FUTURE GENERATION WIND TURBINES COMPLIANCE SOUND MONITORING STUDY

PLYMOUTH, MASSACHUSETTS

May 2018

Future Generation Wind, LLC

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PLYMOUTH, MASSACHUSETTS

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May 16, 2018

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1.0 EXECUTIVE SUMMARY

Tech Environmental, Inc. (Tech) was retained by Atlantic Design Engineers, Inc. (ADE) to perform sound compliance monitoring for Future Generation Wind, LLC (FGW). FGW is composed of four Gamesa G-97 2.0-MW wind turbines installed on a 326 acre property located off Head of the Bay Road in Plymouth, MA. The purpose of this sound compliance study is to verify compliance with both current Massachusetts Department of Environmental Protection's (MassDEP) Noise Policy, and Section 205-73D(8) of the Town of Plymouth's Zoning Bylaw regarding noise as required by the Special Permit issued by the Town of Plymouth Zoning Board for the FGW turbine project.

Based on the results of monitoring conducted during late August 2017 through March 2018, all four of the FGW wind turbines are in compliance with MassDEP Noise Policy broadband sound limit of 10 dBA above ambient and Town of Plymouth Zoning Bylaw for Wind Energy Facilities as described in this report and specifically in Sections 1.2, 8 and 9 of this report.

This report is divided into nine sections and six appendices. Section 1.0 presents an executive summary of the compliance sound study including the purpose, objectives and summary of the sound monitoring results. Section 2.0 describes the MassDEP Noise Policy and Plymouth Zoning Bylaw for Wind Energy Facilities. Section 3.0 presents the sound monitoring locations. Section 4.0 describes the sound monitoring methodology, and Section 5.0 presents the data analysis approach. Section 6.0 presents the commissioning study results. Section 7.0 summarizes the curtailment analysis methodology and results. The sound study monitoring results are presented in Section 8.0, and Section 9.0 states our conclusions.

The appendices in this report include:

- Appendix A discusses sound level terminology and common measures of community noise;
- Appendix B provides the applicable state and local noise standards;
- Appendix C presents the Gamesa G-97 turbine power curve;
- Appendix D provides an example field log sheet and monitoring locations photos;
- Appendix E provides the turbine-ON L_{max}-to-L_{90} summary graphs, and
- Appendix F presents the turbine power production and hub height wind speed graphs.
- Appendix G presents excerpts from the Town of Plymouth Special Permit (Case No. 3608).

1.1 Purpose and Objectives

The purpose of this sound monitoring study is to demonstrate compliance with the MassDEP Noise Policy and the Town of Plymouth's Zoning Bylaw for Wind Energy Facilities. Compliance with these regulations is required by Condition 9 of the Special Permit granted for FGW by the Town of Plymouth.[1] The phases of the sound compliance monitoring program include:

- Preparation of a sound monitoring protocol for review and approval by the Town of Plymouth, and obtaining acceptance from MassDEP on our sound monitoring approach.

- Conduct of an initial sound monitoring as part of the commissioning of the turbines using several different wind speed and wind direction scenarios. This was done prior to commencing the compliance sound monitoring program to determine if any Noise Reduced Operation (NRO) modes are required to comply with by Condition 9(c) of the Town of Plymouth Special Permit (See Appendix G).

- Development of a sound mitigation (curtailment) plan and operational dispatch modes during the commissioning of the turbines.

- Development and implementation of the NRO curtailment program and dispatch modes.

- Conduct of the sound monitoring study following implementation of the NRO curtailment program.

Tech prepared a draft sound monitoring protocol, dated February 24, 2017[2] that was submitted to MassDEP for review. The protocol presented the sound monitoring methodology for demonstrating compliance with the MassDEP Noise Policy, following the L_{max} to L_{90} wind turbine sound monitoring compliance approach. It should be noted that while the MassDEP L_{max} to L_{90} sound monitoring approach has been used to demonstrate compliance with the MassDEP Noise Policy for wind turbines, it is a very conservative approach and is not consistent with the traditional L_{90} to L_{90} comparison historically used for other types of sound sources.

Tech, along with FGW and ADE, met with MassDEP representatives to discuss the draft sound monitoring protocol and solicit comments on March 13, 2017. Based on comments from that meeting, Tech prepared a revised protocol that was submitted to MassDEP on March 17, 2017. During its review, MassDEP concluded that the revised protocol is consistent with current MassDEP policies and guidance.[3] Thereafter, Tech prepared a final sound monitoring protocol, dated April 7, 2017[4].

[1] Plymouth Zoning Board of Appeals Decision Case No. 3608, Future Generation Wind, LLC, May 18, 2011.
[2] Tech Environmental, Inc. Sound Monitoring Protocol for the Future Generation Wind Turbines, February 24, 2017.
[3] Dan DiSalvio, MassDEP email: Revised Sound Monitoring Protocol for the Future Generation Wind turbines, April 6, 2017.
[4] Tech Environmental, Inc. Sound Monitoring Protocol for the Future Generation Wind Turbines, April 7, 2017.

The final sound monitoring protocol defines the monitoring locations, monitoring procedures, data analyses, and reporting. The protocol was submitted to, and approved, by the Town of Plymouth's Inspectional Services Department.

Sound monitoring was performed to collect ambient turbine-OFF and turbine-ON sound level measurements at the following monitoring locations (ML):

- ML-1: 122 Bournehurst Drive (North of Turbine 5 (T5));
- ML-2: 9 Shady Pine Lane (West of Turbine 3 (T3) and Turbine 4 (T4));
- ML-3: Morning Mist Lane (West of Turbine 1 (T1));
- ML-4: 14 Morning Mist Lane (Southwest of Turbine 1(T1)); and
- ML-5: 680 Head of the Bay Road (Southeast of Turbine 1(T1)).

Tech began the initial sound monitoring program in May 2017, with the objective of measuring sound levels under various wind speeds, wind directions, and turbine power production levels during initial operations and commissioning activities. During the commissioning phase several power production models were developed to determine which model would best demonstrate compliance with applicable noise limits. Table 1-1 presents the three wind and turbine power production conditions at the five monitoring locations, totaling to 15 monitoring conditions.

TABLE 1-1

WIND AND POWER PRODUCTION SOUND MONITORING CONDITIONS

Monitoring Locations	Target Wind Direction (blowing from)	Wind Speeds/Power Production	
		Wind Speed (m/s)	Power Production (kW)
ML-1: 122 Bournehurst Drive (Northeast of T5)	South to Southwest	Low: 4.3 - 7.2	<700
		Medium: 7.2 – 8.5	700 – 1,400
		High: >8.5	>1,400
ML-2: 9 Shady Pine Lane (South of T5)	North to Northwest	Low: 4.3 - 7.2	<700
		Medium: 7.2 – 8.5	700 – 1,400
		High: >8.5	>1,400
ML-3: Morning Mist Lane (West of T1)	East	Low: 4.3 - 7.2	<700
		Medium: 7.2 – 8.5	700 – 1,400
		High: >8.5	>1,400
ML-4: 14 Morning Mist Lane (West-southwest of T1)	East to Northeast	Low: 4.3 - 7.2	<700
		Medium: 7.2 – 8.5	700 – 1,400
		High: >8.5	>1,400
ML-5: 680 Head of the Bay Rd (Southeast of T1)	North to Northwest	Low: 4.3 - 7.2	<700
		Medium: 7.2 – 8.5	700 – 1,400
		High: >8.5	>1,400

The commissioning phase revealed, under various dispatch operating modes (i.e., turbine power production modes), that a couple of turbines would require some curtailment during overnight hours to meet the MassDEP Noise Policy broadband sound limit at ML-1, ML-3, ML-4, and ML-5.

All sound results from the commissioning phase were well below the Town's Zoning Bylaw for Wind Energy Facilities sound limit of 60 dBA; thus, all FGW turbines comply with the Town's Zoning Bylaw.

In June 2017, FGW requested Tech to develop a sound mitigation modeling analysis to develop a plan to achieve compliance with the MassDEP Noise Policy. Tech recommended a two-pronged approach that included using both long-term background sound monitoring data, collected by ADE in 2016, and acoustic modeling of the wind turbines to predict sound levels at each of the monitoring locations under the full power operating mode and various curtailment operating modes. Section 7.0 presents the curtailment analysis.

The acoustic modeling results of the full dispatch operations of all four turbines showed that during turbines T1 and T5 may exceed the MassDEP Noise Policy broadband sound limit during nighttime hours. The acoustic modeling results also indicated operations of T3 and T4 did not exceed the MassDEP Noise Policy broadband limit at any time.

On August 8, 2017, FGW implemented the NRO curtailment plan, in accordance with Condition 9 of the Special Permit (Case No. 3608) of the Town of Plymouth Zoning Bylaw.

1.2 Compliance Sound Monitoring Results

Compliance sound monitoring commenced in late August 2017, after the commissioning and dispatch operating modes were configured and tested over the summer of 2017. The final dispatch operating modes included T1 and T5 operating under the curtailment program which is fully described in Section 7.0 of this report. Section 8.0 presents the results of the compliance monitoring program conducted after a final curtailment program and dispatch operating modes were developed. Table 1-1 provides targeted wind and power production conditions for each monitoring location.

Based on the results of the compliance sound monitoring study all turbines in the current curtailment and dispatch operating mode are in compliance with MassDEP broadband sound limit of 10 dBA above ambient and Town of Plymouth requirements as described below.

Tables 1-2 through 1-4 presents the results of the compliance sound monitoring study for the turbines operating at low, medium, and high power production. The MassDEP limit of 10 dBA above ambient is stated as a whole decibel value; thus, monitoring results are rounded to whole decibel values for a proper comparison to the limit. For the three turbine operating conditions, Tech

collected 296 verified five-minute measurements (148 turbine-ON and 148 turbine-OFF) over 10 monitoring events. A comparison of the L_{max}-to-L_{90} for the three operating conditions reveal that the incremental change in sound levels ranged from less than 1 and up to 10 dBA, and all 148 turbine-ON measurements comply with the MassDEP 10 dBA above ambient sound limit, pursuant to 310 CMR 7.10. In addition, results of the octave band analysis demonstrate that the operation of the wind turbines do not produce a pure tone condition under the three operating conditions. Accordingly, the compliance sound monitoring results demonstrate that the turbines are in full compliance with the MassDEP Noise Policy in all test conditions.

The compliance monitoring program results also demonstrate that the turbines comply with the Town of Plymouth Zoning Bylaw for Wind Energy Facilities noise limit of 60 dBA.

TABLE 1-2

SUMMARY OF COMPLIANCE SOUND MONITORING RESULTS (dBA)
TURBINES OPERATING AT LOW POWER PRODUCTION

Monitoring Location	Date	Sampling Time (Turbine-ON)[1]	Average Power Production (kW)	Average Hub Height Wind Speed (m/s)	Five-minute Ambient L_{90} Level (Turbine-OFF)	One-second L_{max} Level (Turbine-ON)[1]	Net Increase[2]
ML1	10/4/2017	2:00 AM-2:15 AM	839.0	8.2	28.1	34.0	**6**
		2:20 AM-2:35 AM	986.9	8.5	28.1	33.1	**5**
		2:35 AM-2:50 AM	1,130.6	8.9	28.1	33.1	**5**
ML2	9/20/2017	1:15 AM-1:30 AM	1,127.5	5.9	49.7	50.3	**1**
	11/4/2017-11/5/2017	11:40 PM-11:55 PM	796.6	7.2	38.3	44.4	**6**
		11:55 PM-12:10 AM	807.4	7.2	38.3	45.3	**7**
		12:10 AM-12:25 AM	742.7	7.1	38.3	45.3	**7**
ML3	9/19/2017	2:30 AM-2:45 AM	747.4	6.3	42.8	44.4	**2**
		2:45 AM-3:00 AM	856.4	5.6	42.8	43.9	**1**
	9/20/2017	1:15 AM-1:30 AM	1,127.5	5.9	41.6	44.2	**3**
ML4	9/19/2017	1:00 AM-1:15 AM	713.9	7.1	39.8	41.2	**1**
	9/20/2017	1:15 AM-1:30 AM	995.8	8.3	43.6	44.8	**1**
		1:30 AM-1:45 AM	1390.6	9.1	43.6	46.4	**3**
	11/4/2017-11/5/2017	11:55 AM-12:10 AM	901.4	7.5	29.9	39.3	**9**
		12:10 AM-12:25 AM	807.7	7.3	29.9	39.7	**10**
ML5	9/1/2017	12:50 AM-1:05 AM	776.3	7.4	35.2	39.4	**4**
		1:05 AM-1:20 AM	713.9	7.1	35.2	40.6	**5**
	10/16/2017-10/17/2017	11:00 PM11:15 PM	1,103.3	7.8	31.5	41.3	**10**
		11:15 PM-11:30 PM	1,068.7	7.7	31.5	41.7	**10**
		12:40 AM-12:55 AM	724.9	7.0	31.5	40.8	**9**

[1]During these compliance tests, three five-minute samples were taken with the turbine-ON, and each monitoring location was located downwind of the nearest turbine.
[2]The increase of L_{max} over L_{90} ambient is rounded to a whole decibel value for proper comparison to the MassDEP Noise Policy limit- see text.

TABLE 1-3

SUMMARY OF COMPLIANCE SOUND MONITORING RESULTS (dBA)
TURBINES OPERATING AT MEDIUM POWER PRODUCTION

Monitoring Location	Date	Sampling Time (Turbine-ON)[1]	Average Power Production (kW)	Average Hub Height Wind Speed (m/s)	Five-minute Ambient L_{90} Level (Turbine-OFF)	One-second L_{max} Level (Turbine-ON)[1]	Net Increase[2]
ML1	10/4/2017	2:00 AM-2:15 AM	839.0	8.2	28.1	34.0	**6**
		2:20 AM-2:35 AM	986.9	8.5	28.1	33.1	**5**
		2:35 AM-2:50 AM	1,130.6	8.9	28.1	33.1	**5**
ML2	9/20/2017	1:15 AM-1:30 AM	1,127.5	5.9	49.7	50.3	**1**
	11/4/2017-11/5/2017	11:40 PM-11:55 PM	796.6	7.2	38.3	44.4	**6**
		11:55 PM-12:10 AM	807.4	7.2	38.3	45.3	**7**
		12:10 AM-12:25 AM	742.7	7.1	38.3	45.3	**7**
ML3	9/19/2017	2:30 AM-2:45 AM	747.4	6.3	42.8	44.4	**2**
		2:45 AM-3:00 AM	856.4	5.6	42.8	43.9	**1**
	9/20/2017	1:15 AM-1:30 AM	1,127.5	5.9	41.6	44.2	**3**
ML4	9/19/2017	1:00 AM-1:15 AM	713.9	7.1	39.8	41.2	**1**
	9/20/2017	1:15 AM-1:30 AM	995.8	8.3	43.6	44.8	**1**
		1:30 AM-1:45 AM	1390.6	9.1	43.6	46.4	**3**
	11/4/2017-11/5/2017	11:55 AM-12:10 AM	901.4	7.5	29.9	39.3	**9**
		12:10 AM-12:25 AM	807.7	7.3	29.9	39.7	**10**
ML5	9/1/2017	12:50 AM-1:05 AM	776.3	7.4	35.2	39.4	**4**
		1:05 AM-1:20 AM	713.9	7.1	35.2	40.6	**5**
	10/16/2017-10/17/2017	11:00 PM11:15 PM	1,103.3	7.8	31.5	41.3	**10**
		11:15 PM-11:30 PM	1,068.7	7.7	31.5	41.7	**10**
		12:40 AM-12:55 AM	724.9	7.0	31.5	40.8	**9**

[1]During these compliance tests, three five-minute samples were taken with the turbine-ON, and each monitoring location was located downwind of the nearest turbine.
[2]The increase of L_{max} over L_{90} ambient is rounded to a whole decibel value for proper comparison to the MassDEP Noise Policy limit- see text.

TABLE 1-4

SUMMARY OF COMPLIANCE SOUND MONITORING RESULTS (dBA)
TURBINES OPERATING AT HIGH POWER PRODUCTION

Monitoring Location	Date[2]	Sampling Time (Turbine-ON)[1]	Average Power Production (kW)	Average Hub Height Wind Speed (m/s)	Five-minute Ambient L_{90} Level (Turbine-OFF)	One-second L_{max} Level (Turbine-ON)[1]	Net Increase[2]
ML1	8/23/2017	12:05 AM-12:20 AM	1,613	12.0	46.9	48.8	**2**
		1:30 AM-1:45 AM	1,870	10.8	44.4	46.6	**2**
ML2	9/20/2017	1:30 AM-1:45 AM	1,442	7.5	48.9	49.5	**1**
		3:00 AM-3:15 AM	1,648	9.7	48.9	50.3	**1**
ML3	9/20/2017	1:30 AM-1:45 AM	1,442	7.5	41.2	45.1	**4**
		3:00 AM-3:15 AM	1,648	9.7	41.2	44.8	**4**
		3:15 AM-3:30 AM	1,893	9.2	41.2	44.5	**3**
		3:30 AM-3:45 AM	1,404	9.0	41.2	44.7	**4**
ML4	9/20/2017	3:00 AM-3:15 AM	1,636	9.9	43.6	47.4	**4**
		3:15 AM-3:30 AM	1,913	10.6	43.6	47.3	**4**
	3/5/2018-3/6/2018	11:00 PM-11:15 PM	1,646	9.4	34.7	44.2	**10**
		11:30 PM-11:45 PM	1,445	8.8	34.7	44.5	**10**
		11:50 PM-12:05 AM	1,464	8.8	34.7	44.6	**10**
ML5	11/3/2017	11:35 PM-11:50 PM	1,540	9.0	34.6	43.8	**9**
	3/5/2018-3/6/2018	11:30 PM-11:45 PM	1,445	8.8	35.4	44.3	**9**
		11:50 PM-12:05 AM	1,464	8.8	35.4	43.8	**8**
		1:10 AM-1:25 AM	1,414	8.6	35.4	43.7	**8**

[1]During these compliance tests, three five-minute samples were taken with the turbine-ON, and each monitoring location was located downwind of the nearest turbine
[2]The increase of L_{max} over L_{90} ambient is rounded to a whole decibel value for proper comparison to the MassDEP Noise Policy limit- see text.

2.0 APPLICABLE NOISE REGULATIONS

This section describes the noise regulations that apply to FGW. Appendix B presents the full text of these state and local noise standards.

2.1 Massachusetts DEP Noise Policy

The MassDEP regulates noise through 310 CMR 7.10, "Air Pollution Control". In these regulations, "air contaminant" is defined to include sound, and a condition of "air pollution" includes the presence of an air contaminant in such concentration and duration as to "cause a nuisance" or "unreasonably interfere with the comfortable enjoyment of life and property."

Regulation 7.10 prohibits "unnecessary emissions" of noise. The Mass DEP Noise Policy (Policy Statement 90-001, February 1, 1990) interprets a violation of this noise regulation to have occurred if the source causes either:

(1) An increase in the broadband sound pressure level of more than 10 A-weighted decibels (dBA) above the ambient, or

(2) A "pure tone" condition.

The ambient background level is defined as the background sound level that is exceeded 90 percent of the time (L_{90}) turbine-OFF. A "pure tone" condition occurs when any octave band sound pressure level exceeds both of the two adjacent octave band sound pressure levels by 3 dB or more. These criteria are measured at the property line and the nearest inhabited residence.

Consistent with recent wind turbine sound compliance testing performed by MassDEP, the L_{max} to L_{90} method was used for the FGW sound compliance monitoring program. See Section 4.0 for a detailed description of the L_{max} to L_{90} monitoring methodology.

2.2 Town of Plymouth

The Town of Plymouth has a sound limit specific to wind turbines in the Plymouth Zoning Bylaw under Article VI Overlay Districts and Special Regulations Section 205-73 Wind Energy Facilities, Subsection D (8) Noise. It states that except during short-term events, such as high windstorms or utility outages, noise from the proposed wind turbine shall not exceed 60 dBA as measured from the nearest property line.

3.0 SOUND MONITORING LOCATIONS

Tech collected ambient (turbine-OFF) and (turbine-ON) sound level measurements for three downwind conditions at night: one with southerly winds, one with easterly winds, and one with northerly winds. Monitoring took place at a total of five locations. Table 3-1 presents the sound monitoring locations and Figure 3-1 shows these locations on an aerial photograph. Each property owner, where sound monitoring was planned to occur, was contacted to receive permission to access their properties during the sound monitoring program. Appendix D presents photos of each monitoring location setup.

TABLE 3-1

SOUND MONITORING LOCATIONS

Location No.	Description	Latitude	Longitude	Elevation (ft)	Distance To Closest Turbine (ft)
ML-1	122 Bournehurst Drive (North of T5)	41° 47' 2.0''	70° 37' 14.4''	58	1,500' (T5)
ML-2	9 Shady Pine Lane (West of T3 & T4)	41° 46' 35.6''	70° 37' 27.8''	42	1,900' (T5)
ML-3	Morning Mist Lane (West of T1)	41° 46' 13.1''	70° 37' 22.3''	58	1,450' (T1)
ML-4	14 Morning Mist Lane (Southwest of T1)	41° 46' 3.9''	70° 37' 18.0''	35	1,360' (T1)
ML-5	680 Head of the Bay Road (Southeast of T1)[1]	41° 46' 4.6"	70° 36' 51.6"	57	1,270' (T1)

[1]Tech was not granted access to ML-5 by the property owner, and instead took measurements at the dune west of the property as representative of the residence, with an elevated and clear line of sight of T1.

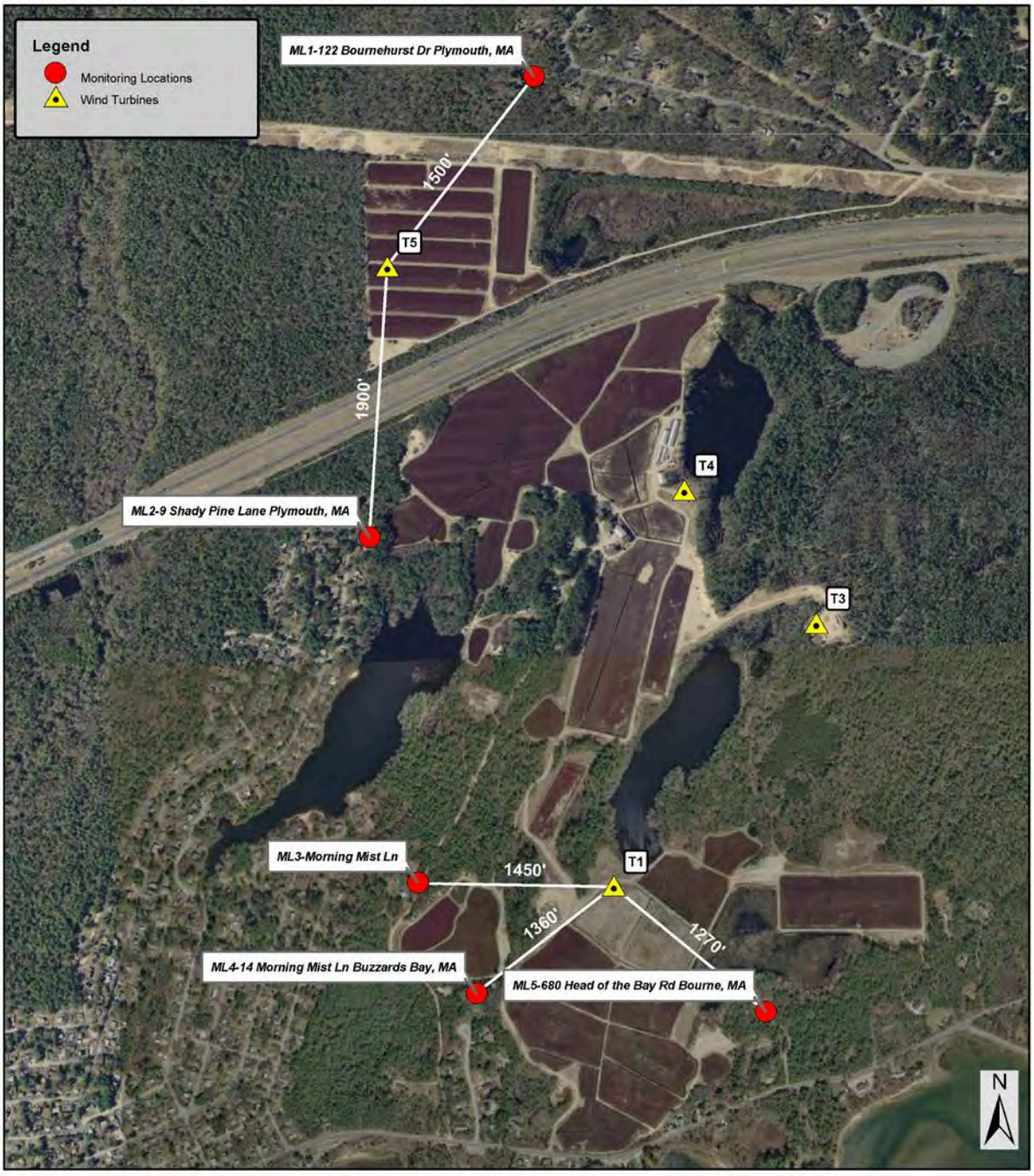

Figure 3-1

Sound Monitoring Locations
Future Generation Wind Project
Plymouth, MA

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4.0 MONITORING METHODOLOGY

This section describes the sound monitoring equipment and sampling procedures implemented for the sound monitoring program.

4.1 Sound Monitoring Equipment and Operations

ANSI Type 1 (precision) real-time sound analyzers (Bruel & Kjaer 2250, Larson Davis 831) or equivalent were used to record A-weighted (dBA) broadband sound pressure levels and one-third octave band frequencies (12.5 to 20,000 Hertz) un-weighted linear (dBZ) sound levels at the five residential locations.

The sound analyzers were calibrated both before and after each sampling night. Consistent with ANSI Standard S12.9-2013/Part 3, the microphone heights were between 1 and 2 meters (m) (3.3 and 6.6 feet) above ground and the microphones were located 7.5 m (25 feet) or farther from any reflecting surface. The microphones were kept at least 1.5 m (5 feet) from any small-dimension reflecting object, such as a tree, post, or vegetation. Each analyzer was tripod mounted and equipped with a 178-mm (7 inch) wind screen to reduce wind interference across the microphone. The analyzers were set to collect one second measurements. During monitoring, concurrent ground-level (2 m above grade) wind speeds were logged using Onset HOBO data loggers to ensure time periods with high winds[5] were screened out of the data set.

4.2 Wind Turbine Sound Monitoring Metrics

MassDEP monitoring method used for recent wind turbine monitoring programs is based on a maximum sound level L_{max}. This L_{max} is represented by the average of the three highest 1-second L_{EQ}[6] (turbines ON) values and compared to a baseline (turbines OFF) L_{90} sound level to determine compliance with the MassDEP Noise Policy.

MassDEP's monitoring method calls for a technician to write down A-weighted sound levels shown on the analyzer screen every five seconds on field log sheets and then select the highest value over each five-minute sample period with the turbines on. The average of the three highest one-second values represents the maximum turbine-ON sound level.

A similar approach is used to define the turbine-OFF ambient sound level. Sound levels are recorded on log sheets every five seconds and the lowest 10 percent value in each of three five-minute sample periods represents the lowest L_{90} ambient sound level. In other words, if 180 measurements are taken

[5] Per ANSI S12.9 Part 3, time periods with ground level (2m) wind speeds of 5 m/s or greater were screened out of the dataset.

[6] The equivalent sound level L_{eq} is the steady-state sound level over a period of time that has the same acoustic energy as the fluctuating sounds that actually occurred during that same period. It is commonly referred to as the energy-average sound level and it includes in its measure all of the sound we hear.

over three five-minute periods, the 18th lowest value represents the L_{90} ambient level used for comparison to the L_{max} sound level.

To be consistent with MassDEP's approach, Tech collected one-second L_{eq} sound levels, and all data were stored in the analyzer. Tech selected the highest one-second L_{eq} sound level recorded in each five-minute sample period (turbine-ON) and averaged these peak values for three five-minute periods to obtain the L_{max} sound level. The lowest L_{90} sound level measured during the three consecutive five-minute sample periods (turbine-OFF) was used to represent the ambient level[7]. In addition to the measurements discussed above, Tech recorded L_{max}, L_{eq} and L_{90} sound levels for each five-minute sampling period for both the turbine-ON and turbine-OFF intervals. Audio recordings (.wav files) of the turbine-ON monitoring periods were collected for quality assurance/quality control (QA/QC) purposes.

The sound analyzers were also set to measure L_{eq} one-third octave band sound levels over each five minute period with the turbines ON. These five-minute one-third octave band measurements were combined into whole octave bands, which were used to test if the wind turbines produce a pure tone per the MassDEP Noise Policy. The one-third octave band sound levels were collected to be consistent with ANSI S12.9-Part 3 methodologies.

4.3 Sound Monitoring Methodology

Tech's meteorologists monitored National Weather Service weather forecasts and analyzed computer numerical models for predicting both upper air and surface wind speed and wind direction conditions. When wind conditions looked favorable for sound monitoring, Tech notified the Town, MassDEP, FGW, Duke Energy, Gamesa Wind and property owners via email that Tech acoustic engineers would be performing sound testing near the turbines. Tech coordinated with Duke Energy during each monitoring event to turn on and turn off the turbines.

Tech collected a series of turbine-ON and turbine-OFF measurements under the following three criteria: 1) no precipitation is anticipated in the monitoring area; 2) wind directions generally place the identified residential properties downwind of the nearby turbine – winds with an easterly component for ML-3 and ML-4, winds with a southerly component for ML-1, and winds from the north or northwest for the ML-2 and ML-5; and 3) wind speeds at the 100-m hub height were consistently above the 4.3 m/s (9.6 mph) cut-in speed and trending towards 10.1 m/s (23 mph), the speed at which maximum acoustic power is achieved. This is equivalent to 10-m wind speeds of 8.0 m/s (17-18 mph) and represents the conditions when the turbine sound levels are typically at their highest. Hub-height wind speed measurements were obtained from FGW and Gamesa Wind via nacelle mounted anemometers.

[7] Hub height wind speeds at the closest turbine during turbine-ON and turbine-OFF measurements had to be within +/- 2 m/s of each other to be considered verified.

For the purposes of completing the sound monitoring during the quietest hours of the night (11:00 p.m. – 4:00 a.m.) at all locations, and to be consistent with the MassDEP wind turbine monitoring procedures, five-minute sampling for turbine-ON and turbine-OFF conditions was done. The test cycle took approximately one hour to complete at each monitoring location, considering the time needed to turn the turbines on and off between measurements and travel between each monitoring location on nights when wind conditions allow for multiple locations to be monitored. Tech collected A-weighted broadband and un-weighted one-third octave band measurements with the turbines ON and OFF. Each round of testing at a monitoring location consisted of at least three five-minute measurements as follows: OFF, OFF, OFF, ON, ON, ON. Monitoring was performed at 122 Bournehurst Drive (ML-1) when winds were out of the south. Monitoring was performed at two locations along Morning Mist Lane (ML-3 and ML-4) when winds were out of the East. Monitoring was performed at 9 Shady Pine Lane and 700/714 Head of the Bay Rd (ML-2 and ML-5) when winds were out of the North or Northwest.

5.0 DATA ANALYSIS

After each sound monitoring event, Tech downloaded the measurements from the sound analyzers to a field laptop computer for storage and analysis. As outlined in the Section 4.0, the sound analyzers measured A-weighted and one-third octave band sound levels from 16 Hz to 20,000 Hz, and logged statistical data (L_{eq}, L_{90}, L_{50}, and L_{10}) for five-minute periods. Consistent with the MassDEP monitoring method, the Tech acoustic engineer flagged other sound sources (e.g., local traffic, leaves rustling, dogs barking, wind gusts, etc.) on data log sheets (a copy of log sheet is presented in Appendix D) or via Microsoft tablets. Tech discarded one-second measurements with audible noise contamination from the data set before determining the L_{max} sound level. During monitoring, concurrent ground-level (2 m above grade) wind speeds were logged using Onset HOBO data loggers to ensure time periods with high winds were screened out of the data set. Per ANSI S12.9 Part 3, time periods with ground level (2m) wind speeds of 5 m/s or greater were screened out of the dataset.

Upon review of the sound recordings, field log sheets and tablets, and surface wind data, Tech selected the highest one-second L_{eq} sound levels recorded by the sound analyzer for each five-minute turbine-ON sample period and averaged these highest values for three consecutive five-minute periods to obtain the L_{max} sound level. The data from this screening process were summarized in the turbines-ON L_{max} to L_{90} sound graphs presented in Appendix E. To understand the contribution of the wind turbines to sound levels in each hour, the analysis also examined whether the residences were downwind of the nearest wind turbine for a given hour and the operating level of the turbine. Tech obtained the hub-height power production and wind speed data from FGW for comparison to ensure that the turbines were operating properly and to screen out any gusty wind conditions that would artificially increase the sound contribution from the wind turbines. Appendix F presents turbine power production and hub height wind speed graphs for each monitoring event.

6.0 COMMISSIONING STUDY RESULTS

The first phase of the sound study was to assess whether initial operation of the FGW turbines complied with the MassDEP Noise Policy broadband sound limit of 10 dBA above ambient, as required by the Town of Plymouth Special Permit (Case No. 3608). During commissioning of the turbines, Tech performed sound monitoring on four separate nights: May 1 to 2, 2017; May 3 to 4, 2017; May 11 to 12, 2017, and June 13 to 14, 2017. The June 13 and 14 monitoring was subsequently deemed unverified, because Turbine 1 was not operating properly due to a malfunction.

The commissioning phase revealed, under various operating modes, that sound limits were not met, specifically at ML-1, ML-3, ML-4, and ML-5 for the three monitoring events.

It should also be stated that all noise results during the commissioning phase were well below the Town's Zoning Bylaw for Wind Energy Facilities sound limit of 60 dBA; thus, all FGW turbines comply with the Town's Zoning Bylaw.

In June 2017, FGW requested Tech to develop a sound mitigation model and plan to achieve compliance, as required by Condition 9 of the Special Permit, issued by the Town of Plymouth. Tech recommended a two-pronged approach that included using long-term background sound monitoring data collected by ADE in 2016, and acoustic modeling of the wind turbines to predict sound levels at each of the monitoring locations under the full power operating mode and various curtailment operating modes. Section 7 presents the curtailment analysis.

7.0 ACOUSTIC MODELING AND ANALYSIS

FGW directed Tech to analyze and model the most efficient turbine curtailment program to achieve compliance, as required by the Town of Plymouth Special Permit. The initial model determined that compliance would be best achieved by modifying operation of Turbine 1 (T1) and Turbine 5 (T5) during certain time periods. Tech proceeded with a two-pronged approach to develop the curtailment program. This included evaluating turbine-OFF sound monitoring data to establish a "reasonable" worst-case floor, or minimum, ambient sound level at each monitoring location and performing an acoustic modeling analysis to determine the hours of curtailment.

7.1 Establishing Reasonable Worst-Case Ambient Levels

To supplement the limited amount of turbine-OFF sound data collected during the commissioning monitoring program, Tech used long-term ambient sound monitoring data collected by ADE and Modeling Specialties over a three week period in 2016. The 2016 survey took place from February 19 through March 10 at four monitoring locations. The long-term measurements were made using an interval of 10 minutes so the resulting levels could be correlated with wind data from the project's meteorological tower.

From the data set, Tech extracted the 10-minute L_{90} sound levels ($L_{90(10\text{-min})}$) for each monitoring location and made a spreadsheet with hourly bins for each 24-hour period, eliminating measurements contaminated by high winds or precipitation. The screened sound levels were then ranked from lowest to highest. Tech then calculated the "nominally lowest" $L_{90(10\text{-min})}$ sound level as the sound level exceeded by 90% of all verified, measured hourly L_{90} sound levels period over the three-week period. The final step was to convert the nominally lowest $L_{90(10\text{-min})}$ level at each monitoring location was then converted into an hourly average. These ambient levels were used in the initial acoustic modeling analysis, described below.

7.2 Acoustic Modeling Analysis Approach

Tech performed acoustic modeling to calculate the sound levels from the four turbines at each of the five monitoring locations using the Cadna-A model. Cadna-A is a sophisticated 3-D model for sound propagation and attenuation based on International Standard ISO 9613. Atmospheric absorption, the process by which sound energy is absorbed by the air, was calculated using ANSI S1.26-1995. The absorption of sound assumed standard conditions and is significant at large distances. Ground surfaces were assumed to be mixed ground consisting of both hard and porous (vegetated) surfaces. This is a reasonable worst-case assumption and approximates winter frozen ground conditions in the area between the turbine and the nearest residences. No attenuation from trees or vegetation was assumed. Digital terrain heights were extracted from MassGIS. The model assumed favorable sound propagation as occurs with a ground-based temperature inversion that

might occur on a clear night. At other times, atmospheric turbulence and wind shadow effects will reduce sound levels by 5 to 20 dBA less than those presented below. This is a reasonable worst-case scenario given that these conditions do not occur routinely day or night or throughout the year. Furthermore, the modeling did not take into consideration wind direction. It was assumed that the turbines produce maximum sound levels in all directions.

For the four Gamesa G-97 2.0-MW turbines, the cut-in wind speed at which the turbines begin operation is a hub height wind speed of 4.3 m/s or 9.6 mph. The maximum sound power level of 105.8 dBA is reached at a hub height wind speed of 10.1 m/s or 22.6 mph, and at the design wind speed, (hub height wind speed of 14.0 m/s or 31.3 mph) the sound power level is still at 105.8 dBA. Appendix C presents the sound power curve for G-97 turbine. An uncertainty factor of 2.0 dBA was added to these sound power levels to account for uncertainty in sound power measurements and variations in turbine manufacturing (IEC Technical Specification 61400-11). Thus, the maximum modeled sound power level was 107.8 dBA. An additional uncertainty factor of 4.0 dBA was added to the sound power levels for T1 and T5 to account for the variations of correlating maximum one-second sound levels as required by the MassDEP. This uncertainty factor was based on our sound level measurements taken near T1 and T5 and given their closer proximity to residential receptors compared to the other turbines.

Acoustic modeling was performed for each hour of the day for hub height wind speeds from 4.3 m/s to 11.6 m/s (i.e., cut-in wind speed to approaching maximum power production). The predicted sound levels at each monitoring location from all the turbines combined were added to the hourly L_{90} sound levels to determine the total sound level. The total sound level was compared to the baseline sound levels to calculate the change and compared to the MassDEP Noise Policy 10-dBA allowable limit. The first round of modeling was performed based on no curtailment of the turbines in order to determine the hours of the day that turbines were most likely to exceed the 10-dBA allowable increase.

7.3 Model and Ambient Sound Data Sensitivity Analysis

Tech performed sensitivity modeling analyses to properly calibrate the Cadna-A model based on the uncertainty factors applied to the turbine sound power levels and the use of the nominally lowest L_{90} sound level. The resulting predicted turbine sound levels were then compared with those measured during the commissioning monitoring program to verify model accuracy.

The results of the initial modeling analysis for the “no-curtailment” scenario, using the nominally lowest L_{90} sound levels, indicated the model over-predicted the turbine sound levels at each of the monitoring locations. Further analysis indicated the nominally lowest L_{90} sound level did not accurately represent ambient levels during some important wind conditions.

Tech re-evaluated the occurrences of the nominally lowest L_{90} sound levels under different wind speed conditions. The results of this re-evaluation showed that the vast majority of these L_{90} levels occurred under very light wind conditions (i.e., less than 5 mph). Tech concluded that using the nominally lowest L_{90} sound level that was measured during the winter (when the lowest ambient sound conditions tend to occur) to be representative of the ambient sound conditions for the entire year was overly conservative.

Further evaluation of the L_{90} sound levels and associated wind speed conditions determined that the fifth lowest L_{90} sound level the best estimate of the ambient sound level. These values were used to represent not only light wind conditions, but also moderate to high wind conditions when ambient sound levels are higher. Therefore, the acoustic modeling analysis is inherently conservative when evaluating the sound impacts from the turbines under those higher wind conditions.

7.4 Curtailment Modeling Results

The modeling results of the "no curtailment" operations indicated that turbines T1 and T5 may exceed the Mass DEP Noise Policy 10-dBA sound limit during nighttime hours, while turbines T3 and T4 do not.

Additional acoustic modeling analyses were conducted based on T1 and T5 operating in "noise reduced operation" (NRO) modes. These turbines are designed to operate in three different NRO modes:

NRO 102 – Sound Reduction of 4 dBA
NRO 103 – Sound Reduction of 3 dBA
NRO 104 – Sound Reduction of 2 dBA

Table 7-1 presents the curtailment modeling results. On August 8, 2017 after all modeling results were reviewed. FGW implemented the curtailment program and developed a schedule to complete the compliance sound monitoring program.

Starting in late August 2017, Tech began performing sound monitoring under the newly developed curtailment program for T1 and T5. Section 8.0 presents the results of the compliance monitoring program performed after this program.

TABLE 7-1

ENACTED CURTAILMENT PROGRAM
FGW WIND TURBINES, PLYMOUTH, MA

Start Time	T1	T3	T4	T5
12:00 AM	OFF	NORMAL	NORMAL	OFF
1:00 AM	OFF	NORMAL	NORMAL	OFF
2:00 AM	OFF	NORMAL	NORMAL	OFF
3:00 AM	OFF	NORMAL	NORMAL	OFF
4:00 AM	OFF	NORMAL	NORMAL	OFF
5:00 AM	OFF	NORMAL	NORMAL	NORMAL
6:00 AM	NRO 102	NORMAL	NORMAL	NORMAL
7:00 AM	NRO 103	NORMAL	NORMAL	NORMAL
8:00 AM	NORMAL	NORMAL	NORMAL	NORMAL
9:00 AM	NORMAL	NORMAL	NORMAL	NORMAL
10:00 AM	NORMAL	NORMAL	NORMAL	NORMAL
11:00 AM	NORMAL	NORMAL	NORMAL	NORMAL
12:00 PM	NORMAL	NORMAL	NORMAL	NORMAL
1:00 PM	NORMAL	NORMAL	NORMAL	NORMAL
2:00 PM	NORMAL	NORMAL	NORMAL	NORMAL
3:00 PM	NORMAL	NORMAL	NORMAL	NORMAL
4:00 PM	NORMAL	NORMAL	NORMAL	NORMAL
5:00 PM	NORMAL	NORMAL	NORMAL	NORMAL
6:00 PM	NRO 103	NORMAL	NORMAL	NORMAL
7:00 PM	NRO 102	NORMAL	NORMAL	NORMAL
8:00 PM	NRO 102	NORMAL	NORMAL	NORMAL
9:00 PM	NRO 102	NORMAL	NORMAL	NORMAL
10:00 PM	OFF	NORMAL	NORMAL	NORMAL
11:00 PM	OFF	NORMAL	NORMAL	NORMAL

8.0 COMPLIANCE MONITORING RESULTS

The compliance monitoring program was performed after implementing the curtailment program and dispatch operating mode described in Section 7.0. The compliance monitoring program was conducted from August 2017 through March 2018. The process of capturing all desired wind directions and speeds proved more complex than anticipated, thus lengthening the time to obtain adequate data to complete the compliance monitoring.

Compliance monitoring was performed downwind of the turbine(s) for low, medium and high power production. Sound monitoring location ML-1 required a southerly wind to be downwind of the nearest non-curtailed turbine, Turbine T4. Monitoring at ML-2 required an easterly wind to be downwind of the nearest non-curtailed turbine, T4. Monitoring at ML-3 required a northeasterly wind to be downwind of the non-curtailed turbines T3 and T4 that are equidistant from ML-3. When comparing monitoring data at ML-3 to power production data, T4 is used since it is slightly closer than T3. Monitoring at ML-4 required northerly or northeasterly winds to be downwind of the nearest non-curtailed turbine, T3. Monitoring at ML-5 required a northerly wind to be downwind of the nearest non-curtailed turbine, T3.

Each turbine is capable of producing 2 megawatts of power per (MW). Tech selected the following power production levels to represent low, medium and high power production:

- Low Power: less than 700 kW (less than 35% of full power),
- Medium Power: 700 kW to 1400 kW (35% – 70% of full power), and
- High Power: greater than 1400 kW (greater than 70% of full power).

Some monitoring events featured increasing or decreasing wind speeds, allowing for more than one wind condition to be captured during a single event. For each wind category and monitoring location, measurements were also taken with the turbines off to establish the ambient sound level under similar conditions similar to when the turbines were on.

8.1 Monitoring Events

The power production and hub height wind speeds for low, medium, and high power production monitoring events are summarized in Tables 8-1, 8-2, and 8-3, respectively.

8.1.1 Low Power Production Events

Sound monitoring during low power production events, defined as producing less than 700 kW, was performed and confirmed valid for six discrete events. The six events include August 31, 2017;

September 18-19, 2017; October 4, 2017; November 4, 2017; November 5, 2017; and November 11, 2017. Table 8-1 presents a summary of the turbine-ON power production and hub height wind speeds for the low power production monitoring events.

TABLE 8-1

TURBINE-ON POWER PRODUCTION AND HUB HEIGHT WIND SPEED SUMMARY FOR THE FUTURE GENERATION WIND PROJECT LOW POWER PRODUCTION

Monitoring Location	Date	Sampling Time (Turbine-ON)[1]	Average Power Production (kW)	Average Hub Height Wind Speed (m/s)
ML1	10/4/2017	12:25 AM-12:40 AM	266.6	5.3
		12:40 AM-12:55 AM	391.2	6.1
ML2	9/18/2017	11:00 PM-11:15 PM	531.1	5.4
		11:15 PM-11:30 PM	588.7	5.8
	11/5/2017	2:15 AM-2:30 AM	269.3	5.2
ML3	11/5/2017	2:00 AM-2:15 AM	362.9	5.7
		2:15 AM-2:30 AM	269.3	5.2
ML4	9/19/2017	12:45 AM-1:00 AM	553.4	6.6
ML5	8/31/2017	11:00 PM-11:15 PM	222.6	5.3
		11:15 PM-11:30 PM	303.6	5.8
	11/4/2017	1:10 AM-1:25 AM	281.4	5.2
		1:25 AM-1:40 AM	339.4	5.5
	11/11/2017	12:55 AM-1:10 AM	245.8	4.4
		1:10 AM-1:25 AM	363.6	4.9
		1:25 AM-1:40 AM	284.5	4.7

[1]During these compliance tests, three five-minute samples were taken with the turbine-ON, and each monitoring location was located downwind of the nearest turbine.

August 31-September 1, 2017

On August 31 and September 1, 2017, Tech performed sound monitoring at ML-5. The monitoring took place between 11:00 PM on August 31st and 3:00 AM the following morning. However, the only verified data were collected between 11:00 PM and 11:30 PM. During monitoring, conditions were dry, skies were clear, and winds were light to moderate from the north to northwest.

During the first verified 15-minute period, 11:00 PM to 11:15 PM, the average power production at Turbine 3 (T3) was 223 kW with an average hub height wind speed of 5.3 m/s. During the second verified 15-minute period, 11:15 PM to 11:30 PM, the average power production at T3 was 304 kW with an average hub height wind speed of 5.8 m/s.

September 18-19, 2017

On September 18 and 19, 2017, Tech performed sound monitoring at ML-2 and ML-4. The monitoring took place between 11:00 PM on September 18th and 4:00 AM the following morning. However, the only verified data were collected between 11:00 PM to 11:30 PM, and 12:45 AM to 1:00 AM for ML-2 and ML-4, respectively. During monitoring, skies were mostly cloudy with persistent fog, accompanied by light to moderate winds from the north to northeast.

During the first verified 15-minute period, 11:00 PM to 11:15 PM, the average power production at Turbine 4 (T4) was 531 kW with an average hub height wind speed of 5.4 m/s. During the second verified 15-minute period, 11:15 PM to 11:30 PM, the average power production at T3 was 589 kW with an average hub height wind speed of 5.8 m/s. During the third verified 15-minute period, 12:45 AM to 1:00 AM, the average power production at T3 was 553 kW with an average hub height wind speed of 6.6 m/s.

October 4, 2017

On October 4, 2017, Tech performed sound monitoring at ML-1. The monitoring took place between 12:00 AM and 3:30 AM; however, the only verified data were collected between 12:25 AM and 12:55 AM. During monitoring, conditions were dry, and skies were clear, and winds were light to moderate from the southwest.

During the first verified 15-minute period, 12:25AM to 12:40 AM, the average power production at T4 was 267 kW with an average hub height wind speed of 5.3 m/s. During the second verified 15-minute period, 12:40 AM to 12:55 AM, the average power production at T4 was 391 kW with an average hub height wind speed of 6.1 m/s.

November 3-4, 2017

On November 3 and 4, 2017, Tech performed sound monitoring at ML-5. The monitoring took place between 11:00 PM on November 3rd and 3:00 AM the following morning. However, the only verified data were collected between 1:10 AM and 1:40 AM. During monitoring, conditions were dry, skies were clear and winds were moderate from the north.

During the first verified 15-minute period, 1:10 AM to 1:25 AM, the average power production at T3 was 281 kW with an average hub height wind speed of 5.2 m/s. During the second verified 15-minute period, 1:25 AM to 1:40 AM, the average power production at T3 was 339 kW with an average hub height wind speed of 5.5 m/s.

November 4-5, 2017

On November 4 and 5, 2017, Tech performed sound monitoring at ML-2 and ML-3. The monitoring took place between 11:00 PM on November 4th and 3:30 AM the following morning. However, the only verified data were collected between 2:00 AM to 2:30 AM. During monitoring, conditions were dry and skies went from clear to cloudy, and winds were light from the east to northeast.

During the first verified 15-minute period, 2:00AM to 2:15 AM, the average power production at T4 was 363 kW with an average hub height wind speed of 5.7 m/s. During the second 15-minute period, 2:15 AM to 2:30 AM, monitoring was performed at ML-2 and ML-3. During this period, the average power production at T4 was 269 kW with an average hub height wind speed of 5.2 m/s.

November 11, 2017

On November 11, 2017, Tech performed sound monitoring at ML-5. The monitoring took place between 12:30 AM and 2:30 AM; however, the only verified data were collected between 12:55 AM and 1:40 AM. During monitoring, conditions were dry, skies were clear, and winds were light to moderate from the northwest.

During the first verified 15-minute period, 12:55 AM to 1:10 AM, the average power production at T3 was 246 kW with an average hub height wind speed of 4.4 m/s. During the second verified 15-minute period, 1:10 AM to 1:25 AM, the average power production at T3 was 364 kW with an average hub height wind speed of 4.9 m/s. During the third verified 15-minute period, 1:25 AM to 1:40 AM, the average power production at T3 was 284 kW with an average hub height wind speed of 4.7 m/s.

8.1.2 Medium Power Production Events

Sound monitoring during medium power production events, defined as producing between 700 kW and 1400 kW, was performed and confirmed valid for six discrete events. The six events include August 31 - September 1, 2017; September 18-19, 2017; September 20, 2017; October 4, 2017; October 16-17, 2017; and November 4-5, 2017. Table 8-2 presents a summary of the turbine-ON power production and hub height wind speeds for the medium power production monitoring events.

August 31-September 1, 2017

On August 31 and September 1, 2017, Tech performed sound monitoring at ML-5. The monitoring took place between 11:00 PM August 31st and 3:00 AM the following morning. However, the only verified data were collected between 12:50 AM and 1:20 AM. During monitoring, conditions were dry, skies were clear, and winds were light to moderate from the north to northwest.

During the first verified 15-minute period, 12:50 AM to 1:05 AM, the average power production at T3 was 776 kW with an average hub height wind speed of 7.4 m/s. During the second verified 15-minute period, 1:05 AM to 1:20 AM, the average power production at T3 was 714 kW with an average hub height wind speed of 7.1 m/s.

September 18-19, 2017

On September 18 and 19, 2017, Tech performed sound monitoring at ML-3 and ML-4. The monitoring took place between 11:00 PM September 18th and 4:00 AM the following morning. However, the only verified data were collected between 1:00 AM to 1:15 AM, and 2:30 AM to 3:00 AM. During monitoring, skies were mostly cloudy with persistent fog, accompanied by light to moderate north to northeast winds.

During the first verified 15-minute period, 1:00 AM to 1:15 AM, the average power production at T3 was 714 kW with an average hub height wind speed of 7.1 m/s. During the second verified 15-minute period, 2:30 AM to 2:45 AM, the average power production at T4 was 747 kW with an average hub height wind speed of 6.3 m/s. During the third verified 15-minute period, 2:45 AM to 3:00 AM, the average power production at T4 was 856 kW with an average hub height wind speed of 5.6 m/s.

September 20, 2017

On September 20, 2017, Tech performed sound monitoring at ML-2, ML-3 and ML-4. The monitoring took place between 1:00 AM and 4:00 AM. However, the only verified data were

collected between 1:15 AM to 1:45 AM. During monitoring, skies were mostly cloudy with persistent fog, accompanied by moderate to strong north to northeast winds.

During the first verified 15-minute period, 1:15 AM to 1:30 AM, monitoring was performed at ML-2, ML-3, and ML-4. During this period, the average power production at T4 was 1,128 kW with an average hub height wind speed of 5.9 m/s. During the same period, the average power production at T3 was 996 kW with an average hub height wind speed of 8.3 m/s. During the second verified 15-minute period, 1:30 AM to 1:45 AM, the average power production at T3 was 1,391 kW with an average hub height wind speed of 9.1 m/s.

October 4, 2017

On October 4, 2017, Tech performed sound monitoring at ML-1. The monitoring took place between 12:00 AM and 3:30 AM. However, the only verified data were collected between 2:00 AM to 2:15 AM, and 2:20 AM to 2:50 AM. During monitoring, conditions were dry, skies were clear, and winds were with light to moderate from the southwest.

During the first verified 15-minute period, 2:00 AM to 2:15 AM, the average power production at T4 was 839 kW with an average hub height wind speed of 8.2 m/s. During the second verified 15-minute period, 2:20 AM to 2:35 AM, the average power production at T4 was 987 kW with an average hub height wind speed of 8.5 m/s. During the third verified 15-minute period, 2:35 to 2:50 AM, the average power production at T4 was 1,131 kW with an average hub height wind speed of 8.9 m/s.

October 16-17, 2017

On October 16 and 17, 2017, Tech performed sound monitoring at ML-5. The monitoring took place between 11:00 PM on October 16th and 1:00 AM the following morning. However, the only verified data were collected between 11:00 PM to 11:30 PM, and 12:40 AM to 12:55 AM. During monitoring, conditions were dry, skies became increasingly clear, and winds were moderate to strong from the north to northwest.

During the first verified 15-minute period, 11:00 PM to 11:15 PM, the average power production at T3 was 1,103 kW with an average hub height wind speed of 7.8 m/s. During the second verified 15-minute period, 11:15 to 11:30 PM, the average power production at T3 was 1,069 kW with an average hub height wind speed of 7.7 m/s. During the third verified 15-minute period, 12:40 AM to 12:55 AM, the average power production at T3 was 725 kW with an average hub height wind speed of 7.0 m/s.

November 4-5, 2017

On November 4 and 5, 2017, Tech performed sound monitoring at ML-2 and ML-4. The monitoring took place between 11:00 PM on November 4th and 3:30 AM the following morning. However, the only verified data were collected between 11:40 PM to 12:25 AM. During monitoring, conditions were dry, skies went from clear to cloudy, and winds were light from the east to northeast.

During the first verified 15-minute period, 11:40 PM to 11:55 PM, the average power production at T4 was 797 kW with an average hub height wind speed of 7.2 m/s. During the second 15-minute period, 11:55 PM to 12:10 AM, the average power production at T4 was 807 kW with an average hub height wind speed of 7.2 m/s. During the same period, the average power production at T3 was 901 kW with an average hub height wind speed of 7.5 m/s. During the third verified 15-minute period, 12:10 AM to 12:25 AM, monitoring was again performed at both ML-2 and ML-4. During this period, the average power production at T4 was 743 kW with an average hub height wind speed of 7.1 m/s. During the same period, the average power production at T3 was 808 kW with an average hub height wind speed of 7.3 m/s.

TABLE 8-2

TURBINE-ON POWER PRODUCTION AND HUB HEIGHT WIND SPEED SUMMARY FOR THE FUTURE GENERATION WIND PROJECT MEDIUM POWER PRODUCTION

Monitoring Location	Date	Sampling Time (Turbine-ON)[1]	Average Power Production (kW)	Average Hub Height Wind Speed (m/s)
ML1	10/4/2017	2:00 AM-2:15 AM	839.0	8.2
		2:20 AM-2:35 AM	986.9	8.5
		2:35 AM-2:50 AM	1,130.6	8.9
ML2	9/20/2017	1:15 AM-1:30 AM	1,127.5	5.9
	11/4/2017-11/5/2017	11:40 PM-11:55 PM	796.6	7.2
		11:55 PM-12:10 AM	807.4	7.2
		12:10 AM-12:25 AM	742.7	7.1
ML3	9/19/2017	2:30 AM-2:45 AM	747.4	6.3
		2:45 AM-3:00 AM	856.4	5.6
	9/20/2017	1:15 AM-1:30 AM	1,127.5	5.9
ML4	9/19/2017	1:00 AM-1:15 AM	713.9	7.1
	9/20/2017	1:15 AM-1:30 AM	995.8	8.3
		1:30 AM-1:45 AM	1390.6	9.1
	11/4/2017-11/5/2017	11:55 AM-12:10 AM	901.4	7.5
		12:10 AM-12:25 AM	807.7	7.3
ML5	9/1/2017	12:50 AM-1:05 AM	776.3	7.4
		1:05 AM-1:20 AM	713.9	7.1
	10/16/2017-10/17/2017	11:00 PM11:15 PM	1,103.3	7.8
		11:15 PM-11:30 PM	1,068.7	7.7
		12:40 AM-12:55 AM	724.9	7.0

[1]During these compliance tests, three five-minute samples were taken with the turbine-ON, and each monitoring location was located downwind of the nearest turbine.

8.1.3 High Power Production Events

Sound monitoring during high power production events, defined as producing more than 1,400 kW, was performed and confirmed valid for four discrete events. The four events include August 22-23, 2017; September 20, 2017; November 3-4, 2017; and March 5-6, 2018. Table 8-3 presents a summary of the turbine-ON power production and hub height wind speeds for the high power production monitoring events.

August 22-August 23, 2017

On August 22 and 23, 2017, Tech performed sound monitoring at ML-1. The monitoring took place between 11:00 PM August 22nd and 2:00 AM the following morning. However, the only verified data were collected between 12:05 AM to 12:20 AM, and 1:30 AM to 1:45 AM. During monitoring, skies were cloudy with brief periods of fog and mist. Due to the warm and humid conditions, tree frogs and other insects were active, but this was not a hindrance since insect noise occurs at a higher frequency than turbine sound. Therefore, the frog and insect noise was easily screened out of the data during the analysis. During the monitoring, hub height winds were moderate to strong from the southwest.

During the first verified 15-minute period, 12:05 AM to 12:20 AM, the average power production at T4 was 1,612 kW with an average hub height wind speed of 12.0 m/s. During the second verified 15-minute period, 1:30 AM to 1:45 AM, the average power production at T4 was 1,870 kW with an average hub height wind speed of 10.8 m/s.

September 20, 2017

On September 20, 2017, Tech performed sound monitoring at ML-2, ML-3 and ML-4. The monitoring took place between 1:00 AM and 4:00 AM. However, the only verified data were collected between 1:30 AM to 1:45 AM, and 3:00 AM to 3:45 AM. During monitoring, skies were mostly cloudy with persistent fog, and winds were moderate to strong from the north to northeast.

During the first verified 15-minute period, 1:30 AM to 1:45 AM, monitoring was performed at ML-2 and ML-3. During this period, the average power production at T4 was 1,442 kW with an average hub height wind speed of 7.5 m/s. During the second verified 15-minute period, 3:00 AM to 3:15 AM, monitoring was performed at ML-2, ML-3, and ML-4. During this period, the average power production at T4 was 1,648 kW with an average hub height wind speed of 9.7 m/s. During the same period, the average power production at T3 was 1,636 kW with an average hub height wind speed of 9.9 m/s. During the third verified 15-minute period, 3:15 AM to 3:30 AM, monitoring was performed at ML-3 and ML-4. During this period, the average power production at T4 was 1,893 kW with an average hub height wind speed of 9.2 m/s. During the same period, the average power

production at T3 was 1,913 kW with an average hub height wind speed of 10.6 m/s. The last 15-minute period of verified monitoring was performed at ML-3 from 3:30 to 3:45 AM. During this period, the average power production at T4 was 1,404 kW with an average hub height wind speed of 9.0 m/s.

TABLE 8-3

TURBINE-ON POWER PRODUCTION AND HUB HEIGHT WIND SPEED SUMMARY FOR THE FUTURE GENERATION WIND PROJECT HIGH POWER PRODUCTION

Monitoring Location	Date[2]	Sampling Time (Turbine-ON)[1]	Average Power Production (kW)	Average Hub Height Wind Speed (m/s)
ML1	8/23/2017	12:05 AM-12:20 AM	1,613	12.0
		1:30 AM-1:45 AM	1,870	10.8
ML2	9/20/2017	1:30 AM-1:45 AM	1,442	7.5
		3:00 AM-3:15 AM	1,648	9.7
ML3	9/20/2017	1:30 AM-1:45 AM	1,442	7.5
		3:00 AM-3:15 AM	1,648	9.7
		3:15 AM-3:30 AM	1,893	9.2
		3:30 AM-3:45 AM	1,404	9.0
ML4	9/20/2017	3:00 AM-3:15 AM	1,636	9.9
		3:15 AM-3:30 AM	1,913	10.6
	3/5/2018-3/6/2018	11:00 PM-11:15 PM	1,646	9.4
		11:30 PM-11:45 PM	1,445	8.8
		11:50 PM-12:05 AM	1,464	8.8
ML5	11/3/2017	11:35 PM-11:50 PM	1,540	9.0
	3/5/2018-3/6/2018	11:30 PM-11:45 PM	1,445	8.8
		11:50 PM-12:05 AM	1,464	8.8
		1:10 AM-1:25 AM	1,414	8.6

[1]During these compliance tests, three five-minute samples were taken with the turbine-ON, and each monitoring location was located downwind of the nearest turbine.

[2]During the overnight period of September 19-20, 2017 momentary curtailment was enforced by ISO-NE at FGW, causing individual turbines to be paused during turbine-on measurements. These paused periods stretched from a few seconds to a few minutes, over multiple occurrences throughout the night. Average power production values displayed, only contain values when the turbines were in operation.

November 3-4, 2017

On November 3 and 4, 2017, Tech performed sound monitoring at ML-5. The monitoring took place between 11:00 PM on November 3rd and 3:00 AM the following morning. However, the only verified data were collected between 11:35 PM and 11:50 PM. During monitoring, conditions were dry, skies were clear, and winds were moderate from the north.

Between 11:35 PM and 11:50 PM, the average power production at T3 was 1,540 kW with an average hub height wind speed of 9.0 m/s.

March 5-6, 2018

On March 5 and 6, 2018, Tech performed sound monitoring at ML-4 and ML-5. The monitoring took place between 11:00 PM on March 5th and 3:00 AM the following morning. However, the only verified data were collected between 11:00 PM and 11:15 PM, 11:30 PM and 11:45 PM, 11:50 PM to 12:05 AM, and 1:10 AM to 1:25 AM. During monitoring, conditions were dry, skies were overcast, and winds were strong from the north.

During the first verified15-minute period, 11:00 PM to 11:15 PM, the average power production at T3 was 1,646 kW with an average hub height wind speed of 9.4 m/s. During the second verified 15-minute period, 11:30 PM to 11:45 PM, the average power production at T3 was 1,445 kW with an average hub height wind speed of 8.8 m/s. During the third verified 15-minute period, 11:50 PM to 12:05 AM, the average power production at T3 was 1,464 kW with an average hub height wind speed of 8.8 m/s. During the last verified 15-minute period, 1:10 AM to 1:25 AM, the average power production at T3 was 1,414 kW with an average hub height wind speed of 8.6 m/s.

8.2 Broadband Monitoring Results

This section presents the broadband monitoring results for T3 and T4 operating at low, medium and high power production. As discussed above, T1 and T5 were off as part of the curtailment program.

As described in Section 5, Tech discarded one-second measurements with audible noise contamination from the data set before determining the L_{max} sound level for each five-minute monitoring period. Upon review of the sound recordings, field log sheets and tablets, Tech selected the highest one-second L_{eq} sound levels recorded by the sound analyzer for each five-minute turbine-ON period and averaged them to calculate the L_{max} sound level. The data from this screening process are summarized in the turbine-ON L_{max} to L_{90} sound graphs presented in Appendix B.

8.2.1 Low Power Production Results

Monitoring during low power production events, defined as the turbines producing less than 700 kW of power, was performed for all five monitoring locations. The results are discussed below and summarized in Table 8-4.

ML-1

Verified turbine-ON sound levels were measured for two 15-minute periods from 12:25 AM to 12:40 AM and from 12:40 AM to 12:55 AM on October 4th at ML-1. Within those periods, Tech measured one-second L_{max} levels of 33.4 dBA and 33.5 dBA. The lowest ambient L_{90} level measured with the turbines off was 27.9 dBA. This sound level represents the lowest of the three five-minute L_{90} levels for each 15-minute monitoring period. The incremental change in sound levels is 6 dBA.

ML-2

Verified turbine-ON sound levels were measured for two 15-minute periods from 11:00 PM to 11:15 PM and 11:15 PM to 11:30 PM on September 18th at ML-2. Within those periods, Tech measured one-second L_{max} levels of 48.0 dBA and 48.4 dBA. The lowest ambient L_{90} level measured with the turbines off was 47.4 dBA. This sound level represents the lowest of the three five-minute L_{90} levels for each 15-minute monitoring period. The incremental change in sound levels is 1 dBA.

Verified turbine-ON sound levels were also measured for one 15-minute period from 2:15 AM to 2:30 AM on November 5th at ML-2. Within those periods, Tech measured one-second L_{max} levels of 33.9 dBA. The lowest ambient L_{90} level measured with the turbines off was 23.9 dBA. This sound level represents the lowest of the three five-minute L_{90} levels for each 15-minute monitoring period. The incremental change in sound levels is 10 dBA.

ML-3

Verified turbine-ON sound levels were measured for two 15-minute periods from 2:00 AM to 2:15 AM and 2:15 AM to 2:30 AM on November 5th at ML-3. Within those periods, Tech measured one-second L_{max} levels of 31.1 dBA and 30.5 dBA. The lowest ambient L_{90} level measured with the turbines off was 26.1 dBA. This sound level represents the lowest of the three five-minute L_{90} levels for each 15-minute monitoring period. The incremental change in sound levels is 5 dBA or less.

ML-4

Verified turbine-ON sound levels were measured for one 15-minute period from 12:45 AM to 1:00 AM on September 19th at ML-4. Within this period, Tech measured a one-second L_{max} of 41.8 dBA. The lowest ambient L_{90} level measured with the turbines off was 39.8 dBA. This sound level represents the lowest of the three five-minute L_{90} levels for each 15-minute monitoring period. The incremental change in sound levels is 2 dBA.

ML-5

Verified turbine-ON sound levels were measured for two 15-minute periods from 11:00 PM to 11:15 PM and 11:15 PM to 11:30 PM on August 31st at ML-5. Within those periods, Tech measured one-second L_{max} levels of 41.0 dBA and 40.2 dBA. The lowest ambient L_{90} level measured with the turbines off was 36.0 dBA. This sound level represents the lowest of the three five-minute L_{90} levels for each 15-minute monitoring period. The incremental change in sound levels is 5 dBA or less.

Verified turbine-ON sound levels were measured for two 15-minute periods from 1:10 AM to 1:25 AM and 1:25 AM to 1:40 AM on November 4th at ML-5. Within those periods, Tech measured one-second L_{max} levels of 35.5 and 37.0 dBA. The lowest ambient L_{90} level measured with the turbines off was 28.5 dBA. This sound level represents the lowest of the three five-minute L_{90} levels for each 15-minute monitoring period. The maximum incremental change in sound levels is 9 dBA or less

Verified turbine-ON sound levels were measured for three 15-minute periods from 12:55 AM to 1:10 AM, 1:10 AM to 1:25 AM, and 1:25 AM to 1:40 AM on November 11th at ML-5. Within those periods, Tech measured one-second L_{max} levels of 32.9, 35.0, and 34.6 dBA. The lowest ambient L_{90} level measured with the turbines off was 26.8 dBA. This sound level represents the lowest of the three five-minute L_{90} levels for each 15-minute monitoring period. The maximum incremental change is 8 dBA or less.

TABLE 8-4

L_{max} to L_{90} COMPARISON FOR THE FUTURE GENERATION WIND PROJECT (dBA) LOW POWER PRODUCTION

Monitoring Location	Date	Time	Five-minute Ambient L_{90} Level (Turbine-OFF)	One-second L_{max} Level (Turbine-ON)[1, 2]	Net Increase[3]
ML1	10/4/2017	12:25 AM-12:40 AM	27.9	33.4	**6**
		12:40 AM-12:55 AM	27.9	33.5	**6**
ML2	9/18/2017	11:00 PM -11:15 PM	47.4	48.0	**1**
		11:15 PM-11:30 PM	47.4	48.4	**1**
	11/5/2017	2:15 AM-2:30 AM	23.9	33.9	**10**
ML3	11/5/2017	2:00 AM-2:15 AM	26.1	31.1	**5**
		2:15 AM-2:30 AM	26.1	30.5	**4**
ML4	9/19/2017	12:45 AM-1:00 AM	39.8	41.8	**2**
ML5	8/31/2017	11:00 PM -11:15 PM	36.0	41.0	**5**
		11:15 PM-11:30 PM	36.0	40.2	**4**
	11/4/2017	1:10 AM-1:25 AM	28.5	35.5	**7**
		1:25 AM- 1:40 AM	28.5	37.0	**9**
	11/11/2017	12:55 AM-1:10 AM	26.8	32.9	**6**
		1:10 AM-1:25 AM	26.8	35.0	**8**
		1:25 AM-1:40 AM	26.8	34.6	**8**

Note: DEP Noise Policy limits the increase in the ambient level to 10 dBA.

[1]During these compliance tests, three five-minute samples were taken with the turbine-ON, and at least three five-minute samples were taken with the turbines off. The turbine-OFF value is the lowest of the five-minute L_{90} levels, and the turbine-ON value is the average of the three five-minute L_{max} levels.

[2]Hub height wind speeds at the closest operating turbine during turbine on and turbine off measurements must be within +/- 2 m/s of each other in order to be verified.

[3] The increase of L_{max} over L_{90} ambient is rounded to a whole decibel value for proper comparison to the MassDEP Noise Policy limit- see text.

8.2.2 Medium Power Production Results

Monitoring during medium power production events, defined as producing from 700 to 1,400 kWh, was performed for all five monitoring locations. The results are discussed below and summarized in Table 8-5.

ML-1

Verified turbine-ON sound levels were measured for three 15-minute periods from 2:00 AM to 2:15 AM, 2:20 AM to 2:35 AM, and 2:35 AM to 2:50 AM on October 4th at ML-1. Within those periods, Tech measured one-second L_{max} levels of 34.0 dBA and 33.1 dBA. The lowest ambient L_{90} level measured with the turbines off was 28.1 dBA. This sound level represents the lowest of the three five-minute L_{90} levels for each 15-minute monitoring period. The maximum incremental change in sound levels is 6 dBA or less.

ML-2

Verified turbine-ON sound levels were measured for one 15-minute periods from 1:15 AM to 1:30 AM on September 20th at ML-2. Within this period, Tech measured a one-second L_{max} level of 50.3 dBA. The lowest ambient L_{90} level measured with the turbines off was 49.7 dBA. This sound level represents the lowest of the three five-minute L_{90} levels for each 15-minute monitoring period. The incremental change in sound levels is less than 1 dBA.

Verified turbine-ON sound levels were also measured for three 15-minute periods from 11:40 PM to 11:55 PM, 11:55 PM to 12:10 AM, and 12:10 AM to 12:25 AM on November 4 and November 5 at ML-2. Within those periods, Tech measured one-second L_{max} levels of 44.4 dBA and 45.3 dBA. The lowest ambient L_{90} level measured with the turbines off was 38.3 dBA. This sound level represents the lowest of the three five-minute L_{90} levels for each 15-minute monitoring period. The maximum incremental change in sound levels is 7 dBA or less.

ML-3

Verified turbine-ON sound levels were measured for two 15-minute periods from 2:30 AM to 2:45 AM and 2:45 AM to 3:00 AM on September 19th at ML-3. Within those periods, Tech measured one-second L_{max} levels of 44.4 dBA and 43.9 dBA. The lowest ambient L_{90} level measured with the turbines off was 42.8 dBA. This sound level represents the lowest of the three five-minute L_{90} levels for each 15-minute monitoring period. The maximum incremental change in sound levels is less than 2 dBA or less.

Verified turbine-ON sound levels were measured for one 15-minute period from 1:15 AM to 1:30 AM on September 20th at ML-3. Within this period, Tech measured a one-second L_{max} level of 44.2 dBA. The lowest ambient L_{90} level measured with the turbines off was 41.6 dBA. This sound level represents the lowest of the three five-minute L_{90} levels for each 15-minute monitoring period. The maximum incremental change in sound levels is 3 dBA.

ML-4

Verified turbine-ON sound levels were measured for one 15-minute period from 1:00 AM to 1:15 AM on September 19th at ML-4. Within this period, Tech measured a one-second L_{max} level of 41.2 dBA. The lowest ambient L_{90} level measured with the turbines off was 39.8 dBA. This sound level represents the lowest of the three five-minute L_{90} levels for each 15-minute monitoring period. The incremental change in sound levels 1 dBA.

Verified turbine-ON sound levels were measured for two 15-minute periods from 1:15 AM to 1:30 AM and 1:30 AM to 1:45 AM on September 20th at ML-4. Within those periods, Tech measured one-second L_{max} levels of 44.8 and 46.4 dBA. The lowest ambient L_{90} level measured with the turbines off was 43.6 dBA. This sound level represents the lowest of the three five-minute L_{90} levels for each 15-minute monitoring period. The incremental change in sound levels is 3 dBA or less.

Verified turbine-ON sound levels were measured for two 15-minute periods from 11:55 PM to 12:10 AM and 12:10 AM to 12:25 AM on November 4th to 5th at ML-4. Within those periods, Tech measured one-second L_{max} levels of 39.3 and 39.7 dBA. The lowest ambient L_{90} level measured with the turbines off was 29.9 dBA. This sound level represents the lowest of the three five-minute L_{90} levels for each 15-minute monitoring period. The maximum incremental change in sound levels is 10 dBA or less.

ML-5

Verified turbine-ON sound levels were measured for two 15-minute periods from 12:50 AM to 1:05 AM and 1:05 AM to 1:20 AM on September 1st at ML-5. Within those periods, Tech measured one-second L_{max} levels of 39.4 and 40.6 dBA. The lowest ambient L_{90} level measured with the turbines off was 35.2 dBA. This sound level represents the lowest of the three five-minute L_{90} levels for each 15-minute monitoring period. The maximum incremental change in sound levels is 5 dBA or less.

Verified turbine-ON sound levels were also measured for three 15-minute periods from 11:00 PM to 11:15 PM, 11:15 PM to 11:30 PM, and 12:40 AM to 12:55 AM on October 16 and October 17 at ML-5. Within those periods, Tech measured one-second L_{max} levels of 41.3 dBA, 41.7 dBA, and

40.8 dBA. The lowest ambient L_{90} level measured with the turbines off was 31.5 dBA. This sound level represents the lowest of the three five-minute L_{90} levels for each 15-minute monitoring period. The maximum incremental change in sound levels is 10 dBA or less.

TABLE 8-5

L_{max} to L_{90} COMPARISON FOR THE FUTURE GENERATION WIND PROJECT (dBA) MEDIUM POWER PRODUCTION

Monitoring Location	Date	Time	Five-minute Ambient L_{90} Level (Turbine-OFF)	One-second L_{max} Level (Turbine-ON)[1, 2]	Net Increase[3]
ML1	10/4/2017	2:00 AM-2:15 AM	28.1	34.0	**6**
		2:20 AM-2:35 AM	28.1	33.1	**5**
		2:35 AM-2:50 AM	28.1	33.1	**5**
ML2	9/20/2017	1:15 AM-1:30 AM	49.7	50.3	**1**
	11/4/2017-11/5/2017	11:40 AM-11:55 PM	38.3	44.4	**6**
		11:55 PM-12:10 AM	38.3	45.3	**7**
		12:10 AM-12:25 AM	38.3	45.3	**7**
ML3	9/19/2017	2:30 AM- 2:45 AM	42.8	44.4	**2**
		2:45 AM- 3:00 AM	42.8	43.9	**1**
	9/20/2017	1:15 AM-1:30 AM	41.6	44.2	**3**
ML4	9/19/2017	1:00 AM-1:15 AM	39.8	41.2	**1**
	9/20/2017	1:15 AM-1:30 AM	43.6	44.8	**1**
		1:30 AM-1:45 AM	43.6	46.4	**3**
	11/4/2017-11/5/2017	11:55 AM-12:10 AM	29.9	39.3	**9**
		12:10 AM-12:25 AM	29.9	39.7	**10**
ML5	9/1/2017	12:50 AM- 1:05 AM	35.2	39.4	**4**
		1:05 AM-1:20 AM	35.2	40.6	**5**
	10/16/2017-10/17/2017	11:00 PM-11:15 PM	31.5	41.3	**10**
		11:15 PM-11:30 PM	31.5	41.7	**10**
		12:40 AM-12:55 AM	31.5	40.8	**9**

Note: DEP Noise Policy limits the increase in the ambient level to 10 dBA.

[1]During these compliance tests, three five-minute samples were taken with the turbine-ON, and at least three five-minute samples were taken with the turbines off. The turbine-OFF value is the lowest of the five-minute L_{90} levels, and the turbine-ON value is the average of the three five-minute L_{max} levels. [2]Hub height wind speeds at the closest operating turbine during turbine on and turbine off measurements must be within +/- 2 m/s of each other in order to be verified.

[3] The increase of L_{max} over L_{90} ambient is rounded to a whole decibel value for proper comparison to the MassDEP Noise Policy limit- see text.

8.2.3 High Power Production Results

Monitoring during high power production events, defined as producing more than 1,400 kWh, was performed for all five monitoring locations. The results are discussed below and summarized in Table 8-6.

ML-1

Verified turbine-ON sound levels were measured in two 15-minute periods from 12:05 AM to 1:20 AM and 1:30 AM to 1:45 AM on August 23rd at ML-1. Within those periods, Tech measured one-second L_{max} levels of 48.8 and 46.6 dBA. The lowest ambient L_{90} level measured with the turbines off was 46.9 dBA and 44.4 dBA for the periods starting at 12:05 AM and 1:30 AM, respectively. These sound levels represent the lowest of the three five-minute L_{90} levels for each 15-minute monitoring period. The maximum incremental change in sound levels is 2 dBA.

ML-2

Verified turbine-ON sound levels were measured in two 15-minute periods from 1:30 AM to 1:45 AM and 3:00 AM to 3:15 AM on September 20th at ML-2. Within those periods, Tech measured one-second L_{max} levels of 49.5 and 50.3 dBA. The lowest ambient L_{90} level measured with the turbines off was 48.9 dBA. This sound level represents the lowest of the three five-minute L_{90} levels for each 15-minute monitoring period. The maximum incremental change in sound levels is 1 dBA.

ML-3

Verified turbine-ON sound levels were also measured in four 15-minute periods from 1:30 AM to 1:45 AM, 3:00 AM to 3:15 AM, 3:15 AM to 3:30 AM, and 3:30 AM to 3:45 AM on September 20th at ML-3. Within those periods, Tech measured one-second L_{max} levels of 45.1 dBA, 44.8 dBA, 44.5 dBA, and 44.7 dBA. The lowest ambient L_{90} level measured with the turbines off was 41.2 dBA. This sound level represents the lowest of the three five-minute L_{90} levels for each 15-minute monitoring period. The maximum incremental change in sound levels is 4 dBA or less.

ML-4

Verified turbine-ON sound levels were measured in two 15-minute periods from 3:00 AM to 3:15 AM and 3:15 AM to 3:30 AM on September 20th at ML-4. Within those periods, Tech measured one-second L_{max} levels of 47.4 and 47.3 dBA. The lowest ambient L_{90} level measured with the turbines off was 43.6 dBA. This sound level represents the lowest of the three five-minute L_{90} levels for each 15-minute monitoring period. The maximum incremental change in sound levels is 4 dBA.

Verified turbine-ON sound levels were measured in three 15-minute periods from 11:00 PM to 11:15 PM, 11:30 PM to 11:45 PM, and 11:50 PM to 12:05 AM on March 5 and 6 at ML-4. Within those periods, Tech measured one-second L_{max} levels of 44.2 dBA, 44.5 dBA, and 44.6 dBA. The lowest ambient L_{90} level measured with the turbines off was 34.7 dBA. This sound level represents the lowest of the three five-minute L_{90} levels for each 15-minute monitoring period. The maximum incremental change in sound levels is 10 dBA.

ML-5

Verified turbine-ON sound levels were measured in one 15-minute period from 11:35 PM to 11:50 PM on November 3rd at ML-5. Within this period, Tech measured a one-second L_{max} of 43.8 dBA. The lowest ambient L_{90} level measured with the turbines off was 34.6 dBA. This sound level represents the lowest of the three five-minute L_{90} levels for each 15-minute monitoring period. The incremental change in sound levels is 9 dBA.

Verified turbine-ON sound levels were measured in three 15-minute periods from 11:30 PM to 11:45 PM, 11:50 PM to 12:05 AM, and 1:10 AM to 1:25 AM on March 5 and 6 at ML-5. Within those periods, Tech measured one-second L_{max} levels of 44.3 dBA, 43.8 dBA, and 43.7 dBA. The lowest ambient L_{90} level measured with the turbines off was 35.4 dBA. This sound level represents the lowest of the three five-minute L_{90} levels for each 15-minute monitoring period. The maximum incremental change in sound levels is 9 dBA.

TABLE 8-6

L_{max} to L_{90} COMPARISON
FOR THE FUTURE GENERATION WIND PROJECT (dBA)
HIGH POWER PRODUCTION

Monitoring Location	Date	Time	Five-minute Ambient L_{90} Level (Turbine-OFF)	One-second L_{max} Level (Turbine-ON)[1, 2]	Net Increase
ML1	8/23/2017	12:05 AM-12:20 AM	46.9	48.8	**2**
		1:30 AM-1:45 AM	44.4	46.6	**2**
ML2	9/20/2017	1:30 AM-1:45 AM	48.9	49.5	**1**
		3:00 AM-3:15 AM	48.9	50.3	**1**
ML3	9/20/2017	1:30 AM-1:45 AM	41.2	45.1	**4**
		3:00 AM-3:15 AM	41.2	44.8	**4**
		3:15 AM-3:30 AM	41.2	44.5	**3**
		3:30 AM-3:45 AM	41.2	44.7	**4**
ML4	9/20/2017	3:00 AM-3:15 AM	43.6	47.4	**4**
		3:15 AM-3:30 AM	43.6	47.3	**4**
	3/5/2018-3/6/2018	11:00 PM-11:15 PM	34.7	44.2	**10**
		11:30 PM-11:45 PM	34.7	44.5	**10**
		11:50 PM-12:05 AM	34.7	44.6	**10**
ML5	11/3/2017	11:35 PM-11:50 PM	34.6	43.8	**9**
	3/5/2018-3/6/2018	11:30 PM-11:45 PM	35.4	44.3	**9**
		11:50 PM-12:05 AM	35.4	43.8	**8**
		1:10 AM-1:25 AM	35.4	43.7	**8**

Note: DEP Noise Policy limits the increase in the ambient level to 10 dBA.

[1]During these compliance tests, three five-minute samples were taken with the turbine-ON, and at least three five-minute samples were taken with the turbines off. The turbine-OFF value is the lowest of the five-minute L_{90} levels, and the turbine-ON value is the average of the three five-minute L_{max} levels.

[2]Hub height wind speeds at the closest operating turbine during turbine on and turbine off measurements must be within +/- 2 m/s of each other in order to be verified.

[3] The increase of L_{max} over L_{90} ambient is rounded to a whole decibel value for proper comparison to the MassDEP Noise Policy limit- see text.

8.3 Octave Band Sounds

Tech collected one-third octave band frequency (12.5 to 20,000 Hertz (Hz)) sound levels at the five monitoring locations during the turbine-ON and turbine-OFF measurements. When measuring wind turbine sound, the assessment of pure tones is complicated by the presence of wind noise, which contributes to the tonal quality of sound, especially at higher wind speeds. Tech converted the one-third octave band data into whole octave bands for the 5-minute periods that comprise the verified 15-minute periods discussed in Section 8.2. Tech reviewed the converted whole octave band equivalent continuous sound level (L_{eq}) data and compared these to the corresponding ambient L_{eq} to assess whether the turbines were creating a pure tone.

Tonal sounds were measured at octave band center frequencies of 125 and 500 Hz at ML-1 on October 4, 2017. Normally, if a pure tone is created by a wind turbine it is while the turbine is operating close to maximum power. At the time the pure tones were measured, the turbines were running at an average power ranging from 13-50%. Although these pure tones were not found in the turbine-OFF measurements, a review of the audio files showed pronounced low frequency noise from the nearby highway. The required conditions for monitoring at ML-1 put the highway upwind, causing an amplification of the highway sound at ML-1. Since these pure tones were not measured during any other monitoring event at ML-1 and coincided with increased highway noise, Tech concluded that these one-time tonal sounds were not produced by the turbines.

Tonal sounds were measured at octave band center frequencies of 4,000 Hz at ML-2, ML-3 and ML-4 on September 20, 2017. When compared to turbine-OFF measurements, the same pure tones were measured at ML-2 and ML-4. Although they were not measured during the turbine-OFF measurement at ML-3, the conditions during the monitoring event were extremely warm and humid leading to tree frog activity. Tech concluded that these tonal sounds were high-pitched insect and tree frog noise and not created by the turbines.

Tonal sounds were measured at octave band center frequencies of 125 Hz at ML-5 on August 31, 2017. At the time the pure tone was measured, the turbine was operating at only 11% power. As stated before, low power turbine operation typically does not correspond to a fast enough blade rotation to create tonal sounds. Additionally, ML-5 is elevated with Head of the Bay Road in direct line of sight. The audio files and monitoring notes reveal that early into monitoring that night, there was significant traffic on Head of the Bay Road. This pure tone was not measured during any other monitoring event at ML-5; thus, Tech concluded that this tonal sound not was caused by the turbines.

Tonal sounds were also measured at octave band center frequencies of 63, 31.5, and 1,000 Hz at ML-5 on November 4, 2017. At the time the pure tones were measured, the turbine was operating at 14-17% power. Additionally, a 63 Hz pure tone was measured during the turbine-OFF measurement. Although a 31.5 Hz pure tone was not measured during the turbine-OFF measurement, it is also a

low frequency sound, adjacent to the 63 Hz octave band. Therefore, it is very likely that the source that caused the 63 Hz pure tone during the turbine-ON and turbine-OFF measurements, also caused the 31.5 Hz pure tone. From reviewing field notes and audio files, Tech concluded that the low frequency tonal sound is from local vehicle traffic noise.

Tech reviewed the audio files from the 5-minute period when the 1,000 Hz pure tone was measured at ML-5 on November 4, 2017. During the time of the measurement, there was very prominent tonal sound coming from truck traffic on the nearby highway. This pure tone was not related to turbine operation.

Tech has concluded that the operation of the wind turbines did not produce a pure tone under the 10 monitoring events, and therefore, complies with the MassDEP Noise Policy.

TABLE 8-7

TURBINE-ON PURE TONES MEASURED WITHIN VERIFIED FIVE-MINUTE SOUND MONITORING DATA

Monitoring Location	Date	Time	Frequency (Hz)	Measured During Off?	Comments
ML 1	10/4/2017	12:30 AM-12:35 AM	500	No	Highway noise
		2:05 AM-2:10 AM			
		2:30 AM-2:35 AM	125	No	Highway Noise
ML 2	9/20/2017	1:15 AM-1:45 AM	4000	Yes	Tree frogs and insects
		3:00 AM-3:15 AM			
ML 3	9/20/2017	3:15 AM-3:20 AM	4000	No	Tree frogs and insects
		3:30 AM-3:40 AM			
ML 4	9/20/2017	1:20 AM-1:40 AM	4000	Yes	Tree frogs and insects
		3:20 AM-3:25 AM			
ML 5	8/31/2017	11:05 PM-11:10 PM	125	No	Vehicle traffic
	11/4/2017	1:10 AM-1:15 AM	63	Yes	Vehicle traffic
		1:25 AM-1:30 AM	31.5	No	Vehicle traffic
		1:30 AM-1:35 AM	1000	No	Highway noise

8.4 Town of Plymouth

The turbine-ON results presented in Tables 8-4 through 8-6 show that all one-second L_{max} sound levels are well below 60 dBA sound limit; thus, FGW turbines comply with the Town Of Plymouth Zoning Bylaw.

9.0 CONCLUSIONS

Tech performed sound compliance monitoring studies for the Future Generation Wind (FGW) wind turbines. The purpose of this compliance study was to demonstrate compliance with MassDEP Noise Policy and the Town of Plymouth Zoning Bylaw for Wind Energy Facilities, in accordance with the Special Permit issued to FGW. This work included: 1) protocol development; 2) conducting initial sound monitoring as part of the commissioning of the turbines; 3) the development of a curtailment program following Condition 9(c) of the Town of Plymouth Special Permit, and 4) compliance sound monitoring with the NRO curtailment program in place.

After implementing the curtailment strategy into the dispatch operating mode, compliance sound monitoring was performed for the turbines operating at low, medium and high power production. For the three turbine operating conditions, Tech collected 296 (five-minute) verified measurements (148 turbine-ON and 148 turbine-OFF) over 10 sampling nights. **The results of compliance monitoring show that for all 148 turbine-ON measurements the incremental change in sound levels meet the MassDEP Noise 10 dBA above ambient sound limits per 310 CMR 7.10. In addition, results of the octave band analysis demonstrate that operation of the wind turbines do not create pure tone conditions under the three operating conditions.**

The results of the compliance monitoring study demonstrate that the turbines comply with the Town of Plymouth Zoning Bylaw for Wind Energy Facilities sound limit of 60 dBA.