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ASSESSMENT REPORT - **Project: 14284.00**

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# Grand Renewable Wind Farm – 1st Immission Audit Receptor Measurements

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Prepared for:

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# Executive Summary

Aercoustics Engineering Limited ("Aercoustics") has been retained by Grand Renewable Wind L.P. to complete the acoustic audit outlined in the Renewable Energy Approval ("REA") for the Grand Renewable Wind Farm ("GRWF"). GRWF operates under REA #0300-8UQPKR, issued on June 15, 2012.

This report details the first measurement campaign of the GRWF immission audit. Monitoring at R2956 and V3276 spanned between August 25, 2015 and October 26, 2015. Monitoring at R2885 also began on August 25, 2015, but was continued until November 9, due to that site having lower winds compared to the other two receptors. Acoustic and weather data was logged simultaneously for the duration of the measurement campaign.

The audit has been completed as per the methodology outlined in Part D of the "*MOE Compliance Protocol for Wind Turbine Noise – Guideline for Acoustic Assessment and Measurement*."

The turbine-only noise contribution was compared to the Ministry of Environment and Climate Change sound level limits and the facility was found to be in compliance.

# 1 Introduction

Aercoustics Engineering Limited ("Aercoustics") has been retained by Grand Renewable Wind L.P. to complete the required acoustic audit outlined in the Renewable Energy Approval ("REA") for the Grand Renewable Wind Farm ("GRWF") [1]. GRWF operates under REA #0300-8UQPKR, issued on June 15, 2012.

The audit was completed as per the methodology outlined in Part D of the "*MOE Compliance Protocol for Wind Turbine Noise – Guideline for Acoustic Assessment and Measurement*", [2] to fulfil Section E, "*Acoustic Audit – Immission*" of the REA. This report outlines the measurement methodology, results, and a comparison of the turbine-only sound contribution to the Ontario Ministry of Environment and Climate Change ("MOECC") sound level limits.

# 2 Facility Description

The GRWF utilizes 67 Siemens SWT-101 wind turbines for power generation, each having a nameplate capacity of either 2.221MW or 2.126MW. Each turbine has a hub height of 99.5 meters and a rotor diameter of 101 meters.

The facility operates 24 hours per day, 7 days per week.

# 3 Audit Details

The acoustic audit was conducted at receptors R2885, R2956, and V3276[1]. Monitoring at R2956 and V3276 spanned between August 25, 2015 and October 26, 2015. Monitoring at R2885 also began on August 25, 2015, but was continued until November 9, due to that site having lower winds compared to the other two receptors.

The following sections detail the test equipment, measurement methodology, measurement locations, and environmental conditions during the audit.

## 3.1 Test Equipment

The equipment, both acoustic and non-acoustic, used at each audit location for the measurement campaign is as follows.

- One (1) Type 1 sound level meter, with microphone and pre-amplifier that meet the MOECC protocol specifications outlined in Part D, Section D2.1 - Acoustic Instrumentation.

[1] Receptor IDs taken from the Noise Assessment Report by Zephyr North, dated May 29, 2012 [3]

- One (1) primary and one (1) secondary windscreen for the microphone. The 1/3 Octave band insertion loss of the secondary windscreen has been tested, and was accounted for in the data analysis.

- One (1) anemometer programmed to sample weather data every 0.5 seconds. The anemometer was located 10m above grade, as defined by Section D3.4. Performance specifications comply with Part D, Section D.2.2 of the MOECC protocol.

The following table lists the specific model and serial numbers for the equipment used during the measurement campaign.

Table 1 Equipment Details

| Location | Equipment | Serial Number |
|---|---|---|
| GRWF R2885 | B&K 2250 Sound Level Meter | 3006580 |
| | B&K 4189 Microphone | 2919505 |
| | B&K ZC 0032 Pre-amplifier | 21172 |
| | Vaisala WXT 520 | J4830029 |
| GRWF R2956 | B&K 2250 Sound Level Meter | 2630244/2630243 |
| | B&K 4189 Microphone | 2386059 |
| | B&K ZC 0032 Pre-amplifier | 7946 |
| | Vaisala WXT 520 | K0550007 |
| GRWF V3276 | B&K 2250 Sound Level Meter | 3006579 |
| | B&K 4189 Microphone | 2919502 |
| | B&K ZC 0032 Pre-amplifier | 21158 |
| | Vaisala WXT 520 | K0630016 |

The sound level meter, microphone, and pre-amplifier were calibrated successfully before and after the measurement campaign using a type 4231 Brüel & Kjær acoustic calibrator with serial number 2513130.

### 3.2 Measurement Methodology

For the duration of the measurement campaign, acoustic and anemometer data was logged simultaneously in one-minute intervals. The measurement equipment was setup to log one minute equivalent sound levels ($L_{eq}$) in broadband and 1/3 octave bands between 20-20,000 Hz. The microphone was placed at a measurement height of 4.5m above grade, at least 5 meters away from any large reflecting surfaces, in direct line of sight to the nearest turbines, and as far away as practically possible from trees or other foliage. Measurement data was filtered into integer wind bins from 3 to 10 m/s. Each bin ranged from 0.5m/s below to 0.5m/s above each respective wind bin (i.e. 5 m/s data represents data between 4.5m/s and 5.5m/s).

A one-minute measurement interval was considered valid if:

- The interval occurred between 10pm – 5am
- No precipitation was detected within an hour before the interval
- The maximum measured wind speed at 10m was no more than 2m/s higher than the recorded average for that interval
- The temperature was above -10˚C
- Either all nearby turbines were on (for turbine ON measurements), or all nearby turbines were off (for ambient measurements). The list of turbines parked for ambient measurements is provided in Section 3.6.
- The measured $L_{eq}$ was no more than 10 dB greater than the L90 value for R2885 and R2956, and no more than 6 dB greater than the L90 for V3276, due to close proximity to intersection of Haldimand Road 20 and Kohler Road.

These filters were designed to obtain measurement data of the wind farm when it is fully operational, as well as reduce the amount of contamination from transient ambient noise sources such as vehicle passbys and dog barks. These filters also are based on equipment operating limitations, and the filters prescribed in the Part D of the Protocol to eliminate noise from precipitation, as well as noise on the microphone from gusty periods where the reliability of the data is reduced.

Additional filtering of the measurement data was required at all three receptor locations due to the presence of frogs and crickets in part of the measurement campaign. The acoustic energy from the crickets chirping was present only above 1600 Hz but was dominating the overall level in both Turbine ON and ambient measurements. As a result, all measurements were filtered to exclude all data above 1600 Hz, thus removing the effect of the crickets.

It should be noted that although the MOECC Protocol calls for data points to be excluded if the minimum wind speed at 10m is more than 2m/s less than the recorded average, this limitation was not employed on this data-set. The effect on the dataset of removing the minimum wind speed filter has been assessed at a number of locations and found to be insignificant; this study is provided in Appendix D.

### 3.3 Sample size requirements

In order to account for the dependence on wind speed of wind turbine noise and ambient noise, the measurement data is sorted into integer wind speed bins according to the measured wind speed. As per Section D3.8 of the MOECC protocol, at least 120 data points in each wind bin are required for Turbine ON measurements, and 60 data points for the ambient measurements.

### 3.4 Measurement Location

Receptors R2885, R2956, and V3276 were chosen to be representative of the worst-case impact from the facility. The receptors are located downwind from the predominant wind direction of the farm. R2885, R2956, and V3276 have a predicted impact of 39.9dBA, 39.8dBA, and 39.9dBA respectively, as per data provided in the Acoustic Assessment Report [3]. The following describes the measurement locations in relation to the above listed receptors:

- R2885: Measurement equipment was placed in an open field north west of R2885, 560m to the nearest turbine, on the west side of Port Maitland Road.

- R2956: Measurement equipment was placed in an open field directly west of R2956, 729m to the nearest turbine and 40 m south of a nearby stand of trees.

- V3276: Measurement equipment was placed in the open field on the property of V3276, 573m to the nearest turbine on the northwest corner of Kohler Road and Haldimand Road 20.

The following table provides a summary of the receptor location. Detailed site plans showing the receptor and audit locations are attached in Appendix A.

Table 2 Receptor Measurement Locations

| | Audit Receptor ID<br>Nearest Turbine ID | R2885<br>T60 | R2956<br>T54 | V3276<br>T20 |
|---|---|---|---|---|
| Receptor | UTM Coordinates (X,Y) | 17T 615610mE<br>4747398mN | 17T 608109mE<br>4746658mN | 17T 593143mE<br>4749588mN |
| | Distance to Nearest Turbine | 640 m | 783 m | 584 m |
| | Predicted Level dBA* | 39.9 | 39.8 | 39.9 |
| Monitor | UTM Coordinates (X,Y) | 17T 615534mE<br>4747476mN | 17T 608065mE<br>4746620mN | 17T 593133mE<br>4749585mN |
| | Distance to Nearest Turbine | 560 m | 729 m | 573 m |

* Predicted level from Noise Assessment Report – Zephyr North [3]

### 3.5 Weather Conditions

Ambient conditions encountered over the measurement campaign were as follows:

- Ambient Humidity: 47% to 95%
- Ambient Temperature: -2˚C to 26˚C
- 10m Wind Speed: 0 m/s to 14 m/s

Historically, the predominant wind direction is from the south-west for this site. The wind direction varied over the course of the audit campaign. Wind roses have been provided in Appendix B that show the measured 10m wind direction at each receptor averaged for all

Turbine ON measurements. Wind directions shown on the wind roses indicate the direction the wind is coming from.

### 3.6 Operational Conditions

Turbine operational data for the duration of the measurement campaign was supplied by GRWF. Measurement data at each receptor was filtered to include only intervals when all turbines in the immediate vicinity were operational, or, in the case of the ambient noise measurements, were not operational. The turbines included in this study were chosen such that when they are turned off, the partial impact of the remaining turbines was less than 30dBA; 10dB below the sound level limit. The specific turbines parked for ambient measurements at R2956 and V3276 were T01, T03, T07, T08, T10, T16, T20, T24, T48, T54, T60, T61, T62, T63, T64 and T69. The specific turbines parked for ambient measurements at R2885 were T60, T61, T62, T63 and T64.

# 4 Sound Level Limits

The purpose of the sound measurements was to confirm whether the sound emitted by the wind facility is in compliance with the MOECC allowable sound level limits. The MOECC sound level limits for wind turbines vary with wind speed defined at a 10m height. The details of the sound level limits are presented in Table 3 below.

Table 3 MOECC Sound Level Limits for Wind turbines

| Wind speed at 10m height [m/s] | MOECC Sound level limit [dBA] |
|---|---|
| ≤ 4 | 40 |
| 5 | 40 |
| 6 | 40 |
| 7 | 43 |
| 8 | 45 |
| 9 | 49 |

# 5 Audit Results

The following tables detail the sound levels measured at all three receptors when all the nearby turbines were on (Turbine ON) and when all the nearby turbines were off (Turbine OFF).

Table 4 R2885 Sound levels measured for Turbine ON and OFF

| | Wind speed at 10m height [m/s] | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Turbine ON | Number of Samples | 2640 | 2175 | 783 | 272 | 121 |
| | LAeq [dBA] | 37 | 39 | 41 | 44 | 46 |
| | Std Dev [dBA] | 2.9 | 2.6 | 2.5 | 1.5 | 1.7 |
| Turbine OFF | Number of Samples | 41 | 120 | 202 | 135 | 82 |
| | LAeq [dBA] | 34 | 35 | 39 | 41 | 44 |
| | Std Dev [dBA] | 1.9 | 2.1 | 1.9 | 2.2 | 2.1 |
| Turbine ONLY | | 34 | 36 | 38 | 41 | 43 |

Table 5 R2956 Sound levels measured for Turbine ON and OFF

| | Wind speed at 10m height [m/s] | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Turbine ON | Number of Samples | 1176 | 496 | 248 | 195 | 120 |
| | LAeq [dBA] | 36 | 39 | 41 | 43 | 46 |
| | Std Dev [dBA] | 3.4 | 2.6 | 1.5 | 1.4 | 1.5 |
| Turbine OFF | Number of Samples | 78 | 101 | 219 | 188 | 183 |
| | LAeq [dBA] | 32 | 37 | 39 | 42 | 46 |
| | Std Dev [dBA] | 4.6 | 3.1 | 2.0 | 1.7 | 1.3 |
| Turbine ONLY | | 34 | 34 | 35 | 37 | 36 |

Table 6 V3276 Sound levels measured for Turbine ON and OFF

| | Wind speed at 10m height [m/s] | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Turbine ON | Number of Samples | 1277 | 806 | 587 | 272 | 125 |
| | LAeq [dBA] | 35 | 38 | 40 | 43 | 45 |
| | Std Dev [dBA] | 3.3 | 3.2 | 2.1 | 1.6 | 1.6 |
| Turbine OFF | Number of Samples | 21 | 106 | 252 | 181 | 81 |
| | LAeq [dBA] | 27 | 33 | 36 | 40 | 44 |
| | Std Dev [dBA] | 3.7 | 2.9 | 2.4 | 1.8 | 1.7 |
| Turbine ONLY | | 34 | 37 | 38 | 39 | 39 |

The following figures are the plots of the measured sound levels at all three receptors when all the nearby turbines were on (Turbine ON) and when all the nearby turbines were off (Turbine OFF). Note that all plots include the 95% confidence interval as a dashed line above and below the average value.

Figure 1 R2885 Measured Turbine ON levels

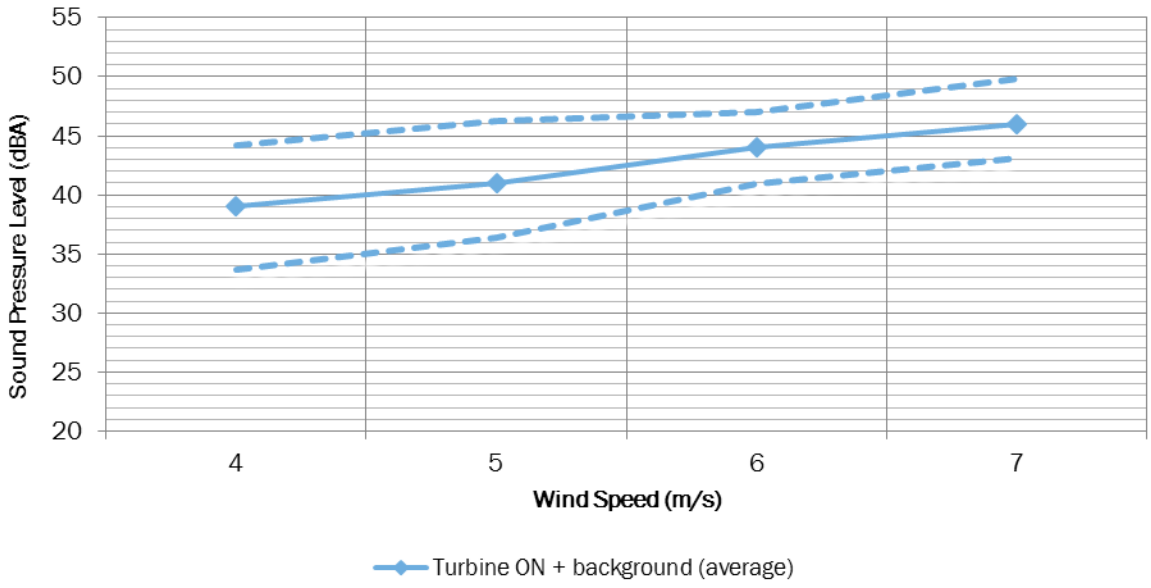



Figure 2 R2885 Measured Turbine OFF (Background) levels

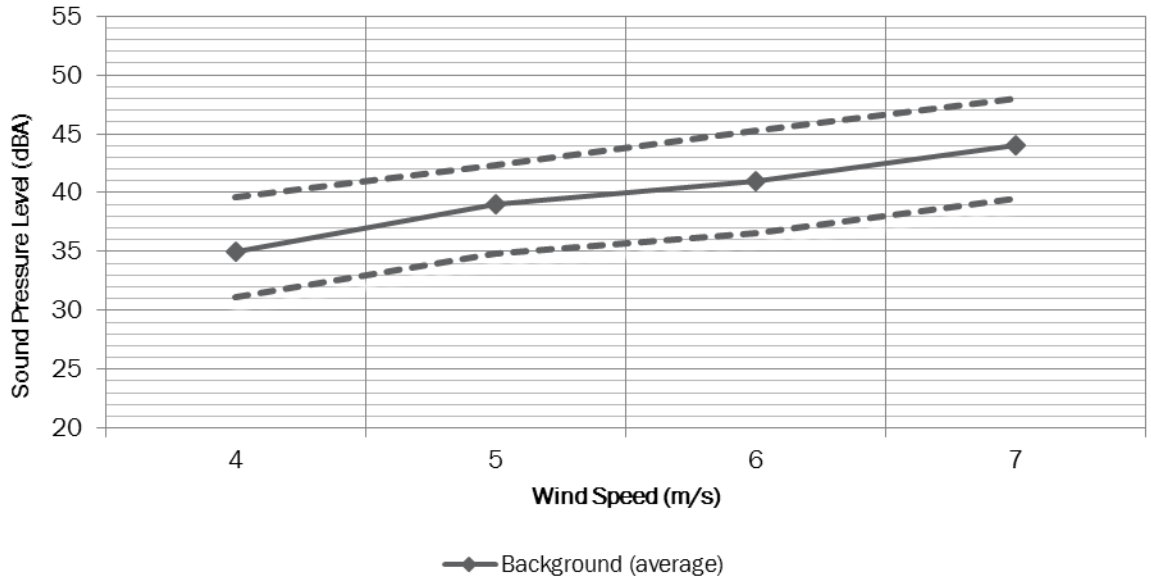


Figure 3 R2956 Measured Turbine ON levels

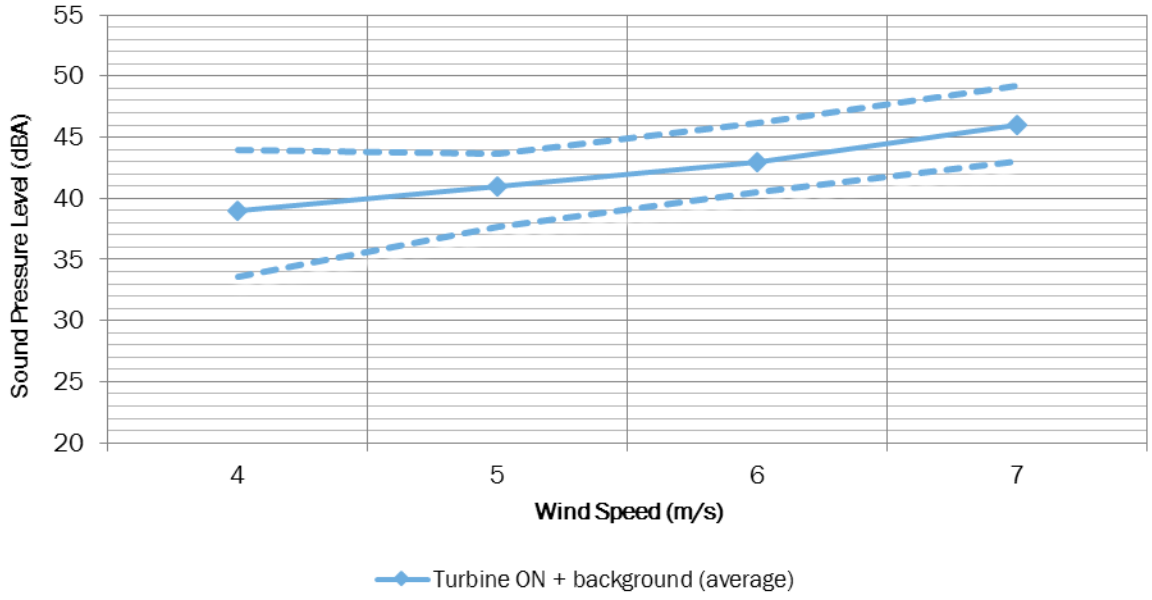



Figure 4 R2956 Measured Turbine OFF (Background) levels

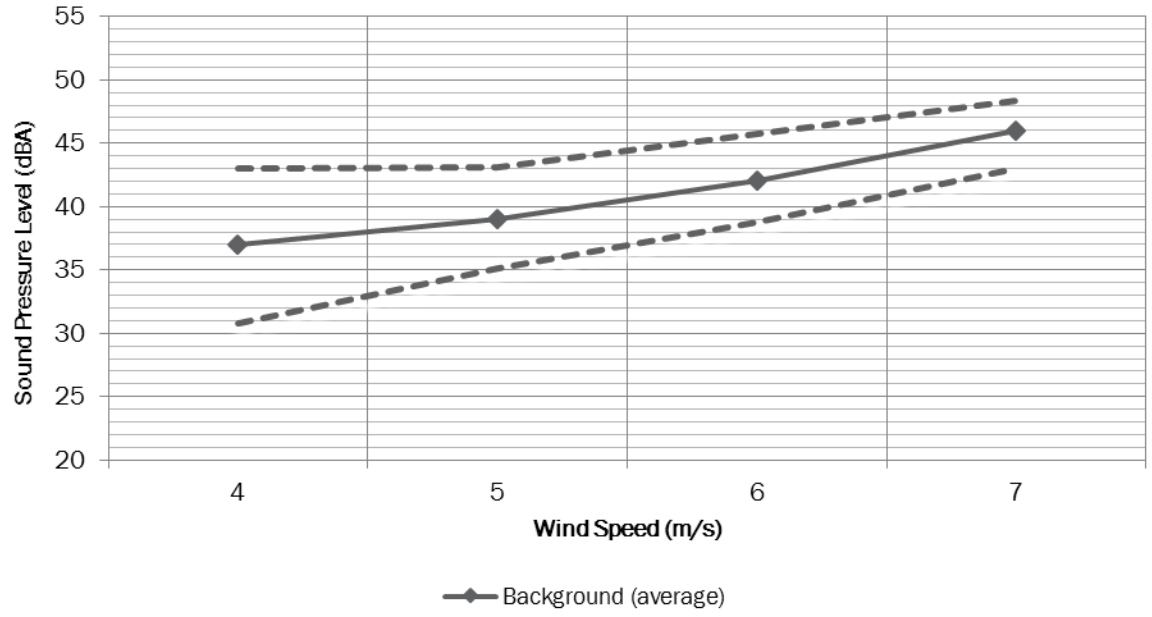


Figure 5 V3276 Measured Turbine ON levels

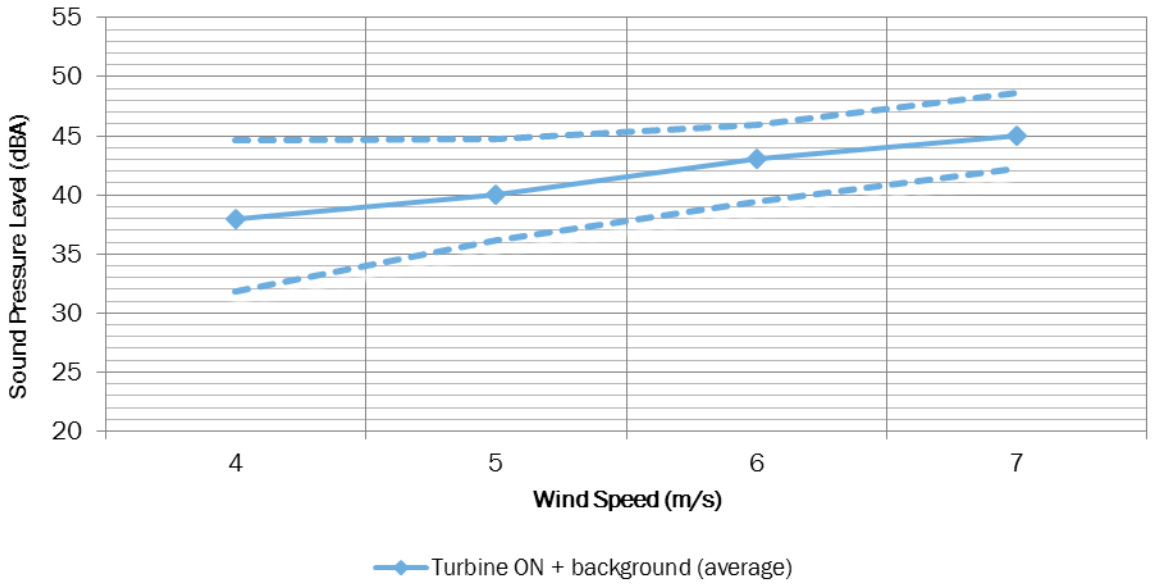
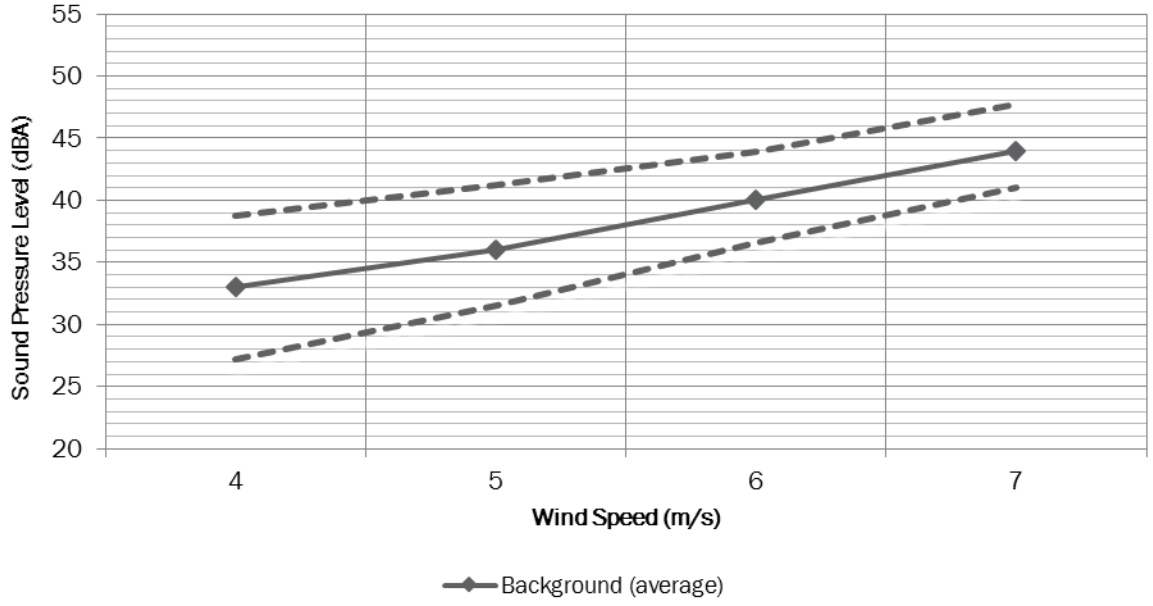



Figure 6 V3276 Measured Turbine OFF (Background) levels



# 6 Discussion

## 6.1 Overall Sound Level

The turbine-only component of the sound level was derived from a logarithmic subtraction of the ambient noise from that of the sound level measured with the turbines operating. The resulting sound level can be attributed to the turbines. It should be noted that all values in Table 7 have been rounded to the nearest integer. Calculated Turbine ONLY levels listed were calculated based on unrounded Turbine ON and Turbine OFF values.

To ensure conservative results and improved signal to noise, all monitors were erected in locations that were closer to the wind farm than their corresponding receptors. The effect of the closer measurement locations was higher sound levels from the turbines than would have been measured at the receptor location itself. Because of this, a correction has been applied to R2885 based on the difference in the predicted sound level between the receptor and monitor locations. This difference was determined using the CadnaA model used for the Noise Assessment Report [3]. As a result 1 dB was subtracted from the Turbine ONLY sound level at the R2885 receptor location. The other monitor locations show compliance without any distance correction (conservative). The Turbine ONLY levels at those receptors are also expected to be lower than those presented.

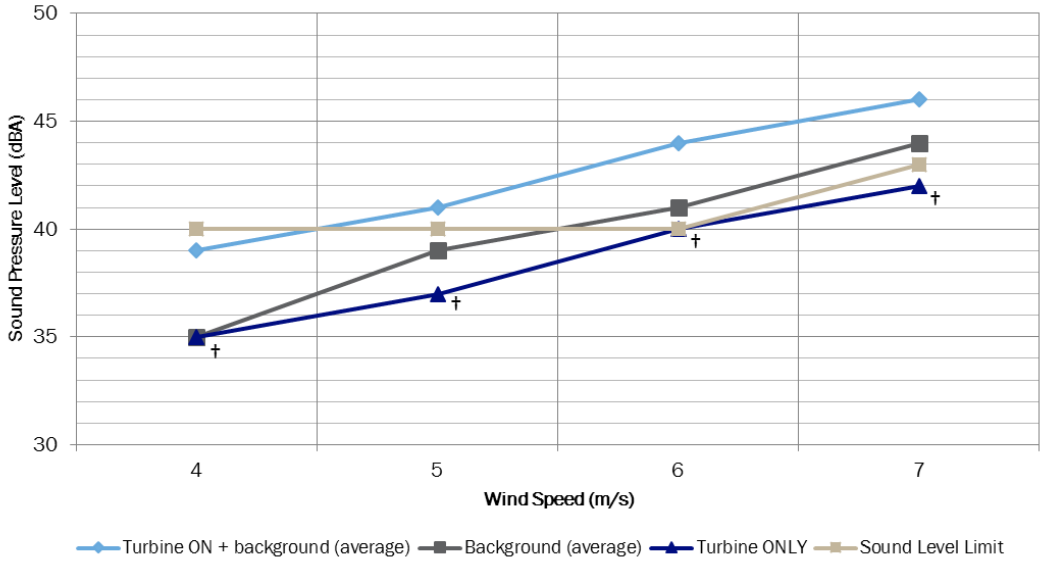
Table 7 Assessment Table

| Measurement Location | Wind speed at 10m height [m/s] | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| R2885 | Turbine ON LAeq [dBA] | 37 | 39 | 41 | 44 | 46 |
| | Turbine OFF LAeq [dBA] | 34 | 35 | 39 | 41 | 44 |
| | Calculated Turbine ONLY LAeq [dBA] | 34* | 36* | 38* | 41* | 43* |
| | Calculated level at R2885 | 33** | 35** | 37** | 40** | 42** |
| R2956 | Turbine ON LAeq [dBA] | 36 | 39 | 41 | 43 | 46 |
| | Turbine OFF LAeq [dBA] | 32 | 37 | 39 | 42 | 46 |
| | Calculated Turbine ONLY LAeq [dBA] | 34 | 34 | 35 | 37 | 36 |
| V3276 | Turbine ON LAeq [dBA] | 35 | 38 | 40 | 43 | 45 |
| | Turbine OFF LAeq [dBA] | 27 | 33 | 36 | 40 | 44 |
| | Calculated Turbine ONLY LAeq [dBA] | 34 | 37 | 38 | 39 | 39 |
| MOECC Limit | | 40 | 40 | 40 | 40 | 43 |

*No background correction applied
**1 dB subtracted from Turbine ONLY component for distance adjustment from monitor to receptor location

The data from Table 7 is plotted in Figure 7, Figure 8, and Figure 9.

Figure 7 R2885 Turbine Levels compared to MOECC Limits




†1 dB subtracted from Turbine ONLY component for distance adjustment from monitor to receptor location

Figure 8 R2956 Turbine Levels compared to MOECC Limits

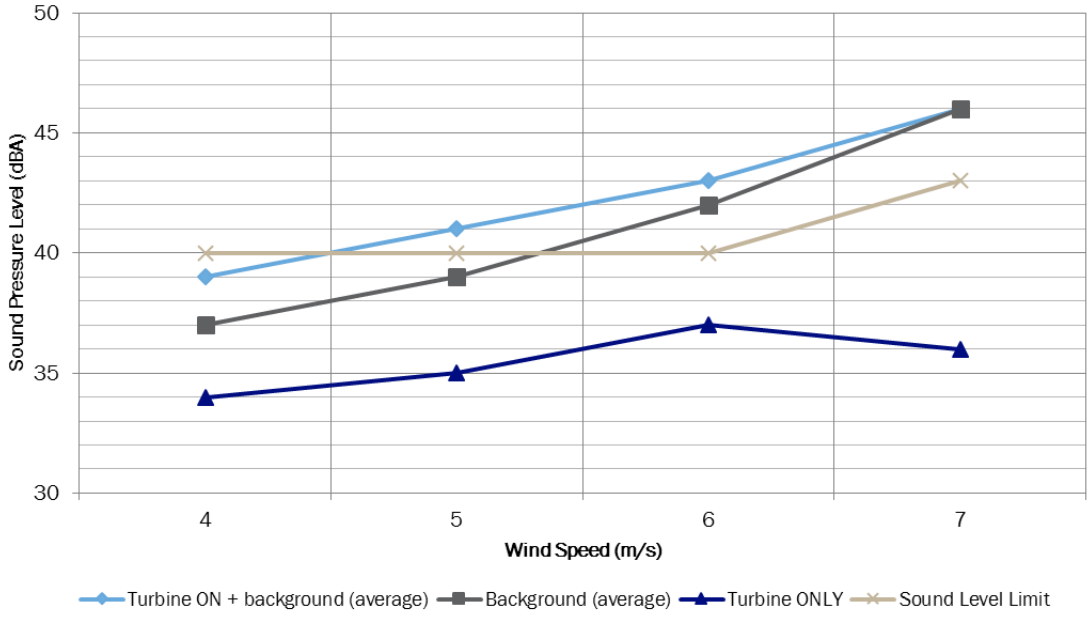
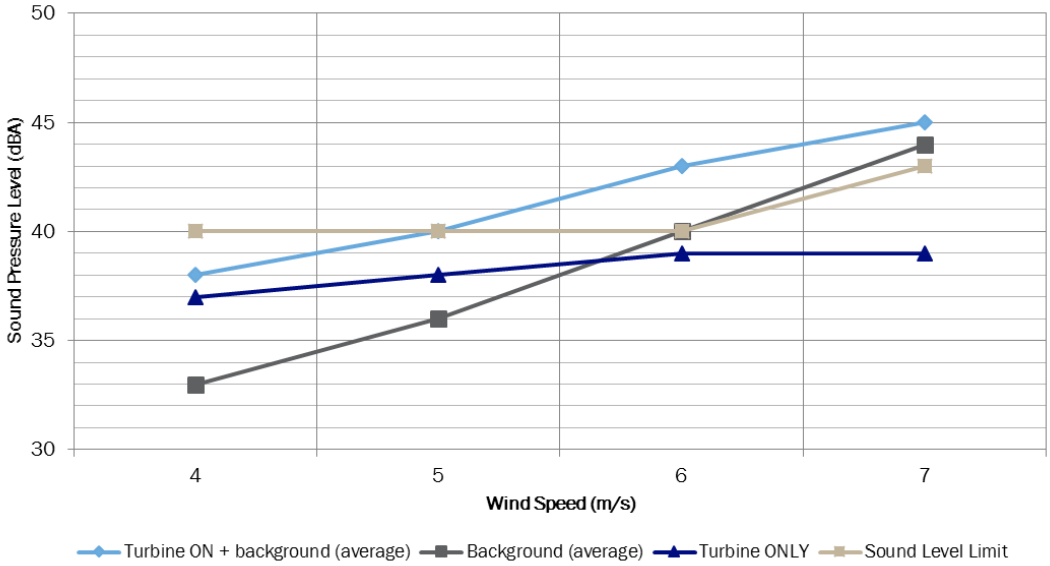


Figure 9 V3276 Turbine Levels compared to MOECC Limits




### 6.2 Tonality

Our site observations qualitatively indicate no presence of distinctly audible tones at the measurement location. The noise from the wind turbines was subjectively assessed not to be tonal.

# 7 Assessment of Compliance

Based on the calculated turbine-only component indicated in Table 7 and Figures 7-9, the Grand Renewable Wind Farm is compliant with MOECC limits at all receptors.

# 8 Conclusion

Aercoustics Engineering Limited has completed the acoustic audit outlined in the Renewable Energy Approval for the Grand Renewable Wind Farm. The audit was completed as per the methodology outlined in Part D of the "*MOE Compliance Protocol for Wind Turbine Noise*." The measured levels were compared to the MOECC limits, and the facility was determined to be in compliance at all receptors.

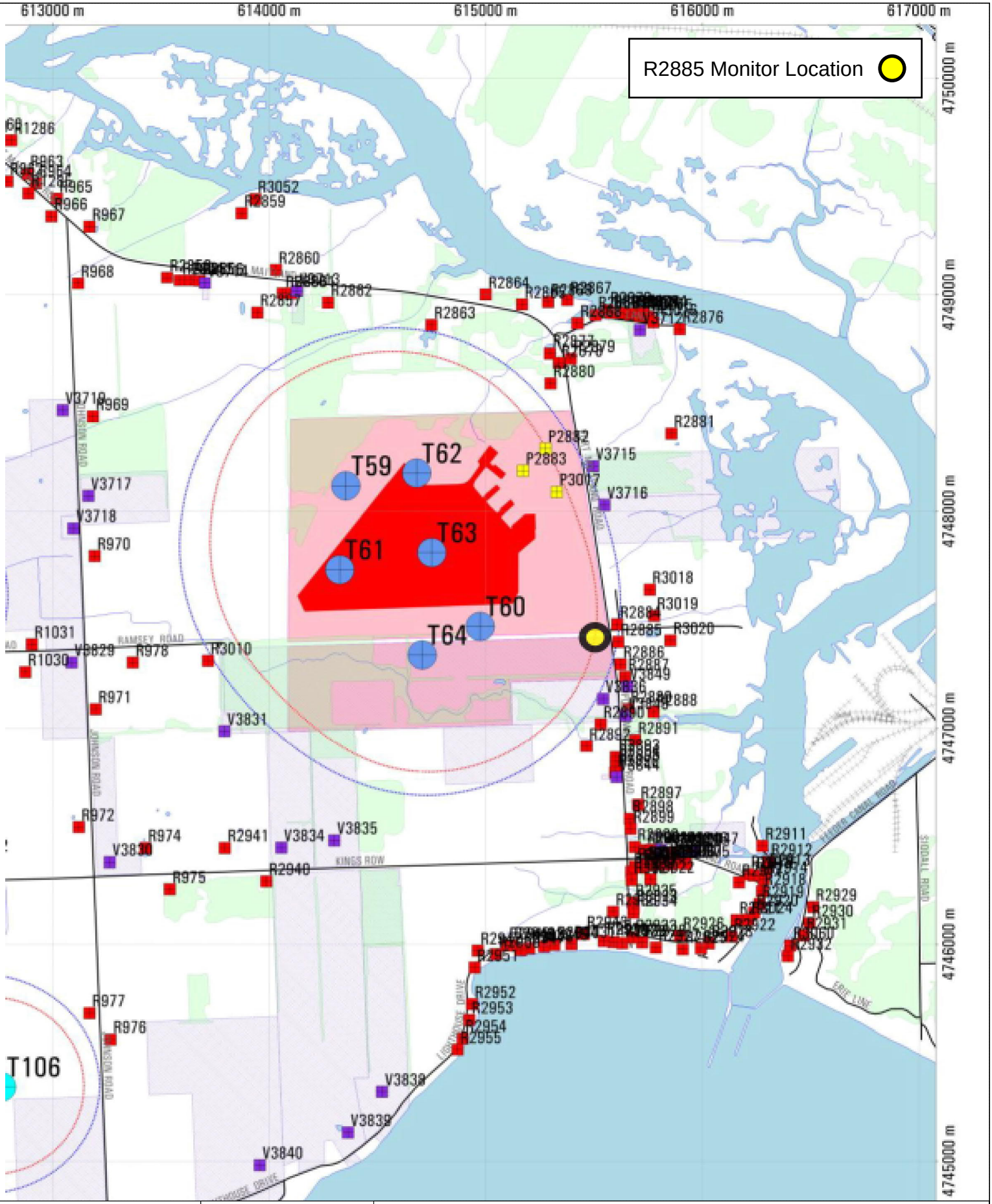
# 9 References

[1] V. Schroter, "Renewable Energy Approval #0300-8UQPKR", Ontario Ministry of the Environment, Toronto, ON, June 15, 2012

[2] Ministry of the Environment, "Compliance Protocol for Wind Turbine Noise – Guideline for Acoustic Assessment and Measurement", Ontario Ministry of the Environment, Toronto, ON.

[3] C.F. Brothers, J.R. Salmon and S.J. Corby., “Grand Renewable Energy Park Noise Assessment Report” Zephyr North, Burlington, ON, Rev. 2, May 29, 2012.

# APPENDIX A – LOCATION DETAILS

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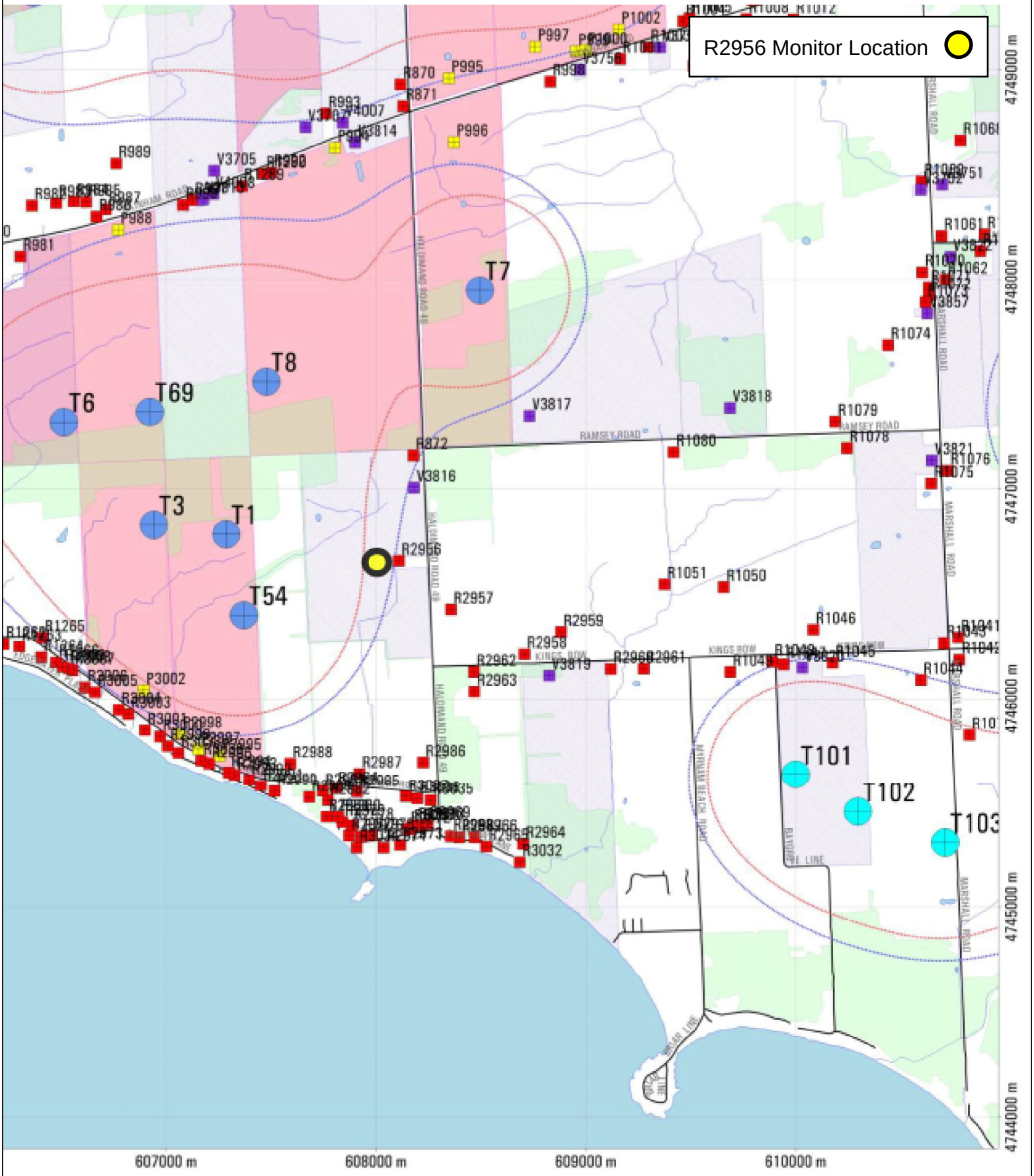
| Project ID: 14284.00 | **Project Name** | |
| Scale: NTS<br>Drawn by: AD<br>Reviewed by: PA<br>Date: Dec 3, 2015<br>Revision: 1 | Grand Renewable Wind Farm - 1st Acoustic Immission Audit Report | |
| | **Figure Title**<br>Site Plan - R2885 | **Figure A.1** |

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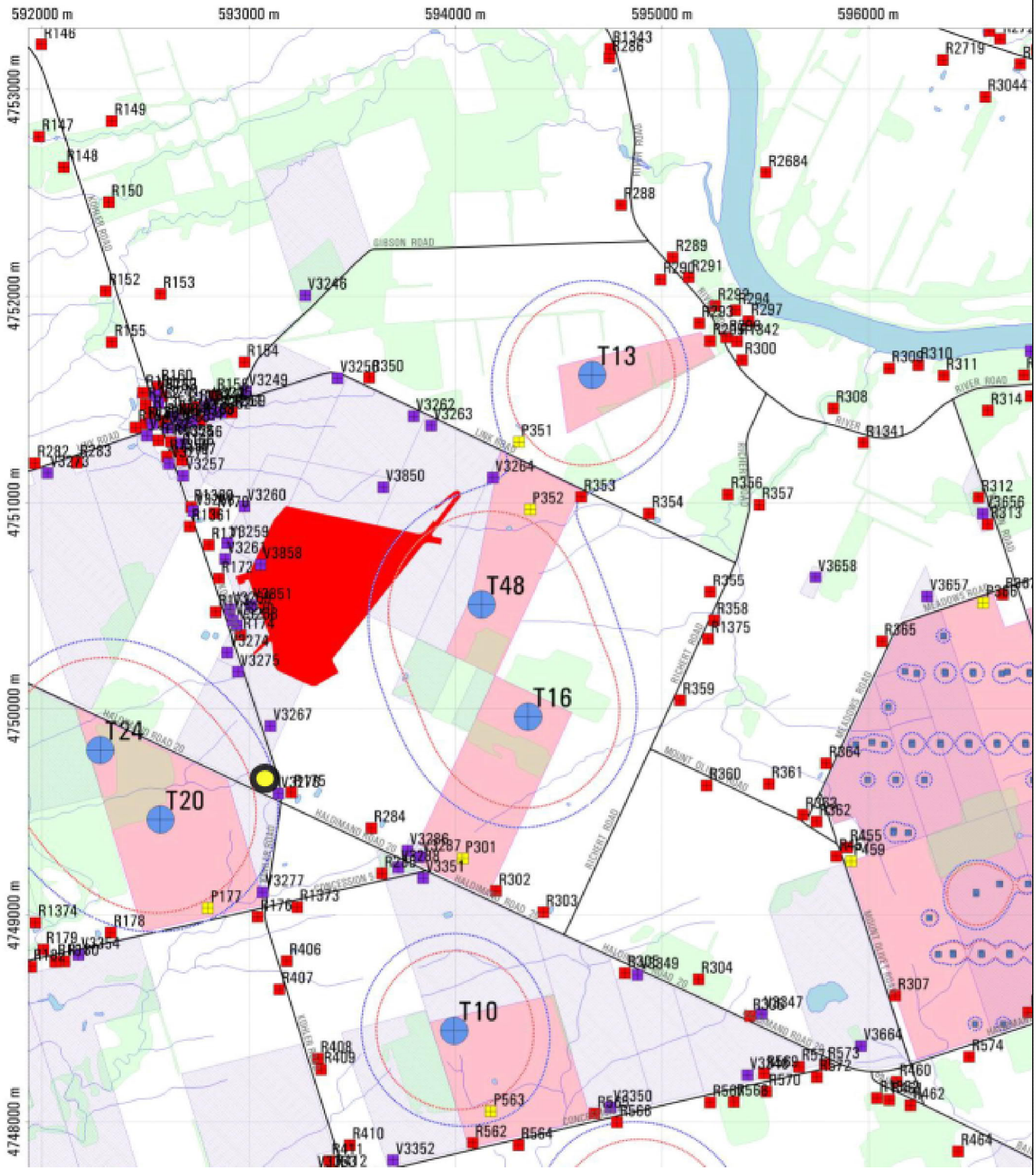
| | | **Figure Title**<br>Site Plan - R2956 | **Figure A.2** |

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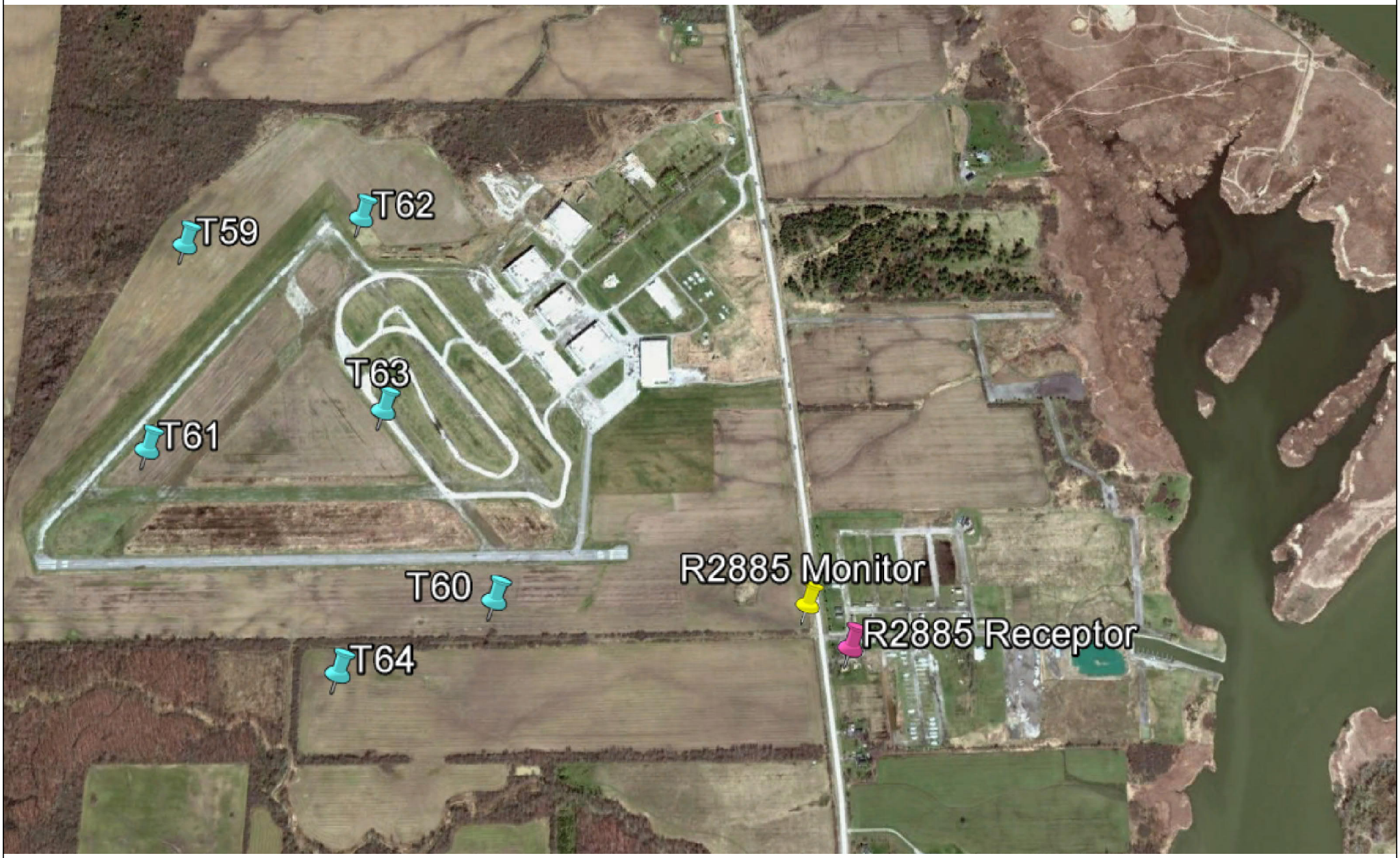
| aercoustics | Project ID: 14284.00<br>Scale: NTS<br>Drawn by: AD<br>Reviewed by: PA<br>Date: April 8, 2016<br>Revision: 1 | **Project Name**<br>Grand Renewable Wind Farm - 1st Acoustic Immission Audit Report<br>**Figure Title**<br>Site Plan - V3276 |
| | | **Figure A.3** |

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Revision: 1

**Project Name**

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**Figure Title**

Measurement Location - R2885

**Figure A.4**


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Revision: 1

**Project Name**

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**Figure Title**

Measurement Location - R2956

**Figure A.5**


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| | | **Figure Title**<br>Measurement Location - V3276 | **Figure A.6** |

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Revision: 1

**Project Name**

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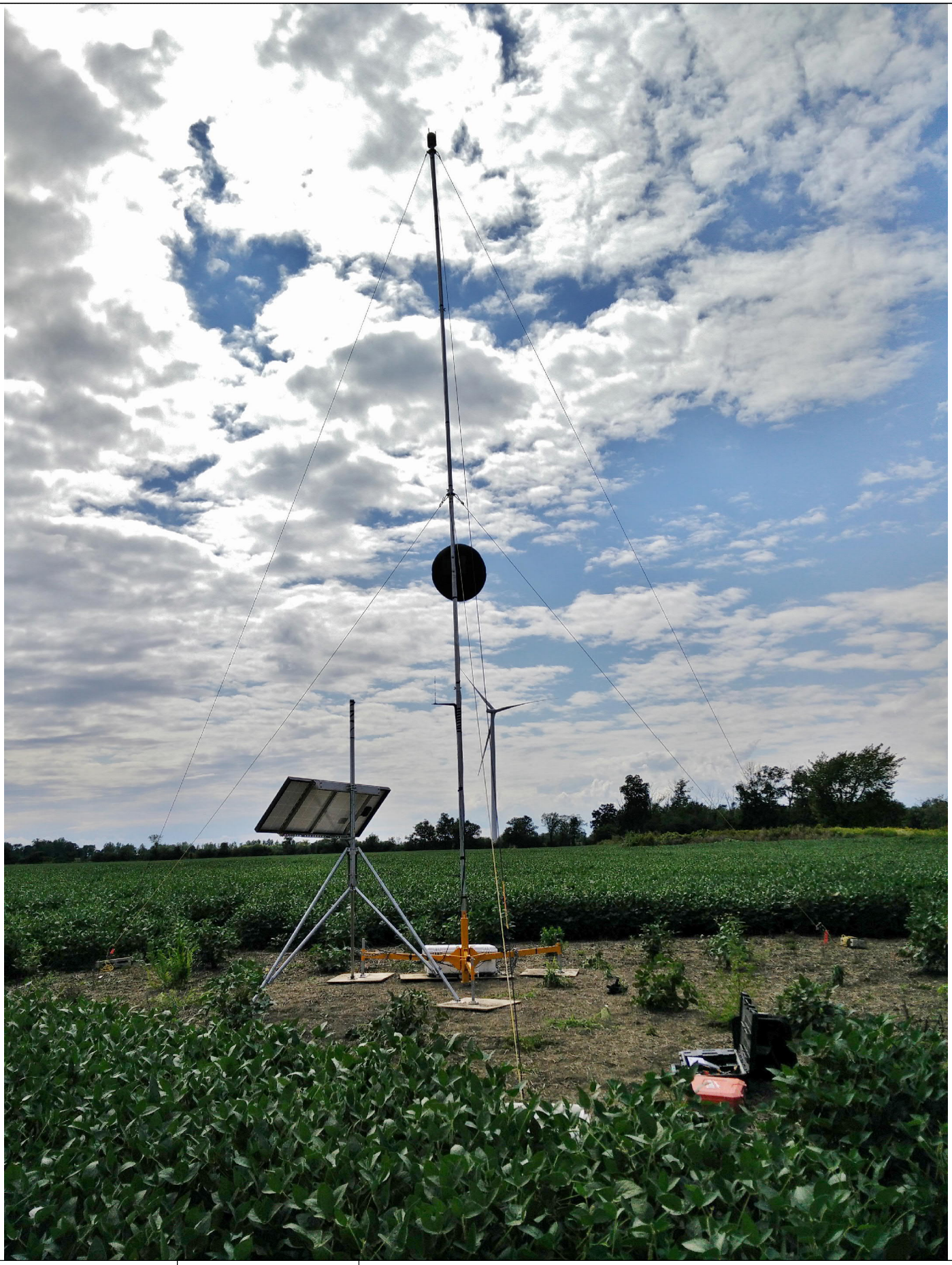
**Figure Title**

Site Photo - R2885

**Figure A.7**



| | | | |
|---|---|---|---|
| aercoustics | Project ID: 14284.00<br>Scale: NTS<br>Drawn by: AD<br>Reviewed by: PA<br>Date: Dec 3, 2015<br>Revision: 1 | **Project Name**<br>Grand Renewable Wind Farm - 1st Acoustic Immission Audit Report | |
| | | **Figure Title**<br>Site Photo - R2956 | **Figure A.8** |

aercoustics

Project ID: 14284.00

Scale: NTS
Drawn by: AD
Reviewed by: PA
Date: April 8, 2016
Revision: 1

**Project Name**

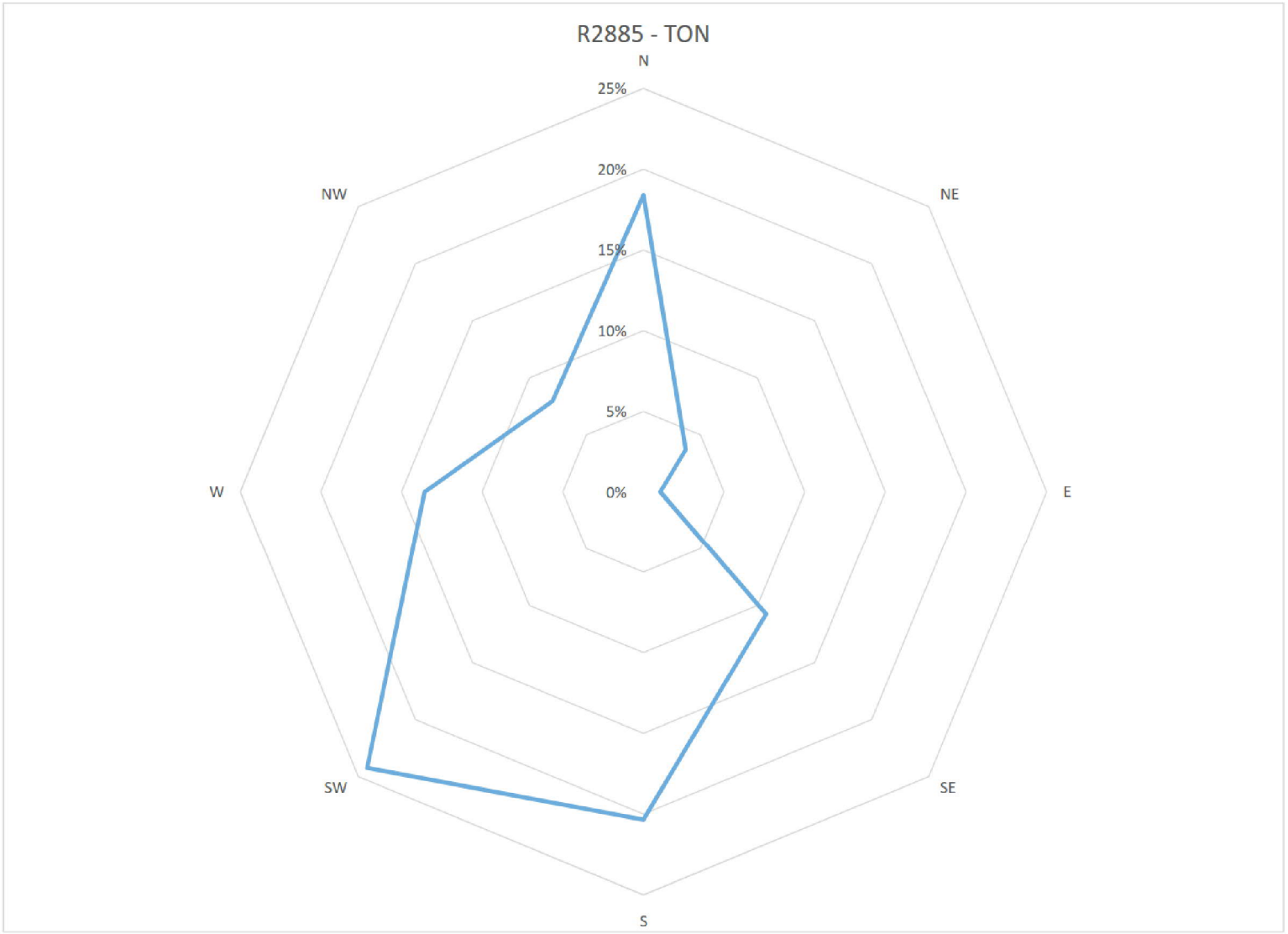
Grand Renewable Wind Farm - 1st Acoustic Immission Audit Report

**Figure Title**

Site Photo - V3276

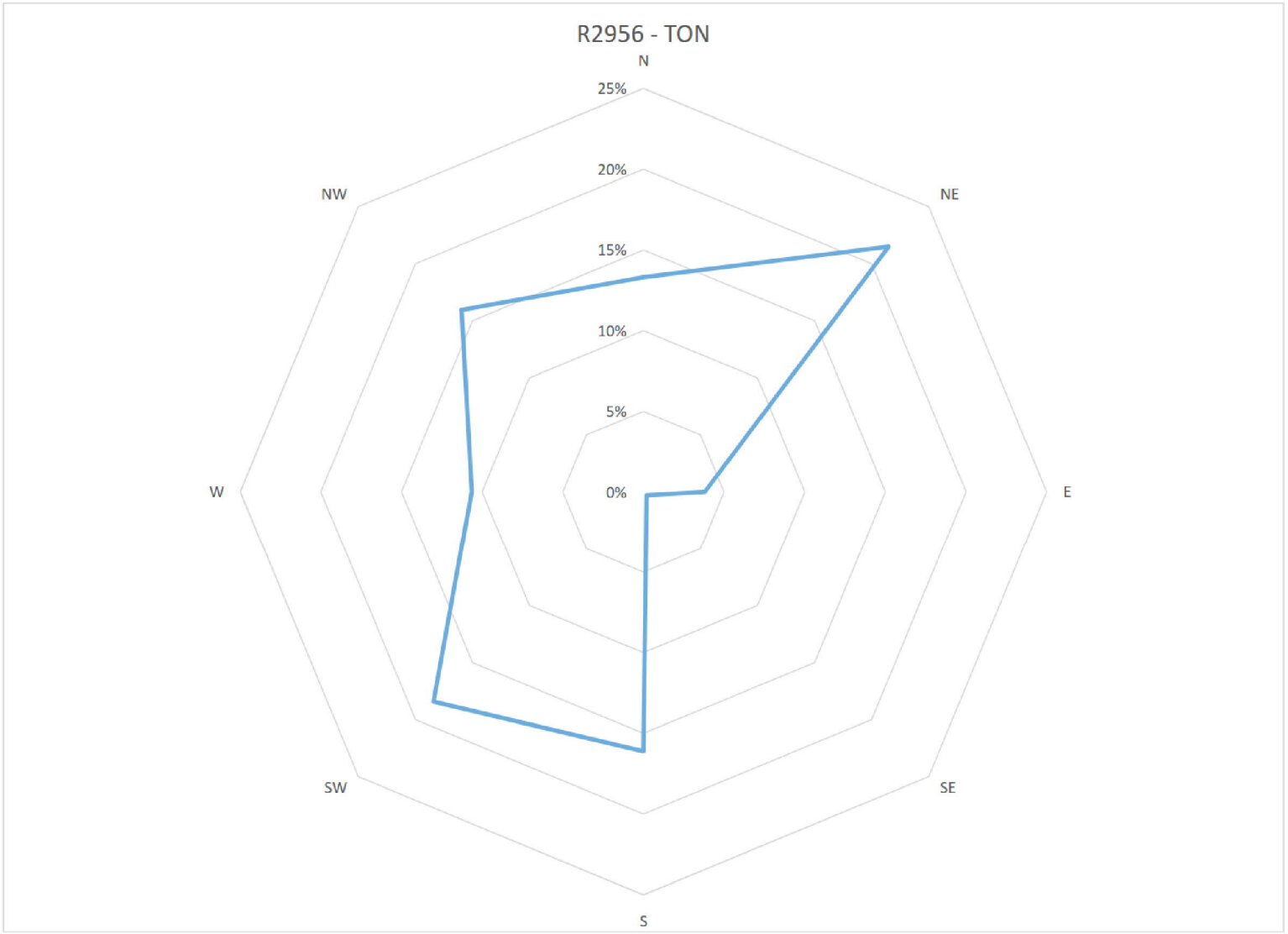
**Figure A.9**

# APPENDIX B – WIND ROSES



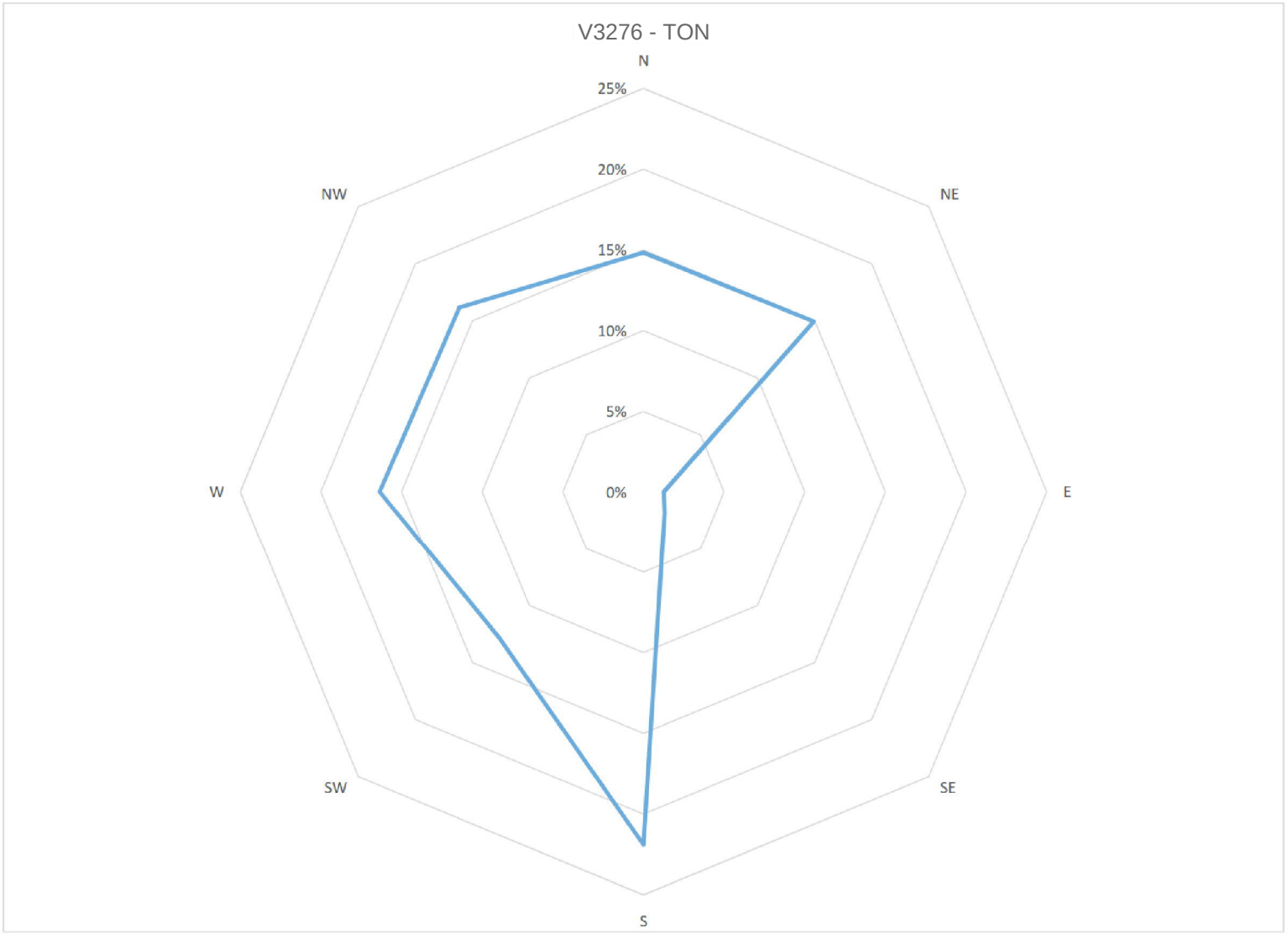

| | | |
|---|---|---|
| aercoustics | Project ID: 14284.00<br>Scale: NTS<br>Drawn by: AD<br>Reviewed by: PA<br>Date: Dec 3, 2015<br>Revision: 1 | **Project Name**<br>Grand Renewable Wind Farm - 1st Acoustic Immission Audit Report<br>**Figure Title**<br>Wind Rose R2885 |

**Figure B.1**




| | | |
|---|---|---|
| aercoustics | Project ID: 14284.00<br>Scale: NTS<br>Drawn by: AD<br>Reviewed by: PA<br>Date: Dec 3, 2015<br>Revision: 1 | **Project Name**<br>Grand Renewable Wind Farm - 1st Acoustic Immission Audit Report<br>**Figure Title**<br>Wind Rose R2956 |

**Figure B.2**




| | | |
|---|---|---|
| aercoustics | Project ID: 14284.00<br>Scale: NTS<br>Drawn by: AD<br>Reviewed by: PA<br>Date: Dec 3, 2015<br>Revision: 1 | **Project Name**<br>Grand Renewable Wind Farm - 1st Acoustic Immission Audit Report<br>**Figure Title**<br>Wind Rose V3276 |

**Figure B.3**

# APPENDIX C – TURBINE OPERATIONAL DATA STATEMENT FROM OPERATOR

Grand Renewable Wind LP
2050 Derry Rd. West 2nd Floor
Mississauga, Ontario
L5N 0B9
http://www.grandrenewablewind.com

November 3th, 2015.

District Manager, MOE Hamilton
12th floor, 119 King street W
Hamilton ON L8P 4Y7

Subject:

**Grand Renewable Wind LP Renewable Energy Approval number 0300-8UQPKR**
**Condition- Receptor audit immission part 1 of 2**

To whom it may concern

Please accept this letter as confirmation that all turbines tested during the summer and fall of 2015 acoustics measurement campaign conducted by Aerocusotics Ltd. From August 25th through November 9th, 2015 were operating normal for the duration of the campaign.

Sincerely,

J. Miranda

***Jonathan Miranda***
Facility Manager
Grand Renewable Wind

2788 Haldimand Rd. 20
Haldimand, ON
N0A 1E0

P:1-905-772-0368 ext. 1
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# APPENDIX D – WIND GUSTING ANALYSIS

aercoustics

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50 Ronson Drive, Suite 165
Toronto, ON M9W 1B3

Tel: 416-249-3361
Fax 416-249-3613
aercoustics.com

# Wind Gusting Analysis Summary

The purpose of this document is to provide supporting information for wind turbine receptor audits in which the wind speed gusting filter deviates from that prescribed by the Ministry of the Environment and Climate Change (MOECC). The Compliance Protocol for Wind Turbine Noise requires that the maximum and minimum wind speeds be within 2 m/s of the average wind speed in a measurement interval (1-minute average). Any intervals that do not meet this requirement would be excluded from the analysis. Aercoustics examined the possibility of changing this filtering to only exclude intervals where the maximum wind speed is more than 2 m/s above the average without filtering based on minimum wind speed.

Aercoustics reviewed 11 different data sets representing measurements from 3 different wind farms and 10 different receptor locations. Each data set was filtered using both the prescribed and the modified methods for wind speed gusting. The resulting sound pressure levels for Turbine On and Background measurements were computed for each wind bin. The change in number of valid data points and the change in measured sound pressure level were calculated. The increase in number of data points and change in sound pressure from the prescribed filtering method to the proposed method were averaged across the 11 data sets. The mean values by wind speed are presented in Table 1 below.

Table 1: Results

| Wind Bins | Turbine ON | | Background | |
|---|---|---|---|---|
| | Difference (pts) | Difference (dB) | Difference (pts) | Difference (dB) |
| **3** | 2% | 0.0 | 3% | 0.0 |
| **4** | 6% | 0.1 | 7% | 0.0 |
| **5** | 10% | 0.1 | 9% | 0.1 |
| **6** | 11% | 0.1 | 13% | 0.1 |
| **7** | 21% | 0.1 | 25% | 0.1 |

These results clearly show that the proposed modification of the wind speed gusting filter increases the number of data points in all wind bins, with a more pronounced effect at high wind speeds. The over 20% increase in data points in the 7 m/s wind bins is significant as these wind speeds are typically the most difficult to measure and can considerably increase the time required to complete an audit. There are negligible increases in the measured sound levels, which occur during both Turbine On and Background measurements.