COMMERCE DEPARTMENT

October 31, 2017

ELECTRONIC FILING

Mr. Daniel P. Wolf, Executive Secretary
Minnesota Public Utilities Commission
127 Seventh Place East, Suite 350
Saint Paul, MN 55101-2147

RE: Comments and Recommendations on Noise Complaint and Noise Compliance
Big Blue Wind Farm, LLC
Docket No. IP-6851/WS-10-1238

Dear Mr. Wolf:

Energy Environmental Review and Analysis (EERA) staff provides the attached comments and recommendations regarding noise complaints from Mr. Dan Moore in the Big Blue Wind Farm docket.

Staff have reviewed the complaint history, corrective actions taken to-date, and a recent noise monitoring study conducted by the Permittee. EERA recommends that corrective action taken to-date has been effective in addressing specific noises that were the subject of complaint. However, EERA recommends that the Permittee should be required to conduct "on/off" noise monitoring to address requirements in the site permit and to elucidate noise limit exceedances that were brought to light during the course of the complaint investigation.

I am available to answer any questions the Commission might have.

Sincerely,

/s/ Louise I Miltich

Louise Miltich
Environmental Review Specialist

Enclosure

cc: John Wachtler, EERA
Richard Davis, EERA
Bret Eknes, Minnesota Public Utilities Commission

COMMERCE DEPARTMENT

BEFORE THE MINNESOTA PUBLIC UTILITIES COMMISSION

Energy Environmental Review and Analysis Comments and Recommendations on Noise Complaint and Noise Compliance

Big Blue Wind Farm, LLC Docket No. IP-6851/WS-10-1238

Date: October 31, 2017 **Staff**: Louise Miltich | (651) 539-1853 | louise.miltich@state.mn.us

Issues Addressed: These comments and recommendations contain the Minnesota Department of Commerce, Energy Environmental Review and Analysis (EERA) staff's noise complaint summary and recommendations in the above stated matter.

Additional documents and information, including the route permit application, can be found on eDockets by searching "10" for year and "1238" for number: https://www.edockets.state.mn.us/EFiling/search.jsp or the EERA webpage: https://mn.gov/commerce/energyfacilities/Docket.html?Id=34748.

This document can be made available in alternative formats, that is, large print or audio, by calling (651) 539-1530 (voice).

On August 17, 2011, the Commission issued an order granting a Large Wind Energy Conversion System (LWECS) site permit to Big Blue Wind Farm, LLC to operate the 36 MW Big Blue Wind Farm In Faribault County.[1] Big Blue Wind Farm has been operational since December of 2012.

[1] August 17, 2011 Order issuing the proposed LWECS Site Permit as amended for the 36 MW Big Blue Wind Farm to Big Blue Wind Farm, LLC **20118-65487-01**

Complaint summary

In an April 4, 2017 noise complaint compliance filing, Big Blue Wind Farm, LLC reported a noise complaint filed by Dan Moore on March 1, 2017 identifying "clicking" sounds and noise similar to "aircraft landing" during operation of certain turbines, and expressing concern about Big Blue Wind Farm, LLC's compliance with noise limits in their site permit[2].

On May 7, 2017 Big Blue Wind Farm, LLC filed a letter in the docket indicating that work to identify and resolve the source of the noise was ongoing[3].

Commission Staff filed an information request to Big Blue Wind Farm, LLC on June 29, 2017 regarding noise issues at the Big Blue Wind Farm[4]. In the information request Commission staff inquired about the status of corrective action and also included a request for results of any original noise monitoring conducted to satisfy conditions of the site permit (Big Blue Wind Farm, LLC LWECS Site Permit, Section 6.6) and any more recent noise studies conducted for the site. As a result of Commission staff's information request Big Blue Wind Farm, LLC submitted to EERA and Commission staff a noise monitoring report detailing the results of noise monitoring conducted in late June to early July of 2017, which is included as an attachment to these comments and recommendations.

On August 1, 2017 Commission staff issued a letter Pursuant to the Commission Procedure for Unresolved Complaints (Section H of the Minnesota Public Utilities Commission Complaint Handling Procedures for Large Wind Energy Conversion Systems, issued in the Site Permit for the Big Blue Wind Farm), initiating the Commission's official review process for the noise complaint of Dan Moore (March 1, 2017)[5].

On September 19 and 28, 2017 Dan Moore filed letters in the docket indicating his dissatisfaction with the complaint resolution process and the effectiveness of Big Blue Wind Farm, LLC's corrective actions at that time[6].

Corrective Action

Since the August 1, 2017 initiation of the unresolved complaint review process, several steps have been taken to resolve both the "clicking" and "aircraft" or "jet engine" noise from the affected turbines (Turbines T8 and T9). These steps include the following:

- On August 9th EERA staff (Richard Davis) conducted a site visit at the Big Blue Wind facility. Big Blue Wind Farm, LLC and Siemens Gamesa representatives were present for the site visit. Two turbines that were producing a "clicking noise" were visited (Turbines T8 and T9). Observations were made directly below the turbine nacelles to hear the clicking, and then the team moved away from the turbines, down the access roads and county roads to assess how far away the clicking noise could be heard. After conducting turbine visits, a conference call with Fagen, Inc. (construction contractor/owner of Big Blue Wind Farm) was conducted to discuss the potential

[2] Big Blue Wind Farm, LLC Compliance Filing – March 27 Complaint Report. E-dockets document id **20174-130488-01**
[3] Big Blue Wind Farm, LLC Compliance Filing – Wind Turbine Noise Complaints. E-dockets document id **20176-132643-01**
[4] PUC Information Requests IR 1-5, E-dockets document id **20176-133262-01**
[5] Big Blue Wind Farm, LLC Compliance Filing – March 27 Complaint Report. E-dockets document id **20174-130488-01**
[6] Dan Moore Letter – Big Blue Complaint Procedure Violation. E-dockets document id **20179-135647-01** & Dan Moore Letter – Unresolved Substantial Noise Complaints. E-dockets document id **20179-135847-01**

issue causing the clicking as the turbine yaws into the wind, and to develop a plan to fix the turbines currently clicking with a full crane method or a craneless remediation method. The conference call also included discussion of "jet engine" sounds during turbine operation. It was hypothesized that the "jet engine" sound was the result of fully operating turbines being curtailed, and that the deceleration/braking of the turbine may be causing the sounds.

- On August 17, 2017, Big Blue Wind Farm, LLC's site manager provided Commission and EERA staff with a schedule for the work on the clicking turbines, which indicated remediation work on Turbine T8 would begin on September 19, 2017.

- On August 31, 2017, Big Blue Wind Farm, LLC's site manager provided Commission and EERA staff with an updated schedule for the work on the clicking turbines indicating that Turbine T8 remediation was scheduled for September 19-22, 2017 and Turbine T9 remediation was scheduled for September 25-29, 2017.

- On October 5, 2017 a conference call was held with Big Blue Wind Farm, LLC. and Fagen, Inc. representatives to discuss remediation progress. At that time Turbine T8 remediation had been completed, but Turbine T9 remediation had been delayed due to poor weather conditions. Big Blue Wind Farm, LLC. and Fagen, Inc. representatives indicated that after remediation Turbine T8 was no longer clicking. They also indicated that the turbine making jet like noises during curtailment seemed to be handled by adjusting turbine curtailment and deceleration.

- On October 16, 2017, Big Blue Wind Farm, LLC provided the Commission and EERA staff with a progress update on Turbines T8 and T9. Turbine T9 remediation work was completed on October 6, 2017, and no clicking noise was observed during turbine operation[7].

Staff Comments

EERA provides technical expertise and assistance to the Commission.[8] EERA and the Commission work cooperatively, but function independently to meet their respective statutory responsibilities. In this matter EERA staff has technical input to offer on both the resolution of this particular noise complaint and on the status of Big Blue Wind Farm, LLC's compliance with noise conditions in their LWECS Site Permit.

Complaint Resolution

Based on the steps taken to-date EERA staff believes that substantial progress has been made in addressing the complaints of Mr. Moore. The corrective actions taken including mechanical work on Turbine T8 and Turbine T9, and operational adjustments during curtailment appear to have resolved both the "clicking" sound and the "jet engine" sound at the affected turbines.

Noise Compliance

As noted above, Big Blue Wind Farm, LLC responded to Commission staff's June 29, 2017 information request for results of any previously conducted noise monitoring data by submitting to Commission staff a noise monitoring report detailing the results of noise monitoring conducted in late June to early July of

[7] Big Blue Wind Farm, LLC Compliance Filing – 10-16-17 Progress Update. E-dockets document id **201710-136585-01**
[8] Minn. Stat. 216E.03, subd. 11.

2017 (attached). Based on a review of the report, EERA staff is not satisfied that Big Blue Wind Farm, LLC is in compliance with noise conditions in the site permit.

While the report indicates it is meant to satisfy Section 6.6 requirements of the Big Blue Wind Farm, LLC Site Permit issued on August 17, 2011, EERA staff does not believe that the submittal is consistent with the requirements of the permit. Section 6.6 of the Big Blue Wind Farm, LLC Site Permit requires that: "The Permittee shall submit a proposal to the Commission at least ten (10) working days prior to the pre-operation compliance meeting for the conduct of a post-construction noise study. Upon the approval of the Commission, the Permittee shall carry out the study. The study shall be designed to determine the operating LWECS noise levels at different frequencies and at various distances from the turbines at various wind directions and speeds. The Permittee shall submit the study within eighteen (18) months after commercial operation." Big Blue Wind Farm LLC's Noise Monitoring Report submittal does not appear to have been based on a protocol submitted to the Commission at least 10 working days prior to the pre-operational compliance meeting, no such protocol appears to have been approved by the Commission, and monitoring was not conducted within 18 months of commercial operation.

Nonetheless, the noise monitoring report submittal was reviewed by EERA. The report indicates noise standard exceedances that may be attributable to Big Blue Wind Farm turbines. Specifically, the report identifies several hours during the monitoring period in which both daytime and nighttime L_{10} and L_{50} limits were exceeded at monitoring sites within the project area. The report concludes that turbine noise may be a factor in a number of these exceedances.

This conclusion in the report suggests that Big Blue Wind Farm may be out of compliance with Section 4.3 of the site permit which requires the following: "The wind turbine towers shall be placed such that the Permittee shall comply with noise standards established as of the date of this permit by the PCA at all times at all appropriate locations. The noise standards are found in Minnesota Rules chapter 7030. Turbine operation shall be modified or turbines shall be removed from service if necessary to comply with these noise standards. The Permittee or its contractor may install and operate turbines as close as the minimum setback required in this permit, but in all cases shall comply with PCA noise standards." As discussed in Appendix A of the LWECS Noise Study Protocol and Report Guidance[9], when noise limit exceedances are recorded, it is necessary to determine the increment due to the turbine noise through completion of an "on/off" monitoring campaign to properly isolate wind turbine sound from total measured sound.

[9] Minnesota Department of Commerce, Energy Facilities Permitting. October 8, 2012. Guidance for Large wind Energy Conversion System Noise Study Protocol and Report. https://mn.gov/commerce/energyfacilities/documents/FINAL%20LWECS%20Guidance%20Noise%20Study%20Protocol%20OCT%208%202012.pdf

Staff Recommendation

Complaint Resolution

On the issue of the unresolved complaint, EERA staff recommends that the completed mechanical work at Turbine T8 and Turbine T9, and necessary changes made to operations are the appropriate corrective actions to address Mr. Moore's complaints of "clicking" and "jet engine" sounds and should be considered complete. EERA does not recommend any further corrective action to address these specific complaints. However, based on the ongoing dissatisfaction of the complainant EERA believes that bringing the issue to the Commission is warranted.

The filing meets applicable permit conditions:	X Yes	☐ No
Permit condition requires an action by the Commission:	☐ Yes	X No
EERA suggests filing be brought to the Commission for decision:	X Yes	☐ No
Response letter to permittee is recommended:	X Yes	☐ No

Noise Compliance

On the issue of noise monitoring and exceedances of noise limits, EERA recommends additional steps are needed to bring Big Blue Wind Farm into compliance with the monitoring requirement and noise limits their permit. While the time period has passed for Big Blue Wind Farm, LLC to fully comply with the procedural requirements of Section 6.6 of the site permit, action to satisfactorily address the post construction/operational monitoring requirement contained in that section is relevant and necessary. EERA recommends that noise monitoring be completed as soon as possible following submittal and approval of a noise monitoring protocol. Based on the exceedances already documented by Big Blue Wind Farm, LLC, EERA recommends an "on/off" monitoring approach consistent with Appendix A of the LWECS Noise Study Protocol and Report, which specifies that if noise exceedances are recorded, it is necessary to determine the increment due to the turbine noise.

Specifically, EERA recommends the following steps:

- The Permittee should select a contractor to perform the noise study and submit the selected contractor's qualifications for review and approval by EERA and Commission staff.

- The Permittee's contractor should prepare and the Permitee should submit a protocol for noise monitoring consistent with Appendix A of the LWECS Noise Study Protocol and Report for EERA and commission staff review and approval.

- The protocol should include a monitoring site on Mr. Moore's property. To the extent that exceedances of noise limits could have been a factor in Mr. Moore's complaints, including a monitor on this property would provide a better understanding of whether the corrective action to-date has appropriately addressed issues at this property.

- Monitoring should be conducted following approval of the protocol.

- If noise exceedances are identified that are attributable to Big Blue Wind Farm turbines, corrective action should be tailored to specific turbines or time periods that are found to be problematic based on the results of the monitoring.

Noise monitoring is typically conducted in late fall or early spring. Because of the limitations in the preferred time windows for noise monitoring, a timely request to the Permitee and rapid response from the Permittee is necessary to avoid a several month delay in monitoring. DOC EERA recommends that Commission staff should issue correspondence to the permittee outlining recommended steps, as discussed above and requesting completion of monitoring as soon as possible.

The filing meets applicable permit conditions:	☐ Yes	X No
Permit condition requires an action by the Commission:	☐ Yes	X No
EERA suggests filing be brought to the Commission for decision:	☐ Yes	X No
Response letter to permittee is recommended:	X Yes	☐ No

/s/ Louise I Miltich — 10/31/17

Louise Miltich
Planner Principal
MN Dept. of Commerce

Date

POST CONSTRUCTION NOISE ANALYSIS AND REPORT

MN-PUC DOCKET NUMBER 10-1238

Prepared For:

Big Blue Wind, LLC
8261 320th Ave.
Blue Earth, MN 56013

Prepared By:

WSB & Associates
701 Xenia Avenue South, Suite 300
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Contents

Introduction 1
Background 1
Measurements 2
Equipment 2
Field Data 2
Locations 2
Data Results 4
  Monitoring location 1 5
  Monitoring Location 2 9
  Monitoring Location 3 12
  Monitoring Location 4 15
  Monitoring Location 5 18
Comparison to Permit Application Model 21
Conclusion 21

Introduction

The post-construction noise analysis prepared by WSB & Associates is meant to satisfy Section 6.6 requirements of the Big Blue Wind Farm, LLC Site Permit issued on August 17, 2011. The noise analysis and report follow guidelines set by the Minnesota Department of Commerce *Guidance for Large Wind Energy Conversion System (LWECS) Noise Study Protocol and Report* (LWECS Noise Guidance).

The purpose of the post-construction noise analysis is to determine the noise impacts of the wind turbines at a range of distances, and sound frequencies and levels on surrounding occupied structures. The recorded noise data used in the study will be compared to the preconstruction modeling conditions found in the LWECS permit application. The Minnesota Department of Commerce will use the information in this noise analysis to confirm that the wind turbines do not create noise levels that exceed Minnesota Pollution Control Agency (MPCA) daytime or nighttime regulations.

Background

The results of the noise analysis will be presented using two different frequency weightings as instructed in the LWECS Noise Guidance. A-weighted sound levels best approximate the range of frequencies detectable by the human ear. C-weighted sound levels include lower ranges of frequencies not necessarily audible to humans. Both A-weighted and C-weighted scales are examined to evaluate a broader range of noise outputs. When checking the sound outputs of the turbines against MPCA noise regulations, only the A-weighted range of sound will be used.

Big Blue Wind Farm uses the Gamesa G97 turbine at each of the 18 locations. The turbine's specifications on sound level output and operating conditions can be found in **Table 1.**

Table 1: Turbine Specifications

	Gamesa G97
Nameplate Capacity	2.0 MW
Hub Height	78 m (256 ft)
Rotor Diameter	97 m (318 ft)
Total Height	121 m (397 ft)
Rotor Swept Area	7,390 m2(79,545 ft^2)
Cut-in Wind Speed	3.0 m/s (6.7 mph)
Cut-out Wind Speed	26 m/s (58.16 mph)
Rotor Speed	9.6-17.8 rpm

Measurements

WSB followed the monitoring process outlined in the LWECS Noise Guidance document. Four on-site monitoring locations and one off-site monitoring location were used to collect turbine noise data. Two of the monitoring stations were near the worst-case noise receptor and the other two represent occupied structures further away, and near fewer turbines. WSB chose a 20-day monitoring period (June 19 to July 10, 2017) in order to collect as much valid data as possible. WSB also collected wind speed and precipitation data from the meteorological towers within the project limits to determine wind speeds at turbine hub heights.

Equipment

WSB used the following list of equipment on the Big Blue Wind farm to collect both noise and atmospheric data. Each of the monitoring locations was outfitted with the following list of hardware

- Larson Davis 831 digital sound level meter
- Vaisala WXT-530 Weather station
- Pelican Weather-Proof Equipment Case
- 5-Foot to 8-Foot Adjustable Tripod
- Microphone – PCB Piezotronics 377B20
- Preamplifier – Larson Davis PRM831
- 12V Deep Cycle and 8 x D-Cell Batteries

WSB used its own equipment at monitoring location M3 and leased the equipment for the remaining four sites, M1, M2, M4 and M5. All the sound level monitors were calibrated to ANSI and IEC standards within 6 months of the data collection period. Additionally, a field calibration was performed with a Larson Davis CAL200 hand-held calibration unit before the equipment was deployed in the field.

Field Data

During the 20-day collection period, A-weighted L_{eq}, L_{10}, L_{50}, L_{90}, C-weighted L_{eq} and unweighted 1/3-octave band frequency data were collected along with wind speed and precipitation data at each location. The Larson Davis 831 unit collected individual readings every minute and produced hourly summaries of data to use for reporting purposes and stored files internally at midnight every day for ease of processing. All data were processed into tabular (Microsoft Excel) format using the Larson Davis SLM Utility G3 software.

Locations

The map of all monitoring locations is shown in **Figure 1** below.

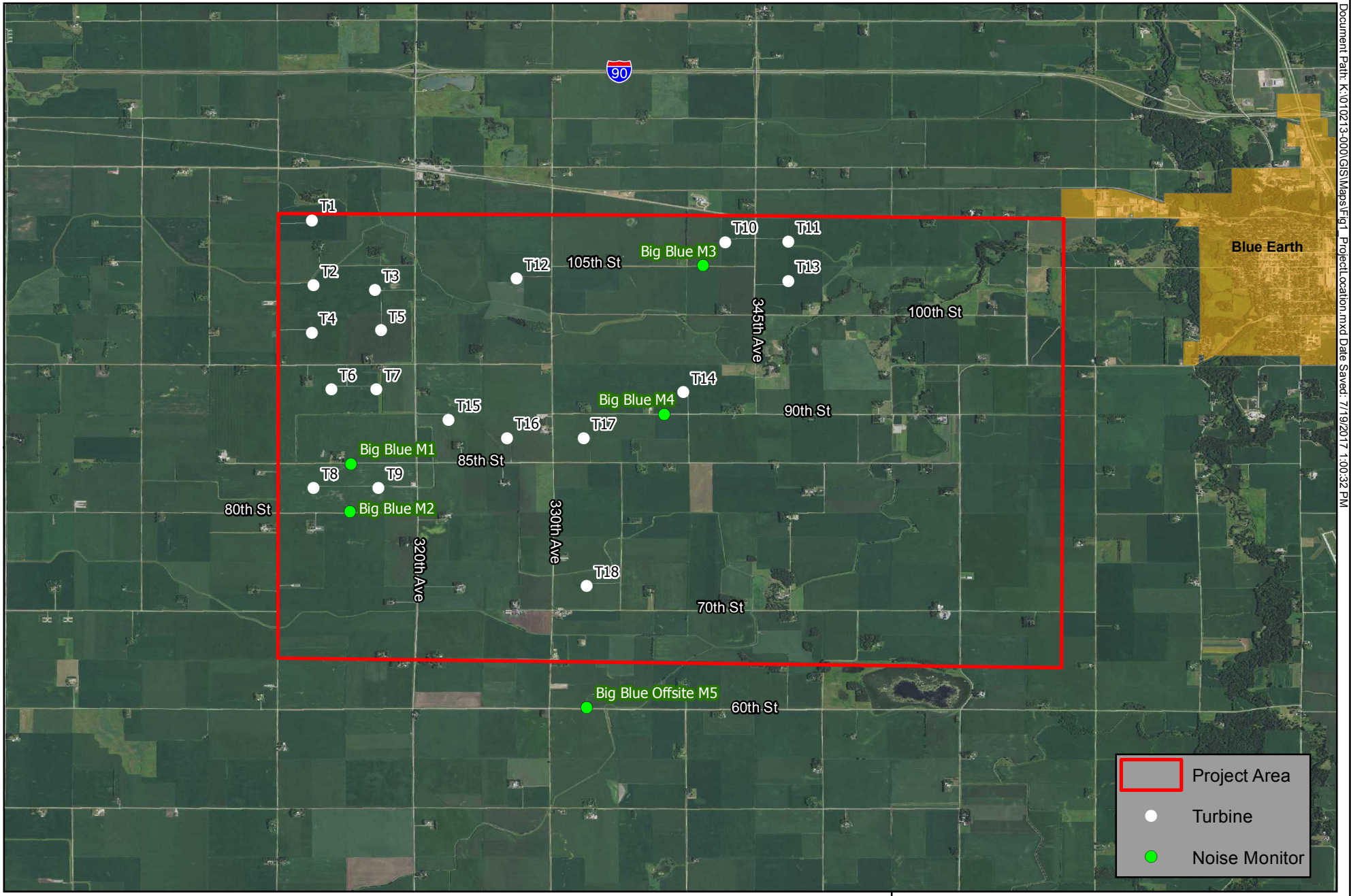


Figure 1 - Project Location

Big Blue Wind Post-Construction Noise Analysis
Big Blue Wind, LLC

N

0 7,000 Feet

1 inch = 7,000 feet

Monitoring locations M1 and M2 were placed with guidance from Big Blue Wind Farm due to their proximity to turbines T06-T09 and T15. There is a group of eight occupied structures within one mile of both M1 and M2. Sites M1 and M2 represent the worst-case receptors due to the number of turbines (five) within a one mile radius. Site M3 is located near turbines T10-T12 and represents a group of five occupied structures within one mile of these turbines. Site M3 is representative of receptors that have a lower concentration of turbines (three) but still within a one-mile radius proximity. Site M4 represents five occupied structures within a one-mile radius that are in proximity to two turbines, T14 and T17 that are spaced at a greater distance than sites M1-M3. Site M5 was selected as the off-site receptor. Site M5 is located approximately 1.25 miles south from turbine T18, which is the most isolated and southerly turbine within the project limits. Site M5 represents six occupied structures within one-mile of the monitoring location. Distances from each of the monitoring locations to the nearest turbine can be found in **Table 2.**

Table 2: Distances to Nearest Turbines

Monitoring Location	Nearest Turbine	Distance to Turbine (ft)
M1	T09	1672
M2	T09	1703
M3	T09	1538
M4	T14	1388
M5	T18	6550

Data Results

Each of the five monitoring locations was analyzed to determine if there were periods of noise exceedance caused by turbines. All hourly data from the five sites were combined for the 20-day period and used as a single data set. Per the LWECS Noise Guidance, three conditions were used to eliminate data from analysis:

- Periods of sustained wind greater than 11 miles per hour (mph)
- Periods of precipitation
- Periods of wind below turbine cut-in speed – 3 mph for the turbines on this project

The first part of analysis performed for each monitoring location compared the A-weighted and C-weighted L_{eq} values against wind speed values to determine whether increased wind speeds correlate to increased noise. The second part of the analysis addresses if the turbines are exceeding Minnesota Pollution Control Agency (MPCA) 2015 noise standards based on time of day and L_{10}/L_{50} values. These noise standards can be found in **Table 3** below. The Land Use for the project monitoring locations was assumed to be residential and corresponds to NAC-1.

Table 3: MPCA Noise Standards

Land Use	Code	Day (7:00 AM to 10:00 PM) dBA		Night (10:00 PM - 7:00 AM) dBA	
		L_{10}	L_{50}	L_{10}	L_{50}
Residential[1]	NAC - 1	65	60	55	50
Commercial[2]	NAC - 2	70	65	70	65
Industrial[3]	NAC - 3	80	75	80	75

[1] NAC-1 includes household units, transient lodging and hotels, educational, religious, cultural, entertainment, camping, and picnicking land uses. Note the daytime standards apply during the nighttime for NAC-1 activities that do not include overnight sleeping/lodging.
[2] NAC-2 includes retail and restaurants, transportation terminals, professional offices, parks, recreational, and amusement land uses.
[3] NAC-3 includes industrial manufacturing, transportation facilities (except terminals), and utilities land uses.

There was no corresponding pre-construction study completed for the Big Blue Wind Farm. This prevents any comparison of measured sound levels to pre-construction conditions.

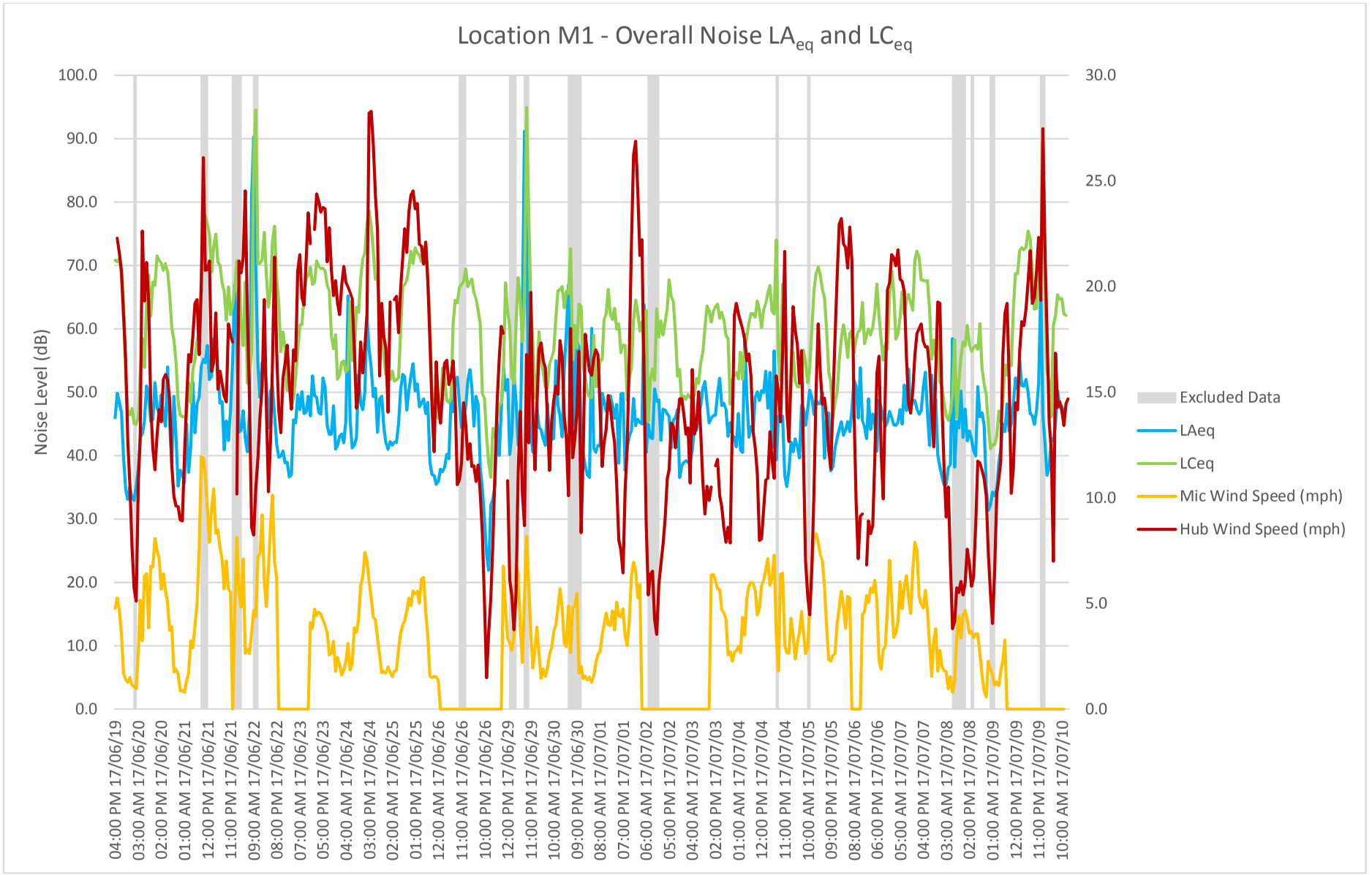
Monitoring location 1

Monitoring Location 1 (M1) is located on the south side of 85th Street near the southwest corner of the project limits (**Figure 1**). Instrumentation was placed at the back of the ditch section of the road out of the clear zone. The A-weighted L_{eq} for the entire 20 days was found to be 67.5 dBA. Monitoring Location M1, along with all other sites, experienced precipitation several times during the monitoring period along with high winds and periods where winds did not reach the turbine cut-in speed. After these data points are eliminated, the A-weighted L_{eq} for the entire 20 days is 49.8 dBA. The hourly A-weighted L_{eq} values range from 21.9 dBA to 91.1 dBA for the full data set and 21.9 to 66.6 dBA for the data set with eliminated points. The C-weighted L_{eq} for the full-time period is 73.1 dBC and 67.6 dBC for the data set with eliminated points. This correlates to the fact that turbines typically produce lower frequency noise that is not included in the A-weighted measurements. The C-weighted noise levels range from 36.6 dBC to 94.9 dBC for the full data set and 36.6 to 89.2 dBC for the data set with eliminated points. The 1/3 octave band data shows higher noise levels in the 6.3 to 100Hz range which is expected with turbine noise. **Figure 2** shows the plot of wind speed and microphone and hub height, A-weighted L_{eq} and C-weighted L_{eq} values. The gray bars indicated data points that have been eliminated from analysis. It should be noted that there are gaps in wind speed data collected at location M1. This is due to battery failure for the Vaisala 530 unit after approximately four days. However, during these gaps, there are no noticeable spikes in noise levels and data from a nearby meteorological tower that were examined for sustained wind conditions. Precipitation data for the weather station gaps were pulled from Monitoring Location M3 to check for possible rain. There is also a gap in measurement history from 6:00 AM on June 27th to 11:00 AM on June 29th. The expected cause of this missing data is loss of battery power to the Larson Davis sound monitor.

The same truncated data set with points excluded for maximum wind speed, precipitation and turbine cut-in speed was analyzed to determine if MPCA noise standards had been exceeded during the 20-day period. **Figure 3** shows the A-weighted L_{10} and L_{50} values for the entire monitoring period. There were two instances during the 20 days where the recorded sound level exceeded the MPCA standards. The first was for one hour between 3:00 AM and 4:00 AM on July 1st where the L_{10} value reached 55.5 dBA.

This is an exceedance of 0.5 decibels based on the nighttime L_{10} MPCA limits. The exceedance could be due to turbine noise as the wind at hub height averaged 16.6 mph but only 1.3 mph at the microphone, thus reducing wind noise. Environmental noise could also have played a factor in this spike. The second exceedance occurred on July 4th also from 3:00 to 4:00 AM. The recorded noise level for the hour had an L_{10} value of 57 dBA which is 2 dBA above MPCA standards. This exceedance could be due to turbine noise like the exceedance on July 1st because of a hub height wind speed of 16.4 mph and a lower microphone wind speed of 3.4 mph. Again, environmental noise may have been a factor in sound levels during this time.

Figure 2


Location M1 - Overall Noise LAeq and LCeq
Noise Level (dB)
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Excluded Data
LAeq
LCeq
Mic Wind Speed (mph)
Hub Wind Speed (mph)
04:00 PM 17/06/19
03:00 AM 17/06/20
02:00 PM 17/06/20
01:00 AM 17/06/21
12:00 PM 17/06/21
11:00 PM 17/06/21
09:00 AM 17/06/22
08:00 PM 17/06/22
07:00 AM 17/06/23
05:00 PM 17/06/23
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05:00 PM 17/07/02
04:00 AM 17/07/03
02:00 PM 17/07/03
01:00 AM 17/07/04
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11:00 PM 17/07/04
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03:00 AM 17/07/08
02:00 PM 17/07/08
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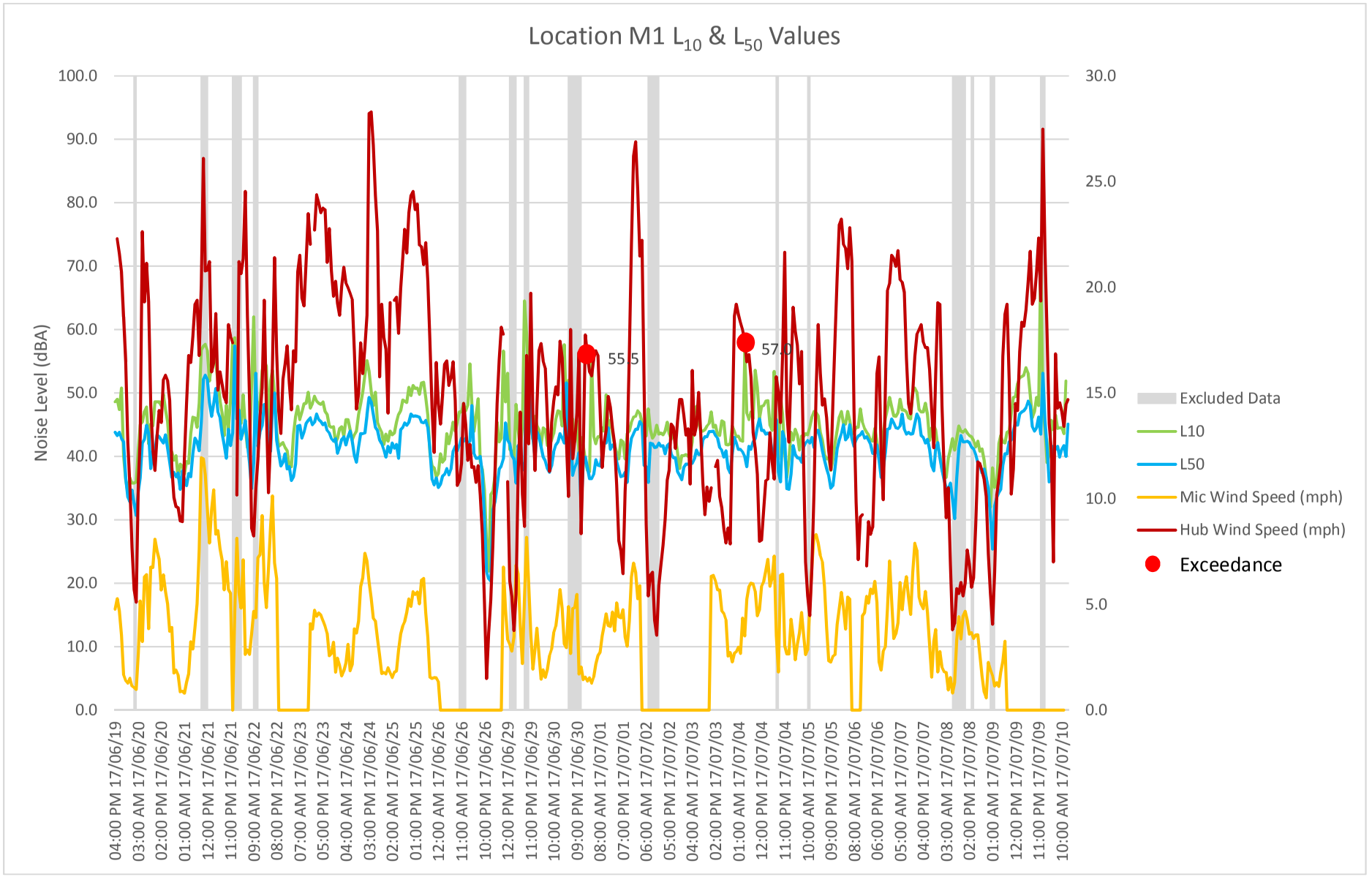
12:00 PM 17/07/09
11:00 PM 17/07/09
10:00 AM 17/07/10

Figure 3


Location M1 L10 & L50 Values
Noise Level (dBA)
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
55.5
57.0
04:00 PM 17/06/19
03:00 AM 17/06/20
02:00 PM 17/06/20
01:00 AM 17/06/21
12:00 PM 17/06/21
11:00 PM 17/06/21
09:00 AM 17/06/22
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04:00 AM 17/06/24
03:00 PM 17/06/24
02:00 AM 17/06/25
01:00 PM 17/06/25
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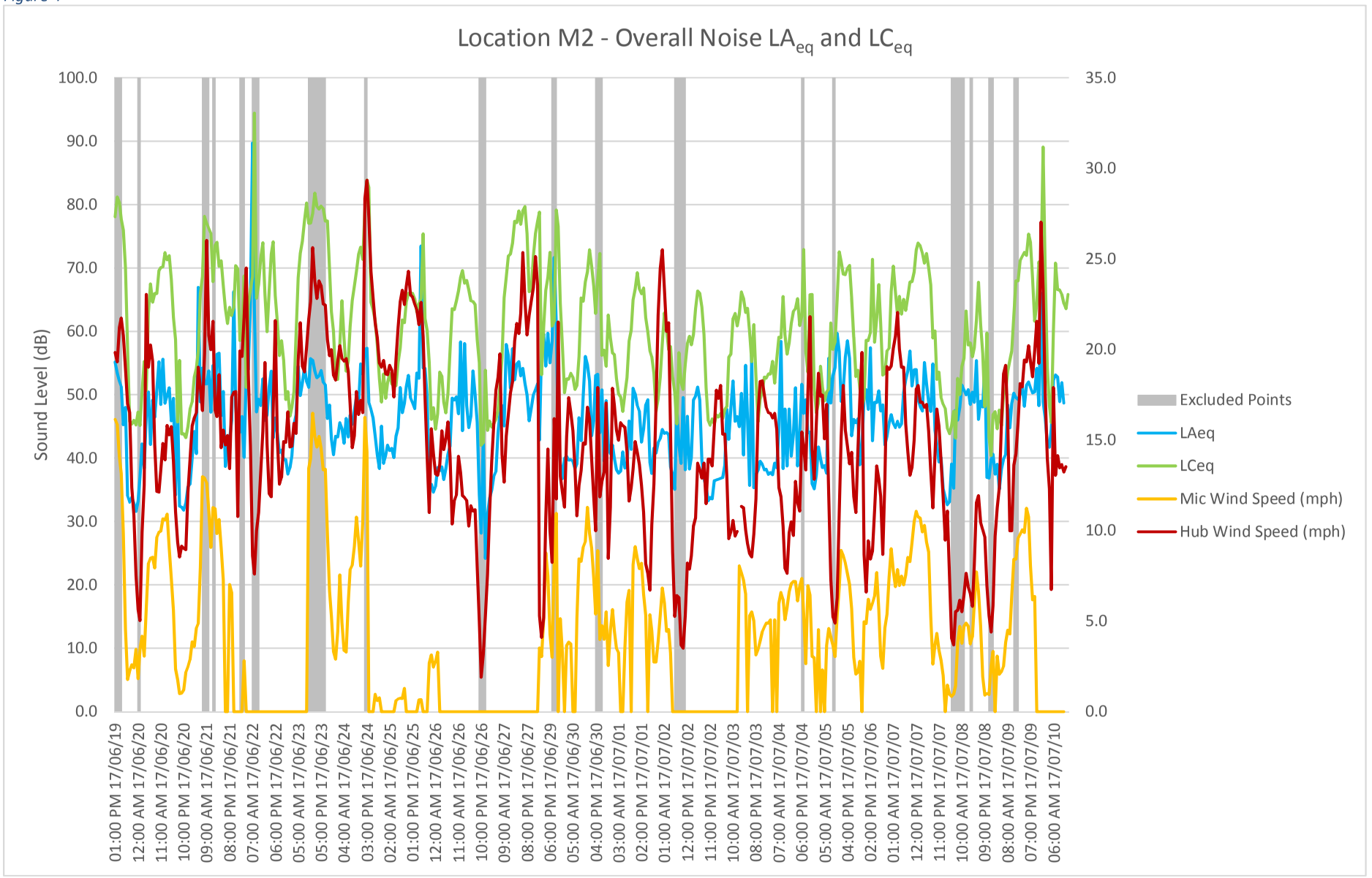
10:00 AM 17/07/05
09:00 PM 17/07/05
08:00 AM 17/07/06
06:00 PM 17/07/06
05:00 AM 17/07/07
04:00 PM 17/07/07
03:00 AM 17/07/08
02:00 PM 17/07/08
01:00 AM 17/07/09
12:00 PM 17/07/09
11:00 PM 17/07/09
10:00 AM 17/07/10
Excluded Data
L10
L50
Mic Wind Speed (mph)
Hub Wind Speed (mph)
Exceedance

Monitoring Location 2

Monitoring Location 2 (M2) is located on the north side of 80th Street near the southwest corner of the project limits. It is ½ mile directly south of Monitoring Location M1. Instrumentation was placed at the back of the ditch section of the road out of the clear zone. The A-weighted L_{eq} for the entire 20 days was found to be 63.5 dBA. Monitoring Location M2 along with all other sites experienced precipitation several times during the monitoring period along with high winds and periods where winds did not reach the turbine cut-in speed. After these data points are eliminated, the A-weighted L_{eq} for the modified 20 days is 52.7 dBA. The hourly A-weighted L_{eq} values range from 24.2 dBA to 89.7 dBA for the full data set and 24.9 to 73.5 dBA for the data set with eliminated points. The C-weighted L_{eq} for the full time period is 73.1 dBC and 68.9 dBC for the data set with eliminated points. This correlates to the fact that turbines typically produce lower frequency noise that is not included in the A-weighted measurements. The C-weighted noise levels range from 40.4 dBC to 94.4 dBC for the full data set and 40.4 to 89 dBC for the data set with eliminated points. The 1/3 octave band data shows higher noise levels in the 6.3 to 100Hz range which is expected with turbine noise. **Figure 4** shows the plot of wind speed at microphone and hub height, A-weighted L_{eq} and C-weighted L_{eq} values. The gray bars indicated data points that have been eliminated from analysis. It should be noted that there are gaps in wind speed and precipitation data collected at location M2. This is due to battery failure for the Vaisala 530 unit after approximately four days. However, during these gaps, there are no noticeable spikes in noise levels and data from a nearby meteorological tower that was examined for sustained wind conditions. Precipitation data were pulled from monitoring site M3 and applied accordingly during the gaps. There is also a measurement history gap from 1:00 AM on June 28 through 1:30 PM on June 29th. This is suspected to be from the instrumentation tripod tipping over sometime during this period. The Larson Davis sound meter was restarted during a battery change-out on June 29 and resumed normal operation. There appears to be some correlation between the wind speed at hub height and the L_{10} and L_{50} values. This would indicate that turbine noise impacts may exist at this monitoring location under certain wind conditions.

Figure 4


Location M2 - Overall Noise LA$_{eq}$ and LC$_{eq}$
Sound Level (dB)
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
01:00 PM 17/06/19
12:00 AM 17/06/20
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07:00 AM 17/06/22
06:00 PM 17/06/22
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04:00 AM 17/06/24
03:00 PM 17/06/24
02:00 AM 17/06/25
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11:00 AM 17/06/26
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11:00 PM 17/07/02
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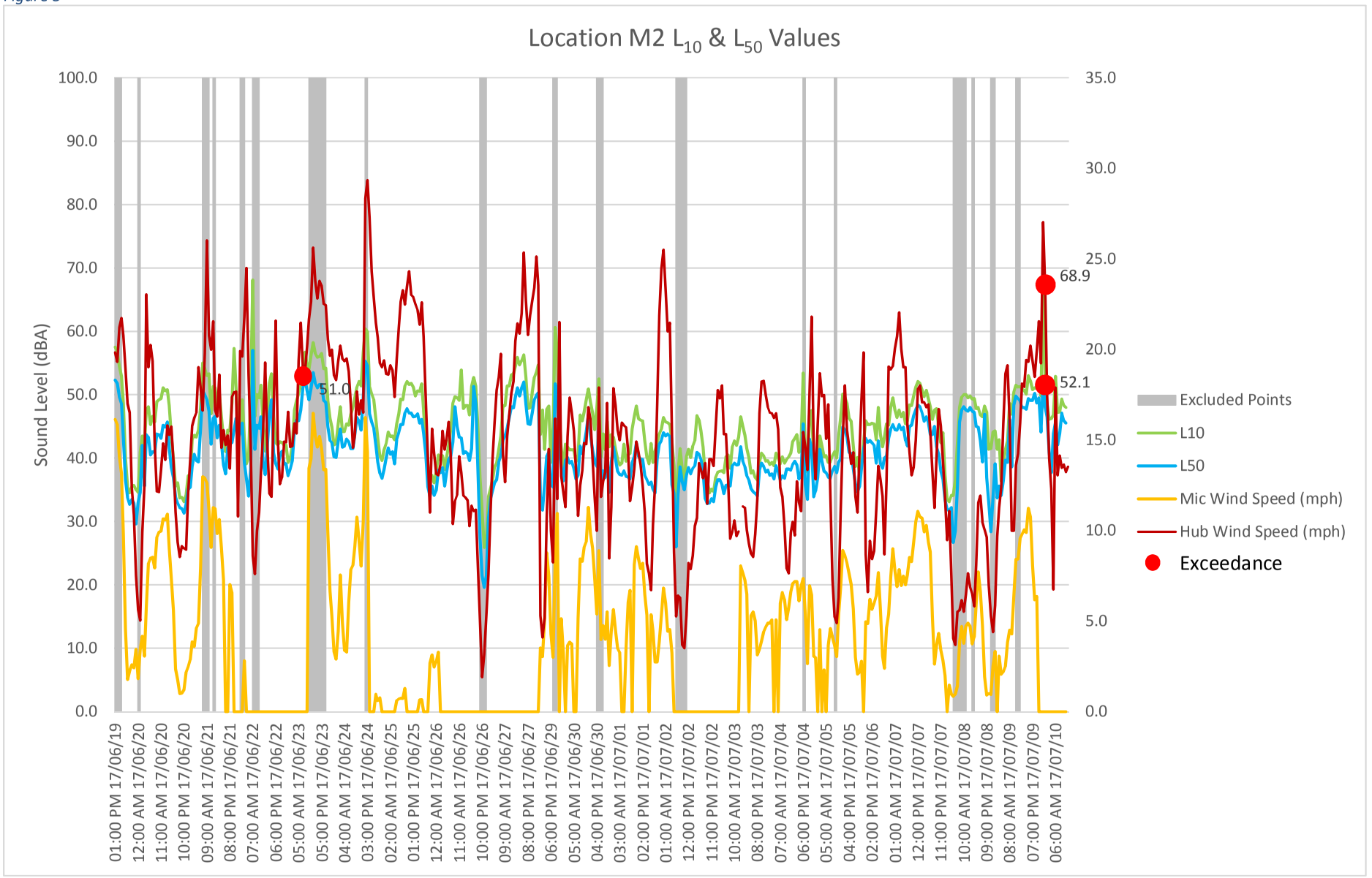
07:00 AM 17/07/04
06:00 PM 17/07/04
05:00 AM 17/07/05
04:00 PM 17/07/05
02:00 PM 17/07/06
01:00 AM 17/07/07
12:00 PM 17/07/07
11:00 PM 17/07/07
10:00 AM 17/07/08
09:00 PM 17/07/08
08:00 AM 17/07/09
07:00 PM 17/07/09
06:00 AM 17/07/10
Excluded Points
LAeq
LCeq
Mic Wind Speed (mph)
Hub Wind Speed (mph)

Figure 5


Location M2 L10 & L50 Values
Sound Level (dBA)
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
51.0
68.9
52.1
Excluded Points
L10
L50
Mic Wind Speed (mph)
Hub Wind Speed (mph)
Exceedance
01:00 PM 17/06/19
12:00 AM 17/06/20
11:00 AM 17/06/20
10:00 PM 17/06/20
09:00 AM 17/06/21
08:00 PM 17/06/21
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05:00 PM 17/06/23
04:00 AM 17/06/24
03:00 PM 17/06/24
02:00 AM 17/06/25
01:00 PM 17/06/25
12:00 AM 17/06/26
11:00 AM 17/06/26
10:00 PM 17/06/26
09:00 AM 17/06/27
08:00 PM 17/06/27
06:00 PM 17/06/29
05:00 AM 17/06/30
04:00 PM 17/06/30
03:00 AM 17/07/01
02:00 PM 17/07/01
01:00 AM 17/07/02
12:00 PM 17/07/02
11:00 PM 17/07/02
10:00 AM 17/07/03
08:00 PM 17/07/03
07:00 AM 17/07/04
06:00 PM 17/07/04
05:00 AM 17/07/05
04:00 PM 17/07/05
02:00 PM 17/07/06
01:00 AM 17/07/07
12:00 PM 17/07/07
11:00 PM 17/07/07
10:00 AM 17/07/08
09:00 PM 17/07/08
08:00 AM 17/07/09
07:00 PM 17/07/09
06:00 AM 17/07/10

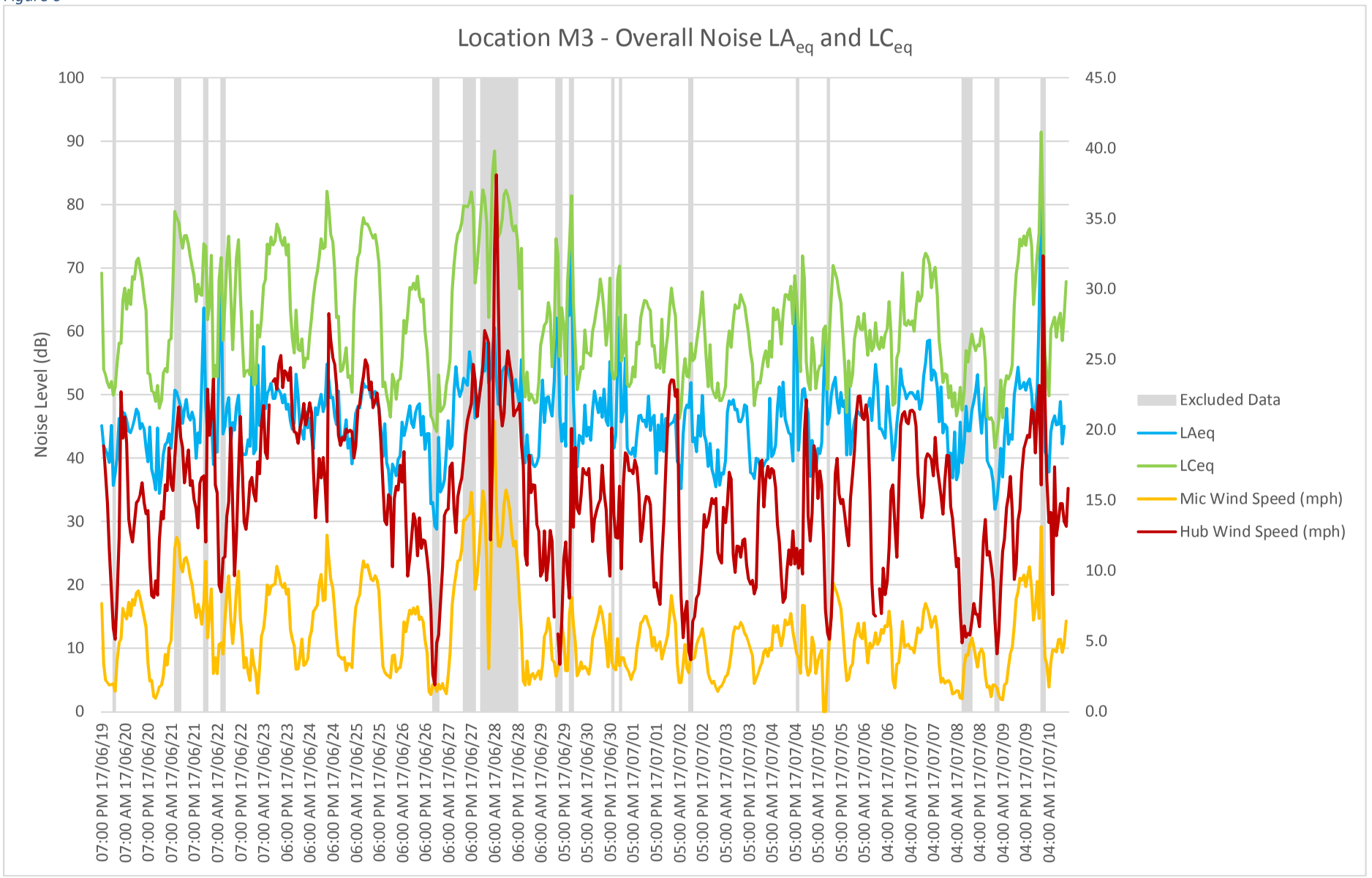
The same truncated data set with points excluded for maximum wind speed, precipitation and turbine cut-in speed were analyzed to determine if MPCA noise standards had been exceeded during the 20-day period. **Figure 5** shows the A-weighted L_{10} and L_{50} values for the entire monitoring period. There were two instances during the 20 days where the recorded sound level exceeded the MPCA standards. The first was for one hour between 6:00 AM and 7:00 AM on June 23rd where the L_{50} value reached 51.0 dBA. This is an exceedance of 1.0 decibels based on the nighttime L_{50} MPCA limits. The exceedance could be due to turbine noise as the wind at hub height averaged 19.1 mph for the hour and no wind data were available at the microphone. Microphone height wind data at Monitoring Location M3 indicates wind speeds less than 11 mph. Environmental noise could also have played a factor in this spike as farm vehicles were likely active at this time. The second exceedance occurred on July 9th between 11:00 PM and midnight. Both the nighttime L_{10} and L_{50} values were over MPCA standards. The recorded noise level for the hour had an L_{10} value of 68.9 dBA and a L_{50} value of 52.1 which are 13.9 dBA and 2.1 dBA above MPCA standards respectively. This exceedance did not have any correlating microphone wind speed data, but the wind speed at the hub height was 27 mph average for the hour. Based on data recorded at the same time period on July 9th at Monitoring Location M3 it is likely that the wind speed at the microphone was over 11 mph creating wind noise levels that would drown out turbine noise, and would be excluded from analysis per LWECS Noise Guidance.

Overall at M2, there appears to be moderate correlation between the wind speed at hub height and the L_{10} and L_{50} values. This would indicate that turbine noise impacts are more pronounced at this monitoring location.

Monitoring Location 3

Monitoring Location 3 is located near the northeast corner of the project limits on the north side of 105th street just west of 345th avenue. The instrumentation was placed near the back of the ditch section of the road to avoid the roadway clear zone. Monitoring Location 3 had no data loss during the 20-day collection period. The A-weighted L_{eq} for the entire 20 days was found to be 56.7 dBA. Monitoring Location M3 along with all other sites experienced precipitation several times during the monitoring period along with high winds and periods where winds did not reach the turbine cut-in speed. After these data points are eliminated, the A-weighted L_{eq} for the modified 20 days is 47.8 dBA. The hourly A-weighted L_{eq} values range from 28.8 dBA to 81.8 dBA for the full data set and 33.7 to 58.6 dBA for the data set with eliminated points. The C-weighted L_{eq} for the entire period is 71.8 dBC and 67.3 dBC for the data set with eliminated points. This correlates to the fact that turbines typically produce lower frequency noise that is not included in the A-weighted measurements. The C-weighted noise levels range from 41.6 dBC to 91.4 dBC for the full data set and 46 to 79.4 dBC for the data set with eliminated points. The 1/3 octave band data shows higher noise levels in the 6.3 to 100Hz range which is expected with turbine noise. **Figure 6** shows the plot of wind speed at microphone and hub height, A-weighted L_{eq} and C-weighted L_{eq} values. The gray bars indicated data points that have been eliminated from analysis

Figure 6


Location M3 - Overall Noise LAeq and LCeq
Noise Level (dB)
100
90
80
70
60
50
40
30
20
10
0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
07:00 PM 17/06/19
07:00 AM 17/06/20
07:00 PM 17/06/20
07:00 AM 17/06/21
07:00 PM 17/06/21
07:00 AM 17/06/22
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07:00 AM 17/06/23
06:00 PM 17/06/23
06:00 AM 17/06/24
06:00 PM 17/06/24
06:00 AM 17/06/25
06:00 PM 17/06/25
06:00 AM 17/06/26
06:00 PM 17/06/26
06:00 AM 17/06/27
06:00 PM 17/06/27
06:00 AM 17/06/28
06:00 PM 17/06/28
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05:00 PM 17/07/05
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04:00 PM 17/07/06
04:00 AM 17/07/07
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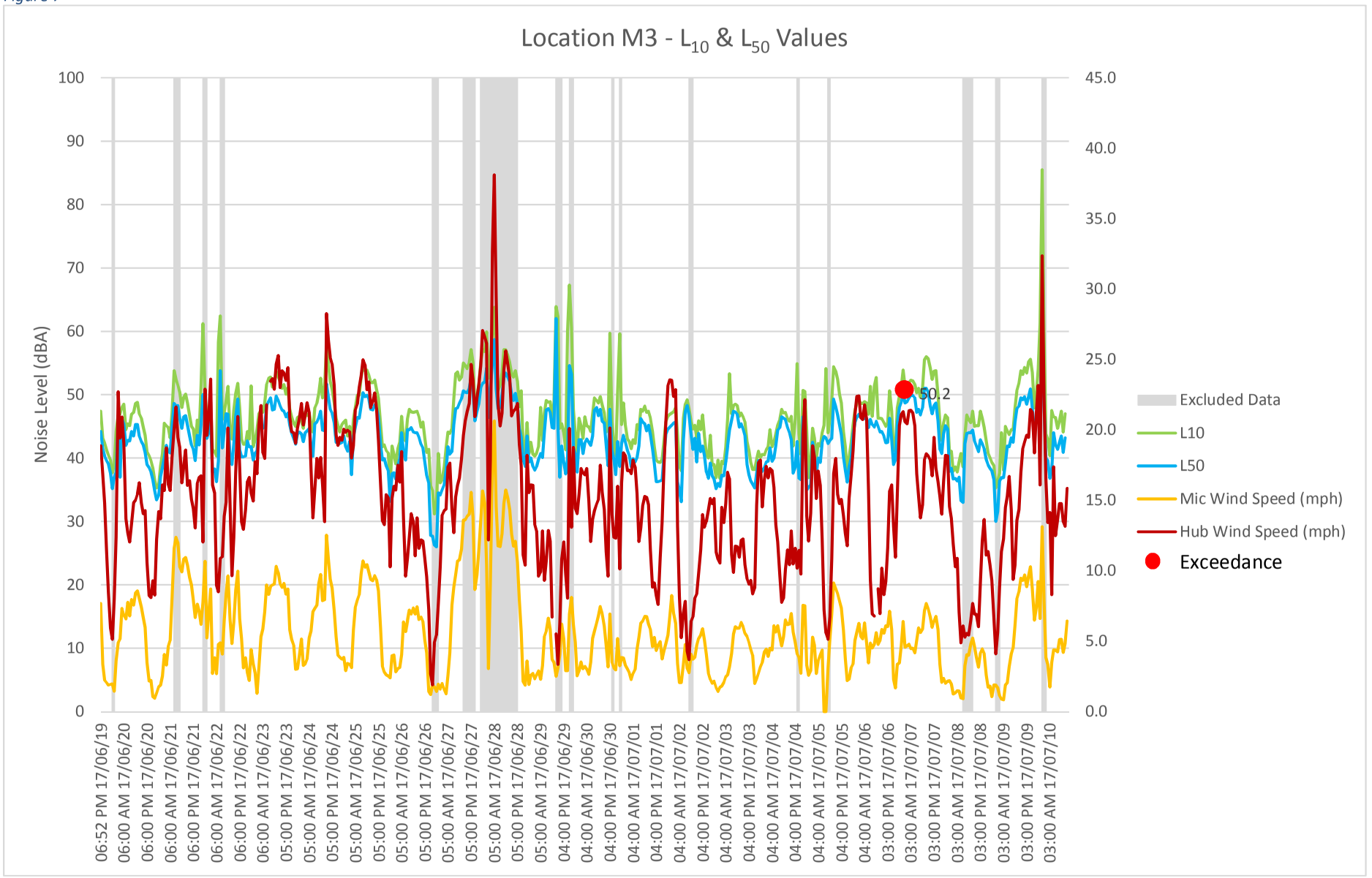
04:00 AM 17/07/08
04:00 PM 17/07/08
04:00 AM 17/07/09
04:00 PM 17/07/09
04:00 AM 17/07/10
Excluded Data
LAeq
LCeq
Mic Wind Speed (mph)
Hub Wind Speed (mph)

Figure 7


Location M3 - L10 & L50 Values
Noise Level (dBA)
100
90
80
70
60
50
40
30
20
10
0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
50.2
Excluded Data
L10
L50
Mic Wind Speed (mph)
Hub Wind Speed (mph)
Exceedance
06:52 PM 17/06/19
06:00 AM 17/06/20
06:00 PM 17/06/20
06:00 AM 17/06/21
06:00 PM 17/06/21
06:00 AM 17/06/22
06:00 PM 17/06/22
06:00 AM 17/06/23
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05:00 AM 17/06/24
05:00 PM 17/06/24
05:00 AM 17/06/25
05:00 PM 17/06/25
05:00 AM 17/06/26
05:00 PM 17/06/26
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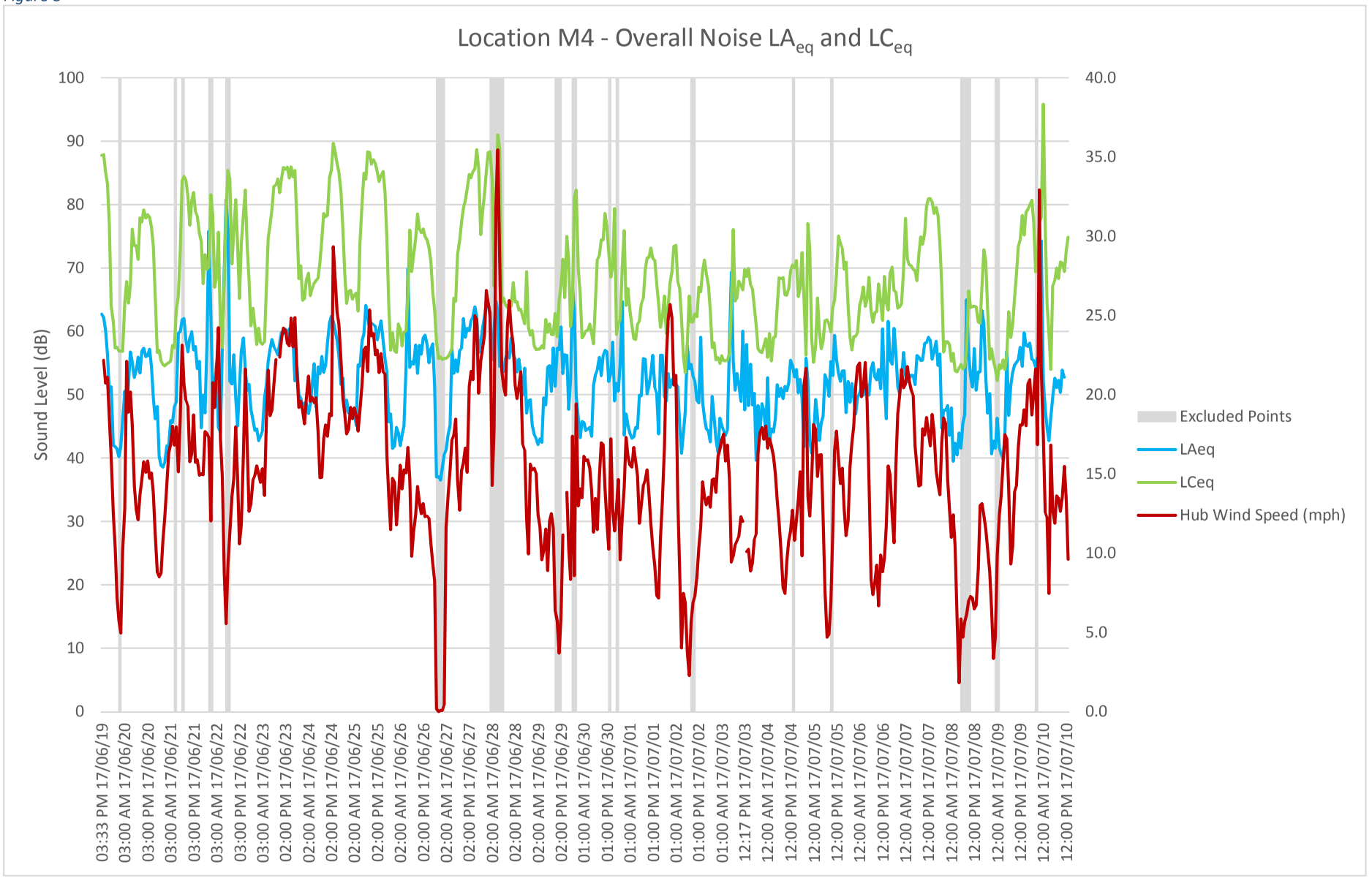
04:00 PM 17/07/05
04:00 AM 17/07/06
03:00 PM 17/07/06
03:00 AM 17/07/07
03:00 PM 17/07/07
03:00 AM 17/07/08
03:00 PM 17/07/08
03:00 AM 17/07/09
03:00 PM 17/07/09
03:00 AM 17/07/10

The modified 20-day period was analyzed to determine if the MPCA daytime and nighttime standards for L_{10} and L_{50} values had been exceeded. **Figure 7** shows the A-weighted L_{10} and L_{50} values for the entire monitoring period. There was one instance during the 20 days where the recorded sound level exceeded the nighttime L_{50} MPCA standards - between 11:00 PM and midnight on July 7th where the L_{50} value reached 50.2 dBA. This is an exceedance of 0.2 decibels based on the nighttime L_{50} MPCA limits. The exceedance is likely because of turbine noise as the wind at hub height averaged 21.3 mph for the hour while the wind data at the microphone was measured at 6.4 mph. The wind at the hub height remained at levels above 20 mph for several hours after the exceedance and L_{50} values hovered just below 50 dBA in each case. There appears to be little correlation between the wind speed at hub height and either L_{10} or L_{50} noise values.

Monitoring Location 4

The last monitoring location within the project area is located on the south side of 90th Street just west of 340th Avenue. The instrument placement along the road was like the previous three, near the back edge of the roadway ditch. Monitoring Location 4 failed to record any meteorological data over the 20 days due to a faulty Vaisala 530 weather station. Wind speeds at the hub height on Turbine 14 were gathered to determine conditions in the area. Precipitation periods were interpolated from the surrounding data collection sites and fit to the hourly measurement histories. These periods of precipitation were eliminated from the analyzed data along with hub wind speeds below cut-in values. Wind speed at the microphone height was not assumed for any of the noise readings, however there are instances where the hourly noise is excessive and correlates with higher hub wind speed and high microphone average wind speed for the surrounding monitoring locations. The A-weighted Leq for the entire 20 days was found to be 59.3 dBA. The A-weighted Leq for the modified 20 days excluding periods of precipitation and low hub height wind is 55.7 dBA. The hourly A-weighted Leq values range from 36.5 dBA to 80.7 dBA for the full data set and 38.6 to 69.9 dBA for the data set with eliminated points. The C-weighted Leq for the entire period is 78.0 dBC and 77.8 dBC for the data set with eliminated points. This correlates to the fact that turbines typically produce lower frequency noise that is not included in the A-weighted measurements. The C-weighted noise levels range from 52.2 dBC to 80.7 dBC for the full data set and 53.6 to 95.8 dBC for the data set with eliminated points. The 1/3 octave band data shows higher noise levels in the 6.3 to 100Hz range which is expected with turbine noise. **Figure 8** shows the plot of wind at hub height, A-weighted L_{eq} and C-weighted L_{eq} values. The gray bars indicated data points that have been eliminated from analysis.

Figure 8


Location M4 - Overall Noise LA$_{eq}$ and LC$_{eq}$
Sound Level (dB)
100
90
80
70
60
50
40
30
20
10
0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
03:33 PM 17/06/19
03:00 AM 17/06/20
03:00 PM 17/06/20
03:00 AM 17/06/21
03:00 PM 17/06/21
03:00 AM 17/06/22
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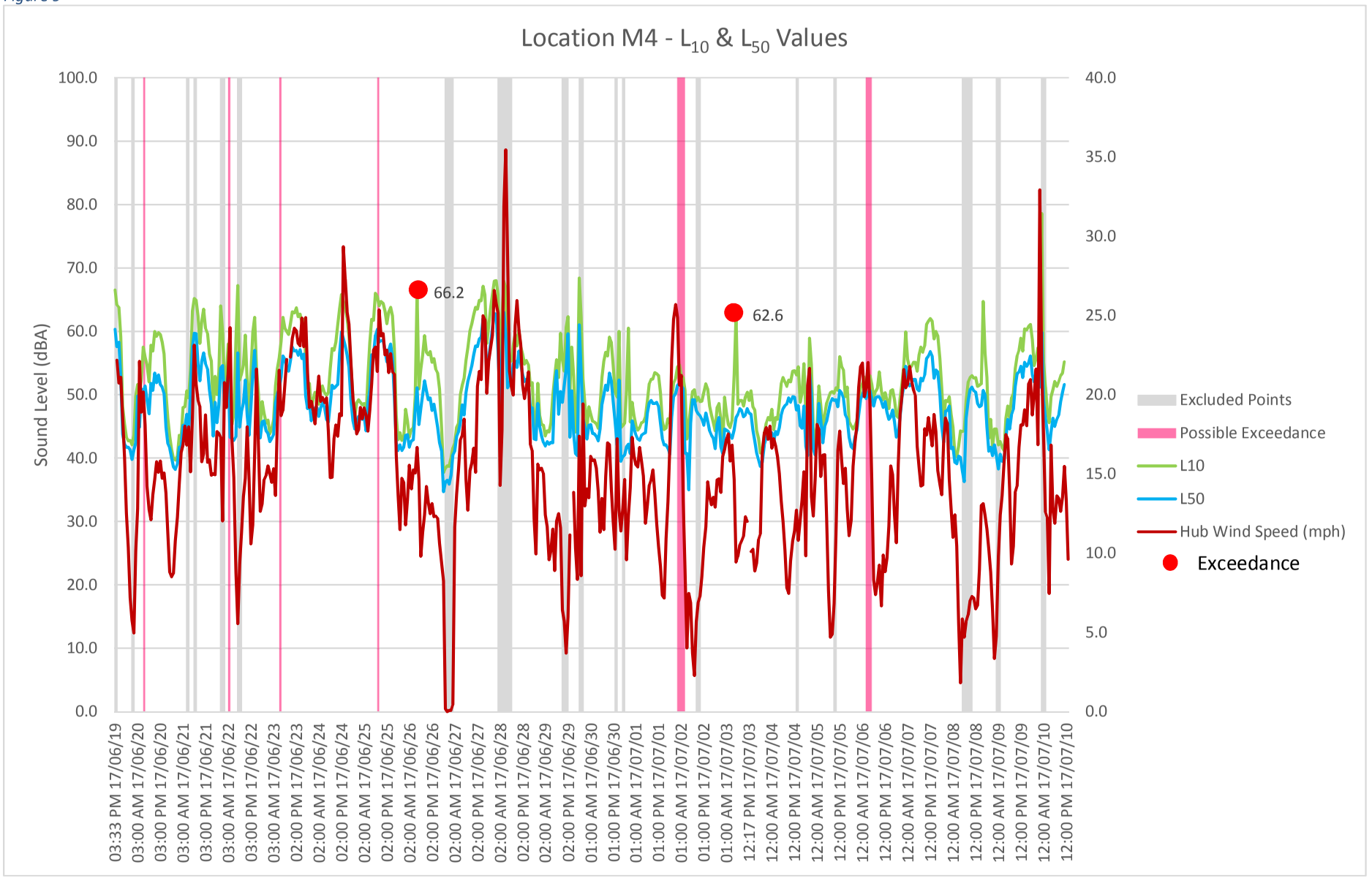
12:00 AM 17/07/08
12:00 PM 17/07/08
12:00 AM 17/07/09
12:00 PM 17/07/09
12:00 AM 17/07/10
12:00 PM 17/07/10
Excluded Points
LAeq
LCeq
Hub Wind Speed (mph)

Figure 9


Location M4 - L10 & L50 Values
Sound Level (dBA)
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
66.2
62.6
03:33 PM 17/06/19
03:00 AM 17/06/20
03:00 PM 17/06/20
03:00 AM 17/06/21
03:00 PM 17/06/21
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02:00 AM 17/06/24
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12:00 AM 17/07/07
12:00 PM 17/07/07
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12:00 PM 17/07/08
12:00 AM 17/07/09
12:00 PM 17/07/09
12:00 AM 17/07/10
12:00 PM 17/07/10
Excluded Points
Possible Exceedance
L10
L50
Hub Wind Speed (mph)
Exceedance

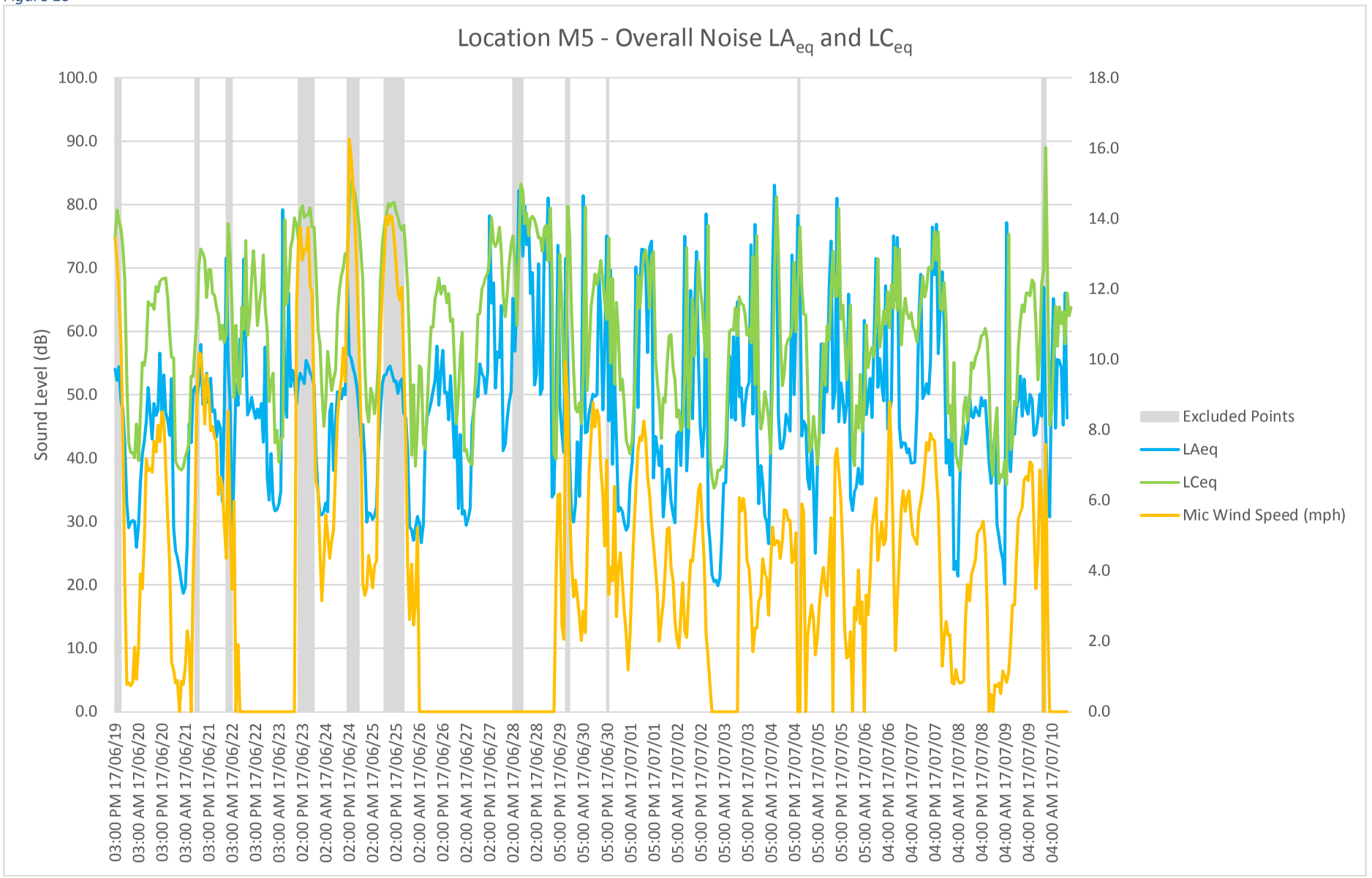
The modified 20-day period was analyzed to determine if the MPCA daytime and nighttime standards for L_{10} and L_{50} values had been exceeded. **Figure 9** shows the A-weighted L_{10} and L_{50} values for the entire monitoring period. There were six instances where the recorded sound level produced by the turbines may have exceeded the daytime or nighttime L_{50} and L_{10} MPCA standards. Without accurate weather data at this monitoring location, it is difficult to say with absolute certainty that the exceedances are not caused by either precipitation or high microphone wind speeds. The highlighted red bars show the times where it is uncertain what is causing the exceedance. In two other cases, environmental noise was likely the cause of higher sound levels due to low hub wind speed; 6:00 AM on June 26th and 6:00 AM on July 3rd.

Overall, the hub wind speed shows sporadic correlation with L_{10} and L_{50} values, especially during the middle 10 days of data collection. This may be expected with a small number of turbines near the receptor location.

Monitoring Location 5

There was a single monitoring location set outside of the project limits to determine noise levels away from the impact of the wind turbines. Monitoring Location 5 is located on north side of 60th Street just east of 330th Avenue, and approximately 1.25 miles south of turbine T18. Turbine T18 is isolated on the extreme south end of the project, approximately 1.5 miles from the next closest turbine. The monitoring equipment was set near the entrance to a field road out of the clear zone of 60th Street. There was no data collected for wind at the hub height for this part of the analysis. The A-weighted L_{eq} for the entire 20 days was found to be 66.5 dBA. Monitoring Location M5 along with all other sites experienced precipitation several times during the monitoring period along with high winds. After these data points are eliminated, the A-weighted L_{eq} for the modified 20 days is 66.1 dBA. The hourly A-weighted L_{eq} values range from 18.7 dBA to 83.0 dBA for the full data set and for the data set with eliminated points. The C-weighted L_{eq} for the entire period is 71.3 dBC and 67.9 dBC for the data set with eliminated points. The C-weighted values are expectedly higher due to the inclusion of a wider frequency band. **Figure 10** shows the plot of wind speed at microphone height, A-weighted L_{eq} and C-weighted L_{eq} values. The gray bars indicated data points that have been eliminated from analysis.

Figure 10


Location M5 - Overall Noise LA$_{eq}$ and LC$_{eq}$
Sound Level (dB)
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
03:00 PM 17/06/19
03:00 AM 17/06/20
03:00 PM 17/06/20
03:00 AM 17/06/21
03:00 PM 17/06/21
03:00 AM 17/06/22
03:00 PM 17/06/22
03:00 AM 17/06/23
02:00 PM 17/06/23
02:00 AM 17/06/24
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05:00 AM 17/07/04
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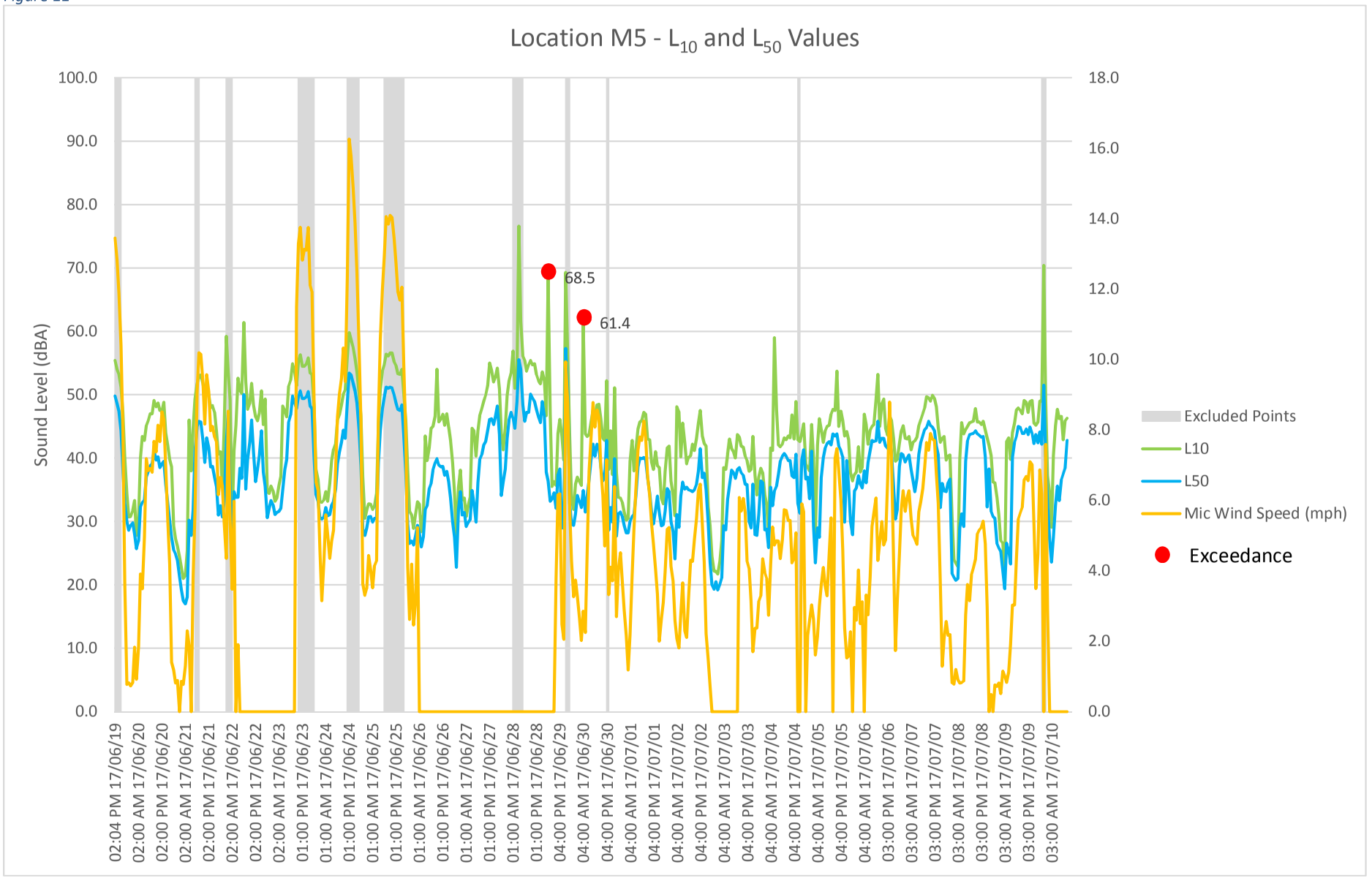
05:00 AM 17/07/05
05:00 PM 17/07/05
05:00 AM 17/07/06
04:00 PM 17/07/06
04:00 AM 17/07/07
04:00 PM 17/07/07
04:00 AM 17/07/08
04:00 PM 17/07/08
04:00 AM 17/07/09
04:00 PM 17/07/09
04:00 AM 17/07/10
Excluded Points
LAeq
LCeq
Mic Wind Speed (mph)

Figure 11


Location M5 - L10 and L50 Values
Sound Level (dBA)
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
68.5
61.4
02:04 PM 17/06/19
02:00 AM 17/06/20
02:00 PM 17/06/20
02:00 AM 17/06/21
02:00 PM 17/06/21
02:00 AM 17/06/22
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03:00 AM 17/07/08
03:00 PM 17/07/08
03:00 AM 17/07/09
03:00 PM 17/07/09
03:00 AM 17/07/10
Excluded Points
L10
L50
Mic Wind Speed (mph)
Exceedance

Monitoring Location 5 was primarily used to collect data representing typical ambient conditions for the region without the addition of turbine noise. There were gaps in the wind data collected similar to what was experienced on Monitoring Locations 1, 2 and 4 due to battery failure. There was also a noise data gap of 16 hours from 11:00 PM on June 28th to 3:00 PM on June 29th. The sustained spikes in noise data are directly related to periods of precipitation or high winds. The short duration spikes in noise are attributed to environmental factors such as birds and vehicles nearby. The ranges of L_{10} and L_{50} data at Monitoring Location 5 fall within the same range as Monitoring Locations 1-4, roughly 45 to 55 dBA on average and these values tend to correlate with wind speed at the microphone. The two exceedances found in the data can be attributed to impulse environmental noise due to the large difference between L_{10} and L_{50} values.

Comparison to Permit Application Model

The Big Blue Wind Farm uses a single type of turbine, the Gamesa G97. For modeling purposes, Monitoring Location M1 was modeled using the Cadna A software with turbines T08 and T09 under wind conditions just short of cut-out speed and a hub height of 78 meters. The sound power level of the turbine was not readily available from the manufacturer, so comparable turbines were used and the sound output increased to 110 dBA for a more conservative model. The resultant noise level at monitoring location M1 from turbines T08 and T09 is 45.3 dBA for maximum wind speeds.

Based on the above information, the worst-case monitoring location M1 was used for comparison during times when hub-height wind speed was over 9m/s but had a low enough microphone wind speed that would not overcome the effects of the turbine. The resulting data is shown below in **Table 5.**

Table 4: Application Permit Modeling - Worst Noise Monitoring Location Comparison

	Date/Time	L_{eq} (dBA)	L_{eq}(dBA)
Modeled Maximum	-	45.3	
M1	6/24/17 - 5:00 PM	-	49.3
M1	6/25/17 - 5:00 AM	-	45
M1	6/25/17 - 3:00 PM	-	47.7

The resulting noise from high hub height wind speed is greater than the predicted worst case scenario, but that is expected when turbine noise is combined with ambient background noise.

Conclusion

This report evaluated the monitored noise levels at four on-site locations and one off-site location to comply with the Big Blue Wind Farm site permit requirements. The data collection and analysis were in accordance with the LWECS Noise Guidance and validated compliance with the MPCA noise standards. A summary of the results per site is in **Table 6** below for comparison.

Table 5: LA_{eq} and LC_{eq} Results per Monitoring Location

Monitoring Location	LA_{eq} (dB)	LC_{eq} (dB)
M1	49.8	67.6
M2	52.7	68.9
M3	47.8	67.3
M4	56.3	77.8
M5	66.1	67.9

All data were removed during periods of precipitation, mic wind speeds over 11 mph and hub height wind speeds under the cut-in specifications. The resultant data were examined for exceedances and they are summarized below in **Table 7.**

Table 6: ***Summary of MPCA Noise Limit Exceedances per Site***

Monitoring Location	Hours Exceeding MPCA Noise Limits			
	Hourly L_{10}		Hourly L_{50}	
	Daytime	Nighttime	Daytime	Nighttime
M1	0	2	0	0
M2	0	2	0	1
M3	0	0	0	1
M4*	4	1	5	8
M5	1	1	0	0

* Exceeding hours at M4 have no meteorological data

The two hours of L_{10} exceedance at M1 indicate that turbine noise may be a factor. The microphone wind speed is low enough during each of these hours where the higher hub height wind speed could generate noticeable turbine noise.

One of the hours of L_{50} exceedance at M2 may be due to turbine noise due to low microphone wind speeds and higher hub-height wind speeds. The time of day (6:00 AM) may also indicate that farm machinery was starting for the day. The second hour of L_{50} and simultaneous L_{10} exceedance is likely due to microphone wind noise rather than turbine noise because of the correlated high wind speed at the microphone and at the hub height.

The single hour of L_{50} exceedance at M3 indicates that turbine noise may be the cause. The sustained hub height winds of greater than 20 mph combined with a lower microphone wind speed of 5-6 mph created conditions that caused the L_{50} values at the site to hover around exceedance levels for several hours.

Monitoring site M4 may have experienced several hours of exceedance of L_{10} and L_{50} standards but there is no way to qualify which of these periods can be eliminated without accurate weather data.

Approximations were made based on wind speed at a nearby turbine hub height and precipitation data from other monitoring locations

The off-site location M5 experienced two hours of L_{10} exceedance during periods of relatively low microphone wind speeds. This and the fact that the corresponding L_{50} values were much lower indicate impulse noise created by the environment.