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September 10, 2015
By electronic mail

William E. Watson, Chair
Kingston Board of Health

Bradford Cleaves
Kingston Wind Independence, LLC

Dear Chairman Watson and Mr. Cleaves,

I am pleased to transmit to you the final Kingston Wind Independence Turbine Acoustical Monitoring Study. The Study was conducted in response to requests from Kingston Wind Independence LLC (KWI) and the Kingston Board of Health to the Massachusetts Clean Energy Center (MassCEC) and the Massachusetts Department of Environmental Protection (MassDEP). The Study was conducted by Harris Miller Miller and Hanson Inc. (HMMH) under contract to MassCEC.

The Study includes a broad range of acoustical data and analysis, including:

- measured sound level data for turbine-on compared to turbine-off collected according to MassDEP's noise policy methodology as applied to wind turbines, and collected using other metrics and methodologies;
- predicted sound level data for turbine-on compared to turbine-off for a range of wind speeds and directions, and times of day; and
- data and analysis specific to low frequency sound and amplitude modulation of sound (i.e. the change in sound levels over relatively short periods of time).

Please note that due to the size of the document the attached version includes only the main body of the Study. The full Study is available on MassCEC's web site at http://www.masscec.com/content/wind-energy-research-and-analysis and MassDEP's web site at http://www.mass.gov/eea/agencies/massdep/climate-energy/energy/wind-turbines/.

Also attached is a letter from Douglas Fine, Assistant Commissioner at MassDEP, describing MassDEP's role in the Study and presenting a summary of the Study findings with respect to MassDEP's noise policy.

You will recall that the prior version of the Study, dated April 15, 2015, was marked "draft for public comment." As we did with the initial scoping of the Study, MassCEC sponsored a process for the public and other interested parties to submit comments on the draft report. That process is complete. The Consensus Building Institute has prepared a summary of comments received. This is posted on MassCEC's web site at the same link as above. The comment process did not lead to changes in HMMH's findings as presented in the April 2015 version of the Study. The process did identify a number of areas where the Study methodology could be presented more clearly. Attached to this letter is a list of specific sections of the Study that were edited or re-written.

MassCEC, MassDEP and HMMH will be available for a follow-up discussion of the report results with the Board of Health. I look forward to being in contact with you to arrange that meeting. Meanwhile, please contact me at 617-315-9311 if you have any questions.

Sincerely,

Nils Bolgen
Program Director

Attachments:
List of edits to April 16, 2015 version of the Kingston Wind Independence Acoustic Monitoring Study
Kingston Wind Independence Acoustical Monitoring Study (abridged), August 19, 2015
MassDEP letter, September 10, 2015

cc:
Thomas Bott, Kingston Planning Director
Kially Ruiz, KWI
Duncan Peterson, KWI
Christopher Menge, HMMH
Eric Cox, HMMH
Douglas Fine, MassDEP

William E. Watson, Chairman, Kingston Board of Health
Bradford Cleaves, Kingston Wind Independence LLC
September 10, 2015
Attachment

KWI Acoustic Monitoring: Summary of Edits to April 16 Draft Report

Section	Location	Edits
Executive Summary	Tables on pages iii and iv	The tables now includes wind turbine power levels.
Table of Contents	Pages v – viii	Sections and tables with edits are shown in red.
2.2 Sound Power Levels	Page 3	New paragraph 3 regarding MassDEP's requirement for direct measurement of turbine sound levels.
2.3 Supervisory Control and Data Acquisition (SCADA)	Page 3	Re-written to better explain how wind and power generation data from the SCADA was used, and the procedure for correcting nacelle wind speed to better correlate with turbine power output.
2.4 Live Deck Monitoring Website	Page 4, paragraph 2	New paragraph added to explain that data from this site is not intended for use in the analysis.
4.2 Monitoring Conditions	Page 10, paragraph 1	New paragraph describing prevailing wind speeds and directions.
4.3 Instrumentation	Page 12, paragraphs 3 and 4	Edits related to wind shear and the use of maximum sound levels in each 1-second monitoring interval.
4.6 Monitoring Schedule and Summary	Page 14	Date corrected to be January 21, 2014.
5.1 Data Analysis Methodology	Page 16, paragraph 2	Edits related to use of maximum sound levels in each 1-second monitoring interval.
5.2 Analysis of Wind Data	Page 18, paragraph 1	Edits related to the procedure for correcting nacelle wind speed to better correlate with turbine power output.
6.0 Monitoring Results for A-weighted Sound Levels 6.1 13 Schofield Road 6.2 3 Leland Road 6.3 11 Leland Road 6.4 38 Prospect Street 6.5 Kingston Intermediate School	 Page 19, paragraph 2 Page 26, paragraph 2 Page 32, paragraph 2 Page 38, paragraph 2 Page 44, paragraph 2	New sentence related to wind shear added at the end of the paragraph in each section.
7.0 Monitoring Results for Low Frequency Sound and Infrasound	Page 46, paragraph 4	Clarifying edit related to use of slow-response data for low frequency sound.
7.2 Octave Band Sound Level Increase Assessment	Page 48, last paragraph	Clarifying edits.
10.4 Estimated KWI Turbine Sound Levels	Page 94, paragraph 3	Clarifying edits and footnote added related to directionality of wind turbine sound.
10.5 Sound Level Increase Predictions	Page 94, paragraph 1	New text added regarding diurnal trends in ambient L90 sound levels.
11 Conclusions	Page 122, Tables 50, 51 and 52	The tables now include wind turbine power levels.

Commonwealth of Massachusetts
Executive Office of Energy & Environmental Affairs

Department of Environmental Protection

One Winter Street Boston, MA 02108 • 617-292-5500

Charles D. Baker
Governor

Karyn E. Polito
Lieutenant Governor

Matthew A. Beaton
Secretary

Martin Suuberg
Commissioner

September 10, 2015

Kingston Board of Health
Attention: Mr. Bill Watson, Chair
Kingston Town House
26 Evergreen Street
Kingston, MA 02364

RE: MassDEP Review of Kingston Wind Independence (KWI) Turbine Acoustical Monitoring Study Final Technical Report, August 19, 2015

Dear Chairman Watson,

As part of MassDEP's ongoing technical support to the Town, this letter summarizes the agency's review of the Kingston Wind Independence (KWI) Turbine Acoustical Monitoring Study Final Technical Report dated August 19, 2015. The study was conducted in response to requests from KWI and the Kingston Board of Health to the Massachusetts Clean Energy Center (MassCEC) and Massachusetts Department of Environmental Protection (MassDEP). This report provides additional data beyond what was contained in the interim report dated June 13, 2014. The acoustical study was performed by the consulting firm of Harris, Miller, Miller and Hanson Inc. (HMMH) under contract to MassCEC. Note that a copy of this report can be found on MassDEP's website at: http://www.mass.gov/eea/agencies/massdep/climate-energy/energy/wind-turbines/

This report provides sampling data and analysis in accordance with the scope of study developed for this project. As you will recall, because HMMH was unable to successfully capture sampled data for all wind conditions at all sites despite weeks of efforts to capture those conditions, MassCEC and MassDEP agreed to ask HMMH to mathematically extrapolate results from those sites with no measured data.

MassDEP has reviewed the enclosed report with a focus on data and analyses related to compliance with the Commonwealth's noise regulations and policy. The findings in the final technical report related to the Commonwealth's noise regulations and policy are unchanged from the findings in the public comment draft, which was issued on April 16, 2015. Agency review focused on findings regarding exceedences of 10 dBA above background, and whether a pure tone condition exists. In doing so, MassDEP evaluated only the A-weighted broadband sound data collected on the slow meter setting, which was performed in accordance with the agency's current acoustic monitoring protocols and in accordance with the approved scope. This letter does not cover all of the information contained in the report, but in this letter we highlight the major conclusions related to the MassDEP noise regulations and policy.

Turbine impact sound data collected in February, March and April 2014, combined with ambient data collected in September 2014, indicates that exceedences of 10 dBA have been measured, and are likely to occur at one or more sampling location to the East of Route 3 in the following conditions:

- Year-round between 12:00 a.m. and 4:00 a.m. at winds of 7 m/s or more from the South to Southwest, and
- Year-round between 11:30 p.m. and 4:30 a.m. at winds of 9 m/s or more from the South to Southwest.

Turbine impact sound data collected in February, March and April 2014, indicates that no occurrences of pure-tone exist.

The report also *predicts, based on mathematical extrapolation,* additional exceedences of 10 dBA at locations East of Route 3 and also in the Copper Beech neighborhood (West of Route 3) under certain wind and seasonal conditions based on interpolation and extrapolation of monitoring data. The predicted exceedences are:

- East of Route 3, year-round, between 12:00 a.m. and 4:00 a.m. at winds of 4 m/s and above, regardless of wind direction;
- East of Route 3, year-round, between 11:00 p.m. and 12:00 a.m. at winds above 9 m/s, regardless of wind direction; and
- West of Route 3 (Copper Beech), in the winter only, between 12:00 a.m. and 4:00 a.m., at winds around 9 m/s, regardless of wind direction.

The Department has high confidence about the measured exceedences included in the full technical report and relies on measured data in definitively determining whether a condition of exceedence exists. The predicted exceedences are based on mathematical extrapolation of actual measured data to additional sites or seasonal conditions and on reference to data from other wind turbine research to provide as much data as possible in the absence of sampled data.

There is additional data and analysis included in the full technical report which goes beyond MassDEP's protocol for determining compliance. This additional data includes sound levels using various filters, speciated sound by octave band (low-frequency sound and infrasound), data on amplitude modulation, and sampling conducted on the fast meter setting. This information was included in the project scope as a result of MassCEC's stakeholder engagement process. MassDEP has not reviewed nor validated this additional information because it does not pertain to the agency's current guidelines and protocols for determining compliance.

MassDEP continues to be available to discuss this report and the options for moving forward to address the measured exceedences identified. We look forward to meeting with the Board after you have reviewed the contents in order to answer any questions you may have about our assessment of the findings.

To follow up on next steps, and should you have any questions regarding MassDEP's assessment of the full report, please feel free to contact me at 617-292-5792.

Sincerely,

Douglas E. Fine
Assistant Commissioner

Cc:
Tom Bott, Planning Director, Kingston
Bradford Cleaves, Kingston Wind Independence
Kially Ruiz, Kingston Wind Independence
Duncan Peterson, Kingston Wind Independence
Millie Garcia-Serrano, Acting Regional Director, Southeast Regional Office, MassDEP
Nancy Seidman, Assistant Commissioner, Bureau of Waste Prevention, MassDEP
Nils Bolgen, Massachusetts Clean Energy Center (MassCEC)
Christopher Menge, Harris Miller Miller & Hanson (HMMH)
Eric Cox, Harris Miller Miller & Hanson (HMMH)

Kingston Wind Independence Turbine

Acoustical Monitoring Study

Final Technical Report

HMMH Report No. 305270.001
August 19, 2015

Prepared for:

Massachusetts Clean Energy Center
63 Franklin Street, 3rd Floor
Boston, MA 02110

Prepared by:

J. Eric Cox
Christopher W. Menge

HARRIS MILLER MILLER & HANSON INC.

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Executive Summary

Harris Miller Miller & Hanson Inc. (HMMH) conducted an acoustical monitoring study of the Kingston Wind Independence (KWI) wind turbine in cooperation with the Massachusetts Department of Environmental Protection (MassDEP), the Massachusetts Clean Energy Center (MassCEC), the Town of Kingston Board of Health, and the KWI operator. The acoustical monitoring study was commissioned in response to a request from the Kingston Board of Health and the KWI operator to MassCEC and MassDEP stemming from concerns and complaints voiced by local residents regarding noise from KWI.

This technical report includes and expands upon the acoustical monitoring results presented in the June 13, 2014 "Interim Report for Kingston Wind Independence Turbine Acoustical Study". The report incorporates the results of data analysis conducted subsequent to publication of the interim study report, and includes measurements and predictions of additional exceedances of MassDEP noise policy on Schofield Road, Leland Road, and Copper Beech Drive.

The findings presented in this technical report are based upon two separate acoustical monitoring campaigns – attended monitoring of turbine on and turbine off sound levels at the quietest times of night between December 2013 and April 2014, and continuous unattended monitoring of background ambient sound levels with the KWI turbine off for a five day period in September 2014.

The **initial acoustical monitoring** was conducted between December 2013 and April 2014. The design of the study was to conduct measurements at some of the closest community locations with the KWI turbine shut down and also with the wind turbine in operation under worst-case conditions, which were during the quietest nighttime periods in the winter season and with downwind conditions. The monitoring data was then analyzed to determine baseline ambient sound levels and the relative increase in A-weighted sound levels due to nighttime operation of the KWI wind turbine, particularly in the context of MassDEP noise policy. Broadband sound level increases were likewise investigated for other sound level weightings (C, G, and Z) that include larger contributions from low frequency audible sound as well as from sound below the lower limit of human audibility (approximately 20 Hz) known as infrasound. A sound level modulation depth analysis was also conducted.

The monitoring conducted on Schofield Road during contiguous periods with the KWI turbine shut down ("ambient" condition) and then operating revealed increases of slow-response A-weighted average maximum (Avg L_{max}) sound levels[1] during turbine operation over nighttime ambient L_{90} sound levels (the sound level exceeded 90% of the time) of up to approximately 15 dBA. The broadband sound level increases measured at this location were also very comparable using other sound level weightings (C, G, and Z) that include a greater contribution from the lowest frequencies of sound. Likewise, octave band sound level increases were found to be similar across most frequencies of sound.

Acoustical monitoring conducted at additional sites to the east of Route 3 and farther from the turbine showed increases of turbine-operating Avg L_{max} over ambient L_{90} of up to approximately 9 to 10 dBA on Leland Road and up to about 8 dBA along Prospect Street. Sound level increases at these distances from the KWI turbine were generally somewhat greater in the lower frequency octave bands, indicating that higher frequency sound generated by the turbine attenuates at a greater rate with distance. For this reason, the A-weighed sound level increases measured in these locations were typically several decibels lower than the increases observed on Schofield Road during comparable periods, while broadband sound level

[1] For utility-scale wind turbines, MassDEP establishes compliance with its noise policy by comparing "slow-response A-weighted average maximum (Avg L_{max}) sound levels" to "L_{90} ambient background sound levels."

increases calculated using other sound level weightings were somewhat higher and closer to the Schofield Road monitoring results.

Overall, increases of turbine-operating Avg L_{max} over ambient L_{90} exceeding 10 dBA were identified in the Schofield Road, Leland Road, and Prospect Street community for nighttime operation of the KWI turbine during downwind conditions with wind speeds above 7 m/s. Analysis of the octave band sound levels measured with the turbine operating showed that it does not create a "pure tone condition", which is an additional component of the MassDEP noise policy.

Also, the turbine-operating Avg L_{max} over ambient L_{90} sound level increases measured at locations on Schofield Road, Leland Road, and Prospect Street using a slow-response sound level meter setting were about 1 to 2 dBA greater when data was collected using a fast-response setting. This difference is largely due to higher L_{max} values; L_{90} values are more comparable between the two meter response settings.

In addition, the sound level modulation depths calculated for periods with the KWI wind turbine operating at low to moderate wind speeds were less than or comparable to the modulation depths computed for periods with the turbine shut down. Modulation depths calculated over intervals with the wind turbine operating at moderate to higher wind speeds were up to approximately 1 to 3 dBA greater as compared with ambient conditions. A modulation frequency of around 1 Hz was observed with the turbine operating, typical for wind turbine sound. Ambient sound level variations with the KWI turbine shut down are generally somewhat random and only very occasionally periodic.

Daytime acoustical monitoring was conducted at the Kingston Intermediate School in the late morning with moderate wind speeds. A-weighted L_{90} sound levels measured with the KWI turbine operating increased from ambient background L_{90} sound levels by less than 1 dBA. Broadband sound level increases calculated using other sound level weightings (C, G, and Z) were less than 2 dB. No difference was found between the sound level modulation depths calculated for contiguous periods with the KWI turbine shut down and then operating. Traffic dominated the ambient sound levels throughout the monitoring and the wind turbine was not audible at any time.

Turbine-operating Avg L_{max} over ambient L_{90} sound level increases exceeding 10 dBA were also estimated in the Copper Beech Drive community for nighttime operation of the KWI turbine during downwind conditions with wind speeds of 9 m/s and above. This estimate was based on comparison of nighttime ambient (KWI turbine off) sound level monitoring data to extrapolations of turbine-only sound level data collected during attended monitoring at other locations.

Summary of Measured Conditions for Sound Level Increases Exceeding 10 dBA due to Operation of the KWI Wind Turbine

Community	Time of Year	Time of Day	Power Level (kW)	Wind Speed (m/s)	Wind Direction
Schofield Rd / Leland Rd / Prospect St	Winter	approx. 1 to 3 AM	above 529 kW	above 7 m/s	South to Southwest

Summary of Initial Estimated Conditions for Sound Level Increases Exceeding 10 dBA due to Operation of the KWI Wind Turbine

Community	Time of Year	Time of Day	Power Level (kW)	Wind Speed (m/s)	Wind Direction
Copper Beech Drive	Winter	approx. 1 to 3 AM	1176 kW and above	9 m/s and above	South to East

Since increases of turbine-operating Avg L_{max} over nighttime ambient L_{90} exceeding 10 dBA were identified at some locations during the acoustical monitoring study, and because sound from traffic on Route 3 is very significant at the closest neighborhood locations outside of the quietest nighttime periods, a **supplemental ambient monitoring program** was conducted in September 2014 to investigate daily and seasonal variations in A-weighted ambient L_{90} sound levels in the affected community.

The ambient L_{90} sound level data were then assessed against measured KWI turbine sound levels interpolated to integer wind speed values for the Schofield Road and Leland Road monitoring locations, as well as additional turbine-only data extrapolated to higher and lower wind speeds not directly measured. KWI turbine-only sound levels were likewise extrapolated for the 18 Copper Beech Drive site to estimate potential increases in ambient background sound levels over a range of wind speeds and during various periods throughout the day. This information was used to evaluate potential sound level increases associated with operation of the KWI wind turbine at different times of day and year and with various wind conditions in the context of MassDEP noise policy.

In the Schofield Road, Leland Road, and Prospect Street community, sound level increases of less than 10 dBA are predicted during daytime operation of the KWI wind turbine from 4:30am to 11:00pm throughout the week and weekend. Exceedances of the 10 dBA maximum increase MassDEP noise policy due to nighttime operation of the KWI turbine are predicted to have the potential to occur throughout the year between 12:00am and 4:00am for wind speeds of 4 m/s and above and between 11:00pm and 4:30am for wind speeds above 9 m/s, regardless of wind direction.

In the Copper Beech Drive community, sound level increases of less than 10 dBA are predicted from 4:00am to 12:00am throughout the week and weekend regardless of the season. Exceedances of the MassDEP noise policy due to nighttime operation of the KWI turbine are predicted to have the potential to occur during the winter season only (no insect noise) between 12:00am and 4:00am for wind speeds around 9 m/s, regardless of wind direction.

Summary of Final Predicted Conditions for Sound Level Increases Potentially Exceeding 10 dBA due to Operation of the KWI Wind Turbine

Community	Time of Year	Time of Day	Power Level (kW)	Wind Speed (m/s)	Wind Direction
Schofield Rd / Leland Rd / Prospect St	All Seasons	12 AM to 4 AM	67 kW and above	4 m/s and above	All
		11 PM to 12 AM	above 1176 kW	above 9 m/s	
		4 AM to 4:30 AM			
Copper Beech Drive	Winter	12 AM to 4 AM	around 1176 kW	around 9 m/s	All

Finally, any noise abatement orders resulting from the findings of this acoustical study that are to be evaluated based on data logs from the KWI turbine SCADA system are recommended to either directly reference power generation levels or otherwise refer to wind speed data that is adjusted using a +1.5 m/s correction factor since the wind speeds measured by the ultrasonic anemometers mounted on the KWI turbine nacelle underestimate actual wind speeds by about 1.5 m/s on average.

HMMH would like to acknowledge and thank the Kingston residents who provided access to their properties and significant cooperation throughout the acoustical monitoring study and also several other organizations and individuals who supported and assisted with the study including MassCEC, MassDEP, the Town of Kingston, the KWI turbine operator, and the operator of the No Fossil Fuel wind turbines.

Table of Contents

Revisions of the April 16, 2015 draft version of this technical report are indicated in red.

List of Figures

List of Tables

1 Introduction

This technical report provides the comprehensive results of an acoustical monitoring study of the Kingston Wind Independence (KWI) wind turbine operating at a closed landfill located on Cranberry Road in Kingston, MA. This study was conducted by Harris Miller Miller & Hanson Inc. (HMMH) in cooperation with the Massachusetts Department of Environmental Protection (MassDEP), the Massachusetts Clean Energy Center (MassCEC), the Town of Kingston Board of Health, and the KWI operator.

The acoustical monitoring study was commissioned in response to concerns and complaints about noise received by the Kingston Board of Health from local residents; therefore community involvement was an important part of the study. A key element of that process was an initial project scoping meeting held at the Kingston Town Hall on December 17, 2012. During this meeting, affected and interested residents provided their input on the study scope, including suggestions regarding measurement locations, appropriate wind conditions, acoustical monitoring procedures, and the methodology for analysis of the data collected. This information was incorporated into a draft study scope document, which was distributed to all stakeholders for written comment on February 14, 2013. All comments received were then carefully reviewed and a revised study scope dated March 15, 2013 reflected this additional input. The acoustical monitoring study scope was finalized, with respect to specific wind conditions and sound monitoring locations, on August 8, 2013 following a delay in commencement of the project due to operational issues with the KWI wind turbine.

The protocols for acoustical monitoring of the KWI turbine detailed in the study scope were then further revised on January 23, 2014 to address issues identified during the initial nights of monitoring. The sound from heavy volumes of overnight traffic on Route 3 and sound generated by auxiliary equipment that operates for several minutes after the wind turbine has been shut down invalidated some field data and required minor modifications in the monitoring protocols. The target wind conditions for acoustical monitoring were also revised on February 6, 2014 to facilitate timely collection of data.

The acoustical monitoring was conducted between December 2013 and April 2014. The final design of the study was to conduct measurements at some of the closest community locations with the KWI turbine shut down and also with the wind turbine in operation under worst-case conditions, which were during the quietest nighttime periods in the winter season and with downwind conditions. The monitoring data was then analyzed to determine baseline ambient sound levels and the relative increase in A-weighted sound levels due to nighttime operation of the KWI wind turbine, particularly in the context of MassDEP noise policy. Broadband sound level increases were likewise investigated for other sound level weightings (C, G, and Z) that include larger contributions from low frequency audible sound as well as from sound below the lower limit of human audibility (approximately 20 Hz) known as infrasound. A sound level modulation depth analysis was also conducted.

The interim results (i.e. for a limited number of monitoring dates and locations) of the acoustical monitoring were provided on June 13, 2014 in an interim study report. A supplemental ambient monitoring study was subsequently conducted during a 5-day period in September 2014 when the wind turbine was shut down for annual maintenance. This additional ambient data plus further analysis of data collected between January and April 2014 was used to estimate sound level increases due to operation of the KWI wind turbine at different times of day and year in the context of MassDEP noise policy.

Technical specifications of the KWI wind turbine are discussed in Section 2 of this technical report. MassDEP noise policy is summarized in Section 3. Information on the acoustical monitoring program including locations, monitoring conditions, instrumentation, procedures, and a summary of monitoring activities are outlined in Section 4. Details of the data analysis methodology are provided in Section 5.

Results of the acoustical monitoring study are presented in Section 6 for A-weighted sound levels, Section 7 for low frequency sound and infrasound, and Section 8 for modulation depth analysis.

Section 9 discusses an additional sound level increase assessment for the Copper Beech Drive neighborhood and Section 10 provides details of the supplemental ambient monitoring program, the ambient monitoring results, and the resulting sound level increase predictions. The final conclusions of the acoustical study are outlined in Section 11.

A detailed description of the sound metrics and terminology used in this report is attached as Appendix A. The complete MassDEP noise policy is provided in Appendix B. Monitoring site photographs and detailed acoustic data are attached as Appendices C and D, respectively.

2 Kingston Wind Independence Turbine Technical Specifications

The KWI wind turbine is a Hyundai Heavy Industries HQ2000 WT86 2.0 Megawatt wind turbine with an approximately 80 meter tower height.

2.1 Power Curve

The power curve shown in Figure 1 indicates the power produced by the KWI turbine as a function of the wind speed at the turbine hub height.

At wind speeds above 3.5 meters per second (m/s) there is sufficient wind for the turbine to begin to operate (i.e. the "cut-in" speed). At wind speeds above 10 m/s the turbine approaches full power generation. The KWI turbine reaches maximum 2000 kW production levels at hub-height wind speeds above 12 m/s.

2.2 Sound Power Levels

The sound power level curve shown in Figure 2 indicates the acoustic sound power produced by the KWI turbine as a function of the wind speed at the turbine hub height, as provided in the January 27, 2011 "Hyundai Heavy Industries Wind Turbine Generator Standard Warranty (Noise Emission)".

At wind speeds above 10 m/s the turbine sound power level exceeds 104 dBA and approaches the maximum sound power level to within less than 1 dBA. The KWI turbine reaches a maximum sound power level of 105 dBA at hub-height wind speeds above 14 m/s.

Note that MassDEP protocols for wind turbine assessments generally rely on direct measurement of turbine sound levels to the extent possible. The KWI turbine sound power curve is provided here for reference purposes only.

2.3 Supervisory Control and Data Acquisition (SCADA)

HMMH was provided hub-height wind speed and direction data for periods when acoustical monitoring was conducted as well as energy production and other meteorological and operational information via the KWI turbine Supervisory Control and Data Acquisition (SCADA) system. The wind speed and wind direction are measured by two ultrasonic anemometers that are mounted on the KWI turbine nacelle.

Wind speed and direction data were recorded by the SCADA system during all acoustical monitoring, both with the KWI turbine operating and shut down. This information allowed for a direct comparison of wind conditions between contiguous turbine-on and turbine-off periods.

Power generation data was also recorded by the SCADA system during periods with the KWI turbine operating. Hub-height wind speed information was derived from the turbine power levels and compared with the wind speed data measured by the nacelle-mounted anemometers. On average, a correction factor of about +1.5 m/s was required to adjust the wind speed data to the turbine power level data (i.e. the actual wind speed is assumed to be slightly higher than the value provided by the SCADA system).

Given that the uncorrected wind speeds were typically similar between contiguous turbine-on and turbine-off periods and a consistent offset was not observed, it was therefore appropriate to adjust all wind speed data analyzed for this study (including acoustical monitoring periods with the KWI turbine operating and also periods with the turbine shut down) so that the wind speed information is accurate and cross-comparable and directly correlates with SCADA power level data during turbine-on periods.

2.4 Live Deck Monitoring Website

Limited energy production data from the turbine SCADA system as well as concurrent meteorological data from the Plymouth Airport are publically available on the KWI Live Deck Monitoring website:

http://www.live.deckmonitoring.com/?id=kingston_wind

Note that the KWI Live Deck website is not intended as an analytical tool and does not display wind speed or wind direction data directly from the turbine SCADA system due to technical and hardware limitations. Therefore, the wind speed and direction information shown on the Live Deck website may not necessarily be exactly representative of what is occurring at the KWI turbine hub at any specific time.

Figure 1. KWI Wind Turbine Power Curve
Hyundai Heavy Industries HQ2000 WT86 2.0 MW Wind Turbine

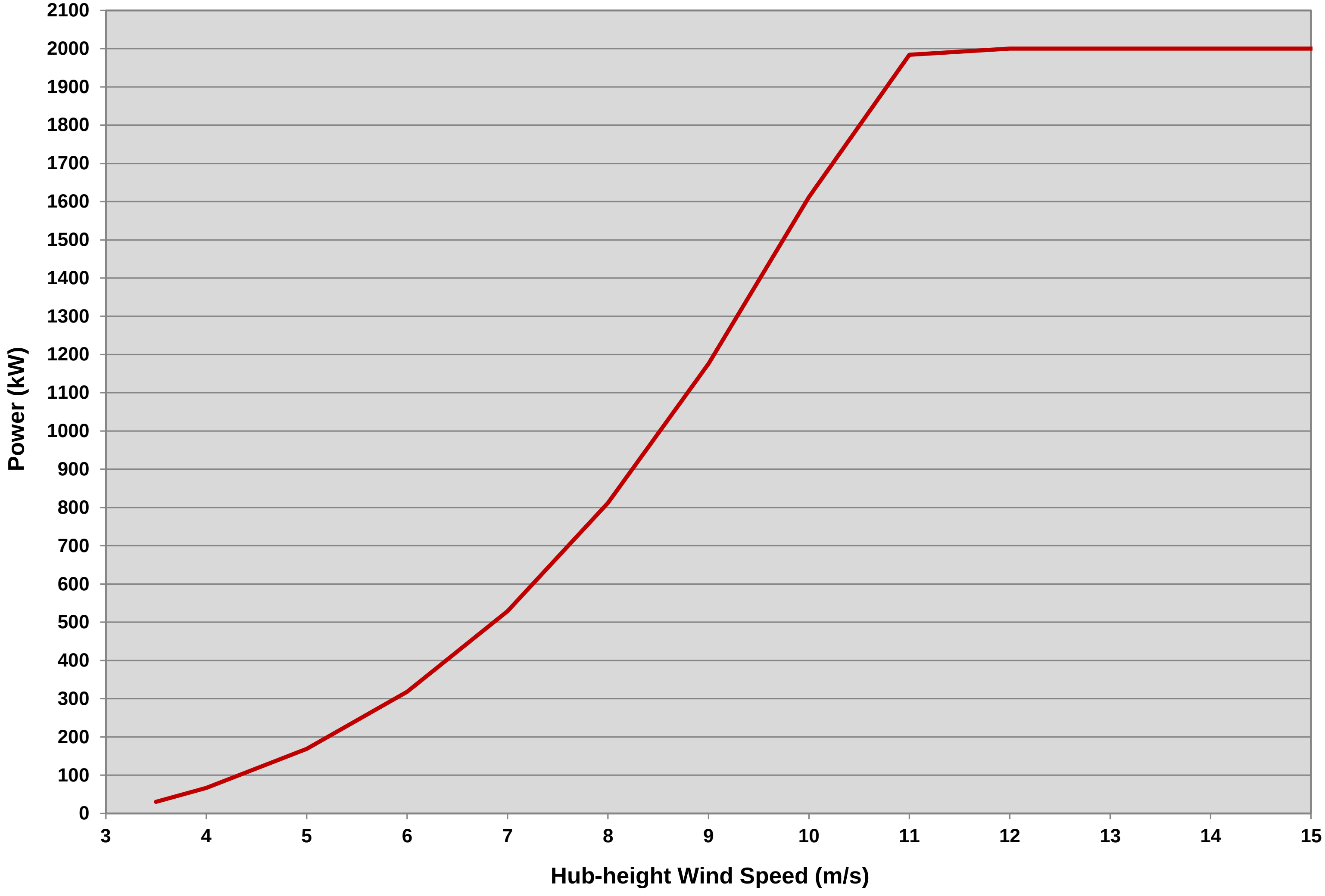
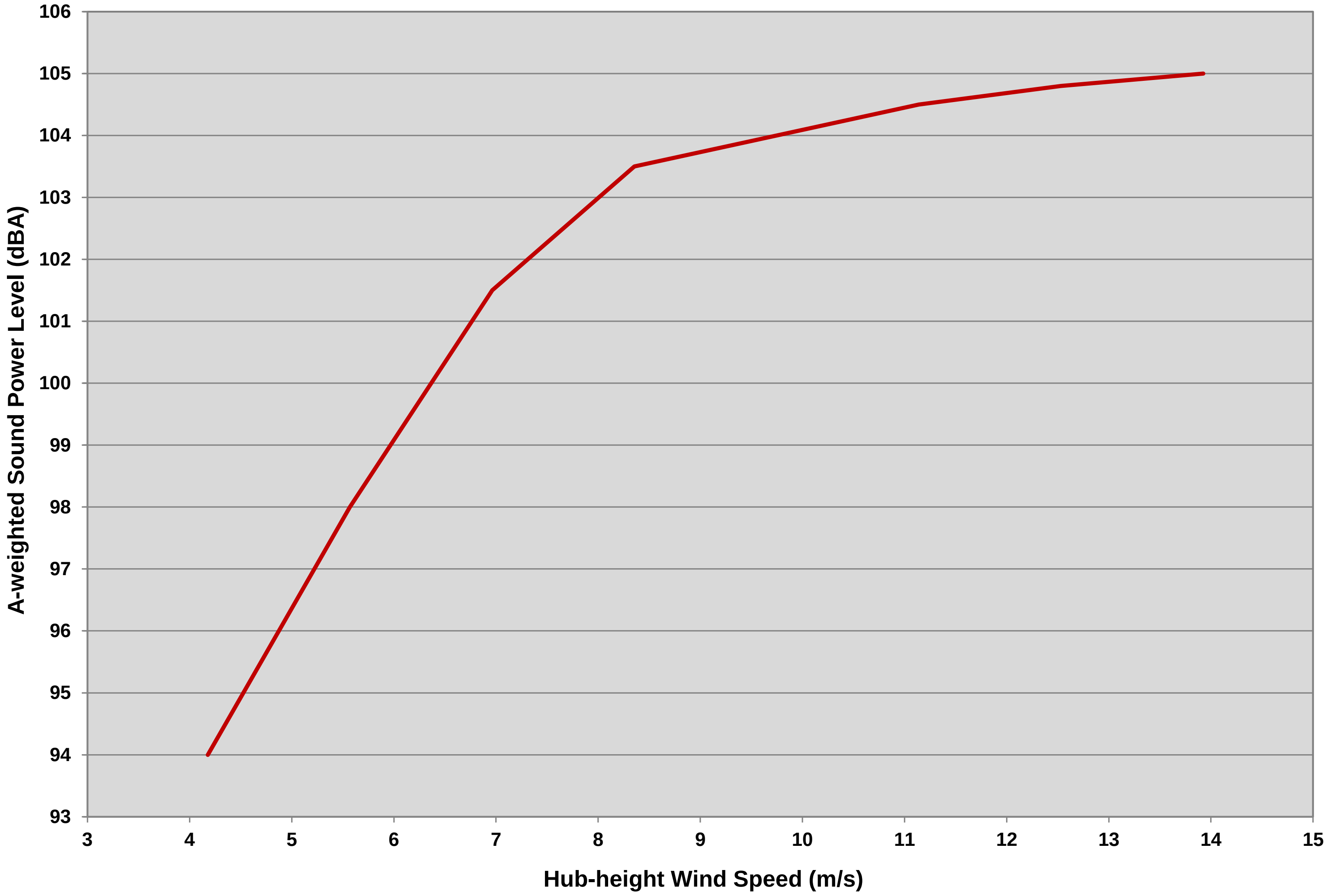


Figure 2. KWI WInd Turbine Sound Power Levels
Hyundai Heavy Industries HQ2000 WT86 2.0 MW Wind Turbine



3 Massachusetts Department of Environmental Protection Noise Policy

The applicable standard for assessment of the KWI wind turbine is the MassDEP noise policy outlined below. Appendix B provides the complete policy from MassDEP.

The Code of Massachusetts Regulations (Title 310, Section 7.10, amended September 1, 1972) empowers the Division of Air Quality Control (DAQC) of the Department of Environmental Protection (DEP) to enforce its noise standards. According to DAQC Policy 90-001 (February 1, 1990), a source of sound will be considered to be violating the MassDEP noise policy if the source:

(1) increases the broadband sound level by more than 10 dBA above ambient, or

(2) produces a "pure tone condition," when any octave-band center frequency sound pressure level exceeds the two adjacent frequency sound pressure levels by 3 decibels or more.

Ambient "background" sound levels are defined as the slow-response A-weighted L_{90} statistical percentile sound levels measured during equipment operating hours. A detailed description of the sound metrics and terminology used in this report is provided in Appendix A.

4 Acoustical Monitoring Program

HMMH collected acoustic data under a variety of wind conditions at several monitoring locations both with the KWI turbine in normal operation and also with the wind turbine shut down. The specific acoustical monitoring sites are shown in Figure 3 and include six residential locations as well as a measurement site at the Kingston Intermediate School. Supplemental site photographs are included in Appendix C.

4.1 Monitoring Locations

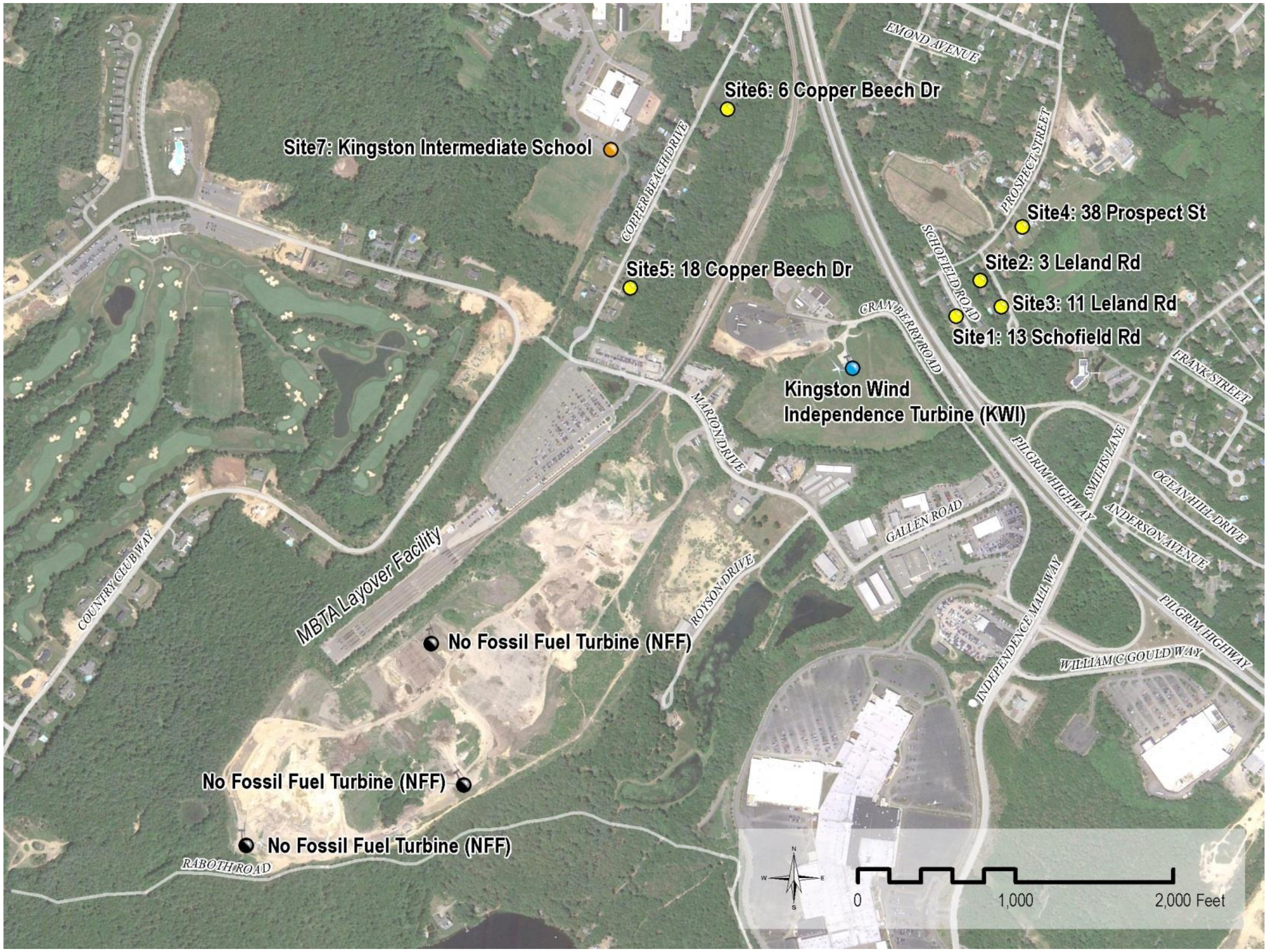
The monitoring site at 13 Schofield Road is located at a multi-family town-house style residential development approximately 740 feet to the northeast from the KWI wind turbine. This is the closest residential neighborhood to the turbine. The monitoring sites at 3 Leland Road, 11 Leland Road, and 38 Prospect Street are located at single-family homes about 990 feet, 1025 feet, and 1410 feet to the northeast of the KWI wind turbine, respectively. Route 3 runs from northwest to southeast between the KWI turbine and these four residential monitoring locations, about 520 feet away from KWI.

The monitoring sites at 18 Copper Beech Drive and 6 Copper Beech Drive are located at single-family homes approximately 1535 feet and 1855 feet to the northwest from the KWI wind turbine, respectively. The residence located at 18 Copper Beech Drive is the closest home in this neighborhood to the KWI turbine and also one of the most distant from Route 3. The monitoring site at the Kingston Intermediate School is located about 2170 feet to the northwest of KWI, on the side of the building in closest proximity to the wind turbine and the farthest from Route 3. Massachusetts Bay Transportation Authority (MBTA) commuter rail tracks run from northeast to southwest between the KWI turbine and these three monitoring locations, about 970 feet away from KWI.

Sound sources observable at the monitoring sites in the daytime include vehicles on Route 3, local traffic, aircraft overflights, and MTBA commuter trains. During the quietest nighttime hours, Route 3 traffic continues and other distant sound sources are at times also audible; these include commercial or industrial equipment, commuter trains that idle overnight during very cold weather at the MBTA layover facility located beyond the end of Copper Beech Drive and adjacent to Country Club Way, and the three No Fossil Fuel (NFF) wind turbines located beyond the MBTA facility between Country Club Way and Raboth Road.

Note that commuter trains were heard idling at the MBTA layover facility on only one occasion, during unsuccessful acoustical monitoring conducted on February 28, 2014 with very cold weather. On all of the nights of successful measurements presented in this report, the air temperature was somewhat higher and MBTA trains were not idled overnight. Also, while the NFF wind turbines were at times audible during the nighttime monitoring, these sources were not observed to dominate ambient sound levels.

Figure 3. Study Area and Acoustical Monitoring Sites



4.2 Monitoring Conditions

An October 10, 2006 wind resource report[2] prepared by the University of Massachusetts at Amherst Renewable Energy Research Laboratory indicates that the most regularly occurring wind conditions at the KWI turbine site are moderate hub-height wind speeds of about 6 to 8 m/s from the southwest.

Table 1 presents target conditions for acoustical monitoring of the KWI wind turbine as outlined in a February 6, 2014 HMMH memorandum[3] on revised acoustical monitoring scenarios. The table incorporates some modifications to protocols provided in an August 5, 2013 letter[4] on the revised study scope regarding target ranges of wind speed and direction and appropriate times of day and year for conducting the monitoring.

The February 6, 2014 revisions to the monitoring protocol (footnote 3) provided the flexibility necessary to complete data collection for the acoustical study in a timely fashion while also providing sufficient information regarding sound level increases due to operation of the KWI wind turbine under worst-case conditions. Results of the acoustical monitoring are presented in Sections 6 through 8 of this report for the following scenarios outlined in the February 6, 2014 memorandum: Scenarios 1 through 3 at the four monitoring sites located to the east of Route 3 and Scenario 7 at the Kingston Intermediate School.

HMMH did not have an opportunity to conduct acoustical monitoring of the KWI turbine in the Copper Beech Drive neighborhood on a night with southeast winds (downwind) for Scenarios 4 through 6. However, nighttime ambient sound level data was successfully collected in this community with the turbine shut down, in an effort to better understand the local ambient sound environment. To estimate sound level increases associated with operation of the KWI wind turbine in the context of MassDEP noise policy, the measured ambient levels were combined with estimates of KWI turbine sound levels in this neighborhood to compute potential sound level increases due to downwind operation of the turbine. The sound level estimates were developed by extrapolating the turbine-only sound levels measured at the four residential sites to the east of Route 3 during periods dominated by the turbine. (Refer to Section 9.)

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[2] University of Massachusetts Renewable Energy Research Lab report, "Final Wind Data Report, Kingston MA" October 10, 2006.

[3] HMMH memorandum, "Revised Acoustical Monitoring Scenarios for Kingston Wind Independence Turbine" February 6, 2014.

[4] HMMH letter, "Revised Scope for Acoustical Monitoring of Kingston Wind Independence Turbine" August 5, 2013.

Table 1. Acoustical Monitoring Locations and Conditions

Scenario	Location	Monitoring Sites	Season	Wind Speed	Wind Direction (note 2)	Receptor position to turbine
1	Schofield Rd, Leland Rd, Prospect St.	4 nighttime	Winter (note 2)	4-6 m/s	S-NW 180°-225°-315°	Downwind approaching Crosswind
2	Schofield Rd, Leland Rd, Prospect St.	4 nighttime	Winter (note 2)	7-9 m/s	S-NW 180°-225°-315°	Downwind approaching Crosswind
3	Schofield Rd, Leland Rd, Prospect St.	4 nighttime	Winter (note 2)	10+ m/s	S-NW 180°-225°-315°	Downwind approaching Crosswind
4	Copper Beech Dr.	2 nighttime	Winter	4-6 m/s	NE-S 45°-135°-180°	Downwind approaching Crosswind
5	Copper Beech Dr.	2 nighttime	Winter	7-9 m/s	NE-S 45°-135°-180°	Downwind approaching Crosswind
6	Copper Beech Dr.	2 nighttime	Winter	10+ m/s	NE-S 45°-135°-180°	Downwind approaching Crosswind
7 (note 1)	Kingston Elementary & Intermediate School	1 daytime	Winter	Any	E-S 90°-135°-180°	Approx. Downwind

Notes:

This table was previously included in the HMMH memorandum dated February 6, 2014 with subject "Revised Acoustical Monitoring Scenarios for Kingston Wind Independence Turbine".

1. Winds from this direction are somewhat rare, thus it may be difficult to capture this scenario. If conditions have not allowed for sampling at the Kingston schools to occur by the end of February 2014 or shortly thereafter, then the monitoring schedule will be re-evaluated.
2. Based on the results of acoustical monitoring of the KWI turbine during the winter season, additional measurements may also be considered, including during the summer.

4.3 Instrumentation

The acoustical monitoring was conducted using ANSI Type 1 “Precision” Bruel & Kjaer model 2250 sound level analyzer kits including a microphone, pre-amplifier, microphone stand, 7 inch windscreen, and an acoustic calibrator. All of the sound measurement instrumentation is owned by HMMH, conforms to ANSI Standard S1.4 for Type 1 (Precision) sound level meters, and have current calibrations traceable to the U.S. National Institute of Standards and Technology (NIST). Additional field calibrations of the instruments were carried out before and after each nighttime measurement using a NIST-certified acoustical calibrator.

All measurements were conducted in accordance with industry best practices and in general compliance with appropriate professional standards such as ASTM E 1779-96a (Reapproved 2004) “Standard Guide for Preparing a Measurement Plan for Conducting Outdoor Sound Measurements”, ANSI S12.18 “Procedures for Outdoor Measurement of Sound Pressure Level” and ANSI S12.9 Part 3 ”Quantities and Procedures for Description and Measurement of Environmental Sound, Part 3: Short-Term Measurements with an Observer”.

Sound measurement microphones were tripod-mounted at a 5-6 foot elevation and placed at least 25 feet from large reflecting surfaces (such as buildings) and at least 5 feet from smaller objects (such as trees and poles) and with a direct line of sight to the KWI turbine. The operator of the sound analyzer was located at least 25-50 feet away from the microphone position and remained silent at all times to prevent interference with the data collection. Anemometers used to monitor wind speeds near ground level were tripod-mounted at a 3-4 foot height and placed near the sound analyzer operator for easy observation. Monitoring wind speeds at this elevation was important for investigation of wind shear conditions during the measurements and also because the 7-inch diameter windscreens used for the monitoring are only rated for accurate measurement of A-weighted sound levels with up to 5 m/s wind speeds near the ground.

The acoustical instrumentation measured sound levels continuously in the frequency range from 5.6 Hz to 20,000 Hz. The instruments were programmed to log both slow-response and fast-response broadband A-weighted and C-weighted sound levels as well as unweighted 1/3-octave band data in 1-second intervals. To account for momentary variation in turbine sound levels, the maximum levels in each 1-second interval were used, which is consistent with MassDEP protocols for wind turbine assessments. Fast-response broadband A-weighted sound levels were also logged simultaneously at a 1/10-second rate to allow for modulation depth analysis. In addition, G-weighted and Z-weighted (unweighted) broadband sound levels and unweighted octave band data were computed from the 1-second 1/3-octave band data.

Simultaneous hub-height wind speed and direction data was obtained in 10-minute intervals from the KWI turbine SCADA system, as well as energy production and other meteorological and operational information. Wind speed and direction data was also collected in 1-second intervals from the real-time SCADA system output using a screen capture video of the SCADA system utility software.

4.4 Measurement Uncertainty

Instrumentation field calibrations were carried out before and after each measurement and included all microphone extension cables in the signal chain. Calibration drift was less than 0.1 dB during all measurements at all seven monitoring sites. In addition, 7-inch diameter windscreens were employed that are rated for accurate measurement of A-weighted sound levels with up to 5 m/s wind speeds near the ground. Winds near ground level were generally calm or very low during the acoustical monitoring and no short-term wind gusts of more than about 3 to 5 m/s were observed.

Overall, the Bruel & Kjaer model 2250 Type 1 (Precision) sound level meters can measure sound levels to an accuracy of about ±1 dBA. Also, the acoustical monitoring procedures included measuring corresponding turbine-on/off periods as contiguously as possible and with the same instrumentation, an approach that results in reduced uncertainty when cross comparing the acoustical data.

4.5 Monitoring Procedures

The protocols for acoustical monitoring of the KWI turbine were outlined in a January 23, 2014 HMMH memorandum[5]. This memo presented some modifications to the August 5, 2013 letter (footnote 4) that were needed to address issues identified during the initial nights of monitoring, which include sound from heavy volumes of overnight traffic on Route 3 and also sound generated by KWI turbine auxiliary equipment that operates for several minutes after the wind turbine has been shut down[6]. The revised acoustical monitoring procedures were as follows:

During each night of monitoring, HMMH staff collected data between the hours of approximately 1 AM and 3 AM, when traffic on Route 3 is lightest, and until 4:30 AM on March 15, 2014 due to a technical issue with the yaw brake rendering the KWI turbine non-operable earlier in the night. At each monitoring site, we first measured with the wind turbine and all auxiliary equipment fully shut down for about 20 minutes to allow for collection of ambient acoustical data. We then measured with the wind turbine in operation for a period of about 30 minutes. It typically took a few minutes for the remote operators to initiate the KWI turbine startup and another couple of minutes for the blades to begin to turn at full speed, so the initial five minutes of monitoring with the wind turbine operating was not analyzed and we have generally focused analysis efforts on the subsequent 20 minutes of data collection. An additional five minutes of monitoring data was also captured for contingency purposes (this data was utilized in some instances to improve the consistency and robustness of the dataset for some measurements with higher volumes of traffic on Route 3 or extended periods of wind generated sound).

HMMH consultants attended all measurements at all sites. Generally, two consultants and sound level monitors were deployed to allow measurements at two locations simultaneously. Using this approach, acoustical monitoring could be conducted at up to four locations during the quietest nighttime hours with the least amount of traffic on Route 3. During the data collection, HMMH staff members logged the sound sources that appeared to dominate measured sound levels on a moment-to-moment basis and also noted wind speeds that occurred near the ground at each site.

During all of the acoustical monitoring, high-quality audio recordings were captured in addition to sound metric data and attended observations. As a result, the sounds heard during all measurements could be listened to subsequently using proprietary software provided by the manufacturer of the sound analyzer instrumentation. This allowed any of the measurements to be reviewed again later and more than once if necessary, to further identify sound sources and select appropriate data for detailed analysis.

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[5] HMMH memorandum, "Kingston KWI Turbine Acoustical Monitoring Protocol – Proposed Revisions" January 23, 2014.

[6] During nighttime acoustical monitoring conducted on January 20, 2014, the HMMH consultant noticed that auxiliary equipment in the wind turbine nacelle continued operating for 10 or more minutes after the turbine was shut down and the blades stopped spinning. HMMH concluded that there was a small but non-negligible effect on the ambient sound levels that were collected while this secondary equipment was still operating. Therefore, to ensure valid and conservative measurement of ambient background sound, HMMH modified the acoustical monitoring procedures to ensure that the wind turbine was completely shut down (blades stopped turning and auxiliary equipment off) before conducting any subsequent nighttime ambient sound level monitoring.

4.6 Monitoring Schedule and Summary

After some delays due to operational issues with the KWI turbine, the acoustical monitoring study commenced in December 2013. The schedule for acoustical monitoring of the wind turbine was finalized in a March 28, 2014 HMMH memorandum[7]. This memo provided notification of an extension of the timeframe for acoustical monitoring into mid-April 2014, with the final night of measurements subsequently conducted on Wednesday April 9, 2014.

A summary and timeline of HMMH's efforts to conduct acoustical monitoring is provided below. Acoustical monitoring results are presented in Sections 6 through 9 of this report for all successful data collection. (Refer to Section 10 of this report for information on the supplemental ambient monitoring.)

- <u>Successful data-collection efforts:</u>
  - **February 18, 2014** – successful daytime acoustical monitoring was conducted at the Kingston Intermediate School (Scenario #7)
  - **March 2, 2014** – successful nighttime acoustical monitoring with moderate wind speeds was conducted in the Schofield/Leland/Prospect neighborhood (Scenario #2)
  - **March 15, 2014** – successful nighttime acoustical monitoring with higher wind speeds was conducted in the Schofield/Leland/Prospect neighborhood (Scenario #3)
  - **March 22, 2014** – additional nighttime acoustical monitoring with moderate wind speeds was conducted in the Schofield/Leland/Prospect neighborhood (Scenario #2)
  - **April 7, 2014** – successful nighttime acoustical monitoring with low wind speeds was conducted in the Schofield/Leland/Prospect neighborhood (Scenario #1)
  - **April 9, 2014** – successful nighttime ambient acoustical monitoring was conducted in the Copper Beech Drive neighborhood

- <u>Notes on other data-collection efforts:</u>
  - **December 13, 2013** – data initially thought to be useful, but later, ambient sound levels were found to be affected by KWI auxiliary equipment sound during shutdown periods, so the monitoring was repeated to ensure a conservative and valid assessment of ambient sound levels
  - **January 21, 2014** – wind direction and speeds that were forecast did not develop and ambient sound levels again affected by KWI auxiliary equipment sound
  - **February 20, 2014** – monitoring unsuccessful due to nearby atypical sound (snow removal)
  - **February 22, 2014** – monitoring cancelled due to technical issue with auto-lubrication system rendering KWI turbine non-operable
  - **February 28, 2014** – high wind speeds were forecast (Scenario #3), but only moderate wind speeds occasionally approaching higher speeds developed, so additional monitoring was conducted on March 15, 2014 with stronger and more steady wind speeds to capture turbine full-power conditions as requested by residents and agreed to by MassDEP and MassCEC; also commuter trains could be heard idling at the MBTA layover facility due to very cold weather
  - **March 15, 2014** – monitoring delayed due to technical issue with yaw brake rendering KWI turbine non-operable early in the night, then monitoring successfully completed later in the night

[7] HMMH memorandum, "Extended Acoustical Monitoring Schedule for Kingston Wind Independence Turbine" March 28, 2014.

- **March 22, 2014** – low wind speeds were forecast (Scenario #1), but moderate wind speeds actually developed (Scenario #2, which had already been measured on March 2, 2014), so additional monitoring during low wind conditions was conducted on April 7, 2014
- **April 3 and April 4, 2014** – the wind speeds that were forecast did not develop, so monitoring was cancelled

5 Analysis of Acoustical Monitoring Data

The methodology for analysis of the KWI wind turbine acoustical monitoring data was outlined initially in an August 5, 2013 HMMH letter (footnote 4) and incorporates key elements of the MassDEP protocols used for acoustical studies of wind turbines. This section of the report largely mirrors that scope letter.

5.1 Data Analysis Methodology

As discussed previously, HMMH conducted nighttime measurements with the KWI wind turbine shut down for approximately 20 minutes to allow collection of ambient acoustical data, followed by approximately 20 minutes of monitoring with the wind turbine operating, with additional time in between for all turbine components to fully shut down or return to normal operating conditions.

The acoustical instrumentation measured sound levels continuously in the frequency range from 5.6 Hz to 20,000 Hz. The instruments were programmed to log both slow-response and fast-response broadband A-weighted and C-weighted sound levels as well as unweighted 1/3-octave band data in 1-second intervals. To account for momentary variation in turbine sound levels, the maximum levels in each 1-second interval were used, which is consistent with MassDEP protocols for wind turbine assessments. Fast-response broadband A-weighted sound levels were also logged simultaneously at a 1/10-second rate to allow for modulation depth analysis. In addition, G-weighted and Z-weighted (unweighted) broadband sound levels and unweighted octave band data were computed from the 1-second 1/3-octave band data.

The acoustical monitoring data was then analyzed in 5-minute and 20-minute intervals[8]. Detailed acoustic data are attached as Appendix D. For each individual 5-minute and total 20-minute measurement period with the turbine on or off, a detailed monitoring report is provided in Appendix D presenting the acoustic data both graphically and numerically. The date and time span of each measurement are clearly indicated, as well as the average wind speed and direction, and other useful information such as the air temperature and the turbine energy production. A log of any atypical sound events and corresponding time periods that were excluded from the measurement data is also provided. When uncharacteristic sound events were very high frequency and occurred intermittently throughout the monitoring, exclusion of all affected times was not feasible, and so the measurement data was instead adjusted using interpolation of the 1-second 1/3-octave band data to remove the sound event contribution. Specific uncharacteristic sound events are discussed further in subsequent sections of this report and include sound from spring peepers at all residential sites, sound from a cord tapping on a flagpole at 38 Prospect Street, and sound from a heating system exhaust vent at the Kingston Intermediate School.

For each measurement, a summary of the acoustical metric data is also provided calculated over both the 20-minute period with the KWI turbine shut down and the subsequent 20 minutes with the turbine operating normally. Comparison summaries between the different sound metrics reported are then provided for the 20-minute ambient period and the 20-minute period of turbine operation using various broadband sound level weightings. The summary and detailed acoustical monitoring reports are provided in Appendix D for both slow-response and fast-response sound level meter settings.

[8] Throughout this report, "5-minute" and "20-minute" measurement periods are referred to both with the wind turbine operating and shut down. Results calculated over these time periods will typically not correspond to exactly 5 minutes or 20 minutes in total duration since the measurements are adjusted to remove any uncharacteristic sound events and are then presented both including and also excluding periods of Route 3 traffic noise, making them shorter in duration. Therefore, the "5-minute" and "20-minute" periods cited throughout this report refer to approximate periods of time. The actual percentages of time included for results calculated over these periods are shown on the detailed acoustical monitoring reports provided in Appendix D.

Broadband sound levels in A-, C-, and G-weightings are reported for a variety of acoustical metrics, including the maximum (L_{max}), equivalent (energy-average) (L_{eq}), and statistical percentile sound levels (L_n, denoting the sound level exceeded n-percent of the time). Statistical sound levels of particular interest are the L_{01}, which represents typical maximum sound levels, the L_{50}, which represents the median sound level, and the L_{90}, which represents the ambient "background" level from relatively continuous sources. Per MassDEP protocols, maximum (L_{max}) sound levels are only reported for each 5-minute period and this data was then combined to determine and report an average maximum (Avg L_{max}) sound level for each corresponding 20-minute period. Unweighted octave-band and one-third octave-band data are also reported, as well as overall broadband Z-weighted (unweighted) sound levels and the calculated sound level modulation depths.

Appendix A provides a detailed description of the sound metrics and terminology used in this report and includes a comparison of the different broadband sound level weighting networks in Figure A-1 and illustrations of various sound metric calculations in Figures A-2 and A-3. Detailed acoustical monitoring data are provided in Appendix D in both 5-minute and 20-minute intervals.

The same set of acoustical metrics was developed for each measurement under two conditions relative to ambient sound. One condition with the KWI turbine operating included all ambient sound (most significantly from traffic on Route 3) along with the sound generated by the wind turbine; the other condition included only periods when the turbine dominated the sound level and other sounds (such as traffic on Route 3 or wind generated sound) were not noticeable.

Analysis of the limited time periods "excluding Route 3 traffic" is useful in determining sound levels directly attributable to the KWI turbine for assessment of sound level increases associated with operation of the wind turbine in the context of MassDEP noise policy. This approach allows average maximum (Avg L_{max}), equivalent (L_{eq}), and statistical L_{90} turbine-only sound levels to be compared with ambient L_{90} background levels. However, this methodology also limits assessment of turbine levels to the very quietest periods in between Route 3 traffic events, which may in some instances result in calculation of turbine-only sound levels that are lower than the measured ambient L_{90} background level for monitoring conducted at lower wind speeds and at greater distances from the KWI turbine. Analysis of each entire measurement period "including Route 3 traffic" only allows for comparison of turbine-operating L_{90} sound levels to ambient L_{90} levels, but provides a more robust and representative L_{90} to L_{90} sound level increase comparison.

Similarly, one set of metrics with all ambient sound present and "including Route 3 traffic" was developed for each entire measurement period with the KWI turbine shut down; another set of metrics "excluding Route 3 traffic" was developed for those periods when sound from Route 3 traffic was not noticeable. Nighttime ambient background L_{90} sound levels during the quietest periods are typically only somewhat influenced by sound from Route 3 traffic and are thus very similar for either data set. However, other acoustical metrics such as average maximum (Avg L_{max}) and equivalent (L_{eq}) sound levels are dominated by sound from Route 3 traffic in the complete data set but are representative of sound levels generated by other less dominant and generally more distant sound sources for the data set excluding periods of Route 3 traffic, which is useful for comparing sound levels produced by the KWI turbine to sound levels associated with Route 3 traffic and also sound levels attributable to other ambient sources.

Note that MassDEP protocols for wind turbine assessments utilize the ambient L_{90} background sound levels calculated over each entire monitoring period "including Route 3 traffic".

5.2 Analysis of Wind Data

Concurrent hub-height wind speed and direction data was obtained for each monitoring period in 10-minute intervals from the KWI turbine SCADA system, as well as energy production and other meteorological and operational information. The wind speed data measured by the anemometers mounted on the KWI turbine nacelle was compared with wind speed information calculated directly from the turbine power generation during each monitoring period, resulting in an average correction factor of +1.5 m/s (i.e. the actual wind speed is assumed to be slightly higher than the value provided by the SCADA system). All wind speed data analyzed for this study was adjusted in this manner (including acoustical monitoring periods with the KWI turbine operating and also periods with the turbine shut down) so that the wind speed information is accurate and cross-comparable and directly correlates with the SCADA power level data during turbine-on periods.

Wind speed and direction data was also collected in 1-second intervals from the real-time KWI SCADA system output. This data could not be obtained in a digital format, so a screen capture video of the SCADA system utility software was used as the only feasible way to record this information for later review. This data was used to determine the hub-height wind speed corresponding with the maximum sound level attributable to the KWI wind turbine in each 5-minute monitoring period, which is highlighted in red text on the detailed acoustical monitoring reports included in Appendix D. This analysis indicated that maximum sound levels generally occurred at wind speeds comparable to 10-minute average wind speed values and were typically not associated with short-term wind gusts.

6 Monitoring Results for A-weighted Sound Levels

A-weighted sound level results for acoustical monitoring of the KWI wind turbine are presented in Tables 2 through 22 for each 20-minute monitoring period. This data was used to assess sound level increases due to nighttime operation of the KWI wind turbine in the context of MassDEP noise policy. Supporting and supplemental detailed acoustic data are provided in Appendix D, which includes results for both 5-minute and 20-minute intervals.

Ambient sound levels are observed to vary somewhat among the measurement sites due to differing view angles and distances to Route 3 as well as the different levels of shielding provided by local terrain and/or nearby buildings at each monitoring location. Also, very high frequency sound generated by spring peepers occurred intermittently throughout the acoustical monitoring conducted on April 7, 2014. While this biogenic sound was only observed to have a significant effect on ambient sound levels at the 38 Prospect Street measurement site, the data collected at all sites was adjusted to remove the sound event contribution (as previously discussed in Section 5.1) to ensure a conservative worst-case assessment representative of winter conditions.

6.1 13 Schofield Road

A summary of A-weighted sound level results is presented in Table 2 for all successful nighttime acoustical monitoring of the KWI wind turbine conducted at the 13 Schofield Road measurement site. More detailed results are also provided in Tables 3 through 6 for each night of monitoring at this location.

Measurements were conducted with average hub-height wind speeds ranging from about 5 to 10 m/s. The wind speed and direction were generally very stable and consistent during each night of acoustical monitoring, with wind speed ranges observed to vary by less than 1 m/s between all contiguous turbine shutdown and operating periods. Ground level wind conditions were generally calm and therefore appropriately representative of worst-case wind shear.

When results were calculated over each entire acoustical monitoring period "including Route 3 traffic", A-weighted L_{90} sound levels measured with the KWI turbine operating increased from ambient background L_{90} sound levels by approximately 5 to 10 dBA with increasing hub-height wind speed when using a slow-response sound level meter setting and by about 5 to 11 dBA using a fast-response setting.

When the data collected with the KWI turbine operating was reduced to include only periods dominated by the wind turbine and to "exclude Route 3 traffic" (as well as any periods of wind generated sound), the 20-minute average maximum (Avg L_{max}) sound levels directly attributable to the KWI turbine were approximately 9 to 15 dBA above ambient background L_{90} sound levels using a slow-response meter setting and were about 9 to 16 dBA above ambient using a fast-response setting. Similarly, the equivalent (L_{eq}) sound levels attributable to the KWI turbine were about 6 to 12 dBA above ambient background sound levels using a slow-response meter setting and were approximately 6 to 13 dBA above ambient using a fast-response setting. The L_{90} sound levels measured during periods dominated by the KWI turbine were approximately 4 to 10 dBA above ambient L_{90} sound levels using a slow-response setting and were about 4 to 11 dBA above ambient using a fast-response setting. (Note that the ambient background sound levels referred to here were calculated over each entire monitoring period with the KWI turbine shut down and "include Route 3 traffic".)

Overall, increases of turbine-operating Avg L_{max} over ambient L_{90} exceeding 10 dBA were identified for nighttime operation of the KWI turbine during downwind conditions with wind speeds above 7 m/s. Analysis of the octave band sound levels measured at this site with the turbine operating showed that it does not create a "pure tone condition", which is an additional component of the MassDEP noise policy.

Also, note that the reported results include an exceedance of the MassDEP 10 dBA maximum increase noise policy measured on March 22, 2014 with 7 to 8 m/s wind speeds which was identified subsequent to publication of the June 13, 2014 HMMH interim study report[9].

[9] HMMH technical memorandum, "Interim Report for Kingston Wind Independence Turbine Acoustical Study" June 13, 2014.

Table 2. Overall Summary of Acoustical Monitoring at 13 Schofield Road (740 feet from KWI)

Date	10-min Avg Wind Speeds (m/s)	10-min Avg Wind Directions	10-min Avg Power Levels (kW)	Sound Level Meter Response	20-min Ambient L90 with KWI Wind Turbine SHUTDOWN (dBA) (incl. Route 3 traffic) (a)	20-min L90 with KWI Wind Turbine OPERATING (dBA) (incl. Route 3 traffic) (b)	L90 to L90 Increase (dBA) (c)	20-min Avg Lmax KWI Wind Turbine ONLY (dBA) (excl. Route 3 traffic) (d)	Avg Lmax to L90 Increase (dBA) (e)
4/7/2014	**5 to 6**	**SW to WSW**	**130 to 210**	**Slow**	**35.5**	**40.7**	**5.2**	**44.8**	**9.3**
				Fast	36.5	41.6	5.1	45.7	9.2
3/22/2014	**7 to 8**	**SW**	**539 to 669**	**Slow**	**33.0**	**41.7**	**8.7**	**45.5**	**12.5**
				Fast	33.4	42.4	9.0	46.4	13.0
3/2/2014	**8 to 9**	**SSW**	**831 to 1026**	**Slow**	**34.1**	**44.2**	**10.1**	**49.2**	**15.0**
				Fast	34.7	44.7	10.0	50.8	16.2
3/15/2014	**10**	**South**	**1505 to 1805**	**Slow**	**39.1**	**49.5**	**10.4**	**52.8**	**13.7**
				Fast	39.5	50.4	10.9	55.2	15.7

Notes:
1) Detailed acoustical monitoring data are provided in **Appendix D**.
2) Results for acoustical monitoring on 3/2/2014 and 3/15/2014 also included in June 13, 2014 interim study report.
3) High frequency sound from spring peepers removed from acoustical monitoring data collected on 4/7/2014.
4) L90 to L90 Increase: c = b - a
5) Avg Lmax to L90 Increase: e = d - a

Table 3. Summary of Acoustical Monitoring at 13 Schofield Road on April 7, 2014

Date	Time	Scenario	KWI Turbine SHUTDOWN		KWI Turbine OPERATING		
			10-min Avg Wind Speeds (m/s)	10-min Avg Wind Directions (deg)	10-min Avg Wind Speeds (m/s)	10-min Avg Wind Directions (deg)	10-min Avg Power Levels (kW)
4/7/2014	**2:20 to 3:10 AM**	**Scenario # 1**	**5.7 to 6.0**	**248 to 258**	**4.8 to 5.2**	**233 to 256**	**130 to 210**

Sound Level Meter Response	20-min Ambient L90 with KWI Wind Turbine SHUTDOWN (dBA) (incl. Route 3 traffic) (a)	20-min L90 with KWI Wind Turbine OPERATING (dBA) (incl. Route 3 traffic) (b)	L90 to L90 Increase (dBA) (c)	20-min Acoustical Metrics KWI Wind Turbine ONLY (dBA) (excl. Route 3 traffic) (d)		Increase from Ambient L90 (dBA) (e)	Pure-tone Condition?
Slow	**35.5**	**40.7**	**5.2**	**Avg Lmax**	**44.8**	**9.3**	**No**
				Leq	**41.9**	**6.4**	
				L90	**39.7**	**4.2**	
Fast	36.5	41.6	5.1	Avg Lmax	45.7	9.2	No
				Leq	42.8	6.3	
				L90	40.6	4.1	

Notes:
1) Detailed acoustical monitoring data are provided in **Appendix D**.
2) High frequency sound from spring peepers removed from data.
3) L90 to L90 Increase: c = b - a
4) Increase from Ambient L90: e = d - a

Table 4. Summary of Acoustical Monitoring at 13 Schofield Road on March 22, 2014

Date	Time	Scenario	KWI Turbine SHUTDOWN		KWI Turbine OPERATING		
			10-min Avg Wind Speeds (m/s)	10-min Avg Wind Directions (deg)	10-min Avg Wind Speeds (m/s)	10-min Avg Wind Directions (deg)	10-min Avg Power Levels (kW)
3/22/2014	**2:20 to 3:05 AM**	**Scenario # 2**	**7.7 to 7.8**	**230 to 235**	**7.1 to 7.3**	**235 to 236**	**539 to 669**

Sound Level Meter Response	20-min Ambient L90 with KWI Wind Turbine SHUTDOWN (dBA) (incl. Route 3 traffic) (a)	20-min L90 with KWI Wind Turbine OPERATING (dBA) (incl. Route 3 traffic) (b)	L90 to L90 Increase (dBA) (c)	20-min Acoustical Metrics KWI Wind Turbine ONLY (dBA) (excl. Route 3 traffic) (d)		Increase from Ambient L90 (dBA) (e)	Pure-tone Condition?
Slow	**33.0**	**41.7**	**8.7**	**Avg Lmax**	**45.5**	**12.5**	**No**
				Leq	**43.2**	**10.2**	
				L90	**41.4**	**8.3**	
Fast	33.4	42.4	9.0	Avg Lmax	46.4	13.0	No
				Leq	43.9	10.5	
				L90	42.0	8.6	

Notes:
1) Detailed acoustical monitoring data are provided in **Appendix D**.
2) L90 to L90 Increase: c = b - a
3) Increase from Ambient L90: e = d - a

Table 5. Summary of Acoustical Monitoring at 13 Schofield Road on March 2, 2014

Date	Time	Scenario	KWI Turbine SHUTDOWN		KWI Turbine OPERATING		
			10-min Avg Wind Speeds (m/s)	10-min Avg Wind Directions (deg)	10-min Avg Wind Speeds (m/s)	10-min Avg Wind Directions (deg)	10-min Avg Power Levels (kW)
3/2/2014	**2:20 to 3:05 AM**	**Scenario # 2**	**7.8 to 8.7**	**197 to 199**	**7.7 to 8.9**	**200 to 205**	**831 to 1026**

Sound Level Meter Response	20-min Ambient L90 with KWI Wind Turbine SHUTDOWN (dBA) (incl. Route 3 traffic) (a)	20-min L90 with KWI Wind Turbine OPERATING (dBA) (incl. Route 3 traffic) (b)	L90 to L90 Increase (dBA) (c)	20-min Acoustical Metrics KWI Wind Turbine ONLY (dBA) (excl. Route 3 traffic) (d)		Increase from Ambient L90 (dBA) (e)	Pure-tone Condition?
Slow	**34.1**	**44.2**	**10.1**	**Avg Lmax**	**49.2**	**15.0**	**No**
				Leq	**46.3**	**12.2**	
				L90	**42.7**	**8.6**	
Fast	34.7	44.7	10.0	Avg Lmax	50.8	16.2	No
				Leq	47.4	12.7	
				L90	43.4	8.7	

Notes:
1) Detailed acoustical monitoring data are provided in **Appendix D**.
2) Results for acoustical monitoring on 3/2/2014 also included in June 13, 2014 interim study report.
3) L90 to L90 Increase: c = b - a
4) Increase from Ambient L90: e = d - a

Table 6. Summary of Acoustical Monitoring at 13 Schofield Road on March 15, 2014

Date	Time	Scenario	KWI Turbine SHUTDOWN		KWI Turbine OPERATING		
			10-min Avg Wind Speeds (m/s)	10-min Avg Wind Directions (deg)	10-min Avg Wind Speeds (m/s)	10-min Avg Wind Directions (deg)	10-min Avg Power Levels (kW)
3/15/2014	**2:20 to 3:05 AM**	**Scenario # 3**	**10.0 to 10.3**	**177 to 178**	**9.8 to 10.3**	**176 to 179**	**1505 to 1805**

Sound Level Meter Response	20-min Ambient L90 with KWI Wind Turbine SHUTDOWN (dBA) (incl. Route 3 traffic) (a)	20-min L90 with KWI Wind Turbine OPERATING (dBA) (incl. Route 3 traffic) (b)	L90 to L90 Increase (dBA) (c)	20-min Acoustical Metrics KWI Wind Turbine ONLY (dBA) (excl. Route 3 traffic) (d)		Increase from Ambient L90 (dBA) (e)	Pure-tone Condition?
Slow	**39.1**	**49.5**	**10.4**	**Avg Lmax**	**52.8**	**13.7**	**No**
				Leq	**50.5**	**11.3**	
				L90	**49.2**	**10.1**	
Fast	39.5	50.4	10.9	Avg Lmax	55.2	15.7	No
				Leq	51.7	12.2	
				L90	50.1	10.6	

Notes:
1) Detailed acoustical monitoring data are provided in **Appendix D**.
2) Results for acoustical monitoring on 3/15/2014 also included in June 13, 2014 interim study report.
3) L90 to L90 Increase: c = b - a
4) Increase from Ambient L90: e = d - a

6.2 3 Leland Road

A summary of A-weighted sound level results is presented in Table 7 for all successful nighttime acoustical monitoring of the KWI wind turbine conducted at the 3 Leland Road measurement site. More detailed results are also provided in Tables 8 through 11 for each night of monitoring at this location.

Measurements were conducted with average hub-height wind speeds ranging from about 5 to 10 m/s. The wind speed and direction were generally stable and consistent during each night of acoustical monitoring, with wind speed ranges observed to vary by less than 1 m/s between contiguous turbine shutdown and operating periods for measurements at moderate and higher wind speeds and by about 2 m/s for the measurement on April 7, 2014 at lower wind speeds. Ground level wind conditions were generally calm and appropriately representative of worst-case wind shear.

When results were calculated over each entire acoustical monitoring period “including Route 3 traffic”, A-weighted L_{90} sound levels measured with the KWI turbine operating increased from ambient background L_{90} sound levels by approximately 2 to 7 dBA with increasing hub-height wind speed when using a slow-response sound level meter setting and by about 2 to 8 dBA using a fast-response setting.

When the data collected with the KWI turbine operating was reduced to include only periods dominated by the wind turbine and to “exclude Route 3 traffic” (as well as any periods of wind generated sound), the 20-minute average maximum (Avg L_{max}) sound levels directly attributable to the KWI wind turbine were approximately 0 to 9 dBA above ambient background L_{90} sound levels using a slow-response meter setting and were about 1 to 11 dBA above ambient using a fast-response setting. Similarly, the equivalent (L_{eq}) sound levels attributable to the KWI turbine were about 1 dBA lower to 8 dBA higher than ambient background sound levels using a slow-response meter setting and were approximately 0 to 9 dBA above ambient using a fast-response setting. The L_{90} sound levels measured during periods dominated by the KWI turbine were approximately 1 dBA lower to 7 dBA higher than ambient L_{90} sound levels using either a slow-response or a fast-response setting. (Note that the ambient background sound levels referred to here were calculated over each entire monitoring period with the KWI turbine shut down and “include Route 3 traffic”. Also, please refer to Section 5.1 regarding calculation of turbine-only sound levels that are lower than the measured ambient L_{90} background level.)

Overall, increases of turbine-operating Avg L_{max} over ambient L_{90} approaching 10 dBA were identified for nighttime operation of the KWI turbine during downwind conditions with wind speeds around 10 m/s. Analysis of the octave band sound levels measured at this site with the turbine operating showed that it does not create a “pure tone condition”.

Table 7. Overall Summary of Acoustical Monitoring at 3 Leland Road (990 feet from KWI)

Date	10-min Avg Wind Speeds (m/s)	10-min Avg Wind Directions	10-min Avg Power Levels (kW)	Sound Level Meter Response	20-min Ambient L90 with KWI Wind Turbine SHUTDOWN (dBA) (incl. Route 3 traffic) (a)	20-min L90 with KWI Wind Turbine OPERATING (dBA) (incl. Route 3 traffic) (b)	L90 to L90 Increase (dBA) (c)	20-min Avg Lmax KWI Wind Turbine ONLY (dBA) (excl. Route 3 traffic) (d)	Avg Lmax to L90 Increase (dBA) (e)
4/7/2014	**5 to 7**	**WSW to W**	**173 to 189**	**Slow**	**39.8**	**41.4**	**1.7**	**40.0**	**0.2**
				Fast	40.7	42.2	1.6	41.6	0.9
3/22/2014	**7 to 8**	**SW**	**586 to 819**	**Slow**	**39.8**	**41.7**	**2.0**	**44.0**	**4.3**
				Fast	39.9	42.4	2.4	45.0	5.1
3/2/2014	**8 to 9**	**SSW**	**827 to 1139**	**Slow**	**41.2**	**45.2**	**3.9**	**46.0**	**4.8**
				Fast	41.5	45.9	4.3	47.9	6.4
3/15/2014	**10**	**South**	**1505 to 1805**	**Slow**	**40.5**	**47.6**	**7.1**	**49.3**	**8.8**
				Fast	40.8	48.5	7.7	51.6	10.8

Notes:
1) Detailed acoustical monitoring data are provided in **Appendix D**.
2) Results for acoustical monitoring on 3/2/2014 and 3/15/2014 also included in June 13, 2014 interim study report.
3) High frequency sound from spring peepers removed from acoustical monitoring data collected on 4/7/2014.
4) L90 to L90 Increase: c = b - a
5) Avg Lmax to L90 Increase: e = d - a

Table 8. Summary of Acoustical Monitoring at 3 Leland Road on April 7, 2014

Date	Time	Scenario	KWI Turbine SHUTDOWN		KWI Turbine OPERATING		
			10-min Avg Wind Speeds (m/s)	10-min Avg Wind Directions (deg)	10-min Avg Wind Speeds (m/s)	10-min Avg Wind Directions (deg)	10-min Avg Power Levels (kW)
4/7/2014	1:00 to 1:45 AM	Scenario # 1	6.7 to 6.9	263 to 264	4.5 to 5.1	257 to 280	173 to 189

Sound Level Meter Response	20-min Ambient L90 with KWI Wind Turbine SHUTDOWN (dBA) (incl. Route 3 traffic) (a)	20-min L90 with KWI Wind Turbine OPERATING (dBA) (incl. Route 3 traffic) (b)	L90 to L90 Increase (dBA) (c)	20-min Acoustical Metrics KWI Wind Turbine ONLY (dBA) (excl. Route 3 traffic) (d)		Increase from Ambient L90 (dBA) (e)	Pure-tone Condition?
Slow	**39.8**	**41.4**	**1.7**	**Avg Lmax**	**40.0**	**0.2**	**No**
				Leq	**39.2**	**-0.5**	
				L90	**38.4**	**-1.3**	
Fast	40.7	42.2	1.6	Avg Lmax	41.6	0.9	No
				Leq	40.4	-0.3	
				L90	39.5	-1.2	

Notes:
1) Detailed acoustical monitoring data are provided in **Appendix D**.
2) High frequency sound from spring peepers removed from data.
3) L90 to L90 Increase: c = b - a
4) Increase from Ambient L90: e = d - a

Table 9. Summary of Acoustical Monitoring at 3 Leland Road on March 22, 2014

Date	Time	Scenario	KWI Turbine SHUTDOWN		KWI Turbine OPERATING		
			10-min Avg Wind Speeds (m/s)	10-min Avg Wind Directions (deg)	10-min Avg Wind Speeds (m/s)	10-min Avg Wind Directions (deg)	10-min Avg Power Levels (kW)
3/22/2014	**1:00 to 1:45 AM**	**Scenario # 2**	**7.3 to 7.8**	**227 to 228**	**7.1 to 7.8**	**228 to 230**	**586 to 819**

Sound Level Meter Response	20-min Ambient L90 with KWI Wind Turbine SHUTDOWN (dBA) (incl. Route 3 traffic) (a)	20-min L90 with KWI Wind Turbine OPERATING (dBA) (incl. Route 3 traffic) (b)	L90 to L90 Increase (dBA) (c)	20-min Acoustical Metrics KWI Wind Turbine ONLY (dBA) (excl. Route 3 traffic) (d)		Increase from Ambient L90 (dBA) (e)	Pure-tone Condition?
Slow	**39.8**	**41.7**	**2.0**	**Avg Lmax**	**44.0**	**4.3**	**No**
				Leq	**42.3**	**2.6**	
				L90	**40.7**	**0.9**	
Fast	39.9	42.4	2.4	Avg Lmax	45.0	5.1	No
				Leq	43.1	3.1	
				L90	41.1	1.2	

Notes:
1) Detailed acoustical monitoring data are provided in **Appendix D**.
2) L90 to L90 Increase: c = b - a
3) Increase from Ambient L90: e = d - a

Table 10. Summary of Acoustical Monitoring at 3 Leland Road on March 2, 2014

Date	Time	Scenario	KWI Turbine SHUTDOWN		KWI Turbine OPERATING		
			10-min Avg Wind Speeds (m/s)	10-min Avg Wind Directions (deg)	10-min Avg Wind Speeds (m/s)	10-min Avg Wind Directions (deg)	10-min Avg Power Levels (kW)
3/2/2014	1:00 to 1:50 AM	Scenario # 2	8.5 to 8.9	196 to 197	8.4 to 8.8	199 to 200	827 to 1139

Sound Level Meter Response	20-min Ambient L90 with KWI Wind Turbine SHUTDOWN (dBA) (incl. Route 3 traffic) (a)	20-min L90 with KWI Wind Turbine OPERATING (dBA) (incl. Route 3 traffic) (b)	L90 to L90 Increase (dBA) (c)	20-min Acoustical Metrics KWI Wind Turbine ONLY (dBA) (excl. Route 3 traffic) (d)		Increase from Ambient L90 (dBA) (e)	Pure-tone Condition?
Slow	**41.2**	**45.2**	**3.9**	**Avg Lmax**	**46.0**	**4.8**	**No**
				Leq	**45.4**	**4.2**	
				L90	**44.3**	**3.1**	
Fast	41.5	45.9	4.3	Avg Lmax	47.9	6.4	No
				Leq	46.4	4.9	
				L90	45.0	3.4	

Notes:
1) Detailed acoustical monitoring data are provided in **Appendix D**.
2) Results for acoustical monitoring on 3/2/2014 also included in June 13, 2014 interim study report.
3) L90 to L90 Increase: c = b - a
4) Increase from Ambient L90: e = d - a

Table 11. Summary of Acoustical Monitoring at 3 Leland Road on March 15, 2014

Date	Time	Scenario	KWI Turbine SHUTDOWN		KWI Turbine OPERATING		
			10-min Avg Wind Speeds (m/s)	10-min Avg Wind Directions (deg)	10-min Avg Wind Speeds (m/s)	10-min Avg Wind Directions (deg)	10-min Avg Power Levels (kW)
3/15/2014	2:20 to 3:10 AM	Scenario # 3	10.0 to 10.3	177 to 178	9.8 to 10.3	176 to 179	1505 to 1805

Sound Level Meter Response	20-min Ambient L90 with KWI Wind Turbine SHUTDOWN (dBA) (incl. Route 3 traffic) (a)	20-min L90 with KWI Wind Turbine OPERATING (dBA) (incl. Route 3 traffic) (b)	L90 to L90 Increase (dBA) (c)	20-min Acoustical Metrics KWI Wind Turbine ONLY (dBA) (excl. Route 3 traffic) (d)		Increase from Ambient L90 (dBA) (e)	Pure-tone Condition?
Slow	40.5	47.6	7.1	Avg Lmax	49.3	8.8	No
				Leq	48.1	7.6	
				L90	47.1	6.6	
Fast	40.8	48.5	7.7	Avg Lmax	51.6	10.8	No
				Leq	49.4	8.6	
				L90	47.9	7.1	

Notes:
1) Detailed acoustical monitoring data are provided in **Appendix D**.
2) Results for acoustical monitoring on 3/15/2014 also included in June 13, 2014 interim study report.
3) L90 to L90 Increase: c = b - a
4) Increase from Ambient L90: e = d - a

6.3 11 Leland Road

A summary of A-weighted sound level results is presented in Table 12 for all successful nighttime acoustical monitoring of the KWI wind turbine conducted at the 11 Leland Road measurement site. More detailed results are also provided in Tables 13 through 16 for each night of monitoring at this location.

Measurements were conducted with average hub-height wind speeds ranging from about 5 to 11 m/s. The wind speed and direction were generally very stable and consistent during each night of acoustical monitoring, with wind speed ranges observed to vary by less than 1 m/s between all contiguous turbine shutdown and operating periods. Ground level wind conditions were generally calm and appropriately representative of worst-case wind shear.

When results were calculated over each entire acoustical monitoring period “including Route 3 traffic”, A-weighted L_{90} sound levels measured with the KWI turbine operating increased from ambient background L_{90} sound levels by approximately 3 to 6 dBA with increasing hub-height wind speed when using either a slow-response sound level meter setting or a fast-response setting.

When the data collected with the KWI turbine operating was reduced to include only periods dominated by the wind turbine and to “exclude Route 3 traffic” (as well as any periods of wind generated sound), the 20-minute average maximum (Avg L_{max}) sound levels directly attributable to the KWI wind turbine were approximately 6 to 10 dBA above ambient background L_{90} sound levels using a slow-response meter setting and were about 7 to 11 dBA above ambient using a fast-response setting. Similarly, the equivalent (L_{eq}) sound levels attributable to the KWI turbine were about 4 to 8 dBA above ambient background sound levels using either a slow-response meter setting or a fast-response setting. The L_{90} sound levels measured during periods dominated by the KWI turbine were approximately 2 to 6 dBA above ambient L_{90} sound levels using either a slow-response or a fast-response setting. (Note that the ambient background sound levels referred to here were calculated over each entire monitoring period with the KWI turbine shut down and “include Route 3 traffic”.)

Overall, increases of turbine-operating Avg L_{max} over ambient L_{90} exceeding 10 dBA were identified for nighttime operation of the KWI turbine during downwind conditions with wind speeds around 7 m/s. Analysis of the octave band sound levels measured at this site with the turbine operating showed that it does not create a “pure tone condition”, which is an additional component of the MassDEP noise policy.

Also, note that the reported results include an exceedance of the MassDEP 10 dBA maximum increase noise policy measured on March 22, 2014 with 7 to 8 m/s wind speeds which was identified subsequent to publication of the June 13, 2014 interim study report (footnote 9).

Table 12. Overall Summary of Acoustical Monitoring at 11 Leland Road (1025 feet from KWI)

Date	10-min Avg Wind Speeds (m/s)	10-min Avg Wind Directions	10-min Avg Power Levels (kW)	Sound Level Meter Response	20-min Ambient L90 with KWI Wind Turbine SHUTDOWN (dBA) (incl. Route 3 traffic) (a)	20-min L90 with KWI Wind Turbine OPERATING (dBA) (incl. Route 3 traffic) (b)	L90 to L90 Increase (dBA) (c)	20-min Avg Lmax KWI Wind Turbine ONLY (dBA) (excl. Route 3 traffic) (d)	Avg Lmax to L90 Increase (dBA) (e)
4/7/2014	**5 to 6**	**SW to WSW**	**130 to 210**	**Slow**	**35.6**	**39.0**	**3.3**	**42.0**	**6.3**
				Fast	36.6	40.0	3.4	43.3	6.7
3/22/2014	**7 to 8**	**SW**	**539 to 669**	**Slow**	**35.0**	**41.2**	**6.2**	**45.1**	**10.1**
				Fast	35.5	41.9	6.4	46.7	11.2
3/2/2014	**8 to 9**	**SSW**	**827 to 1139**	**Slow**	**41.2**	**44.8**	**3.7**	**46.9**	**5.8**
				Fast	41.5	45.7	4.2	49.0	7.5
3/15/2014	**10 to 11**	**South**	**1422 to 1880**	**Slow**	**43.4**	**48.9**	**5.5**	**50.8**	**7.3**
				Fast	43.7	49.6	5.9	53.1	9.4

Notes:
1) Detailed acoustical monitoring data are provided in **Appendix D**.
2) High frequency sound from spring peepers removed from acoustical monitoring data collected on 4/7/2014.
3) L90 to L90 Increase: c = b - a
4) Avg Lmax to L90 Increase: e = d - a

Table 13. Summary of Acoustical Monitoring at 11 Leland Road on April 7, 2014

Date	Time	Scenario	KWI Turbine SHUTDOWN		KWI Turbine OPERATING		
			10-min Avg Wind Speeds (m/s)	10-min Avg Wind Directions (deg)	10-min Avg Wind Speeds (m/s)	10-min Avg Wind Directions (deg)	10-min Avg Power Levels (kW)
4/7/2014	**2:20 to 3:10 AM**	**Scenario # 1**	**5.7 to 6.0**	**248 to 258**	**4.8 to 5.2**	**233 to 256**	**130 to 210**

Sound Level Meter Response	20-min Ambient L90 with KWI Wind Turbine SHUTDOWN (dBA) (incl. Route 3 traffic) (a)	20-min L90 with KWI Wind Turbine OPERATING (dBA) (incl. Route 3 traffic) (b)	L90 to L90 Increase (dBA) (c)	20-min Acoustical Metrics KWI Wind Turbine ONLY (dBA) (excl. Route 3 traffic) (d)		Increase from Ambient L90 (dBA) (e)	Pure-tone Condition?
Slow	**35.6**	**39.0**	**3.3**	**Avg Lmax**	**42.0**	**6.3**	**No**
				Leq	**39.8**	**4.1**	
				L90	**37.8**	**2.1**	
Fast	36.6	40.0	3.4	Avg Lmax	43.3	6.7	No
				Leq	40.8	4.2	
				L90	38.9	2.3	

Notes:
1) Detailed acoustical monitoring data are provided in **Appendix D**.
2) High frequency sound from spring peepers removed from data.
3) L90 to L90 Increase: c = b - a
4) Increase from Ambient L90: e = d - a

Table 14. Summary of Acoustical Monitoring at 11 Leland Road on March 22, 2014

Date	Time	Scenario	KWI Turbine SHUTDOWN		KWI Turbine OPERATING		
			10-min Avg Wind Speeds (m/s)	10-min Avg Wind Directions (deg)	10-min Avg Wind Speeds (m/s)	10-min Avg Wind Directions (deg)	10-min Avg Power Levels (kW)
3/22/2014	**2:20 to 3:10 AM**	**Scenario # 2**	**7.7 to 7.8**	**230 to 235**	**7.1 to 7.3**	**235 to 236**	**539 to 669**

Sound Level Meter Response	20-min Ambient L90 with KWI Wind Turbine SHUTDOWN (dBA) (incl. Route 3 traffic) (a)	20-min L90 with KWI Wind Turbine OPERATING (dBA) (incl. Route 3 traffic) (b)	L90 to L90 Increase (dBA) (c)	20-min Acoustical Metrics KWI Wind Turbine ONLY (dBA) (excl. Route 3 traffic) (d)		Increase from Ambient L90 (dBA) (e)	Pure-tone Condition?
Slow	**35.0**	**41.2**	**6.2**	**Avg Lmax**	**45.1**	**10.1**	**No**
				Leq	**42.7**	**7.7**	
				L90	**41.0**	**5.9**	
Fast	35.5	41.9	6.4	Avg Lmax	46.7	11.2	No
				Leq	43.5	8.0	
				L90	41.6	6.1	

Notes:
1) Detailed acoustical monitoring data are provided in **Appendix D**.
2) L90 to L90 Increase: c = b - a
3) Increase from Ambient L90: e = d - a

Table 15. Summary of Acoustical Monitoring at 11 Leland Road on March 2, 2014

Date	Time	Scenario	KWI Turbine SHUTDOWN		KWI Turbine OPERATING		
			10-min Avg Wind Speeds (m/s)	10-min Avg Wind Directions (deg)	10-min Avg Wind Speeds (m/s)	10-min Avg Wind Directions (deg)	10-min Avg Power Levels (kW)
3/2/2014	1:00 to 1:50 AM	Scenario # 2	8.5 to 8.9	196 to 197	8.4 to 8.8	199 to 200	827 to 1139

Sound Level Meter Response	20-min Ambient L90 with KWI Wind Turbine SHUTDOWN (dBA) (incl. Route 3 traffic) (a)	20-min L90 with KWI Wind Turbine OPERATING (dBA) (incl. Route 3 traffic) (b)	L90 to L90 Increase (dBA) (c)	20-min Acoustical Metrics KWI Wind Turbine ONLY (dBA) (excl. Route 3 traffic) (d)		Increase from Ambient L90 (dBA) (e)	Pure-tone Condition?
Slow	**41.2**	**44.8**	**3.7**	**Avg Lmax**	**46.9**	**5.8**	**No**
				Leq	**45.4**	**4.2**	
				L90	**43.9**	**2.7**	
Fast	41.5	45.7	4.2	Avg Lmax	49.0	7.5	No
				Leq	46.5	5.0	
				L90	44.6	3.1	

Notes:
1) Detailed acoustical monitoring data are provided in **Appendix D**.
2) L90 to L90 Increase: c = b - a
3) Increase from Ambient L90: e = d - a

Table 16. Summary of Acoustical Monitoring at 11 Leland Road on March 15, 2014

Date	Time	Scenario	KWI Turbine SHUTDOWN		KWI Turbine OPERATING		
			10-min Avg Wind Speeds (m/s)	10-min Avg Wind Directions (deg)	10-min Avg Wind Speeds (m/s)	10-min Avg Wind Directions (deg)	10-min Avg Power Levels (kW)
3/15/2014	3:40 to 4:30 AM	Scenario # 3	10.7 to 11.0	182	10.1 to 10.4	179 to 181	1422 to 1880

Sound Level Meter Response	20-min Ambient L90 with KWI Wind Turbine SHUTDOWN (dBA) (incl. Route 3 traffic) (a)	20-min L90 with KWI Wind Turbine OPERATING (dBA) (incl. Route 3 traffic) (b)	L90 to L90 Increase (dBA) (c)	20-min Acoustical Metrics KWI Wind Turbine ONLY (dBA) (excl. Route 3 traffic) (d)		Increase from Ambient L90 (dBA) (e)	Pure-tone Condition?
Slow	**43.4**	**48.9**	**5.5**	**Avg Lmax**	**50.8**	**7.3**	**No**
				Leq	**49.3**	**5.8**	
				L90	**48.1**	**4.6**	
Fast	43.7	49.6	5.9	Avg Lmax	53.1	9.4	No
				Leq	50.4	6.8	
				L90	48.9	5.2	

Notes:
1) Detailed acoustical monitoring data are provided in **Appendix D**.
2) L90 to L90 Increase: c = b - a
3) Increase from Ambient L90: e = d - a

6.4 38 Prospect Street

A summary of A-weighted sound level results is presented in Table 17 for all successful nighttime acoustical monitoring of the KWI wind turbine conducted at the 38 Prospect Street measurement site. More detailed results are provided in Tables 18 through 21 for each night of monitoring at this location.

Measurements were conducted with average hub-height wind speeds ranging from about 5 to 11 m/s. The wind speed and direction were generally stable and consistent during each night of acoustical monitoring, with wind speed ranges observed to vary by less than 1 m/s between contiguous turbine shutdown and operating periods for measurements at moderate and higher wind speeds and by about 2 m/s for the measurement on April 7, 2014 at lower wind speeds. Ground level wind conditions were generally calm and appropriately representative of worst-case wind shear.

When results were calculated over each entire acoustical monitoring period "including Route 3 traffic", A-weighted L_{90} sound levels measured with the KWI turbine operating increased from ambient background L_{90} sound levels by approximately 1 to 5 dBA with increasing hub-height wind speed when using either a slow-response sound level meter setting or a fast-response setting.

When the data collected with the KWI turbine operating was reduced to include only periods dominated by the wind turbine and to "exclude Route 3 traffic" (as well as any periods of wind generated sound), the 20-minute average maximum (Avg L_{max}) sound levels directly attributable to the KWI wind turbine were approximately 1 dBA lower to 8 dBA higher than ambient background L_{90} sound levels using a slow-response meter setting and were about 1 dBA lower to 9 dBA higher than ambient using a fast-response setting. Similarly, the equivalent (L_{eq}) sound levels attributable to the KWI turbine were about 2 dBA lower to 6 dBA higher than ambient background sound levels using either a slow-response meter setting or a fast-response setting. The L_{90} sound levels measured during periods dominated by the KWI turbine were approximately 3 dBA lower to 3 dBA higher than ambient L_{90} sound levels using a slow-response setting and were about 3 dBA lower to 4 dBA higher than ambient using a fast-response setting. (Note that the ambient background sound levels referred to here were calculated over each entire monitoring period with the KWI turbine shut down and "include Route 3 traffic". Also, please refer to Section 5.1 regarding calculation of turbine-only sound levels that are lower than the measured ambient L_{90} background level.)

Overall, measured increases of turbine-operating Avg L_{max} over ambient L_{90} did not exceed 10 dBA.

Analysis of the octave band sound levels measured at this site with the turbine operating showed that it does not create a "pure tone condition".

Table 17. Overall Summary of Acoustical Monitoring at 38 Prospect Street (1410 feet from KWI)

Date	10-min Avg Wind Speeds (m/s)	10-min Avg Wind Directions	10-min Avg Power Levels (kW)	Sound Level Meter Response	20-min Ambient L90 with KWI Wind Turbine SHUTDOWN (dBA) (incl. Route 3 traffic) (a)	20-min L90 with KWI Wind Turbine OPERATING (dBA) (incl. Route 3 traffic) (b)	L90 to L90 Increase (dBA) (c)	20-min Avg Lmax KWI Wind Turbine ONLY (dBA) (excl. Route 3 traffic) (d)	Avg Lmax to L90 Increase (dBA) (e)
4/7/2014	**5 to 7**	**WSW to W**	**173 to 189**	**Slow**	**40.3**	**41.0**	**0.7**	**38.9**	**-1.4**
				Fast	41.2	42.0	0.8	40.1	-1.1
3/22/2014	**7 to 8**	**SW**	**586 to 819**	**Slow**	**39.5**	**41.8**	**2.3**	**42.1**	**2.6**
				Fast	39.8	42.6	2.7	43.4	3.6
3/2/2014	**8 to 9**	**SSW**	**831 to 1026**	**Slow**	**37.2**	**42.2**	**5.0**	**44.7**	**7.5**
				Fast	37.7	42.9	5.2	46.3	8.6
3/15/2014	**10 to 11**	**South**	**1422 to 1880**	**Slow**	**42.1**	**46.1**	**3.9**	**48.3**	**6.2**
				Fast	43.2	47.3	4.1	51.2	8.0

Notes:
1) Detailed acoustical monitoring data are provided in **Appendix D**.
2) High frequency sound from spring peepers removed from acoustical monitoring data collected on 4/7/2014.
3) High frequency sound from cord tapping on a flagpole removed from acoustical monitoring data collected on 3/15/2014.
4) L90 to L90 Increase: c = b - a
5) Avg Lmax to L90 Increase: e = d - a

Table 18. Summary of Acoustical Monitoring at 38 Prospect Street on April 7, 2014

Date	Time	Scenario	KWI Turbine SHUTDOWN		KWI Turbine OPERATING		
			10-min Avg Wind Speeds (m/s)	10-min Avg Wind Directions (deg)	10-min Avg Wind Speeds (m/s)	10-min Avg Wind Directions (deg)	10-min Avg Power Levels (kW)
4/7/2014	**1:00 to 1:45 AM**	**Scenario # 1**	**6.7 to 6.9**	**263 to 264**	**4.5 to 5.1**	**257 to 280**	**173 to 189**

Sound Level Meter Response	20-min Ambient L90 with KWI Wind Turbine SHUTDOWN (dBA) (incl. Route 3 traffic) (a)	20-min L90 with KWI Wind Turbine OPERATING (dBA) (incl. Route 3 traffic) (b)	L90 to L90 Increase (dBA) (c)	20-min Acoustical Metrics KWI Wind Turbine ONLY (dBA) (excl. Route 3 traffic) (d)		Increase from Ambient L90 (dBA) (e)	Pure-tone Condition?
Slow	**40.3**	**41.0**	**0.7**	**Avg Lmax**	**38.9**	**-1.4**	**No**
				Leq	**38.6**	**-1.7**	
				L90	**37.6**	**-2.7**	
Fast	41.2	42.0	0.8	Avg Lmax	40.1	-1.1	No
				Leq	39.7	-1.5	
				L90	38.7	-2.6	

Notes:
1) Detailed acoustical monitoring data are provided in **Appendix D**.
2) High frequency sound from spring peepers removed from data.
3) L90 to L90 Increase: c = b - a
4) Increase from Ambient L90: e = d - a

Table 19. Summary of Acoustical Monitoring at 38 Prospect Street on March 22, 2014

Date	Time	Scenario	KWI Turbine SHUTDOWN		KWI Turbine OPERATING		
			10-min Avg Wind Speeds (m/s)	10-min Avg Wind Directions (deg)	10-min Avg Wind Speeds (m/s)	10-min Avg Wind Directions (deg)	10-min Avg Power Levels (kW)
3/22/2014	**1:00 to 1:45 AM**	**Scenario # 2**	**7.3 to 7.8**	**227 to 228**	**7.1 to 7.8**	**228 to 230**	**586 to 819**

Sound Level Meter Response	20-min Ambient L90 with KWI Wind Turbine SHUTDOWN (dBA) (incl. Route 3 traffic) (a)	20-min L90 with KWI Wind Turbine OPERATING (dBA) (incl. Route 3 traffic) (b)	L90 to L90 Increase (dBA) (c)	20-min Acoustical Metrics KWI Wind Turbine ONLY (dBA) (excl. Route 3 traffic) (d)		Increase from Ambient L90 (dBA) (e)	Pure-tone Condition?
Slow	**39.5**	**41.8**	**2.3**	**Avg Lmax**	**42.1**	**2.6**	**No**
				Leq	**41.2**	**1.8**	
				L90	**40.3**	**0.8**	
Fast	39.8	42.6	2.7	Avg Lmax	43.4	3.6	No
				Leq	42.0	2.2	
				L90	40.7	0.9	

Notes:
1) Detailed acoustical monitoring data are provided in **Appendix D**.
2) L90 to L90 Increase: c = b - a
3) Increase from Ambient L90: e = d - a

Table 20. Summary of Acoustical Monitoring at 38 Prospect Street on March 2, 2014

Date	Time	Scenario	KWI Turbine SHUTDOWN		KWI Turbine OPERATING		
			10-min Avg Wind Speeds (m/s)	10-min Avg Wind Directions (deg)	10-min Avg Wind Speeds (m/s)	10-min Avg Wind Directions (deg)	10-min Avg Power Levels (kW)
3/2/2014	**2:20 to 3:05 AM**	**Scenario # 2**	**7.8 to 8.7**	**197 to 199**	**7.7 to 8.9**	**200 to 205**	**831 to 1026**

Sound Level Meter Response	20-min Ambient L90 with KWI Wind Turbine SHUTDOWN (dBA) (incl. Route 3 traffic) (a)	20-min L90 with KWI Wind Turbine OPERATING (dBA) (incl. Route 3 traffic) (b)	L90 to L90 Increase (dBA) (c)	20-min Acoustical Metrics KWI Wind Turbine ONLY (dBA) (excl. Route 3 traffic) (d)		Increase from Ambient L90 (dBA) (e)	Pure-tone Condition?
Slow	**37.2**	**42.2**	**5.0**	**Avg Lmax**	**44.7**	**7.5**	**No**
				Leq	**43.0**	**5.8**	
				L90	**39.4**	**2.2**	
Fast	37.7	42.9	5.2	Avg Lmax	46.3	8.6	No
				Leq	44.1	6.4	
				L90	40.1	2.4	

Notes:
1) Detailed acoustical monitoring data are provided in **Appendix D**.
2) L90 to L90 Increase: c = b - a
3) Increase from Ambient L90: e = d - a

Table 21. Summary of Acoustical Monitoring at 38 Prospect Street on March 15, 2014

Date	Time	Scenario	KWI Turbine SHUTDOWN		KWI Turbine OPERATING		
			10-min Avg Wind Speeds (m/s)	10-min Avg Wind Directions (deg)	10-min Avg Wind Speeds (m/s)	10-min Avg Wind Directions (deg)	10-min Avg Power Levels (kW)
3/15/2014	**3:40 to 4:25 AM**	**Scenario # 3**	**10.7 to 11.0**	**182**	**10.1 to 10.4**	**179 to 181**	**1422 to 1880**

Sound Level Meter Response	20-min Ambient L90 with KWI Wind Turbine SHUTDOWN (dBA) (incl. Route 3 traffic) (a)	20-min L90 with KWI Wind Turbine OPERATING (dBA) (incl. Route 3 traffic) (b)	L90 to L90 Increase (dBA) (c)	20-min Acoustical Metrics KWI Wind Turbine ONLY (dBA) (excl. Route 3 traffic) (d)		Increase from Ambient L90 (dBA) (e)	Pure-tone Condition?
Slow	**42.1**	**46.1**	**3.9**	**Avg Lmax**	**48.3**	**6.2**	**No**
				Leq	**46.7**	**4.6**	
				L90	**45.5**	**3.4**	
Fast	43.2	47.3	4.1	Avg Lmax	51.2	8.0	No
				Leq	48.3	5.2	
				L90	46.7	3.5	

Notes:
1) Detailed acoustical monitoring data are provided in **Appendix D**.
2) High frequency sound from cord tapping on a flagpole removed from data.
3) L90 to L90 Increase: c = b - a
4) Increase from Ambient L90: e = d - a

6.5 Kingston Intermediate School

A summary of A-weighted sound level results is presented in Table 22 for daytime acoustical monitoring of the KWI wind turbine at the Kingston Intermediate School on February 18, 2014.

Measurements were conducted with average hub-height wind speeds ranging from about 6 to 8 m/s. The wind speed and direction were generally very stable and consistent during the acoustical monitoring, with the wind speed range observed to vary by about 1 m/s between the contiguous turbine shutdown and operating periods. Ground level wind conditions were mostly calm and appropriately representative of worst-case wind shear.

When results were calculated over each entire acoustical monitoring period "including Route 3 traffic", A-weighted L_{90} sound levels measured with the KWI turbine operating increased from ambient background L_{90} sound levels by less than 1 dBA using either a slow-response sound level meter setting or a fast-response setting.

Further analyses were not conducted because traffic dominated sound levels throughout the monitoring and the wind turbine was not audible at any time. Therefore, sound levels "excluding Route 3 traffic" and directly attributable to the KWI wind turbine could not be calculated.

Table 22. Summary of Acoustical Monitoring at Kingston Intermediate School (2170 feet from KWI)

Date	Time	Scenario	10-min Avg Wind Speeds (m/s)	10-min Avg Wind Directions	10-min Avg Power Levels (kW)	Sound Level Meter Response	20-min Ambient L90 with KWI Wind Turbine SHUTDOWN (dBA) (incl. Route 3 traffic) (a)	20-min L90 with KWI Wind Turbine OPERATING (dBA) (incl. Route 3 traffic) (b)	L90 to L90 Increase (dBA) (c)
2/18/2014	**10:30 to 11:15 AM**	**Scenario #7**	**6 to 8**	**East**	**428 to 690**	**Slow**	**46.0**	**46.4**	**0.4**
						Fast	46.9	47.4	0.4

Notes:
1) Detailed acoustical monitoring data are provided in **Appendix D**.
2) High frequency sound from heating system exhaust removed from data.
4) L90 to L90 Increase: c = b - a

7 Monitoring Results for Low Frequency Sound and Infrasound

In addition to the acoustical monitoring results for A-weighted sound levels presented in Section 6, broadband sound level increases were investigated for other sound level weighting networks that include larger contributions from low frequency audible sound and also contributions from sound below the lower limit of human audibility (approximately 20Hz) known as infrasound. Octave band sound level increases due to operation of the KWI wind turbine were also examined.

As described in Appendix A, there are several broadband sound level weighting networks, or scales, and each weighting emphasizes or de-emphasizes specific frequency ranges of the sound spectrum. A-weighting is most typically used for environmental sound analyses since it has been found to best correlate with human response to sound, while C-weighting is often used to assess the prominence of low frequency sound (relative to the A-level) and G-weighting is intended to isolate and measure only very low frequency sound and infrasound. Z-weighting is also commonly used and denotes completely unweighted broadband sound levels.

Figure A-1 of Appendix A presents a graph comparing the various broadband sound level weighting networks. As shown in this figure, the A-weighting, C-weighting, and Z-weighting networks comprise the frequency range from 10 Hz to 20,000 Hz, while the G-weighting network includes the frequency range from 0.25 Hz to 315 Hz. Also, as discussed previously, the acoustical monitoring instrumentation collected data down to 5.6 Hz, which is the lower frequency limit of both the 6.3Hz 1/3-octave band and the 8 Hz octave band. Therefore, a complete assessment of G-weighted sound levels was not possible, since the frequency range from 0.25 Hz to 5.5 Hz could not be sampled.

Tables 23 through 27 present broadband sound level increase comparisons between the various sound level weighting networks for the acoustical monitoring conducted at each measurement site. This analysis utilizes slow-response sound level data since the lower frequencies of sound which were of interest have longer periods of oscillation and are more slowly varying than mid to high frequency sound.

Figures 4 through 15 provide octave band sound levels for monitoring periods with the KWI turbine operating and shut down, as well as the corresponding octave sound level increases calculated between the ambient L_{90} sound levels and the equivalent (L_{eq}) sound levels measured during periods dominated by sound from the wind turbine. The L_{eq} metric was selected for the octave-band analysis in order to best assess characteristic octave band sound level variations.

Additional detailed acoustic data are attached as Appendix D and include sound level increase calculations for various sound metrics and sound level weightings using both slow-response and fast-response meter settings, as well as supplemental octave band and 1/3-octave band data.

7.1 Broadband Sound Level Increase Comparisons

A summary of low frequency and infrasound monitoring results is presented in Table 23 comparing the broadband sound level increases calculated using various sound level weightings for each night of acoustical monitoring of the KWI wind turbine conducted at the 13 Schofield Road measurement site.

The results indicate that broadband sound level increases from ambient conditions due to operation of the KWI turbine are very comparable when calculated using any of the sound level weightings included in Table 23. The results within each range of wind speed generally differ by only about 1 to 2 dB among the various weighting networks for any particular sound level metric. Greater variation in the results of around 2 to 4 dB is only observed for the Avg L_{max} metric at the highest wind speeds, which may be at least partially due to wind-induced sound in the instruments from wind gusts that occurred near ground level on this night of measurements. While the 7-inch windscreens used throughout the acoustical monitoring allowed for accurate measurement of A-weighted sound levels even with such winds, the sound levels calculated using other weighting networks may have at times been briefly affected.

No particular sound level weighting shows a consistent association with the greatest broadband sound level increases. This suggests that the increases from ambient sound conditions due to operation of the KWI turbine that were measured at 13 Schofield Road are likely comparable across most frequencies of the sound spectrum, as further supported by the octave band sound level increase analysis discussed below in Section 7.2.

Tables 24 through 26 present low frequency and infrasound monitoring results comparing the broadband sound level increases calculated using various weighting networks for each night of acoustical monitoring of the KWI wind turbine conducted at the 3 Leland Road, 11 Leland Road, and 38 Prospect Street measurement sites, respectively.

The monitoring results for these locations indicate that broadband sound level increases from ambient conditions due to operation of the KWI turbine are often several decibels lower when calculated using A-weighting as compared to the other sound level weightings. The A-weighted sound level increases measured at these sites are also generally several decibels lower than the increases observed at 13 Schofield Road for comparable wind speed ranges, while somewhat smaller relative differences are found using the other sound level weightings. These findings imply that turbine sound level attenuation with distance is greater for higher frequencies of sound and somewhat less for lower frequencies, as further supported by the octave band analysis discussed in Section 7.2.

Table 27 presents low frequency and infrasound monitoring results comparing the sound level increases calculated using various broadband weighting networks for daytime acoustical monitoring of the KWI wind turbine conducted at the Kingston Intermediate School on February 28, 2014.

The results of the daytime monitoring at the Intermediate School indicate that the broadband sound level increase from ambient conditions due to operation of the KWI turbine was very small (less than 2 dB) when calculated using any of the sound level weightings included in Table 27. Also, note that the HMMH technician/analyst observed an increase in aircraft overflights and wind-generated sound during the period when the wind turbine was operating. These ambient sound events likely contributed to the marginal sound level increases observed.

7.2 Octave Band Sound Level Increase Assessment

Figures 4 through 15 provide slow-response octave band sound levels for monitoring periods with the KWI turbine operating and shut down as well as corresponding octave band sound level increases for each night of acoustical monitoring conducted at the 13 Schofield Road, 3 Leland Road, 11 Leland Road, and 38 Prospect Street measurement sites, respectively. Results from the daytime acoustical monitoring conducted at the Kingston Intermediate School are not included because traffic dominated sound levels throughout the measurement and therefore sound levels “excluding Route 3 traffic“ and directly attributable to the KWI wind turbine could not be calculated.

Figures 4, 7, 10, and 12 present the slow-response equivalent (L_{eq}) octave band sound levels measured at each monitoring location during periods dominated by sound from the KWI turbine. In some instances peaks are observed in the turbine sound spectra at 250 Hz and 500 Hz. However, the increases relative to adjacent octave bands were below the 3 dB threshold for a pure-tone condition per MassDEP noise policy as outlined in Section 3 and Appendix B.

Figures 5, 8, 11, and 13 present the slow-response ambient L_{90} octave band sound levels that were measured at each monitoring site. In some instances peaks are observed in the ambient sound spectra at 1000 Hz due to sound from distant commercial/industrial equipment.

Figures 6, 9, 12, and 15 provide the turbine-only L_{eq} to ambient L_{90} octave band sound level increases measured at each site for corresponding monitoring periods with the KWI turbine operating and shut down. Overall, the data collected at 13 Schofield Road indicates octave band sound level increases with moderate to higher wind speeds in the range of 10 to 14 dB or more for most octave bands up to 2000 Hz, while the largest octave band increases are closer to 10 to 12 dB in certain octave bands at the more distant monitoring locations.

Furthermore, the octave band sound level increases measured at the 13 Schofield Road monitoring site are generally comparable among the various octave bands, which supports the finding in Section 7.1 that measured broadband sound level increases were very similar among the different sound level weightings.

Also, octave band sound level increases measured at the more distant monitoring locations are generally somewhat greater in the lower frequency octave bands (relative to the higher frequency octave bands), indicating that higher frequency sound generated by the turbine attenuates at a greater rate with distance. This supports the findings in Section 7.1 that 1) the broadband sound level increases measured at these sites were somewhat lower when calculated using A-weighting as compared with other sound level weightings that include larger contributions from low frequency sound and that 2) the A-weighted sound level increases measured in these locations were typically several decibels lower than the increases observed on Schofield Road during comparable periods, while broadband sound level increases calculated using other sound level weighting networks were much closer to the Schofield Road monitoring results.

Table 23. Summary of Low Frequency and Infrasound Monitoring at 13 Schofield Road

Date	10-min Avg Wind Speeds (m/s)	10-min Avg Wind Directions	10-min Avg Power Levels (kW)	KWI Wind Turbine Acoustical Metric	Increase from Ambient L90 (slow response) 20-min Acoustical Metrics for KWI Wind Turbine ONLY (excl. Route 3 traffic) 20-min Ambient L90 with KWI Wind Turbine SHUTDOWN (incl. Route 3 traffic)			
					(dBA)	(dBC)	(dBZ)	(dBG)
4/7/2014	5 to 6	SW to WSW	130 to 210	Avg Lmax	9.3	8.6	7.6	7.4
				Leq	6.4	5.5	4.8	4.6
				L90	4.2	3.2	3.0	3.0
3/22/2014	7 to 8	SW	539 to 669	Avg Lmax	12.5	10.9	11.5	12.6
				Leq	10.2	8.6	9.3	10.1
				L90	8.3	7.3	7.7	8.4
3/2/2014	8 to 9	SSW	831 to 1026	Avg Lmax	15.0	15.5	15.7	17.3
				Leq	12.2	12.7	12.7	13.4
				L90	8.6	9.4	8.8	9.5
3/15/2014	10	South	1505 to 1805	Avg Lmax	13.7	15.1	17.8	16.6
				Leq	11.3	12.7	12.4	12.5
				L90	10.1	11.4	10.8	10.7

Notes:
1) Detailed acoustical monitoring data are provided in **Appendix D**.
2) High frequency sound from spring peepers removed from data collected on 4/7/2014.

Figure 4. 20-minute Slow-response Octave Band Equivalent (Leq) Sound Levels
13 Schofield Road - KWI Wind Turbine ONLY (excluding Route 3 traffic)

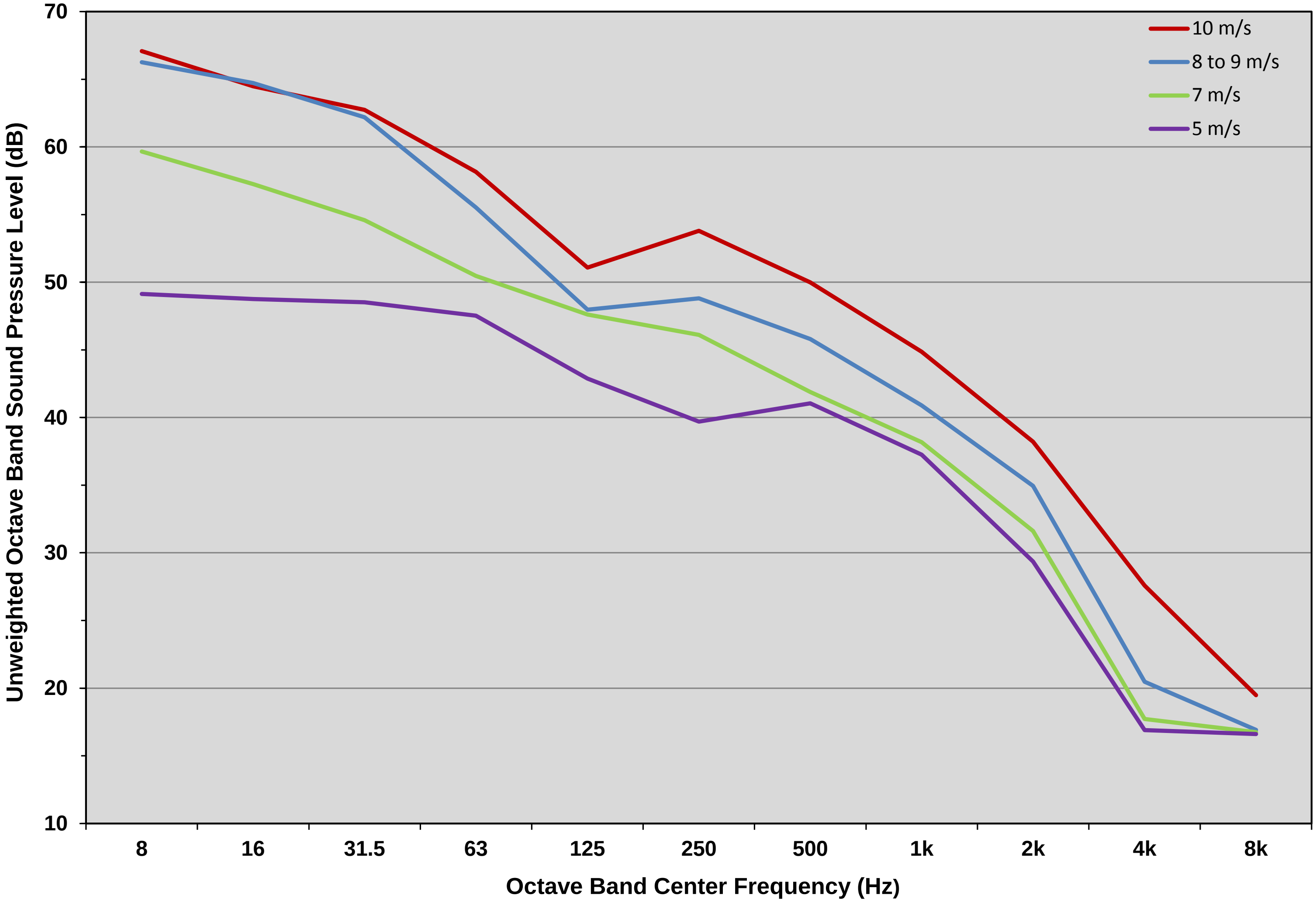


Figure 5. 20-minute Slow-response Octave Band Ambient (L90) Sound Levels
13 Schofield Road - KWI Wind Turbine SHUTDOWN (including Route 3 traffic)

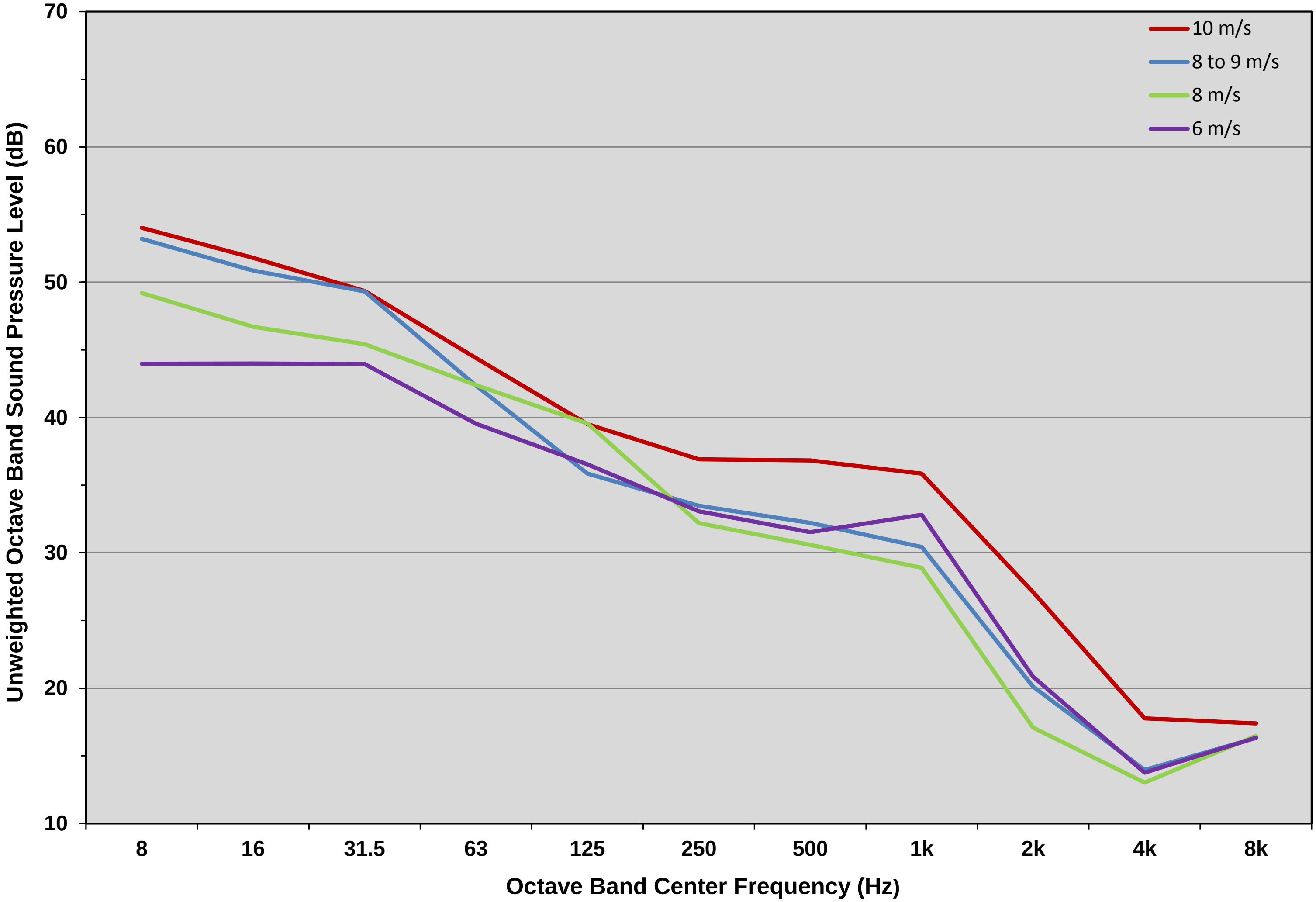


Figure 6. Slow-response Octave Band Sound Level Increases
from Ambient L90 to KWI Wind Turbine ONLY Leq - 13 Schofield Road

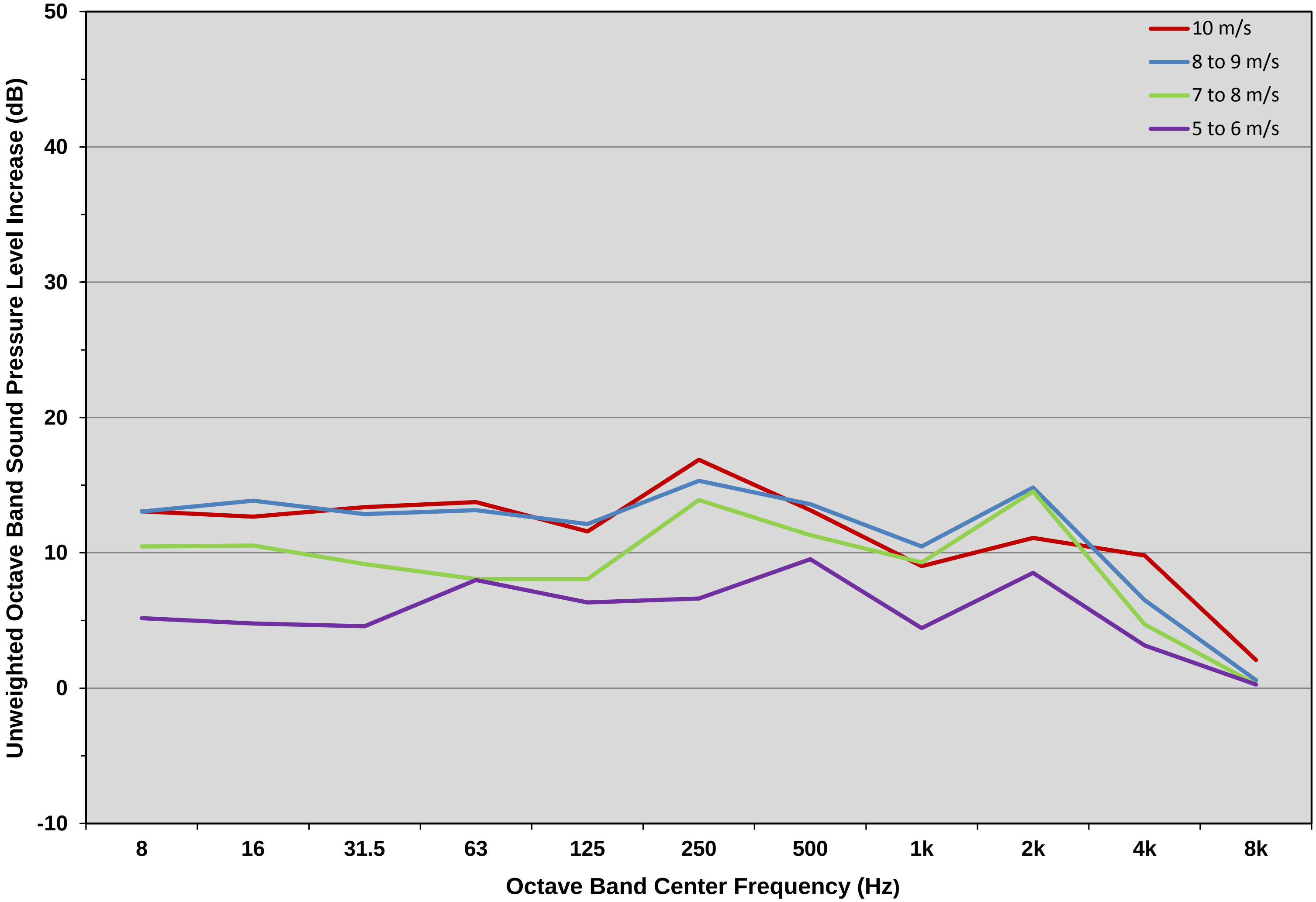


Table 24. Summary of Low Frequency and Infrasound Monitoring at 3 Leland Road

Date	10-min Avg Wind Speeds (m/s)	10-min Avg Wind Directions	10-min Avg Power Levels (kW)	KWI Wind Turbine Acoustical Metric	Increase from Ambient L90 (slow response) 20-min Acoustical Metrics for KWI Wind Turbine ONLY (excl. Route 3 traffic) 20-min Ambient L90 with KWI Wind Turbine SHUTDOWN (incl. Route 3 traffic)			
					(dBA)	(dBC)	(dBZ)	(dBG)
4/7/2014	5 to 7	WSW to W	173 to 189	Avg Lmax	0.2	1.6	1.4	3.0
				Leq	-0.5	0.4	0.5	2.0
				L90	-1.3	-0.5	-0.4	0.7
3/22/2014	7 to 8	SW	586 to 819	Avg Lmax	4.3	8.0	10.5	12.4
				Leq	2.6	6.2	8.5	9.9
				L90	0.9	5.0	7.0	8.1
3/2/2014	8 to 9	SSW	827 to 1139	Avg Lmax	4.8	10.7	11.9	14.1
				Leq	4.2	9.3	10.2	11.8
				L90	3.1	7.8	8.5	9.7
3/15/2014	10	South	1505 to 1805	Avg Lmax	8.8	12.9	14.9	15.1
				Leq	7.6	10.4	10.8	11.1
				L90	6.6	9.2	8.7	9.1

Notes:
1) Detailed acoustical monitoring data are provided in **Appendix D**.
2) High frequency sound from spring peepers removed from data collected on 4/7/2014.

Figure 7. 20-minute Slow-response Octave Band Equivalent (Leq) Sound Levels
3 Leland Road - KWI Wind Turbine ONLY (excluding Route 3 traffic)

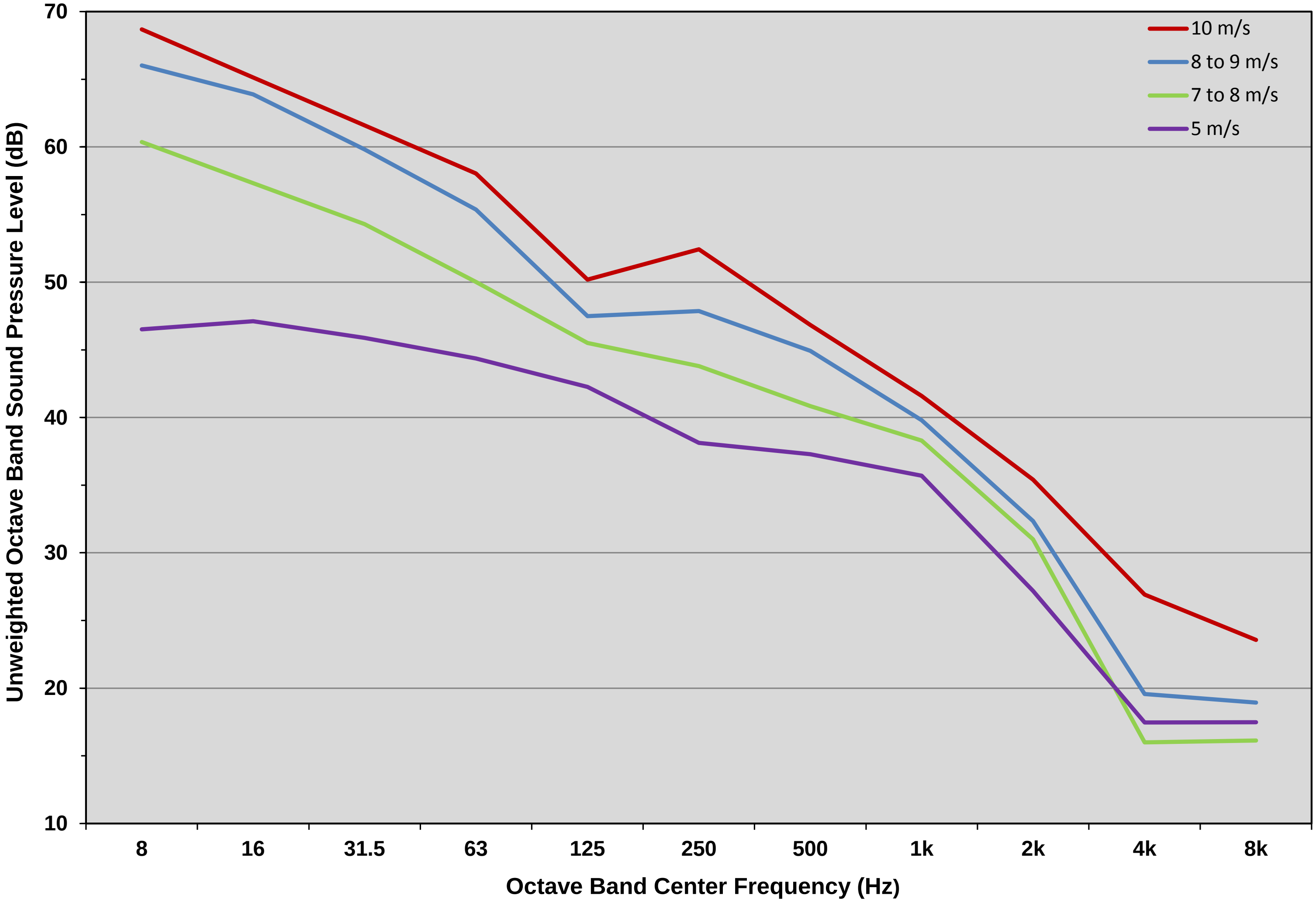


Figure 8. 20-minute Slow-response Octave Band Ambient (L90) Sound Levels
3 Leland Road - KWI Wind Turbine SHUTDOWN (including Route 3 traffic)

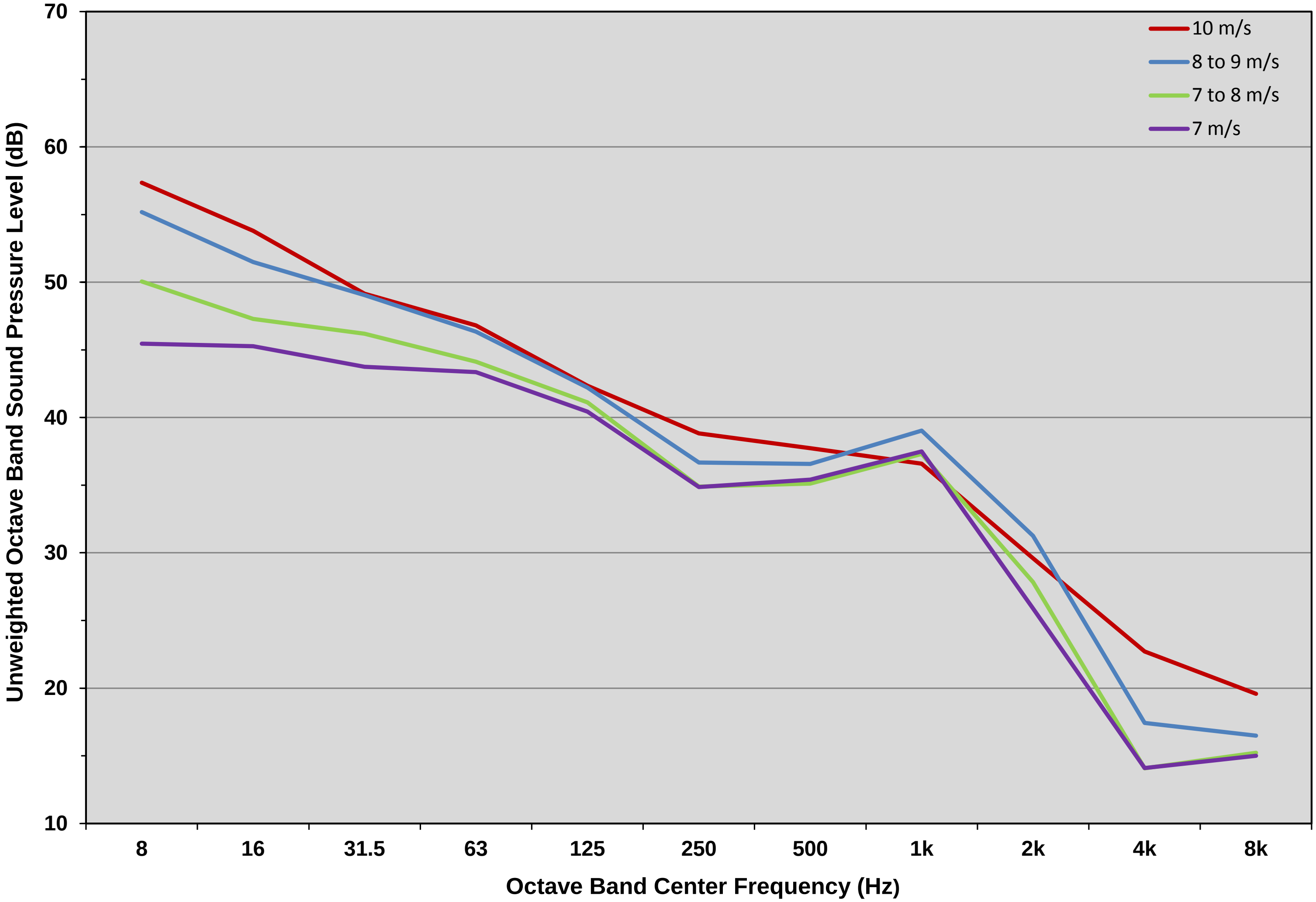


Figure 9. Slow-response Octave Band Sound Level Increases
from Ambient L90 to KWI Wind Turbine ONLY Leq - 3 Leland Road

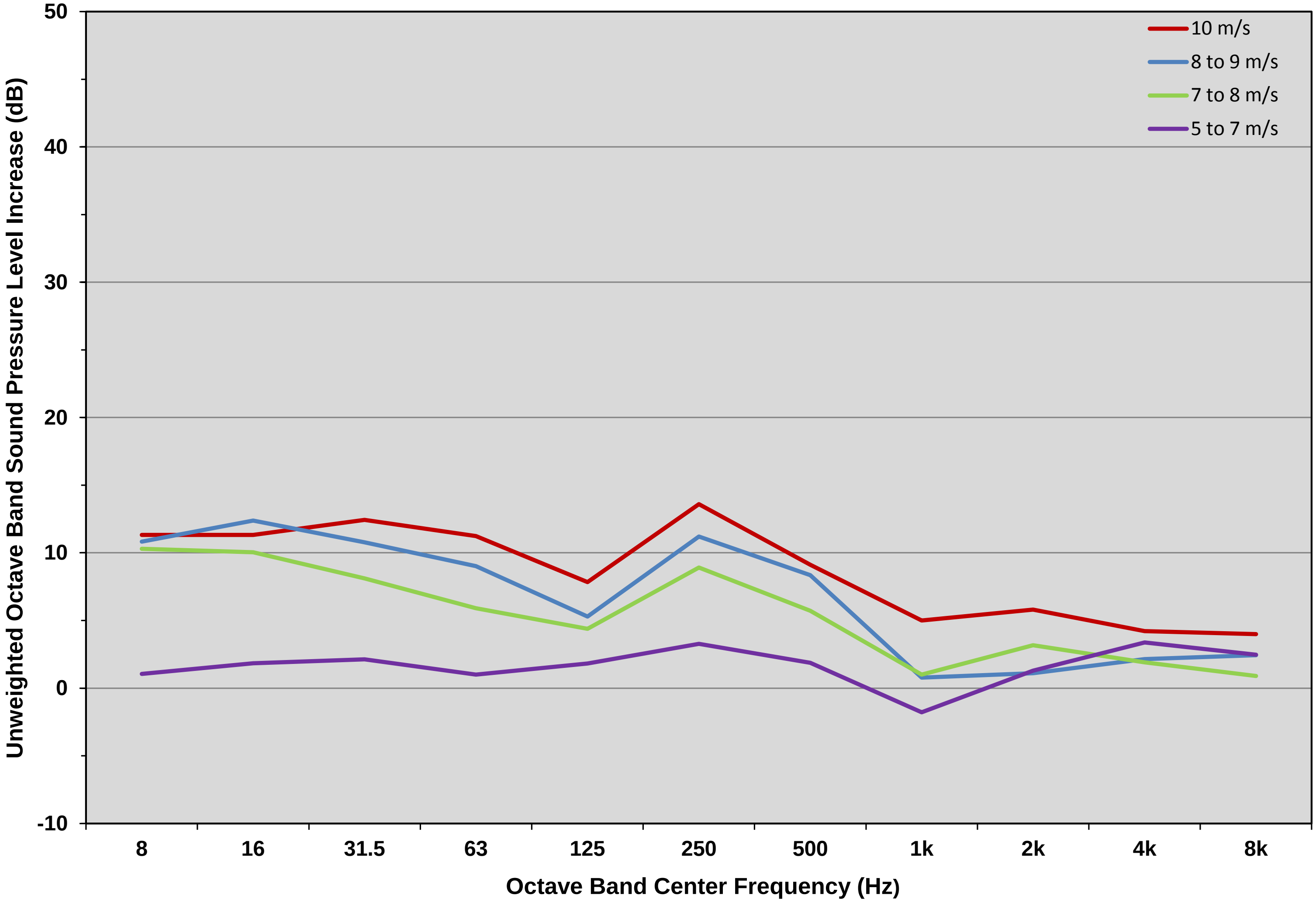


Table 25. Summary of Low Frequency and Infrasound Monitoring at 11 Leland Road

Date	10-min Avg Wind Speeds (m/s)	10-min Avg Wind Directions	10-min Avg Power Levels (kW)	KWI Wind Turbine Acoustical Metric	Increase from Ambient L90 (slow response) 20-min Acoustical Metrics for KWI Wind Turbine ONLY (excl. Route 3 traffic) 20-min Ambient L90 with KWI Wind Turbine SHUTDOWN (incl. Route 3 traffic)			
					(dBA)	(dBC)	(dBZ)	(dBG)
4/7/2014	5 to 6	SW to WSW	130 to 210	Avg Lmax	6.3	7.2	6.5	7.4
				Leq	4.1	3.9	3.5	3.9
				L90	2.1	1.9	2.0	2.0
3/22/2014	7 to 8	SW	539 to 669	Avg Lmax	10.1	7.5	9.0	10.4
				Leq	7.7	5.9	7.0	7.9
				L90	5.9	5.1	5.8	6.5
3/2/2014	8 to 9	SSW	827 to 1139	Avg Lmax	5.8	10.4	11.7	12.6
				Leq	4.2	8.3	9.1	9.9
				L90	2.7	6.3	7.0	8.0
3/15/2014	10 to 11	South	1422 to 1880	Avg Lmax	7.3	10.8	10.8	11.3
				Leq	5.8	9.0	9.1	9.2
				L90	4.6	7.6	7.7	7.5

Notes:

1) Detailed acoustical monitoring data are provided in **Appendix D**.

2) High frequency sound from spring peepers removed from data collected on 4/7/2014.

Figure 10. 20-minute Slow-response Octave Band Equivalent (Leq) Sound Levels
11 Leland Road - KWI Wind Turbine ONLY (excluding Route 3 traffic)

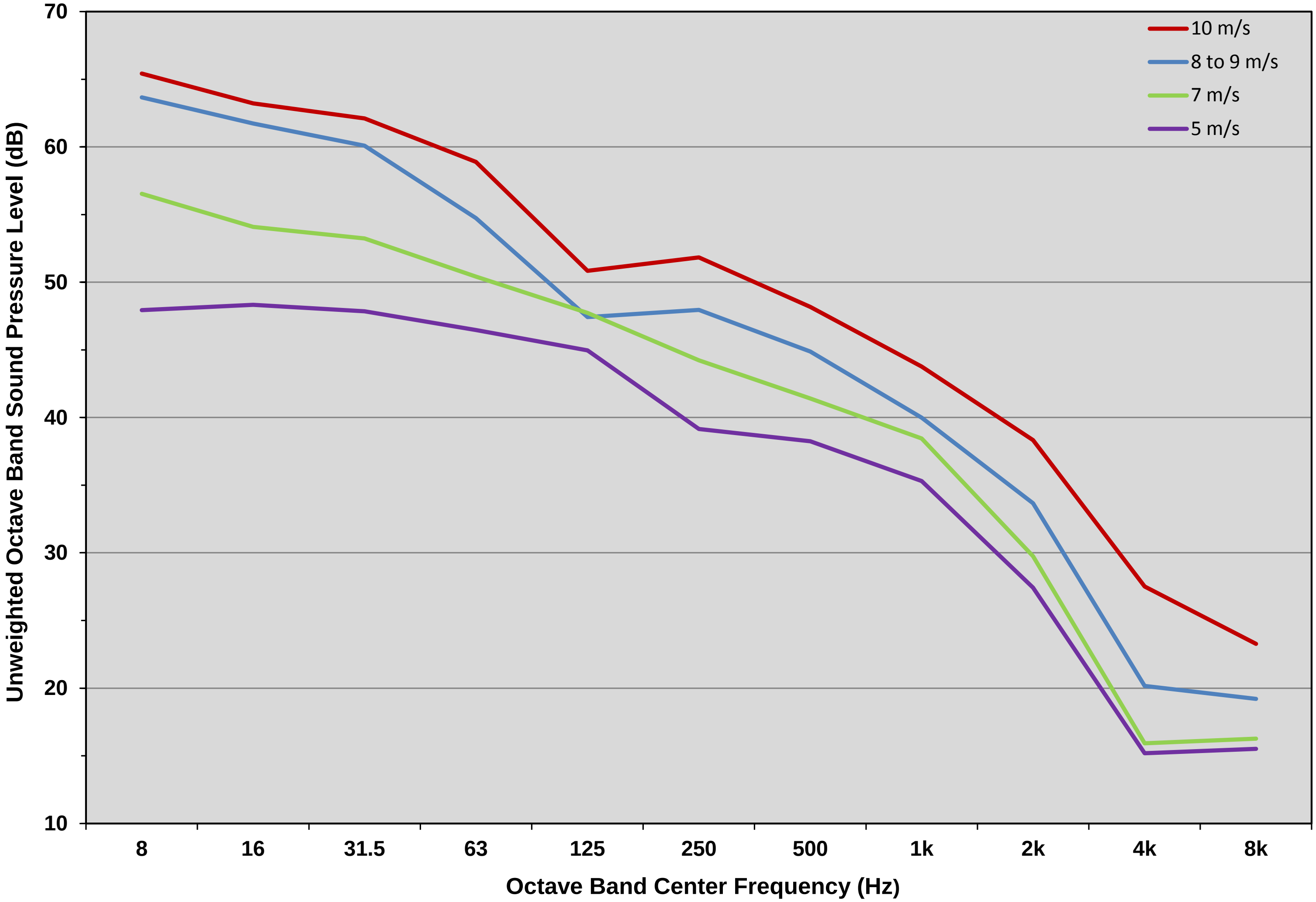


Figure 11. 20-minute Slow-response Octave Band Ambient (L90) Sound Levels
11 Leland Road - KWI Wind Turbine SHUTDOWN (including Route 3 traffic)

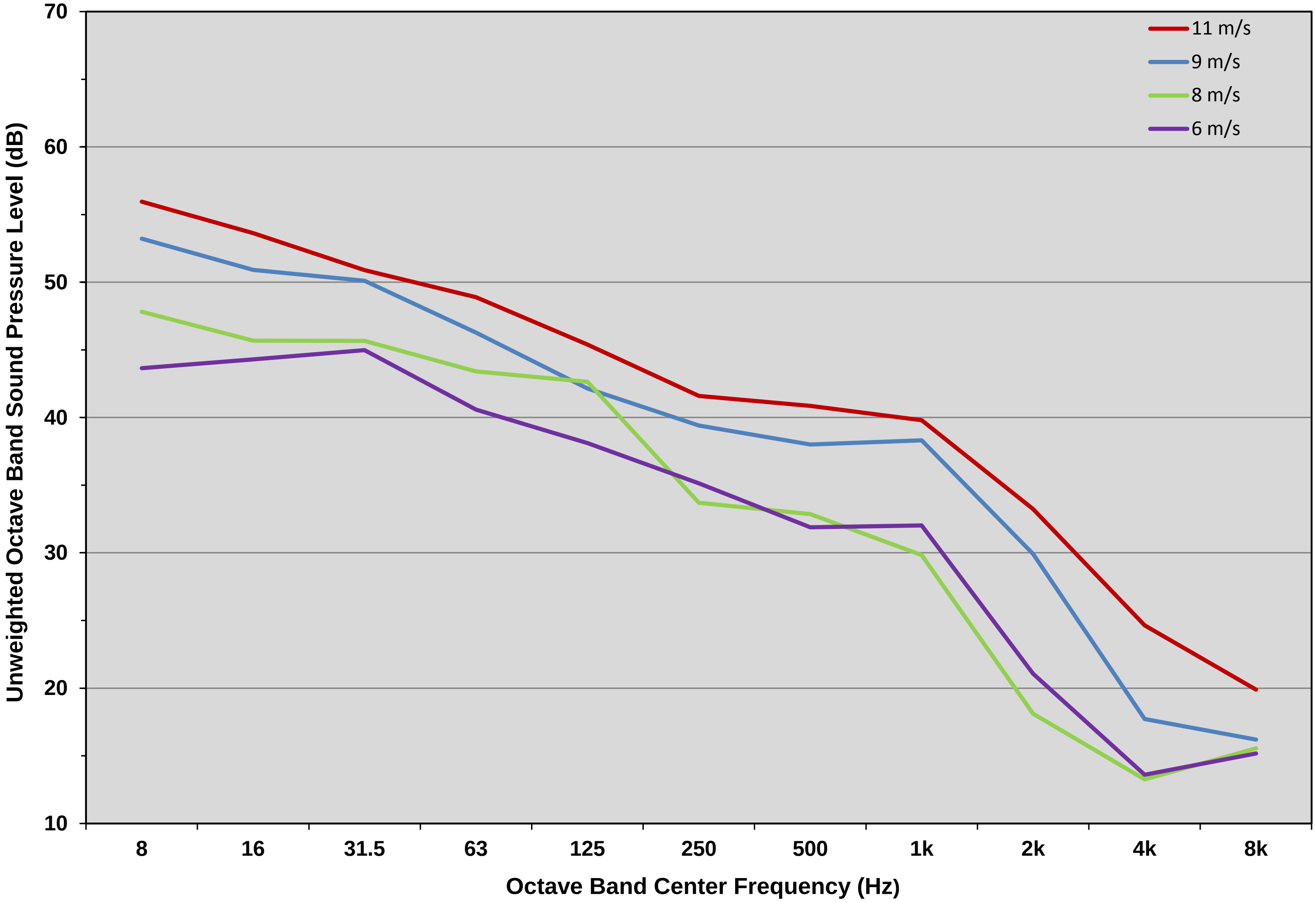


Figure 12. Slow-response Octave Band Sound Level Increases from Ambient L90 to KWI Wind Turbine ONLY Leq - 11 Leland Road

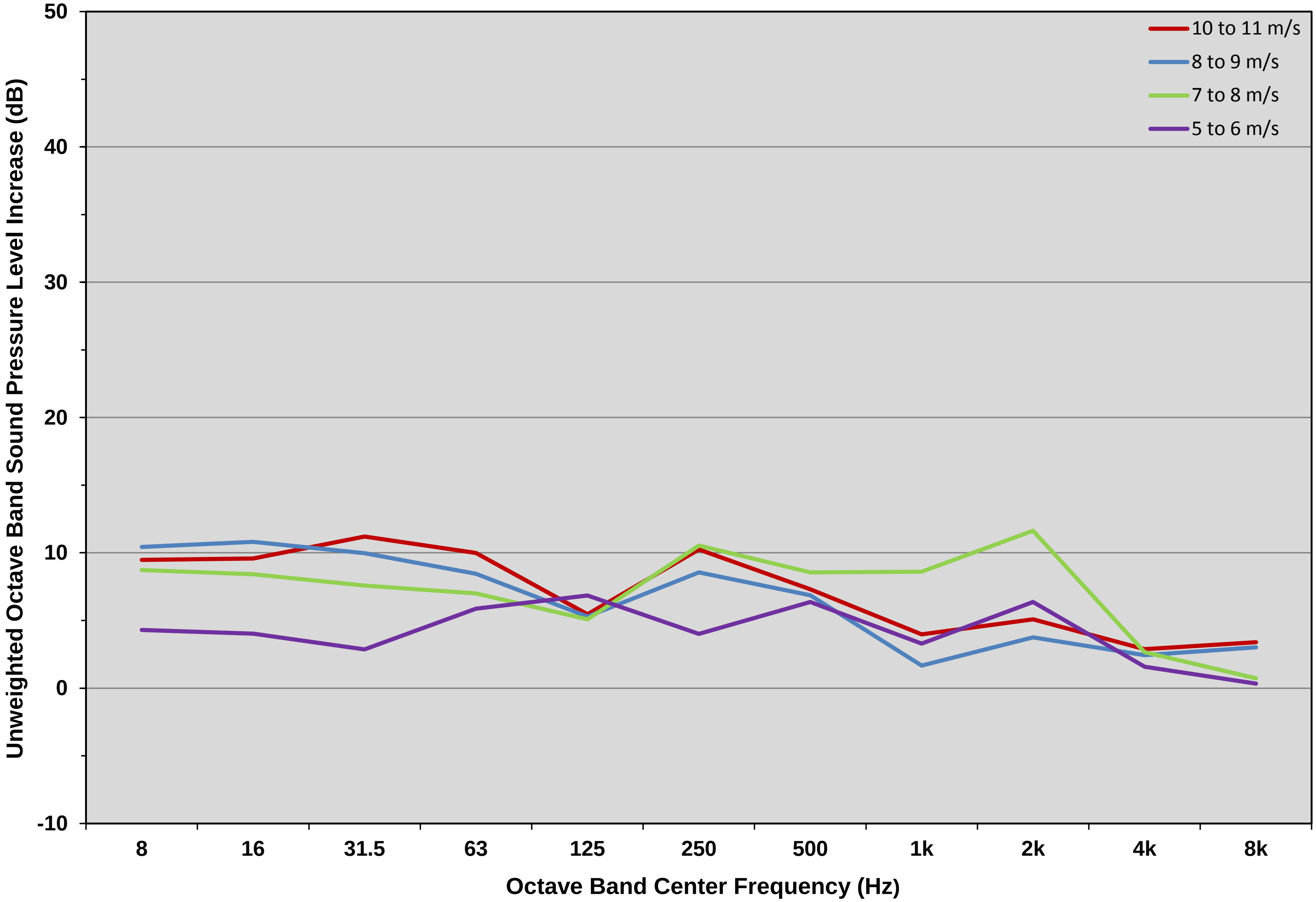


Table 26. Summary of Low Frequency and Infrasound Monitoring at 38 Prospect Street

Date	10-min Avg Wind Speeds (m/s)	10-min Avg Wind Directions	10-min Avg Power Levels (kW)	KWI Wind Turbine Acoustical Metric	Increase from Ambient L90 (slow response) 20-min Acoustical Metrics for KWI Wind Turbine ONLY (excl. Route 3 traffic) 20-min Ambient L90 with KWI Wind Turbine SHUTDOWN (incl. Route 3 traffic)			
					(dBA)	(dBC)	(dBZ)	(dBG)
4/7/2014	5 to 7	WSW to W	173 to 189	Avg Lmax	-1.4	-1.4	-0.5	2.8
				Leq	-1.7	-1.6	-1.0	1.4
				L90	-2.7	-2.8	-1.9	0.0
3/22/2014	7 to 8	SW	586 to 819	Avg Lmax	2.6	5.6	8.2	10.8
				Leq	1.8	4.0	6.3	8.1
				L90	0.8	2.7	4.9	6.2
3/2/2014	8 to 9	SSW	831 to 1026	Avg Lmax	7.5	9.5	11.7	13.0
				Leq	5.8	7.3	8.8	9.9
				L90	2.2	3.6	5.1	6.0
3/15/2014	10 to 11	South	1422 to 1880	Avg Lmax	6.2	9.7	13.9	13.8
				Leq	4.6	7.2	9.6	9.7
				L90	3.4	5.7	6.4	7.0

Notes:
1) Detailed acoustical monitoring data are provided in **Appendix D**.
2) High frequency sound from spring peepers removed from data collected on 4/7/2014.
3) High frequency sound from cord tapping on a flagpole removed from data collected on 3/15/2014.

Figure 13. 20-minute Slow-response Octave Band Equivalent (Leq) Sound Levels
38 Prospect Street - KWI Wind Turbine ONLY (excluding Route 3 traffic)

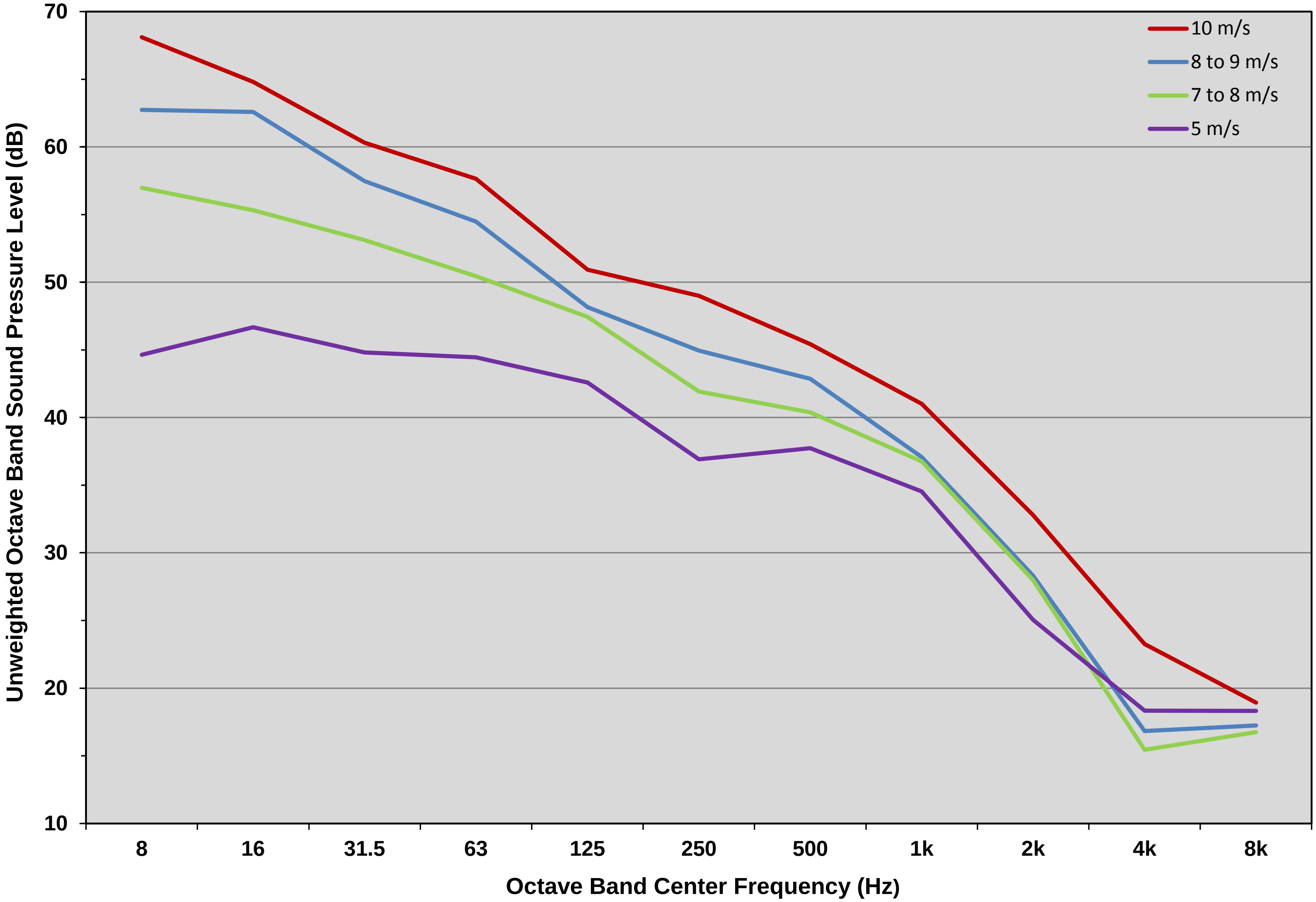


Figure 14. 20-minute Slow-response Octave Band Ambient (L90) Sound Levels
38 Prospect Street - KWI Wind Turbine SHUTDOWN (including Route 3 traffic)

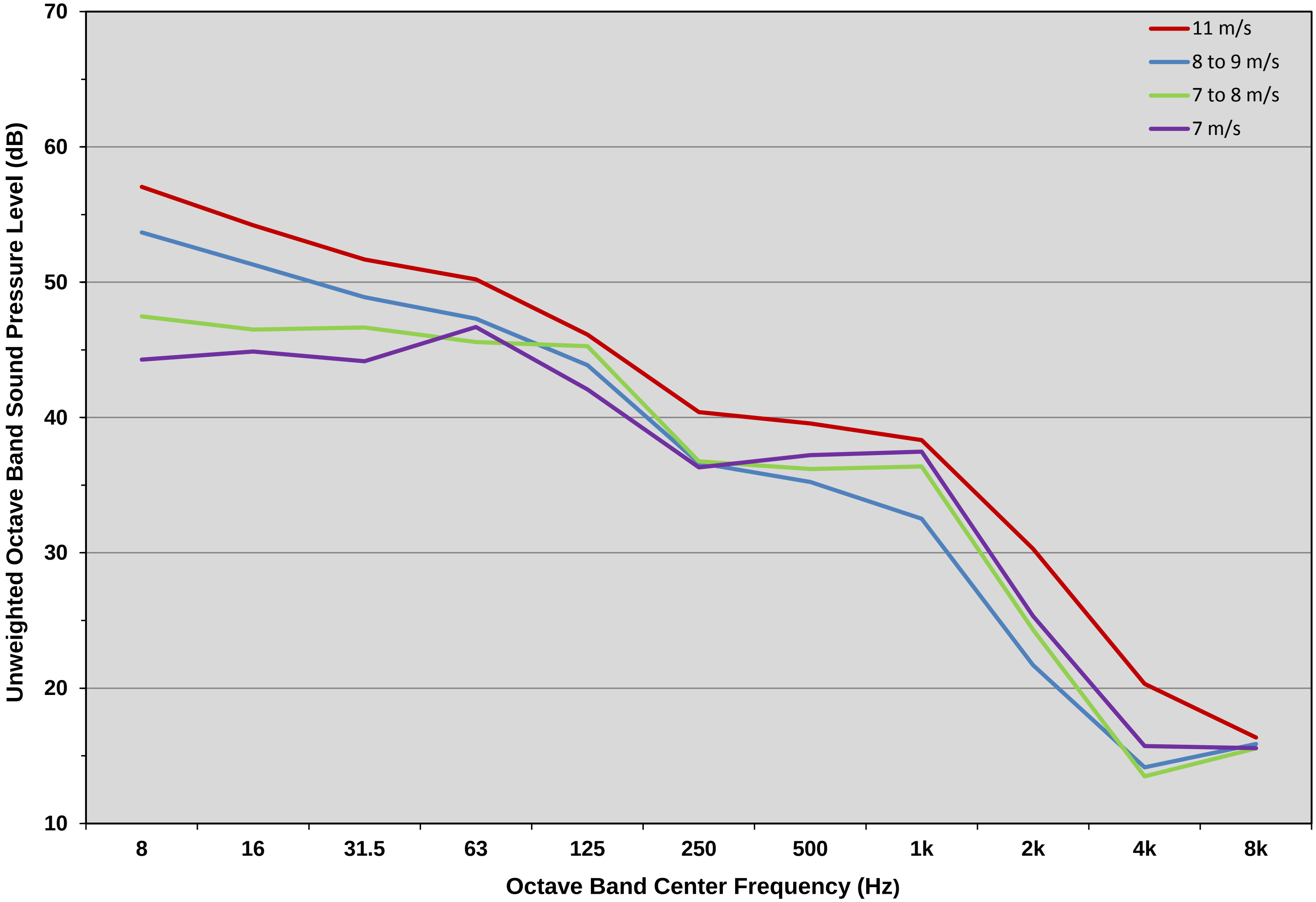


Figure 15. Slow-response Octave Band Sound Level Increases from Ambient L90 to KWI Wind Turbine ONLY Leq - 38 Prospect Street

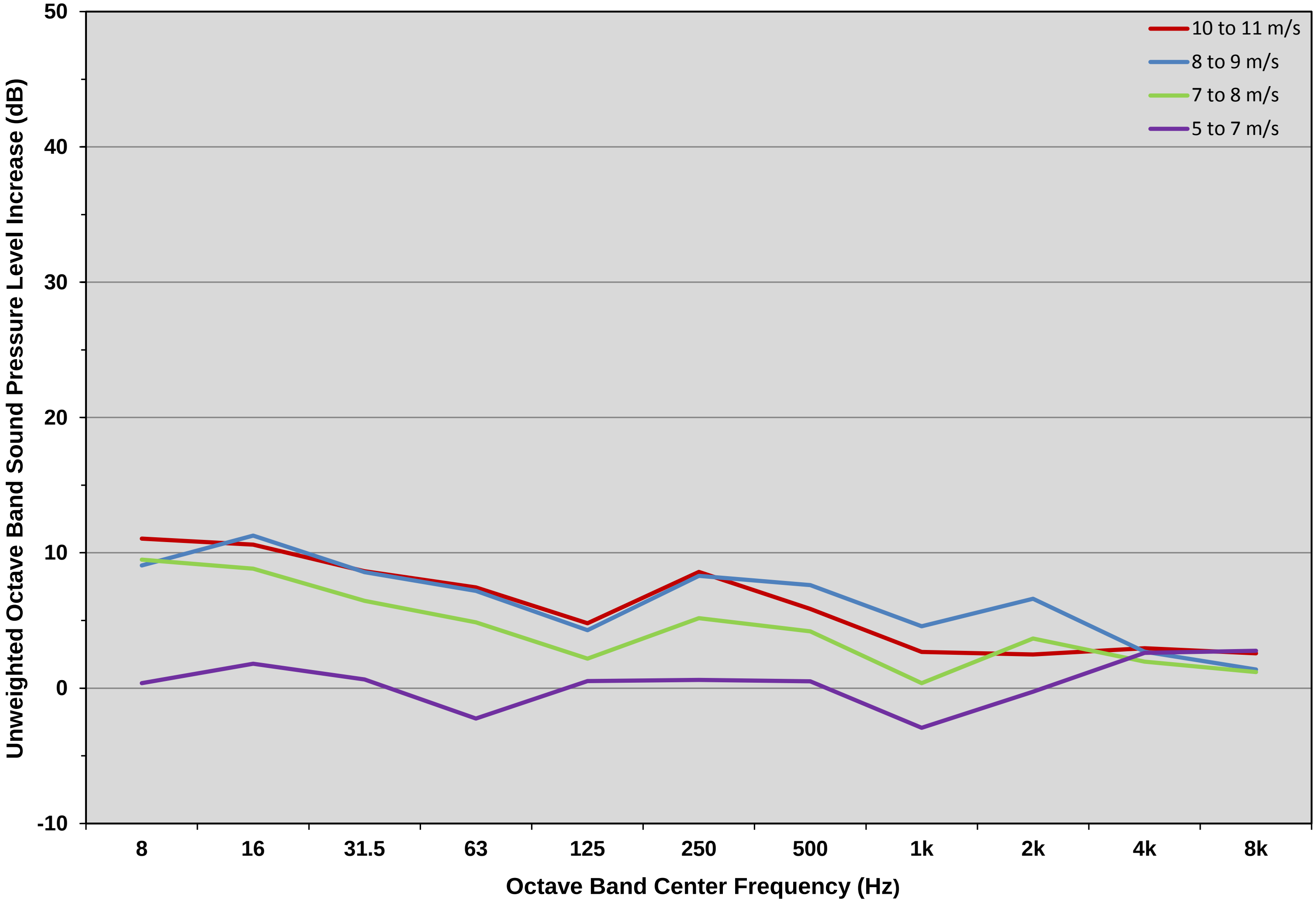


Table 27. Summary of Low Frequency and Infrasound Monitoring at Kingston Intermediate School

Date	10-min Avg Wind Speeds (m/s)	10-min Avg Wind Directions	10-min Avg Power Levels (kW)	L90 to L90 Increase (slow response) 20-min L90 with KWI Wind Turbine OPERATING (incl. Route 3 traffic) 20-min Ambient L90 with KWI Wind Turbine SHUTDOWN (incl. Route 3 traffic)			
				dBA	dBC	dBZ	dBG
2/18/2014	6 to 8	East	428 to 690	0.4	1.5	1.8	1.5

Notes:

1) Detailed acoustical monitoring data are provided in **Appendix D**.

2) High frequency sound from heating system exhaust removed from data.

3) Increases in aircraft overflights and wind-generated noise contributed to L90 sound level increases.

8 Results of Modulation Depth Analysis

A sound level amplitude modulation analysis was conducted in supplement to the acoustical monitoring results detailed in Sections 6 and 7 for broadband and octave band sound level increases.

Amplitude modulation is defined as a periodic variation in sound levels over time. Wind turbines regularly generate broadband amplitude-modulated sound that is often characterized as a “swishing” sound and is associated with the turbine rotational speed and blade passage frequency, typically with a period of around 1 second which is equivalent to a modulation frequency of about 1 Hz and corresponds with one blade on a three-blade turbine passing a point in space each second. Ambient sound sources such as traffic on Route 3 may at times also generate broadband amplitude-modulated sound, though generally ambient sound level variations are somewhat random and only very occasionally periodic.

Modulation depth is a metric used to assess the degree of sound level amplitude modulation associated with an acoustic signal. Sound level modulation depths were calculated for monitoring periods with the KWI turbine operating and compared to the modulations depths computed for ambient conditions. One limitation of this approach is that modulation depth analysis cannot distinguish between random ambient sound level variations that occur briefly within a short time span and periodic sound level modulations associated with the KWI turbine that occur more regularly over a longer timeframe.

For purposes of this study, modulation depth was defined as the maximum fast-response A-weighted sound level difference (peak-to-trough) within 1/2 second of each 1/10th second data sample. This design allowed sound level modulations with frequencies from 0.5 to 5 Hz to be evaluated, an appropriate range for examining wind turbine sound. The individual 1/10-second modulation depth calculations were subsequently analyzed in 5-minute and 20-minute intervals using the same metrics that were utilized for the measured sound level data.

Appendix A provides a detailed description of the sound metrics and terminology used in this report and includes an illustration of modulation depth calculations in Figure A-3.

Tables 28 through 32 present comparisons of modulation depth calculations between the various periods of acoustical monitoring conducted at each measurement site, including with the KWI turbine operating and also shut down and both with and without Route 3 traffic sound. Statistical percentile modulation depth levels are shown in these tables (L_n, denoting the modulation depth exceeded n-percent of the time), and include the L_{01}, which represents typical maximum modulation depths, the L_{50}, which represents the median modulation depth, and the L_{90}, which represents the modulation depth exceeded 90% of the time.

Figures 16 through 19 provide example fast-response A-weighted sound level time histories that depict varying levels of amplitude modulation measured during periods dominated by wind turbine sound.

Additional detailed modulation depth data are included in Appendix D.

Also, very high frequency sound generated by spring peepers occurred intermittently throughout the acoustical monitoring conducted on April 7, 2014. This sound could not be filtered out of the data used for the modulation depth analysis since the instrumentation could only log broadband A-weighted sound levels at a 1/10-second rate and additional octave band data could not be collected. However, this biogenic sound was only observed to have a significant effect on sound levels at the 38 Prospect Street measurement site. Other high frequency sound events that occurred intermittently during the acoustical monitoring are likewise included in the modulation depth calculations in some instances, such as sound from a cord tapping on a flagpole at 38 Prospect Street and sound from a heating system exhaust vent at the Kingston Intermediate School.

8.1 Modulation Depth Calculations

Tables 28 through 32 present comparisons of modulation depth calculations between the various periods of nighttime acoustical monitoring conducted at the 13 Schofield Road, 3 Leland Road, 11 Leland Road, 38 Prospect Street, and Kingston Intermediate School measurement sites, respectively.

The results indicate that sound level modulation depths calculated for periods with the KWI turbine operating at low to moderate wind speeds of 5 to 8 m/s are less than or comparable to the modulation depths calculated for periods with the wind turbine shut down. However, the modulation depths calculated for periods with the KWI turbine operating at moderate to higher wind speeds of 8 to 10 m/s are up to approximately 1 to 3 dBA greater as compared with ambient conditions, a level of increase which is likely noticeable to the average person.

Also, there was no significant difference observed between the sound level modulation depths calculated for periods with the KWI turbine operating and shut down during the daytime acoustical monitoring conducted at the Kingston Intermediate School. This finding is consistent with our experience that Route 3 traffic dominated sound levels throughout the measurement.

8.2 Modulation Depth Example Time-histories

Figures 16 through 19 provide example fast-response A-weighted sound level time histories that depict varying levels of amplitude modulation measured at different wind speeds at the 13 Schofield Road, 3 Leland Road, 11 Leland Road, and 38 Prospect Street measurement sites, respectively, during periods dominated by sound from the KWI wind turbine. In addition to illustrating a general increase in modulation depth with increasing wind speed, the fast-response sound level time histories also indicate a modulation frequency of around 1 Hz, which is typical for wind turbine sound.

While a detailed analysis of the frequency of occurrence of sound level amplitude modulation was beyond the scope of this study, it is anticipated that modulations associated with operation of the KWI wind turbine are generally periodic (as illustrated in Figures 16 through 19) and recur on a regular basis, whereas ambient sound level variations are generally more random and only very occasionally periodic.

Also, results from the daytime acoustical monitoring conducted at the Kingston Intermediate School are not included because traffic sound dominated sound levels throughout the measurement and there were not any periods dominated by wind turbine sound.

Table 28. Summary of Modulation Depth Analysis for 13 Schofield Road

Date	10-min Avg Wind Speeds (m/s)	10-min Avg Wind Directions	10-min Avg Power Levels (kW)	Modulation Depth Acoustical Metric (fast response)	KWI Wind Turbine OPERATING (dBA) (incl. Route 3 traffic)	KWI Wind Turbine ONLY (dBA) (excl. Route 3 traffic)	KWI Wind Turbine SHUTDOWN (dBA) (incl. Route 3 traffic)	KWI Wind Turbine SHUTDOWN (dBA) (excl. Route 3 traffic)
4/7/2014	5 to 6	SW to WSW	130 to 210	L01	3.0	2.4	3.9	3.0
				L50	0.6	1.0	1.2	1.1
				L90	0.6	0.6	0.7	0.6
3/22/2014	7 to 8	SW	539 to 669	L01	3.0	3.0	3.7	3.6
				L50	0.8	1.5	1.1	1.0
				L90	0.8	0.9	0.6	0.6
3/2/2014	8 to 9	SSW	831 to 1026	L01	4.5	4.9	3.2	2.9
				L50	1.1	2.1	1.1	1.0
				L90	1.1	1.2	0.6	0.6
3/15/2014	10	South	1505 to 1805	L01	5.2	5.4	3.2	2.2
				L50	1.3	2.5	1.0	0.9
				L90	1.2	1.5	0.6	0.6

Notes:
1) Detailed acoustical monitoring data are provided in **Appendix D**.
2) Data used for modulation depth analysis on 4/7/2014 includes high frequency sound from spring peepers.
3) Modulation depth is maximum fast response A-weighted sound level difference within 1/2 second of each 1/10th second data sample.

Figure 16. Modulation Depth Comparison: Fast-response A-level Time Histories
13 Schofield Road - KWI Wind Turbine ONLY (excluding Route 3 traffic)

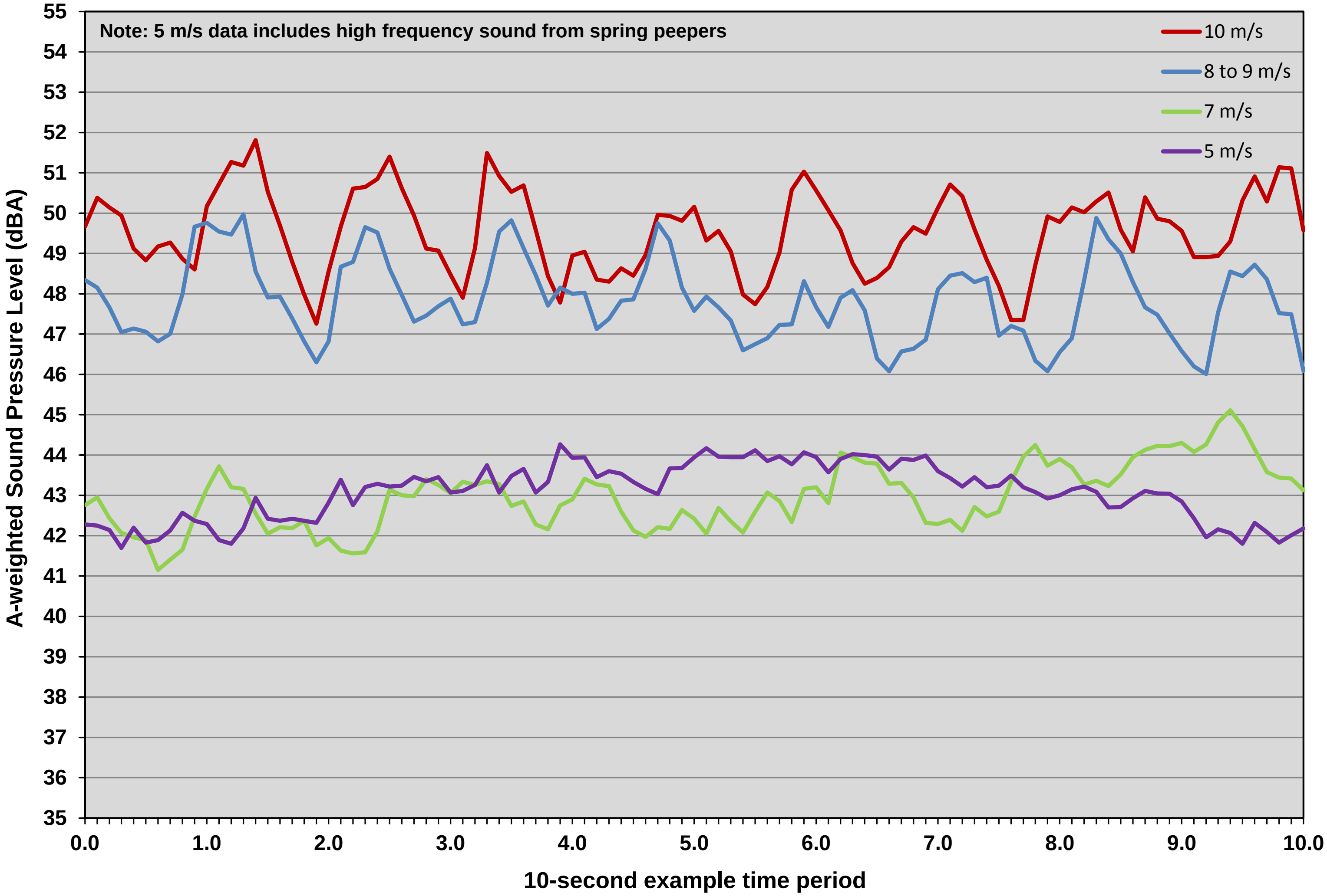


Table 29. Summary of Modulation Depth Analysis for 3 Leland Road

Date	10-min Avg Wind Speeds (m/s)	10-min Avg Wind Directions	10-min Avg Power Levels (kW)	Modulation Depth Acoustical Metric (fast response)	KWI Wind Turbine OPERATING (dBA) (incl. Route 3 traffic)	KWI Wind Turbine ONLY (dBA) (excl. Route 3 traffic)	KWI Wind Turbine SHUTDOWN (dBA) (incl. Route 3 traffic)	KWI Wind Turbine SHUTDOWN (dBA) (excl. Route 3 traffic)
4/7/2014	5 to 7	WSW to W	173 to 189	L01	4.7	2.2	4.6	2.0
				L50	0.7	1.0	1.3	1.0
				L90	0.7	0.6	0.7	0.6
3/22/2014	7 to 8	SW	586 to 819	L01	3.0	3.4	3.6	2.2
				L50	0.8	1.4	1.1	0.8
				L90	0.7	0.8	0.6	0.5
3/2/2014	8 to 9	SSW	827 to 1139	L01	3.6	4.3	3.7	2.4
				L50	0.9	2.2	1.1	0.8
				L90	0.8	1.4	0.6	0.5
3/15/2014	10	South	1505 to 1805	L01	5.2	5.3	2.9	2.0
				L50	1.1	2.6	0.9	0.9
				L90	1.1	1.5	0.5	0.5

Notes:

1) Detailed acoustical monitoring data are provided in **Appendix D**.

2) Data used for modulation depth analysis on 4/7/2014 includes high frequency sound from spring peepers.

3) Modulation depth is maximum fast response A-weighted sound level difference within 1/2 second of each 1/10th second data sample.

Figure 17. Modulation Depth Comparison: Fast-response A-level Time Histories
3 Leland Road - KWI Wind Turbine ONLY (excluding Route 3 traffic)

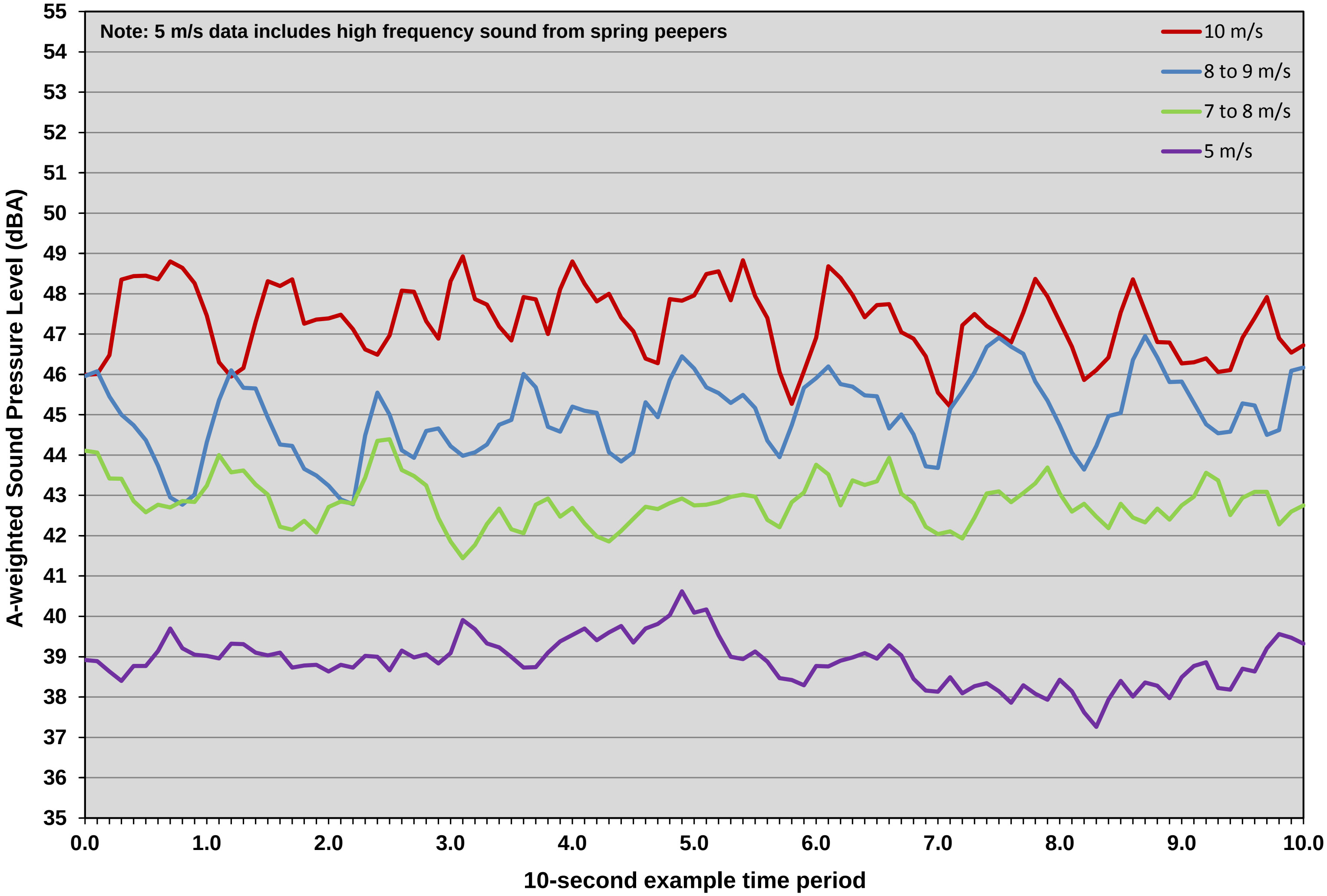


Table 30. Summary of Modulation Depth Analysis for 11 Leland Road

Date	10-min Avg Wind Speeds (m/s)	10-min Avg Wind Directions	10-min Avg Power Levels (kW)	Modulation Depth Acoustical Metric (fast response)	KWI Wind Turbine OPERATING (dBA) (incl. Route 3 traffic)	KWI Wind Turbine ONLY (dBA) (excl. Route 3 traffic)	KWI Wind Turbine SHUTDOWN (dBA) (incl. Route 3 traffic)	KWI Wind Turbine SHUTDOWN (dBA) (excl. Route 3 traffic)
4/7/2014	5 to 6	SW to WSW	130 to 210	L01	4.0	2.0	4.5	2.2
				L50	0.6	0.9	1.2	1.0
				L90	0.6	0.6	0.7	0.6
3/22/2014	7 to 8	SW	539 to 669	L01	3.8	3.7	3.9	2.3
				L50	0.9	1.6	1.1	1.0
				L90	0.9	1.0	0.6	0.6
3/2/2014	8 to 9	SSW	827 to 1139	L01	4.5	4.7	4.1	1.7
				L50	1.0	2.0	1.2	0.8
				L90	0.9	1.2	0.6	0.6
3/15/2014	10 to 11	South	1422 to 1880	L01	5.1	5.0	4.6	1.9
				L50	1.1	2.4	1.1	0.9
				L90	1.1	1.4	0.6	0.5

Notes:
1) Detailed acoustical monitoring data are provided in **Appendix D**.
2) Data used for modulation depth analysis on 4/7/2014 includes high frequency sound from spring peepers.
3) Modulation depth is maximum fast response A-weighted sound level difference within 1/2 second of each 1/10th second data sample.

Figure 18. Modulation Depth Comparison: Fast-response A-level Time Histories
11 Leland Road - KWI Wind Turbine ONLY (excluding Route 3 traffic)

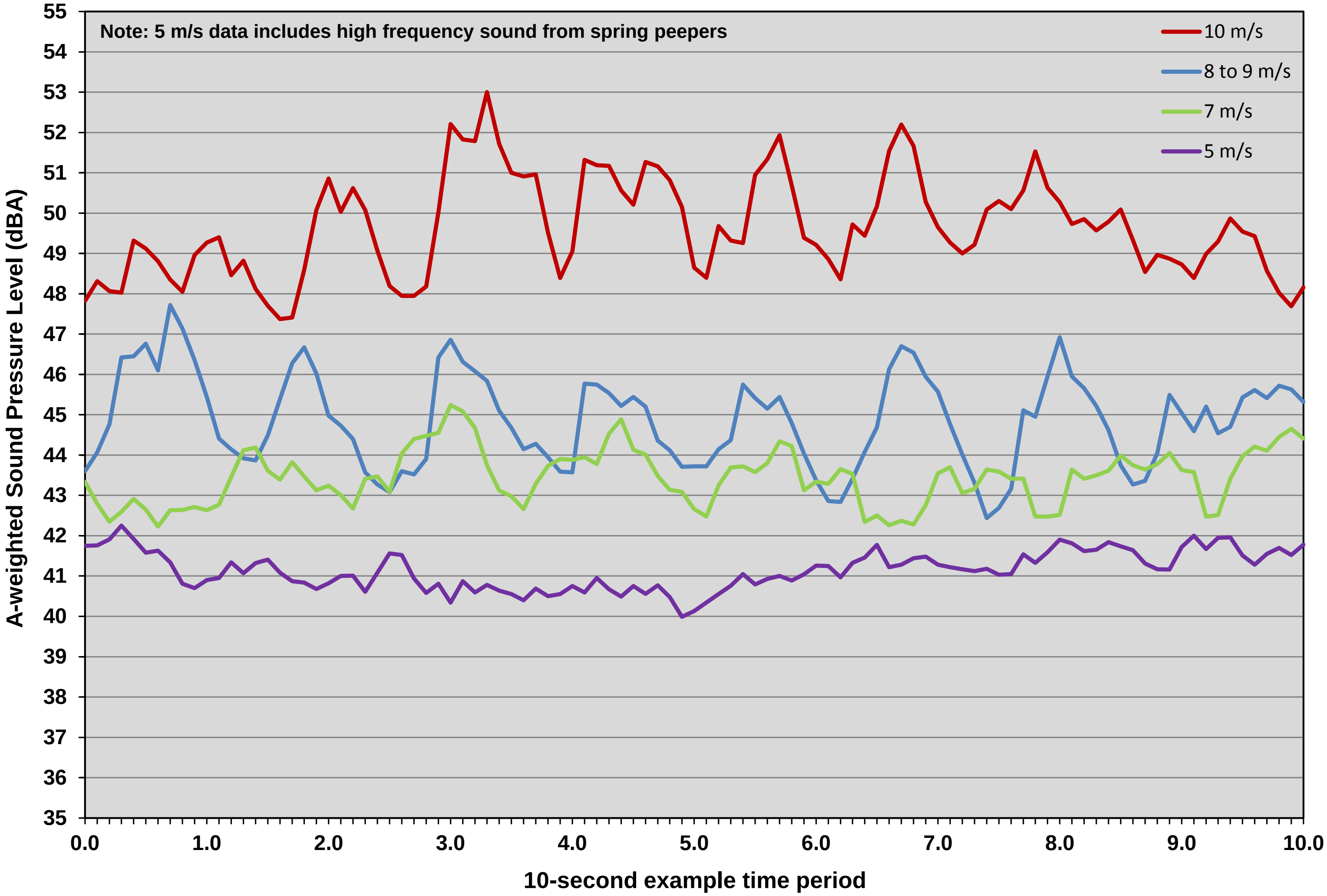


Table 31. Summary of Modulation Depth Analysis for 38 Prospect Street

Date	10-min Avg Wind Speeds (m/s)	10-min Avg Wind Directions	10-min Avg Power Levels (kW)	Modulation Depth Acoustical Metric (fast response)	KWI Wind Turbine OPERATING (dBA) (incl. Route 3 traffic)	KWI Wind Turbine ONLY (dBA) (excl. Route 3 traffic)	KWI Wind Turbine SHUTDOWN (dBA) (incl. Route 3 traffic)	KWI Wind Turbine SHUTDOWN (dBA) (excl. Route 3 traffic)
4/7/2014	5 to 7	WSW to W	173 to 189	L01	5.0	3.9	5.8	5.6
				L50	0.8	1.5	1.5	1.6
				L90	0.8	0.8	0.8	0.9
3/22/2014	7 to 8	SW	586 to 819	L01	3.5	2.8	4.2	1.7
				L50	0.8	1.6	1.1	0.9
				L90	0.7	0.9	0.6	0.6
3/2/2014	8 to 9	SSW	831 to 1026	L01	4.5	4.4	3.9	1.7
				L50	1.1	1.9	1.1	0.9
				L90	1.1	1.1	0.6	0.6
3/15/2014	10 to 11	South	1422 to 1880	L01	5.1	5.5	6.0	3.2
				L50	1.1	2.1	1.2	0.9
				L90	1.0	1.2	0.6	0.6

Notes:
1) Detailed acoustical monitoring data are provided in **Appendix D**.
2) Data used for modulation depth analysis on 4/7/2014 includes high frequency sound from spring peepers.
3) Data used for modulation depth analysis on 3/15/2014 includes high frequency sound from cord tapping on a flagpole.
4) Modulation depth is maximum fast response A-weighted sound level difference within 1/2 second of each 1/10th second data sample.

Figure 19. Modulation Depth Comparison: Fast-response A-level Time Histories
38 Prospect Street - KWI Wind Turbine ONLY (excluding Route 3 traffic)

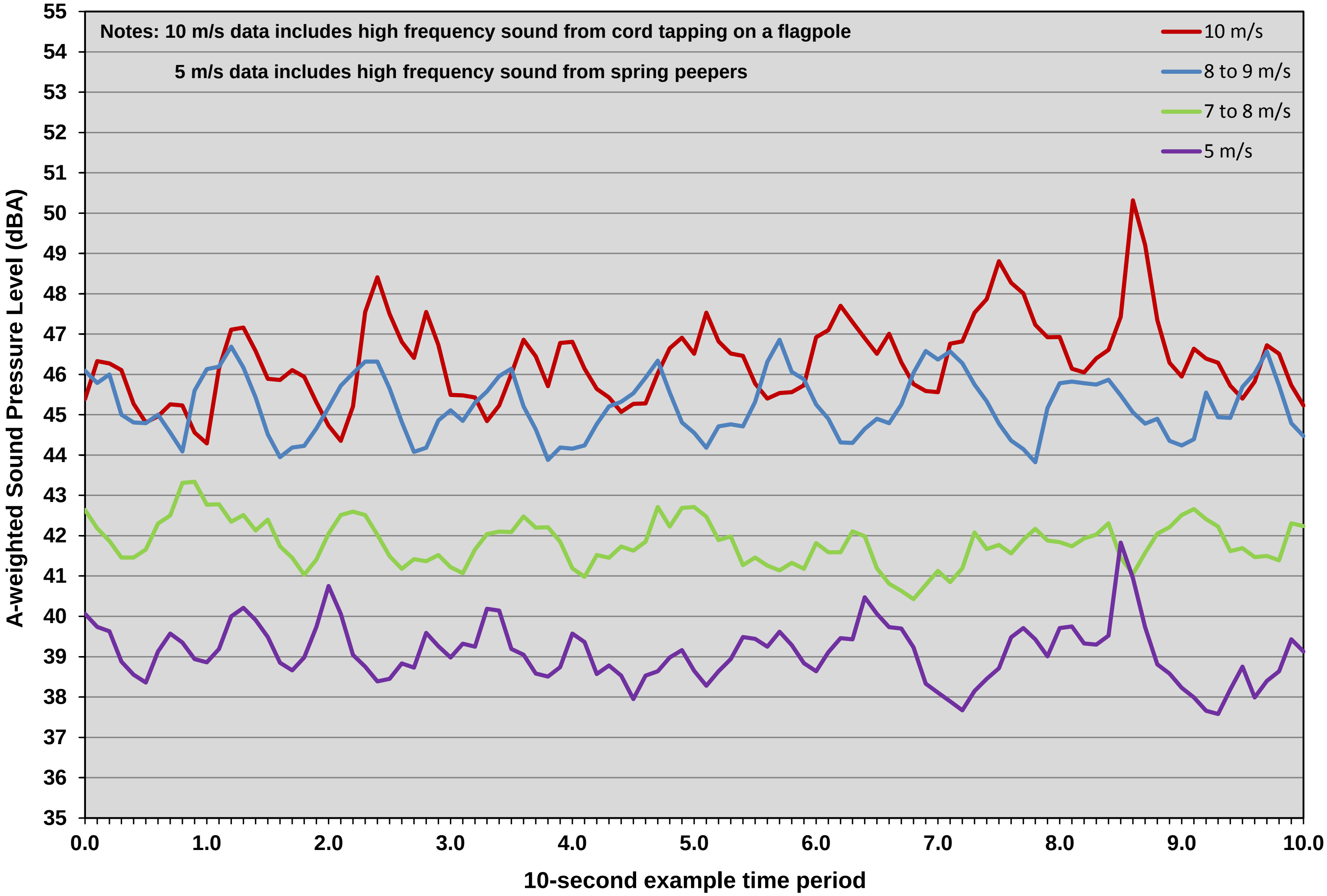


Table 32. Summary of Modulation Depth Analysis for Kingston Intermediate School

Date	10-min Avg Wind Speeds (m/s)	10-min Avg Wind Directions	10-min Avg Power Levels (kW)	Modulation Depth Acoustical Metric (fast response)	KWI Wind Turbine OPERATING (dBA) (incl. Route 3 traffic)	KWI Wind Turbine ONLY (dBA) (excl. Route 3 traffic)	KWI Wind Turbine SHUTDOWN (dBA) (incl. Route 3 traffic)	KWI Wind Turbine SHUTDOWN (dBA) (excl. Route 3 traffic)
2/18/2014	6 to 8	East	428 to 690	L01	5.0	-	5.1	-
				L50	0.6	-	1.0	-
				L90	0.6	-	0.6	-

Notes:

1) Detailed acoustical monitoring data are provided in **Appendix D**.

2) Data used for modulation depth analysis includes high frequency sound from heating system exhaust.

3) Modulation depth is maximum fast response A-weighted sound level difference within 1/2 second of each 1/10th second data sample.

9 Assessment for Copper Beech Drive Neighborhood

HMMH did not have an opportunity to conduct acoustical monitoring of the KWI wind turbine in the Copper Beech Drive neighborhood on a night with southeast winds (downwind, worst case for sound propagation) because this condition is somewhat rare and did not occur during the monitoring program. However, nighttime ambient background sound level data was successfully collected in this community with the wind turbine shut down, in an effort to better understand the local ambient sound environment.

To assess sound level increases due to operation of the KWI wind turbine in the context of MassDEP noise policy, an effort was then made to estimate the impact of the KWI turbine on the Copper Beech neighborhood by combining measured turbine sound levels for sites east of Route 3 with the ambient monitoring data collected at sites along Copper Beech Drive and adjusting for distance from the wind turbine. This approached was used to compute potential increases in sound levels due to downwind operation of the KWI turbine. The turbine-only sound level estimates for the Copper Beech sites were developed by extrapolating the turbine-only sound levels measured at the four residential sites to the east of Route 3 during periods dominated by the turbine (refer to Section 6).

Section 9.1 summarizes the results of the nighttime ambient monitoring conducted at two residential sites along Copper Beech Drive. Section 9.2 provides the turbine-only sound levels measured at several sites/distances to the east of Route 3. Section 9.3 discusses the extrapolation of those sound levels to the Copper Beech Drive monitoring locations and Section 9.4 presents the resulting sound level increase estimates for downwind conditions with the KWI wind turbine operating over a range of wind speeds.

Tables 33 and 34 summarize the slow-response A-weighted L_{90} sound level results for the nighttime ambient monitoring conducted at the two measurement sites along Copper Beech Drive.

Figures 20 through 23 depict the slow-response A-weighted KWI wind turbine sound levels that were measured at various wind speeds at the four monitoring locations to the east of Route 3. Interpolations of the measurement data to integer average wind speed values are also shown.

Figures 24 and 25 illustrate the sound levels that were extrapolated to each Copper Beech Drive monitoring site using measurement data collected at various distances from the KWI wind turbine at locations to the east of Route 3.

Tables 35 and 36 present estimates of nighttime sound level increase for each Copper Beech Drive site.

The wind speed data shown in these tables and figures were adjusted using a correction factor of +1.5 m/s. (Refer to Sections 2.3 and 5.2 for additional details.)

9.1 Ambient Sound Level Monitoring

Ambient sound level monitoring during the quietest nighttime hours was conducted at two residential measurement sites located at 18 Copper Beech Drive and 6 Copper Beech Drive on April 9, 2014 with winds from due west, which is a typical and frequently-occurring wind direction. Measurements were conducted with average hub-height wind speeds ranging from about 7 to 9 m/s.

Since there is a direct line of sight from Copper Beech Drive to the No Fossil Fuel (NFF) wind turbines, acoustical monitoring was conducted with the NFF turbines operating and then shut down to investigate the relative impact on ambient sound levels. Therefore, data were first collected for a period of about 40 minutes with the KWI wind turbine shut down and the three more distant NFF turbines operating normally, then measurements were conducted over an additional 40-minute period with both the KWI and NFF turbines shut down.

The NFF turbines were crosswind to the Copper Beech Drive measurement sites during the monitoring. They were only very occasionally audible when operating and ambient L_{90} sound levels only decreased about 1 to 2 dBA when shut down. This small decrease in ambient background levels was likely also at least partially attributable to decreased Route 3 traffic volumes as well as slightly lower wind speeds.

Very high frequency sound generated by spring peepers occurred intermittently throughout the acoustical monitoring conducted on April 9, 2014. While this biogenic sound was only observed to have a small effect on ambient L_{90} sound levels at the 6 Copper Beech Drive measurement site, the data collected at both monitoring sites was adjusted to remove this sound event contribution (refer to Section 5.1 for additional details) to ensure a conservative worst-case assessment representative of winter conditions.

Also, commuter trains that are stored overnight at the MBTA layover facility located beyond the end of Copper Beech Drive were not idling during the ambient monitoring, although other mechanical noise generated at the MTBA facility was at times audible.

Tables 33 and 34 summarize the slow-response A-weighted L_{90} sound level results measured at each site on Copper Beech Drive during the nighttime ambient monitoring conducted on April 9, 2014. Somewhat higher ambient levels were measured at 6 Copper Beech Drive because this site is much closer to Route 3 and therefore more influenced by traffic sound.

Table 33. Summary of Ambient Monitoring at 18 Copper Beech Drive on April 9, 2014

NFF Wind Turbine Operating Condition	Time	10-min Avg Wind Speed (m/s)	10-min Avg Wind Direction (deg)	Slow-response Ambient L90 (dBA) (including Route 3 traffic)
ON	1:00 to 1:10 AM	8.7	265	35.7
	1:10 to 1:20 AM	7.8	260	34.1
	1:20 to 1:30 AM	8.0	264	34.2
	1:30 to 1:40 AM	7.6	264	33.9
OFF	2:00 to 2:10 AM	7.3	269	32.9
	2:10 to 2:20 AM	8.5	271	34.1
	2:20 to 2:30 AM	7.9	268	32.7
	2:30 to 2:40 AM	7.1	268	32.7

Notes:

1) Winds from the west during monitoring, therefore NFF turbines crosswind to measurement site.

2) High frequency sound from spring peepers removed from data.

Table 34. Summary of Ambient Monitoring at 6 Copper Beech Drive on April 9, 2014

NFF Wind Turbine Operating Condition	Time	10-min Avg Wind Speed (m/s)	10-min Avg Wind Direction (deg)	Slow-response Ambient L90 (dBA) (including Route 3 traffic)
ON	1:00 to 1:10 AM	8.7	265	39.8
	1:10 to 1:20 AM	7.8	260	40.3
	1:20 to 1:30 AM	8.0	264	39.4
	1:30 to 1:40 AM	7.6	264	37.2
OFF	2:00 to 2:10 AM	7.3	269	35.4
	2:10 to 2:20 AM	8.5	271	38.4
	2:20 to 2:30 AM	7.9	268	35.1
	2:30 to 2:40 AM	7.1	268	36.6

Notes:
1) Winds from the west during monitoring, therefore NFF turbines crosswind to measurement site.
2) High frequency sound from spring peepers removed from data.

9.2 Measured KWI Turbine Sound Levels by Wind Speed

Figures 20 through 23 depict the slow-response A-weighted KWI turbine-only sound levels that were measured at wind speeds ranging from about 5 to 10 m/s at the 13 Schofield Road, 3 Leland Road, 11 Leland Road, and 38 Prospect Street monitoring sites during periods dominated by sound from the wind turbine. The measured data points are shown with solid color markers for three different sound-level metrics: Avg L_{max}, L_{eq} and L_{90}. Similar data was provided in Section 6 (in tabular form), but those results have been adjusted here to remove the ambient sound level contribution so that the data are cross-comparable and can be accurately assessed against different ambient sound levels. In addition, KWI turbine-only sound levels for each integer wind speed from 5 to 10 m/s were interpolated from the measurement data and are shown along each sound metric curve using white markers. Note that the measured (solid color) and interpolated (white) data markers may directly overlap in some instances.

Also, it is notable that the measured turbine-only sound level ranges of approximately 8 to 10 dBA for wind speeds from about 5 to 10 m/s agree well with the KWI turbine sound power data provided in Figure 2. This suggests that although some variability was observed for data collected at moderate wind speeds, the measured turbine-only sound levels are appropriately representative overall.

Figure 20. Variation in KWI Wind Turbine Slow-response A-levels with Wind Speed
13 Schofield Rd (740 feet from KWI) excluding Route 3 traffic & ambient removed

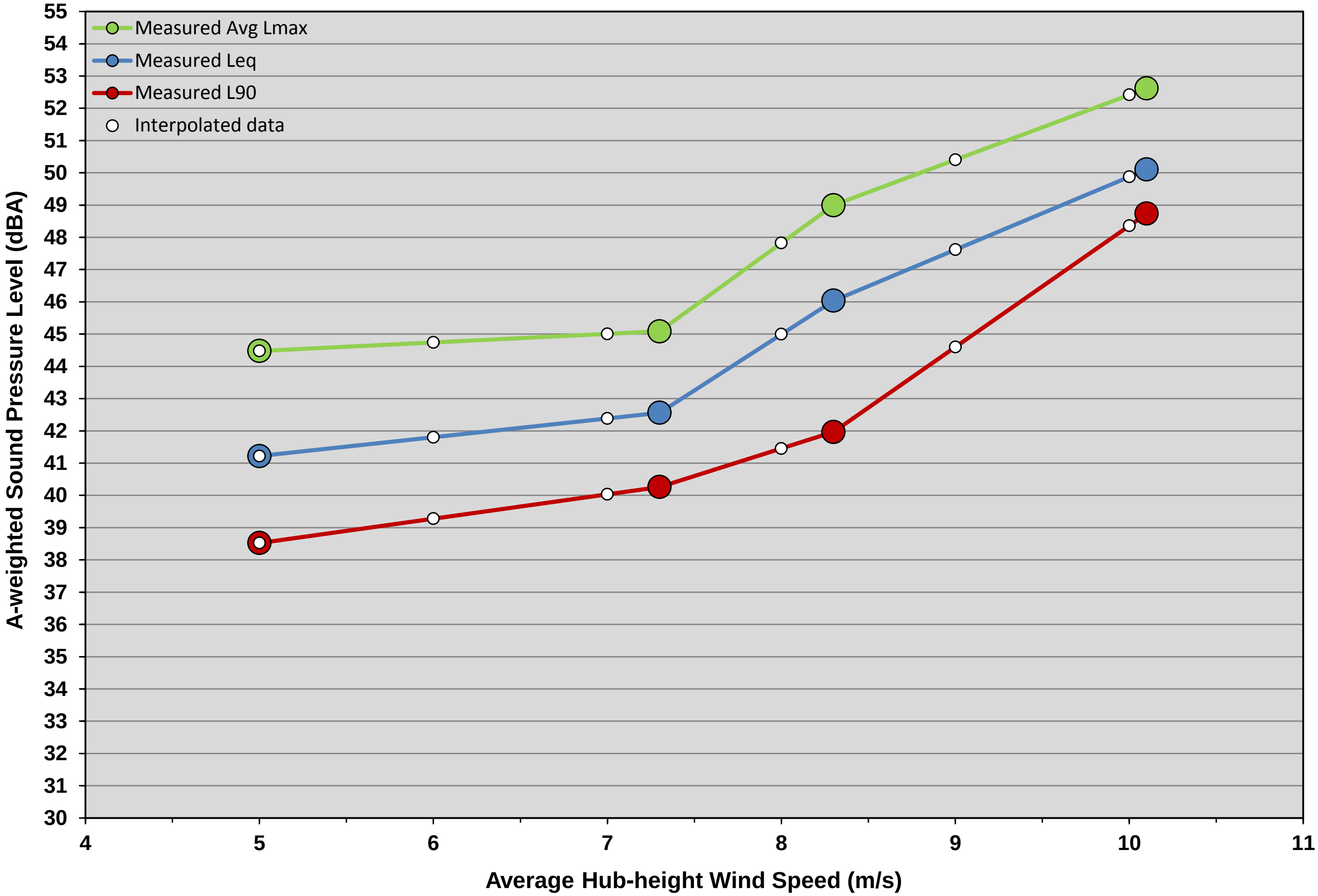


Figure 21. Variation in KWI Wind Turbine Slow-response A-levels with Wind Speed
3 Leland Rd (990 feet from KWI) excluding Route 3 traffic & ambient removed

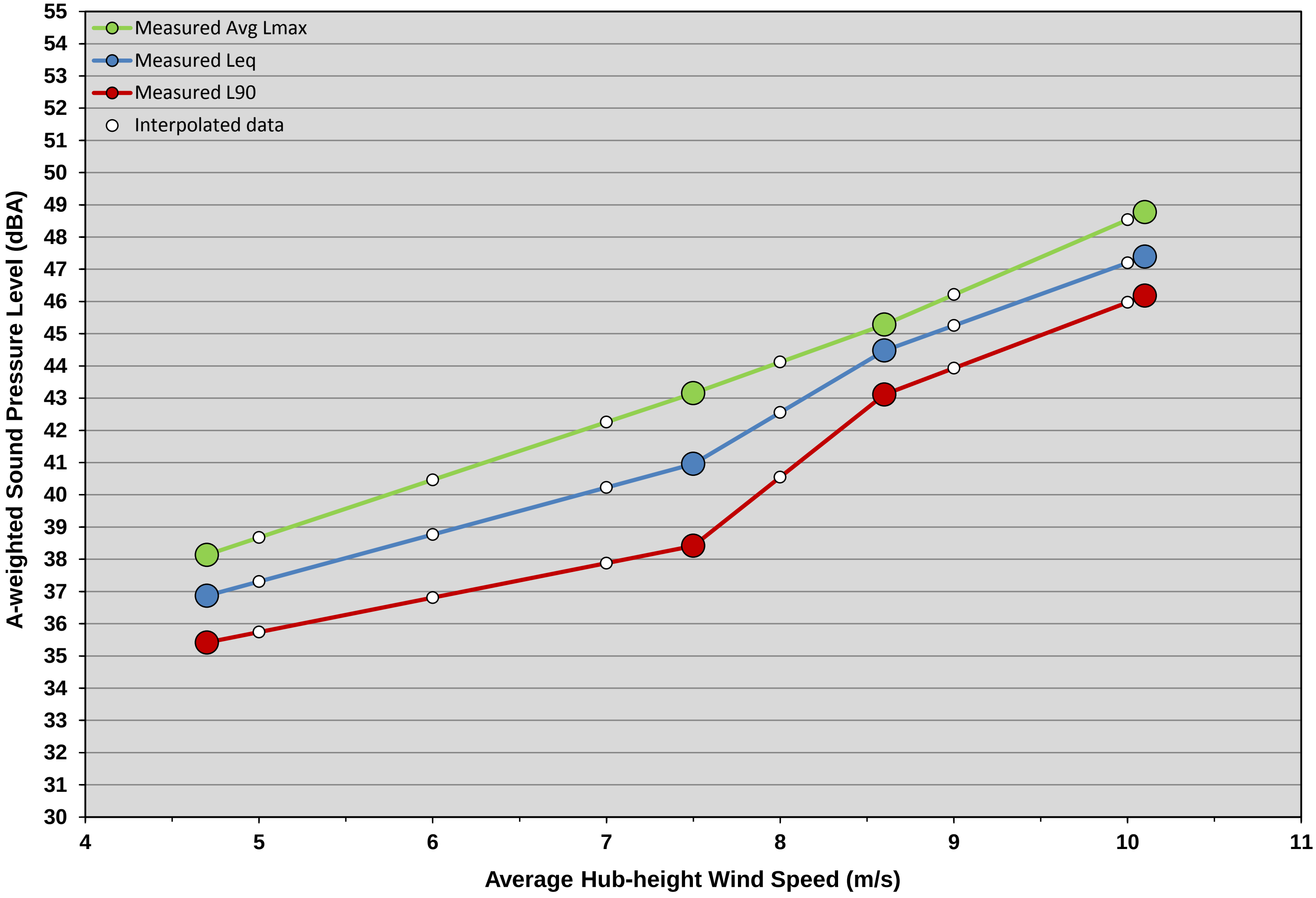


Figure 22. Variation in KWI Wind Turbine Slow-response A-levels with Wind Speed
11 Leland Rd (1025 feet from KWI) excluding Route 3 traffic & ambient removed

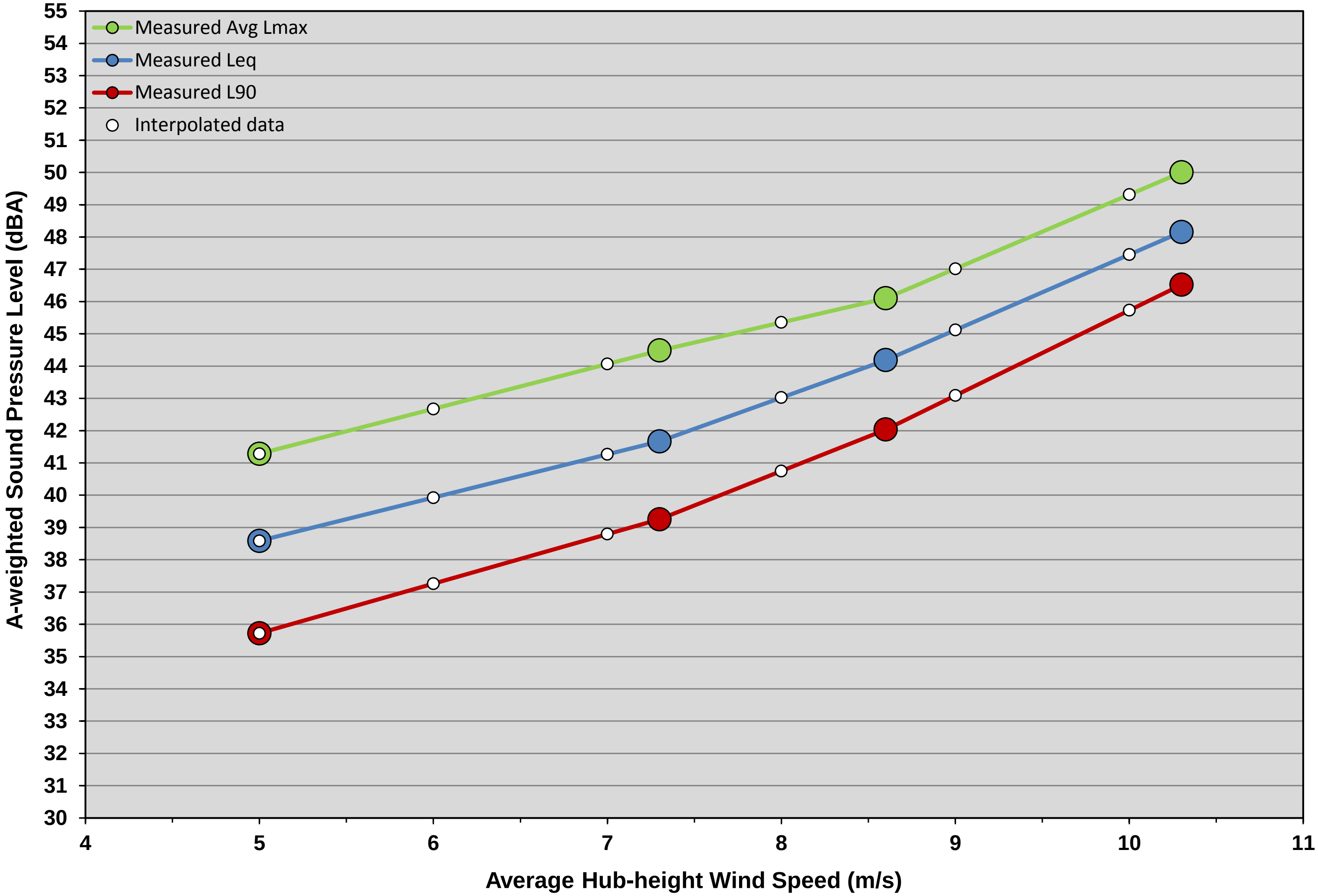
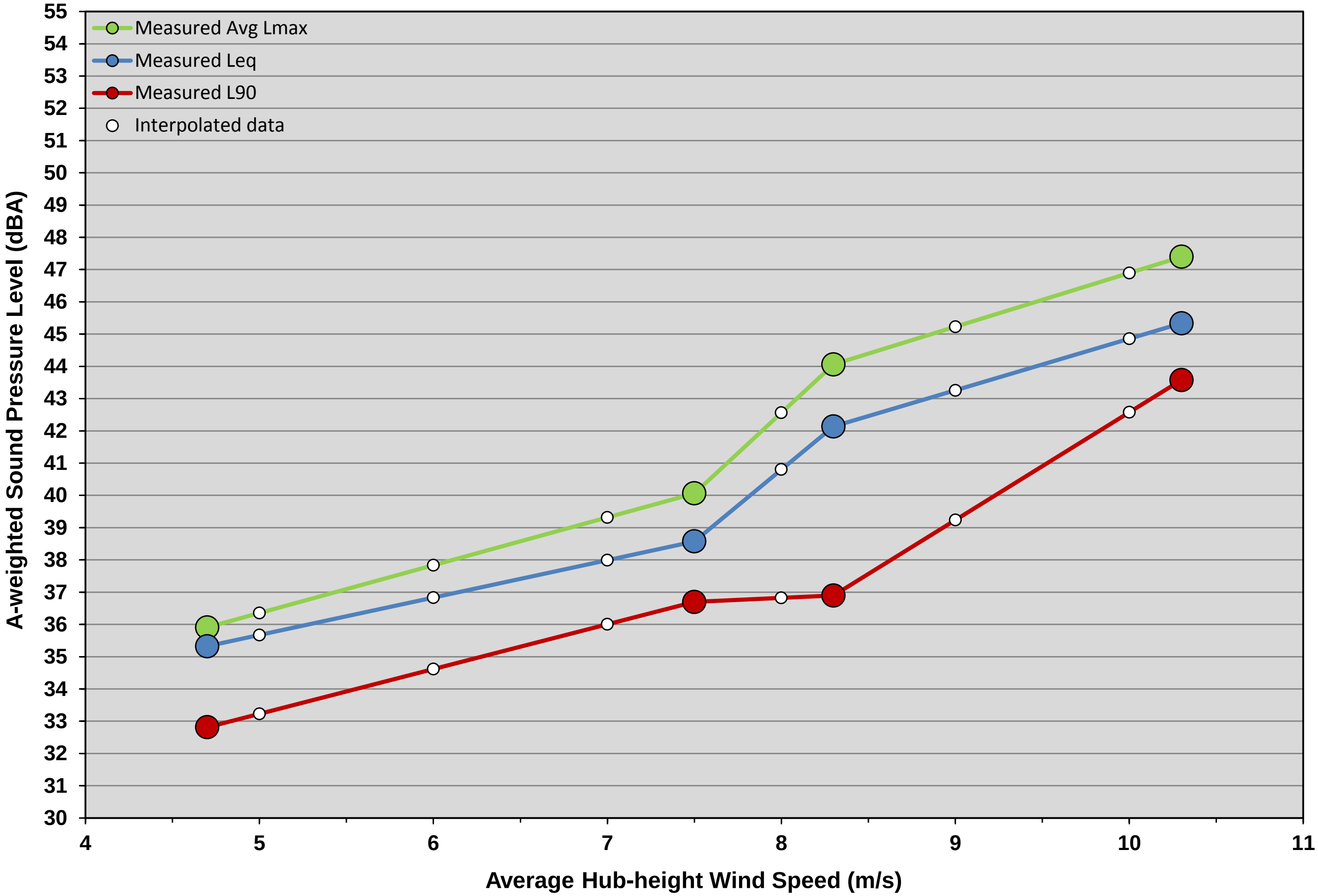


Figure 23. Variation in KWI Wind Turbine Slow-response A-levels with Wind Speed
38 Prospect St (1410 feet from KWI) excluding Route 3 traffic & ambient removed



9.3 KWI Turbine Sound Level Estimates for Copper Beech Drive

The measured KWI turbine-only sound levels that were interpolated to integer wind speed values for the 13 Schofield Road, 3 Leland Road, 11 Leland Road, and 38 Prospect Street monitoring locations were cross-compared and the overall trend with increasing site distance from the KWI turbine was determined to fit the standard "inverse-square law" (20 times the logarithm of the distance ratio) relationship for sound attenuation with distance from a point source. The distances of the sites from the KWI wind turbine range from 740 feet at 13 Schofield Road to 1410 feet at 38 Prospect Street (refer to Section 4.1).

When the turbine-only sound levels measured at 13 Schofield Road, 3 Leland Road, and 11 Leland Road were extrapolated to the 38 Prospect Street monitoring location using the standard inverse-square law relationship, the estimates were within ±1 dBA of the turbine-only sound levels measured at this site.

KWI turbine sound levels were then extrapolated using the same inverse-square law to estimate downwind turbine-only sound levels at 18 Copper Beech Drive and 6 Copper Beech Drive. These sites are located at distances from the KWI wind turbine of 1535 feet and 1855 feet, respectively. An additional adjustment for ground cover attenuation was not necessary since the measurement data already included appropriate ground effects. Likewise, terrain shielding attenuation from the nearby MBTA commuter rail embankment was evaluated, but given the height of the KWI turbine an adjustment was not included since most residential locations along Coper Beech Drive have a direct line-of-sight over the embankment to the turbine nacelle and the rotational path of the turbine blades.

Figures 24 and 25 illustrate the extrapolated KWI turbine-only sound level estimates as a function of hub-height wind speed for each of the Copper Beech Drive monitoring locations.

Figure 24. Variation in KWI Wind Turbine Slow-response A-levels with Wind Speed
18 Copper Beech Dr (1535 feet from KWI) - estimates using data for Sites 1 to 4

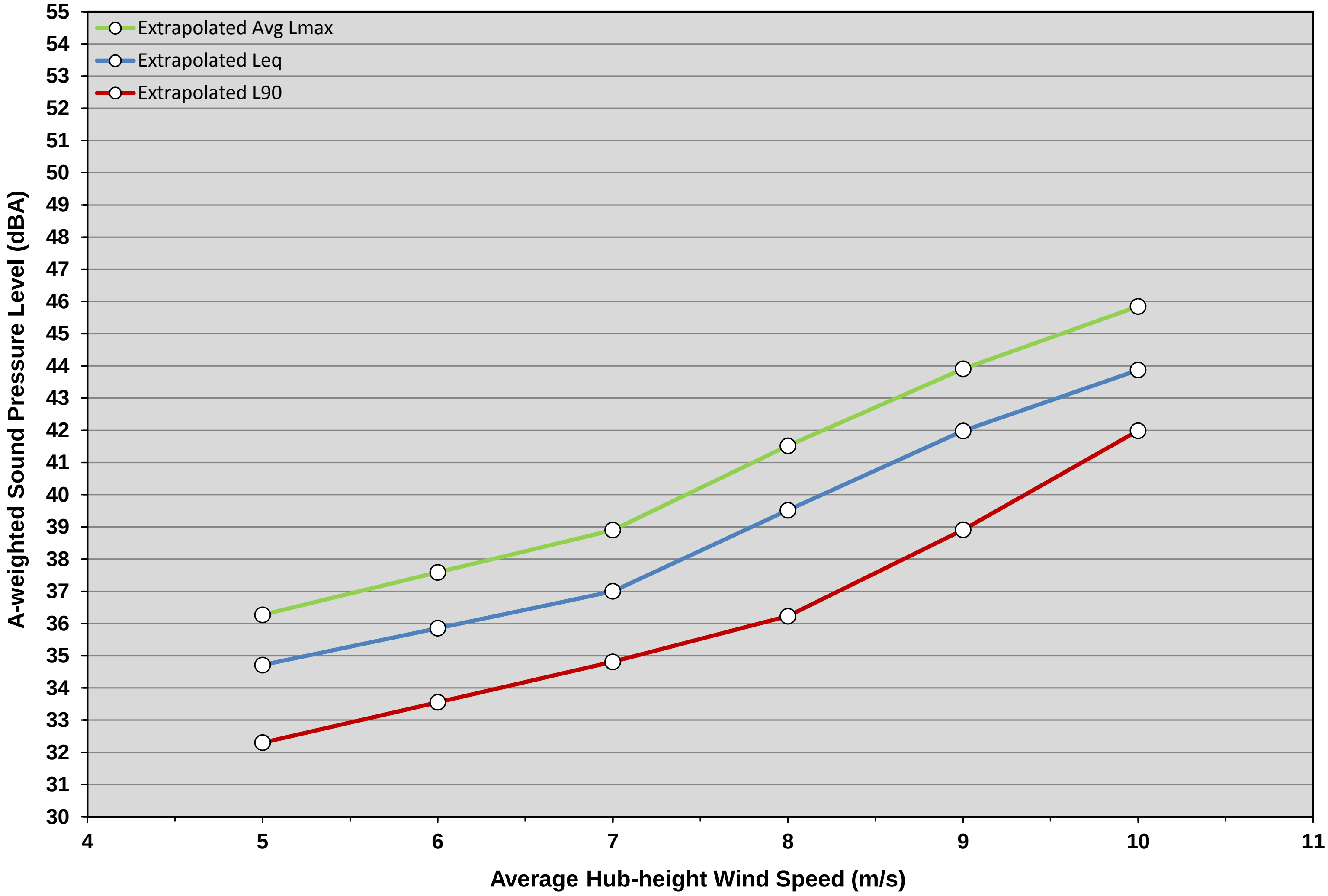
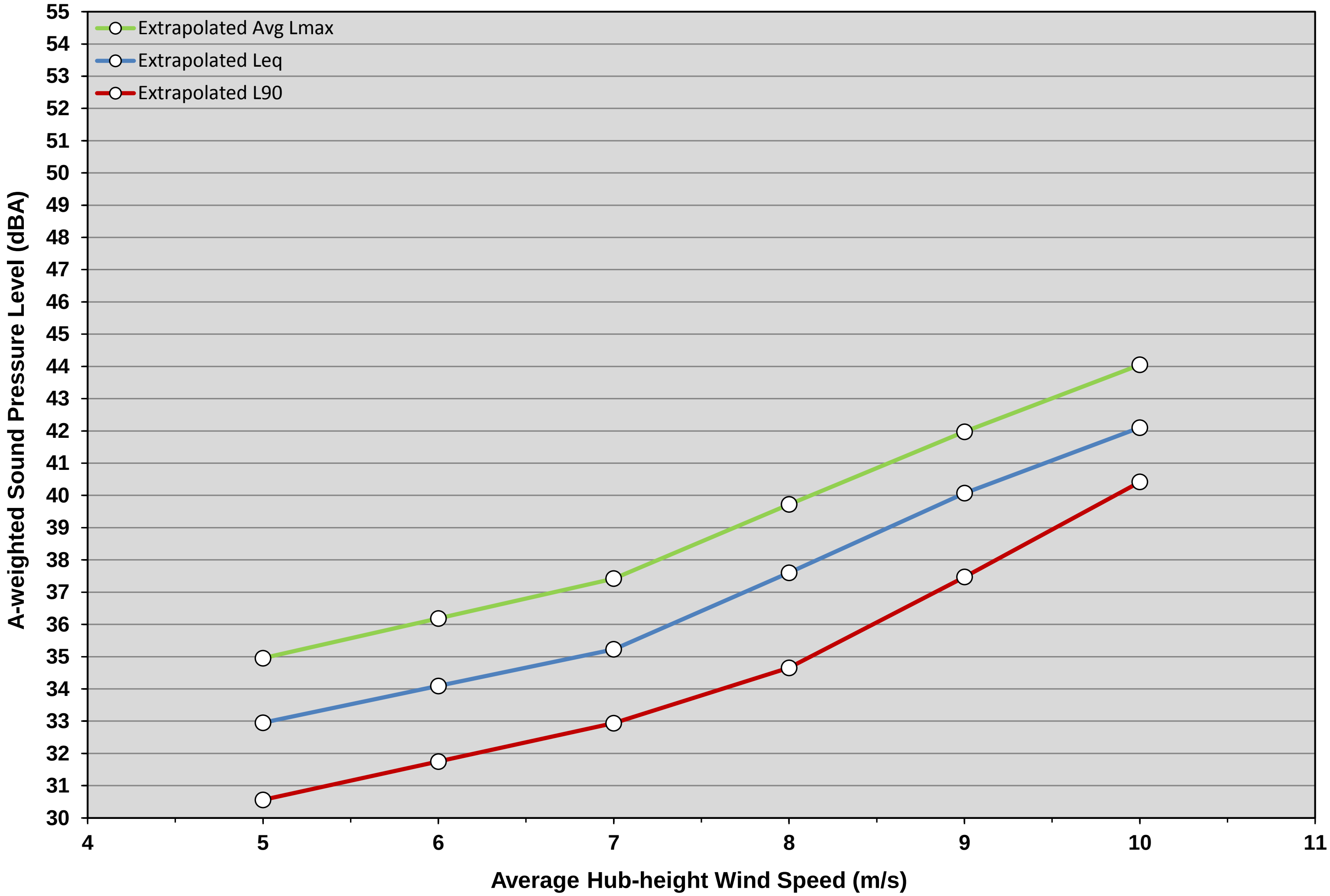


Figure 25. Variation in KWI Wind Turbine Slow-response A-levels with Wind Speed
6 Copper Beech Dr (1855 feet from KWI) - estimates using data for Sites 1 to 4



9.4 Nighttime Sound Level Increase Estimates for Copper Beech Drive

The extrapolated KWI turbine-only sound levels were compared to measured ambient L_{90} sound levels to determine potential nighttime sound level increases for downwind conditions with the KWI turbine operating over a typical range of wind speeds[10]. Tables 35 and 36 present the resulting sound level increase estimates for each Copper Beech Drive monitoring location. Because the wind speed data measured by the ultrasonic anemometers mounted on the KWI turbine nacelle underestimate actual wind speeds by about 1.5 m/s on average, both corrected wind speed information and corresponding power generation levels are provided in the sound level increase tables for reference.

Also, since KWI turbine-only sound levels could be extrapolated to integer wind speeds from 5 to 10 m/s while ambient background sound level data was only collected with wind speeds of about 7 to 9 m/s, ambient L_{90} sound levels at slightly higher and lower wind speeds were estimated. Because nighttime ambient sound levels typically either remain about the same or increase somewhat with increasing wind speed, it was assumed that ambient background sound levels at a 10 m/s wind speed would be no lower than measured at about 9 m/s and that ambient sound levels at wind speeds of 5 to 6 m/s would be at least as low as measured around 7 m/s. This approach was also used to select representative minimum ambient L_{90} values for wind speeds from 7 to 9 m/s.

The results indicate that slow-response A-weighted sound level increases from nighttime ambient conditions due to operation of the KWI wind turbine are not estimated to exceed 10 dBA at 6 Copper Beech Drive under worst-case downwind conditions. The turbine-operating Avg L_{max} over ambient L_{90} sound level increases estimated for 18 Copper Beech Drive exceed 10 dBA at higher wind speeds of 9 m/s and above. This result is largely due to the fact that the residence located at 18 Copper Beech Drive is the closest home in this neighborhood to the KWI turbine and also one of the most distant from Route 3, resulting in slightly higher turbine-only sound levels and somewhat lower nighttime ambient sound levels.

[10] For example, KWI turbine-only Avg L_{max} sound levels of 44.7 dBA to 37.8 dBA were interpolated for a 6 m/s average wind speed using the measurement data collected at 13 Schofield Road, 3 Leland Road, 11 Leland Road, and 38 Prospect Street at wind speeds ranging from about 5 to 7 m/s and at distances from the KWI turbine ranging from 740 to 1410 feet. This interpolated data was then extrapolated to the 18 Copper Beech Drive measurement site (located at a distance of 1535 feet from KWI) using the standard inverse-square law (20 times the logarithm of the distance ratio) relationship to generate a turbine-only sound level estimate of 37.6 dBA at 6 m/s. The ambient L_{90} sound level at 6 m/s was estimated for the 18 Copper Beech Drive site using the minimum nighttime ambient L_{90} of 32.7 dBA measured in this location at a wind speed of 7.1 m/s. The turbine-only sound level of 37.6 dBA was then combined with the ambient L_{90} of 32.7 dBA using logarithmic decibel addition to generate a turbine-operating sound level estimate of 38.8 dBA at a 6 m/s average wind speed. This results in a turbine-operating Avg L_{max} (38.8 dBA) over ambient L_{90} (32.7 dBA) sound level increase estimate of 6.1 dBA at 6m/s, as shown in Table 35.

Table 35. Nighttime Sound Level Increase Estimates for 18 Copper Beech Dr (1535 ft from KWI)

Downwind Direction	Average Wind Speed (m/s)	KWI Turbine Power Level (kW)	Minimum Slow-response Ambient L90 (dBA) (incl. Rt. 3 traffic) (a)	Extrapolated KWI Turbine Slow-response Sound Levels (dBA) (excl. Route 3 traffic) (ambient removed) (b)			KWI Wind Turbine + Ambient L90 (dBA) (c)			Sound Level Increase from Ambient L90 (dBA) (d)		
				Avg Lmax	Leq	L90	Avg Lmax	Leq	L90	Avg Lmax	Leq	L90
South to East	5	169	32.7	36.3	34.7	32.3	37.9	36.8	35.5	5.2	4.1	2.8
	6	318	32.7	37.6	35.9	33.6	38.8	37.6	36.2	6.1	4.9	3.5
	7	529	32.7	38.9	37.0	34.8	39.8	38.4	36.9	7.1	5.7	4.2
	8	812	32.7	41.5	39.5	36.2	42.1	40.3	37.8	9.4	7.6	5.1
	9	1176	34.1	43.9	42.0	38.9	44.3	42.6	40.1	10.2	8.5	6.0
	10	1612	34.1	45.8	43.9	42.0	46.1	44.3	42.6	12.0	10.2	8.5

Notes:
1) KWI Wind Turbine + Ambient L90: $c = 10\log\left(10^{(b/10)} + 10^{(a/10)}\right)$
2) Increase from Ambient L90: d = c - a

Table 36. Nighttime Sound Level Increase Estimates for 6 Copper Beech Dr (1855 ft from KWI)

Downwind Direction	Average Wind Speed (m/s)	KWI Turbine Power Level (kW)	Minimum Slow-response Ambient L90 (dBA) (incl. Rt. 3 traffic) (a)	Extrapolated KWI Turbine Slow-response Sound Levels (dBA) (excl. Route 3 traffic) (ambient removed) (b)			KWI Wind Turbine + Ambient L90 (dBA) (c)			Sound Level Increase from Ambient L90 (dBA) (d)		
				Avg Lmax	Leq	L90	Avg Lmax	Leq	L90	Avg Lmax	Leq	L90
South to East	5	169	35.1	35.0	33.0	30.6	38.0	37.2	36.4	2.9	2.1	1.3
	6	318	35.1	36.2	34.1	31.7	38.7	37.6	36.7	3.6	2.5	1.6
	7	529	35.1	37.4	35.2	32.9	39.4	38.2	37.2	4.3	3.1	2.1
	8	812	35.1	39.7	37.6	34.7	41.0	39.5	37.9	5.9	4.4	2.8
	9	1176	38.4	42.0	40.1	37.5	43.6	42.3	41.0	5.2	3.9	2.6
	10	1612	38.4	44.0	42.1	40.4	45.1	43.6	42.5	6.7	5.2	4.1

Notes:

1) KWI Wind Turbine + Ambient L90: $c = 10\log\left(10^{(b/10)} + 10^{(a/10)}\right)$

2) Increase from Ambient L90: d = c - a

10 Supplemental Ambient Monitoring Program

The acoustical monitoring results presented in Sections 6 through 9 of this report represent an assessment of increases in ambient sound levels due to operation of the KWI turbine under worst-case conditions, which were during the quietest nighttime periods in the winter season and with downwind conditions.

Since increases of turbine-operating Avg L_{max} over nighttime ambient L_{90} exceeding 10 dBA were identified at some locations during the acoustical monitoring study, and because sound from traffic on Route 3 is very significant at the closest neighborhood locations outside of the quietest nighttime periods, a supplemental ambient monitoring program was conducted in September 2014 (referred to as the "summer" season elsewhere in this report) to investigate daily and seasonal variations in A-weighted ambient L_{90} sound levels in the affected community.

The ambient L_{90} sound level data were then assessed against measured KWI turbine sound levels interpolated to integer wind speed values for the Schofield Road and Leland Road monitoring locations (see Section 9.2), as well as additional turbine-only data extrapolated to higher and lower wind speeds not directly measured. Turbine-only sound levels were likewise extrapolated for the 18 Copper Beech Drive site (see Section 9.3) to estimate potential increases in ambient sound levels over a range of wind speeds and during various periods throughout the day. Seasonal variations in ambient sound levels were also examined at each site. This information was used to evaluate potential sound level increases due to operation of the KWI turbine at different times of day and year and with various wind conditions in the context of MassDEP noise policy.

Additional details of the supplemental ambient monitoring program, the ambient L_{90} sound level results, and the resulting sound level increase predictions are presented in the following report sub-sections.

10.1 Monitoring Dates and Locations

The supplemental ambient monitoring was conducted over a 5-day period commencing at 12:00pm on Sunday September 15, 2014 and ending about 12:30pm on Friday September 19, 2014. Hub-height wind speeds over this interval reached above 10 m/s during the day and also at night. The data collection occurred while the KWI wind turbine was undergoing annual maintenance and therefore not operating, however the ultrasonic anemometers remained functional and the KWI turbine SCADA system continued to record 10-minute average wind speed data as usual, except during a few brief periods.

Three of the previous measurement sites were selected for the additional ambient monitoring, located at 13 Schofield Road, 3 Leland Road, and 18 Copper Beech Drive.

10.2 Instrumentation

The ambient monitoring was conducted with the same instrumentation used for the acoustical monitoring conducted during February, March, and April 2014 (referred to as the "winter" season elsewhere in this report). These instruments were ANSI Type 1 "Precision" Bruel & Kjaer model 2250 sound level analyzer kits, each including a microphone, pre-amplifier, microphone stand, 7-inch windscreen, and an acoustic calibrator. All of the noise measurement instrumentation is owned by HMMH, conforms to ANSI Standard S1.4 for Type 1 sound level meters, and have current calibrations traceable to the U.S. National Institute of Standards and Technology (NIST). Additional calibration checks were carried out when the instruments were deployed and collected.

The measurements were also conducted in accordance with industry best practices and in general compliance with appropriate professional standards such as ASTM E 1779-96a (Reapproved 2004) "Standard Guide for Preparing a Measurement Plan for Conducting Outdoor Sound Measurements", ANSI S12.18 "Procedures for Outdoor Measurement of Sound Pressure Level" and ANSI S12.9 Part 2 " Quantities and Procedures for Description and Measurement of Environmental Sound, Part 2: Measurement of Long-Term, Wide Area Sound".

Sound measurement microphones were tripod-mounted at a 5-6 foot elevation and placed at least 25 feet from large reflecting surfaces (such as buildings) and at least 5 feet from smaller objects (such as trees and poles). While previous acoustical monitoring utilized short-term attended measurements, during the ambient monitoring program the instrumentation were unattended and collected sound level data continuously over the entire 5-day period. The instruments measured in the frequency range from 5.6 Hz to 20,000 Hz, and were programmed to log slow-response broadband A-weighted sound levels as well as unweighted 1/3-octave band octave band data in 1-second and 10-minute intervals.

Throughout the ambient monitoring, audio recordings were captured in addition to sound metric data. As a result, the sounds heard during the measurements could be listened to subsequently using proprietary software provided by the manufacturer of the sound analyzer instrumentation. This allowed any of the measurements to be reviewed, and more than once if necessary, to identify individual sound sources.

Simultaneous hub-height wind speed and direction data was obtained for each monitoring period in 10-minute intervals from the KWI turbine SCADA system. The wind speed data was adjusted using a correction factor of +1.5 m/s. (Refer to Section 2.3 for additional details.)

10.3 Analysis of Ambient Monitoring Data

The slow-response A-weighted L_{90} ambient background sound level data collected at each of the three monitoring sites were evaluated against corresponding time of day and average hub-height wind speed information. The hours from 12:00am to 4:00am were identified as a key time period for subsequent analyses because the quietest ambient sound levels measured among the various sites were observed to occur within this time interval. The ambient sound level data were also compared against average hub-height wind direction data, however no direct correlation was observed and measured ambient sound levels were about the same overall regardless of wind direction.

Since ambient sound level data was only collected with wind speeds up to about 10 to 11 m/s, ambient L_{90} sound levels at higher wind speeds were estimated. Because ambient sound levels typically either remain about the same or increase somewhat with increasing wind speed, it was assumed that ambient background sound levels at wind speeds above 11 m/s would be no lower than measured at wind speeds right around 10 to 11 m/s. This approach was also used to select representative minimum ambient L_{90} values for wind speeds from turbine cut-in (3.5 m/s) up to 11 m/s.

Very high frequency sound generated by insects was audible throughout the supplemental ambient monitoring. However, the nighttime ambient L_{90} sound levels measured at 13 Schofield Road and 3 Leland Road during this period with intermittent insect noise were very comparable with the ambient data previously collected at these sites during the winter with no insect noise. Overall, seasonal variation in nighttime ambient L_{90} sound levels due to insects or other factors was not observed in these locations.

At 18 Copper Beech Drive, the nighttime ambient L_{90} sound levels measured during the summer season were somewhat higher than the ambient data previously collected during the winter season. However, when the summertime ambient data was adjusted to remove the contribution from insect noise, the resulting sound levels were approximately 4 to 5 dBA lower on average and now approached the ambient data measured at this site during the wintertime. Therefore, seasonal variability in ambient L_{90} sound levels due to insects was found to be important factor at this location. For this reason, sound level increases associated with operation of the KWI wind turbine were calculated using both the ambient monitoring data that included insect noise (representative of summer conditions) and also ambient data that did not include insect noise (generally representative of winter conditions).

10.4 Estimated KWI Turbine Sound Levels

The ambient L_{90} sound level data were then assessed against measured KWI turbine sound levels interpolated to integer wind speed values for the Schofield Road and Leland Road monitoring locations (see Section 9.2), as well as additional turbine-only data extrapolated to wind speeds not directly measured. Turbine-only sound levels were likewise extrapolated for the 18 Copper Beech Drive site (see Section 9.3) to estimate potential increases in ambient sound levels over a range of wind speeds and during various periods throughout the day.

Since measured turbine sound levels could only be interpolated to wind speeds from 5 to 10 m/s, KWI turbine-only sound levels at higher wind speeds above 10 m/s and lower wind speeds down to turbine cut-in (3.5 m/s) were estimated. Because the measured turbine-only sound level ranges of approximately 8 to 10 dBA for wind speeds from about 5 to 10 m/s shown in Figures 20 through 23 agree well with the KWI turbine sound power data provided in Figure 2 (refer to Sections 2.2 and 9.2), it is appropriate to use the sound power curve to estimate the relative increase/decrease in turbine sound levels at the highest and lowest wind speeds. The sound power data provided in Figure 2 indicates that KWI turbine sound levels increase by up to approximately 0.9 dBA at wind speeds from 10 m/s to above 14 m/s and decrease by up to approximately 4.3 dBA at wind speeds from 5 m/s down to 3.5 m/s.

Furthermore, recent research on wind turbine sound directivity and current best practices[11] for acoustical modeling of wind turbine sound propagation indicate that utility-scale turbine sound levels are typically about the same for any wind direction and generally only vary by at most about 2 decibels directly at the crosswind direction (given site distances within approximately 2000 feet of the wind turbine).

10.5 Sound Level Increase Predictions

The supplemental ambient monitoring results and corresponding sound level increase predictions are presented in the following report sub-sections. Note that diurnal trends in ambient L_{90} sound levels were observed to differ slightly on each day of monitoring. The sound level increase predictions incorporate this variability to appropriately establish periods when exceedances of the MassDEP noise policy have the potential to occur and times when sound level increases of less than 10 dBA are anticipated.

Figures 26, 28, 30, and 32 illustrate the slow-response A-weighted L_{90} sound levels measured over time at each ambient monitoring site. The data collected at 18 Copper Beech is provided with insect noise included and also with the contribution from insect noise removed.

Figures 27, 29, 31, and 33 depict the same ambient L_{90} sound levels now plotted against corresponding wind speed data (above turbine cut-in) and also highlighted to indicate various time periods. Additional ambient data previously collected during March and April of 2014 is also included for reference and in supplement to the September 2014 data set in order to include all available information on ambient conditions in subsequent sound level increase predictions. (Refer to ambient L_{90} data provided in Appendix D for 5-mintue and 20-minute monitoring intervals.)

Tables 37 through 49 present ambient sound level increase predictions for each monitoring location during various periods throughout the day. Because the wind speed data measured by the ultrasonic

[11] Institute of Acoustics, "A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise" May 2013.

anemometers mounted on the KWI turbine nacelle underestimate actual wind speeds by about 1.5 m/s on average, both corrected wind speed information and corresponding power generation levels are provided in the sound level increase tables for reference (Refer to Section 2.3 for additional explanation.)

10.5.1 Schofield Road

The ambient L_{90} sound levels measured at 13 Schofield Road are shown in Figure 26. Time periods selected for subsequent consideration are identified at the top of this figure. Note that observed diurnal sound level variations correlate well with typical daily traffic patterns on nearby Route 3.

The measured ambient sound data are plotted against corresponding wind speed data in Figure 27 and are also highlighted to indicate the different time periods of interest. Additional nighttime ambient data previously collected during March and April 2014 is also included in this figure.

Ambient background sound levels were assessed against measured KWI turbine sound levels interpolated to integer wind speed values for 13 Schofield Road (see Section 9.2) as well as additional turbine-only data extrapolated to higher and lower wind speeds not measured (refer to Section 10.4) to compute the sound level increase predictions presented in Tables 37 through 39.

Ambient sound levels were highest between about 4:30am and 11:00pm, which includes times with peak traffic on Route 3 and adjacent shoulder periods. This data is shown in Figure 27 with red markers for data collected on weekdays and yellow markers for data collected on Sunday. Ambient L_{90} sound levels varied between approximately 46 and 59 dBA during this interval. The sound level increase predictions shown in Table 37 indicate that worst-case turbine-operating Avg L_{max} over ambient L_{90} increases in this time period are at most about 8 dBA. Therefore, exceedances of the MassDEP noise policy due to daytime operation of the KWI turbine are not predicted to occur on Schofield Road between 4:30am and 11:00pm on any day during the week or weekend.

Ambient sound levels were lowest between about 12:00am and 4:00am, though still somewhat variable due to changing traffic volumes on Route 3. This data is shown in Figure 27 with blue markers for data collected in September 2104 and purple markers for data collected in March and April 2014. Ambient L_{90} sound levels varied between approximately 32 and 46 dBA during this interval and comparable minimum levels were measured during the summer and winter seasons. The sound level increase predictions shown in Table 38 indicate that worst-case turbine-operating Avg L_{max} over ambient L_{90} increases in this time period exceed 10 dBA at most wind speeds. Consequently, exceedances of the MassDEP noise policy due to nighttime operation of the KWI turbine during downwind conditions (winds from south to west) are predicted to have the potential to occur on Schofield Road throughout the year between 12:00am and 4:00am at wind speeds of 4 m/s and above.

Ambient sound levels transitioned between higher and lower values due to decreasing or increasing traffic volumes on Route 3 from about 11:00pm to 12:00am and also from 4:00am to 4:30am. This data is shown in Figure 27 with green markers. Ambient L_{90} sound levels varied between approximately 41 dBA and 49 dBA during this interval. The sound level increase predictions shown in Table 39 indicate that worst-case turbine-operating Avg L_{max} over ambient L_{90} increases in this time period are greater than 10 dBA at higher wind speeds. Thus, exceedances of the MassDEP noise policy due to nighttime operation of the KWI turbine during downwind conditions (winds from south to west) are predicted to have the potential to occur on Schofield Road throughout the year at wind speeds above 9 m/s between 11:00pm and 12:00am and also from 4:00am to 4:30am.

In summary, sound level increases of less than 10 dBA are predicted during daytime operation of the KWI wind turbine from 4:30am to 11:00pm throughout the week and weekend regardless of season.

Exceedances of the 10 dBA maximum increase MassDEP noise policy due to nighttime operation of the KWI turbine during downwind conditions (winds from south to west) are predicted to have the potential to occur on Schofield Road throughout the year between 12:00am and 4:00am at wind speeds of 4 m/s and above and between 11:00pm and 4:30am for wind speeds above 9 m/s.

While these conclusions are based only on monitoring conducted during downwind conditions, comparable results are also anticipated with other wind directions given that turbine sound levels are likely about the same for most wind directions at the distance of this neighborhood from the KWI turbine (refer to Section 10.4) and since measured ambient sound levels were about the same overall regardless of wind direction (see Section 10.3).

Figure 26. Slow-response A-weighted Ambient (L90) Sound Level Measurement
13 Schofield Road - 12pm on Sunday 9/14 through 12pm on Friday 9/19/2014

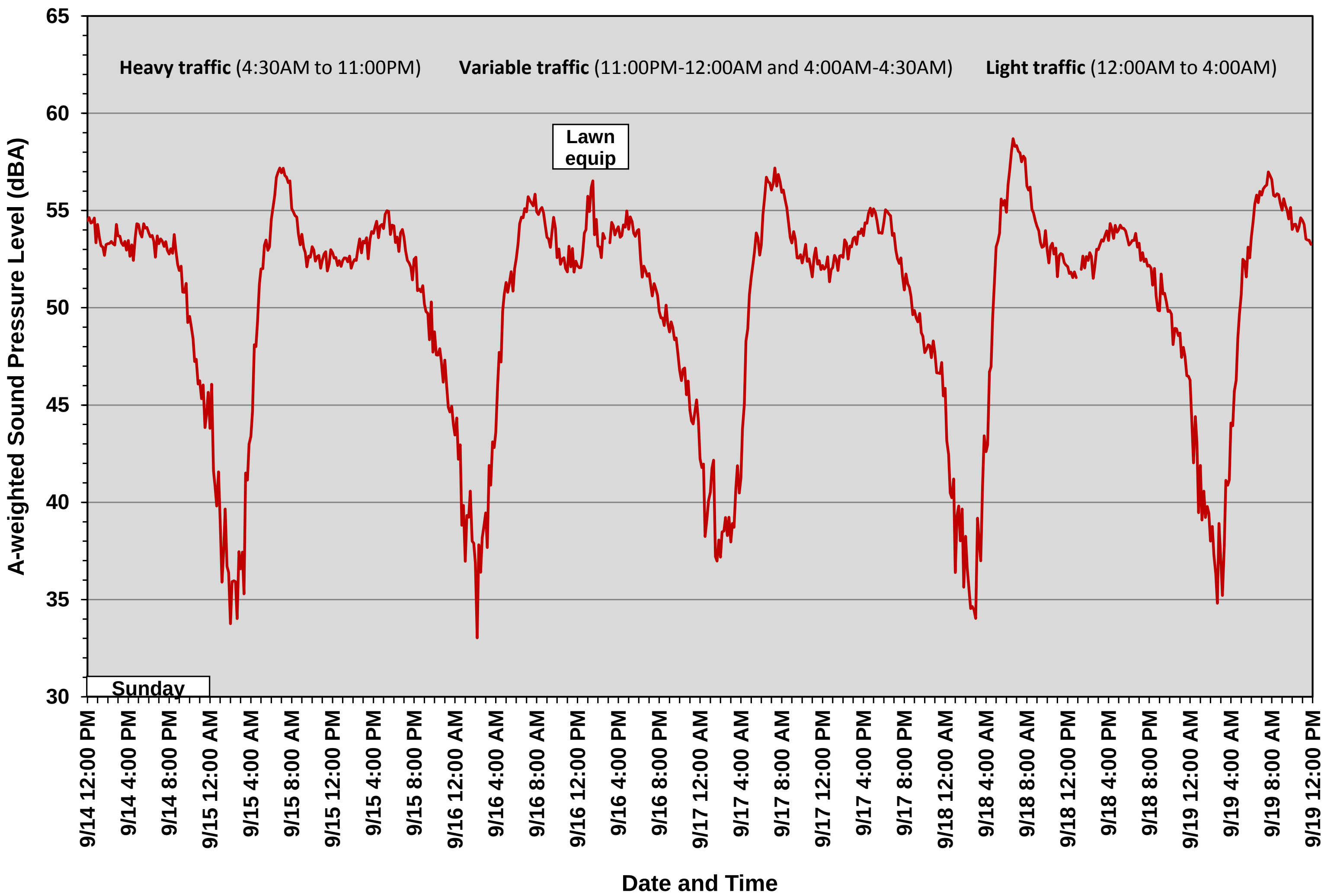


Figure 27. Variation in Slow-response A-weighted Ambient (L90) Sound Levels with Average Hub-height Wind Speed - 13 Schofield Road - September 2014

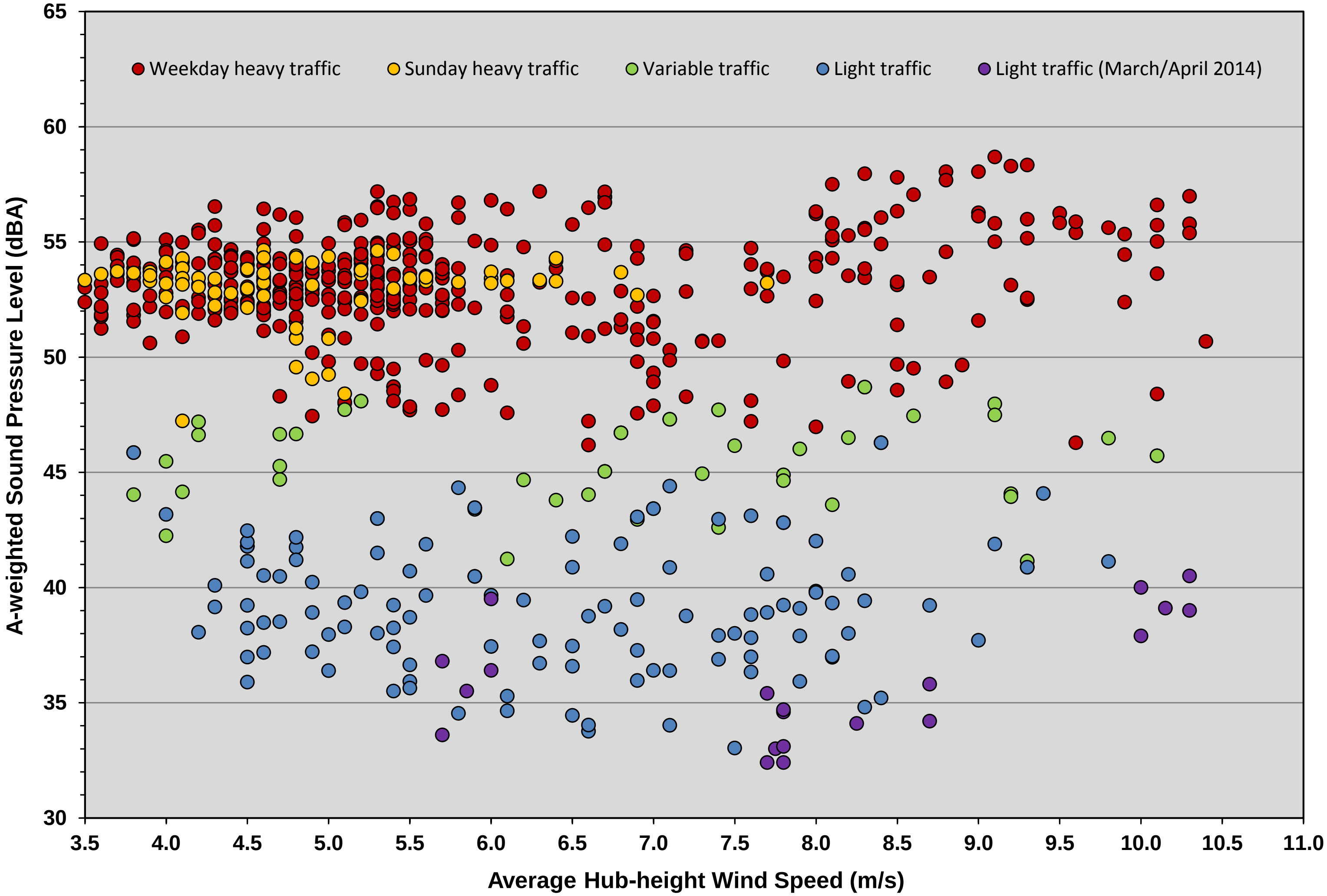


Table 37. Daytime Sound Level Increase Predictions for 13 Schofield Road with Heavy Traffic

Downwind Direction	Average Wind Speed (m/s)	KWI Turbine Power Level (kW)	Minimum Slow-response Ambient L90 (dBA) (incl. Rt. 3 traffic) (a)	Interpolated / Extrapolated KWI Turbine Slow-response Sound Levels (dBA) (excl. Route 3 traffic) (ambient removed) (b)			KWI Wind Turbine + Ambient L90 (dBA) (c)			Sound Level Increase from Ambient L90 (dBA) (d)		
				Avg Lmax	Leq	L90	Avg Lmax	Leq	L90	Avg Lmax	Leq	L90
South to West	3.5	30	46.2	40.2	36.9	34.2	47.2	46.7	46.5	1.0	0.5	0.3
	4	67	46.2	42.1	38.8	36.1	47.6	46.9	46.6	1.4	0.7	0.4
	5	169	46.2	44.5	41.2	38.5	48.4	47.4	46.9	2.2	1.2	0.7
	6	318	46.2	44.7	41.8	39.3	48.5	47.5	47.0	2.3	1.3	0.8
	7	529	46.2	45.0	42.4	40.0	48.7	47.7	47.1	2.5	1.5	0.9
	8	812	46.3	47.8	45.0	41.5	50.1	48.7	47.5	3.8	2.4	1.2
	9	1176	46.3	50.4	47.6	44.6	51.8	50.0	48.5	5.5	3.7	2.2
	10	1612	46.3	52.4	49.9	48.4	53.4	51.5	50.5	7.1	5.2	4.2
	11	1984	46.3	52.8	50.3	48.8	53.7	51.7	50.7	7.4	5.4	4.4
	12	2000	46.3	53.0	50.5	49.0	53.9	51.9	50.8	7.6	5.6	4.5
	13	2000	46.3	53.2	50.7	49.2	54.0	52.0	51.0	7.7	5.7	4.7
	14 and above	2000	46.3	53.3	50.8	49.3	54.1	52.1	51.0	7.8	5.8	4.7

Notes:
1) KWI Wind Turbine + Ambient L90: $c = 10\log\left(10^{(b/10)} + 10^{(a/10)}\right)$
2) Increase from Ambient L90: d = c - a
3) Analysis includes period from 4:30AM to 11:00PM
4) Minimum ambient L90 values dominated by traffic noise at all wind speeds

Table 38. Nighttime Sound Level Increase Predictions for 13 Schofield Road with Light Traffic

Downwind Direction	Average Wind Speed (m/s)	KWI Turbine Power Level (kW)	Minimum Slow-response Ambient L90 (dBA) (incl. Rt. 3 traffic) (a)	Interpolated / Extrapolated KWI Turbine Slow-response Sound Levels (dBA) (excl. Route 3 traffic) (ambient removed) (b)			KWI Wind Turbine + Ambient L90 (dBA) (c)			Sound Level Increase from Ambient L90 (dBA) (d)		
				Avg Lmax	Leq	L90	Avg Lmax	Leq	L90	Avg Lmax	Leq	L90
South to West	3.5	30	32.4	40.2	36.9	34.2	40.8	38.2	36.4	8.4	5.8	4.0
	4	67	32.4	42.1	38.8	36.1	42.5	39.7	37.7	10.1	7.3	5.3
	5	169	32.4	44.5	41.2	38.5	44.7	41.8	39.5	12.3	9.4	7.1
	6	318	32.4	44.7	41.8	39.3	45.0	42.3	40.1	12.6	9.9	7.7
	7	529	32.4	45.0	42.4	40.0	45.2	42.8	40.7	12.8	10.4	8.3
	8	812	32.4	47.8	45.0	41.5	47.9	45.2	42.0	15.5	12.8	9.6
	9	1176	34.2	50.4	47.6	44.6	50.5	47.8	45.0	16.3	13.6	10.8
	10	1612	37.9	52.4	49.9	48.4	52.6	50.1	48.7	14.7	12.2	10.8
	11	1984	37.9	52.8	50.3	48.8	53.0	50.5	49.1	15.1	12.6	11.2
	12	2000	37.9	53.0	50.5	49.0	53.1	50.7	49.3	15.2	12.8	11.4
	13	2000	37.9	53.2	50.7	49.2	53.3	50.9	49.5	15.4	13.0	11.6
	14 and above	2000	37.9	53.3	50.8	49.3	53.4	51.0	49.6	15.5	13.1	11.7

Notes:
1) KWI Wind Turbine + Ambient L90: $c = 10\log\left(10^{(b/10)} + 10^{(a/10)}\right)$
2) Increase from Ambient L90: d = c - a
3) Analysis includes period from 12:00AM to 4:00AM

Table 39. Nighttime Sound Level Increase Predictions for 13 Schofield Road with Variable Traffic

Downwind Direction	Average Wind Speed (m/s)	KWI Turbine Power Level (kW)	Minimum Slow-response Ambient L90 (dBA) (incl. Rt. 3 traffic) (a)	Interpolated / Extrapolated KWI Turbine Slow-response Sound Levels (dBA) (excl. Route 3 traffic) (ambient removed) (b)			KWI Wind Turbine + Ambient L90 (dBA) (c)			Sound Level Increase from Ambient L90 (dBA) (d)		
				Avg Lmax	Leq	L90	Avg Lmax	Leq	L90	Avg Lmax	Leq	L90
South to West	3.5	30	41.2	40.2	36.9	34.2	43.7	42.6	42.0	2.5	1.4	0.8
	4	67	41.2	42.1	38.8	36.1	44.7	43.2	42.4	3.5	2.0	1.2
	5	169	41.2	44.5	41.2	38.5	46.2	44.2	43.1	5.0	3.0	1.9
	6	318	41.2	44.7	41.8	39.3	46.3	44.5	43.4	5.1	3.3	2.2
	7	529	41.2	45.0	42.4	40.0	46.5	44.8	43.7	5.3	3.6	2.5
	8	812	41.2	47.8	45.0	41.5	48.7	46.5	44.3	7.5	5.3	3.1
	9	1176	41.2	50.4	47.6	44.6	50.9	48.5	46.2	9.7	7.3	5.0
	10	1612	41.2	52.4	49.9	48.4	52.7	50.4	49.1	11.5	9.2	7.9
	11	1984	41.2	52.8	50.3	48.8	53.1	50.8	49.5	11.9	9.6	8.3
	12	2000	41.2	53.0	50.5	49.0	53.3	51.0	49.6	12.1	9.8	8.4
	13	2000	41.2	53.2	50.7	49.2	53.5	51.1	49.8	12.3	9.9	8.6
	14 and above	2000	41.2	53.3	50.8	49.3	53.6	51.2	49.9	12.4	10.0	8.7

Notes:
1) KWI Wind Turbine + Ambient L90: $c = 10\log\left(10^{(b/10)} + 10^{(a/10)}\right)$
2) Increase from Ambient L90: d = c - a
3) Analysis includes period from 11:00PM to 12:00AM and from 4:00AM to 4:30AM
4) Minimum ambient L90 values dominated by traffic noise at all wind speeds

10.5.2 Leland Road

The ambient L_{90} sound levels measured at 3 Leland Road are shown in Figure 28. Time periods selected for subsequent consideration are identified at the top of this figure. Note that observed diurnal sound level variations correlate well with typical daily traffic patterns on nearby Route 3.

The measured ambient sound data are plotted against corresponding wind speed data in Figure 29 and are also highlighted to indicate the different time periods of interest. Additional nighttime ambient data previously collected during March and April 2014 is also included in this figure and measurements at 3 Leland Road and directly adjacent at 11 Leland Road have both been included in an effort to utilize as much useful information as possible. Note that on March 2, 2014 when monitoring was conducted simultaneously at these two sites, ambient levels were found to be nearly the same (as observed in Figure 29 for wind speeds of about 8.5 to 9 m/s). Taken together, the additional ambient data agrees well overall with the September 2014 nighttime data.

Ambient background sound levels were assessed against measured KWI turbine sound levels interpolated to integer wind speed values for 3 Leland Road and 11 Leland Road (see Section 9.2) as well as additional turbine-only data extrapolated to other wind speeds not measured (refer to Section 10.4) to compute the sound level increase predictions presented in Tables 40 through 45.

Ambient sound levels were highest between about 4:30am and 11:00pm, which includes times with peak traffic on Route 3 and adjacent shoulder periods. This data is shown in Figure 29 with red markers for data collected on weekdays and yellow markers for data collected on Sunday. Ambient L_{90} sound levels varied between approximately 44 and 58 dBA during this interval. The sound level increase predictions shown in Tables 40 and 41 indicate worst-case turbine-operating Avg L_{max} over ambient L_{90} increases in this time period of at most 4 to 5 dBA. Therefore, exceedances of the MassDEP noise policy due to daytime operation of the KWI turbine are not predicted to occur on Leland Road between 4:30am and 11:00pm on any day during the week or weekend.

Ambient sound levels were lowest between about 12:00am and 4:00am, though still somewhat variable due to changing traffic volumes on Route 3. This data is shown in Figure 29 with blue markers for data collected in September 2104 at 3 Leland Road, purple markers for data collected in March/April 2014 at 3 Leland Road, and pink markers for data collected in March/April 2014 at 11 Leland Road. Ambient L_{90} sound levels generally varied between approximately 33 and 48 dBA during this interval and comparable levels were measured during the summer and winter seasons. The sound level increase predictions shown in Tables 42 and 43 indicate that worst-case turbine-operating Avg L_{max} over ambient L_{90} increases in this time period exceed 10 dBA at moderate to higher wind speeds. Consequently, exceedances of the MassDEP noise policy due to nighttime operation of the KWI turbine during downwind conditions (winds from south to west) are predicted to have the potential to occur on Leland Road throughout the year between 12:00am and 4:00am at wind speeds from about 6 to 10 m/s.

Ambient sound levels transitioned between higher and lower values due to decreasing or increasing traffic volumes on Route 3 from about 11:00pm to 12:00am and also from 4:00am to 4:30am. This data is shown in Figure 29 with green markers. Ambient L_{90} sound levels varied between approximately 41 dBA and 49 dBA during this interval. The sound level increase predictions shown in Table 44 and Table 45 indicate that worst-case turbine-operating Avg L_{max} over ambient L_{90} increases in this time period are at most about 5 to 6 dBA. Thus, exceedances of the MassDEP noise policy due to nighttime operation of the KWI turbine are not predicted to occur on Leland Road between 11:00pm and 12:00am or between 4:00am and 4:30am.

In summary, sound level increases of less than 10 dBA are predicted during daytime operation of the KWI wind turbine from 4:00am to 12:00am throughout the week and weekend. Exceedances of the 10 dBA maximum increase MassDEP noise policy due to nighttime operation of the KWI turbine during downwind conditions (winds from south to west) are predicted to have the potential to occur on Leland Road throughout the year between 12:00am and 4:00am at wind speeds from about 6 to 10 m/s.

While these conclusions are based only on monitoring conducted during downwind conditions, comparable results are also anticipated with other wind directions given that turbine sound levels are likely about the same for most wind directions at the distance of this neighborhood from the KWI turbine (refer to Section 10.4) and since measured ambient sound levels were about the same overall regardless of wind direction (see Section 10.3).

Figure 28. Slow-response A-weighted Ambient (L90) Sound Level Measurement
3 Leland Road - 12:30pm on Sunday 9/14 through 12:30pm on Friday 9/19/2014

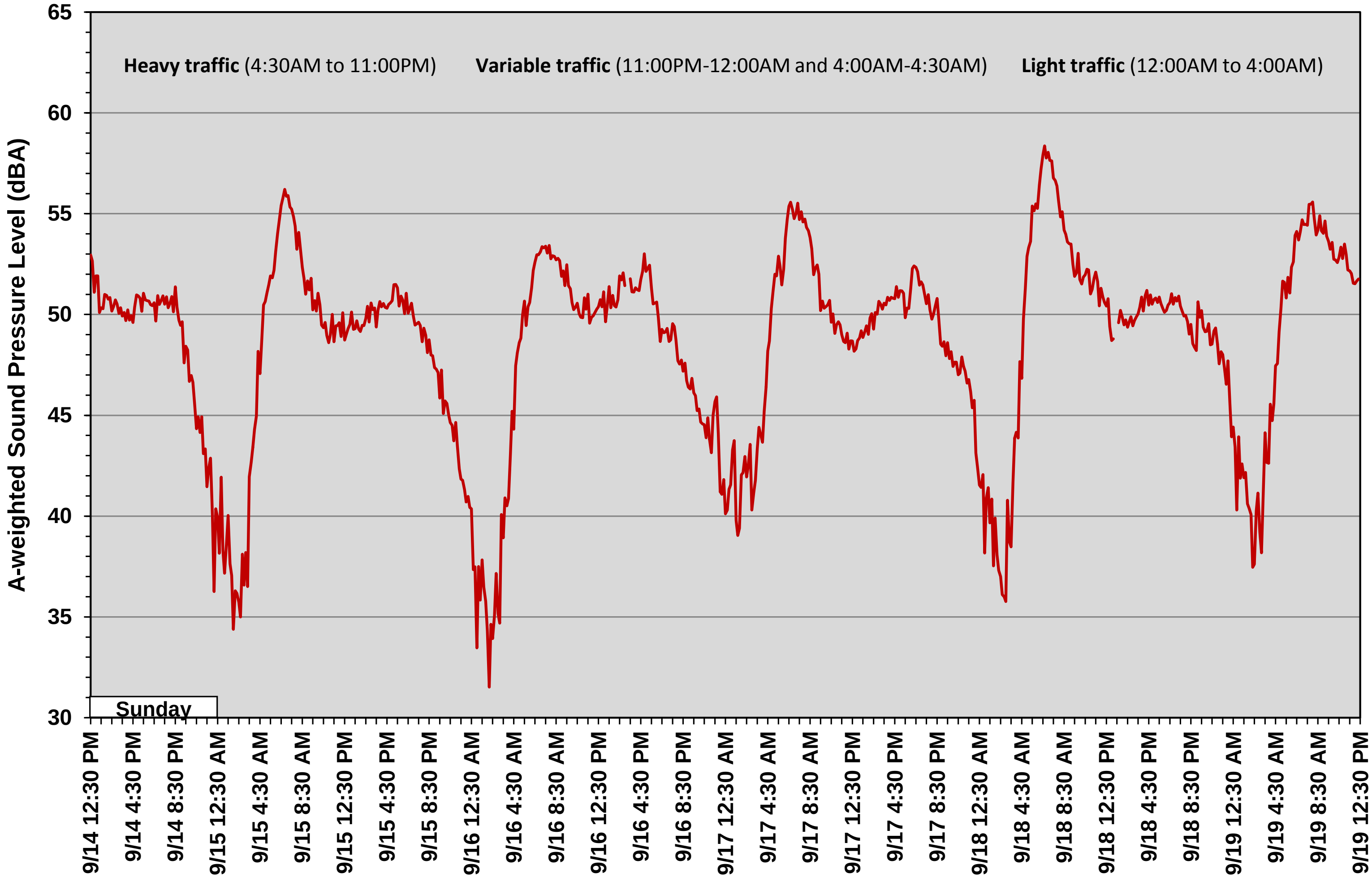


Figure 29. Variation in Slow-response A-weighted Ambient (L90) Sound Levels with Average Hub-height Wind Speed - 3 Leland Road - September 2014

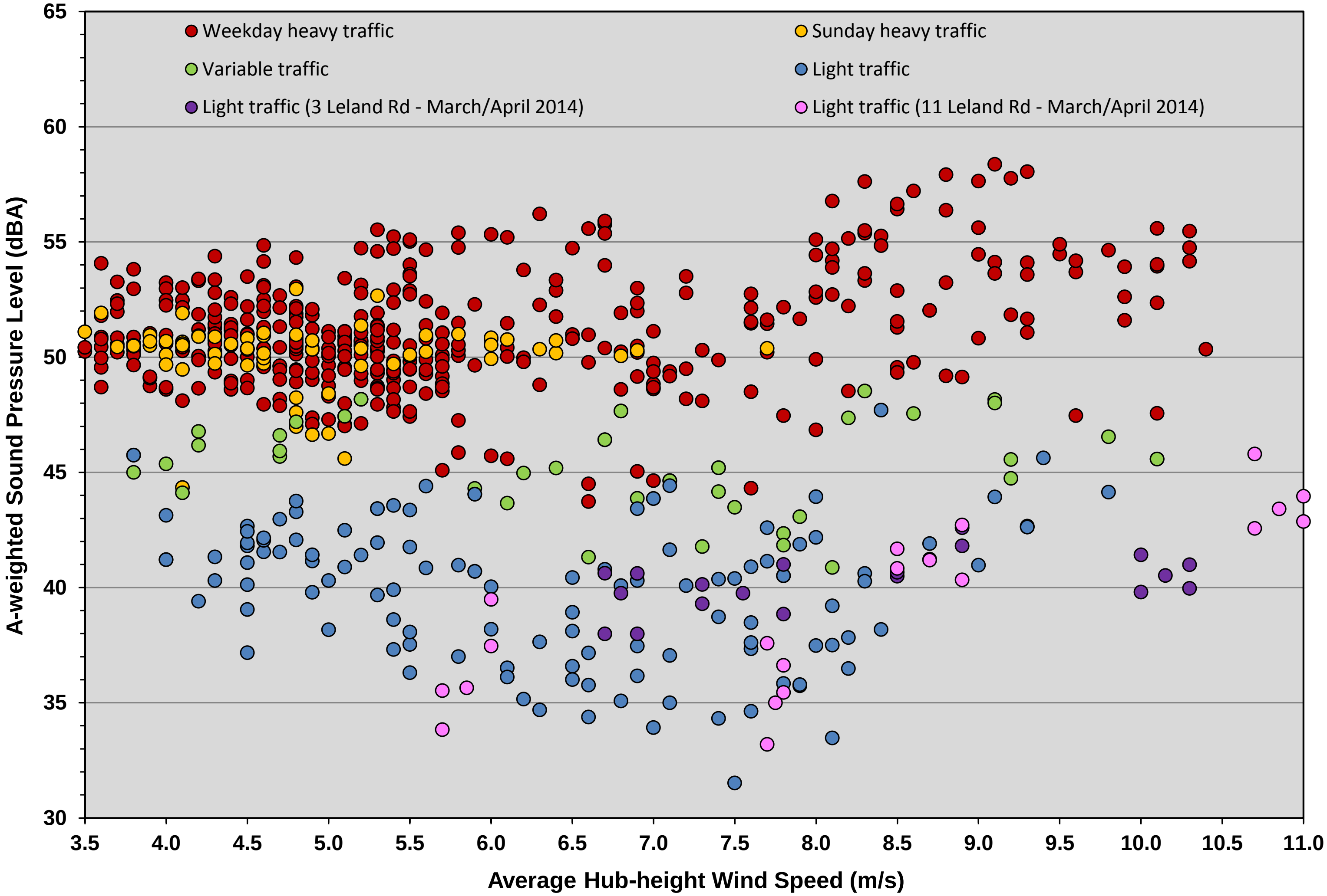


Table 40. Daytime Sound Level Increase Predictions for 3 Leland Road with Heavy Traffic

Downwind Direction	Average Wind Speed (m/s)	KWI Turbine Power Level (kW)	Minimum Slow-response Ambient L90 (dBA) (incl. Rt. 3 traffic) (a)	Interpolated / Extrapolated KWI Turbine Slow-response Sound Levels (dBA) (excl. Route 3 traffic) (ambient removed) (b)			KWI Wind Turbine + Ambient L90 (dBA) (c)			Sound Level Increase from Ambient L90 (dBA) (d)		
				Avg Lmax	Leq	L90	Avg Lmax	Leq	L90	Avg Lmax	Leq	L90
South to West	3.5	30	43.7	34.4	33.0	31.4	44.2	44.1	44.0	0.5	0.4	0.3
	4	67	43.7	36.3	34.9	33.3	44.4	44.2	44.1	0.7	0.5	0.4
	5	169	43.7	38.7	37.3	35.7	44.9	44.6	44.3	1.2	0.9	0.6
	6	318	43.7	40.5	38.8	36.8	45.4	44.9	44.5	1.7	1.2	0.8
	7	529	44.3	42.3	40.2	37.9	46.4	45.7	45.2	2.1	1.4	0.9
	8	812	46.8	44.1	42.6	40.5	48.7	48.2	47.7	1.9	1.4	0.9
	9	1176	47.5	46.2	45.3	43.9	49.9	49.5	49.1	2.4	2.0	1.6
	10	1612	47.6	48.5	47.2	46.0	51.1	50.4	49.9	3.5	2.8	2.3
	11	1984	47.6	48.9	47.6	46.4	51.3	50.6	50.0	3.7	3.0	2.4
	12	2000	47.6	49.1	47.8	46.6	51.4	50.7	50.1	3.8	3.1	2.5
	13	2000	47.6	49.3	48.0	46.8	51.6	50.8	50.2	4.0	3.2	2.6
	14 and above	2000	47.6	49.4	48.1	46.9	51.6	50.9	50.3	4.0	3.3	2.7

Notes:
1) KWI Wind Turbine + Ambient L90: $c = 10\log\left(10^{(b/10)} + 10^{(a/10)}\right)$
2) Increase from Ambient L90: d = c - a
3) Analysis includes period from 4:30AM to 11:00PM

Table 41. Daytime Sound Level Increase Predictions for 11 Leland Road with Heavy Traffic

Downwind Direction	Average Wind Speed (m/s)	KWI Turbine Power Level (kW)	Minimum Slow-response Ambient L90 (dBA) (incl. Rt. 3 traffic) (a)	Interpolated / Extrapolated KWI Turbine Slow-response Sound Levels (dBA) (excl. Route 3 traffic) (ambient removed) (b)			KWI Wind Turbine + Ambient L90 (dBA) (c)			Sound Level Increase from Ambient L90 (dBA) (d)		
				Avg Lmax	Leq	L90	Avg Lmax	Leq	L90	Avg Lmax	Leq	L90
South to West	3.5	30	43.7	37.0	34.3	31.4	44.5	44.2	43.9	0.8	0.5	0.2
	4	67	43.7	38.9	36.2	33.3	44.9	44.4	44.1	1.2	0.7	0.4
	5	169	43.7	41.3	38.6	35.7	45.7	44.9	44.3	2.0	1.2	0.6
	6	318	43.7	42.7	39.9	37.3	46.2	45.2	44.6	2.5	1.5	0.9
	7	529	44.3	44.1	41.3	38.8	47.2	46.1	45.4	2.9	1.8	1.1
	8	812	46.8	45.4	43.0	40.8	49.1	48.3	47.8	2.3	1.5	1.0
	9	1176	47.5	47.0	45.1	43.1	50.3	49.5	48.8	2.8	2.0	1.3
	10	1612	47.6	49.3	47.5	45.7	51.6	50.5	49.8	4.0	2.9	2.2
	11	1984	47.6	49.7	47.9	46.1	51.8	50.7	49.9	4.2	3.1	2.3
	12	2000	47.6	49.9	48.1	46.3	51.9	50.8	50.0	4.3	3.2	2.4
	13	2000	47.6	50.1	48.3	46.5	52.0	50.9	50.1	4.4	3.3	2.5
	14 and above	2000	47.6	50.2	48.4	46.6	52.1	51.0	50.2	4.5	3.4	2.6

Notes:
1) KWI Wind Turbine + Ambient L90: $c = 10\log\left(10^{(b/10)} + 10^{(a/10)}\right)$
2) Increase from Ambient L90: d = c - a
3) Analysis includes period from 4:30AM to 11:00PM

Table 42. Nighttime Sound Level Increase Predictions for 3 Leland Road with Light Traffic

Downwind Direction	Average Wind Speed (m/s)	KWI Turbine Power Level (kW)	Minimum Slow-response Ambient L90 (dBA) (incl. Rt. 3 traffic) (a)	Interpolated / Extrapolated KWI Turbine Slow-response Sound Levels (dBA) (excl. Route 3 traffic) (ambient removed) (b)			KWI Wind Turbine + Ambient L90 (dBA) (c)			Sound Level Increase from Ambient L90 (dBA) (d)		
				Avg Lmax	Leq	L90	Avg Lmax	Leq	L90	Avg Lmax	Leq	L90
South to West	3.5	30	33.2	34.4	33.0	31.4	36.8	36.1	35.4	3.6	2.9	2.2
	4	67	33.2	36.3	34.9	33.3	38.0	37.1	36.3	4.8	3.9	3.1
	5	169	33.2	38.7	37.3	35.7	39.8	38.7	37.7	6.6	5.5	4.5
	6	318	33.2	40.5	38.8	36.8	41.2	39.8	38.4	8.0	6.6	5.2
	7	529	33.2	42.3	40.2	37.9	42.8	41.0	39.2	9.6	7.8	6.0
	8	812	33.2	44.1	42.6	40.5	44.5	43.0	41.3	11.3	9.8	8.1
	9	1176	36.5	46.2	45.3	43.9	46.7	45.8	44.7	10.2	9.3	8.2
	10	1612	39.8	48.5	47.2	46.0	49.1	47.9	46.9	9.3	8.1	7.1
	11	1984	42.6	48.9	47.6	46.4	49.8	48.8	47.9	7.2	6.2	5.3
	12	2000	42.6	49.1	47.8	46.6	50.0	48.9	48.0	7.4	6.3	5.4
	13	2000	42.6	49.3	48.0	46.8	50.2	49.1	48.2	7.6	6.5	5.6
	14 and above	2000	42.6	49.4	48.1	46.9	50.3	49.2	48.3	7.7	6.6	5.7

Notes:
1) KWI Wind Turbine + Ambient L90: $c = 10\log\left(10^{(b/10)} + 10^{(a/10)}\right)$
2) Increase from Ambient L90: d = c - a
3) Analysis includes period from 12:00AM to 4:00AM

Table 43. Nighttime Sound Level Increase Predictions for 11 Leland Road with Light Traffic

Downwind Direction	Average Wind Speed (m/s)	KWI Turbine Power Level (kW)	Minimum Slow-response Ambient L90 (dBA) (incl. Rt. 3 traffic) (a)	Interpolated / Extrapolated KWI Turbine Slow-response Sound Levels (dBA) (excl. Route 3 traffic) (ambient removed) (b)			KWI Wind Turbine + Ambient L90 (dBA) (c)			Sound Level Increase from Ambient L90 (dBA) (d)		
				Avg Lmax	Leq	L90	Avg Lmax	Leq	L90	Avg Lmax	Leq	L90
South to West	3.5	30	33.2	37.0	34.3	31.4	38.5	36.8	35.4	5.3	3.6	2.2
	4	67	33.2	38.9	36.2	33.3	39.9	38.0	36.3	6.7	4.8	3.1
	5	169	33.2	41.3	38.6	35.7	41.9	39.7	37.7	8.7	6.5	4.5
	6	318	33.2	42.7	39.9	37.3	43.1	40.8	38.7	9.9	7.6	5.5
	7	529	33.2	44.1	41.3	38.8	44.4	41.9	39.9	11.2	8.7	6.7
	8	812	33.2	45.4	43.0	40.8	45.6	43.5	41.5	12.4	10.3	8.3
	9	1176	36.5	47.0	45.1	43.1	47.4	45.7	44.0	10.9	9.2	7.5
	10	1612	39.8	49.3	47.5	45.7	49.8	48.1	46.7	10.0	8.3	6.9
	11	1984	42.6	49.7	47.9	46.1	50.5	49.0	47.7	7.9	6.4	5.1
	12	2000	42.6	49.9	48.1	46.3	50.7	49.1	47.9	8.1	6.5	5.3
	13	2000	42.6	50.1	48.3	46.5	50.8	49.3	48.0	8.2	6.7	5.4
	14 and above	2000	42.6	50.2	48.4	46.6	50.9	49.4	48.1	8.3	6.8	5.5

Notes:
1) KWI Wind Turbine + Ambient L90: $c = 10\log\left(10^{(b/10)} + 10^{(a/10)}\right)$
2) Increase from Ambient L90: d = c - a
3) Analysis includes period from 12:00AM to 4:00AM

Table 44. Nighttime Sound Level Increase Predictions for 3 Leland Road with Variable Traffic

Downwind Direction	Average Wind Speed (m/s)	KWI Turbine Power Level (kW)	Minimum Slow-response Ambient L90 (dBA) (incl. Rt. 3 traffic) (a)	Interpolated / Extrapolated KWI Turbine Slow-response Sound Levels (dBA) (excl. Route 3 traffic) (ambient removed) (b)			KWI Wind Turbine + Ambient L90 (dBA) (c)			Sound Level Increase from Ambient L90 (dBA) (d)		
				Avg Lmax	Leq	L90	Avg Lmax	Leq	L90	Avg Lmax	Leq	L90
South to West	3.5	30	40.9	34.4	33.0	31.4	41.8	41.6	41.4	0.9	0.7	0.5
	4	67	40.9	36.3	34.9	33.3	42.2	41.9	41.6	1.3	1.0	0.7
	5	169	40.9	38.7	37.3	35.7	42.9	42.5	42.1	2.0	1.6	1.2
	6	318	40.9	40.5	38.8	36.8	43.7	43.0	42.3	2.8	2.1	1.4
	7	529	40.9	42.3	40.2	37.9	44.6	43.6	42.7	3.7	2.7	1.8
	8	812	40.9	44.1	42.6	40.5	45.8	44.8	43.7	4.9	3.9	2.8
	9	1176	44.7	46.2	45.3	43.9	48.5	48.0	47.3	3.8	3.3	2.6
	10	1612	45.6	48.5	47.2	46.0	50.3	49.5	48.8	4.7	3.9	3.2
	11	1984	45.6	48.9	47.6	46.4	50.6	49.7	49.0	5.0	4.1	3.4
	12	2000	45.6	49.1	47.8	46.6	50.7	49.8	49.1	5.1	4.2	3.5
	13	2000	45.6	49.3	48.0	46.8	50.9	50.0	49.2	5.3	4.4	3.6
	14 and above	2000	45.6	49.4	48.1	46.9	50.9	50.0	49.3	5.3	4.4	3.7

Notes:
1) KWI Wind Turbine + Ambient L90: $c = 10\log\left(10^{(b/10)} + 10^{(a/10)}\right)$
2) Increase from Ambient L90: d = c - a
3) Analysis includes period from 11:00PM to 12:00AM and from 4:00AM to 4:30AM

Table 45. Nighttime Sound Level Increase Predictions for 11 Leland Road with Variable Traffic

Downwind Direction	Average Wind Speed (m/s)	KWI Turbine Power Level (kW)	Minimum Slow-response Ambient L90 (dBA) (incl. Rt. 3 traffic) (a)	Interpolated / Extrapolated KWI Turbine Slow-response Sound Levels (dBA) (excl. Route 3 traffic) (ambient removed) (b)			KWI Wind Turbine + Ambient L90 (dBA) (c)			Sound Level Increase from Ambient L90 (dBA) (d)		
				Avg Lmax	Leq	L90	Avg Lmax	Leq	L90	Avg Lmax	Leq	L90
South to West	3.5	30	40.9	37.0	34.3	31.4	42.4	41.8	41.4	1.5	0.9	0.5
	4	67	40.9	38.9	36.2	33.3	43.0	42.2	41.6	2.1	1.3	0.7
	5	169	40.9	41.3	38.6	35.7	44.1	42.9	42.1	3.2	2.0	1.2
	6	318	40.9	42.7	39.9	37.3	44.9	43.4	42.5	4.0	2.5	1.6
	7	529	40.9	44.1	41.3	38.8	45.8	44.1	43.0	4.9	3.2	2.1
	8	812	40.9	45.4	43.0	40.8	46.7	45.1	43.8	5.8	4.2	2.9
	9	1176	44.7	47.0	45.1	43.1	49.0	47.9	47.0	4.3	3.2	2.3
	10	1612	45.6	49.3	47.5	45.7	50.9	49.6	48.7	5.3	4.0	3.1
	11	1984	45.6	49.7	47.9	46.1	51.1	49.9	48.9	5.5	4.3	3.3
	12	2000	45.6	49.9	48.1	46.3	51.3	50.0	49.0	5.7	4.4	3.4
	13	2000	45.6	50.1	48.3	46.5	51.4	50.1	49.1	5.8	4.5	3.5
	14 and above	2000	45.6	50.2	48.4	46.6	51.5	50.2	49.2	5.9	4.6	3.6

Notes:
1) KWI Wind Turbine + Ambient L90: $c = 10\log\left(10^{(b/10)} + 10^{(a/10)}\right)$
2) Increase from Ambient L90: d = c - a
3) Analysis includes period from 11:00PM to 12:00AM and from 4:00AM to 4:30AM

10.5.3 Copper Beech Drive

The ambient L_{90} sound levels measured at 18 Copper Beech Drive are shown in Figure 30 with insect noise removed and in Figure 32 with insect noise included. Time periods selected for subsequent consideration are identified at the top of this figure. Note that the observed diurnal sound level variations are somewhat erratic but correlate at times with increased activity at the nearby MTBA parking lot which may occur between the early morning and mid-afternoon commuting period or from mid-afternoon into the evening as commuters return home. Ambient sound levels at this site were not observed to follow daily traffic patterns on Route 3.

The measured ambient sound data are plotted against corresponding wind speed data in Figures 31 and 33 (with and without insect noise, respectively) and are also highlighted to indicate the different time periods of interest. Figure 31 includes additional nighttime ambient data previously collected in April 2014. The nighttime ambient L_{90} sound levels that exclude insect noise are observed to increase somewhat at wind speeds above about 8 to 9 m/s. This is consistent with the trend in ambient sound levels observed with increasing wind speed for the acoustical monitoring sites located on Schofield Road and Leland Road (refer to Figures 27 and 29). Overall, nighttime ambient levels are found to be slightly higher at wind speeds of about 10 m/s than were initially estimated for 18 Copper Beech Drive (refer to Section 9.4).

The ambient background sound level measurements were assessed against extrapolated KWI turbine-only sound levels estimated for 18 Copper Beech Drive (see Section 9.3) as well as additional extrapolations of the turbine-only levels to higher and lower wind speeds (refer to Section 10.4) to compute the sound level increase predictions presented in Tables 46 through 49.

Ambient sound levels were highest between about 4:00am and 12:00am, which includes times with peak traffic on Route 3 and peak activity at the nearby MBTA commuter rail parking lot. This data is shown in Figures 31 and 33 with red markers for data collected on weekdays and yellow markers for data collected on Sunday. Ambient L_{90} sound levels varied between about 34 and 61 dBA during this interval. The sound level increase predictions shown in Tables 46 and 48 indicate that worst-case turbine-operating Avg L_{max} over ambient L_{90} increases in this time period are at most about 6 to 7 dBA. Therefore, exceedances of the MassDEP noise policy due to daytime operation of the KWI turbine are not predicted to occur on Copper Beech Drive between 4:00am and 12:00am on any day of the week or weekend.

Ambient levels were lower between about 12:00am and 4:00am when traffic volumes on Route 3 are reduced and there is no activity at the nearby MBTA parking lot. This data is shown in Figures 31 and 33 with blue markers for data collected in September 2104 and in Figure 31 with purple markers for data collected in March and April 2014. Ambient L_{90} sound levels varied between about 32 and 47 dBA during this interval. The sound level increase predictions shown in Tables 47 and 49 indicate that worst-case turbine-operating Avg L_{max} over ambient L_{90} increases in this time period approach or slightly exceed 10 dBA at wind speeds of about 9 m/s only when insect noise is not included in ambient sound levels. Consequently, exceedances of the MassDEP noise policy due to nighttime operation of the KWI turbine during downwind conditions (winds from south to east) are predicted to have the potential to occur on Copper Beech Drive during the winter season between 12:00am and 4:00am at wind speeds around 9 m/s.

While these conclusions are based only on monitoring conducted during downwind conditions, comparable results are also anticipated with other wind directions given that turbine sound levels are likely about the same for most wind directions at the distance of this neighborhood from the KWI turbine (refer to Section 10.4) and since measured ambient sound levels were about the same overall regardless of wind direction (see Section 10.3).

Figure 30. Slow-response A-weighted Ambient (L90) Sound Level Measurement
18 Copper Beech Drive - 12pm on Sunday 9/14 to 12pm on Friday 9/19/2014 (no insects)

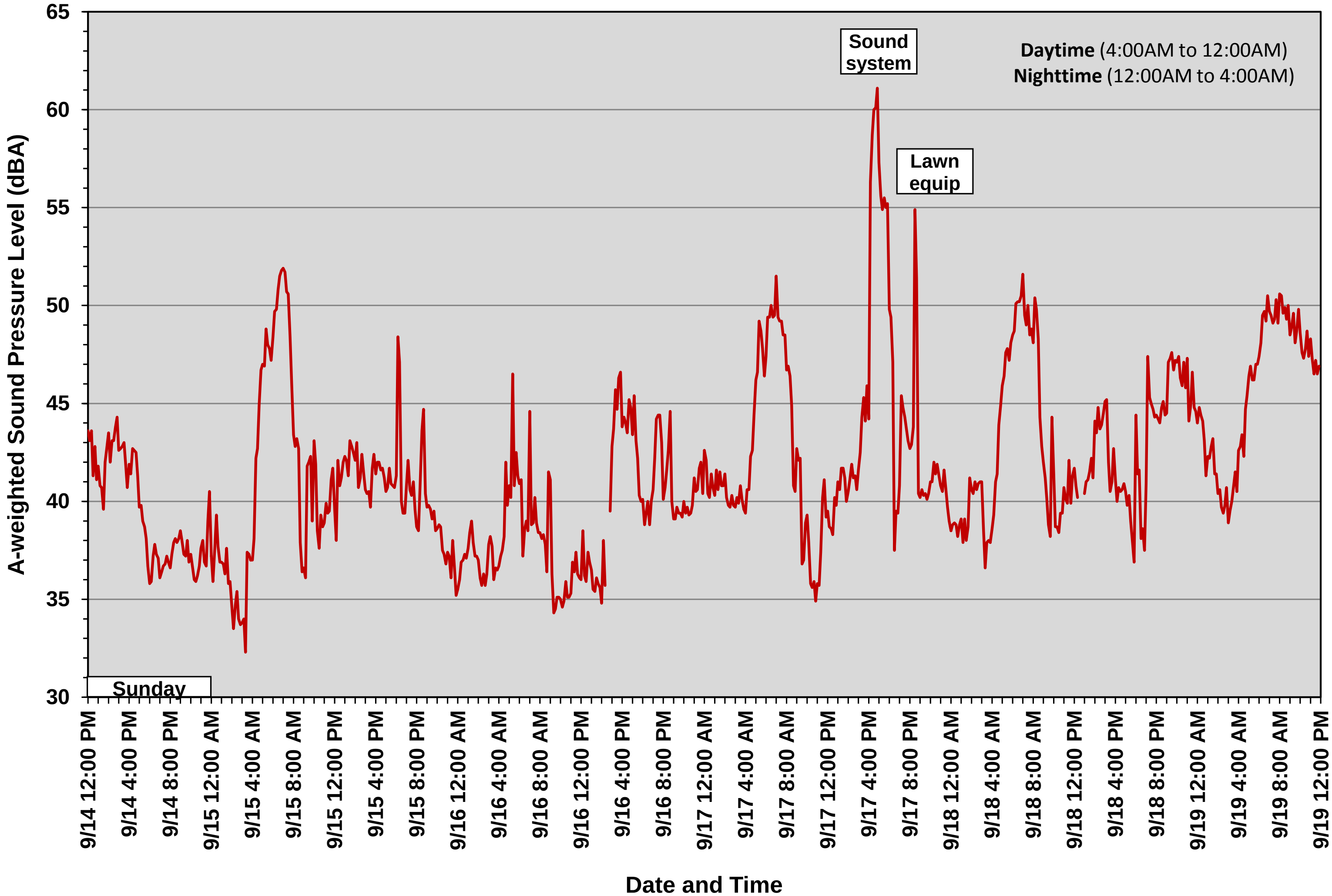


Figure 31. Variation in Slow-response A-weighted Ambient (L90) Sound Levels with Avg Hub-height Wind Speed - 18 Copper Beech Drive - Sept 2014 (no insects)

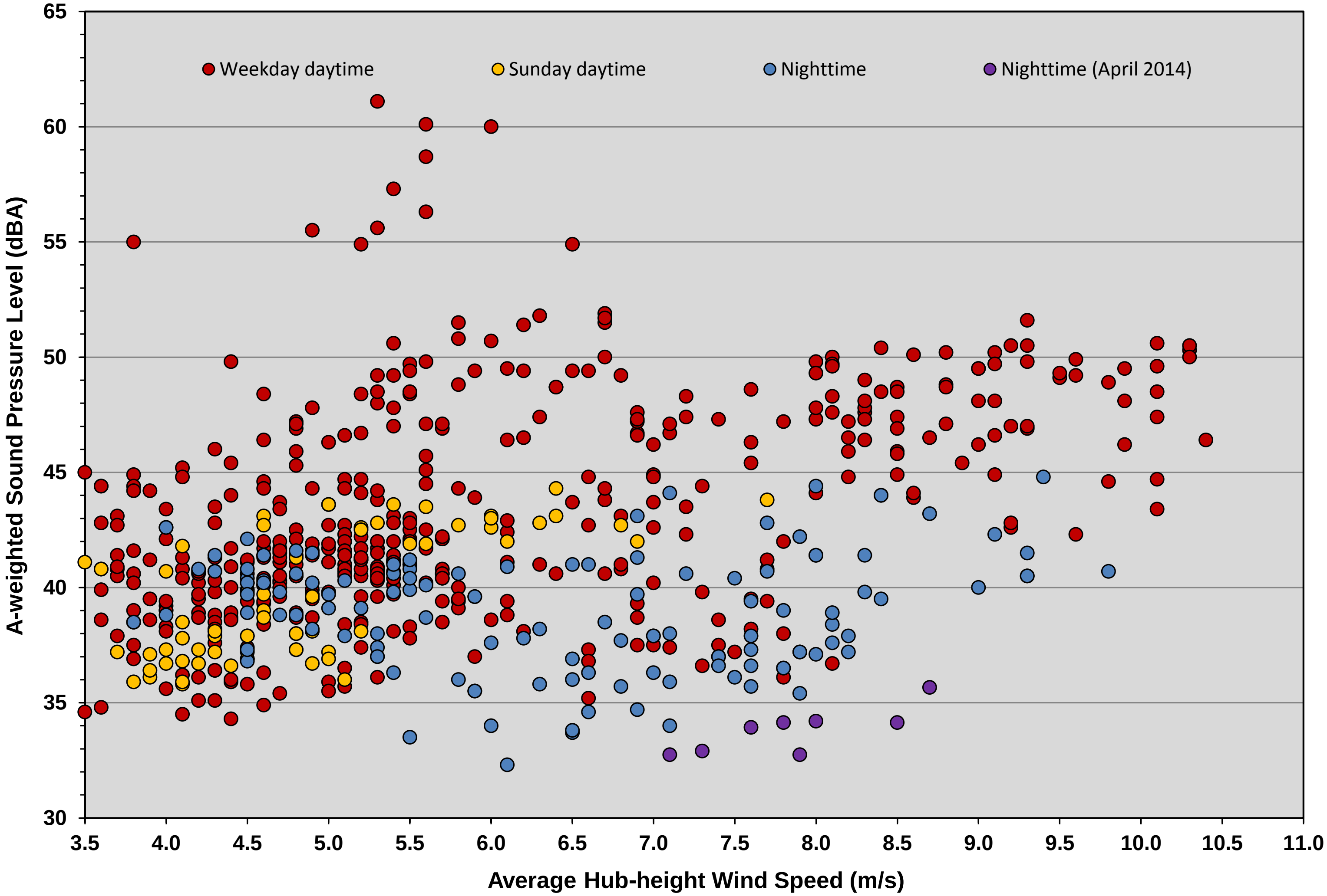


Table 46. Daytime Sound Level Increase Predictions for 18 Copper Beech Drive (no insect noise)

Downwind Direction	Average Wind Speed (m/s)	KWI Turbine Power Level (kW)	Minimum Slow-response Ambient L90 (dBA) (incl. Rt. 3 / MBTA) (a)	Extrapolated KWI Turbine Slow-response Sound Levels (dBA) (excl. Route 3 / MBTA) (ambient removed) (b)			KWI Wind Turbine + Ambient L90 (dBA) (c)			Sound Level Increase from Ambient L90 (dBA) (d)		
				Avg Lmax	Leq	L90	Avg Lmax	Leq	L90	Avg Lmax	Leq	L90
South to East	3.5	30	34.3	32.0	30.4	28.0	36.3	35.8	35.2	2.0	1.5	0.9
	4	67	34.3	33.9	32.3	29.9	37.1	36.4	35.6	2.8	2.1	1.3
	5	169	34.9	36.3	34.7	32.3	38.6	37.8	36.8	3.7	2.9	1.9
	6	318	35.2	37.6	35.9	33.6	39.6	38.5	37.5	4.4	3.3	2.3
	7	529	35.2	38.9	37.0	34.8	40.4	39.2	38.0	5.2	4.0	2.8
	8	812	36.1	41.5	39.5	36.2	42.6	41.1	39.2	6.5	5.0	3.1
	9	1176	39.2	43.9	42.0	38.9	45.2	43.8	42.1	6.0	4.6	2.9
	10	1612	42.3	45.8	43.9	42.0	47.4	46.2	45.2	5.1	3.9	2.9
	11	1984	43.6	46.2	44.3	42.4	48.1	47.0	46.0	4.5	3.4	2.4
	12	2000	43.6	46.4	44.5	42.6	48.3	47.1	46.1	4.7	3.5	2.5
	13	2000	43.6	46.6	44.7	42.8	48.4	47.2	46.2	4.8	3.6	2.6
	14 and above	2000	43.6	46.7	44.8	42.9	48.5	47.2	46.3	4.9	3.6	2.7

Notes:
1) KWI Wind Turbine + Ambient L90: $c = 10\log\left(10^{(b/10)} + 10^{(a/10)}\right)$
2) Increase from Ambient L90: d = c - a
3) Analysis includes period from 4:00AM to 12:00AM
4) High frequency sound from insects removed from data.

Table 47. Nighttime Sound Level Increase Predictions for 18 Copper Beech Drive (no insect noise)

Downwind Direction	Average Wind Speed (m/s)	KWI Turbine Power Level (kW)	Minimum Slow-response Ambient L90 (dBA) (incl. Rt. 3 traffic) (a)	Extrapolated KWI Turbine Slow-response Sound Levels (dBA) (excl. Route 3 traffic) (ambient removed) (b)			KWI Wind Turbine + Ambient L90 (dBA) (c)			Sound Level Increase from Ambient L90 (dBA) (d)		
				Avg Lmax	Leq	L90	Avg Lmax	Leq	L90	Avg Lmax	Leq	L90
South to East	3.5	30	32.3	32.0	30.4	28.0	35.1	34.5	33.7	2.8	2.2	1.4
	4	67	32.3	33.9	32.3	29.9	36.2	35.3	34.3	3.9	3.0	2.0
	5	169	32.3	36.3	34.7	32.3	37.7	36.7	35.3	5.4	4.4	3.0
	6	318	32.3	37.6	35.9	33.6	38.7	37.4	36.0	6.4	5.1	3.7
	7	529	32.7	38.9	37.0	34.8	39.8	38.4	36.9	7.1	5.7	4.2
	8	812	32.7	41.5	39.5	36.2	42.1	40.3	37.8	9.4	7.6	5.1
	9	1176	34.1	43.9	42.0	38.9	44.3	42.6	40.1	10.2	8.5	6.0
	10	1612	40.7	45.8	43.9	42.0	47.0	45.6	44.4	6.3	4.9	3.7
	11	1984	40.7	46.2	44.3	42.4	47.3	45.9	44.6	6.6	5.2	3.9
	12	2000	40.7	46.4	44.5	42.6	47.5	46.0	44.8	6.8	5.3	4.1
	13	2000	40.7	46.6	44.7	42.8	47.6	46.1	44.9	6.9	5.4	4.2
	14 and above	2000	40.7	46.7	44.8	42.9	47.7	46.2	44.9	7.0	5.5	4.2

Notes:
1) KWI Wind Turbine + Ambient L90: $c = 10\log\left(10^{(b/10)} + 10^{(a/10)}\right)$
2) Increase from Ambient L90: d = c - a
3) Analysis includes period from 12:00AM to 4:00AM
4) High frequency sound from insects removed from data.

Figure 32. Slow-response A-weighted Ambient (L90) Sound Level Measurement
18 Copper Beech Dr - 12pm on Sunday 9/14 to 12pm on Friday 9/19/2014 (with insects)

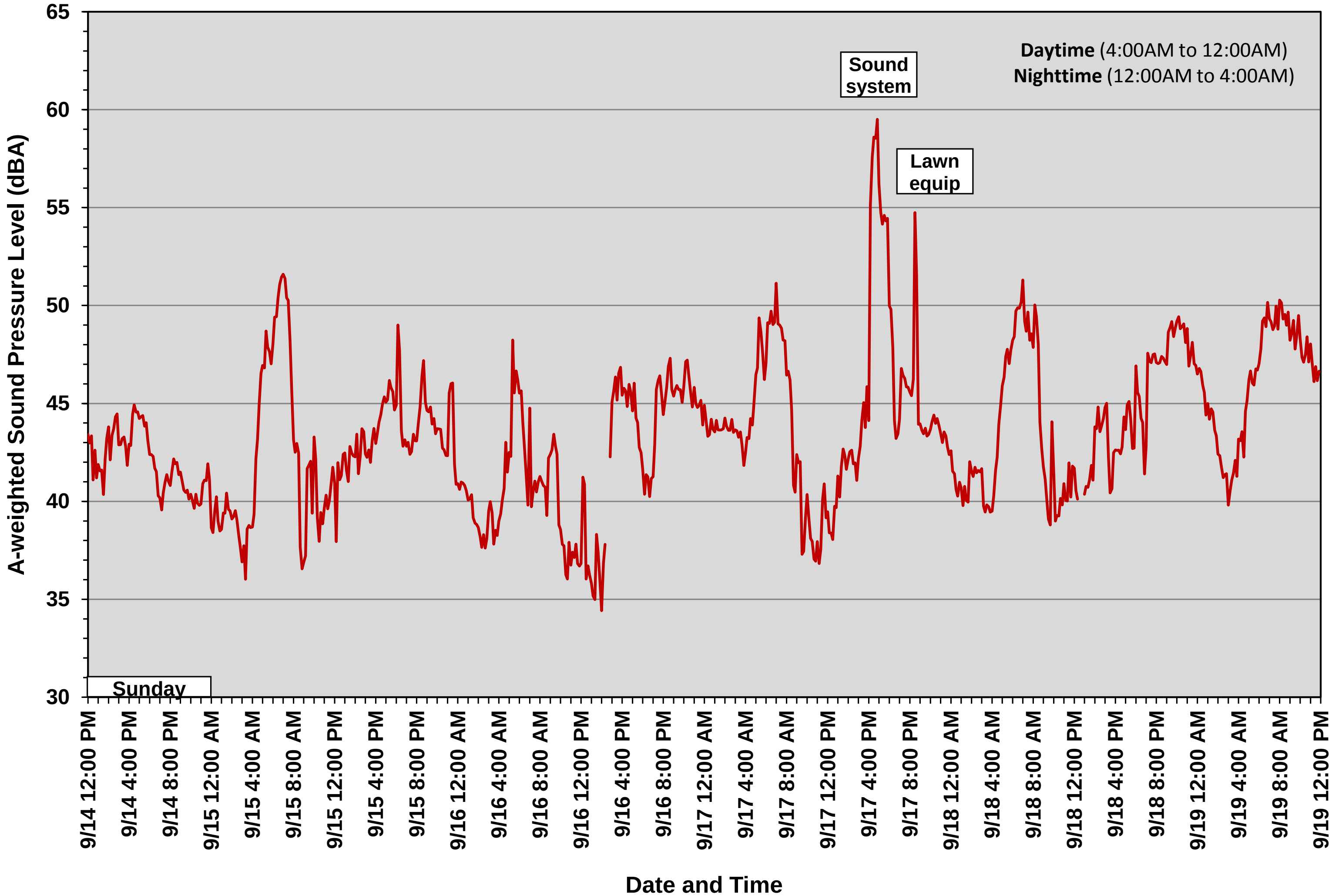


Figure 33. Variation in Slow-response A-weighted Ambient (L90) Sound Levels
with Avg Hub-height Wind Speed - 18 Copper Beech Drive - Sept 2014 (with insects)

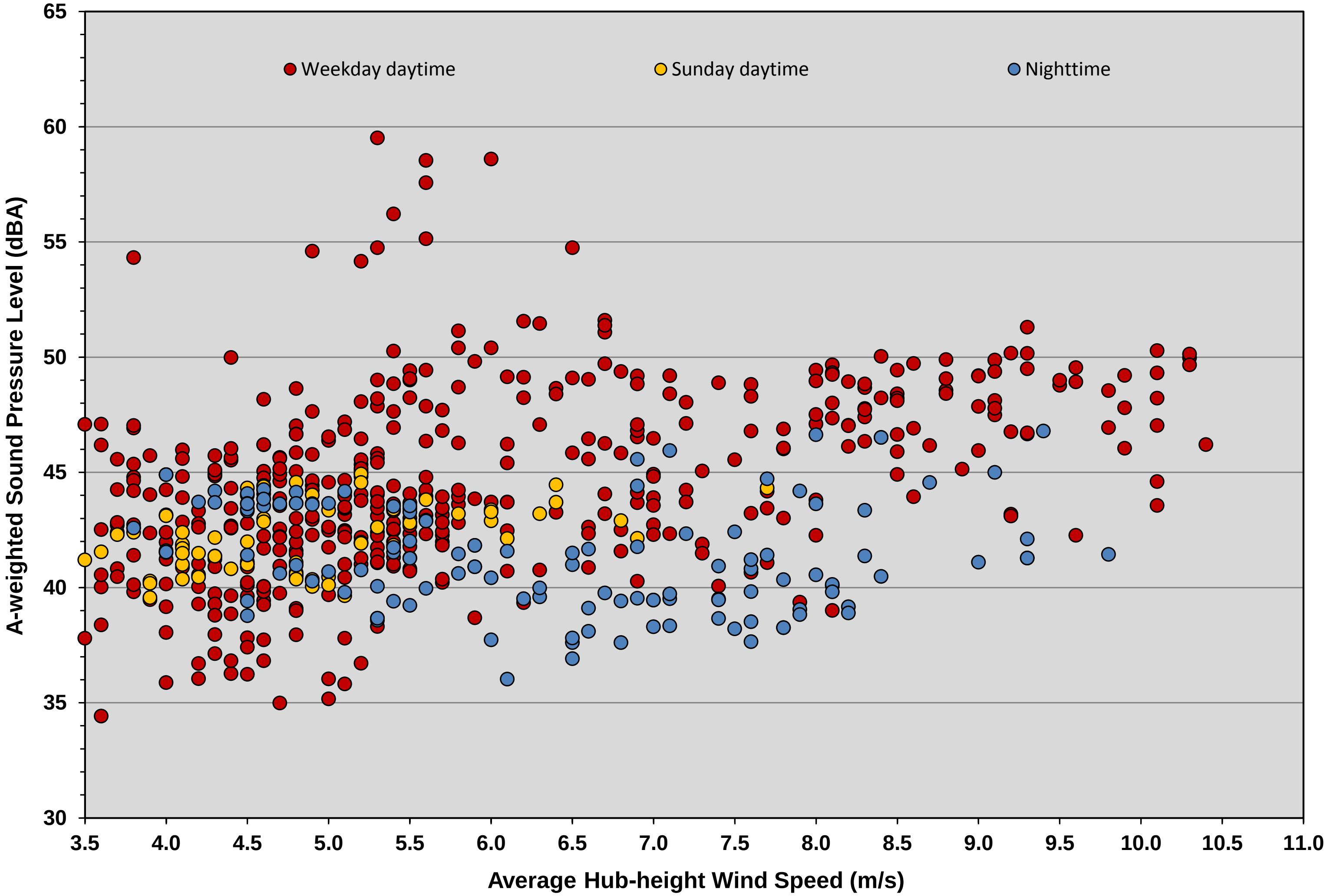


Table 48. Daytime Sound Level Increase Predictions for 18 Copper Beech Drive (with insect noise)

Downwind Direction	Average Wind Speed (m/s)	KWI Turbine Power Level (kW)	Minimum Slow-response Ambient L90 (dBA) (incl. Rt. 3 / MBTA) (a)	Extrapolated KWI Turbine Slow-response Sound Levels (dBA) (excl. Route 3 / MBTA) (ambient removed) (b)			KWI Wind Turbine + Ambient L90 (dBA) (c)			Sound Level Increase from Ambient L90 (dBA) (d)		
				Avg Lmax	Leq	L90	Avg Lmax	Leq	L90	Avg Lmax	Leq	L90
South to East	3.5	30	34.4	32.0	30.4	28.0	36.4	35.9	35.3	2.0	1.5	0.9
	4	67	35.0	33.9	32.3	29.9	37.5	36.9	36.2	2.5	1.9	1.2
	5	169	35.0	36.3	34.7	32.3	38.7	37.9	36.9	3.7	2.9	1.9
	6	318	38.7	37.6	35.9	33.6	41.2	40.5	39.9	2.5	1.8	1.2
	7	529	39.0	38.9	37.0	34.8	42.0	41.1	40.4	3.0	2.1	1.4
	8	812	39.0	41.5	39.5	36.2	43.4	42.3	40.8	4.4	3.3	1.8
	9	1176	42.3	43.9	42.0	38.9	46.2	45.2	43.9	3.9	2.9	1.6
	10	1612	42.3	45.8	43.9	42.0	47.4	46.2	45.2	5.1	3.9	2.9
	11	1984	42.3	46.2	44.3	42.4	47.7	46.4	45.4	5.4	4.1	3.1
	12	2000	42.3	46.4	44.5	42.6	47.9	46.5	45.5	5.6	4.2	3.2
	13	2000	42.3	46.6	44.7	42.8	48.0	46.7	45.6	5.7	4.4	3.3
	14 and above	2000	42.3	46.7	44.8	42.9	48.1	46.7	45.6	5.8	4.4	3.3

Notes:
1) KWI Wind Turbine + Ambient L90: $c = 10\log\left(10^{(b/10)} + 10^{(a/10)}\right)$
2) Increase from Ambient L90: d = c - a
3) Analysis includes period from 4:00AM to 12:00AM

Table 49. Nighttime Sound Level Increase Predictions for 18 Copper Beech Drive (with insect noise)

Downwind Direction	Average Wind Speed (m/s)	KWI Turbine Power Level (kW)	Minimum Slow-response Ambient L90 (dBA) (incl. Rt. 3 traffic) (a)	Extrapolated KWI Turbine Slow-response Sound Levels (dBA) (excl. Route 3 traffic) (ambient removed) (b)			KWI Wind Turbine + Ambient L90 (dBA) (c)			Sound Level Increase from Ambient L90 (dBA) (d)		
				Avg Lmax	Leq	L90	Avg Lmax	Leq	L90	Avg Lmax	Leq	L90
South to East	3.5	30	34.4	32.0	30.4	28.0	36.4	35.9	35.3	2.0	1.5	0.9
	4	67	35.0	33.9	32.3	29.9	37.5	36.9	36.2	2.5	1.9	1.2
	5	169	35.0	36.3	34.7	32.3	38.7	37.9	36.9	3.7	2.9	1.9
	6	318	36.0	37.6	35.9	33.6	39.9	38.9	38.0	3.9	2.9	2.0
	7	529	36.9	38.9	37.0	34.8	41.0	40.0	39.0	4.1	3.1	2.1
	8	812	37.7	41.5	39.5	36.2	43.0	41.7	40.0	5.3	4.0	2.3
	9	1176	41.1	43.9	42.0	38.9	45.7	44.6	43.2	4.6	3.5	2.1
	10	1612	41.4	45.8	43.9	42.0	47.2	45.8	44.7	5.8	4.4	3.3
	11	1984	41.4	46.2	44.3	42.4	47.5	46.1	44.9	6.1	4.7	3.5
	12	2000	41.4	46.4	44.5	42.6	47.6	46.2	45.0	6.2	4.8	3.6
	13	2000	41.4	46.6	44.7	42.8	47.8	46.3	45.2	6.4	4.9	3.8
	14 and above	2000	41.4	46.7	44.8	42.9	47.9	46.4	45.2	6.5	5.0	3.8

Notes:
1) KWI Wind Turbine + Ambient L90: $c = 10\log\left(10^{(b/10)} + 10^{(a/10)}\right)$
2) Increase from Ambient L90: d = c - a
3) Analysis includes period from 12:00AM to 4:00AM

11 Conclusions

This technical report includes and expands upon the acoustical monitoring results presented in the June 13, 2014 “Interim Report for Kingston Wind Independence Turbine Acoustical Study”. The report incorporates the results of data analysis conducted subsequent to publication of the interim study report, and includes measurements and predictions of additional exceedances of MassDEP noise policy on Schofield Road, Leland Road, and Copper Beech Drive.

The findings presented in this technical report are based upon two separate acoustical monitoring campaigns – attended monitoring of turbine on and turbine off sound levels at the quietest times of night between December 2013 and April 2014, and continuous unattended monitoring of background ambient sound levels with the KWI turbine off for a five day period in September 2014.

The **initial acoustical monitoring** was conducted between December 2013 and April 2014. The design of the study was to conduct measurements at some of the closest community locations with the KWI turbine shut down and also with the wind turbine in operation under worst-case conditions, which were during the quietest nighttime periods in the winter season and with downwind conditions. The monitoring data was then analyzed to determine baseline ambient sound levels and the relative increase in A-weighted sound levels due to nighttime operation of the KWI wind turbine, particularly in the context of MassDEP noise policy. Broadband sound level increases were likewise investigated for other sound level weightings (C, G, and Z) that include larger contributions from low frequency audible sound as well as from sound below the lower limit of human audibility (approximately 20 Hz) known as infrasound. A sound level modulation depth analysis was also conducted.

The monitoring conducted on Schofield Road during contiguous periods with the KWI turbine shut down and then operating revealed increases of slow-response A-weighted Avg L_{max} sound levels during turbine operation over nighttime ambient L_{90} sound levels of up to approximately 15 dBA. The broadband sound level increases measured at this location were also very comparable using other sound level weightings (C, G, and Z) that include a greater contribution from the lowest frequencies of sound. Likewise, octave band sound level increases were found to be similar across most frequencies of sound.

Acoustical monitoring conducted at additional sites to the east of Route 3 and farther from the turbine showed increases of turbine-operating Avg L_{max} over ambient L_{90} of up to approximately 9 to 10 dBA on Leland Road and up to about 8 dBA along Prospect Street. Sound level increases at these distances from the KWI turbine were generally somewhat greater in the lower frequency octave bands, indicating that higher frequency sound generated by the turbine attenuates at a greater rate with distance. For this reason, the A-weighed sound level increases measured in these locations were typically several decibels lower than the increases observed on Schofield Road during comparable periods, while broadband sound level increases calculated using other sound level weightings were somewhat higher and closer to the Schofield Road monitoring results.

Overall, increases of turbine-operating Avg L_{max} over ambient L_{90} exceeding 10 dBA were identified in the Schofield Road, Leland Road, and Prospect Street community for nighttime operation of the KWI turbine during downwind conditions with wind speeds above 7 m/s (as summarized in Table 50). Analysis of the octave band sound levels measured with the turbine operating showed that it does not create a “pure tone condition”, which is an additional component of the MassDEP noise policy.

Also, the turbine-operating Avg L_{max} over ambient L_{90} sound level increases measured at locations on Schofield Road, Leland Road, and Prospect Street using a slow-response sound level meter setting were about 1 to 2 dBA greater when data was collected using a fast-response setting. This difference is largely due to higher L_{max} values; L_{90} values are more comparable between the two meter response settings.

In addition, the sound level modulation depths calculated for periods with the KWI wind turbine operating at low to moderate wind speeds were less than or comparable to the modulation depths computed for periods with the turbine shut down. Modulation depths calculated over intervals with the wind turbine operating at moderate to higher wind speeds were up to approximately 1 to 3 dBA greater as compared with ambient conditions. A modulation frequency of around 1 Hz was observed with the turbine operating, typical for wind turbine sound. Ambient sound level variations with the KWI turbine shut down are generally somewhat random and only very occasionally periodic.

Daytime acoustical monitoring was conducted at the Kingston Intermediate School in the late morning with moderate wind speeds. A-weighted L_{90} sound levels measured with the KWI turbine operating increased from ambient background L_{90} sound levels by less than 1 dBA. Broadband sound level increases calculated using other sound level weightings (C, G, and Z) were less than 2 dB. No difference was found between the sound level modulation depths calculated for contiguous periods with the KWI turbine shut down and then operating. Traffic dominated the ambient sound levels throughout the monitoring and the wind turbine was not audible at any time.

Turbine-operating Avg L_{max} over ambient L_{90} sound level increases exceeding 10 dBA were also estimated in the Copper Beech Drive community for nighttime operation of the KWI turbine during downwind conditions with wind speeds of 9 m/s and above (as summarized in Table 51). This estimate was based on comparison of nighttime ambient (KWI turbine off) sound level monitoring data to extrapolations of turbine-only sound level data collected during attended monitoring at other locations.

Table 50. Summary of Measured Conditions for Sound Level Increases Exceeding 10 dBA due to Operation of the KWI Wind Turbine

Community	Time of Year	Time of Day	Power Level (kW)	Wind Speed (m/s)	Wind Direction
Schofield Rd / Leland Rd / Prospect St	Winter	approx. 1 to 3 AM	above 529 kW	above 7 m/s	South to Southwest

Table 51. Summary of Initial Estimated Conditions for Sound Level Increases Exceeding 10 dBA due to Operation of the KWI Wind Turbine

Community	Time of Year	Time of Day	Power Level (kW)	Wind Speed (m/s)	Wind Direction
Copper Beech Drive	Winter	approx. 1 to 3 AM	1176 kW and above	9 m/s and above	South to East

Since increases of turbine-operating Avg L_{max} over nighttime ambient L_{90} exceeding 10 dBA were identified at some locations during the acoustical monitoring study, and because sound from traffic on Route 3 is very significant at the closest neighborhood locations outside of the quietest nighttime periods, a **supplemental ambient monitoring program** was conducted in September 2014 to investigate daily and seasonal variations in A-weighted ambient L_{90} sound levels in the affected community.

The ambient L_{90} sound level data were then assessed against measured KWI turbine sound levels interpolated to integer wind speed values for the Schofield Road and Leland Road monitoring locations, as well as additional turbine-only data extrapolated to higher and lower wind speeds not directly measured. KWI turbine-only sound levels were likewise extrapolated for the 18 Copper Beech Drive site to estimate potential increases in ambient background sound levels over a range of wind speeds and during various periods throughout the day. This information was used to evaluate potential sound level increases associated with operation of the KWI wind turbine at different times of day and year and with various wind conditions in the context of MassDEP noise policy.

In the Schofield Road, Leland Road, and Prospect Street community, sound level increases of less than 10 dBA are predicted during daytime operation of the KWI wind turbine from 4:30am to 11:00pm throughout the week and weekend. Exceedances of the 10 dBA maximum increase MassDEP noise policy due to nighttime operation of the KWI turbine are predicted to have the potential to occur throughout the year between 12:00am and 4:00am for wind speeds of 4 m/s and above and between 11:00pm and 4:30am for wind speeds above 9 m/s, regardless of wind direction (as summarized in Table 52).

In the Copper Beech Drive community, sound level increases of less than 10 dBA are predicted from 4:00am to 12:00am throughout the week and weekend regardless of the season. Exceedances of the MassDEP noise policy due to nighttime operation of the KWI turbine are predicted to have the potential to occur during the winter season only (no insect noise) between 12:00am and 4:00am for wind speeds around 9 m/s, regardless of wind direction (as summarized in Table 52).

Table 52. Summary of Final Predicted Conditions for Sound Level Increases Potentially Exceeding 10 dBA due to Operation of the KWI Wind Turbine

Community	Time of Year	Time of Day	Power Level (kW)	Wind Speed (m/s)	Wind Direction
Schofield Rd / Leland Rd / Prospect St	All Seasons	12 AM to 4 AM	67 kW and above	4 m/s and above	All
		11 PM to 12 AM	above 1176 kW	above 9 m/s	
		4 AM to 4:30 AM			
Copper Beech Drive	Winter	12 AM to 4 AM	around 1176 kW	around 9 m/s	All

Finally, any noise abatement orders resulting from the findings of this acoustical study that are to be evaluated based on data logs from the KWI turbine SCADA system are recommended to either directly reference power generation levels or otherwise refer to wind speed data that is adjusted using a +1.5 m/s correction factor since the wind speeds measured by the ultrasonic anemometers mounted on the KWI turbine nacelle underestimate actual wind speeds by about 1.5 m/s on average.

Appendix A Description of Sound Metrics

This Appendix describes the terminology and sound metrics used in this report.

A.1 Decibels (dB), Frequency and Sound Level Weightings

Loudness is a subjective quantity that enables a listener to order the magnitude of different sounds on a scale from quiet to loud. Although the perceived loudness of a sound is based somewhat on its frequency and duration, chiefly it depends upon the sound pressure level. This is a measure of the sound pressure at a point relative to a standard reference value; sound pressure level is always expressed in decibels (dB).

Decibels are logarithmic quantities, so combining decibels is unlike common arithmetic. For example, if two sound sources each produce 100 dB operating individually and they are then operated together, they produce 103 dB. Each doubling of the number of sources produces another three decibels of sound. A tenfold increase in the number of sources makes the sound pressure level go up 10 dB, and a hundredfold increase makes the level go up 20 dB. If two sources differ in sound pressure level by more than 10 decibels, then operating together, the total level will approximately equal the level of the louder source as the quieter source doesn't contribute significantly to the total.

People hear changes in sound level according to the following rules of thumb: 1) a change of 1 decibel or less in a given sound's level is generally not readily perceptible except in a laboratory setting; 2) a 5-dB change in a sound is considered to be generally noticeable in a community setting; and 3) it takes approximately a 10-dB change to be heard as a doubling or halving of a sound's loudness.

Another important characteristic of sound is its frequency, or "pitch." This is the rate of repetition of sound pressure oscillations as they reach our ears. Frequency is expressed in units known as Hertz (abbreviated "Hz" and equivalent to one cycle per second). Sounds heard in the environment usually consist of a range of frequencies. The distribution of sound energy as a function of frequency is termed the "frequency spectrum."

The human ear does not respond equally to identical sound levels at different frequencies. Although the normal frequency range of hearing for most people extends from a low of approximately 20 Hz to a high of around 10,000 Hz to 20,000 Hz, people are generally most sensitive to sounds in the voice range, between about 500 Hz to 2,000 Hz. Therefore, to correlate the amplitude of a sound with its level as perceived by people, the sound energy spectrum is adjusted, or "weighted."

A.1.1 A-weighting Network

The weighting system most commonly used to correlate with human response to sound is "A-weighting" (or the "A-filter") and the resultant sound level is called the "A-weighted sound level" (dBA). A-weighting significantly de-emphasizes those parts of the frequency spectrum from a sound source that occurs both at lower frequencies (those below about 500 Hz) and at very high frequencies (above 10,000 Hz) where we do not hear as well. The filter has very little effect, or is nearly "flat," in the middle range of frequencies between 500 and 10,000 Hz. In addition to representing human hearing sensitivity, A-weighted sound levels have been found to correlate better than other weighting networks with human perception of "noisiness." One of the primary reasons for this is that the A-weighting network emphasizes the frequency range where human speech occurs, and sound in this range interferes with speech communication. Another reason is that the increased hearing sensitivity makes sound more annoying in this frequency range.

A.1.2 Other Broadband Sound Level Weightings

Another commonly-used weighting network is "C-weighting," originally developed to mimic the human ear's frequency response at a level of approximately 100 dB. C-weighting is flat (has no weighting) throughout most of the audible range, but tapers with small amounts of attenuation at the very highest and lowest frequency regions (above about 8000 Hz and below about 32 Hz). In recent years, C-weighted sound levels have sometimes been used for comparison with the A-weighted sound levels measured during the same time period as an indicator of the prominence of low frequency sound. The A- and C-weightings are similar at the highest frequencies, but A-weighting filters out much more of the low-frequency sound below about 500 Hz.

G-weighting is a more recently-developed weighting network that is intended to isolate and measure only very low frequency sound, including sounds below the lower limit of human audibility (approximately 20 Hz) commonly known as infrasound. G-weighting actually incorporates 9 dB of amplification (gain) in the sound level signal at 20 Hz, with a steep taper at higher and lower frequencies, such that the weighting is 20 dB lower at approximately 5 Hz and 40 Hz.

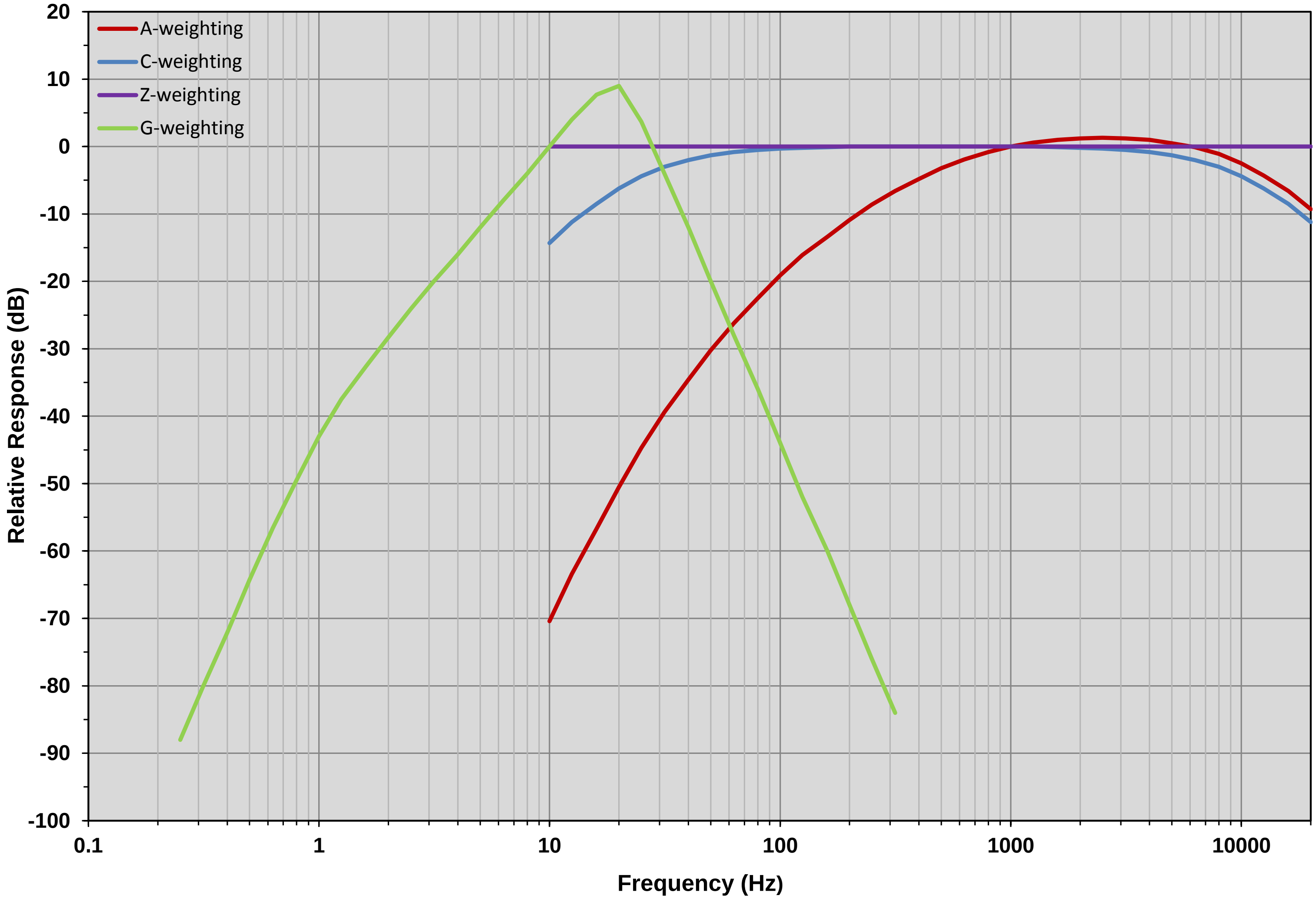
An unweighted sound level is commonly called "Z-weighted," although technically there is no weighting.

Figure A-1 presents a graph comparing the various broadband sound level weighting networks. As shown in this figure, the A-weighting, C-weighting, and Z-weighting networks comprise the frequency range from 10 Hz to 20,000 Hz, while the G-weighting network includes the frequency range from 0.25 Hz to 315 Hz.

A.1.3 Octave Band and 1/3-Octave Band Sound Levels

For analysis purposes, sound is also often broken down into different frequency divisions, or bands. The most common division is the standard octave band. An octave is a band of frequencies whose lower frequency limit is half of the upper frequency limit. An octave band is identified by its center frequency. For example the 1000 Hz octave band contains all the frequencies between 720 Hz and 1440 Hz. The next octave band higher would have values twice these, and the next octave lower would have values half of these. The range of human hearing is commonly divided into 10 standard octave bands that encompass the range from 20 Hz to 20,000 Hz: 31.5 Hz, 63 Hz, 125 Hz, 250 Hz, 500 Hz, 1 kHz, 2 kHz, 4 kHz, 8 kHz, and 16 kHz. For analyses that require even further frequency detail, each octave-band is often broken down into parts, such as 1/3 octave-bands.

Figure A-1. Broadband Sound Level Weighting Networks



A.2 Metrics that Describe Sound Levels over Time

Figure A-2 illustrates the different sound metrics that are calculated from a sound level that varies by several decibels over a period of time. A description of each metric is provided in the subsections below.

A.2.1 Maximum Sound Level (L_{max})

The variation in sound level over time often makes it convenient to describe a particular sound "event" by its maximum sound level, abbreviated as $L_{max.}$ The maximum level describes only one dimension of an event; it provides no information on the cumulative sound exposure. In fact, two events with identical maxima may produce very different total exposures. One may be of very short duration, while the other may continue for an extended period and be judged more annoying.

A.2.2 Minimum Sound Level (L_{min})

The lowest sound level measured over a period of time is called the minimum sound level, and is abbreviated $L_{min.}$

A.2.3 Equivalent Sound Level (L_{eq})

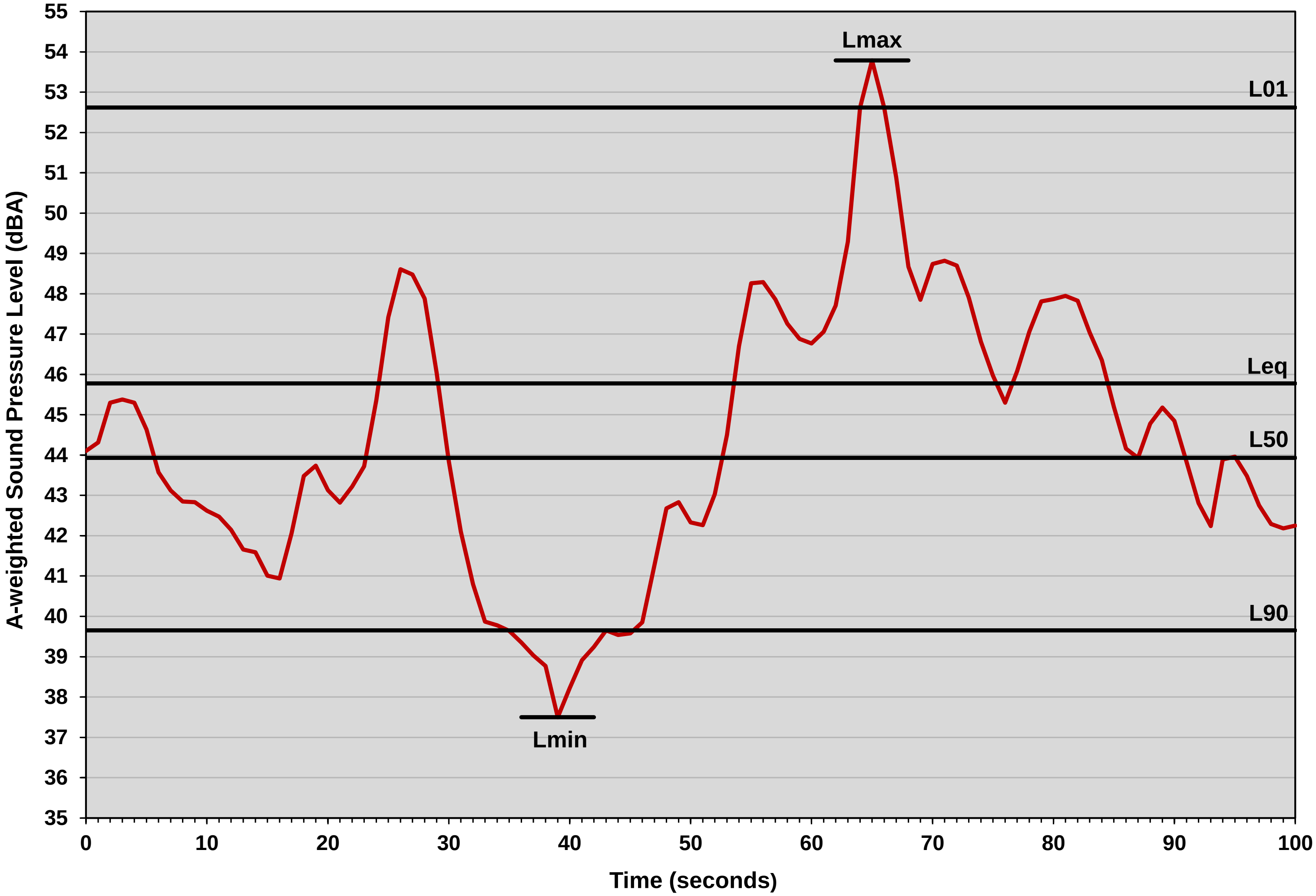
The Equivalent Sound Level, abbreviated L_{eq}, is a measure of the total exposure resulting from the accumulation of A-weighted sound levels over a particular period of interest -- for example, an hour, an 8-hour school day, nighttime, or a full 24-hour day. However, because the length of the period can be different depending on the time frame of interest, the applicable period should always be identified or clearly understood when discussing the metric.

L_{eq} may be thought of as a constant sound level over the period of interest that contains as much sound energy as (is "equivalent" to) the actual time-varying sound level with its normal peaks and valleys. It is important to recognize, however, that the two signals (the constant one and the time-varying one) would sound very different from each other. Also, the "average" sound level suggested by L_{eq} is not an arithmetic value, but a logarithmic, or "energy-averaged" sound level. Thus, the loudest events may dominate the sound environment described by the metric, depending on the relative loudness of the events.

A.2.4 Statistical Sound Level Descriptors

Statistical descriptors of the time-varying sound level are often used to provide more information about how the sound level varied during the time period of interest. The descriptor includes a subscript that indicates the percentage of time the sound level is exceeded during the period. The L_{50} is an example, which represents the sound level exceeded 50 percent of the time, and equals the median sound level. Another commonly used descriptor is the L_{01}, which represents the sound level exceeded 1 percent of the measurement period and describes the sound level during the loudest portions of the period. The L_{90} is often used to describe the quieter background sound levels that occurred, since it represents the level exceeded 90 percent of the period. The Massachusetts Department of Environmental Protection's noise policy specifies the L_{90} metric as the appropriate sound level metric to describe the "ambient" background sound level.

Figure A-2. Sound Metric Calculations for an A-weighted Sound Level Time History



A.3 Sound Level Meter Response Time

Sound level meters have a few response times available to measure rapidly-varying sound levels, so that one can read the meter and determine sound levels reliably. The electronic response networks use “exponential” time averaging of the sound signal to provide the readings. “Slow” response is most commonly used for measurements of environmental sound, and has an averaging time of one second. “Fast” response is also commonly used; its response time is comparable to that of the human ear, and has an averaging time of 1/8 second (125 milliseconds). The sound metrics for a time-varying sound level can be quite different depending on whether a slow or fast meter response is used to establish the values.

A.4 Sound Level Amplitude Modulation

Amplitude modulation is defined as a periodic variation in sound levels over time.

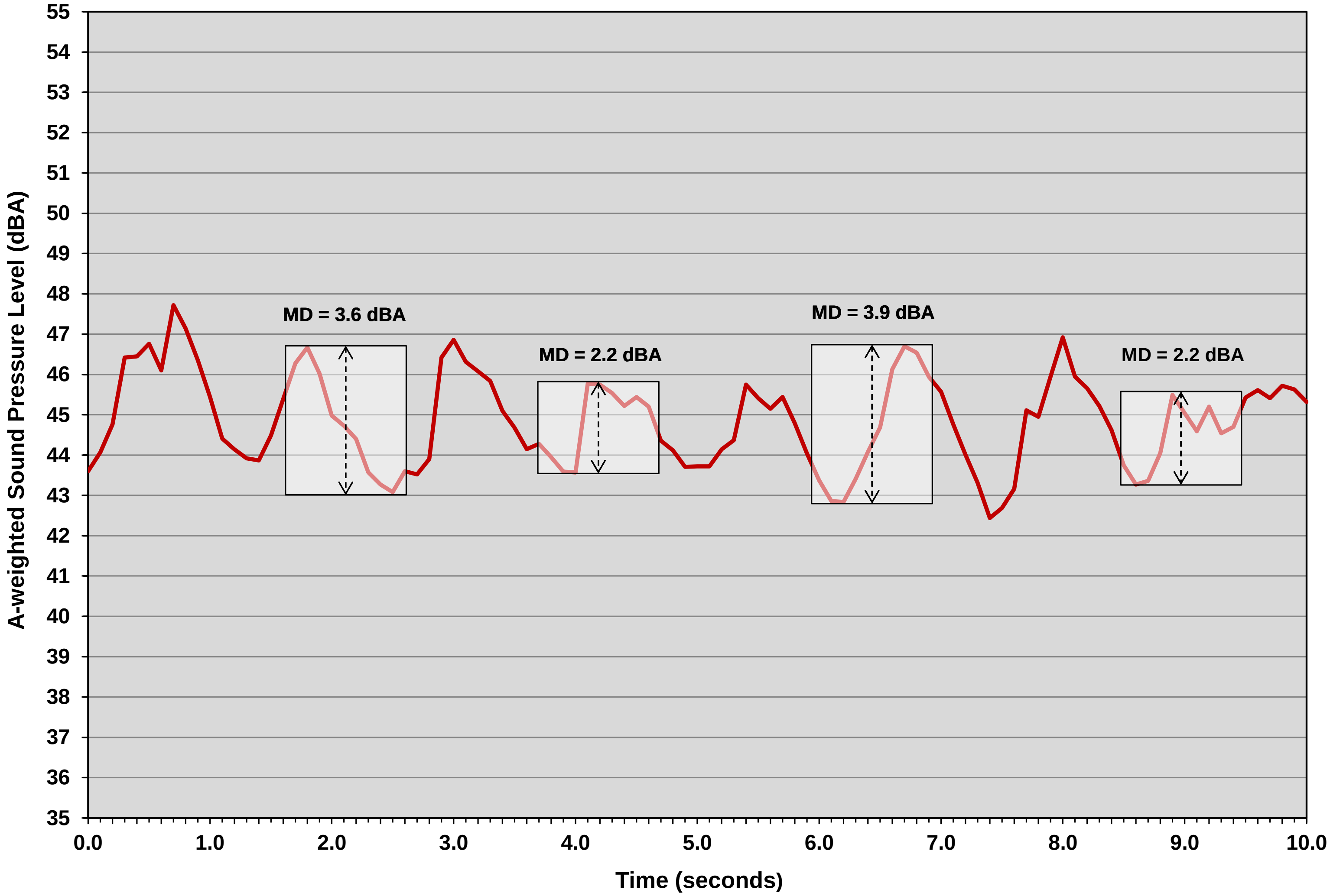
A.4.1 Modulation Depth

Modulation depth is a metric used to assess the degree of sound level amplitude modulation associated with an acoustic signal. One limitation of modulation depth analysis is that this approach cannot distinguish between random sound level variations that occur briefly within a short time span and periodic sound level modulations that occur more regularly over a longer timeframe.

For purposes of this study, modulation depth was defined as the maximum fast-response A-weighted sound level difference (peak-to-trough) within 1/2 second of each 1/10th second data sample. This design allowed sound level modulations with frequencies from 0.5 to 5 Hz to be evaluated.

Figure A-3 illustrates modulation depth calculations for an amplitude-modulated acoustic signal that periodically varies in sound level by several decibels over time.

Figure A-3. Modulation Depth Calculations for an Amplitude-Modulated Signal



Appendix B MassDEP Noise Policy

Massachusetts Department of ENVIRONMENTAL PROTECTION

f a c t s h e e t

Noise

Background

Noise is a type of air pollution that results from sounds that cause a nuisance, are or could injure public health, or unreasonably interfere with the comfortable enjoyment of life, property, or the conduct of business. Types of sounds that may cause noise include:

- "Loud" continuous sounds from industrial or commercial activity, demolition, or highly amplified music;
- Sounds in narrow frequency ranges such as "squealing" fans or other rotary equipment; and
- Intermittent or "impact" sounds such as those from pile drivers, jackhammers, slamming truck tailgates, public address systems, etc.

Policy

A noise source will be considered to be violating the Department's noise regulation (310 CMR 7.10) if the source:

1. Increases the broadband sound level by more than 10 dB(A) above ambient, or
2. Produce a "pure tone" condition – when any octave band center frequency sound pressure level exceeds the two adjacent center frequency sound pressure levels by 3 decibels or more.

These criteria are measured both at the property line and at the nearest inhabited residence. "Ambient" is defined as the background A-weighted sound level that is exceeded 90% of the time, measured during equipment operating hours. "Ambient" may also be established by other means with consent of the Department.

For more information:

For complaints about specific noise sources, call the Board of Health for the municipality in which the noise source is located.

To learn more about responding to noise, odor and dust complaints or to request state assistance or support, please contact the service center in the nearest DEP regional office.

- Central Region, Worcester: (508) 792-7683
- Northeast Region, Wilmington: (978) 661-7677
- Southeast Region, Lakeville: (508) 946-2714
- Western Region, Springfield: (413) 755-2214

This Policy was originally adopted by the MA Department of Public Health in the early 1970's. It was reaffirmed by DEP's Division of Air Quality Control on February 1, 1990, and has remained in effect.

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Mitt Romney, Governor

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Ellen Roy Herzfelder, Secretary

Department of Environmental Protection
Edward P. Kunce, Acting Commissioner

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This information is available in alternate format by calling our ADA Coordinator at (617) 574-6872.

Appendix C Acoustical Monitoring Site Photographs