APPENDIX E
ACOUSTIC ENVIRONMENT

Appendix E ACOUSTIC ENVIRONMENT

E.1 NOISE ASSESSMENT TECHNICAL REPORT

E.1.2

Blue Hill Wind Energy Project
Noise Impact Assessment

Prepared for:
Algonquin Power

Prepared by:
Stantec Consulting Ltd.

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Abbreviations

dBA	A-Weighted Decibel
G	Ground Absorption Factor
ISO	International Organization for Standardization
L_{eq}	Energy Equivalent Sound Level
LAA	Local Assessment Area
km	kilometre
m	metre
MW	megawatt
MOECC	Ministry of Environment and Climate Change
ONAF	Oil Natural Air Forced
PDA	Project Development Area
PWL	Sound Power Level re 10^{-12} Watt
RM	Rural Municipality
SLL	Sound Level Limit
WTG	Wind Turbine Generator

Glossary

Ambient Sound Level or Ambient Noise	All-encompassing sound that is associated with a given environment, usually a composite of sounds from many sources near and far. Includes noise from all sources other than the sources of interest (i.e., sound other than that being measured), such as sound from other industrial sources, transportation sources, animals, and nature.
Attenuation	The reduction of sound intensity achieved by various means (e.g., air, humidity, and porous materials).
A-Weighting	The weighting network used to account for changes in level sensitivity as a function of frequency. The A-weighting network de-emphasizes the low (i.e., below 1 kHz) frequencies, and emphasizes the frequencies between 1 kHz and 6.3 kHz, in an effort to simulate the relative response of the human ear. See also frequency weighting.
Background Sound Level or Background Noise	Same as the ambient sound level.
Daytime	Defined as the hours (h) from 07:00h to 19:00h.
Decibel	A logarithmic measure of any measured physical quantity and commonly used in the measurement of sound. The decibel (dB) provides the possibility of representing a large span of signal levels in a simple manner. The difference between the sound pressure for silenced versus a loud sound is a factor of 1:1,000,000 or more and the same in Decibel is 0-130 dB, therefore it is less cumbersome to use a small range of equivalent values. A tenfold increase in sound power is equal to +10 dB; a tenfold increase in sound amplitude is equal to +20 dB.
Decibel, A-weighted	A-weighted decibels (dBA). Most common units for expressing sound levels since they approximate the response of the human ear.

Energy Equivalent Sound Level (L_{eq})	An energy-equivalent sound level (L_{eq}) over a specified period of time that would have the same sound energy as the actual (i.e., unsteady) time varying sound over the same period of time. It represents the average sound pressure encountered for the period. The period is often added as a suffix to the label (i.e., L_{eq}(24) for the 24-hour equivalent sound level). A L_{eq} value expressed in dBA is a good, single-value descriptor to use as a measure of annoyance due to noise.
Frequency	The number of times per second that the sine wave of sound repeats itself. It can be expressed in cycles per second, or Hertz (Hz).
Frequency Weighting	A method used to account for changes in sensitivity as a function of frequency. Three standard weighting networks, A, B, and C, are used to account for different responses to sound pressure levels. Note: The absence of frequency weighting is referred to as "flat" response or linear weighting. See also A-weighting.
Ground Absorption Coefficient	A parameter defined based on noise reflection characteristics of a surface. It varies between 0.0 (fully reflective) to 1.0 (fully absorptive).
Ground Effect	The change in sound level, either positive or negative, due to intervening ground between source and receiver. Ground effect is a relatively complex acoustic phenomenon, which is a function of ground characteristics, source-to-receiver geometry, and the spectral characteristics of the source. A commonly used rule-of-thumb for propagation over soft ground (e.g., grass) is that ground effects will account for about 1.5 dB per doubling of distance. This relationship is empirical and tends to break down for distances greater than about 30 to 61 metres (100 to 200 feet).
Hertz (Hz)	A unit of frequency, expressed as cycles per second.
International Organization for Standardization	An international body that provides scientific standards and guidelines related to various technical subjects and disciplines.

Line Source	Multiple point sources moving in one direction (e.g., a continuous stream of roadway traffic, radiating sound cylindrically). Sound levels from a line source decrease at an ideal rate of 3 dB per doubling of distance.
Mitigation	Measures taken to reduce, avoid, or control effects on the environment.
Night-time	Defined as the hours from 23:00h to 07:00h in Ontario noise guidelines.
Noise	Any unwanted sound. "Noise" and "sound" are used interchangeably in this document.
Noise level	Same as sound level.
Octave	The interval between two frequencies having a ratio of two to one. For acoustic measurements, the octave bands start at 1,000 Hz centre frequency and go up or down from that point, at a 2:1 ratio. From 1,000 Hz, the next centre frequency is 2,000 Hz; the next is 4,000 Hz, or 500 Hz, 250 Hz, etc.
Point of Reception	A representative point considered for the purpose of assessment within noise-sensitive receptor such as a residence (i.e., dwelling inhabited at least 6 months of the year).
Point Source	Source that radiates sound spherically (i.e., equally in all directions). Sound levels from a point source decrease at a theoretical rate of 6 dB per doubling of distance.
Predictable Worst Case Operation	A planned and predictable mode of operation for stationary source(s), during the hour when the noise emissions from the stationary source(s) have the greatest impact at a point of reception, relative to the applicable limit.
Sound	A wave motion in air, water, or other media. It is the rapid oscillatory compression changes in a medium that propagate to distant points. It is characterized by changes in density, pressure, motion, and temperature as well as other physical properties. Not all rapid changes in the medium are due to sound (e.g., wind distortion on a microphone diaphragm).

Sound Level	Generally, sound level refers to the weighted sound pressure level obtained by frequency weighting, usually A- or C-weighted, and expressed in decibels
Sound level meter	An instrument consisting of a microphone, amplifier, output meter and frequency-weighting networks that is used to measure noise and sound levels.
Sound Power Level	The total sound energy radiated by a source per unit time (i.e. rate of acoustical energy radiation). The unit of measurement is the Watt. The acoustic power radiated from a given sound source as related to a reference power level (i.e., typically 1E-12 watts, or 1 picowatt) and expressed as decibels. A sound power level of 1 watt = 120 decibels relative to a reference level of 1 picowatt.
Sound Pressure	The root-mean-square of the instantaneous sound pressures during a specified time interval in a stated frequency band.
Sound Pressure Level	Logarithmic ratio of the root mean square sound pressure to the sound pressure at the threshold of human hearing (i.e., 20 micropascals).
Spectrum (Frequency Spectrum)	The frequency dependent characteristic of sound often express as amplitude versus octave band frequency (see octave band).

1.0 INTRODUCTION

Algonquin Power (Algonquin) is proposing to construct the Blue Hill Wind Energy Project (the Project), a 177 megawatt (MW) facility located in southern Saskatchewan (SK) within the rural municipalities (RMs) of Morse and Lawtonia. The Project will consist of between 49 and 56 wind turbine generators (WTG) and associated infrastructure, including access roads, electrical collector lines and a substation. It is intended that seven of the 56 WTGs will be for contingency use; however, to be conservative, the maximum number of WTGs is considered for the Noise Impact Assessment (NIA). Each WTG will have a capacity between 3.2 MW and 3.7 MW; a capacity of 3.6 MW is used for assessment purposes. Three possible substation locations (one planned and two contingency) are proposed for the Project. Each substation development includes one 200 MVA transformer. All three locations are included in the assessment as a conservative approach.

The objective of the NIA is to assess the Project noise effect at identified points of reception. The associated methods and results are described in this technical data report. The prediction result was generated based on technical standards, manufacturer's information, and computer noise propagation modelling.

2.0 ASSESSMENT AREA

The Project is located approximately 10 km south of the town of Herbert, SK. The Project surrounding area is largely cultivated land. The Project Development Area (PDA) is represented by the physical Project footprint and consists of the area of physical disturbance associated with Project components, i.e., WTGs, access roads, collector lines, substation, and temporary workspaces. The Local Assessment Area (LAA) is defined as a 3 km buffer around the Project PDA as this area encompasses Project-related noise emissions. There is no Regional Assessment Area (RAA) defined for the acoustic environment as the Ontario Ministry of Environment and Climate Change's (MOECC) *Noise Guidelines for Wind Farms* (MOECC 2016) considers Project-only noise effects; therefore, there are no cumulative noise effects to consider and the LAA is sufficient for the assessment of potential effects on the acoustic environment. The PDA and LAA are shown in Figure E1-1.

There are 25 points of reception (i.e., receptors) identified inside the LAA. The receptor locations are presented in Table 1 and shown in Figure E1-1. All receptors are assumed to be residential dwelling locations and were assessed at an elevation of 4.5 m above ground level.

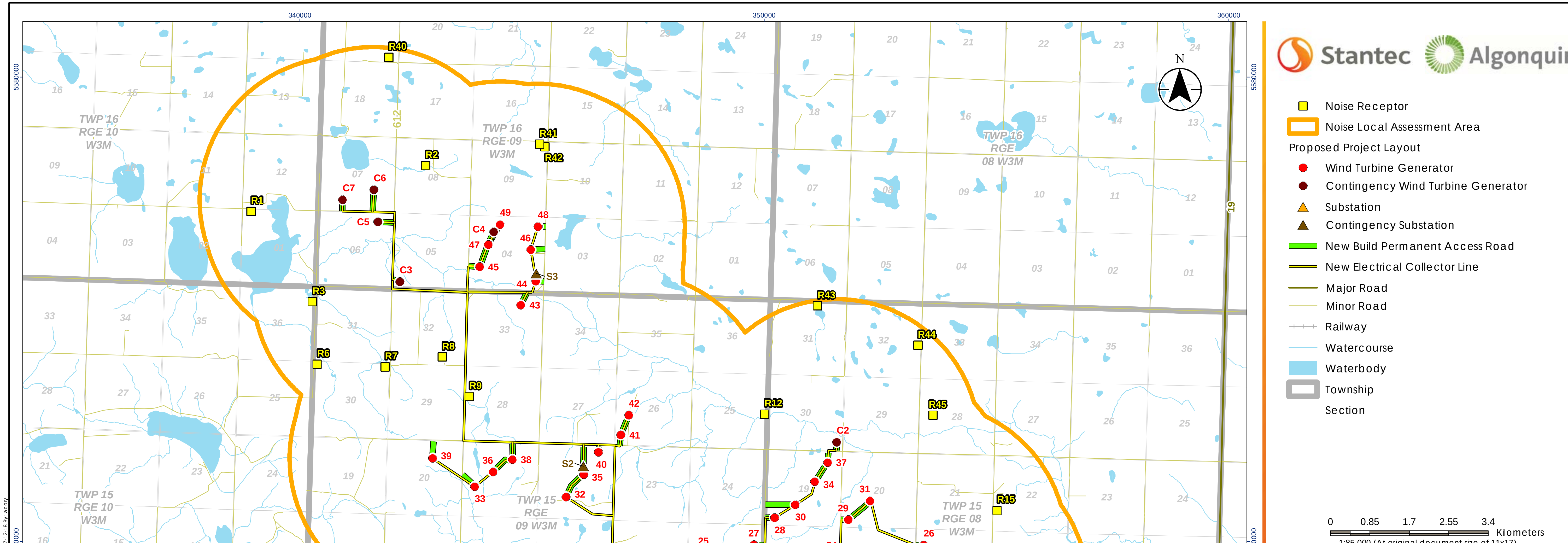
Table 1 Receptor Locations

Receptor Name[1]	Universal Transverse Mercator (UTM) Coordinates [2] (m)		Nearest Wind Turbine	Approximate Distance to Nearest Wind Turbine (m)
	Easting	Northing		
R22	349430	5568624	WTG_21	800
R32	350422	5565781	WTG_7	810
R21	349444	5568481	WTG_21	940
R9	343653	5573124	WTG_39	1550
R2	342713	5578097	WTG_C6	1250
R12	350006	5572745	WTG_C1	1670
R25	345134	5568958	WTG_18	1840
R8	343073	5573974	WTG_C4	1870
R24	345492	5568122	WTG_18	1760
R28	347205	5566787	WTG_12	1580
R42	345278	5578504	WTG_48	1740
R41	345165	5578557	WTG_48	1790
R15	355014	5570674	WTG_26	1760
R7	341841	5573759	WTG_C4	1860
R45	353635	5572719	WTG_C1	2150
R3	340281	5575166	WTG_C4	1920
R46	348896	5564382	WTG_1	2490
R48	348838	5564156	WTG_1	2560
R47	348666	5564186	WTG_1	2730
R6	340378	5573819	WTG_C4	2500
R1	338956	5577108	WTG_C7	2000
44	353312	5574224	WTG_C1	2720
R40	341917	5580425	WTG_C6	2890
R43	351152	5575074	WTG_C1	2950
R39	350774	5561113	WTG_1	2980

NOTE:

[1] Receptors R43 and R47 were identified by examining satellite imagery and were not field verified.

[2] UTM Zone 13 NAD 83



Notes

1. Coordinate System: NAD 1983 UTM Zone 13N
2. Base features produced under license with the Government of Saskatchewan and the Government of Canada
3. Layout: Algonquin, Sept 06, 2017, V3
4. Receptors: Field Validated by Stantec/Algonquin, 2017

Project Location
Near Herbert, SK

113254088-043 REVC
Prepared by acory on 2017-12-18
Technical Review by jchui on 2017-12-18

Client/Project
Algonquin Power Co.
Blue Hill Wind Energy Project

Figure No.
E1-1

Title
Noise Local Assessment Area and Receptor Locations

3.0 REGULATORY FRAMEWORK

There is no noise regulation in the Province of Saskatchewan. As such, in the absence of provincial guidance or regulations, assessment of the acoustic environment uses the Ontario Ministry of the Environment and Climate Change (MOECC) *Noise Guidelines for Wind Farms* (MOECC 2016) level of 40 dBA sound level limit (SLL) to determine a significant adverse effect threshold.

Other relevant assumptions appropriate for a prairie environment were also used during modeling of the potential acoustic effects and are stated in this report.

3.1 CLASSIFICATION OF RECEPTOR AREA

The MOECC noise guideline provides definitions of three possible classifications for receptor areas. Class 1, Class 2, and Class 3 areas are described as urban, mixed, and rural areas, respectively. The classification of an area is one of the determining factors for the SLL of receptors located within that area. The Project location and LAA is best described by the characteristics of a Class 3 area, which is defined in the noise guideline (MOECC 2008) as the following:

> **"Class 3 Area**
> Means a rural area with an acoustical environment that is dominated by natural sound having little or no road traffic, such as the following:
>
> - A small community
> - Agricultural area
> - A rural recreational area such as a cottage or a resort area; or
> - A wilderness area."

Typically, a receptor located within approximately 500 m of a provincial highway can be classified as a Class 2 area. As a conservative approach, the LAA is considered as a Class 3 area despite the location of some receptors being close to roadways and commercial operations. The regulatory requirements are most stringent for a Class 3 area.

3.2 SOUND LEVEL LIMIT

The SLL for wind turbine noise emissions at receptors provided in the MOECC noise guideline also vary according to wind speed at a 10 m reference height. The SLL is measured in A-weighted one hour equivalent sound level ($L_{eq,\ 1hr}$). As wind speed at the reference height increases, the SLL also increases to address the corresponding increase in wind-induced background sound levels. Table 2 summarizes the SLLs prescribed in the MOECC noise guideline at each wind speed for a Class 3 area.

Table 2 Sound Level Limit for Wind Facilities for a Class 3 Area

Wind Speed (m/s) at 10 m height	≤ 6	7	8	9	≥10
Wind Turbine SLLs for a Class 3 Area. Expressed in A-weighted equivalent sound level ($L_{eq,\ 1hr}$), applied at the Point of Receptions	40 dBA	43 dBA	45 dBA	49 dBA	51 dBA
NOTE: The SLL is based on a one hour equivalent sound level ($L_{eq,1HR}$)					

The SLL does not apply to participating receptors according to Section 6.5.6.1 of the noise guideline (MOECC 2013); however, to be conservative, this assessment includes all participating (i.e., lease agreement with Algonquin) and non-participating receptors within the LAA.

The SLL of 40 dBA at the wind speed of 6 m/s or less (at 10 m height) for a Class 3 area is the most stringent in the guideline. As a conservative approach, the SLL of 40 dBA was used at all receptors in this assessment.

4.0 METHODS

4.1 Environmental Noise Descriptors

Environmental noise typically varies over time. To account for this variation, a single number descriptor known as the energy equivalent sound level (L_{eq}) is used. It is defined as the steady, continuous sound level over that specified time that has the same acoustic energy as the actual varying sound levels over the same time. The unit for L_{eq} is in A-weighted decibel (dBA). dBA reflects the response of the human ear to different sound frequencies. The time period used for L_{eq} measurements and regulatory criteria is the 1 hour equivalent sound level ($L_{eq,1HR}$).

4.2 Acoustic Modelling

Noise prediction was conducted using Cadna/A acoustic modeling software (DataKustik 2017), based on the internationally accepted sound propagation algorithms (ISO 1993, 1996). These standards are commonly used by noise practitioners. All predictions were based on noise emission in full octave band frequencies; frequencies ranging from 31.5 Hz to 8,000 Hz were included.

A conservative approach is incorporated in the model such that meteorological conditions enhancing noise propagation (e.g., downwind and temperature inversion conditions) exist 100% of the time. The meteorological conditions used in the acoustics model do not occur all the time; therefore, model predictions are expected to be conservative.

The modelling parameters used in the assessment are summarized in Table 3. The wind speed is based on ISO 9613-2 standard, which assumes 1 to 5 m/s downwind condition from the source (i.e., at hub height) to the receptor in the sound propagation calculation. A ground absorption factor (G) of 0.7 is used in the model to represent the Project surrounding area is largely cultivated land. G is an index with value ranges from 0 to 1 where 0 represents reflective ground and 1 represent absorptive ground condition. Ground terrain is not incorporated in the noise model as the Project area is relatively flat; as well, it represents a conservative approach to the modeling.

Table 3 Acoustic Modelling Parameters

Item	Model Parameters	Model Setting
1	Temperature	10 °C
2	Relative humidity	70 %
3	Wind speed	Downwind condition, as per ISO 9613-2 standard downwind setting (wind speed of 1 to 5 m/s)
4	Noise propagation software	Cadna/A (DataKustik 2017)
5	Noise propagation calculation standard	ISO 9613
6	Ground conditions and attenuation factor	Ground absorption (G) of 0.7
7	Terrain Parameters (terrain resolution)	No terrain data incorporated

4.3 OPERATION SCENARIO

The wind farm will operate continuously throughout the year during the daytime (07:00 – 19:00) and nighttime (19:00 – 07:00) hours when favorable wind conditions exist within the cut-in (3 m/s) and cut-out wind speeds (22.5 m/s) at hub height. The NIA assumed that all sources of noise operate at 100% of the rated capacity which represents a conservative scenario for the predictable worst case hour of operation.

4.4 NOISE EMISSION SOURCES

The Project includes the operation of 49 WTGs and one substation. As a conservative approach, seven contingency WTGs and two contingency substations are included in this assessment. Therefore, a total of 56 WTGs and three substations are included in the assessment. All WTGs are assumed to be Vestas V136 3.6 MW model with serrated blade design and a hub height of 105 m. The WTGs will be operating in the standard P01 mode. Three possible substation locations (one planned and two contingency) are proposed for the Project. Each substation development includes one 200 MVA transformer. All three locations are included in the assessment as a conservative approach.

Table 4 summarizes the sound power levels for the WTG and substation. The WTG and substation locations are shown in Figure E1-1. The Universal Transverse Mercator (UTM) coordinates for the WTG and substation locations are presented in Appendix A of this report.

The sound power level for the WTGs was established using noise data information provided by Vestas. The sound power levels represent the WTG operation during a hub height wind speed of 10 m/s under standard operation mode “P-01 mode”. The hub height wind speed of 10 m/s is equivalent to the wind speed of 6 m/s at 10 m. In the MOECC noise guideline, the SLL increases with the wind speed at 10 m. The lowest SLL of 40 dBA corresponds to the wind speed of 6 m/s at

10 m. The overall sound power level for the WTG remains the same at operating windspeed higher than 10 m/s at hub height. Therefore, the NIA approach is conservative by using information that represent wind speed condition at the lowest noise threshold of 40 dBA.

The sound power level for the substation 200 MVA transformers under ONAF operation conditions were estimated by theoretical predication methods from acoustic literature (Crocker 2007).

Table 4 Wind Turbine Generator and Substation Sound Power Levels

Noise Source	Sound Power Level (dB) in Octave Band Center Frequency (Hz) per Unit									Overall dBA
	31.5	63	125	250	500	1000	2000	4000	8000	
Vestas V136 3.6 MW wind turbine generator [1]	117	114	109	106	102	100	98	90	73	105.5
Substation (200 MVA) [2]	101	107	109	104	104	98	93	88	81	104.7

NOTES:

[1] Based on manufacturer information.

[2] Based on theoretical prediction from acoustic literature (Crocker 2007).

5.0 RESULTS

Table 5 summarizes the predicted Project-only noise effect at the receptors. Figure E1-2 presents the Project-only noise contour results within the LAA. The model assumes that all 56 WTGs and three substation transformers are operating continuously during both the daytime and nighttime period; therefore, results are representative of the predictable worst case hour of operation.

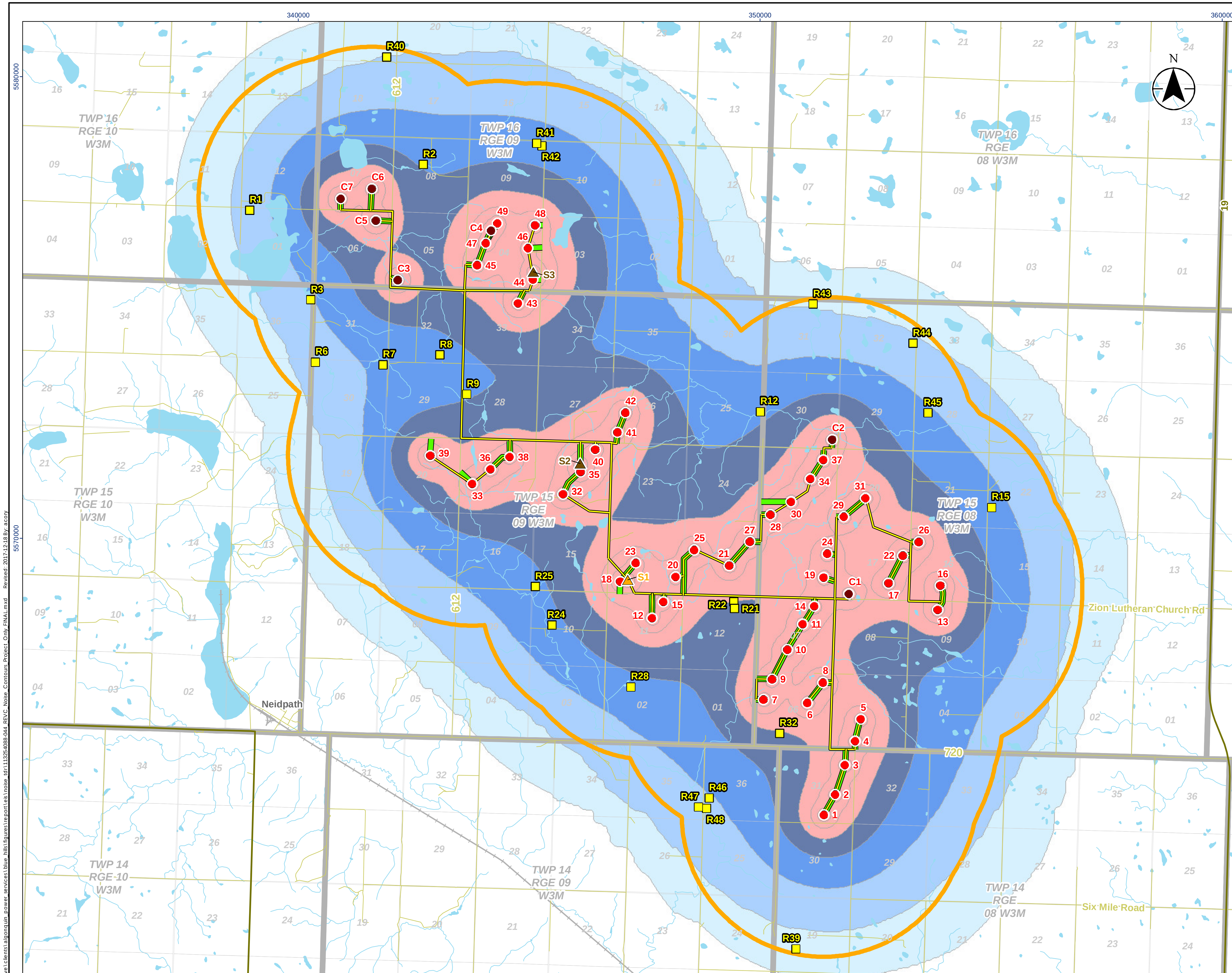
R22 is the receptor location with the highest predicted noise level of 40.0 dBA; it is located approximately 800 m from the closest WTG (ID# WTG 21). The results indicate that the Project noise effect meets the SLL of 40 dBA at all receptor locations.

Table 5 Project-Only Noise Effect

Receptor Name[1]	L_{eq} (dBA)
R22	40.0
R32	39.6
R21	39.4
R9	34.9
R2	34.7
R12	34.1
R25	34.3
R8	33.9
R24	33.9
R28	33.6
R42	32.5
R41	32.4
R15	31.7
R7	31.4
R45	30.6
R3	29.9
R46	29.6
R48	28.9
R47	28.3
R6	27.1
R1	27.0
R44	26.0
R40	25.1
R43	24.6
R39	22.6

NOTE:

[1] Receptors R43 and R47 were identified by examining satellite imagery and were not field verified.



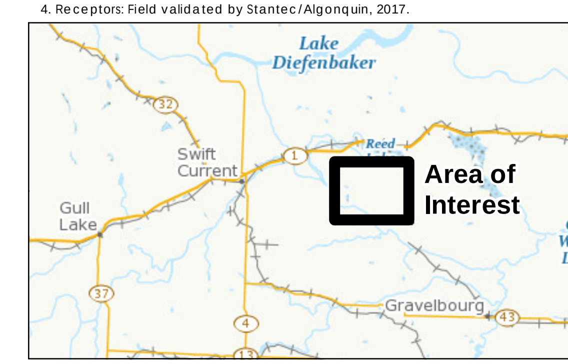
Noise Receptor
Noise Local Assessment Area

Noise Contour
- 20 to 25 dBA
- 25 to 30 dBA
- 30 to 35 dBA
- 35 to 40 dBA
- Greater than 40 dBA

Proposed Project Layout
- Wind Turbine Generator
- Contingency Wind Turbine Generator
- Substation
- Contingency Substation
- New Build Permanent Access Road
- New Electrical Collector Line
- Major Road
- Minor Road
- Railway
- Watercourse
- Waterbody
- Township
- Section

0 0.85 1.7 2.55 3.4 Kilometers
1:85,000 (At original document size of 11x17)

Notes
1. Coordinate System: NAD 1983 UTM Zone 13N
2. Base features produced under license with the Government of Saskatchewan and the Government of Canada
3. Layout: Algonquin, Sept 06, 2017, V3
4. Receptors: Field validated by Stantec/Algonquin, 2017.



Project Location
Near Herbert, SK

113254088-044 REVC
Prepared by acory on 2017-12-18
Technical Review by jchui on 2017-12-18

Client/Project
Algonquin Power Co.
Blue Hill Wind Energy Project

Figure No.
E1-2

Title
Predicted Leq Noise Contour Map - Project Only

6.0 SUMMARY AND CONCLUSIONS

Project noise effects have been predicted for all 25 receptors within the LAA. The predicted sound level the receptors are compared to the SLL of 40 dBA prescribed for Class 3 areas (i.e., rural areas) in the MOECC noise guideline. The predicted results at all receptors are at or below the SLL.

7.0 REFERENCES

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Appendix A WIND TURBINE AND SUBSTATION LOCATIONS

A.1 WIND TURBINE GENERATOR AND SUBSTATION LOCATIONS

Table A-1 Wind Turbine Generator and Substation Locations

IDs	UTM Coordinates [1] (m)	
	Easting	Northing
WTG_1	351379	5564017
WTG_2	351625	5564457
WTG_3	351834	5565097
WTG_4	352054	5565611
WTG_5	352177	5566087
WTG_6	351022	5566442
WTG_7	350073	5566510
WTG_8	351357	5566881
WTG_9	350258	5566951
WTG_10	350587	5567594
WTG_11	350924	5568142
WTG_12	347660	5568278
WTG_13	353840	5568455
WTG_14	351169	5568533
WTG_15	347906	5568624
WTG_16	353899	5568980
WTG_17	352776	5569032
WTG_18	346972	5569067
WTG_19	351377	5569155
WTG_20	348173	5569168
WTG_21	349330	5569414
WTG_22	353087	5569631
WTG_23	347306	5569466
WTG_24	351452	5569669
WTG_25	348572	5569751
WTG_26	353433	5569924
WTG_27	349777	5569929
WTG_28	350220	5570510
WTG_29	351814	5570469

Table A-1 Wind Turbine Generator and Substation Locations

IDs	UTM Coordinates [1] (m)	
	Easting	Northing
WTG_30	350667	5570792
WTG_31	352284	5570874
WTG_32	345733	5570960
WTG_33	343768	5571185
WTG_34	351089	5571287
WTG_35	346110	5571440
WTG_36	344162	5571498
WTG_37	351366	5571703
WTG_38	344580	5571763
WTG_39	342858	5571791
WTG_40	346433	5571922
WTG_41	346915	5572296
WTG_42	347083	5572719
WTG_43	344763	5575093
WTG_44	345082	5575605
WTG_45	343873	5575915
WTG_46	344978	5576282
WTG_47	344061	5576389
WTG_48	345125	5576779
WTG_49	344318	5576827
WTG_C1 [2]	351561	5572142
WTG_C2 [2]	351922	5568801
WTG_C3 [2]	344176	5576668
WTG_C4 [2]	342155	5575591
WTG_C5 [2]	341683	5576882
WTG_C6 [2]	341593	5577569
WTG_C7 [2]	340922	5577357
S1	347136	5569104
S2 [2]	346110	5571621
S3 [2]	345095	5575772

NOTES:
[1] UTM Zone 13 NAD 83.
[2] Contingency locations.