		114.7	121.0	132.4	118.7	123.0	123.3	118.7	119.5	119.2	117.5	115.4	122.3	113.4	109.8
		630Hz	800Hz	1kHz	1.25kHz	1.6kHz	2kHz	2.5kHz	3.15kHz	4kHz	5kHz	6.3kHz	8kHz	10kHz	
		111.3	108.7	108.7	108.2	110.2	105.2	103.2	103.6	102.8	98.2	91.8	88.2	84.1	

Figure 4A: Winter facility PWL

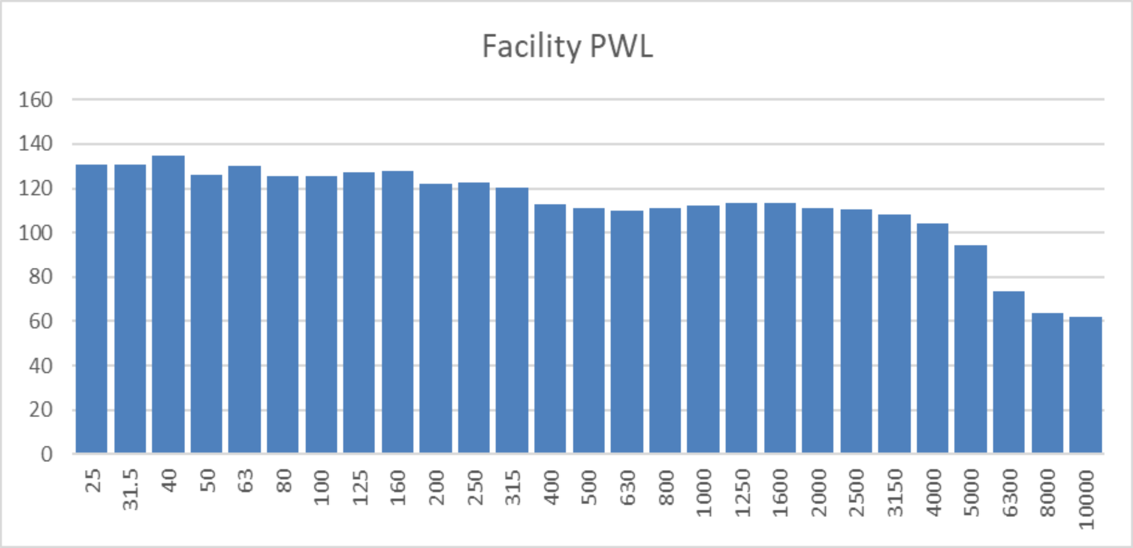
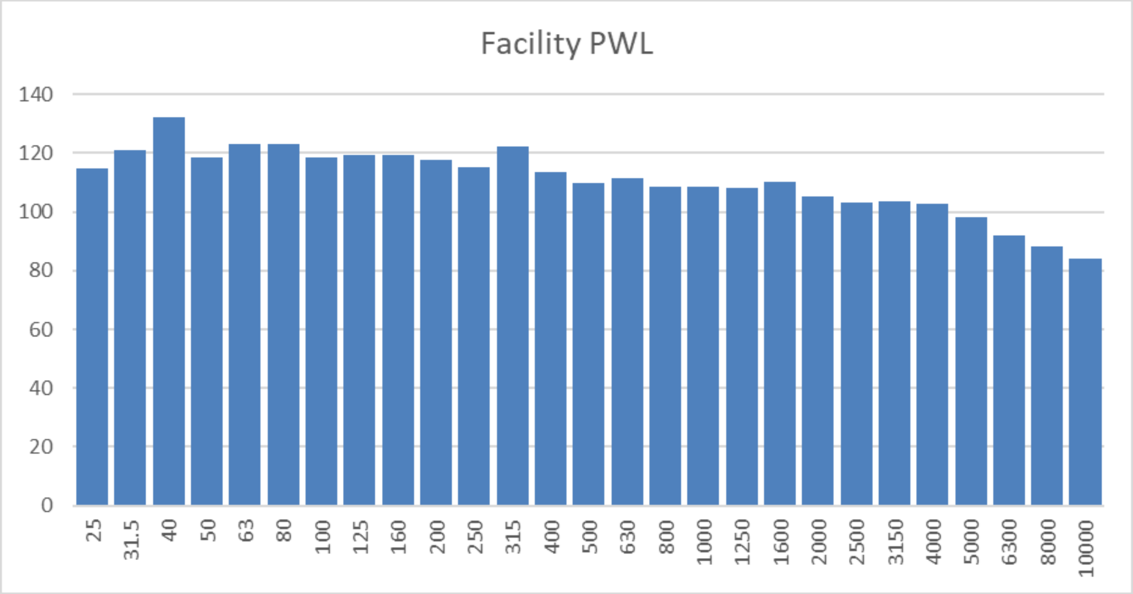
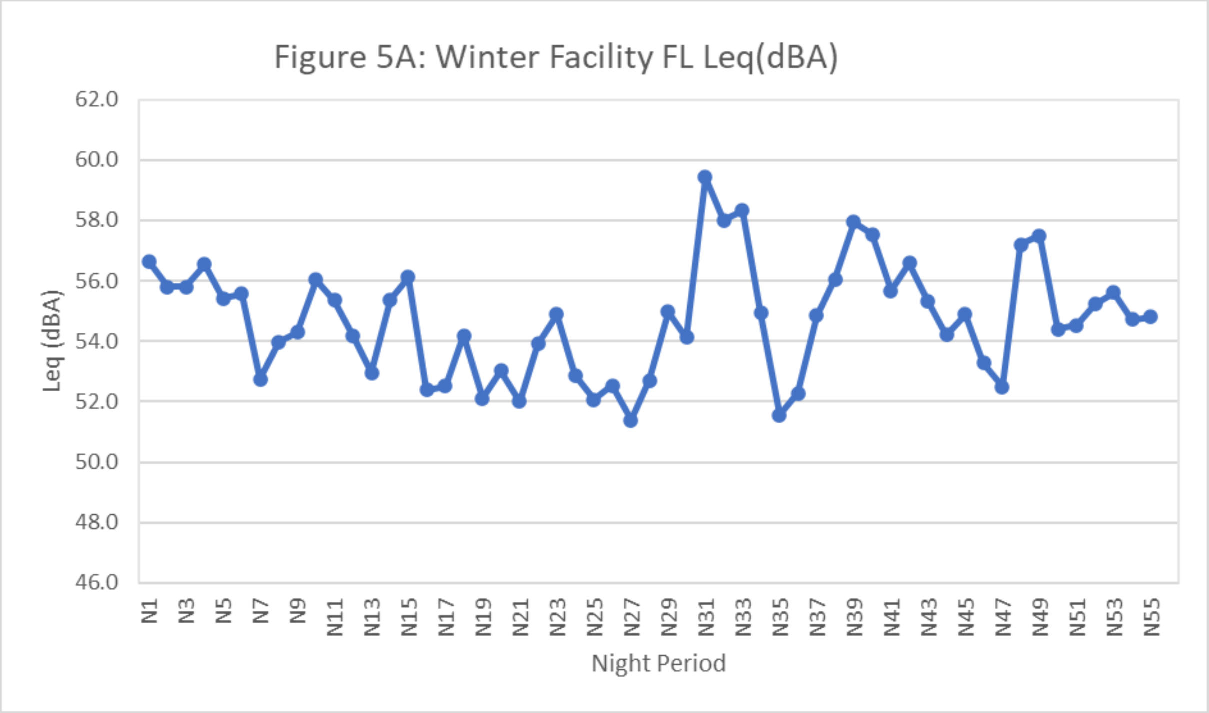
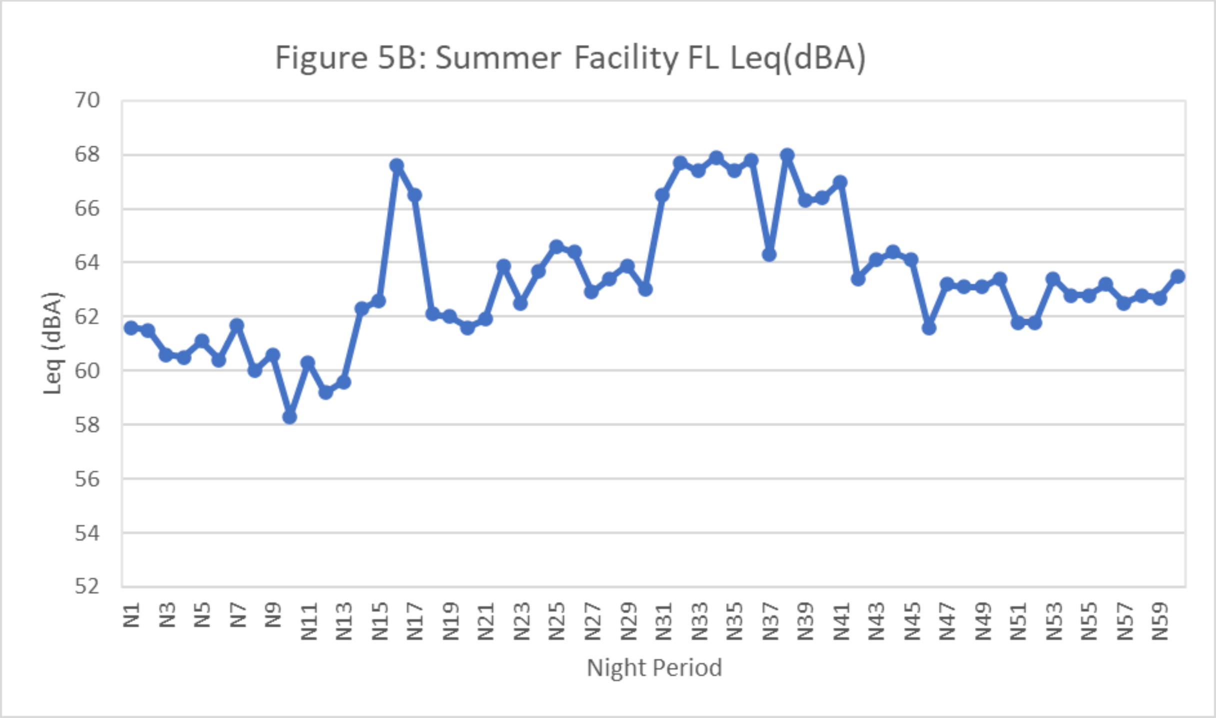


Figure 4B: Summer facility PWL



Figures 5A and 5B show the measurement results at the fence line location for the nighttime periods of the survey for the winter and summer facilities.





During the wintertime survey between March 24 and May 18, 2022, the facility equipment was operating normally with some of equipment powered on or off. For the nighttime periods of the survey, the levels ranged between 51.7 and 59.2 dBA which is more variation than typical for a facility monitor; this can be explained due to wind affecting levels measured at the facility monitoring location and equipment running situation changes.

During the summertime survey between July 12 and September 15, 2022, the facility equipment was operating normally, but the facility running situation did change in some of the time periods, ranging from around 58 dBA to 68 dBA with some of equipment powered on or off, which was also impacted by the wind conditions.

Noise measurement Results – Wintertime Study

Continuous noise measurements were conducted at the selected locations. The following summarizes the CSS Monitor results as per wind conditions and for the nighttime periods of the survey for the selected remote sites. As the daytime noise level is dominated by human and domestic animal activity and transportation, the daytime levels have not been analyzed as closely as the nighttime levels.

Remote Site 1

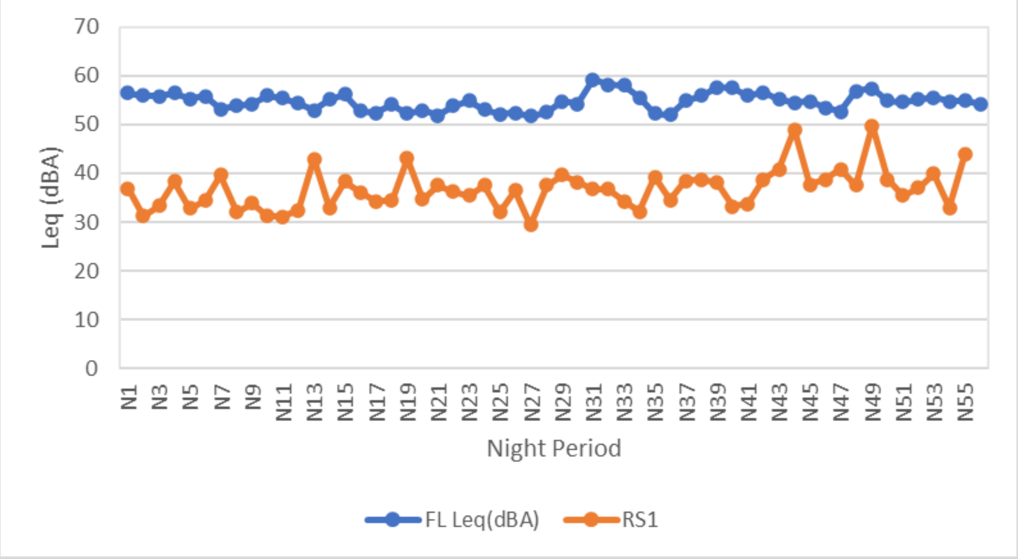
Remote Site 1 was located at approximately 3078m northeast from the gas plant, 2080m west from highway. Based on site observations during the survey and from the audio playback, the sound environment is dominated by sound from wind and transportation.

Table 4 summarizes the sound level measurement results for the wintertime monitoring period of the survey based on wind conditions. Figure 6 shows the comprehensive sound level measurement results for the wintertime period of the survey for the nighttime periods.

Table 4: Monitoring Sound level Results - Remote Site 1

Receiver	Weather Condition	Measured Daytime SPL (dBA)	Measured Nighttime SPL (dBA)	Measured Daytime Hours	Measured Nighttime Hours	Measured Daytime Wind Speed (kph)	Measured Nighttime Wind Speed (kph)
Remote Site 1, 3078m NE	Total Period	44.4	39.2	814.5	486.0	5.9	4.4
	Downwind	46.7	40.2	254.7 (31%)	145.4 (30%)	6.8	4.9
	Crosswind	43.0	39.0	409.9 (50%)	295.6 (61%)	5.5	4.1
	Upwind	41.7	36.1	149.9 (18%)	45.1 (9%)	5.6	4.2

Figure 6: Measured Nighttime SPL (Remote Site 1) Compared with Fenceline SPL



The results of the survey show that the acoustic environment was dominated by wind, transportation and nearby facility operation noise during the monitoring period. Based on site observations and audio recordings, the sources of sounds in the study area includes sounds from transportation (highway), local activities (i.e., human and other local industrial related activities), fauna and weather and sounds of nature, and nearby facility operations.

The results indicate that the sound pressure levels ranged from 29.4 to 49.8 dBA during the wintertime period. The acoustic environment was dominated by weather conditions, with some fluctuation by the strong wind and direction during the monitoring period, and nearby facility operations. There would be some contamination due to the strong winds in some of the data captured.

Remote Site 2

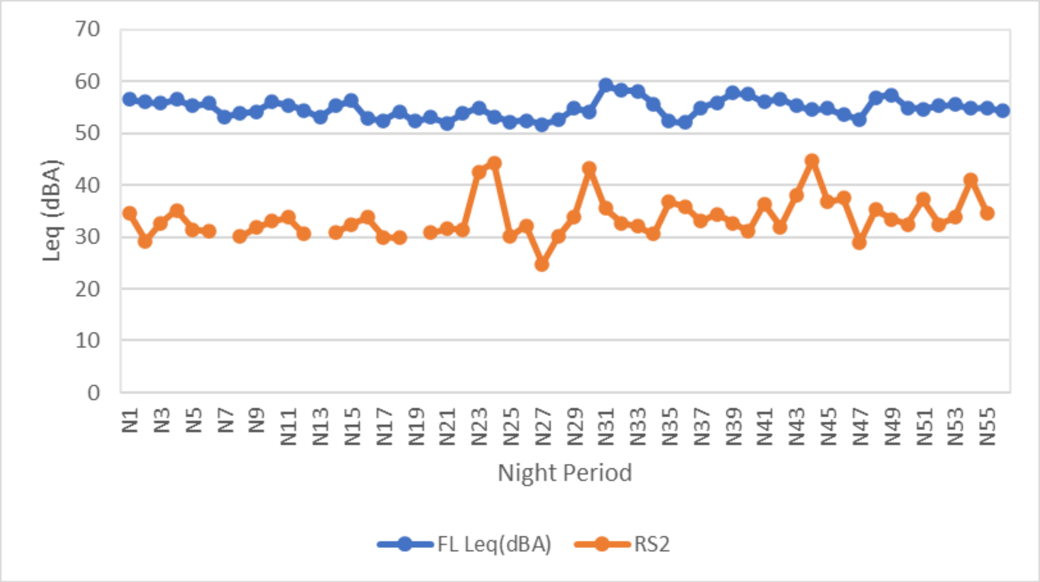
Remote Site 2 was located at approximately 3212m north from the gas plant, 3900m west from highway. Based on site observations during the survey and from the audio playback, the sound environment is dominated by sound from wind and transportation.

Table 5 summarizes the sound level measurement results for the wintertime monitoring period of the survey based on wind conditions. Figure 7 shows the comprehensive sound level measurement results for the wintertime period of the survey for the nighttime periods compared with Fenceline SPL.

Table 5: Monitoring Sound level Results - Remote Site 2

Receiver	Weather Condition	Measured Daytime SPL (dBA)	Measured Nighttime SPL (dBA)	Measured Daytime Hours	Measured Nighttime Hours	Measured Daytime Wind Speed (kph)	Measured Nighttime Wind Speed (kph)
Remote Site 2, 3212m N	Total Period	42.1	36.2	667.8	448.3	5.5	4.1
	Downwind	43.1	35.6	164.3 (25%)	169.1 (38%)	5.8	4.3
	Crosswind	42.7	36.8	357.6 (54%)	216.6 (48%)	5.7	4.2
	Upwind	38.0	35.6	145.9 (22%)	62.7 (14%)	4.7	3.2

Figure 7: Measured Nighttime SPL (Remote Site 2) Compared with Fenceline SPL



The results of the survey show that the acoustic environment was dominated by wind, transportation and nearby facility operation noise during the monitoring period. Based on site observations and audio recordings, the sources of sounds in the study area includes sounds from transportation (plans, local traffic), local activities (i.e., human and other local industrial related activities), fauna and weather and sounds of nature, and nearby facility operations.

The results indicate that the sound pressure levels ranged from 24.7 to 71.5 dBA during the wintertime period. The acoustic environment was dominated by weather conditions, with some fluctuation by the strong wind and direction during the monitoring period, and nearby facility operations. There would be some contamination due to the strong winds in some of the data captured.

Remote Site 3

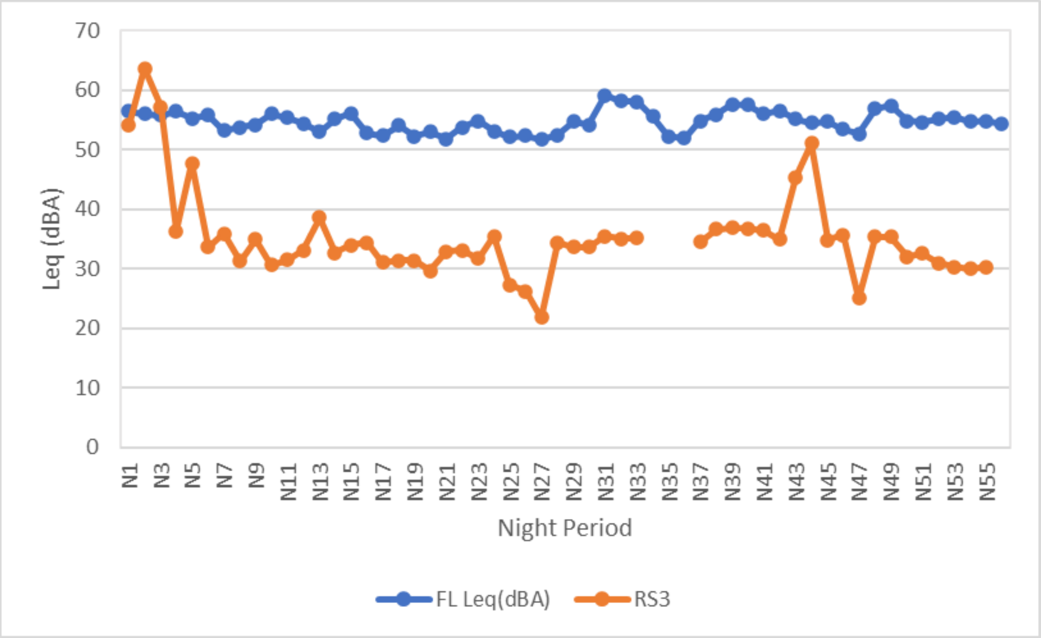
Remote Site 3 was located at approximately 3793 m northwest from the gas plant. Based on site observations during the survey and from the audio playback, the sound environment is dominated by sound from wind and transportation.

Table 6 summarizes the sound level measurement results for the wintertime monitoring period of the survey based on wind conditions. Figure 8 shows the comprehensive sound level measurement results for the wintertime period of the survey for the nighttime periods compared with Fenceline SPL.

Table 6: Monitoring Sound level Results - Remote Site 3

Receiver	Weather Condition	Measured Daytime SPL (dBA)	Measured Nighttime SPL (dBA)	Measured Daytime Hours	Measured Nighttime Hours	Measured Daytime Wind Speed	Measured Nighttime Wind Speed
						(kph)	(kph)
Remote Site 3, 3793 m NW	Total Period	48.5	48.3	775.2	458.9	6.0	4.3
	Downwind	47.6	46.0	173.6 (22%)	158.5 (35%)	5.5	4.5
	Crosswind	47.5	50.7	386.2 (50%)	176.1 (38%)	6.4	4.6
	Upwind	50.2	45.0	215.4 (28%)	124.3 (28%)	5.7	3.6

Figure 8: Measured Nighttime SPL (Remote Site 3) Compared with Fenceline SPL



The results of the survey show that the acoustic environment was dominated by wind and nearby facility operation noise during the monitoring period. Based on site observations and audio recordings, the sources of sounds in the study area includes sounds from local activities (i.e., human and other local industrial related activities), fauna and weather and sounds of nature, and nearby facility operations.

The results indicate that the sound pressure levels ranged from 21.9 to 63.7 dBA during the wintertime period. The acoustic environment was dominated by weather conditions and nearby facility operations. There would be some contamination due to the strong winds in some of the data captured.

Remote Site 4

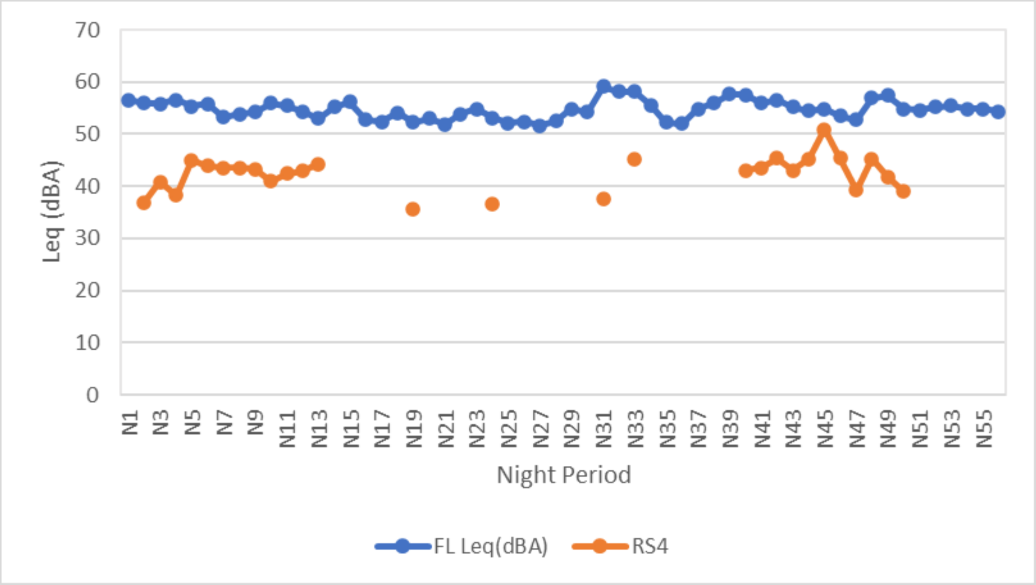
Remote Site 4 was located at approximately 909 m east northeast from the gas plant. Based on site observations during the survey and from the audio playback, the sound environment is dominated by sound from wind and transportation.

Table 7 summarizes the sound level measurement results for the wintertime monitoring period of the survey based on wind conditions. Figure 9 shows the comprehensive sound level measurement results for the wintertime nighttime periods compared with Fenceline SPL.

Table 7: Monitoring Sound level Results - Remote Site 4

Receiver	Weather Condition	Measured Daytime SPL (dBA)	Measured Nighttime SPL (dBA)	Measured Daytime Hours	Measured Nighttime Hours	Measured Daytime Wind Speed	Measured Nighttime Wind Speed
						(kph)	(kph)
Remote Site 4, 909 m ENE	Total Period	50.8	43.9	360.0	203.0	6.3	5.0
	Downwind	54.6	45.9	114.4 (32%)	54.1 (27%)	7.1	5.3
	Crosswind	46.8	43.1	195.2 (54%)	134.8 (66%)	6.1	4.9
	Upwind	42.2	39.8	50.5 (14%)	14.1 (7%)	5.5	4.4

Figure 9: Measured Nighttime SPL (Remote Site 4) Compared with Fenceline SPL



The results of the survey show that the acoustic environment was dominated by wind, nearby facility operation and subject facility operation noise during the monitoring period. Based on site observations and audio recordings, the sources of sounds in the study area includes sounds from local activities (i.e., human and other local industrial related activities), fauna and weather and sounds of nature, and nearby facility operations (piping & flare intermittent).

The results indicate that the sound pressure levels ranged from 35.7 to 50.9 dBA during the wintertime period. The acoustic environment was dominated by weather conditions, with some fluctuations due to strong wind and direction, and nearby facility operations during the monitoring period. There would be some contamination due to the strong winds in some of the data captured.

Remote Site 5

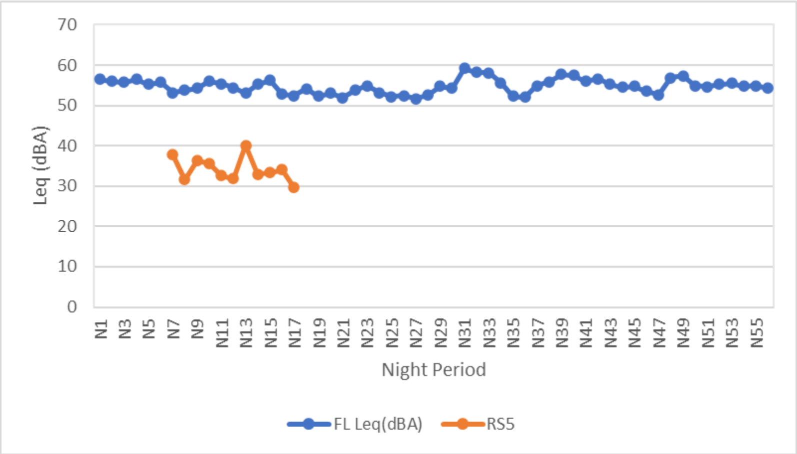
Remote Site 5 was located at approximately 2589 m east northeast from the gas plant, 2100m west from Highway 2. Based on site observations during the survey and from the audio playback, the sound environment is dominated by sound from wind and transportation.

Table 8 summarizes the sound level measurement results for the wintertime monitoring period of the survey based on wind conditions. Figure 10 shows the comprehensive sound level measurement results for the wintertime nighttime periods compared with Fenceline SPL.

Table 8: Monitoring Sound level Results - Remote Site 5

Receiver	Weather Condition	Measured Daytime SPL (dBA)	Measured Nighttime SPL (dBA)	Measured Daytime Hours	Measured Nighttime Hours	Measured Daytime Wind Speed (kph)	Measured Nighttime Wind Speed (kph)
Remote Site 5, 2589 m ENE	Total Period	41.6	35.3	174.1	99.0	7.1	5.0
	Downwind	41.1	33.9	55.5 (32%)	18.6 (19%)	7.1	4.0
	Crosswind	42.6	35.7	96.1 (55%)	71.9 (73%)	7.0	5.3
	Upwind	33.9	34.1	22.5 (13%)	8.6 (9%)	7.2	4.9

Figure 10: Measured Nighttime SPL (Remote Site 5) Compared with Fenceline SPL



The results of the survey show that the acoustic environment was dominated by wind, transportation and nearby facility operation noise during the monitoring period. Based on site observations and audio recordings, the sources of sounds in the study area includes sounds from transportation (highway), local activities (i.e., human and other local industrial related activities), fauna and weather and sounds of nature, and nearby facility operations.

The results indicate that the ambient sound pressure levels ranged from 29.6 to 40.1 dBA during the wintertime period. The acoustic environment was dominated by weather conditions, with some fluctuation by strong wind and direction during the monitoring period, and nearby facility operations. There would be some contamination due to the strong winds in some of the data captured.

Remote Site 6

One off-the-shelf acoustic IOT sensor was installed at this location, approximately 1454 m NNE to capture the noise levels during May 1-18, 2022, but only 8 sound records were captured on May 10, 2022, which were listed in the following table.

Table 9 Noise Levels captured at Remote Site 6

Sound Level Type	Sound levels (dBA)
L10	42.5
L50	34.6
L90	33.4
L95	33.2
Leq	44.3

Remote Site 7

One off-the-shelf acoustic IOT sensor was installed at this location, approximately 4022 m NNE to capture the noise levels, which was running normally during May 1-18, 2022, but no data was captured.

Noise measurement Results – Summertime Study

Continuous noise measurements were conducted at the selected locations. The following summarizes the CSS Monitor results as per wind conditions and for the nighttime periods of the survey for the selected remote sites.

Remote Site 1

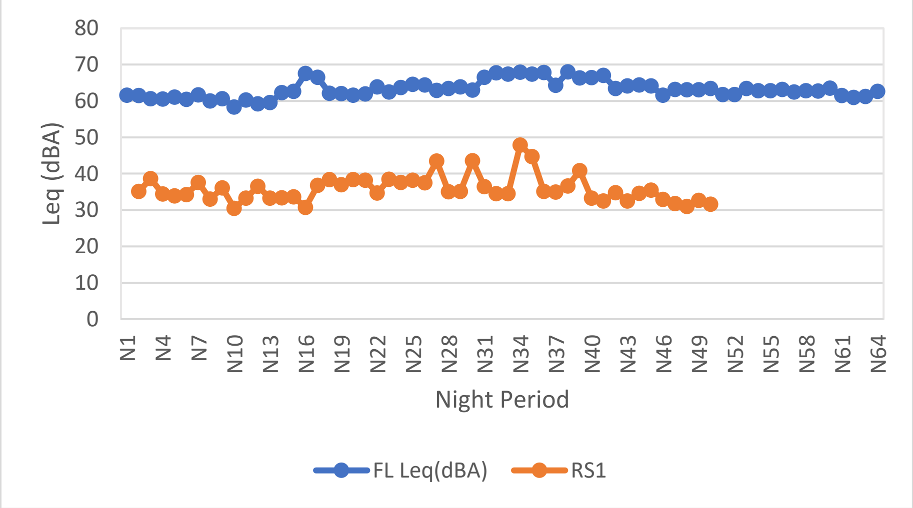
Remote Site 1 was located at approximately 2160m west from the compressor station. Based on site observations during the survey and from the audio playback, the sound environment is dominated by sound from nearby facility, wind and transportation.

Table 10 summarizes the sound level measurement results for the summertime monitoring period of the survey based on wind conditions. Figure 11 shows the comprehensive sound level measurement results for the nighttime periods compared with the Fenceline SPL.

Table 10: Monitoring Sound level Results - Remote Site 1

Receiver	Weather Condition	Measured Daytime SPL (dBA)	Measured Nighttime SPL (dBA)	Measured Daytime Hours	Measured Nighttime Hours	Measured Daytime Wind Speed	Measured Nighttime Wind Speed
						(kph)	(kph)
Remote Site 1, 2160m west	Total Period	43.3	37.9	730.3	436.5	6.2	4.4
	Downwind	42.2	35.8	103.3 (14%)	46.9 (11%)	5.0	3.6
	Crosswind	42.8	37.2	364.4 (50%)	199.3 (46%)	5.1	4.0
	Upwind	44.3	38.9	262.6 (36%)	190.3 (44%)	8.1	5.1

Figure 11: Measured Nighttime SPL (Remote Site 1) Compared with Fenceline SPL



The results of the survey show that the acoustic environment was dominated by nearby facility operation noise, wind, and transportation during monitoring period. Based on site observations and audio recordings, the sources of sounds in the study area includes sounds from nearby facility operations, fauna and weather and sounds of nature, and local activities (i.e., human and other local industrial related activities). The subject facility was audible, but the sound pressure levels under downwind condition were lower, which indicated that the subject facility may not be the dominant noise due to nearby facility operations.

The results indicate that the ambient sound pressure levels ranged from 30.5 to 47.9 dBA during the summertime period, and mostly ranged from 30 - 40 dBA during the nighttime period. The acoustic environment was dominated by nearby facility operations and weather conditions, with some fluctuation by strong wind and direction during the monitoring period.

Remote Site 2

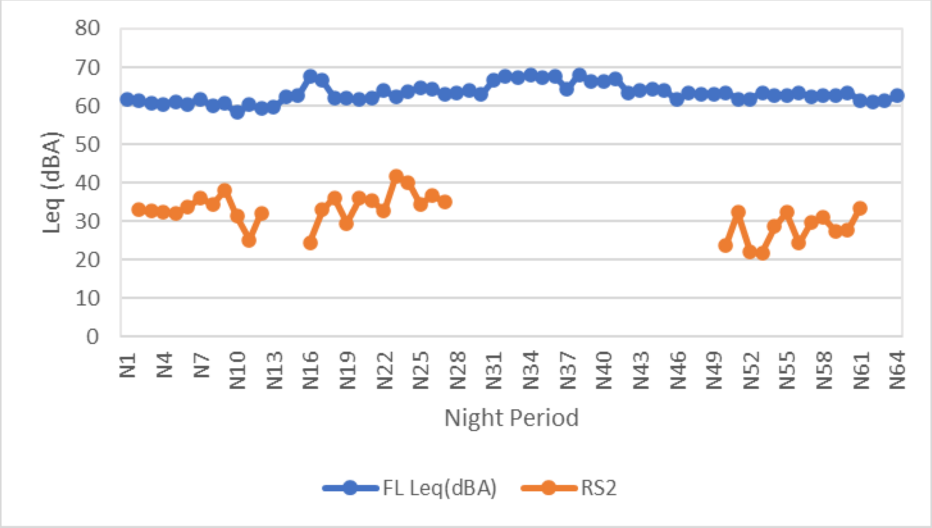
Remote Site 2 was located at approximately 2000m southwest from the compressor station. Based on site observations during the survey and from the audio playback, the sound environment is dominated by sound from wind and transportation.

Table 11 summarizes the sound level measurement results for the summertime monitoring period of the survey based on wind conditions. Figure 12 shows the comprehensive sound level measurement results for the nighttime periods compared with the Fenceline SPL.

Table 11: Monitoring Sound level Results - Remote Site 2

Receiver	Weather Condition	Measured Daytime SPL (dBA)	Measured Nighttime SPL (dBA)	Measured Daytime Hours	Measured Nighttime Hours	Measured Daytime Wind Speed	Measured Nighttime Wind Speed
						(kph)	(kph)
Remote Site 2, 3212m N	Total Period	41.9	34.0	508.5	300.0	7.1	5.3
	Downwind	39.0	34.5	59.8 (12%)	50.5 (17%)	6.8	5.6
	Crosswind	40.3	35.6	128.5(25%)	82.6 (28%)	5.6	3.9
	Upwind	42.8	32.7	320.2 (63%)	166.8 (56%)	7.8	5.9

Figure 12: Measured Nighttime SPL (Remote Site2) Compared with Fenceline SPL



The results of the survey show that the acoustic environment was dominated by wind, transportation and nearby facility operation noise during monitoring period. Based on site observations and audio recordings, the sources of sounds in the study area includes sounds from transportation (plans, local traffic), local activities (i.e., human and other local industrial related activities), fauna and weather and sounds of nature, and nearby facility operations. The measurement data was lost in some periods due to power issues.

The results indicate that the ambient sound pressure levels ranged from 21.8 to 41.7 dBA during the summertime period, and mostly less than 40 dBA during the nighttime period. The acoustic environment was dominated by weather conditions, with some fluctuation by strong wind and direction during the monitoring period, and nearby facility operations. There would be some contamination due to the strong winds in some of the data captured.

Remote Site 3

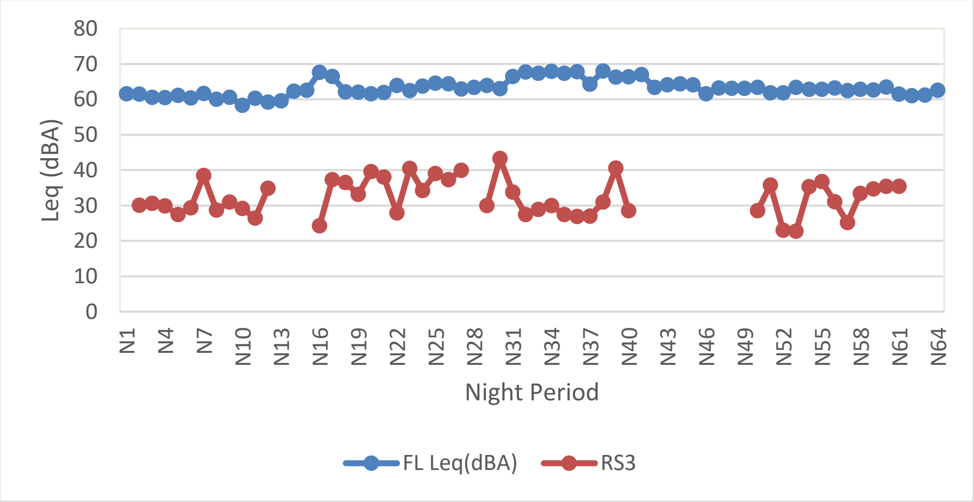
Remote Site 3 was located at approximately 1030 m south southwest from the compressor station. Based on site observations during the survey and from the audio playback, the sound environment is dominated by sound from wind and transportation.

Table 12 summarizes the sound level measurement results for the summertime monitoring period of the survey based on wind conditions. Figure 11 shows the comprehensive sound level measurement results for the nighttime periods compared with the Fenceline SPL.

Table 12: Monitoring Sound level Results - Remote Site 3

Receiver	Weather Condition	Measured Daytime SPL (dBA)	Measured Nighttime SPL (dBA)	Measured Daytime Hours	Measured Nighttime Hours	Measured Daytime Wind Speed (kph)	Measured Nighttime Wind Speed (kph)
Remote Site 3, 1030 m south southwest	Total Period	42.1	34.9	689.1	397.0	6.7	5.1
	Downwind	39.8	38.7	78.4 (11%)	72.5 (18%)	6.5	5.2
	Crosswind	42.1	34.1	265.1 (38%)	164.1 (41%)	6.9	4.8
	Upwind	42.4	32.5	345.7 (50%)	160.4 (40%)	6.6	5.2

Figure 11: Measured Nighttime SPL (Remote Site 3) Compared with Fenceline SPL



The results of the survey show that the acoustic environment was dominated by wind, and nearby facility operation noise during monitoring period. Based on site observations and audio recordings, the sources of sounds in the study area includes sounds from local activities (i.e., human and other local industrial related activities), fauna and weather and sounds of nature, and nearby facility operations. The measurement data was lost in some periods due to power issues.

The results indicate that the ambient sound pressure levels ranged from 22.7 to 43.3 dBA during the summertime period, and mostly less than 40 dBA during the nighttime period. The acoustic environment was dominated by weather conditions and nearby facility operations. There would be some contamination due to strong winds in some of the data captured.

Remote Site 4

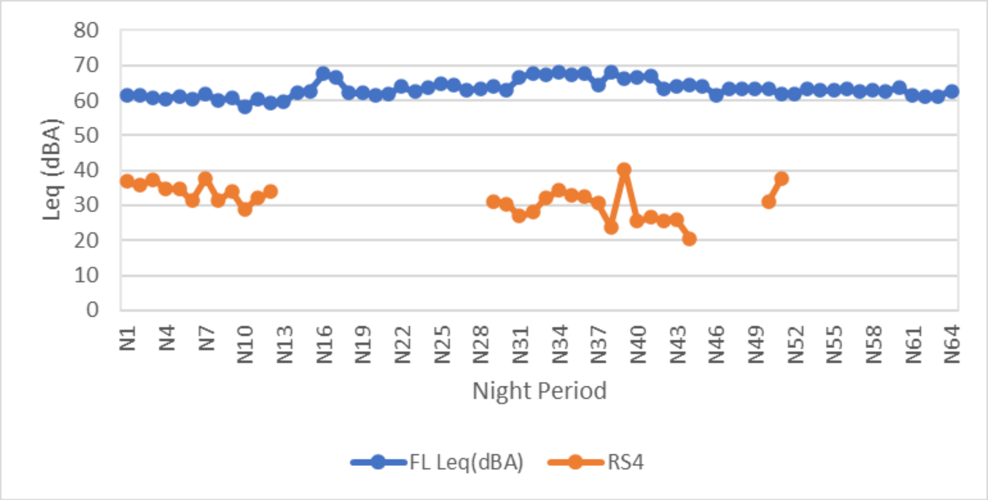
Remote Site 4 was located at approximately 2600 m southeast from the compressor station. Based on site observations during the survey and from the audio playback, the sound environment is dominated by sound from wind and transportation.

Table 13 summarizes the sound level measurement results for the summertime monitoring period of the survey based on wind conditions. Figure 12 shows the comprehensive sound level measurement results for the nighttime periods compared with the Fenceline SPL.

Table 13: Monitoring Sound level Results - Remote Site 4

Receiver	Weather Condition	Measured Daytime SPL (dBA)	Measured Nighttime SPL (dBA)	Measured Daytime Hours	Measured Nighttime Hours	Measured Daytime Wind Speed (kph)	Measured Nighttime Wind Speed (kph)
Remote Site 4, 2600 m southeast	Total Period	39.9	33.7	417.0	255.2	6.3	4.5
	Downwind	37.5	35.7	22.6 (5%)	48.0 (19%)	6.3	3.8
	Crosswind	40.3	33.2	297.5 (71%)	184.6 (72%)	7.1	4.9
	Upwind	38.9	32.5	96.9 (23%)	22.5 (9%)	4.1	2.2

Figure 12: Measured Nighttime SPL (Remote Site 4) Compared with Fenceline SPL



The results of the survey show that the acoustic environment was dominated by wind, nearby facility operation and subject facility operation noise during monitoring period. Based on site observations and audio recordings, the sources of sounds in the study area includes sounds from local activities (i.e., human and other local industrial related activities), fauna and weather and sounds of nature, and nearby facility operations. The measurement data was lost in some periods due to power issues.

The results indicate that the ambient sound pressure levels ranged from 20.5 to 46.9 dBA during the summertime period. The acoustic environment was dominated by weather conditions, with some fluctuation by strong wind and direction, and nearby facility operations during the monitoring period. There would be some contamination due to the strong winds in some of the data captured.

Remote Site 5

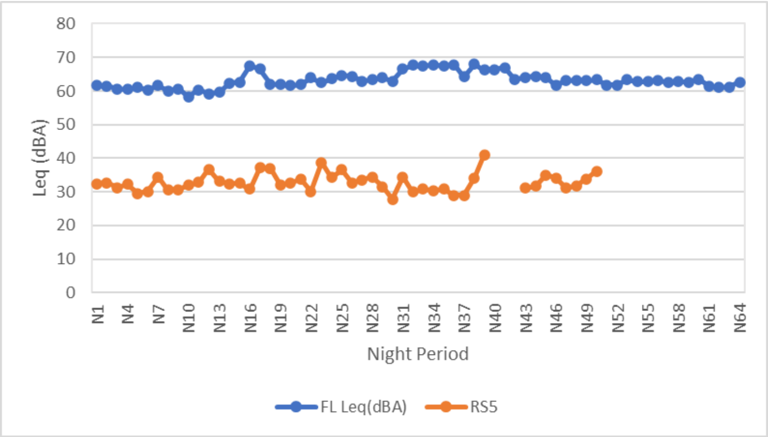
Remote Site 5 was located at approximately 3860 m east southeast from the compressor station, 2100m west from Highway 2. Based on site observations during the survey and from the audio playback, the sound environment is dominated by sound from wind and transportation.

Table 14 summarizes the sound level measurement results for the summertime monitoring period of the survey based on wind conditions. Figure 13 shows the comprehensive sound level measurement results for the nighttime period compared with the Fenceline SPL

Table 14: Monitoring Sound level Results - Remote Site 5

Receiver	Weather Condition	Measured Daytime SPL (dBA)	Measured Nighttime SPL (dBA)	Measured Daytime Hours	Measured Nighttime Hours	Measured Daytime Wind Speed (kph)	Measured Nighttime Wind Speed (kph)
Remote Site 5, 3860 m east southeast	Total Period	41.9	47.6	690.5	415.2	6.3	4.5
	Downwind	39.2	37.5	222.1 (32%)	171.0 (41%)	8.1	5.1
	Crosswind	43.5	40.1	382.8 (55%)	217.0 (52%)	5.5	4.3
	Upwind	37.4	58.9	85.6 (12%)	27.2 (7%)	4.9	2.9

Figure 13: Measured Nighttime SPL (Remote Site 5) Compared with Fenceline SPL



The results of the survey show that the acoustic environment was dominated by wind, transportation and nearby facility operation noise during monitoring period. Based on site observations and audio recordings, the sources of sounds in the study area includes sounds from transportation (highway), local activities (i.e., human and other local industrial related activities), fauna and weather and sounds of nature, and nearby facility operations. The subject facility was audible, and the sound pressure levels under upwind condition were much higher, which indicated that the subject facility may not be the dominant noise in this situation, possibly due to nearby facility operations.

The results indicate that the ambient sound pressure levels ranged from 29.0 to 53.6 dBA during summertime period, and mostly less than 40 dBA during the nighttime period. The acoustic environment was dominated by weather conditions, with some fluctuation by strong wind and direction during the monitoring period, and nearby facility operations. There would be some contamination due to the strong winds in some of the data captured.

Remote Site 6

One off-the-shelf acoustic IOT sensor was installed at this location, approximately 1340 m southeast to capture the noise levels during the period of July 12 – Sept 14, 2022, 2022, which are listed in the following table.

Table 15 Noise Levels captured at Remote Site 6

Sound Level Type	Sound levels (dBA)
L10	37.2
L50	35.1
L90	33.5
L95	33.1
Leq	36.2

One IOT prototype acoustic sensor was also installed at this location, which was running normally during August 12, 2022, which captured the overall sound levels as per minute intervals, and audio recording, which will be processed later to determine the overall and spectral measurement results.

Remote Site 7

One off-the-shelf acoustic IOT sensor was installed at this location, approximately 2020 m west to capture the noise levels, which was running normally during the period of July 12 – Sept 14, 2022, 2022, which are listed in the following table.

Table 16 Noise Levels captured at Remote Site 6

Sound Level Type	Sound levels (dBA)
L10	37.8
L50	37.5
L90	37.1
L95	37.0
Leq	37.5

Low Frequency Noise Analysis

In order to investigate the low frequency noise propagations of the selected facility, a secondary analysis was conducted to determine the existence of LFN at the selected five remote sites for each of the winter and summer study, which had the detailed noise measurement data. According to the Guidelines, an LFN component exists when:

- the dBC minus dBA sound level is equal to or greater than 20 dB, and
- there is a clear tonal component at a $^{1}/_{3}$ octave frequency of 250 Hz or below.

Detailed 1/3 octave band analysis were conducted to determine the existence of Low Frequency Noise (LFN) at the fence line location and five selected remote sites for each of the winter and summer studies. The nighttime periods were selected to study in greater detail and when other environmental contamination was lower. Tables 17A and 17B summarizes the LFN analysis results for the nighttime periods of the survey for the remote sites during the wintertime and summertime study periods. Fence line monitoring results were also included. The values of dBC-dBA are highlighted if the 20 dB criterion is exceeded.

This methodology follows current best practise methods in the BC OGC Guideline and other jurisdictions in Alberta.

Table 17A: Low Frequency Noise Data – Winter Study

Period	Date (2022)	Fenceline			Remote Site 1			Remote Site 2			Remote Site 3			Remote Site 4			Remote Site 5		
		Tonal Component Detected	dBC - dBA	LFN Identified	Tonal Component Detected	dBC - dBA	LFN Identified	Tonal Component Detected	dBC - dBA	LFN Identified	Tonal Component Detected	dBC - dBA	LFN Identified	Tonal Component Detected	dBC - dBA	LFN Identification	Tonal Component Detected	dBC - dBA	LFN Identified
Night 01	Mar 24 - Mar 25	None	18.8	No	None	15.0	No	None	14.4	No	31.5 Hz	11.5	No	-	-	-	-	-	-
Night 02	Mar 25 - Mar 26	None	17.3	No	None	19.6	No	None	12.3	No	250 Hz	8.2	No	None	8.2	No	-	-	-
Night 03	Mar 26 - Mar 27	None	18.0	No	None	16.4	No	None	16.0	No	None	12.9	No	None	13.4	No	-	-	-
Night 04	Mar 27 - Mar 28	None	18.5	No	None	12.0	No	None	16.2	No	None	13.8	No	None	12.0	No	-	-	-
Night 05	Mar 28 - Mar 29	None	19.5	No	None	17.1	No	None	17.1	No	None	15.4	No	None	17.5	No	-	-	-
Night 06	Mar 29 - Mar 30	31.5 Hz	20.6	Yes	None	15.8	No	None	21.5	No	None	13.2	No	40 Hz	18.8	No	-	-	-
Night 07	Mar 30 - Mar 31	None	20.7	No	None	30.0	No				None	24.2	No	None	22.8	No	None	27.3	No
Night 08	Mar 31 - Apr 01	None	18.7	No	None	16.6	No	None	18.2	No	None	16.1	No	None	15.9	No	None	21.7	No
Night 09	Apr 01 - Apr 02	None	19.5	No	None	27.9	No	None	24.6	No	None	25.2	No	None	20.7	No	None	27.1	No
Night 10	Apr 02 - Apr 03	None	18.3	No	None	23.4	No	None	23.4	No	None	18.6	No	None	15.4	No	None	20.9	No
Night 11	Apr 03 - Apr 04	None	18.8	No	None	25.0	No	None	24.8	No	None	23.6	No	None	16.2	No	None	22.9	No
Night 12	Apr 04 - Apr 05	None	19.2	No	None	14.9	No	None	19.2	No	None	12.3	No	None	17.1	No	None	20.3	No
Night 13	Apr 05 - Apr 06	None	20.9	No	None	30.0	No				None	24.2	No	None	23.8	No	None	28.1	No
Night 14	Apr 06 - Apr 07	None	18.9	No	None	18.1	No	None	19.5	No	None	17.1	No	-	-	-	None	20.8	No
Night 15	Apr 07 - Apr 08	None	19.7	No	None	10.4	No	None	14.6	No	None	12.4	No	-	-	-	None	16.9	No
Night 16	Apr 08 - Apr 09	None	19.2	No	None	27.0	No	None	23.5	No	None	19.2	No	-	-	-	None	26.3	No
Night 17	Apr 09 - Apr 10	40 Hz	19.3	No	None	16.3	No	None	16.1	No	None	15.5	No	-	-	-	None	19.4	No
Night 18	Apr 10 - Apr 11	None	18.6	No	None	16.6	No	None	14.1	No	None	16.4	No	-	-	-	-	-	-
Night 19	Apr 11 - Apr 12	None	18.8	No	None	29.3	No	-	-	-	None	15.9	No	None	21.8	No	-	-	-
Night 20	Apr 12 - Apr 13	40 Hz, 50 Hz	17.5	No	None	19.1	No	None	13.9	No	None	17.1	No	-	-	-	-	-	-
Night 21	Apr 13 - Apr 14	40 Hz	19.7	No	None	10.5	No	None	14.3	No	None	18.4	No	-	-	-	-	-	-
Night 22	Apr 14 - Apr 15	None	18.9	No	None	9.8	No	None	13.4	No	None	17.6	No	-	-	-	-	-	-

Table 17A: Low Frequency Noise Data – Winter Study

Period	Date (2022)	Fenceline			Remote Site 1			Remote Site 2			Remote Site 3			Remote Site 4			Remote Site 5		
		Tonal Component Detected	dBC - dBA	LFN Identified	Tonal Component Detected	dBC - dBA	LFN Identified	Tonal Component Detected	dBC - dBA	LFN Identified	Tonal Component Detected	dBC - dBA	LFN Identified	Tonal Component Detected	dBC - dBA	LFN Identification	Tonal Component Detected	dBC - dBA	LFN Identified
Night 23	Apr 15 - Apr 16	None	18.6	No	None	14.5	No	None	12.8	No	None	17.0	No	-	-	-	-	-	-
Night 24	Apr 16 - Apr 17	None	19.6	No	None	9.7	No	None	12.0	No	None	14.4	No	None	14.0	No	-	-	-
Night 25	Apr 17 - Apr 18	None	19.9	No	None	28.8	No	None	24.3	No	None	18.8	No	-	-	-	-	-	-
Night 26	Apr 18 - Apr 19	None	18.3	No	None	17.8	No	None	16.8	No	None	19.7	No	-	-	-	-	-	-
Night 27	Apr 19 - Apr 20	None	14.2	No	None	9.9	No	None	11.7	No	None	20.2	No	-	-	-	-	-	-
Night 28	Apr 20 - Apr 21	None	15.1	No	None	5.9	No	None	9.5	No	None	9.5	No	-	-	-	-	-	-
Night 29	Apr 21 - Apr 22	None	16.9	No	None	7.9	No	None	12.0	No	None	14.2	No	-	-	-	-	-	-
Night 30	Apr 22 - Apr 23	31.5 Hz	20.3	Yes	None	13.8	No	None	7.2	No	None	23.1	No	-	-	-	-	-	-
Night 31	Apr 23 - Apr 24	None	16.8	No	None	18.4	No	None	15.5	No	None	15.5	No	None	15.9	No	-	-	-
Night 32	Apr 24 - Apr 25	31.5 Hz	17.8	No	None	11.9	No	None	15.1	No	None	18.2	No	-	-	-	-	-	-
Night 33	Apr 25 - Apr 26	None	16.3	No	None	19.8	No	None	17.1	No	None	20.4	No	None	15.6	No			
Night 34	Apr 26 - Apr 27	31.5 Hz	18.8	No	None	24.8	No	None	21.3	No	-	-	-	-	-	-	-	-	-
Night 35	Apr 27 - Apr 28	None	20.3	No	None	30.8	No	None	21.6	No	-	-	-	-	-	-	-	-	-
Night 36	Apr 28 - Apr 29	40 Hz	19.5	No	None	29.2	No	None	15.8	No	-	-	-	-	-	-	-	-	-
Night 37	Apr 29 - Apr 30	40 Hz	18.1	No	None	8.7	No	None	13.0	No	None	11.0	No	-	-	-	-	-	-
Night 38	Apr 30 - May 01	40 Hz	17.1	No	None	9.3	No	None	14.2	No	None	14.2	No	-	-	-	-	-	-
Night 39	May 01 - May 02	None	15.9	No	None	10.3	No	None	12.7	No	None	15.2	No	-	-	-	-	-	-
Night 40	May 02 - May 03	None	16.4	No	None	17.8	No	None	18.0	No	None	23.7	No	31.5 Hz	17.2	No	-	-	-
Night 41	May 03 - May 04	None	18.9	No	None	28.6	No	None	26.0	No	None	24.3	No	None	20.1	No	-	-	-
Night 42	May 04 - May 05	None	18.6	No	None	15.2	No	None	16.3	No	None	17.3	No	31.5 Hz	18.4	No	-	-	-

Table 17A: Low Frequency Noise Data – Winter Study

Period	Date (2022)	Fenceline			Remote Site 1			Remote Site 2			Remote Site 3			Remote Site 4			Remote Site 5		
		Tonal Component Detected	dBC - dBA	LFN Identified	Tonal Component Detected	dBC - dBA	LFN Identified	Tonal Component Detected	dBC - dBA	LFN Identified	Tonal Component Detected	dBC - dBA	LFN Identified	Tonal Component Detected	dBC - dBA	LFN Identification	Tonal Component Detected	dBC - dBA	LFN Identified
Night 43	May 05 - May 06	None	17.8	No	None	25.3	No	None	18.1	No	None	23.1	No	40 Hz	21.9	Yes	-	-	-
Night 44	May 06 - May 07	None	19.7	No	None	25.7	No	None	19.1	No	None	24.5	No	None	25.7	No	-	-	-
Night 45	May 07 - May 08	None	17.9	No	None	30.1	No	None	25.1	No	None	21.1	No	None	16.2	No	-	-	-
Night 46	May 08 - May 09	None	19.3	No	None	30.2	No	None	22.3	No	None	20.8	No	100 Hz	20.5	Yes	-	-	-
Night 47	May 09 - May 10	None	20.1	No	None	12.8	No	None	16.3	No	None	20.4	No	None	17.5	No	-	-	-
Night 48	May 10 - May 11	None	17.8	No	None	24.3	No	None	25.1	No	None	20.6	No	31.5 Hz	19.3	No	-	-	-
Night 49	May 11 - May 12	None	18.4	No	None	10.8	No	None	19.7	No	None	13.8	No	31.5 Hz	21.1	Yes	-	-	-
Night 50	May 12 - May 13	31.5 Hz	20.0	Yes	None	10.5	No	None	13.0	No	None	16.2	No	31.5 Hz, 40 Hz	24.0	Yes	-	-	-
Night 51	May 13 - May 14	None	19.1	No	None	27.6	No	None	25.3	No	None	24.0	No	-	-	-	-	-	-
Night 52	May 14 - May 15	None	19.4	No	None	15.2	No	None	16.7	No	None	17.7	No	-	-	-	-	-	-
Night 53	May 15 - May 16	31.5 Hz	19.8	No	None	13.0	No	None	13.1	No	None	16.8	No	-	-	-	-	-	-
Night 54	May 16 - May 17	None	19.0	No	None	27.2	No	None	16.7	No	None	18.9	No	-	-	-	-	-	-
Night 55	May 17 - May 18	None	18.9	No	None	9.7	No	None	13.3	No	None	18.8	No	-	-	-	-	-	-

Table 17B: Low Frequency Noise Data – Summer Study

Period	Date (2022)	Fenceline			Remote Site 1			Remote Site 2			Remote Site 3			Remote Site 4			Remote Site 5		
		Tonal Component Detected	dBC - dBA	LFN Identified	Tonal Component Detected	dBC - dBA	LFN Identified	Tonal Component Detected	dBC - dBA	LFN Identified	Tonal Component Detected	dBC - dBA	LFN Identified	Tonal Component Detected	dBC - dBA	LFN Identified	Tonal Component Detected	dBC - dBA	LFN Identified
Night 01	Jul 12 - Jul 13	250 Hz	10.4	No	-	-	-	-	-	-	-	-	-	None	10.6	No	None	13.7	No
Night 02	Jul 13 - Jul 14	250 Hz	10.1	No	None	13.6	No	None	9.5	No	None	14.0	No	None	11.2	No	None	12.1	No
Night 03	Jul 14 - Jul 15	250 Hz	9.9	No	None	12.3	No	None	11.3	No	None	16.4	No	None	10.6	No	None	16.7	No
Night 04	Jul 15 - Jul 16	250 Hz	9.3	No	None	14.8	No	None	11.6	No	None	17.0	No	None	11.3	No	None	15.3	No
Night 05	Jul 16 - Jul 17	250 Hz	9.0	No	None	16.6	No	None	12.1	No	None	16.4	No	None	10.4	No	None	14.4	No
Night 06	Jul 17 - Jul 18	250 Hz	9.2	No	None	14.5	No	None	13.4	No	None	14.5	No	None	13.2	No	None	12.7	No
Night 07	Jul 18 - Jul 19	250 Hz	12.3	No	None	20.8	No	None	18.5	No	None	13.5	No	None	15.9	No	None	17.9	No
Night 08	Jul 19 - Jul 20	250 Hz	9.5	No	None	13.7	No	None	13.0	No	None	14.4	No	100 Hz, 125 Hz	11.0	No	None	8.8	No
Night 09	Jul 20 - Jul 21	250 Hz	10.1	No	None	17.1	No	None	13.1	No	None	14.8	No	None	12.5	No	None	14.7	No
Night 10	Jul 21 - Jul 22	63 Hz, 250 Hz	10.2	No	None	13.9	No	None	14.2	No	None	15.6	No	None	11.9	No	None	6.2	No
Night 11	Jul 22 - Jul 23	250 Hz	9.3	No	None	14.1	No	None	15.9	No	None	15.9	No	None	12.6	No	None	10.1	No
Night 12	Jul 23 - Jul 24	250 Hz	9.7	No	None	21.2	No	None	16.0	No	None	14.5	No	None	13.3	No	None	8.7	No
Night 13	Jul 24 - Jul 25	None	9.6	No	None	17.2	No	-	-	-	-	-	-	-	-	-	None	7.4	No
Night 14	Jul 25 - Jul 26	63 Hz, 250 Hz	8.5	No	None	13.9	No	-	-	-	-	-	-	-	-	-	None	10.2	No
Night 15	Jul 26 - Jul 27	63 Hz, 250 Hz	8.3	No	None	18.4	No	-	-	-	-	-	-	-	-	-	None	11.2	No
Night 16	Jul 27 - Jul 28	160 Hz	9.1	No	None	15.7	No	None	16.1	No	None	18.4	No	-	-	-	None	12.8	No
Night 17	Jul 28 - Jul 29	160 Hz	9.5	No	None	21.1	No	None	19.7	No	None	17.5	No	-	-	-	None	14.8	No
Night 18	Jul 29 - Jul 30	63 Hz, 250 Hz	8.1	No	None	14.1	No	None	9.1	No	None	12.2	No	-	-	-	None	10.5	No
Night 19	Jul 30 - Jul 31	63 Hz, 250 Hz	8.4	No	None	12.2	No	None	14.6	No	None	12.3	No	-	-	-	None	6.8	No
Night 20	Jul 31 - Aug 01	250 Hz	8.3	No	None	14.8	No	None	17.0	No	None	14.2	No	-	-	-	None	11.7	No
Night 21	Aug 01 - Aug 02	63 Hz, 250 Hz	8.0	No	None	14.8	No	None	14.9	No	None	11.6	No	-	-	-	None	9.9	No

Table 17B: Low Frequency Noise Data – Summer Study

Period	Date (2022)	Fenceline			Remote Site 1			Remote Site 2			Remote Site 3			Remote Site 4			Remote Site 5		
		Tonal Component Detected	dBC - dBA	LFN Identified	Tonal Component Detected	dBC - dBA	LFN Identified	Tonal Component Detected	dBC - dBA	LFN Identified	Tonal Component Detected	dBC - dBA	LFN Identified	Tonal Component Detected	dBC - dBA	LFN Identified	Tonal Component Detected	dBC - dBA	LFN Identified
Night 22	Aug 02 - Aug 03	63 Hz, 250 Hz	7.7	No	None	13.2	No	None	13.1	No	None	16.5	No	-	-	-	None	14.0	No
Night 23	Aug 03 - Aug 04	63 Hz, 250 Hz	8.6	No	None	22.1	No	None	10.2	No	None	9.8	No	-	-	-	None	13.7	No
Night 24	Aug 04 - Aug 05	63 Hz, 250 Hz	7.7	No	None	18.4	No	None	12.4	No	None	13.2	No	-	-	-	125 Hz	8.5	No
Night 25	Aug 05 - Aug 06	63 Hz, 250 Hz	10.3	No	None	19.1	No	None	17.4	No	None	11.9	No	-	-	-	None	19.7	No
Night 26	Aug 06 - Aug 07	250 Hz	9.6	No	None	19.4	No	100 Hz	18.0	No	None	11.4	No	-	-	-	None	15.8	No
Night 27	Aug 07 - Aug 08	250 Hz	9.3	No	None	17.4	No	None	19.8	No	None	21.9	No	-	-	-	None	10.7	No
Night 28	Aug 08 - Aug 09	250 Hz	8.8	No	None	20.3	No	-	-	-	-	-	-	-	-	-	None	8.4	No
Night 29	Aug 09 - Aug 10	250 Hz	8.7	No	None	20.9	No	-	-	-	None	14.7	No	None	13.0	No	None	12.9	No
Night 30	Aug 10 - Aug 11	250 Hz	12.5	No	None	23.8	No	-	-	-	None	18.9	No	100 Hz, 125 Hz	14.1	No	None	10.4	No
Night 31	Aug 11 - Aug 12	160 Hz	9.1	No	None	19.9	No	-	-	-	None	14.3	No	None	14.1	No	None	10.0	No
Night 32	Aug 12 - Aug 13	160 Hz	9.0	No	None	20.7	No	-	-	-	None	16.7	No	125 Hz	13.8	No	None	10.3	No
Night 33	Aug 13 - Aug 14	160 Hz	9.1	No	None	17.6	No	-	-	-	None	17.1	No	None	14.4	No	None	14.1	No
Night 34	Aug 14 - Aug 15	160 Hz	9.1	No	None	6.7	No	-	-	-	None	12.8	No	None	13.2	No	None	10.9	No
Night 35	Aug 15 - Aug 16	160 Hz	9.1	No	None	9.4	No	-	-	-	None	17.5	No	None	12.3	No	None	14.4	No
Night 36	Aug 16 - Aug 17	160 Hz	9.2	No	None	20.0	No	-	-	-	None	16.4	No	None	12.3	No	None	14.6	No

Table 17B: Low Frequency Noise Data – Summer Study

Period	Date (2022)	Fenceline			Remote Site 1			Remote Site 2			Remote Site 3			Remote Site 4			Remote Site 5		
		Tonal Component Detected	dBC - dBA	LFN Identified	Tonal Component Detected	dBC - dBA	LFN Identified	Tonal Component Detected	dBC - dBA	LFN Identified	Tonal Component Detected	dBC - dBA	LFN Identified	Tonal Component Detected	dBC - dBA	LFN Identified	Tonal Component Detected	dBC - dBA	LFN Identified
Night 37	Aug 17 - Aug 18	250 Hz	8.8	No	None	14.1	No	-	-	-	None	16.8	No	125 Hz, 250 Hz	13.8	No	None	12.7	No
Night 38	Aug 18 - Aug 19	160 Hz	8.9	No	None	12.8	No	-	-	-	None	13.7	No	None	12.1	No	None	7.6	No
Night 39	Aug 19 - Aug 20	160 Hz	9.3	No	None	22.7	No	-	-	-	None	13.3	No	None	10.5	No	None	17.3	No
Night 40	Aug 20 - Aug 21	160 Hz	9.2	No	None	14.5	No	-	-	-	None	16.3	No	None	10.5	No	-	-	-
Night 41	Aug 21 - Aug 22	160 Hz	9.1	No	None	13.8	No	-	-	-	-	-	-	None	14.8	No	-	-	-
Night 42	Aug 22 - Aug 23	250 Hz	8.3	No	None	14.1	No	-	-	-	-	-	-	None	9.4	No	-	-	-
Night 43	Aug 23 - Aug 24	250 Hz	8.3	No	None	13.9	No	-	-	-	-	-	-	None	9.3	No	None	8.6	No
Night 44	Aug 24 - Aug 25	250 Hz	8.1	No	250 Hz	16.2	No	-	-	-	-	-	-	None	10.3	No	None	7.9	No
Night 45	Aug 25 - Aug 26	250 Hz	8.2	No	None	14.6	No	-	-	-	-	-	-	-	-	-	None	8.3	No
Night 46	Aug 26 - Aug 27	63 Hz, 250 Hz	9.4	No	None	16.9	No	-	-	-	-	-	-	-	-	-	None	6.8	No
Night 47	Aug 27 - Aug 28	63 Hz, 250 Hz	8.5	No	None	14.6	No	-	-	-	-	-	-	-	-	-	None	15.1	No
Night 48	Aug 28 - Aug 29	250 Hz	8.7	No	None	15.8	No	-	-	-	-	-	-	-	-	-	250 Hz	17.3	No
Night 49	Aug 29 - Aug 30	250 Hz	8.7	No	None	16.4	No	-	-	-	-	-	-	-	-	-	250 Hz	19.9	No
Night 50	Aug 30 - Aug 31	250 Hz	9.0	No	None	14.4	No	None	16.6	No	None	17.3	No	None	11.9	No	63 Hz	17.0	No
Night 51	Aug 31 - Sep 01	63 Hz, 250 Hz	8.6	No	-	-	-	None	16.7	No	None	14.6	No	None	10.3	No	-	-	-

Table 17B: Low Frequency Noise Data – Summer Study

Period	Date (2022)	Fenceline			Remote Site 1			Remote Site 2			Remote Site 3			Remote Site 4			Remote Site 5		
		Tonal Component Detected	dBC - dBA	LFN Identified	Tonal Component Detected	dBC - dBA	LFN Identified	Tonal Component Detected	dBC - dBA	LFN Identified	Tonal Component Detected	dBC - dBA	LFN Identified	Tonal Component Detected	dBC - dBA	LFN Identified	Tonal Component Detected	dBC - dBA	LFN Identified
Night 52	Sep 01 - Sep 02	63 Hz, 250 Hz	8.6	No	-	-	-	None	18.4	No	None	19.2	No	-	-	-	-	-	-
Night 53	Sep 02 - Sep 03	63 Hz, 250 Hz	7.9	No	-	-	-	None	16.5	No	None	17.3	No	-	-	-	-	-	-
Night 54	Sep 03 - Sep 04	63 Hz, 250 Hz	8.5	No	-	-	-	None	18.8	No	None	16.5	No	-	-	-	-	-	-
Night 55	Sep 04 - Sep 05	63 Hz, 250 Hz	9.5	No	-	-	-	None	16.3	No	None	12.1	No	-	-	-	-	-	-
Night 56	Sep 05 - Sep 06	63 Hz, 250 Hz	8.6	No	-	-	-	31.5 Hz	17.9	No	None	12.1	No	-	-	-	-	-	-
Night 57	Sep 06 - Sep 07	63 Hz, 250 Hz	8.3	No	-	-	-	None	10.3	No	None	15.7	No	-	-	-	-	-	-
Night 58	Sep 07 - Sep 08	63 Hz, 250 Hz	8.3	No	-	-	-	None	11.4	No	None	11.4	No	-	-	-	-	-	-
Night 59	Sep 08 - Sep 09	63 Hz, 250 Hz	8.7	No	-	-	-	None	14.7	No	None	12.4	No	-	-	-	-	-	-
Night 60	Sep 09 - Sep 10	63 Hz, 250 Hz	9.6	No	-	-	-	31.5 Hz	21.0	Yes	31.5 Hz	13.3	No	-	-	-	-	-	-
Night 61	Sep 10 - Sep 11	63 Hz, 250 Hz	9.1	No	-	-	-	None	16.3	No	None	14.4	No	-	-	-	-	-	-
Night 62	Sep 11 - Sep 12	63 Hz, 250 Hz	9.5	No	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Night 63	Sep 12 - Sep 13	63 Hz, 250 Hz	9.2	No	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Night 64	Sep 13 - Sep 14	63 Hz, 250 Hz	8.5	No	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Wintertime Study:

During the wintertime monitoring period between March 24 and May 19, at the fence line location, there were several nights during which dBC-dBA are higher than 20 dB, and there were also some tones recognized at this location shown in Table 17A. Low frequency tones were also identified during the nighttime periods of May 5-6, 8-9, 11-12, and 12-13, 2022 at Remote Site 4, the dominant frequency of the tones at Remote Site 4 and the facility fenceline did not consistently match, suggesting that the tones captured at Remote Site 4 could have originated from another noise source, or providing unreliable correlation.

Additional narrow band FFT analysis as per Class 1 meters during the nighttime between March 31 and April 1 shown in Figure 14A indicated that several spikes at 50 Hz, 75 Hz, 87.5 Hz,100 Hz, 112.5 Hz, and 150Hz can be recognized at remote sites R04 and R05, but only the 50 Hz tone is shared at the facility fenceline. This further suggests that other noise sources may have contributed to the tonal results at R04 and R05.

Observations at the facility fenceline indicate the dominant tonal frequency emanating from the facility changed over time. Sometimes centered at 31.5Hz, and other times at 40Ha or 50Hz. This indicates that tonal noise emissions are dynamic, requiring time matched fenceline and remote location assessment to identify correlation. From this, the investigation criteria for LFN concerns should include measurement at multiple locations in order to confirm source attribution for low frequency tones.

Summertime Study:

During the summertime monitoring period between July 12 and September 14, at the fence line location, there was no day or night during which dBC-dBA are higher than 20 dB, and there were tones at 63 Hz, 160 Hz or 250 Hz identified consistently at this location.

The secondary analysis also found tonal components existed at 31.5 Hz, 80 Hz, 100 Hz, 125 Hz, or 250 Hz for some of the nighttime periods at remote monitoring sites, these rarely corelated in frequency to the fenceline monitors.

Additional narrow band FFT analysis as per Class 1 meters during the nighttime between July 19-20 shown in Figure 14B indicated that several spikes at 7.5 Hz, 20 Hz, 22.5 Hz, 30 Hz, 45 Hz, 62 Hz, 67.5 Hz, 112 Hz, 120 Hz, 150Hz, and 180 Hz can be recognized at the fenceline location and the remote sites R02-R04, and are not recognizable at the remote sites R01 and R05. Of the tones identified, the strongest correlation between the facility fence line and remote sites was 30Hz. This suggests that some of the tonal components assessed at the remote sites were not attributable to the subject facility.

Tonal Assessment for Prototype IoT Sensor:

FFT analysis shown in Figure 14C also indicated that the almost same spikes can be found from both the Class 1 meter and prototype IoT sensor at the fenceline location. The prototype sensor did provide reliable results, which can be used for FFT analysis and tonal components recognition, but may not be reliable for calibrated dBA and need longer measurement time if further away from the facility.

The current methodologies for assessing LFN may not be effective for investigating multiple potential LFN noise sources where the source of the noise is not obvious. For these situations additional consideration for fenceline monitoring and narrow band FFT will reduce false positive attribution error as well as increase confidence when positive attribution is identified. Recommend updating guideline procedure for situations with no obvious source to include simultaneous narrow band noise monitoring at facility fenceine and subject receiver.

Figure 14A FFT Analysis of the Winter Facility
(Nighttime 0:00-0:10am Mar. 31- Apr 1, 2022)

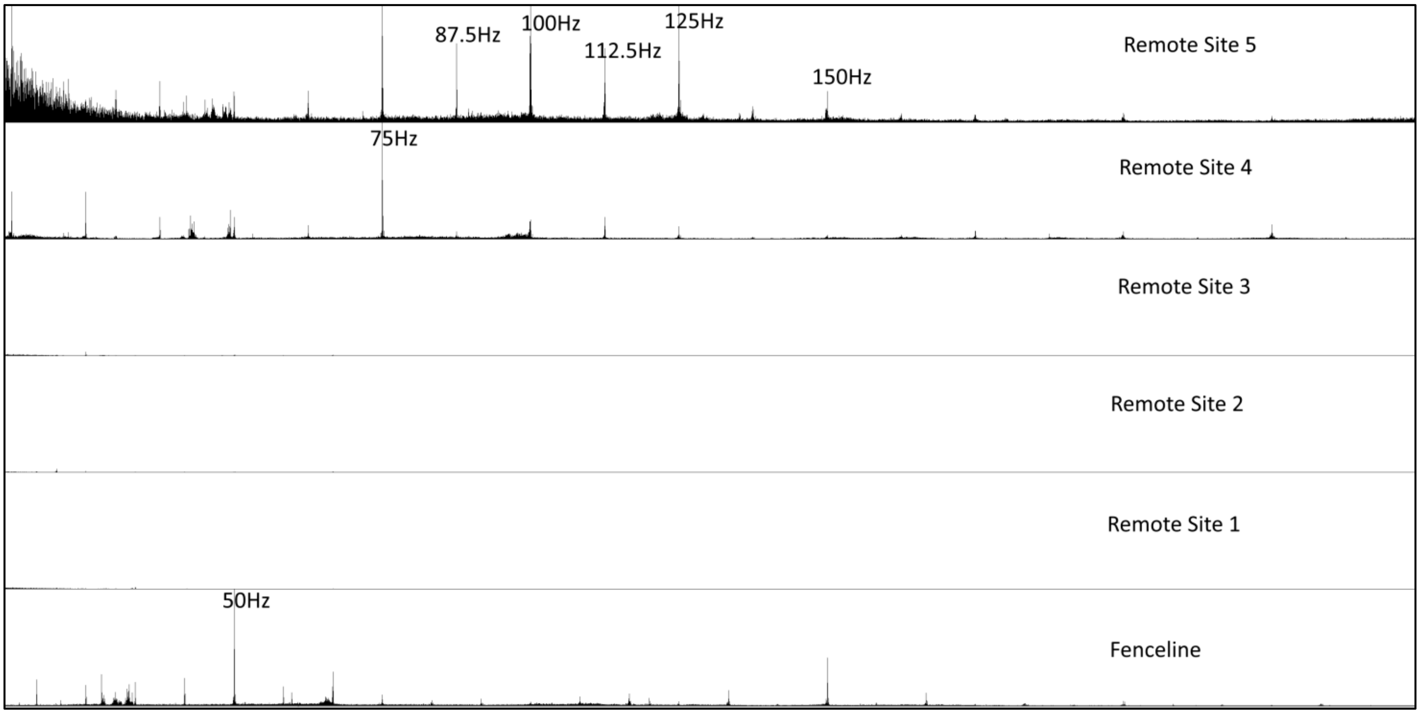


Figure 14B FFT Analysis of the Summer Facility

(0:00am-0:10am nighttime July 19-20, 2022)

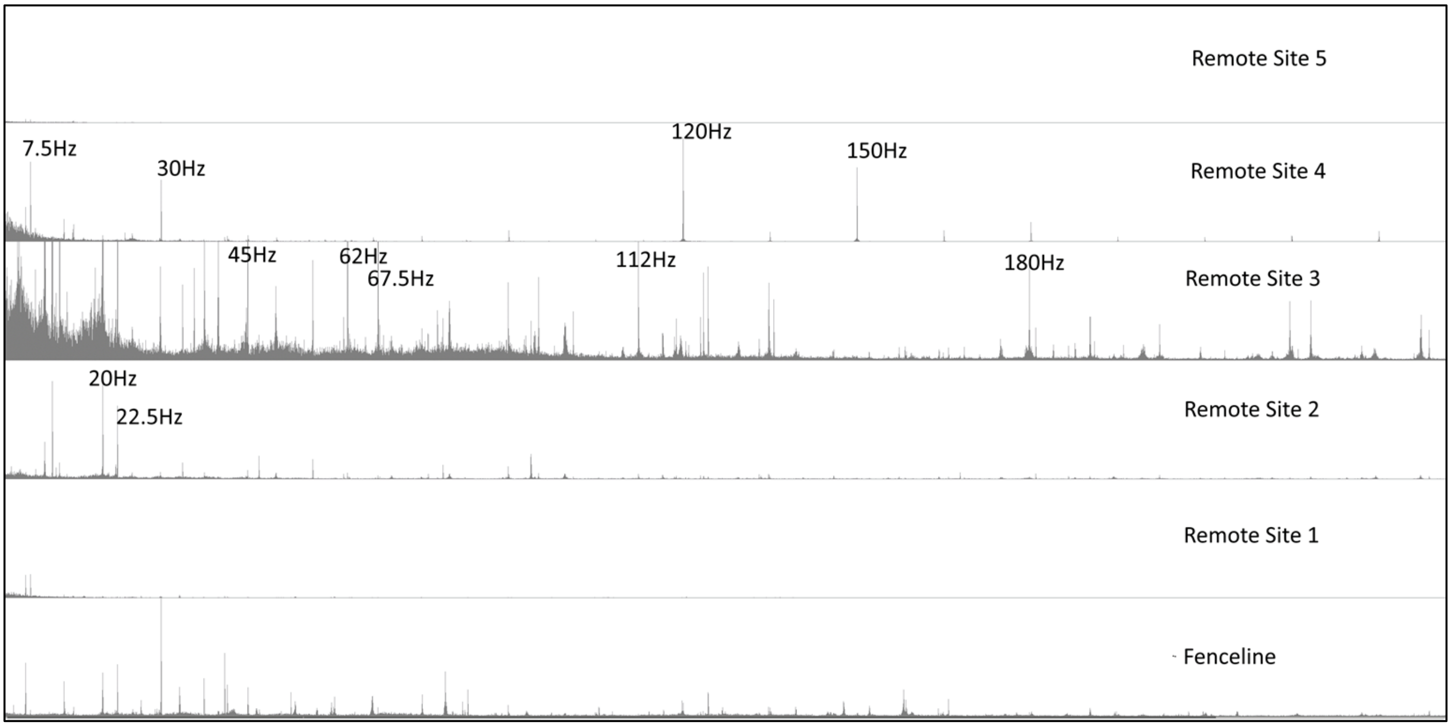
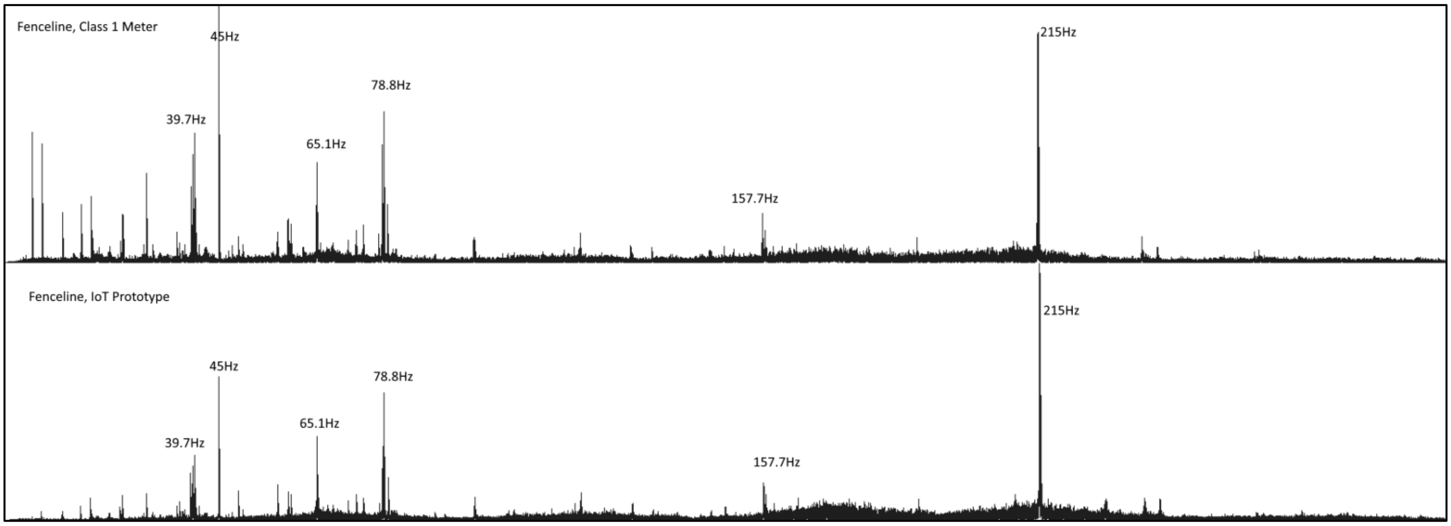


Figure 14C FFT Analysis of the Summer Facility (Class 1 Meter and IoT Prototype)

(22:00pm-1:00am nighttime Aug. 12-13, 2022)

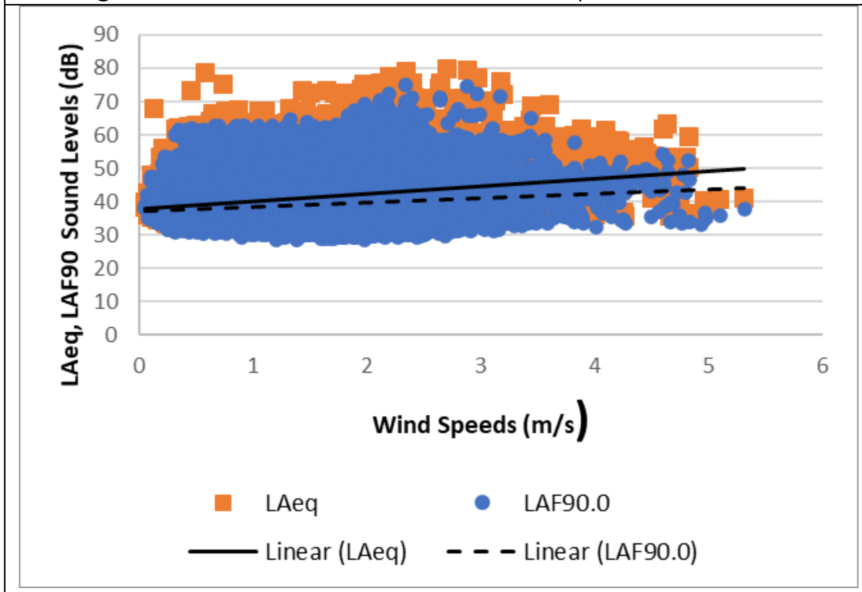


Analysis of Sound Level Results with Wind Conditions

During this study period, there were some variations on the weather conditions, which are normal in this area. All the data available from the weather monitor in the study area shows most of the time at the monitoring locations were calm to winds with speed less than 6 m/s.

Based on the available measurements during the winter and summer study, the noise levels were investigated with the wind speeds as per one-minute period. Figure 15A/B and 16A/B show the sound pressure levels with the wind speeds for the two selected locations for each of the winter and summer studies.

Figure 15A Correlation SPL with Wind Speed- Winter RS4



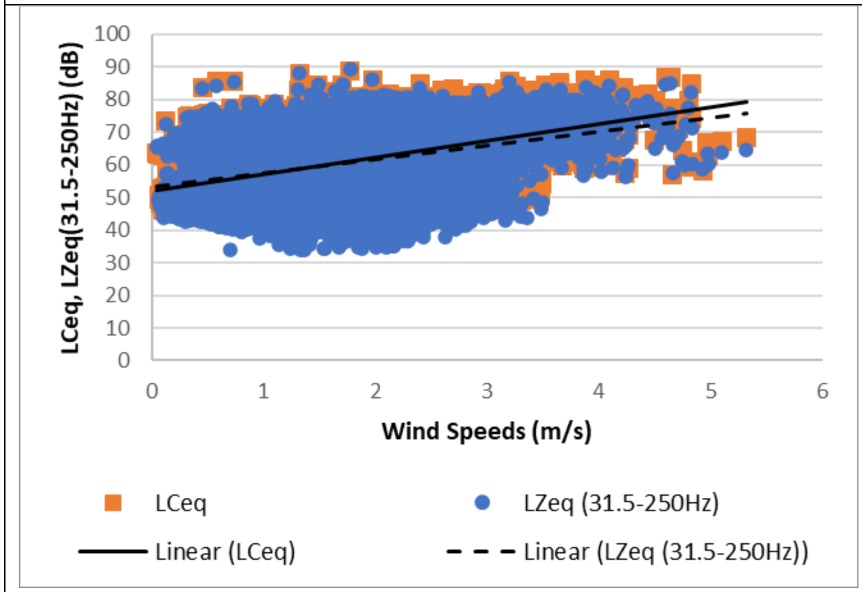
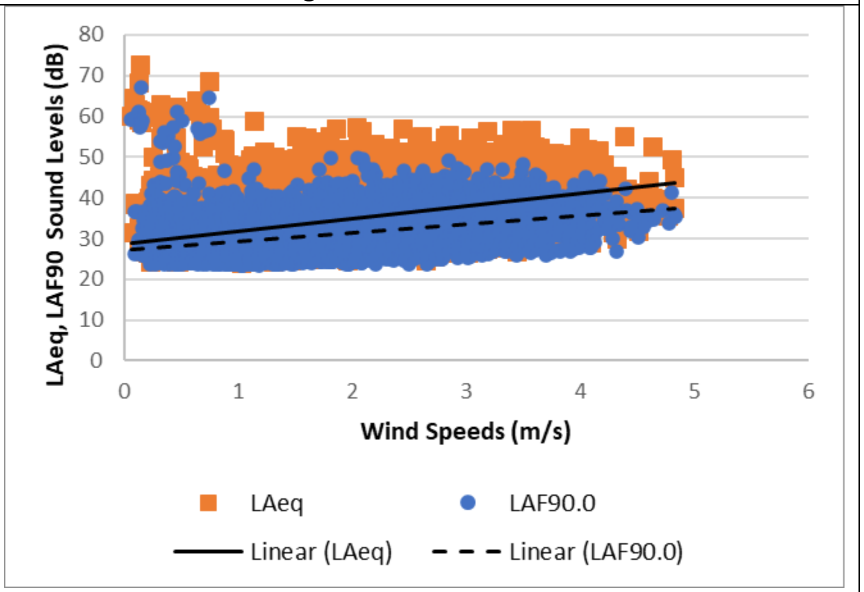


Figure 15B Winter RS5



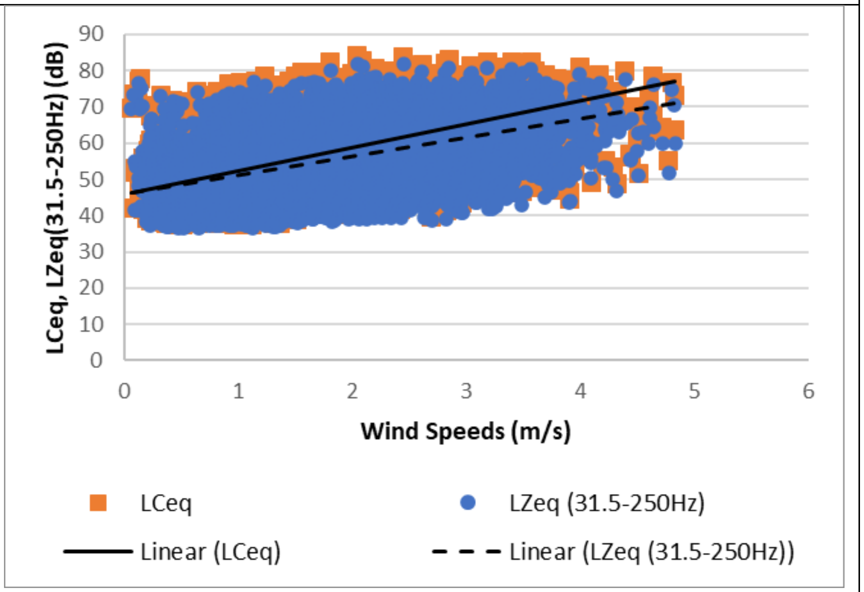
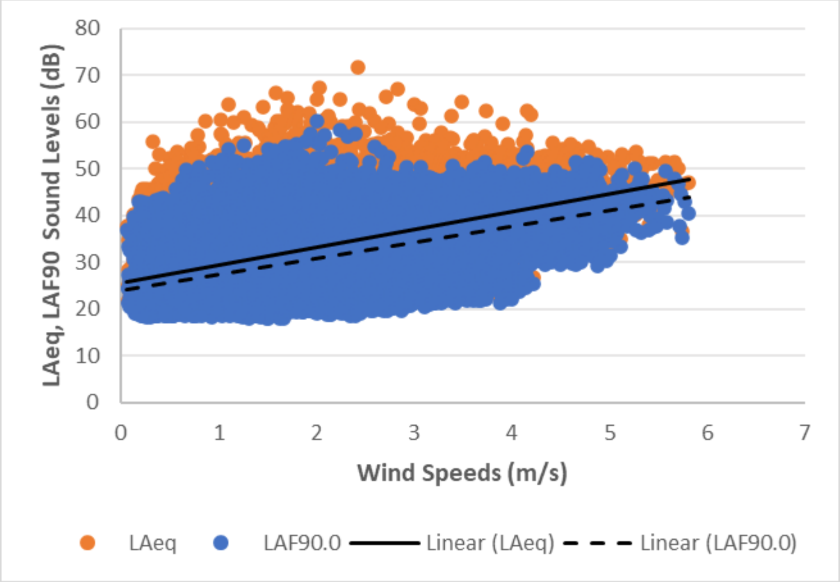
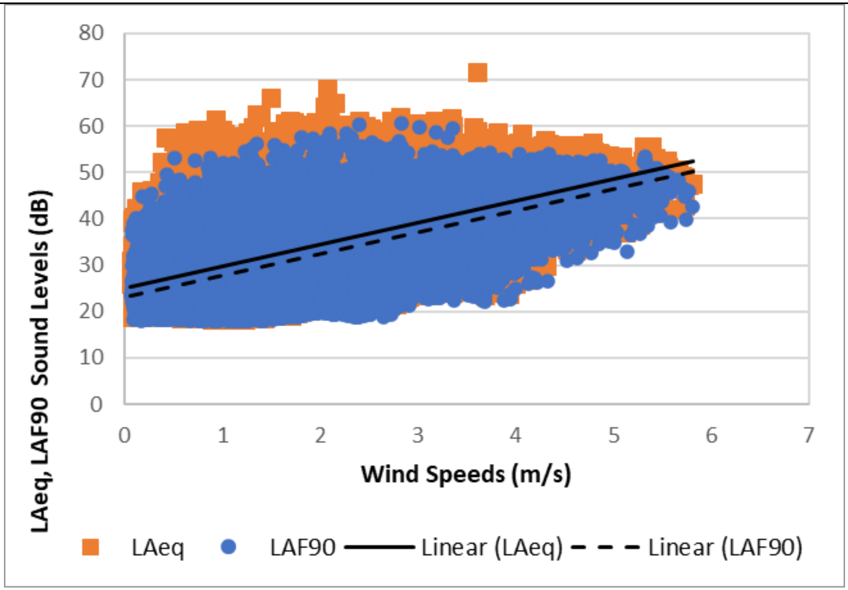
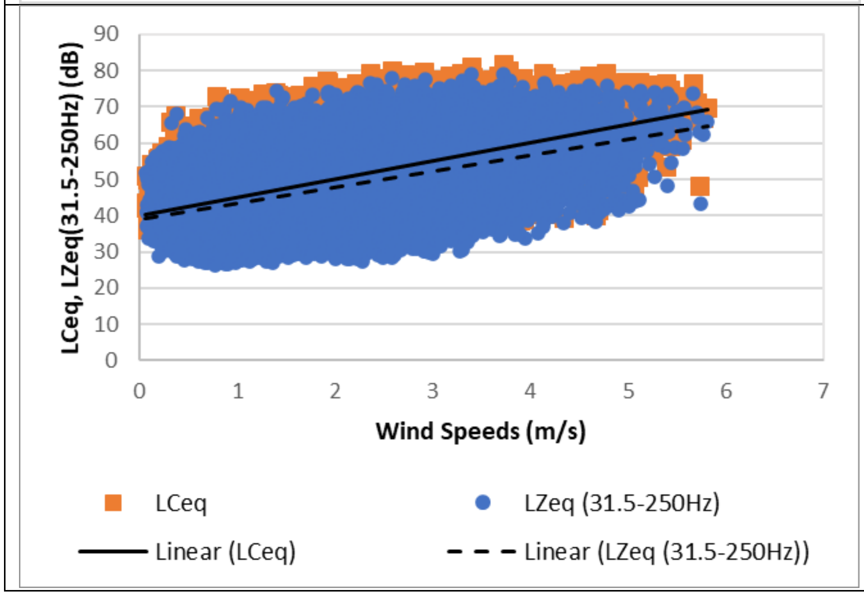
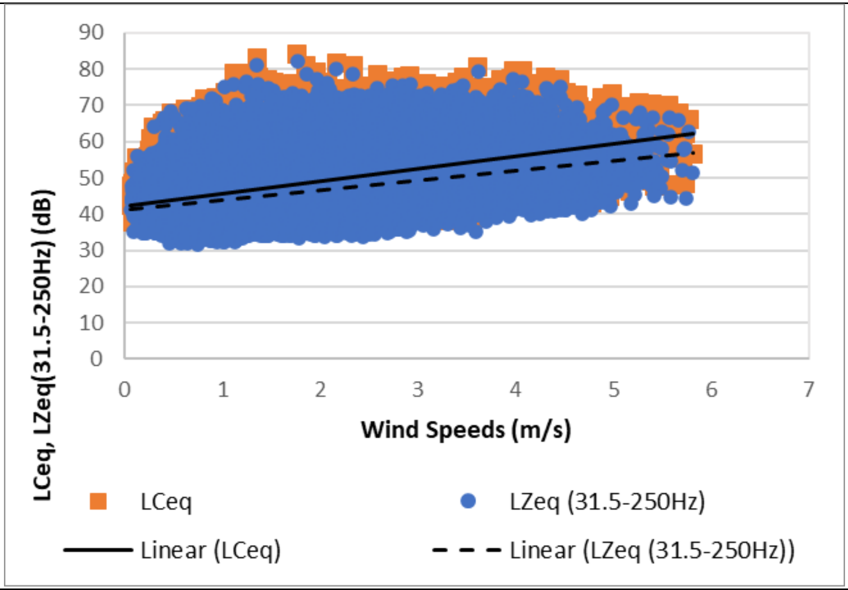


Figure 16A Summer RS2	Figure 16B Summer RS3
	
	

The results indicate that all the noise levels including overall noise levels LeqA and leqC, Leq90 and noise level for low frequency range (31.5 Hz-250 Hz) increased with wind speed; LeqC will have slight higher rate than LeqA, which may be because the C-Weighting includes nearly all of the low frequency energy in a signal and more related with the wind induced noise. LeqC would be more than 60 dB, which indicated wind noise became more obvious when the wind was above 3 m/s speed in the winter study and above 5 m/s speed in the winter study.

LAF90, normally considered as background noise level, also changes with wind speed, but with a lower rate; the background levels were normally higher than 25 dBA as per the regression analysis, which means the facility level if lower than 25 dBA would possibly cannot be recognized at the location; noise level for low frequency range (31.5 Hz-250 Hz) were close to the dBC levels at the selected locations, which means that most of the sound energy at these remote sites were in the low frequency range.

Noise Predictions

In order to assess the potential impact from the selected typical oil and gas facility, noise prediction model was built in the study area. The method used in the NIA follows the requirements set forth in the regulations.

- The study area and facility physical layouts were determined from drawings obtained by the client, satellite images and field reconnaissance conducted by PAAE staff in March, 2022 for the winter study, and in July, 2022 for the summer study.
- The Sound Power Levels (PWL) were determined for the major facility noise sources through field diagnostics.
- Field diagnostics were performed with a Sound Intensity Level meter to quantify the subject facility PWL in detail. The noise model used for this study was calibrated using reference SPL measurements conducted at several locations within the existing facility fence line during the field diagnostic measurements.
- It is assumed that the facility operating conditions do not change significantly between the daytime and the nighttime periods. As such, the NIA analysis focuses solely on the nighttime period, as the PSL is more stringent during the nighttime than during the daytime.
- Sound propagation calculations were undertaken using the noise modeling software package CadnaA to determine the facility SPL at the receivers. All calculations were undertaken in linear one-third octave bands.

Table 18 lists the major parameters used in the noise model including the winter and summer studies. These parameters follow accepted acoustical engineering methodologies. The modeled conditions produce results representative of meteorological conditions favouring sound propagation (e.g., downwind or mild temperature inversion conditions), as prescribed by the Guideline. These conditions do not occur all the time at the receiver and the resulting SPL are expected to be lower than those predicted for most of the time. Therefore, the environmental conditions modelled represent “close-to-worst-case” sound propagation conditions. The conditions such as downwind condition, crosswind, and upwind conditions during the summertime and wintertime periods were considered in this noise study.

Table 18: Modeling Parameters

Parameter	Value	Description
Modeling software	CadnaA by Datakustik Version 2022	An advanced noise propagation model that considers geometric spreading, atmospheric sound absorption, ground impedance effects, site topography and geometry, vegetation and environmental conditions. The CadnaA model calculates the contribution level of each noise source at the receiver location in octave bands as well as calculating the overall facility sound level.
Standard followed	Concawe	Specifies an engineering method for calculating the attenuation of sound during propagation outdoors to predict the levels of environmental noise at a distance from a variety of sources. Published accuracy is not available and the method has been tested for distances between 100m and 2000m, for wind speeds up to 7m/s.
	ISO 9613	As recommended in the guidelines. Specifies an engineering method for calculating the attenuation of sound during propagation outdoors in order to predict the levels of environmental noise at a distance from a variety of sources. The published accuracy for this standard is ±3 dBA between 100 m to 1000 m. Accuracy levels beyond 1000 m are not published.
Wind Condition (Concawe)	Normal Condition: 2 m/s Downwind Pasquil Stability Factor F	Conditions are typically considered adverse, encouraging propagation from source to the receiver, modelled as all sources up wind from the receiver, along with a moderate inversion condition.
	Downwind Condition	Modeled as wind with a speed of 3 m/s (10.8 kph) as per weather station collected data in this area during the monitoring period.
	Upwind Condition	Modeled as wind with a speed of 3 m/s (10.8 kph) as per weather station collected data in this area during the monitoring period.
	Crosswind Condition	Modeled as wind with a speed of 3 m/s (10.8 kph) as per weather station collected data in this area during the monitoring period.
Wind Condition (ISO 9613)	1 – 5 m/s Downwind	ISO 9613 uses a slight downwind condition from each noise source to each receiver. Wind speed is measured at a height of 3 m to 11 m above ground and covers the acceptable range specified in the AER Directive 038 and BC OGC Guideline.
Ground Factor	0.0 for water bodies and roads 0.6 everywhere else	The ground factor G is a property of the ground material, with value ranging from 0 to 1. The typical values below were determined from several standards and guidelines, including ISO 9613, Commission Directive EU 2015/996, and Nord 2000. G = 0.0 is suitable for asphalt, concrete, pavement, water G = 0.3 is suitable for compacted dense ground, gravel road, hard soil G = 0.6 is suitable for sand, compacted field and gravel, roadside dirt G = 0.8 is suitable for cultivated land, such as farmland G = 1.0 is suitable for uncultivated land, such as forest floor and loose ground For residential properties, the ground factor was determined from the proportion of the above typical values, based on satellite images.
Order of Reflection	3	The model calculates reflection effects from the reflective surfaces included in the model.
Foliage	Included	Modeled as ground absorption 0.8, based on conservative considerations due to the presence of human dwelling residences in the study area.

Table 18: Modeling Parameters

Parameter	Value	Description
Temperature	10ºC (Summertime) -20ºC (Wintertime)	Represents typical nighttime temperature.
Relative Humidity	80% (Summertime) 50% (Wintertime)	Represents typical nighttime relative humidity.
Topography	Included	Topographical data obtained from Natural Resources Canada. Resolution of 1 m.

The main purpose of this research was to investigate the accuracy of the sound propagation models as per ISO 9613-2 and CONCAWE for outdoor sound propagation, by comparing the equivalent sound pressure values of the sound measurements with the equivalent sound pressure level of the calculations results according to the models.

Different parameters were investigated on the computational calculations in order to compare with the sound measurements. For the ISO 9613-2 calculation, only the worst downwind situation was considered. For CONCAWE calculations, the parameters investigated were wind speed and direction. Downwind condition is when the wind is blowing from the source to the receiver and upwind the other way around. Crosswind is when the wind is blowing perpendicular to the source and receiver.

To be comparable to the results from the calculations, the sound measurement data were filtered for the matching wind speed and direction with the calculations.

Tables 19A and 19B show the predicted sound level results for the selected seven monitoring locations for each of the winter and summer studies, compared with the measurement results. Please note that the wind conditions for each monitoring location were acquired from the weather station installed at the subject facility fenceline and the local weather conditions may be different to some extent due to terrain and distance differences.

Table 19A: Predicted Sound Level Results (Wintertime)

Receiver	Weather Condition	Residual CSS Daytime SPL (dBA)	Residual CSS Nighttime SPL (dBA)	Predicted Nighttime SPL (dBA) (ISO)	Predicted Nighttime SPL (dBA) (Concawe)
Fence line	Normal Condition		51.7 - 59.2 dBA	56.5	59.0
Sound Monitor 1 (3100 m NE)	Normal Condition	44.4	39.2	25.0	20.2
	Downwind	46.7	40.2	-	19.5
	Crosswind	43.0	39.0	-	19.6
	Upwind	41.7	36.1	-	17.2
Sound Monitor 2 (3210 m N)	Normal Condition	42.1	36.2	24.7	19.1
	Downwind	43.1	35.6	-	17.9
	Crosswind	42.7	36.8	-	18.9
	Upwind	38.0	35.6	-	15.4
Sound Monitor 3 (3780 m WNW)	Normal Condition	48.5	48.3	21.1	20.7
	Downwind	47.6	46.0	-	19.1
	Crosswind	47.5	50.7	-	20.1
	Upwind	50.2	45.0	-	16.4
Sound Monitor 4 (960 m ENE)	Normal Condition	50.8	43.9	43.1	43.9
	Downwind	54.6	45.9	-	42.1
	Crosswind	46.8	43.1	-	42.6
	Upwind	42.2	39.8	-	41.1
Sound Monitor 5 (2600 m ENE)	Normal Condition	41.6	35.3	27.7	25.9
	Downwind	41.1	33.9	-	24.1
	Crosswind	42.6	35.7	-	25.5
	Upwind	33.9	34.1	-	23.5
Sound Monitor 6 (1480 m NNE)	Normal Condition		44.3	32.3	27.1
	Downwind	-	-	-	26.3
	Crosswind	-	-	-	26.1
	Upwind	-	-	-	23.7
Sound Monitor 7 (4030 m NNE)	Normal Condition		-	21.6	16.3
	Downwind	-	-	-	14.8
	Crosswind	-	-	-	15.8
	Upwind	-	-	-	12.2

Table 19B: Predicted sound level Results (Summertime)

Receiver	Weather Condition	Residual CSS Daytime SPL (dBA)	Residual CSS Nighttime SPL (dBA)	Predicted Nighttime SPL (dBA) (ISO)	Predicted Nighttime SPL (dBA) (Concawe)
Fence line	Normal Condition		60-67 dBA	61.6	65.7
Sound Monitor 1 (2160m west)	Normal Condition	43.3	37.9	35.1	30.5
	Downwind	42.2	35.8	-	29.5
	Crosswind	42.8	37.2	-	29.8
	Upwind	44.3	38.9	-	24.8
Sound Monitor 2 (2000m southwest)	Normal Condition	41.9	34.0	34.7	30.7
	Downwind	39.0	34.5	-	29.7
	Crosswind	40.3	35.6	-	29.6
	Upwind	42.8	32.7	-	26.6
Sound Monitor 3 (1030 m south southwest)	Normal Condition	42.1	34.9	37.5	35.6
	Downwind	39.8	38.7	-	33.6
	Crosswind	42.1	34.1	-	34.4
	Upwind	42.4	32.5	-	31.6
Sound Monitor 4 (2600 m southeast)	Normal Condition	39.9	33.7	30.1	25.8
	Downwind	37.5	35.7	-	24.8
	Crosswind	40.3	33.2	-	24.9
	Upwind	38.9	32.5	-	22.5
Sound Monitor 5 (3860 m east southeast)	Normal Condition	41.9	47.6	27.3	21.3
	Downwind	39.2	37.5	-	19.3
	Crosswind	43.5	40.1	-	20.3
	Upwind	37.4	58.9	-	15.2
Sound Monitor 6 (1340 m southeast)	Normal Condition		36.2	35.0	33.6
	Downwind	-	-	-	32.3
	Crosswind	-	-	-	32.5
	Upwind	-	-	-	30.4
Sound Monitor 7 (2020 m west)	Normal Condition		37.5	36.2	32.4
	Downwind	-	-	-	31.1
	Crosswind	-	-	-	31.7
	Upwind	-	-	-	27.6

The predicted results above are facility sound pressure levels only, which do not include the ambient noise levels and not available due to continuous running of the facility in the study area.

Both Concawe and ISO methods provide better results within 1500m from the selected facility, which were close to the monitoring results. However, the predicted noise results from Concawe were generally higher than from ISO method in the near field, and lower than from ISO method in the far field.

Noise levels at different locations during downwind conditions can be more than 5 dB than during upwind conditions, and this difference was higher as per monitoring results than predicted results.

The predicted noise results were much lower than the monitoring results in the far field, such as more than 2000m away, which is because the lower facility noise contribution at these locations, and the monitoring results do not represent the impact from the selected facility and dominated by background noise or other nearby noise sources.

The predicted noise results during the summertime conditions will be higher than the wintertime situation, especially from the ISO method, this will need further investigation.

The noise prediction results with distances from the subject facility indicate that there will be significant noise impacts on the nearby area within 1500m, but minor impact if more than 2000m from the selected facility. Figures 17A and 17B show the noise propagation from the subject facility for the wintertime and summertime studies, which include the noise levels LAeq, LCeq and low frequency noise for the selected tone for each study.

Figure 17A Facility Noise Propagation with Distances – Wintertime Study

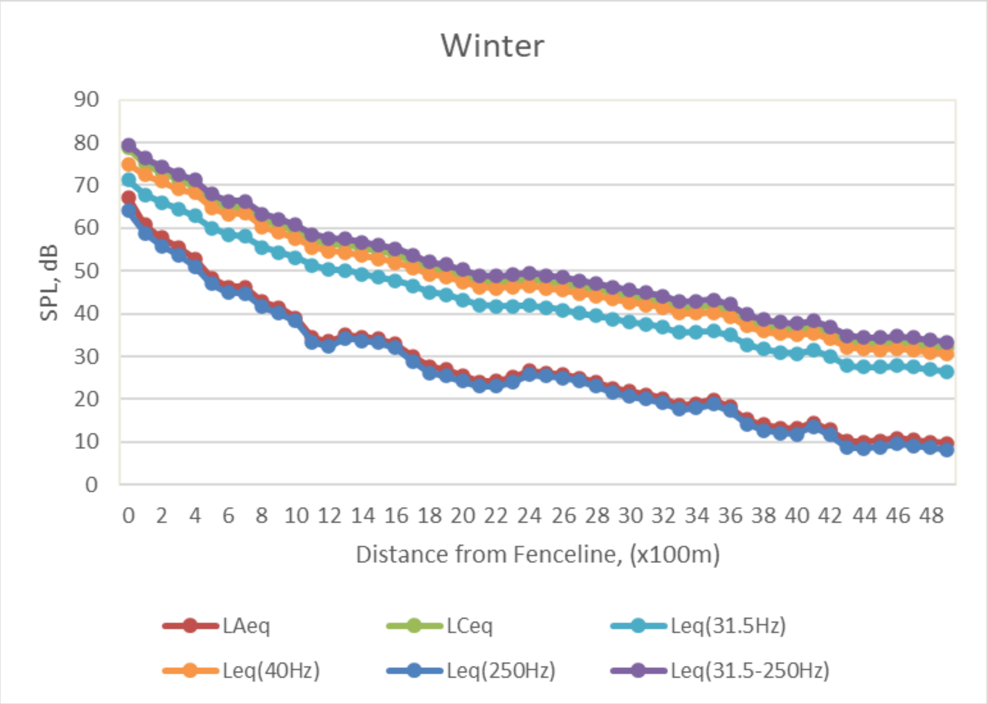
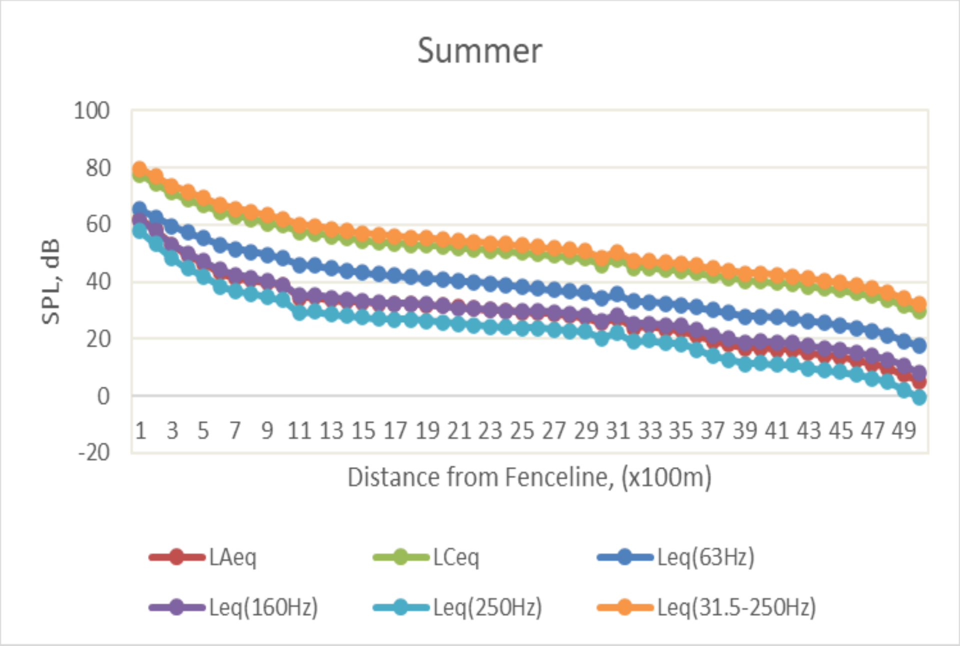


Figure 17B Facility Noise Propagation with Distances – Summertime Study



Figures 18A and 18B depict the winter and summer nighttime predicted sound level from each of the selected facility excluding the ambient sound levels (ASL) under the worst-case wind conditions.

Figure 18A: Study Area Map – Wintertime Facility

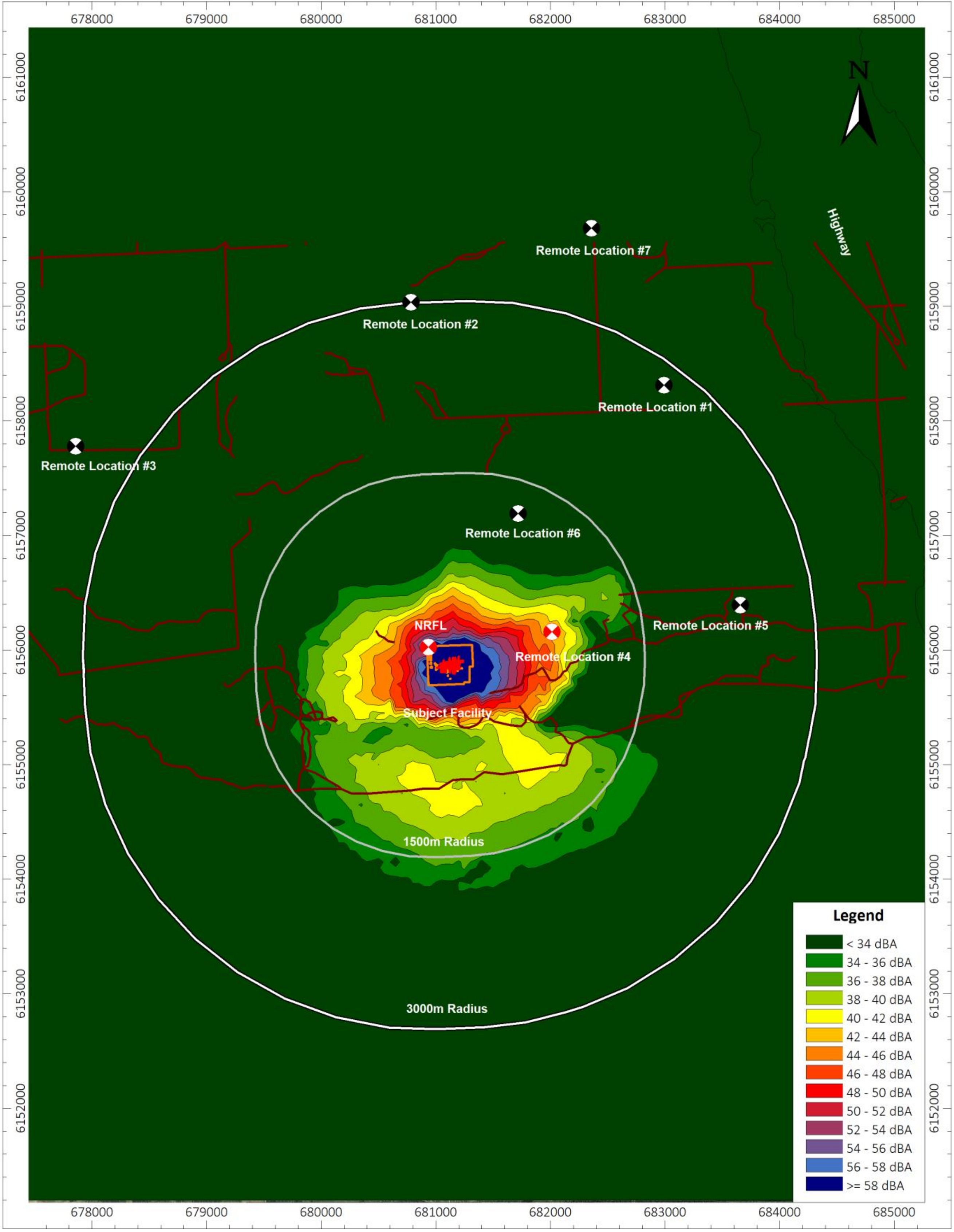
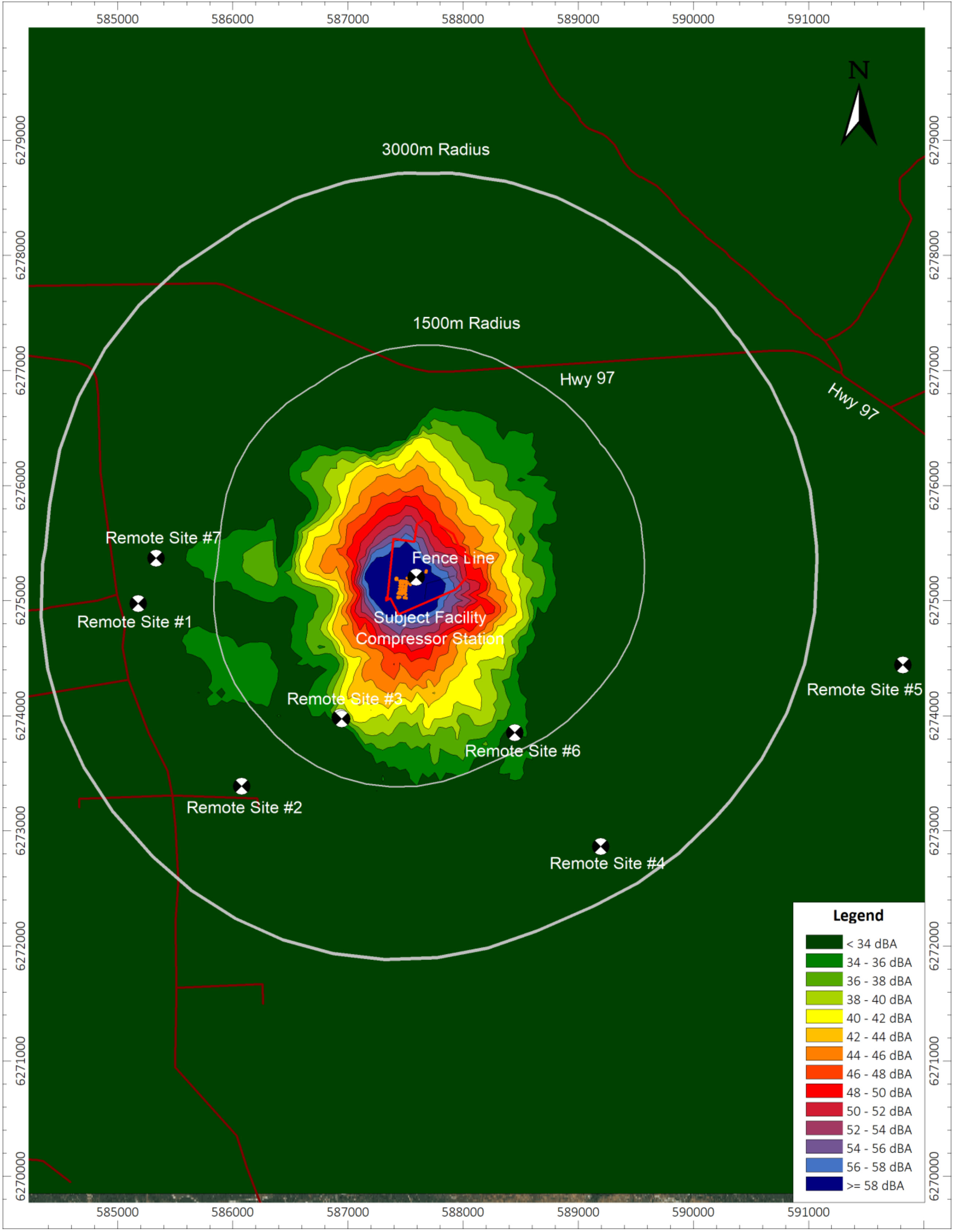


Figure 18B: Study Area Map – Summertime Facility



Comparison of IoT sensors

One of the purposes of this project is to create opportunities for local contractors to gain experience in the field of acoustics and to evaluate the applicability of new lower cost sensors technology; both of which will reduce barriers for operators to gather more data on their operations and mitigation efforts. Local contractors have been trained with PAAE and OGC best practices to help install and check the operation of equipment, which did make the monitoring process more efficient and reliable. For the equipment evaluation, Tables 20A and 20B provide the details of different equipment installed at different monitoring locations, compared with standard equipment used in the noise study.

Table 20A Equipment Comparison During Winter Noise Study

Location	Equipment	Description	Intended Running Time, Hrs	Actual Running Time, Hrs (% of Overall monitoring period)	Notes
Fence line Monitoring Location	Sound Level Meter	• Traditional Class 1 meter • Northwest corner in the gas plant • Mic is 1.5 m above ground • Monitoring period: Mar. 24– May 18, 2022	1318.6	1318.6 (100%)	Running Well
	Off-the-shelf IOT Sensor	• IOT off shelf Mic is 1.2 m above ground • 1m away from the Class 1 meter • Monitoring period: Mar. 24 – May 12, 2022	1318.6	712.0 (54.0%)	Running Well most of the time, missing data between Apr 6 and May 1, 2022, possibly due to power, memory card capacity, or connection issues
	Standard Weather Station	• 3.5 meters high • Monitoring period: Mar. 24 – May 18, 2022	1319.7	1319.7 (100%)	Running Well
Remote Site 1	Sound Level Meter	• Traditional Class 1 meter • 3078m northeast from the gas plant • Mic is 1.5 m above ground • Monitoring period: Mar. 24 – May 18, 2022	1324.7	1324.7 (100%)	Running Well
	Off-the-shelf IOT Sensor	• IOT off shelf Mic is 1.2 m above ground • Same location as the Class 1 meter • Monitoring period: May 02 – May 08, 2022	1324.7	4.75 (0.4%)	Running intermittently and worked very short period after setup, possibly due to power, installation, or connection issues
Remote Site 2	Sound Level Meter	• Traditional Class 1 meter • 3212m north from the gas plant • Mic is 1.5 m above ground • Monitoring period: Mar. 24 – May 18, 2022	1324.0	1324.0 (100%)	Running Well
	Off-the-shelf IOT Sensor	• IOT off shelf Mic is 1.2 m above ground • Same location as the Class 1 meter • Monitoring period: Mar. 25 – May 18, 2022	1324.06	488.8 (36.9%)	Running Well most of the time, missing data between Mar. 30 and May 1, 2022, possibly due to power, memory card capacity, or connection issues

Table 20A Equipment Comparison During Winter Noise Study

Location	Equipment	Description	Intended Running Time, Hrs	Actual Running Time, Hrs (% of Overall monitoring period)	Notes
	KFX Prototype	• Mic is 1.2 m above ground, no windscreen • 30cm from the Class 1 meter • Monitoring period: May 11 – May 19, 2022	203.0	203.0 (100%)	Measurements taken instantaneously as per 69-70 seconds' intervals instead of average SPL per minute, but did agree well with Class 1 meter, running stably.
	Another off-the-shelf acoustic IOT sensor	• Monitoring period: May 11 – May 18, 2022	160	0	•The IOT off shelf acoustic sensor was installed at this location, which was running normally, but the data was lost due to improper setup, which will be improved in the future.
Remote Site 3	Sound Level Meter	• Traditional Class 1 meter • 3793 m northwest from the gas plant • Mic is 1.5 m above ground • Monitoring period: Mar. 24 – May 18, 2022	1322.8	100%	Running Well
	Off-the-shelf IOT Sensor	• IOT off shelf Mic is 1.2 m above ground • Same location as the Class 1 meter • Monitoring period: Mar25 – 30, May 02, 2022	1322.8	68 (5.1%)	Running Well until Mar 30, short period of data available on May 2, possibly due to power, memory card capacity, or connection issues
	Alternative Weather Station	• 3.5 meters high • Monitoring period: May. 2 (14:32) – May 17, 2022	354.9	354.9 (100%)	Running Well
Remote Site 4	Sound Level Meter	• Traditional Class 1 meter B&K 2250-3 • 909 m east northeast from the gas plant • Mic is 1.5 m above ground • Monitoring period: Mar. 25 (4:08pm)– May 18, 2022 (ending May 12 23:40)	1296.6	563.6 (43.5%)	Running Well before Apr 6 and after May 2, running intermittently between Apr 6 and May 2, possibly due to power, memory card capacity, or connection issues
	Off-the-shelf IOT Sensor	• IOT off shelf Mic is 1.2 m above ground • Same location as the B&K 2250 Mic • Monitoring period: Mar25 – May 08, 2022	1296.6	460.5 (35.5%)	Running Well most of the time, missing data between Mar. 29 and May 2, 2022, possibly due to power, memory card capacity, or connection issues
Remote Site 5	Sound Level Meter	• Traditional Class 1 meter • 2589 m east northeast from the gas plant • Mic is 1.5 m above ground • Monitoring period: Mar. 30 – May 18, 2022	1183.8	273.1 (23.1%)	Running Well until Apr 10, no data available after then, possibly due to power, memory card capacity, or connection issues
	Off-the-shelf IOT Sensor	• IOT off shelf Mic is 1.2 m above ground • Same location as the Class 1 meter • Monitoring period: Mar25 – May 08, 2022	1183.8	34.25 (2.6%)	Running intermittently, missing a lot of data, possibly due to power, installation, or connection issues

Table 20A Equipment Comparison During Winter Noise Study

Location	Equipment	Description	Intended Running Time, Hrs	Actual Running Time, Hrs (% of Overall monitoring period)	Notes
Remote Site 6	Off-the-shelf IOT Sensor	• Mic is 1.2 m above ground • 1454 m north northeast from the gas plant • Monitoring period: Mar25 – May 08, 2022	170.2	2 (1.2%)	Running intermittently only on May 10 for short period, missing a lot of data, possibly due to power, installation, or connection issues
Remote Site 7	Off-the-shelf IOT Sensor	• Mic is 1.2 m above ground • 4022 m north northeast from the gas plant • Monitoring period: Mar25 – May 08, 2022	171.0	23 (13.5%)	Running intermittently until Mar 29, missing a lot of data, possibly due to power, installation, or connection issues

Table 20B Equipment Comparison During Summer Noise Study

Location	Equipment	Description	Intended Running Time, Hrs	Actual Running Time, Hrs (% of Overall monitoring period)	Notes
Fence line Monitoring Location	Sound Level Meter	• Traditional Class 1 sound meter • Northeast corner in the subject facility • Mic is 1.5 m above ground • Measurement period: July 12 – Sept 14, 2022	1538.4	1538.4 (100%)	Running Well
	Off-the-shelf IOT Sensor	• IOT off shelf Mic is 1.2 m above ground • 1m away from the Traditional Class 1 sound meter • Monitoring period: July 12 – Aug 25, 2022	1538.4	627.5 (40.8%)	Running Well until Aug 25, after then no data available, possibly due to power or connection issues
	Standard Weather Station	• 3.5 meters high • Monitoring period: July 13 – Sept 14, 2022	1538.4	1538.4 (100%)	Running Well
	Sound Meter IOT Prototype	• Mic is 1.2 m above ground, no windscreen • 30cm from the Traditional Class 1 sound metre • Monitoring period: August 12 - 24, 2022	798.3	289.1 (36.2%)	Running Well until Aug 24, after then no data available, possibly due to power, memory card capacity, or connection issues. The meter captured the audio recording, processed later to get the 1/3 Octave band spectrum results (31.5Hz – 5kHz)
Remote Site 1	Sound Level Meter	• Traditional Class 1 sound meter • 2160m west from the subject facility • Mic is 1.5 m above ground • Monitoring period: July 13 – August 31, 2022	1534.6	1171.8 (76.4%)	Running Well until Aug 31, after then no data available, possibly due to memory card capacity or connection issues

Table 20B Equipment Comparison During Summer Noise Study

Location	Equipment	Description	Intended Running Time, Hrs	Actual Running Time, Hrs (% of Overall monitoring period)	Notes
	Sound Meter Off-the-shelf IOT	• Mic is 1.2 m above ground • Same location as the Traditional Class 1 sound meter • Monitoring period: July 12 –28, 2022	1534.6	251.7 (16.4%)	Running Well until July 28, after then no data available, possibly due to power or connection issues
Remote Site 2	Sound Level Meter	• Traditional Class 1 sound meter • 2000m southwest from the subject facility • Mic is 1.5 m above ground • Monitoring period: July 13 – Sept 11	1534.6	819.0 (53.4%)	Running Well until memory card full, missing some data due to memory card capacity issue
	Sound Meter Off-the-shelf IOT	• Mic is 1.2 m above ground • Same location as the Traditional Class 1 sound meter • Monitoring period: July 12, 2022	1534.6	0.58 (0.04%)	Running Well very short period after setup, after then no data available, possibly due to power, installation, or connection issues
	Sound Meter IOT Prototype	• Mic is 1.2 m above ground, no windscreen • 30cm from the Traditional Class 1 sound meter • Monitoring period: August 12 - 22, 2022	824.5	241.4 (29.3%)	Running Well until Aug 22, after then no data available, possibly due to power, memory card capacity, or connection issues.
Remote Site 3	Sound Level Meter	• Traditional Class 1 sound meter • 1030 m south southwest from the subject facility • Mic is 1.5 m above ground • Monitoring period: July 13 – Sept 11, 2022	1536.5	1092.4 (71.1%)	Running Well until memory card full, missing some data due to memory card capacity issue
	Sound Meter Off-the-shelf IOT	• Mic is 1.2 m above ground • Same location as the Traditional Class 1 sound meter • Monitoring period: July 12 – Sept 14, 2022	1536.5	8.6 (0.6%)	Running intermittently after setup, possibly due to installation, or connection issues
	Second Sound Meter Off-the-shelf IOT	• Mic is 1.5 m above ground • Monitoring period: Aug 10-11, 2022	472	16.0 (3.4%)	Running Well very short period after setup, after then no data available, possibly due to equipment heat dissipation, or connection issues.
	Sound Meter IOT Prototype	• Mic is 1.2 m above ground, no windscreen • 30cm from the Traditional Class 1 sound meter • Monitoring period: August 12 – sept 15, 2022	814	0	No data available, possibly due to power, installation, or connection issues
Remote Site 4	Traditional Class 1 Type 1	• Traditional Class 1 sound meter • 2600 m southeast from the subject facility • Mic is 1.5 m above ground • Monitoring period: July 12 – Sept. 1, 2022	1552.6	686.4 (44.2%)	Running intermittently, due to power issues
	Sound Meter Off-the-shelf IOT	• Mic is 1.2 m above ground • Same location as the Traditional Class 1 sound meter Monitoring period: July 12 – Aug 23, 2022	1552.6	345.8 (22.3%)	Running Well, missing some data, possibly due to power or connection issues

Table 20B Equipment Comparison During Summer Noise Study

Location	Equipment	Description	Intended Running Time, Hrs	Actual Running Time, Hrs (% of Overall monitoring period)	Notes
	Sound Meter IOT Prototype	• Mic is 1.2 m above ground, no windscreen • 30cm from the Traditional Class 1 sound meter • Monitoring period: August 12 – sept 15, 2022	810	0	No data available, possibly due to power, installation, or connection issues
Remote Site 5	Traditional Class 1 Type 1	• Traditional Class 1 sound meter • 3860 m east southeast from the subject facility, 1300m west from Hwy 97 • Mic is 1.5 m above ground • Monitoring period: July 12 – August 31, 2022(should running to sept 14)	1537.6	1262.0 (82.1%)	Running intermittently, possibly due to power, or connection issues; measurement stopped due to equipment mal-function.
	Sound Meter Off-the-shelf IOT	• Mic is 1.2 m above ground • Same location as the Traditional Class 1 sound meter • Monitoring period: July 12 – Sept. 14, 2022	1537.6	0 (0%)	No data available, possibly due to power, installation, or connection issues
	Sound Meter IOT Prototype	• Mic is 1.2 m above ground, no windscreen • 30cm from the Traditional Class 1 sound meter • Monitoring period: August 12 - 21, 2022	797.2	212.5	Running Well until Aug 21, after then no data available, possibly due to power, memory card capacity, or connection issues
Remote Site 6	Sound Meter Off-the-shelf IOT	• Mic is 1.2 m above ground • 1340 m southeast from the subject facility • Monitoring period: July 12 – Sept 14, 2022	1522.4	558.8 (36.7%)	Running intermittently, possibly due to power, installation, or connection issues.
	Sound Meter IOT Prototype	• Mic is 1.2 m above ground, no windscreen • 30cm from the Traditional Class 1 sound meter • Monitoring period: August 12 -24, 2022	786.2	275.6 (35.0%)	Running Well until Aug 24, after then no data available, possibly due to power, memory card capacity, or connection issues; the sensor also got damaged by deer on Aug 30, 2022.
Remote Site 7	Sound Meter Off-the-shelf IOT	• Mic is 1.2 m above ground • 2020 m west from the subject facility • Monitoring period: July 12 – Sept 14, 2022	1533.2	1283.9 (83.7%)	Running Well most of the time, but missing some measurement data, possibly due to equipment setup, or connection issues

Table 20B Equipment Comparison During Summer Noise Study

Location	Equipment	Description	Intended Running Time, Hrs	Actual Running Time, Hrs (% of Overall monitoring period)	Notes
	Sound Meter IOT Prototype	• Mic is 1.2 m above ground, no windscreen • 30cm from the Traditional Class 1 sound meter • Monitoring period: August 12 - 28, 2022	811.8	376.2 (46.3%)	Running Well until Aug 28, after then no data available, possibly due to power, memory card capacity, or connection issues; the sensor also got damaged at pick-up on Sept. 15, 2022.

"Internet of Things (IoT)" off-the-shelf sensors operated at all the setup locations, and portions of each period suffered data loss due to power and connectivity issues when distances were greater than 2 km were predominantly due to intervening land and limitations in achieving an adequate placement height for the gateway antenna. There was reasonable coverage when sensors were placed within 1 km of the gateway. Data payload size did affect transmission distance. This highlights a limitation of these sensors, including opportunities to capture learnings. This type of sensor doesn't capture the spectrum data and dBC noise levels, which is an identified gap in capabilities for LFN analysis and limits utility to establishing broadband emissions (I.E. facility run status). Search into sensors by various manufacturers indicate that sensors capable of capturing spectral data currently does not exist or is not readily attainable. This limits the utility for investigating LFN at this time. Another problem encountered is measurement results at some of the sensors fluctuated significantly and didn't agree well with the Class 1 meter, which could be caused by the installation situation or wind conditions. Future implementation of this type of sensor may be on a facility location, near the gateway and used for monitoring changes in sound levels as opposed to an absolute calibrated value. A windscreen should also be incorporated to reduce effects of wind. The gateway should also be setup at locations where there is adequate cell reception for data transmission as well as access to uninterrupted power as the device does require at least 20 watts of power continuously.

During the summertime noise study, the IoT Prototype sensors were improved and installed at the fence line, and all Remote sites other than Remote site 1. The IoT Prototype sensors vs Class 1 sound meter comparison was studied at only two locations, the Fence line and Remote site 5. Three 1/3 octave bands – 63 Hz, 160 Hz, and 250 Hz were selected at the two sites and compared as per the corresponding bands recorded by Class 1 sensors. The results indicate that both sensors recorded data and were shown in a consistent manner throughout the course of the study. Another finding was that, at both sites, the IoT Prototype sensor recorded slightly higher band values than the Class 1 sensor, and this trend also persisted throughout the monitoring period. Appendix D shows the detailed sound levels comparison between the Class 1 meter vs IoT Prototype as per the four setup locations during the summertime study.

During the wintertime study, the IOT prototype captured the instantaneous noise levels for around 69-70 seconds' intervals, which agree with the Traditional Class 1 sound meter spectrum data as per the instantaneous noise levels. During the summertime study, improved wind screen was used for these IOT prototype microphones to avoid wind gust effects on the measurement. IOT prototype microphones were installed at some locations and captured the one-third octave band sound levels (31.5 Hz – 6.3 kHz) as per minute intervals, and audio recordings, which require post processing to assess viability for use for LFN tonal assessment. A major limitation of the current design of the prototype is that the processor selected was under powered to simultaneously calculate Leq and spectral data. An upgraded processor will be needed for future iterations of this prototype. Improved wireless connectivity should also be addressed with an IoT transceiver selected and matched specifically to this device.

During the wintertime study, new type weather station worked well and reliably for the duration of the installation, with easy downloading, nearly zero maintenance and all the data needed for weather conditions. However, some data intervals were missing as it was observed that the device lost connection for a period. There were some discrepancies between the fenceline weather station and this new weather station, which was mainly due to the differences of local weather conditions. While the output and interface was easy to use and displayed information well, the connection is geared for a permanent location with a reliable internet connection. The adaptation used in this study included a wifi cellular modem and it was observed that data consumption was significant for this type of device. Future devices should look for sensors that can store text data on device and send packets later as needed reducing the possibility of data loss. Appendix E shows the detailed comparison of the two Weather Stations during the wintertime study.

Findings and Recommendations

The key findings and recommendations of the study results are as follows:

- **Key Finding 1:** The two facilities studied included typical gas processing and compression facilities. The assessment finds that the sound levels beyond 1500 meters are at low risk for exceeding the established PSL of 40 dBA Leq at night. This conclusion is based on analysis of 14 weeks of data using current Class 1 noise monitoring technology. The sound environment beyond 1500m is dominated by sound from the environment (wind, flora, fauna), traffic, human activity, and other nearby facilities.

- **Key Finding 2:** Current best practise noise modeling methods using the Concawe noise modeling algorithm produce reliable results within 1000m for downwind, crosswind and upwind conditions, opening alternatives to ISO downwind conditions when conducting noise modeling. This finding was based on two monitoring locations and should be confirmed with additional study.

- **Key Finding 3:** Modeling accuracy beyond 1500m was not verified as sound measurement results beyond 1500m were contaminated by background contamination. Modeling validated for distances less than 1500m indicates upwind/downwind variability of 2-5 dBA. This forms a hypothesis to test as part of additional study using a higher sound power (louder) source. See recommendation 1.

- **Key Finding 4:** Findings show that Low Frequency Noise (LFN) tones can exist beyond 1500 m and the current methodologies for measuring (LFN) may not be effective for investigating multiple potential LFN noise sources where the source of the noise is not obvious. For these situations additional consideration for fenceline monitoring and narrow band FFT will reduce false positive attribution error as well as increase confidence when positive attribution is identified. Recommend updating guideline procedure for situations with no obvious source to include simultaneous narrow band noise monitoring at facility fenceline and subject receiver.

- **Key Finding 5:** Weather monitoring results suggest that wind conditions can vary significantly over a 2-3 km study area and represent an area of uncertainty for confidentially establishing the effect of meteorologic conditions. This forms a hypothesis to test as part of an additional study using more weather sensors to establish more detailed insights on weather conditions and the validity of low-cost sensors. See recommendation 1.

- **Key Finding 6:** “Internet of Things (IoT)” low cost off-the-shelf sensors are currently capable of overall broadband dBA assessment. This limits utility to determining the operating status of a facility and the current technology does not support investigation of LFN sound due to technology gaps. As technology advances, the current gaps are likely to be filled, at which time connectivity limitations will need to be solved to support a wide use application to investigate LFN.

- **Key Finding 7:** Prototype IoT sensors allow for frequency analysis; filling a gap present in off-the-shelf sensors. This frequency analysis capability provides a low-cost alternative to Class 1 monitoring equipment for LFN tonal assessment. The technology is not yet reliable for calibrated monitoring to establish compliance. Recommend expanding guideline procedure for LFN investigation to included IoT sensors used for tonal analysis to support source attribution.

- **Key Finding 8:** For locations outside the facility fenceline, environmental sound not related to the oil and gas facility operation dominated, and wind noise dominated the acoustic environment with wind speed above 3 m/s. Investigation of LFN at longer distances require detailed assessment of both local (at microphone) and environmental (overall area wide) wind conditions.

- **Key Finding 9:** Due to high amounts of contamination from ambient non-facility noise, audio recording and post processing as a standard requirement for assessing LFN is required to have meaningful results. At the current state of technology, and without further automation, this will require manual effort to conduct post processing to conduct isolation analysis described in the guidelines. This represents opportunity for application of machine learning (ML) as well as opportunity for local contractors to support creating training datasets.

- **Key Finding 10:** Local Contractors: The wintertime study included training and dedicated staff from local contractors. This supported equipment uptime through weekly battery inspections as well as monitoring for damage from wildlife, this was successful as it reduced air travel and long-distance driving. During the summertime study, local contractors were busier and finding dedicated personnel to train was not possible. This study demonstrates that local contractors can improve data quality and reduce travel costs. Recommend investment in training programs so as to ensure multiple staff members are available, as well as a consistent log term schedule for monitoring.

- **Recommendation 1:** Based on learnings from this assessment conduct focused validation study following similar process to confirm hypothesis from this research, specific features include:
    - Noise source selection 10-15 dBA higher than gas plants selected, suggest drilling or hydraulic fracturing site.
    - Limit study to 2 weeks; and simplify to 4 monitoring locations (including fenceline, nominally fenceline, 500m, 1000m, 2000m, 3500m in one direction).
    - Each monitoring location include Class 1 sound meter, Prototype IoT sensor, and a weather station; do not include off-the-shelf IoT sensors, avoiding need for gateway setup.
    - Include weather monitoring at 10m elevation for at least one location.
    - Conduct detailed isolation analysis and narrow-band FFT analysis at each location to improve insights on tonal assessment as well as meteorological correlation.
    - Use the results of the study above to prepare supplemental guidelines for investigating LFN when the source is not apparent, those that fall outside current guidelines. Include guidance on use of lower-cost non-Class 1 sound monitoring systems as these become available on the market.
    - Use the results of the study above to confirm upwind, crosswind, and downwind modeling method and update guideline to allow for upwind or crosswind as alternative mitigation for planning temporary operations if results are confirmed.

- **Recommendation 2:** Make the dataset from this assessment available to post secondary institutions for establishing use case for machine learning training procedure to automate isolation analysis and increase value from data.

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APPENDIX A

Technical Details Regarding
Sound Measurement and Analysis

Technical Details

Sound is the phenomena of vibrations transmitted through air, or other medium such as water or a building structure. The range of pressure amplitudes, intensities, and frequencies of the sound energy is very wide, and many specialized fields have developed using different ranges of these variables, such as room acoustics and medical ultrasound.

Due to the wide range of intensities, which are perceived as sound, standard engineering units become inconvenient. Sound levels are commonly measured on a logarithmic scale, with the level (in decibels, or dB) being proportional to ten times the common logarithm of the sound energy or intensity. Normal human hearing covers a range of about twelve to fourteen orders of magnitude in energy, from the threshold of hearing to the threshold of pain. On the decibel scale, the threshold of hearing is set as zero, written as 0 dB, while the threshold of pain varies between 120 to 140 dB. The most usual measure of sound is the sound pressure level (SPL), with 0 dB SPL set at 2.0 X 10^{-5} N/m^2 (also written 20 μPa), which corresponds to a sound intensity of 10^{-12} Watts/m^2 (or 1 picoWatt/m^2, written 1 pW/m^2).

Normal human hearing spans a frequency range from about 20 Hertz (Hz, or cycles per second) to about 20,000 Hz (written 20 kHz). However, the sensitivity of human hearing is not the same at all frequencies. To accommodate the variation in sensitivity, various frequency-weighting scales have been developed. The most common is the A-weighting scale, which is based on the sensitivity of human hearing at moderate levels; this scale reflects the low sensitivity to sounds of very high or very low frequencies. Sound levels measured on the A-weighted scale are written in A-weighted decibels, commonly shown as dBA or dB(A).

Human hearing becomes more sensitive to lower frequency sounds as the level of the sound increases. For this purpose, the C-weighing scale was developed to assess reaction to higher levels sounds. Although the C-weighting scale, or the sound level in dBC, is seldom used on its own, the levels in dBC and dBA are often used together to assess the significance of the low-frequency components of sound. In some cases, a limit is placed on the dBC level at a location in order to limit the amount of low-frequency noise.

When sound is measured using the A-weighting scale, the reading is often called the “Noise level”, to confirm that human sensitivity and reactions are being addressed. A table of some common noise sources and their associated noise levels are shown in the table below.

When the A-weighting scale is not used, the measurement is said to have a “linear” weighting, or to be unweighted, and may be called a “linear” level. As the linear reading is an accurate measurement of the physical (sound) pressure, the term “Sound Pressure Level”, or SPL, is usually (but not universally) reserved for unweighted measurements.

Noise is usually defined as “unwanted sound”, which indicates that it is not just the physical sound that is important, but also the human reaction to the sound that leads to the perception of sound as noise. It implies a judgment of the quality or quantity of sound experienced. As a human reaction to sound is involved, noise levels are usually given in A-weighted decibels (dBA). However, use of the C-weighting scale, usually in combination with the dBA level, is becoming more common as well. An alternate definition of noise is “sound made by somebody else”, which emphasizes that the ability to control the level of the sound alters the perception of noise.

Table A1: Noise Levels of Familiar Sources

Source Or Environment	Noise Level (dBA)
High Pressure Steam Venting To Atmosphere (3 m)	121
Steam Boiler (2 m)	90-95
Drilling Rig (10 m)	80-90
Pneumatic Drill (15 m)	85
Pump Jack (10 m)	68-72
Truck (15 m)	65-70
Business Office	65
Conversational Speech (1 m)	60
Light Auto Traffic (30 m)	50
Living Room	40
Library	35
Soft Whisper (5 m)	20-35

The single number A-weighted level is often inadequate for engineering purposes, although it does supply a good estimate of people's reaction to a noise environment. As noise sources, control measures, and materials differ in the frequency dependence of their noise responses or production, sound is measured with a narrower frequency bandwidth; the specific methodology varies with the application. For most work, the acoustic frequency range is divided into frequency bands where the center frequency of each band is twice the frequency of the next lower band; these are called "Octave" bands, as their frequency relation is called an "Octave" in music, where the field of acoustics has its roots. For more detailed work, the octave bands, and certain standard octave and 1/3 octave bands have been specified by international agreements.

Where the noise at the receiver is steady, it is easy to assess the noise level. However, both the production of noise at the source and the transmission of noise can vary with time; most noise levels are not constant, either because of the motion of the noise source (as in traffic noise), because the noise source itself varies, or because the transmission of sound to the receiver location is not steady as over long distances. This is almost always the case for environmental noise studies. Several single number descriptors have been developed and are used to assess noise in these conditions.

The most common is the measurement of the "equivalent continuous" sound level, or L_{eq}, which is the level of a hypothetical source of a constant level which would give the same total sound energy as is measured during the sampling period. This is the "energy" average noise level. Typical sampling periods are one hour, nighttime (9 hours) or one day (24 hours); the sampling period used must be reported when using this unit.

The greatest value of the L_{eq} is that the contributions of different sources to the total noise level can be assessed, or in a case where a new noise source is to be added to an existing environment, the total noise level from new and old sources can be easily calculated. It is also sensitive to short term high noise levels.

Statistical noise levels are sometimes used to assess an unsteady noise environment. They indicate the levels that are exceeded a fixed percentage of the measurement time period measured. For example, the 10th percentile level, written L_{10}, is the levels exceeded 10% of the time; this level is a good measure of frequent noisy occurrences such as steady road traffic. The 90% level, L_{90}, is the level exceeded 90% of the time, and is the background level, or noise floor. A steady noise source will modify the background level, while an intermittent noise source such as road or rail traffic will affect the short-term levels only.

One disadvantage with the L_{eq} measure, when used alone, is that nearby loud sources (e.g. dogs barking, or birds singing) can confuse the assessment of the situation when it is the noise from a distant plant that is the concern. For this reason, the equivalent level and the statistical levels can be used together to better understand the noise environment. One such indication is the difference between the L_{eq} and the L_{90} levels. A large difference between the L_{eq} and L_{90}, greater than 10 dB, indicates the intrusion of short-term noise events on the general background level. A small difference, less than 5 dB, indicates a very steady noise environment. If the L_{eq} value exceeds the L_{10} value this indicates the presence of significant short-term loud events.

For most noise measurement, instruments are adjusted so that the time response of the instrument is similar to the response of the human ear; this is the “Fast” setting. Measurement with the “Fast” setting therefore assesses the sound environment according to the way humans would hear it and react to it. Where the noise level varies substantially and an average level is wanted without the complexity of and L_{eq} or statistical measurement, the “Slow” setting is used on the sound level meter. The “Slow” setting is also typically used in industrial settings where hearing damage is a concern. Where the noise level changes very rapidly, for example due to impacts or detonations, the “Fast” and “Slow” settings do not respond quickly enough to assess the maximum levels, and the “Impulse” meter setting us used.

The Sound Power Level (abbreviated L_w, SWL or PWL) is the decibel equivalent of the total energy emitted from a source in the form of noise. The reference level for the sound power is 10^{-12} Watts, or 1 picoWatt (abbreviated pW). The sound power level is given by:

$$L_w,\ SWL,\ PWL = 10 \times \log_{10} (\text{Emitted Power} / 1\ \text{pW})\ \text{dB}$$

Therefore, a source emitting 1 Watt of power in the form of sound would have a sound power level of 120 dB. Sound power levels can be expressed in terms of frequency bands, an overall linear-weighted level or A-weighted, as is the case for sound pressure levels. However, sound power levels are inherent to the source of noise, whereas the sound pressure level is dependant on the source, but also on the distance from the source and other environmental factors.

Note that according to the acoustical literature (E.g. Noise Control Engineering from Bies and Hanson), the subjective effect of changes in SPL is as follows:

- A 3 dB change is “just perceptible”.
- A 5 dB change is “clearly noticeable”.
- A 10 dB change is “twice as loud or half as loud”.
- A 20 dB change is “much louder or much quieter”.

Table A2: Glossary

Term	Description
Average Annual Daily Traffic (AADT)	The total volume of vehicle traffic of a highway or road for a year divided by 365 days.
Alberta Energy Regulator (AER)	The Alberta Energy Regulator ensures the safe, efficient, orderly, and environmentally responsible development of hydrocarbon resources over their entire life cycle. This includes allocating and conserving water resources, managing public lands, and protecting the environment while providing economic benefits for all Albertans.
Ambient sound level (ASL)	The sound pressure level that is a composite of different airborne sounds from many sources far away from and near the point of measurement. The ASL does not include any energy-related industrial component and must be measured without it. The ASL is assumed to be 5 dBA below the determined PSL as per Rule 012.
A-weighted sound level (dBA)	The sound level as measured on a sound level meter using a setting that emphasizes the middle frequency components similar to the frequency response of the human ear at levels typical of rural backgrounds in mid frequencies.
Bands (full octave or 1/3 octave)	A series of electronic filters separate sound into discrete frequency bands, making it possible to know how sound energy is distributed as a function of frequency. Each octave band has a centre frequency that is double the centre frequency of the octave band preceding it. The 1/3 octave band analysis provides a finer breakdown of sound distribution as a function of frequency.
Cumulative SPL	The cumulative sound pressure level from the facilities and the ambient sound level.
Comprehensive Sound Level (CSL)	The sound level that is a composite of different airborne sounds from many sources far away from and near the point of measurement. The CSL does include industrial components and must be measured with them, but it should exclude abnormal noise events. The CSL is used to determine whether a facility is in compliance with the Directive.
Cumulative noise level	The sound level that is the total contribution of all industrial noise sources (existing and proposed) from EUB-regulated facilities at the receptor.
C-weighted sound level (dBC)	The C-weighting approximates the sensitivity of human hearing at industrial noise levels (above about 85 dBA). The C-weighted sound level (i.e., measured with the C-weighting) is more sensitive to sounds at low frequencies than the A-weighted sound level and is sometimes used to assess the low-frequency content of complex sound environments.
Daytime	Defined as the hours from 07:00 to 22:00.
Deferred facility	Facilities constructed and in operation prior to October 1988. These facilities do not have to demonstrate compliance in the absence of a complaint. This does not exempt them from the requirements but does recognize that they were potentially designed without the same considerations for noise as facilities approved after the date when the first comprehensive noise control directive (ID 88-1) was published and put into effect.
Directive 038: Noise Control	Directive 038: Noise Control states the requirements for noise control as they apply to all operations and facilities under the jurisdiction of the Alberta Energy and Utilities Board (EUB). The directive also provides background information and describes an approach to deal with noise problems. This directive is the fifth edition, superseding Interim Directive (ID) 99-8.
Energy equivalent sound level (Leq)	The average weighted sound level over a specified period of time. It is a single-number representation of the cumulative acoustical energy measured over a time interval. The time interval used should be specified in brackets following the Leq—e.g., Leq (9) is a 9-hour Leq. If a sound level is constant over the measurement period, the Leq will equal the constant sound level.
Emergency	An unplanned event requiring immediate action to prevent loss of life or property. Events occurring more than four times a year are not considered unplanned.
Facility SPL	The overall sound pressure level from all the facilities in the study area

Table A2: Glossary

Term	Description
Heavily Travelled Road	Generally includes highways and any other road where the average traffic count is at least 10 vehicles/hour over the nighttime period. It is acknowledged that highways are sometimes lightly travelled during the nighttime period, which is usually the period of greatest concern. The AER will use the 10 vehicles/hour criterion to determine whether highways qualify as heavily travelled during the nighttime period.
Low Frequency Noise (LFN)	Where a clear tone is present below and including 250Hz and the difference between the overall C-weighted sound level and the overall A-weighted sound level exceeds 20 dB.
Nighttime	Defined as the hours from 22:00 to 07:00.
Noise	Generally associated with the unwanted portion of sound.
Noise Impact Assessment (NIA)	An NIA identifies the expected sound level emanating from a facility as measured 15 m from the nearest or most impacted permanently or seasonally occupied dwelling. It also identifies what the permissible sound level is and how it was calculated.
Permanent facility	A facility that is in operation for more than two months.
Permissible Sound Level (SPL)	The maximum SPL that a facility must not exceed at receivers located within 1500 m from the subject facility fence line. The PSL for each receiver is determined as per section 2.1 of the Directive.
Receiver	The location of the residences existing in the NIA study area for which the SPL is determined. In the event that there are no residences existing in the study area, then hypothetical receivers are included at 1500 m from the subject facility fence line.
Representative conditions	Those conditions typical for an area and/or the nature of a complaint. For ASLs, these are conditions that portray the typical activities for the area, not the quietest time. For CSLs, these do not constitute absolute worst-case conditions or the exact conditions the complainant has highlighted if those conditions are not easily duplicated. Sound levels must be taken only when representative conditions exist; this may necessitate a survey of extensive duration (two or more consecutive nights).
Sound Power Level (PWL)	The sound level emitted. The decibel equivalent of the rate of energy (or power) emitted in the form of noise. The sound power level is given by: $PWL = 10 \times LOG_{10}\left(\frac{Sound\ as\ Power}{W_0}\right)$ Where $W_0 = 10^{-12}$ watts (or 1 pW)
Sound Pressure Level (SPL)	The sound level received. The decibel equivalent of the pressure of sound waves at a specific location, which is measured with a microphone. The sound pressure level is given by: $SPL = 10 \times LOG_{10}\left(\frac{Sound\ as\ Pressure}{P_0}\right)$ Where $P_0 = 2 \times 10^{-5}$ Pa (or 20 μPa)
Subject facility	The energy industry facility which is the object of the NIA.
Temporary facility	Any facility that will be in operation less than 60 days.
Tonal component	A pronounced peak clearly obvious within the sound level spectrum.

APPENDIX B

Permissible Sound Level Determination

BC OGC Noise Control Guideline: Permissible Sound Level Determination
Sound Monitors 1-7 (Wintertime and Summertime Studies)

Basic Nighttime Sound Level

Proximity to Transportation	Dwelling Unit Density per ¼ Section of Land			Nighttime	Daytime
	1 – 8 Dwellings	9 – 160 Dwellings	>160 Dwellings		
Category 1	40	43	46	40	40
Category 2	45	48	51		
Category 3	50	53	56		

	Nighttime	Daytime
Daytime Adjustment	N/A	10
Basic Sound Levels	40	50

Class A Adjustments

Class	Reason for Adjustment	Value (dBA L_{eq})	Nighttime	Daytime
A1	Seasonal Adjustment (Wintertime Operation)	+5	N/A	N/A
A2	Ambient Monitoring Adjustment	-10 to +10	N/A	N/A
	Class Adjustment = Sum of A1 and A2 (as applicable), but not to exceed a maximum of 10 dBA L_{eq}			

	Nighttime	Daytime
Total Class A Adjustments	0	0

Class B Adjustments

Class	Duration of Activity	Value (dBA L_{eq})	Nighttime	Daytime
B1	1 day	+15		
B2	7 days	+10		
B3	< or = to 60 days	+5		
B4	> 60 days	0	0	0
Class B Adjustment = one only of B1, B2, B3 or B4				

	Nighttime	Daytime
Class B Adjustment	0	0
PERMISSIBLE SOUND LEVEL (dBA)	40	50

Category 1: Dwelling units more than 500 m from heavily travelled roads and/or rail lines and not subject to frequent aircraft flyovers.
Category 2: Dwelling units more than 30 m but less than 500 m from heavily travelled roads and/or rail lines and not subject to frequent aircraft flyovers.
Category 3: Dwelling units less than 30 m from heavily travelled roads and/or rail lines and/or subject to frequent aircraft flyovers.

APPENDIX C

Sound Levels Comparison - Class 1 Meter vs IoT Sensors

A comparison was performed between the Class 1 and IoT sensors at Fence line, Site 1, Site 3 and Site 4 locations during the summertime study, where sufficient amount of data was available. The following table summarises the insights we observed from the comparison.

Table C: Comparative study on Sound Levels obtained from Class 1 vs IoT Sensors

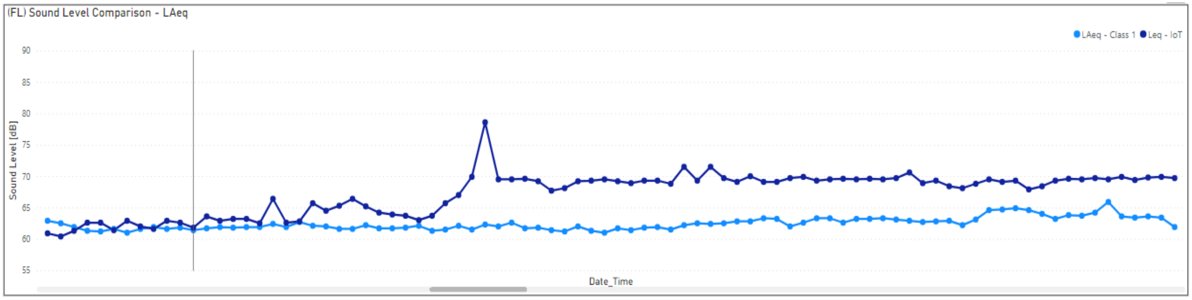
SL. No.	Study Item	Fence Line	Remote Site #1	Remote Site #3	Remote Site #4
1	No. of data points available for **Class 1** sensor	92174	29777	85769	40724
2	No. of data points available from **Iot** Sensor	37650	15102	515	20751
3	Total no. of data points at **matching** timestamps	37524	15064	335	7404
4	**Average LAeq** (dB) observed with **class 1** sensor	61.6	34.5	33.9	34.1
5	**Average Leq** (dB) observed with **IoT** sensor	65.0	41.5	38. 6	41.7
6	**Average Difference** between class 1 and IoT sensor	**4.2**	**8.3**	**8.4**	**10.1**
7	**Standard Deviation** of LAeq (Class 1, IoT)	(2.1, 5.3)	(4.2, 8.0)	(7.3, 7.8)	(6.1, 10.0)

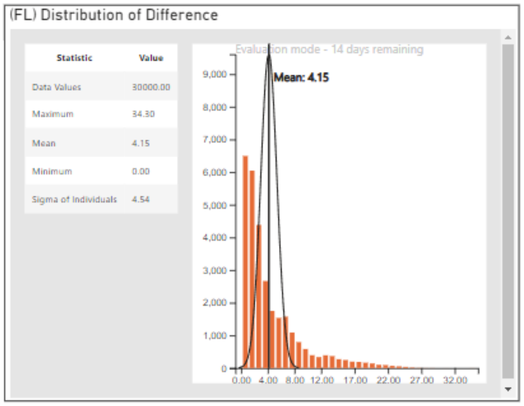
The following finding as the comparison above:

1. Significant difference in sound levels between class 1 and IoT.

   A line chart of class 1 and IoT sensor sound levels, indicates that the values recorded by IoT sensor are generally higher than the class 1 sensor at same time stamps. This continuous trend is observed throughout the monitoring period and for all the locations. We observe an average difference of 4.15, 8.28, 8.41 and 10.06 decibels between class 1 sensor and IoT sensor for the above-mentioned four sites respectively.

Figure C1: Comparison of Class 1 and IoT sensor sound levels at Fence Line

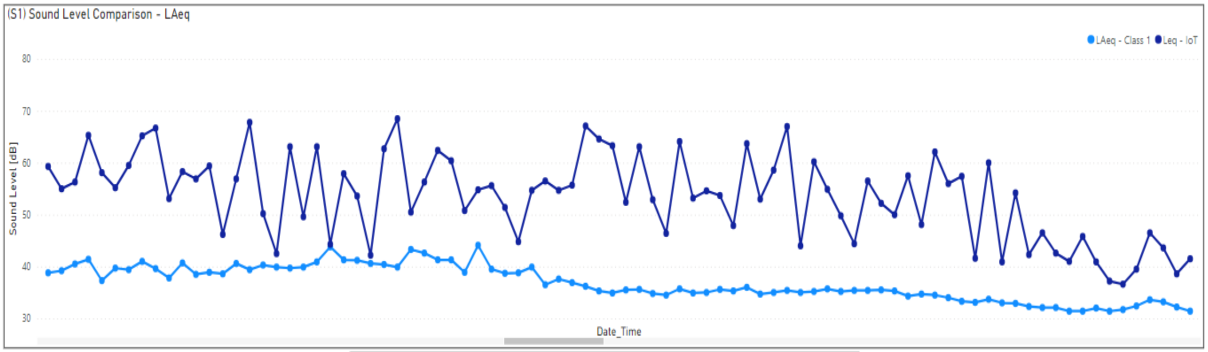


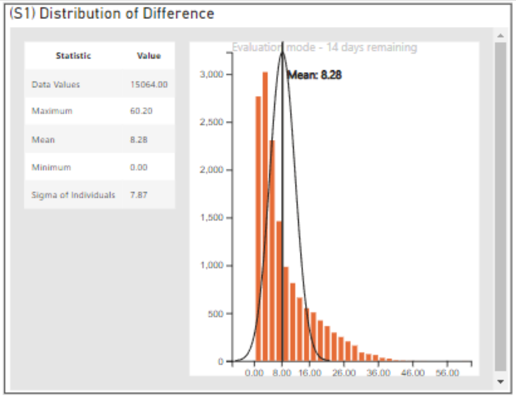


(FL) Distribution of Difference

Statistic	Value
Data Values	30000.00
Maximum	34.30
Mean	4.15
Minimum	0.00
Sigma of Individuals	4.54

Figure C2: Comparison of Class 1 and IoT sensor sound levels at Remote Site 1

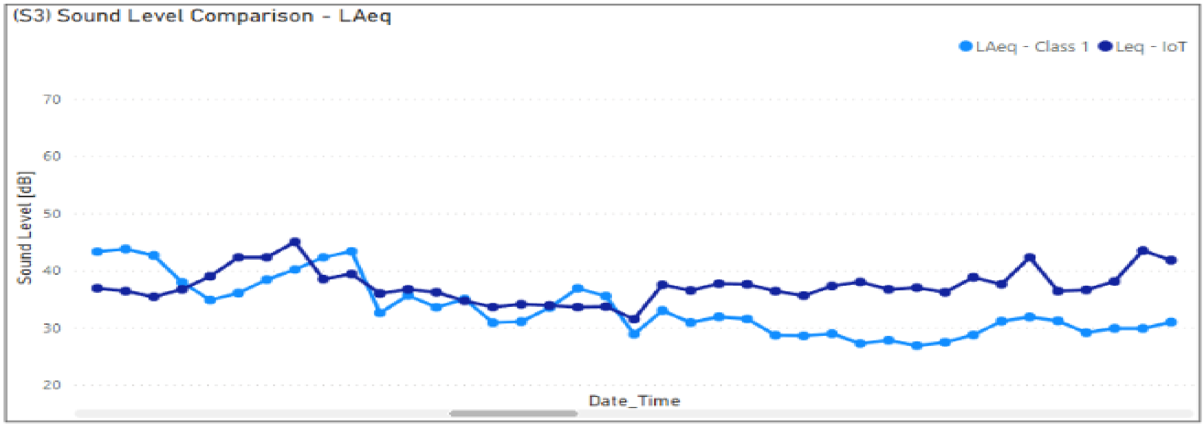


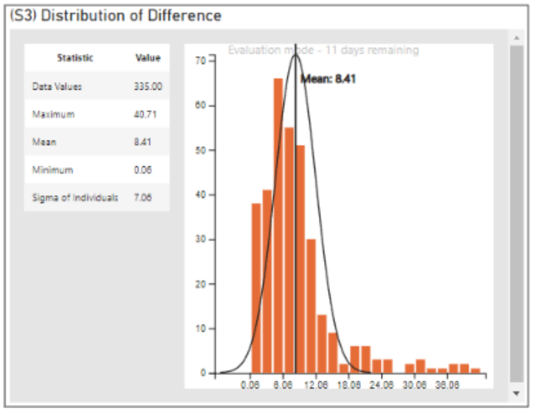


(S1) Distribution of Difference

Statistic	Value
Data Values	15064.00
Maximum	60.20
Mean	8.28
Minimum	0.00
Sigma of Individuals	7.87

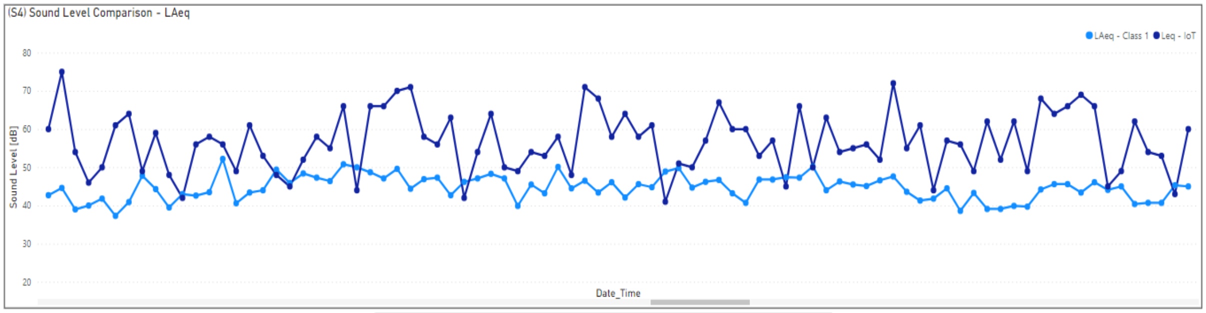
Figure C3: Comparison of Class 1 and IoT sensor sound levels at Remote Site 3

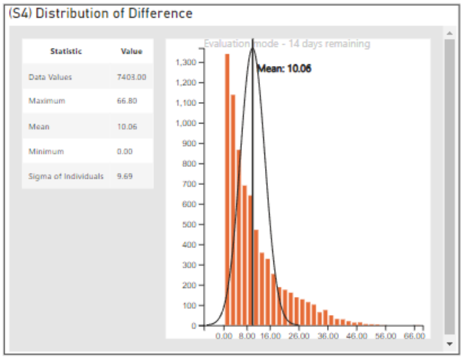




Statistic	Value
Data Values	335.00
Maximum	40.71
Mean	8.41
Minimum	0.06
Sigma of Individuals	7.06

Figure C4: Comparison of Class 1 and IoT sensor sound levels at Remote Site 4





Statistic	Value
Data Values	7403.00
Maximum	66.80
Mean	10.06
Minimum	0.00
Sigma of Individuals	9.69

2. High variability in the recoding of sound levels from IoT sensor.

To further study the trend, dispersion, and variability in sound values of both these sensors, the Standard Deviation of the LAeq values were calculated. Standard Deviation is a measure of how dispersed the data is in relation to the mean. It shows us how much variation or spread from the mean exists. We observe that the standard deviations calculated for IoT sensor are quite high when compared to the values calculated for Class 1 sensor, which indicates a relatively high variability of values from its mean.

APPENDIX D

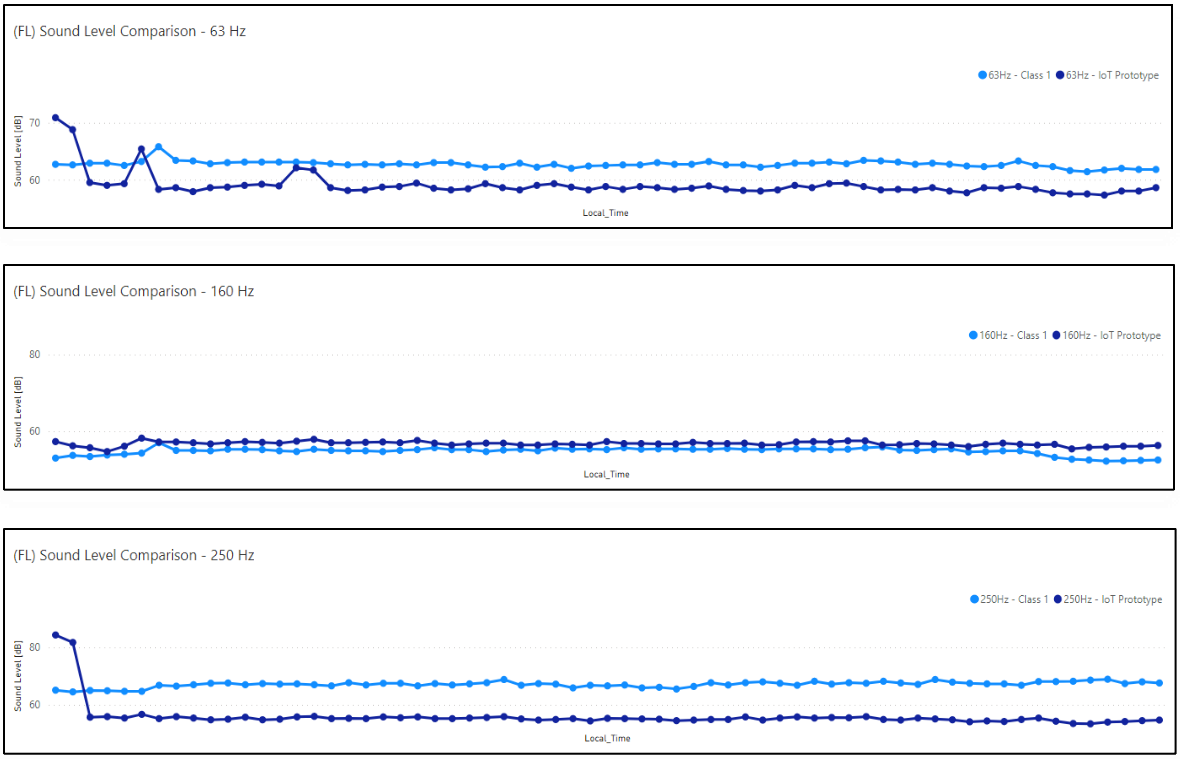
Sound Levels Comparison
- Class 1 sound meter vs IoT Prototype sensor

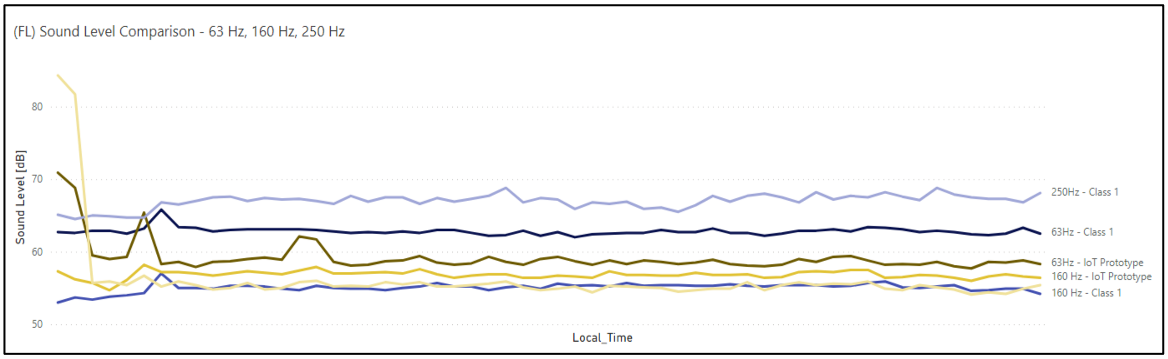
During the summertime noise study, IoT Prototype sensors were improved and installed at fence line, and all Remote sites other than Remote site 1. Data wasn't collected at Remote sites 3 and 4 though, due to problems with the installation, connection, or power. The IoT Prototype sensors vs Class 1 sound meter comparison was studied at only two locations, the Fence line and Remote site 5, where a significant amount of sound data was collected at same time periods.

The sound levels of 1/3 octave bands between 31.5 Hz and 6300Hz were obtained from the processed sound recordings of the IoT Prototype sensors. Three 1/3 octave bands - 63 Hz, 160 Hz, and 250 Hz were selected at the two sites and compared as per the corresponding bands recorded by Class 1 sensors. Throughout the course of the study, both sensors recorded data were shown in a consistent manner. In other words, the peaks, lows, and variations in these bands by both the sensors at exactly same places in a line graph were observed throughout the monitoring period. Another finding was that, at both sites, the IoT Prototype sensor recorded slightly higher band values than the Class 1 sensor, and this trend also persisted throughout the monitoring period.

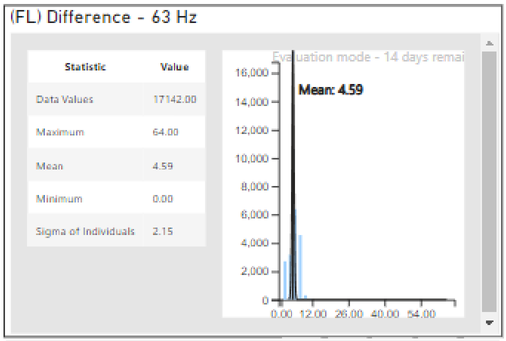
For these three bands, the difference between IoT Prototype sensor recorded values and Class 1 values was calculated, and the distributions of differences were examined using histograms. Between IoT Prototype sensor and Class 1 sensor and the bands 63, 160, and 250, respectively, an average difference of 4.59 dB, 5.99 dB, and 4.03 dB was observed at the Fence line location. At Remote site 5, the average difference between the two sensors and for each of the three bands was much higher at 14.42 dB, 12.36 dB, and 11.44 dB. Similar data recordings were observed by both the sensors and one type can be a good alternative for another.

Figure D1: Octave Bands Comparison - Class 1 vs IoT Prototype sensors at Fence Line



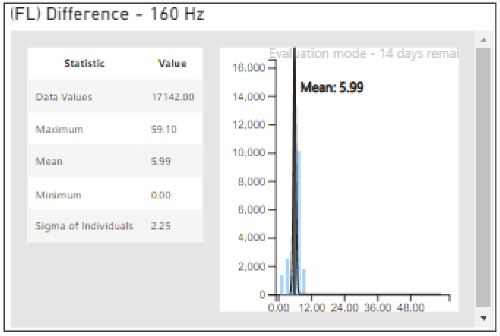


(FL) Sound Level Comparison - 63 Hz, 160 Hz, 250 Hz



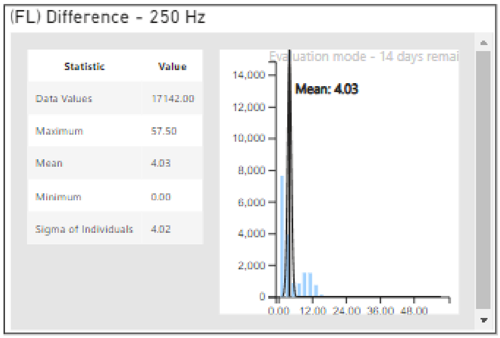
(FL) Difference - 63 Hz

Statistic	Value
Data Values	17142.00
Maximum	64.00
Mean	4.59
Minimum	0.00
Sigma of Individuals	2.15



(FL) Difference - 160 Hz

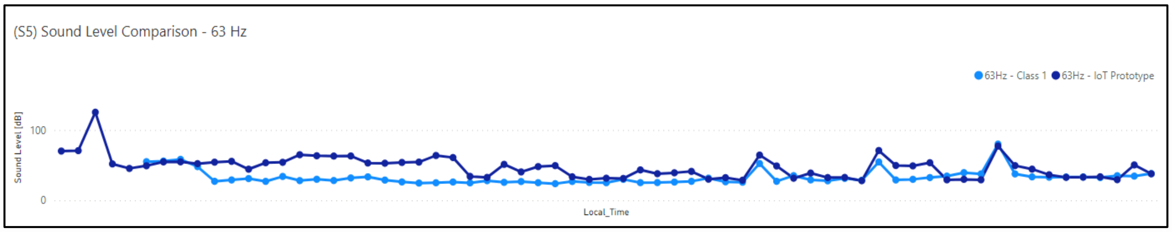
Statistic	Value
Data Values	17142.00
Maximum	59.10
Mean	5.99
Minimum	0.00
Sigma of Individuals	2.25

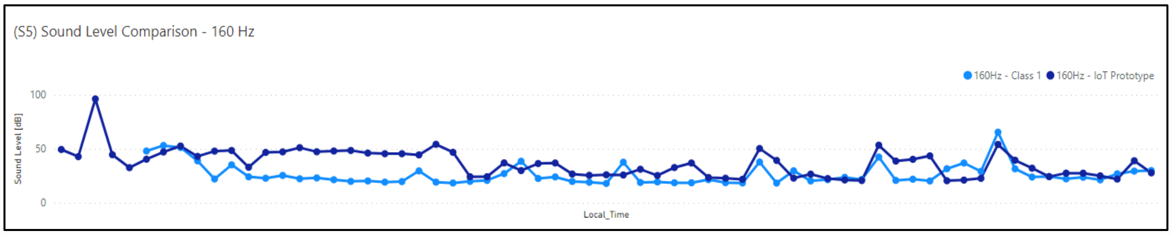


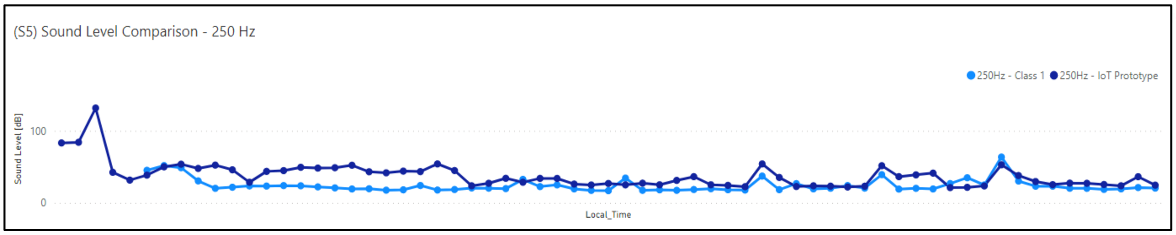
(FL) Difference - 250 Hz

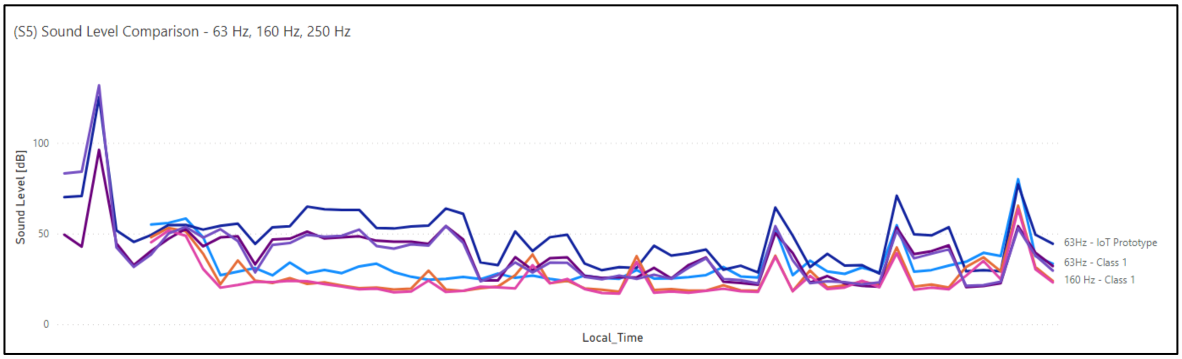
Statistic	Value
Data Values	17142.00
Maximum	57.50
Mean	4.03
Minimum	0.00
Sigma of Individuals	4.02

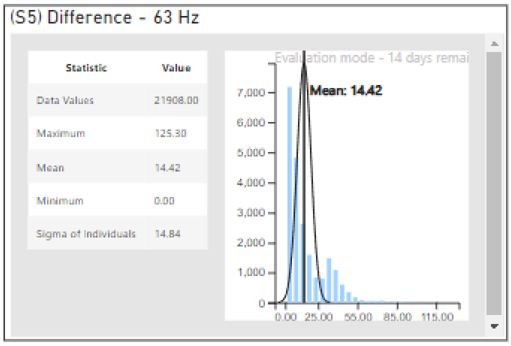
Figure D1: Octave Bands Comparison - Class 1 vs IoT Prototype sensors at Remote Site 5



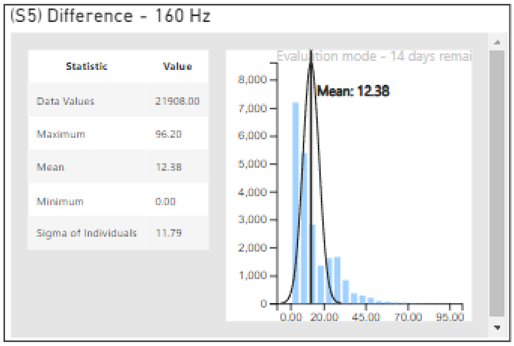






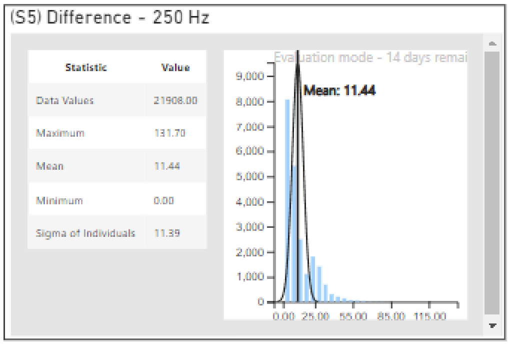

(S5) Difference - 63 Hz

Statistic	Value
Data Values	21908.00
Maximum	125.30
Mean	14.42
Minimum	0.00
Sigma of Individuals	14.84



(S5) Difference - 160 Hz

Statistic	Value
Data Values	21908.00
Maximum	96.20
Mean	12.38
Minimum	0.00
Sigma of Individuals	11.79



(S5) Difference - 250 Hz

Statistic	Value
Data Values	21908.00
Maximum	131.70
Mean	11.44
Minimum	0.00
Sigma of Individuals	11.39

APPENDIX E

Weather Stations Comparison

One standard weather station was setup at Fence line and one new type weather station was setup at Remote site 3 location during wintertime study. The weather data collected by these stations were studied with the help of a detailed comparison between these stations on data captured at same time frames only. The matching period between both these stations are May 5th, 2022, 14:58 to May 17th, 2022, 20:24 respectively. As a result, 20,770 per minute data points were obtained. Following are some of the major insights derived from the above comparison.

1. The new type weather station captured a relatively high wind speed values than the standard weather station with an average difference of 6.83 kph. The average wind speed observed with standard weather station is 5.98 kph whereas that observed with the new type weather station is 12.30 kph. The maximum wind speeds every captured by the standard weather station is 19.14 kph whereas at some point, the new type weather station recorded a maximum value of 77.40 kph during the above-mentioned study duration.

2. A considerable difference in the average wind speeds for the three wind conditions under study were also observed. For upwind, downwind and crosswind conditions respectively, an average wind speed of 5.42, 5.58 and 6.47 kph was observed for the standard weather station whereas that for the new type weather station were 10.47, 10.65 and 14.03 kph respectively.

3. The differences under wind directions by plotting a line chart of wind direction values by both weather stations were further investigated, which indicated a difference of 90 to 100 degrees between both weather stations and this difference was constant throughout the study period. Overall, about 38% of the data captured by both the wind stations had a difference of greater than 90 degrees at same time stamps.

Figure E1: Wind Stations comparison -Wind Speed

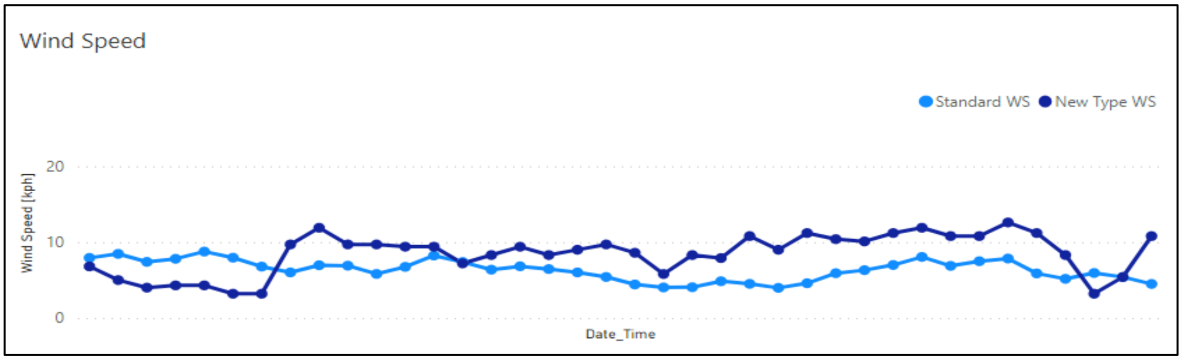


Figure E2: Wind Stations comparison -Wind Direction

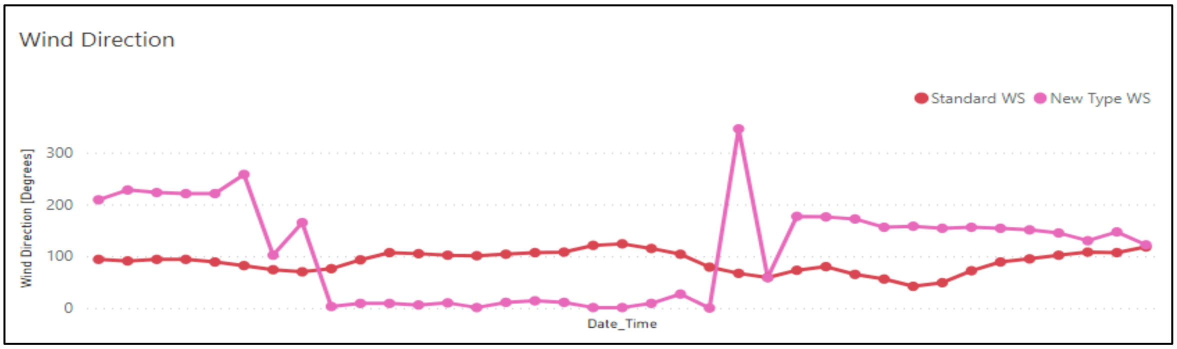
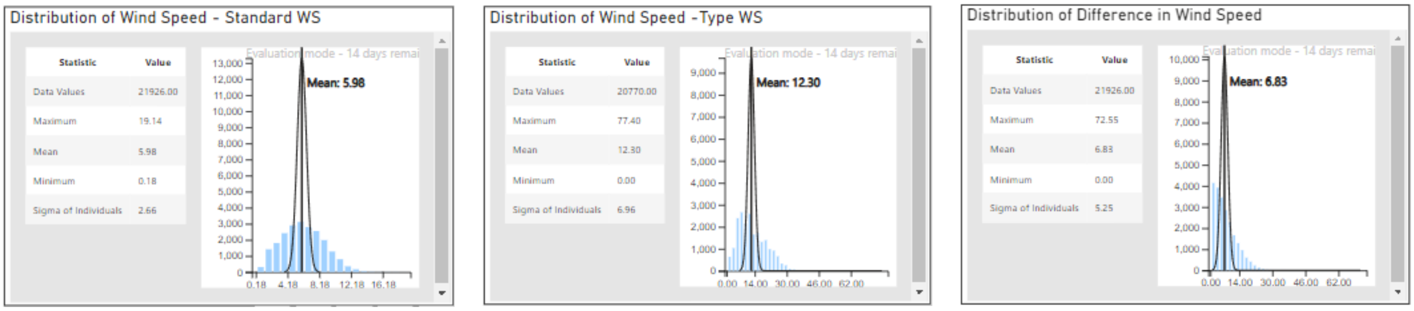


Figure E3: Wind Stations comparison -Data Distribution



Distribution of Wind Speed - Standard WS

Statistic	Value
Data Values	21926.00
Maximum	19.14
Mean	5.98
Minimum	0.18
Sigma of Individuals	2.66

Distribution of Wind Speed -Type WS

Statistic	Value
Data Values	20770.00
Maximum	77.40
Mean	12.30
Minimum	0.00
Sigma of Individuals	6.96

Distribution of Difference in Wind Speed

Statistic	Value
Data Values	21926.00
Maximum	72.55
Mean	6.83
Minimum	0.00
Sigma of Individuals	5.25