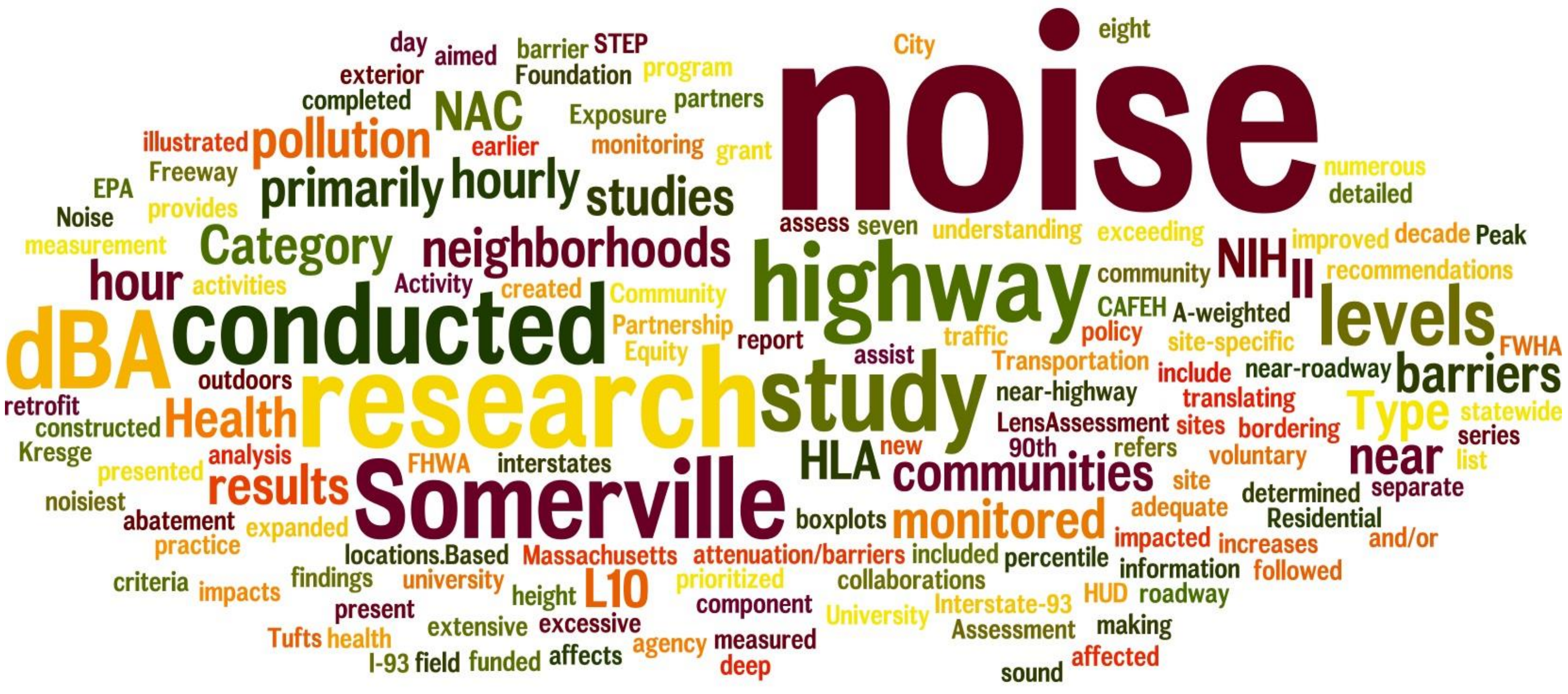
Noise Impacts in Somerville

A Noise Report



Thank you to all the participants who contributed to this project!

This document was produced by CAFEH (Community Assessment of Freeway Exposure & Health) in partnership with Tufts University, The Somerville Transportation Equity Partnership, The Welcome Project, and The Metropolitan Area Planning Council. Funding support for this document was provided by the National Institute of Environmental Health Sciences grant #ES026980

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With a special thanks to...

All the property owners who permitted to test for noise in their properties

Report on Near-Highway and Near-Roadway Noise Monitoring Somerville, Massachusetts (June –August 2018)

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Executive Summary

The Community Assessment of Freeway Exposure and Health study (CAFEH) has conducted extensive research on near highway pollution and health in the Somerville neighborhoods bordering Interstate-93. This research, which was conducted over more than a decade from 2008 to the present, provides deep and detailed, site-specific information and understanding of how highway pollution affects the communities near the highway. This research was primarily funded by NIH, HUD, EPA and the Kresge Foundation. It was conducted by a series of collaborations between Tufts University and the Somerville Transportation Equity Partnership (STEP), the City of Somerville and numerous other university, agency and community partners.

The research was expanded in 2018 to include measurement of near-highway and near-roadway traffic noise impacts to Somerville neighborhoods. The results of these studies will be presented in a Health Lens Assessment (HLA), under a separate research grant from NIH that followed on the earlier studies and aimed at translating our findings into policy and practice in the affected communities. The noise monitoring component of the HLA was primarily conducted to assess if the Massachusetts statewide Type II Noise study of all interstates completed in 1988, which included I-93, is adequate for noise attenuation/barriers where constructed, and to assist in making recommendations for improved noise barriers and/or new barriers. Type II refers to a voluntary program that created a prioritized list of noise barrier retrofit locations.

During the summer of 2018 (June-August), a field team of Tufts-affiliated engineers and public health scientists conducted a noise monitoring campaign at three Somerville neighborhoods – Mystic Ave., States Aves, and Ten Hills. The field team worked with residents and property owners at selected sites to host temporary deployment of REED-4023 class 2 sound level meters. The field team collected 24 -48 continuous hours of roadway noise data from eight (8) sites at selected residential/commercial sampling locations to measure and assess road/traffic noise impacts. Three monitoring heights were sampled at each site: 5, 15 and 25 feet above grade, per Federal Highway Administration (FHWA) guidelines for assessment of noise barrier design and efficacy. Highest priority for consideration of site selection was sensitive land uses; second priority was residential; third was public recreation and gathering spots. The number of people exposed to noise modeled and measured outdoors is part of the consideration as are local preferences and cost and site feasibility for installation of sound barrier walls. Due to property access limitations and site architectural and spatial considerations, the study monitoring sites were limited to FHWA Categories B and C - Residential (B) and Other (C) uses of high concern, such as parks, schools, hospitals, cemeteries, etc.

The FHWA noise abatement procedures are codified in the Code of Federal Regulations (23 CFR 772). For determining existing noise levels per 23 CFR 772, the needed noise descriptor is the one-hour A weighted equivalent sound level, or the A-weighted sound level that is exceeded 10 percent of the time (the 90th percentile) for the period under consideration. The former descriptor Leq(h), is the constant, average sound level, which over a period of time contains the same amount of sound energy as the varying levels of the traffic noise. The latter descriptor (L10(h)) is the noise level exceeded 10% of the time in the noisiest hour of the day. For FWHA Activity Categories Residential (B) and Parks/Public Uses (C), the noise abatement criteria (NAC) for hourly A-weighted sound levels (dBA) is L10(h) ≥70 dBA, measured in the exterior (outdoors).

The analysis presented in this report additionally focused on the number of individuals exposed to noise levels greater than 60 dBA at baseline – a metric that affirms chronic or long-term exposure to transportation noise levels above 60 dBA that has been associated with high-blood pressure, hypertension, and ischemic heart disease (Munzel et. al., Journal of the American College of Cardiology, 2018) The U.S. Environmental Protection Agency (USEPA) more conservatively recommends an average 24-hr exposure limit of 55 dBA to protect the public from all adverse effects on health and welfare in residential areas.

The results of the noise monitoring field campaign conducted June –August 2018 indicate that locations monitored along Mystic Ave, Somerville (#114 Moreland Ave., 70-80-90 Mystic Ave., and the Mystic Activity Center) are dually impacted from local roadway noise along Mystic Ave. (Route 38) and concurrent highway noise from I-93. The L10(h) noise descriptor for measurement of peak hour exceeded the 70 dBA threshold for FWHA Activity Categories Residential (B) and Parks/Public Uses (C) at all study sites, with exception of 50 Puritan Road. Based solely on exceedance of the L10(h) metric, this study concludes that noise levels approach or exceed the noise abatement criteria (NAC), confirming a traffic noise impact to the study sites. Where traffic noise impacts are identified, various noise abatement measures are typically considered to mitigate adverse impacts. Construction of a noise barrier is the mitigation measure most often associated with the concept of noise abatement.

At several sites tested, noise levels increased with increasing height, as the sound level meters captured the increased intensity of both local roadway noise and highway noise at the higher meter elevations. The gradient in noise intensity (dBA) ranged from +2.7 dBA/10 feet to +6.6 dBA/10 feet elevation. Noise barriers can achieve -5 dB attenuation when tall enough to break the line of sight from a highway, with a barrier insertion loss goal of -10 dB (typical values are between -6 and -8 dB). An additional -1.5 dB attenuation can be achieved for every meter of barrier above the line of sight, with a theoretical total noise reduction of -20 dB (FHWA). Given these guidelines, a noise barrier constructed to a 15 foot (5 meter) height in the States Aves neighborhood could potentially attenuate highway and onramp noise -7 to -10 dB, reducing peak hour, adjusted noise levels to the 59.1 – 68.3 dBA range, which is still at or above health risk-based thresholds.

In the Mystic Ave neighborhood, installation of a noise barrier would need to consider noise reduction goals of either attenuating highway noise from I-93 or from local Mystic Ave (Route 38) traffic or both. Installation of a continuous noise barrier along the length of Mystic Ave is complicated by the numerous intersections. Other geographic and topographic conditions in the Mystic Ave neighborhood may limit barrier installation and efficacy.

Data collected in this study suggests that the existing noise barrier located along I-93 North in Somerville attenuates some of the highway traffic noise in the Ten Hills neighborhood, but still left some locations above the thresholds quoted. For all other areas outside of Ten Hills, peak hour noise levels were excessive, with L10(h) levels above the 70 dBA FHWA Activity Categories Residential (B) and Parks/Public Uses (C) NAC threshold.

Background

When interstate I-93 was constructed in the 1970s the Commonwealth of Massachusetts proposed to build noise barriers to reduce noise for residents living near the highway. Type I sound wall noise barriers were constructed in several impacted communities along I-93 from the Charlestown area to the northern suburbs of Boston. A sound wall (noise barrier) was constructed adjacent to the northbound lanes of I-93, buffering the Ten Hills, Somerville neighborhood from highway noise. No barriers or sound walls were constructed along the south side of I-93 along Mystic Avenue (Moreland Street to Foss Park) nor along I-93 or its southbound on-ramp in the States Avenues, East Somerville area. A general locus map of Somerville, MA is presented in Figure 1.

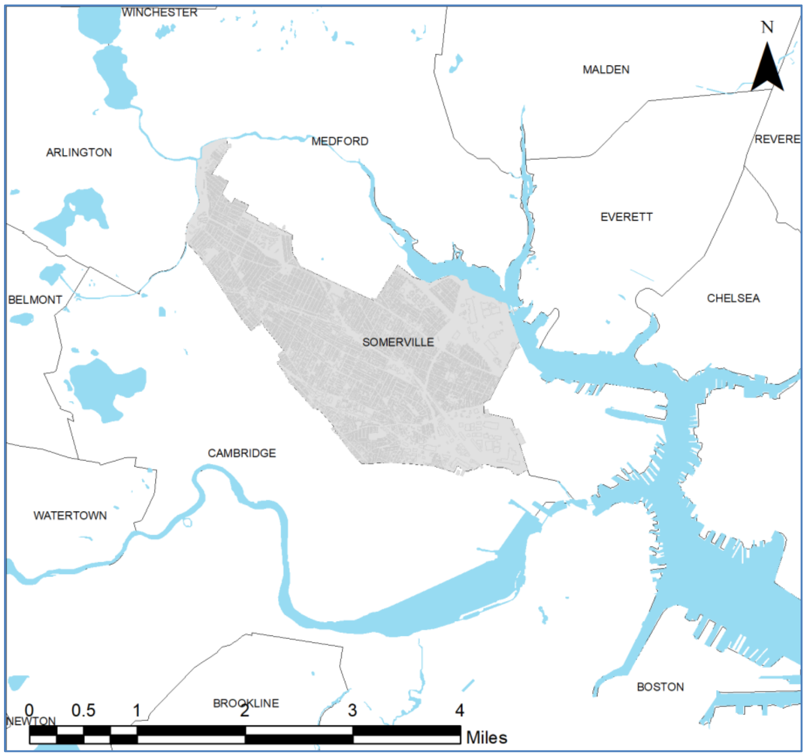


Figure 1 - Locus Map of Somerville, Massachusetts

Many Somerville residents living near I-93 are exposed to elevated noise and air pollution levels from highway and roadway transportation sources and face potential health risks due to the dual exposures. This study focused on measurement of noise impacts to Somerville residents in the study area (Figure 2), in support of a Health Lens Assessment (HLA) evidence-informed estimation of how construction of additional noise barriers along I-93 might potentially impact the health and well-being of the surrounding community.

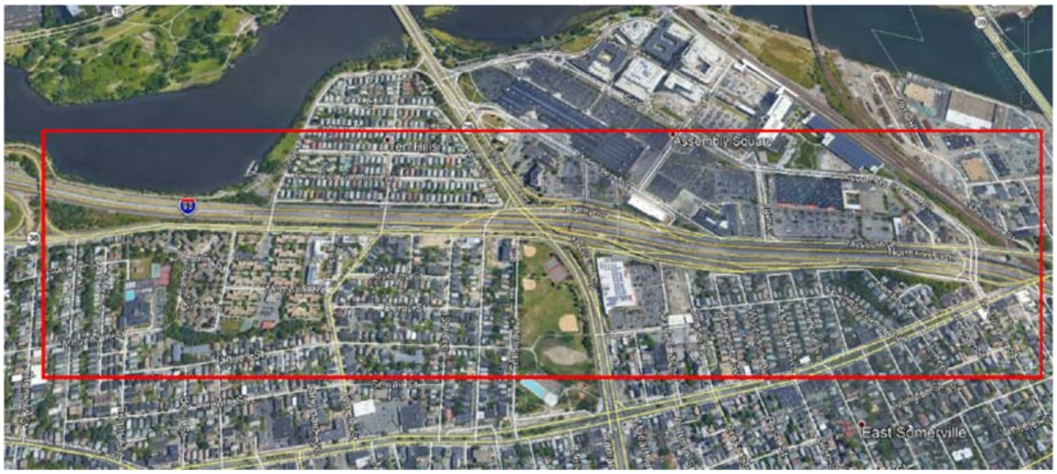


Figure 2 - Noise Monitoring Study Area, Somerville, Massachusetts

To assess "baseline" current conditions, noise was monitored at selected sites in the study area over an 8-week period during June through August 2018. Prior to the noise monitoring campaign, a site walkover (scoping walk) was conducted to identify potential sites within the area for monitoring roadway noise (Figure 3).

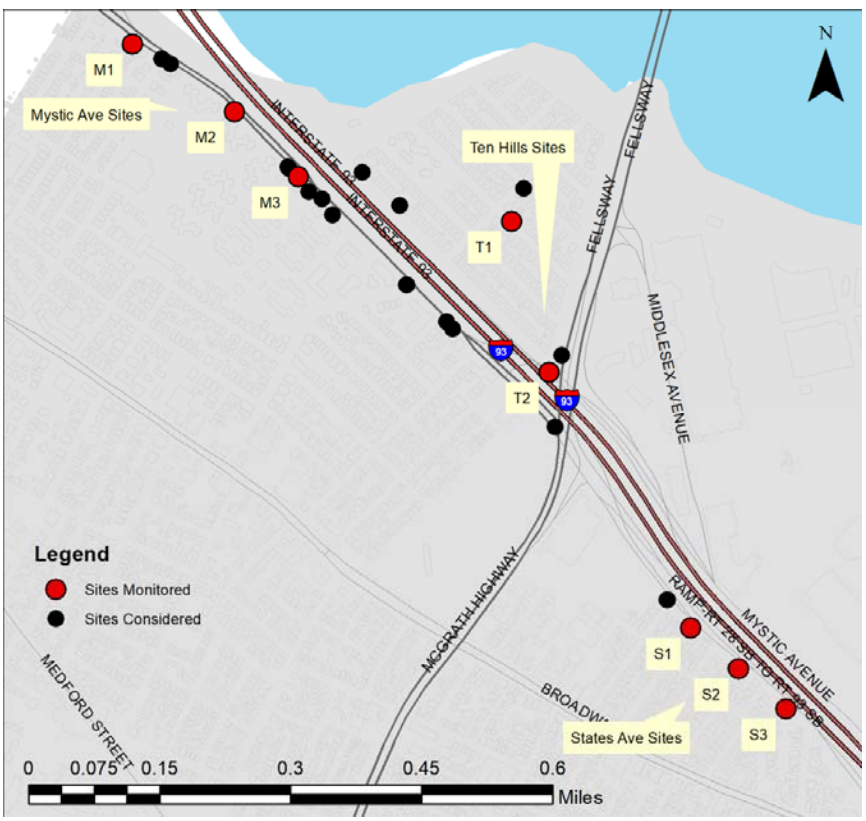


Figure 3- Site Map of Locations Proposed and Sampled for Noise Monitoring

Sites were identified per FHWA-PD-96-046 (1996) regulations that specify “site selection and monitoring should establish an overall sound level for the purpose of assessing noise impact of a nearby highway and should be guided by the location of noise-sensitive receptors.” When selecting potential representative sites for the overall sound level measurements, this campaign adhered to the FHWA-PD-96-046 Guideline that the monitoring site(s) should exhibit typical conditions (e.g., ambient, roadway, and meteorological) for the entire community.

Instrumentation and Methods

For noise monitoring instrumentation in this study six (6) REED SD-4023 Class 2 Sound level meters (SLM) were deployed, with a spare unit as a back-up. Prior to field deployment, the REED SLM instruments were co-located in an indoor environment (quiet office) and calibrated (Figure 4) to both 94 dB and 114 dB at 1 kilohertz (kHz) using a REED-R8090 sound level calibrator. Specifications for the REED-4023 SLM can be found at: www.reedinstruments.com

Figure 4 - REED-4023 Sound Level Meters (SLM)

For field deployment, REED-4023 SLM instruments were enclosed in plastic snap-locking containers to shelter the instruments from weather, fitted with wind-shield balls and mounted on L-brackets (Figure 5) attached to three PVC 2-inch diameter pipes, each 10 feet in length with the REED-4023’s mounted at mid-length. The PVC pipes were connected with couplings and raised to a total height of 30 feet to facilitate noise monitoring with microphones at three heights: 5 feet for single-story structures and additionally at 15 feet and 25 feet above grade for multi-story structures, per recommendations of FHWA-PD-96-046 (1996), Section 6: Highway Barrier Insertion Loss Measurements. As defined in this Section, “Insertion loss is the difference in sound level at a receiver location with and without the presence of a noise barrier.”

Figure 5 - REED-4023 SLM Field Mounting Hardware

Prior to each field deployment day and following data collection, a calibration check and instrument clock time reset was performed on all deployed REED-4023 instruments. If calibration drift was >+/- 1 dB from the reference of 94 dB at 1 kHz (auto range setting), the calibration was field-adjusted to 94.0 dB. SLM internal clocks were synchronized on deployment to the National Institute of Standards and Technology (NIST) web clock found at www.time.gov

REED-4023 internal data loggers were set to 1 second sampling times at A-weighted, fast setting for each instrument, with all data logged recorded to 16 GB SD-cards inserted into each REED-4023 SLM. The power the REED-4023 SLM units batteries utilized in the study were AA-rechargeable alkaline cells, which facilitated an average run time of approximately 50 hours.

Meteorological data was not collected on-site, but was downloaded as raw data from Boston Logan international (KBOS) weather records: https://mesonet.agron.iastate.edu/request/download.phtml?network=MA_ASOS and analyzed by monitoring date for this study. Selected meteorological data parameters are plotted and presented in the Appendix of this report. Live traffic counts from I-93, Mystic Ave or highway on-ramps and off-ramps were not available during this field campaign. The Appendix of this report presents traffic flow diagram schematics prepared by the Boston Regional Metropolitan Planning Organization (www.ctps.org)

Monitoring Sites

Monitoring sites were selected per recommendations of FHWA-PD-96-046 (1996), Section 6: specifying "five to ten monitoring sites, with microphones positioned in flat open space free of large reflecting surfaces (such as parked vehicles, signboards, buildings, or hillsides, located within 30 m (100 ft) of either the vehicle path), with line-of-sight from the microphone(s) to the roadway unobscured within an arc of 150 degrees." Actual field deployments were limited by site architecture and physical factors of site terrain.

Table 1 presents a list of all sites monitored in this campaign, with monitoring dates of deployment for the REED-4023 SLM instruments and monitoring run times by SLM height at each site. Total monitoring time for this study was 413 hours and 38 minutes. Typical sampling periods of 15 mins, 1 hour, 24 hours are specified in FHWA-PD-96-046 (1996), Section 6. The monitoring periods in this study captures these metrics, with additional sampling periods logged in Table 1. A subtotal of 230 hours and 41 minutes (56%) of the total monitoring time includes data logged concurrently at multiple heights. The concurrently-logged, overlapping data was analyzed in this study to compare and contrast noise levels at varying heights for the same address, during identical time sequences, with stable meteorological conditions (i.e. - dry pavement conditions, stable temperature, humidity, wind direction and wind speed). Data analysis is presented in the next section of this report.

Table 1 REED-4023 Data Log by Site Location and Monitoring Times

Location Address	Map Key (Fig. 3)	5 ft	15 ft	25 ft	Total Time (hr:mm)
16 New Hampshire Ave	S1	6/27: 10:12a to 6/29: 9:44a	6/27: 10:10a to 6/29: 11:12a	6/27: 9:59a to 6/29: 8:00a	49:00
114 Moreland St	M1	7/17: 10:08a to 7/17: 11:25pm	7/17: 10:00a to 7/19: 11:13am	not deployed (no access to home)	49:13
70-80-90 Mystic Av	M2	7/17: 11:42am to 7/18: 5:05am	7/17: 11:44am to 7/18: 1:50am	7/17: 11:27am to 7/19: 7:13am	43:46
9 Maine Ave	S2	7/24: 1:11pm to 7/25: 9:08am	7/24: 1:11pm to 7/26: 9:27pm	7/24: 1:11pm to 7/26: 9:01am	57:22
Mystic Activity Ctr	M3	7/24: 12:12pm to 7/26: 11:35am	7/24: 12:05pm to 7/26: 2:12am	7/24: 12:11pm to 7/24: 6:31pm	47:30
50 Puritan Rd	T1	8/1: 11:33am to 8/3: 4:52pm	8/1: 11:33am to 8/3: 2:19pm	8/1: 11:33am to 8/3: 4:38pm	53:19
10 TenHills Rd	T2	8/7: 10:14am to 8/9: 259am	8/7: 10:22am to 8/10: 3:44am	8/7: 10:26am to 8/9: 4:26pm	65:30
14 Maine Ave	S3	8/15: 2:50pm to 8/17: 6:45am	8/15: 12:50p to 8/17: 9:58a	8/15: 2:52p to 8/17: 12:48pm	47:58

Results

The following annotated plots represent data analysis conducted for each of the eight (8) sites. Presented by site are: site photos showing deployed REED-4023 analyzers; boxplots of noise (dBA) for each height monitored, with dates and times overlapping; hourly noise boxplots (dBA) for each height, overlapping dates and times during similar meteorological conditions; moving mean plots of hourly average noise (dBA) for the conservative-case scenario height, based on hourly boxplots, or if a specific height data set provided a more complete monitoring record. In several representative plots, the peak hourly traffic counts for I-93 NB and SB lanes are annotated. Moving mean, hourly average plots are further annotated with the 60 dBA health risk-based threshold as a benchmark for comparison.

Sites Monitored

114 Moreland St.

Figures 6(a) and (b)- REED-4023 SLMs Deployed at 5 ft and 15 ft (25 ft not deployed)

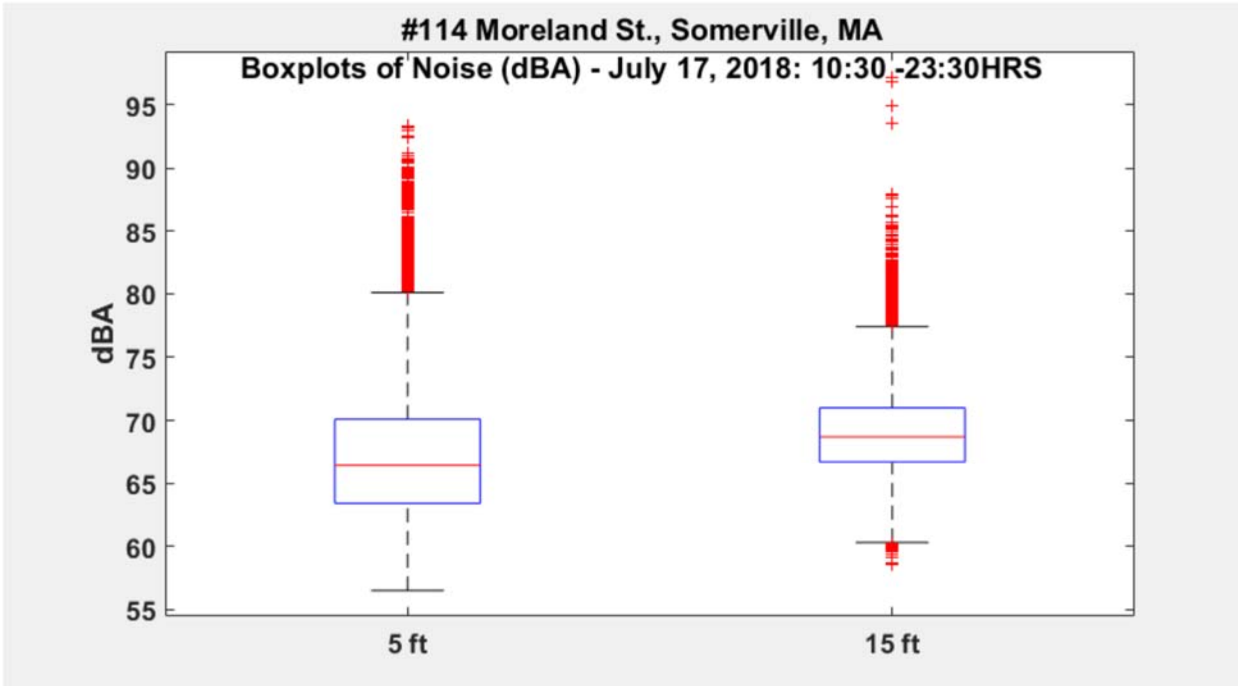
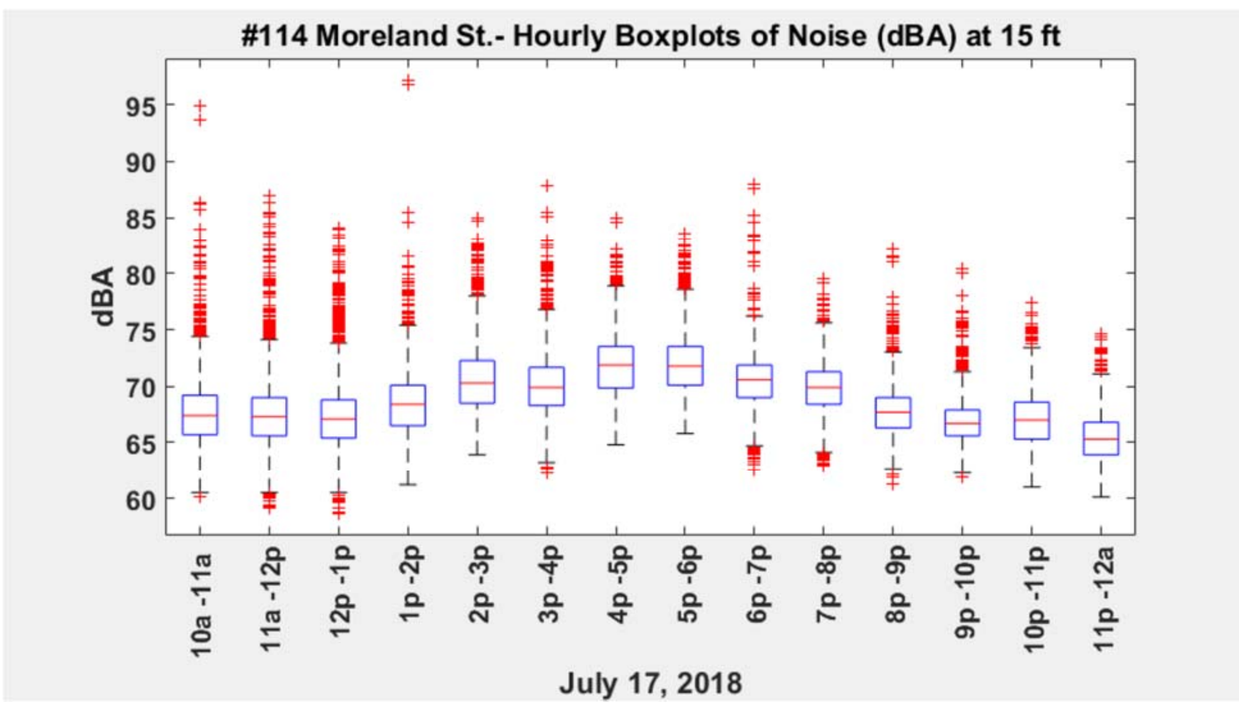
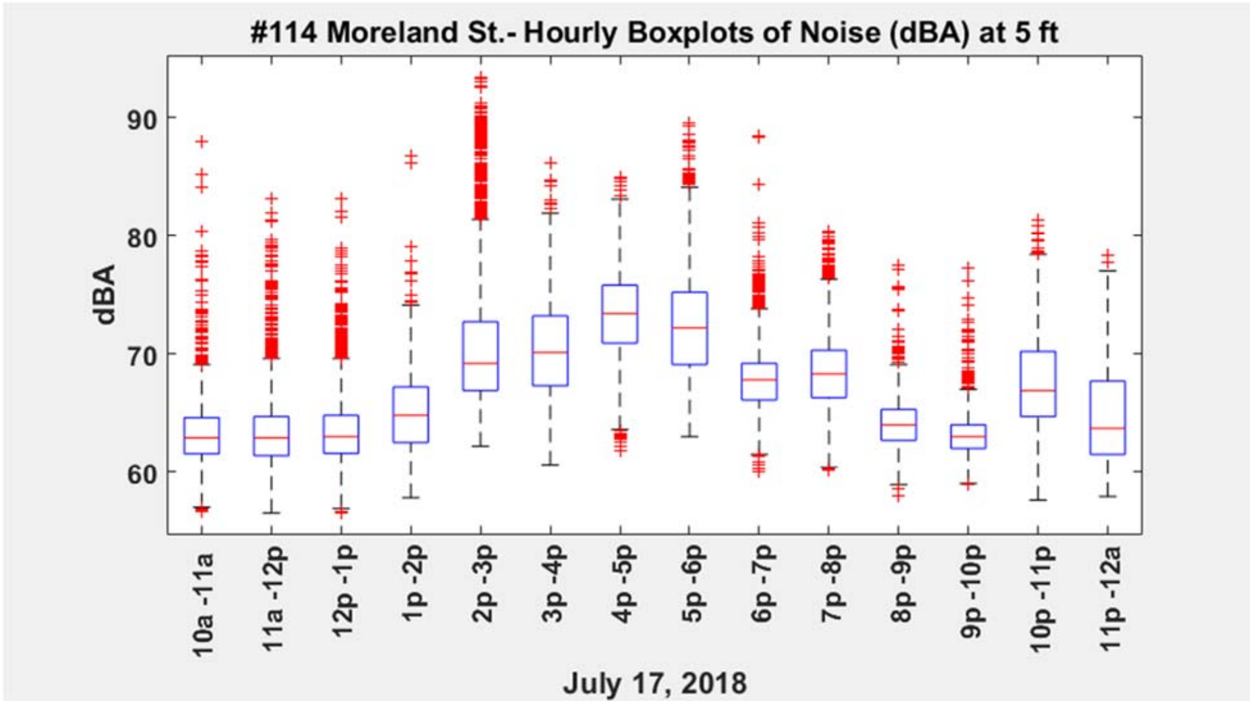


Fig.7- Boxplots of Noise at 5ft and 15ft (25ft monitor not deployed due to site access restrictions)





Figures 8(a) and (b) – Hourly Boxplots of Noise (dBA) for 15 feet (upper fig.) and 5 feet (lower fig.)

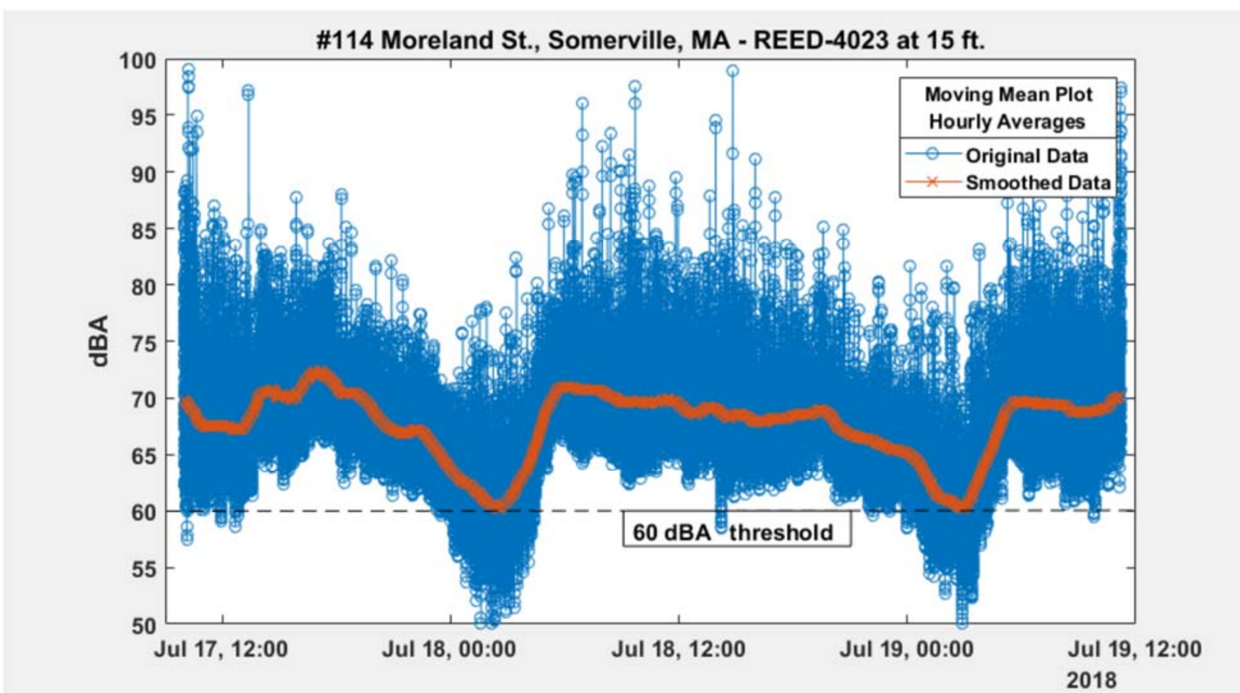


Figure 9 – Moving Mean, Hourly Average Noise Plot for 15 feet REED-4023 vs. 60 dBA threshold

70-80-90 Mystic Ave

Figs 10(a) and (b)- REED-4023 SLMs at 5 ft, 15 ft and 25 ft (I-93 SB traffic visible at right)

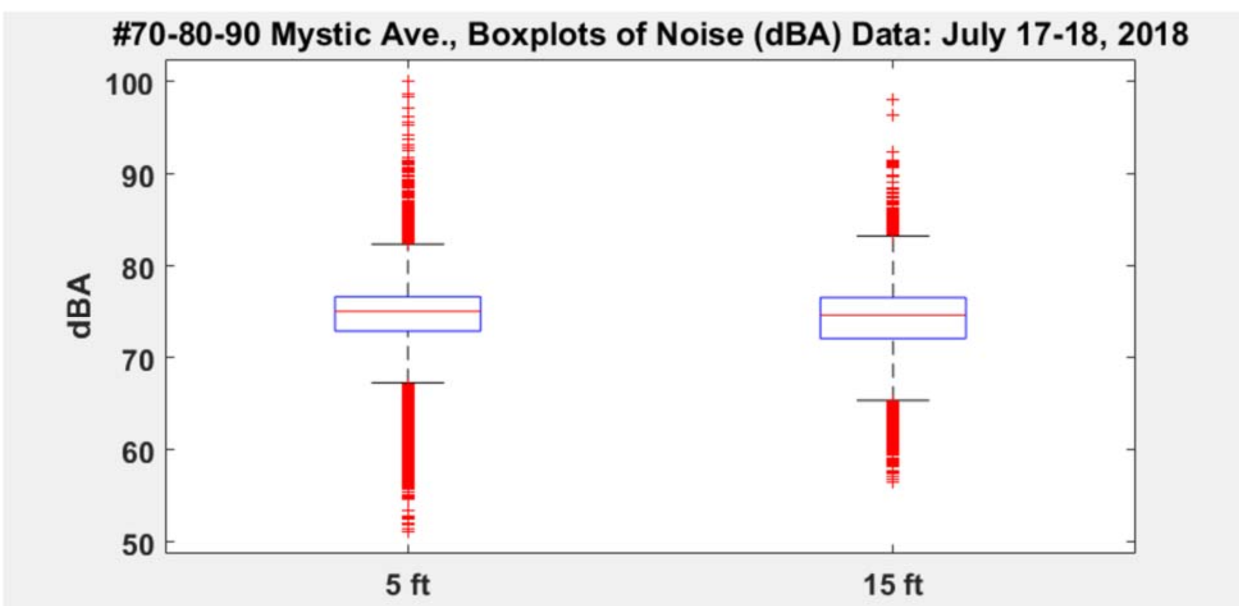
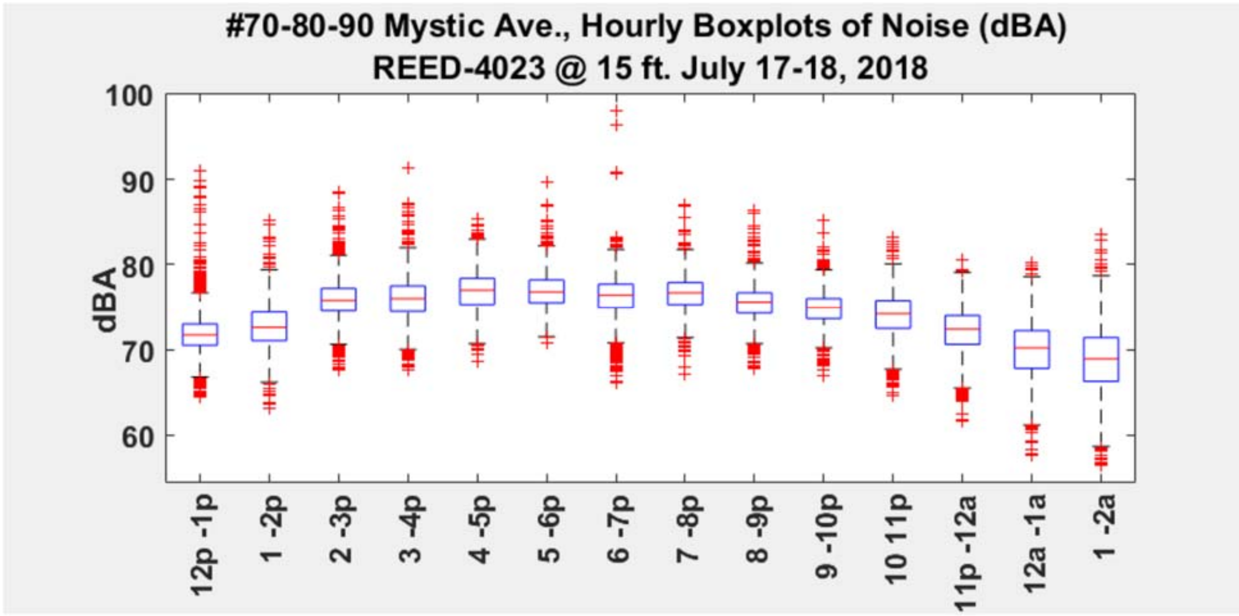
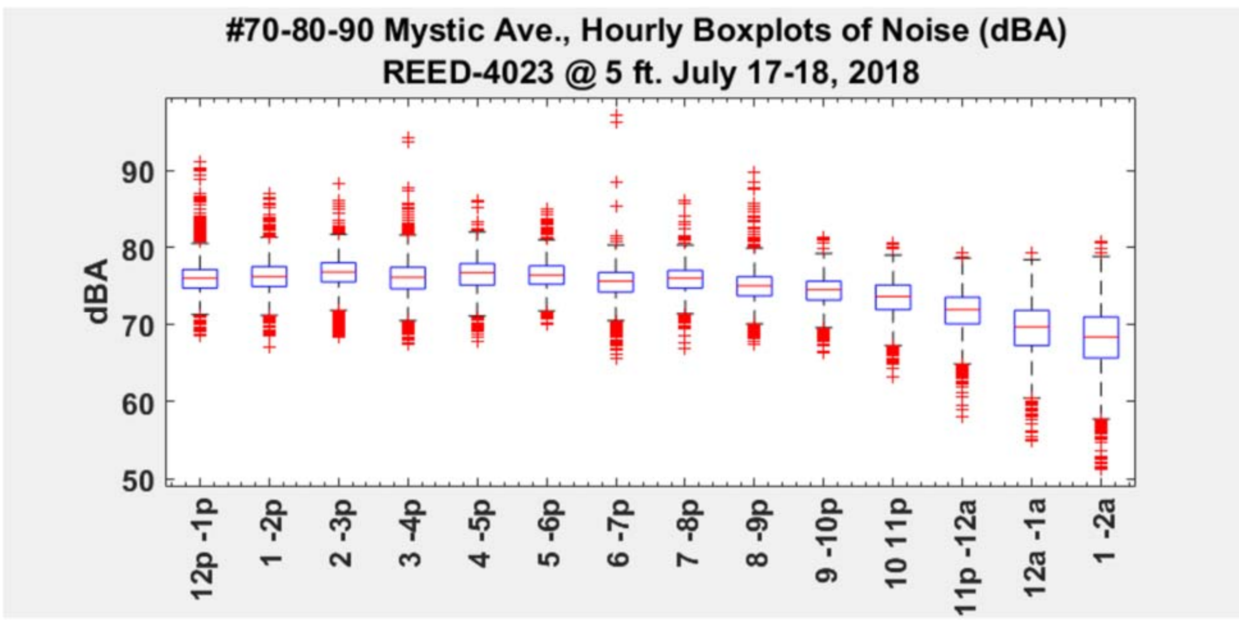


Figure 11 Boxplots of Noise (dBA) at 5 ft and 15 ft (25 ft REED-4023 malfunctioned, data N/A)





Figs 12-13 - Hourly Boxplots of Noise (dBA) for 15 feet (upper fig.) and 5 feet (lower fig.)

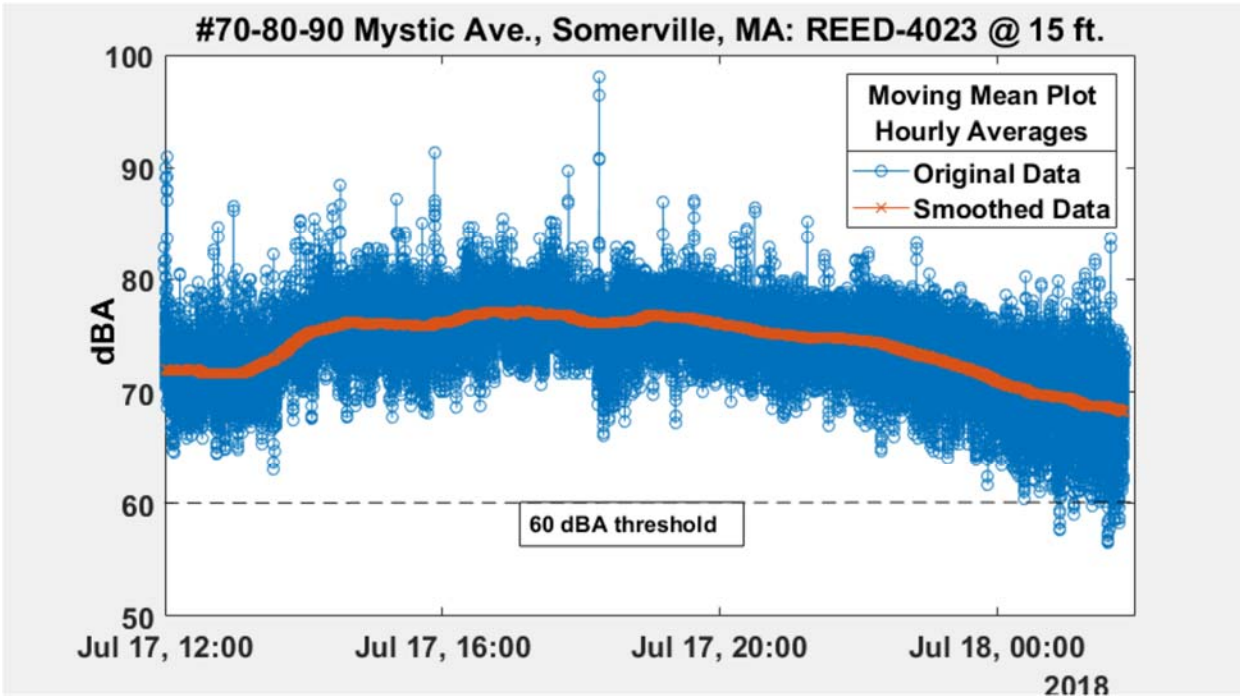


Figure 14 - Moving Mean, Hourly Average Noise Plot for 15 feet REED-4023 vs. 60 dBA threshold

<u>Mystic Activity Center</u>

Figs 15(a) and (b) – REED-4023 Sound Level Meters deployed at site

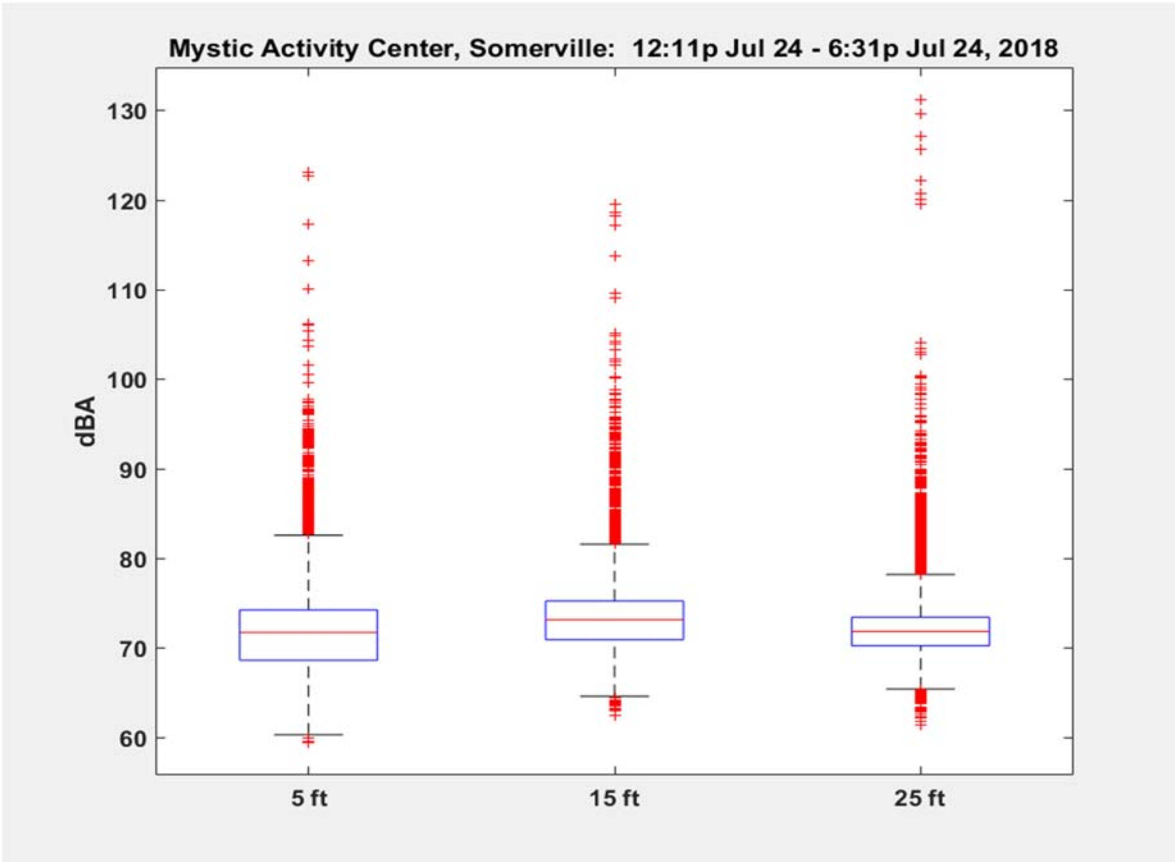
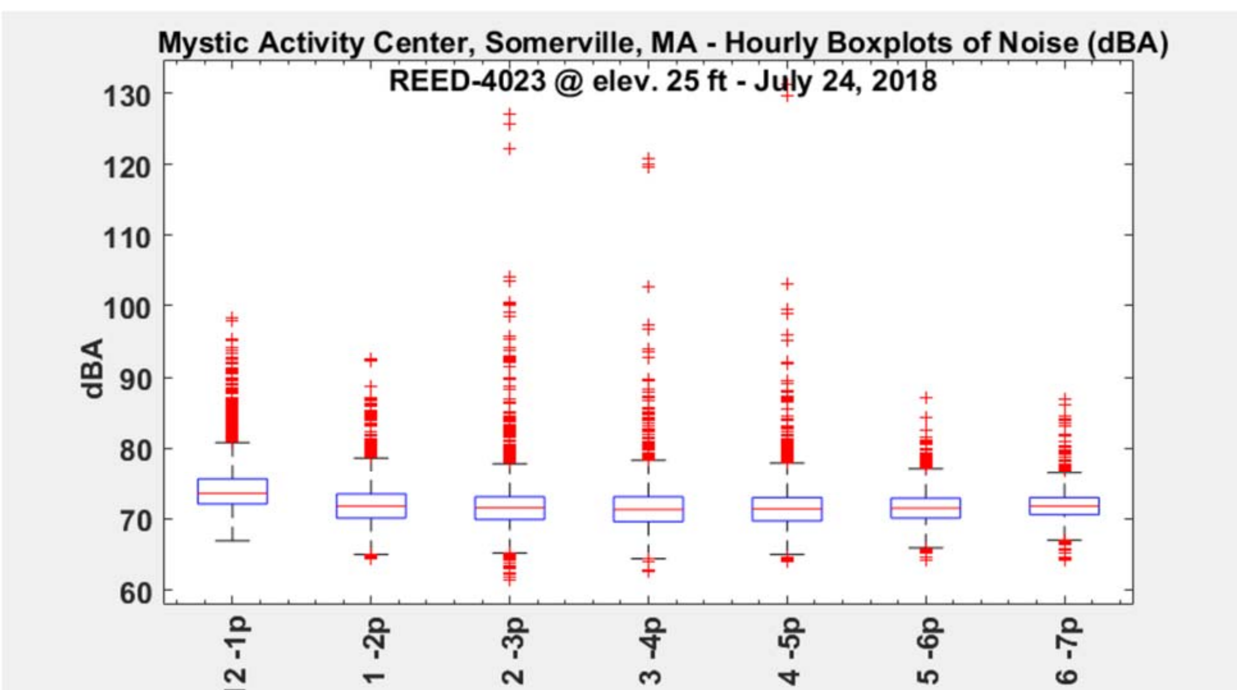
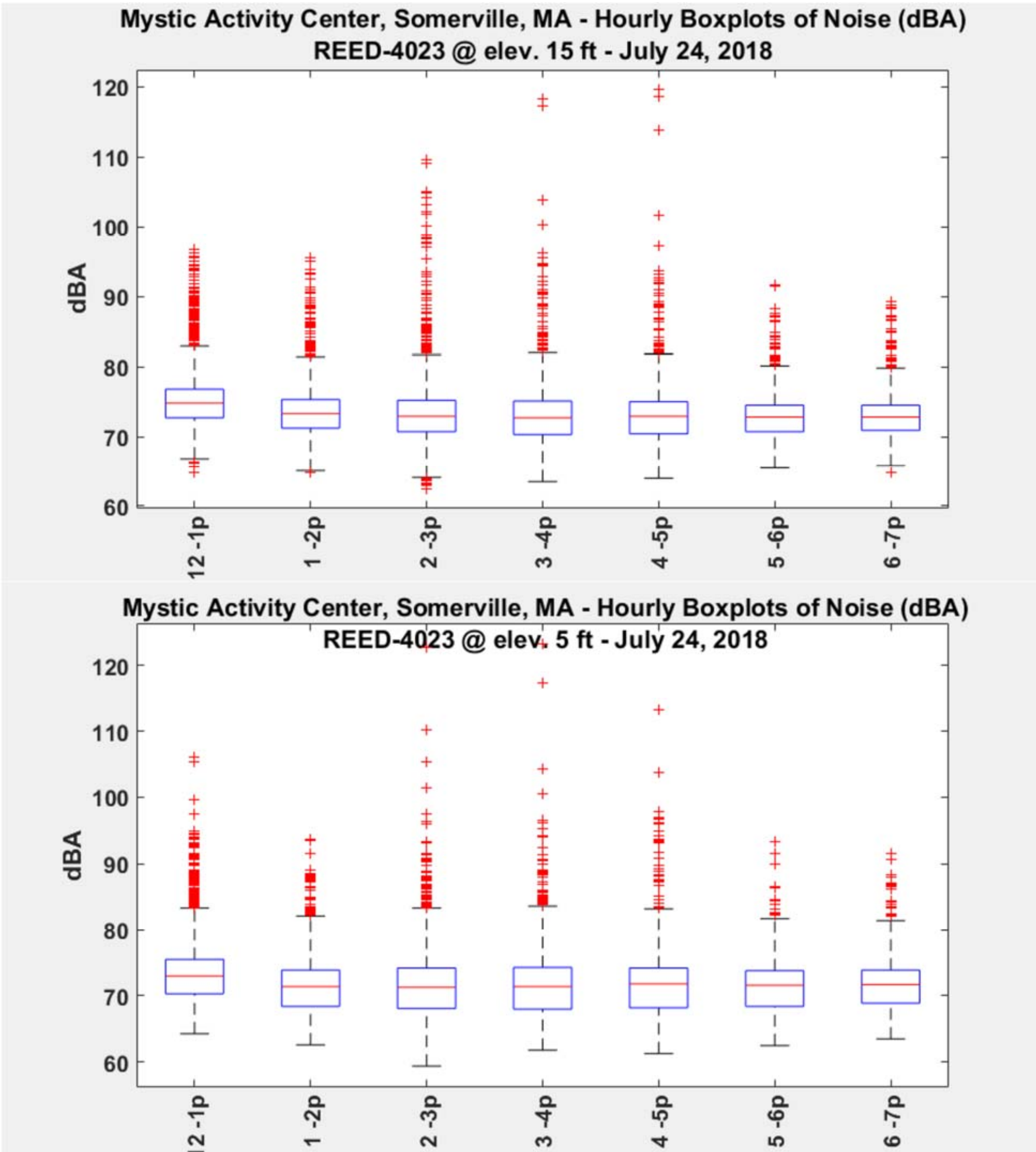


Figure 16 - Boxplots of Noise (dBA) at 5 ft, 15 ft and 25 ft (full data set)





Figures 17(a)(b)(c) - Hourly Boxplots of Noise (dBA) for 25 feet, 15 feet, and 5 feet

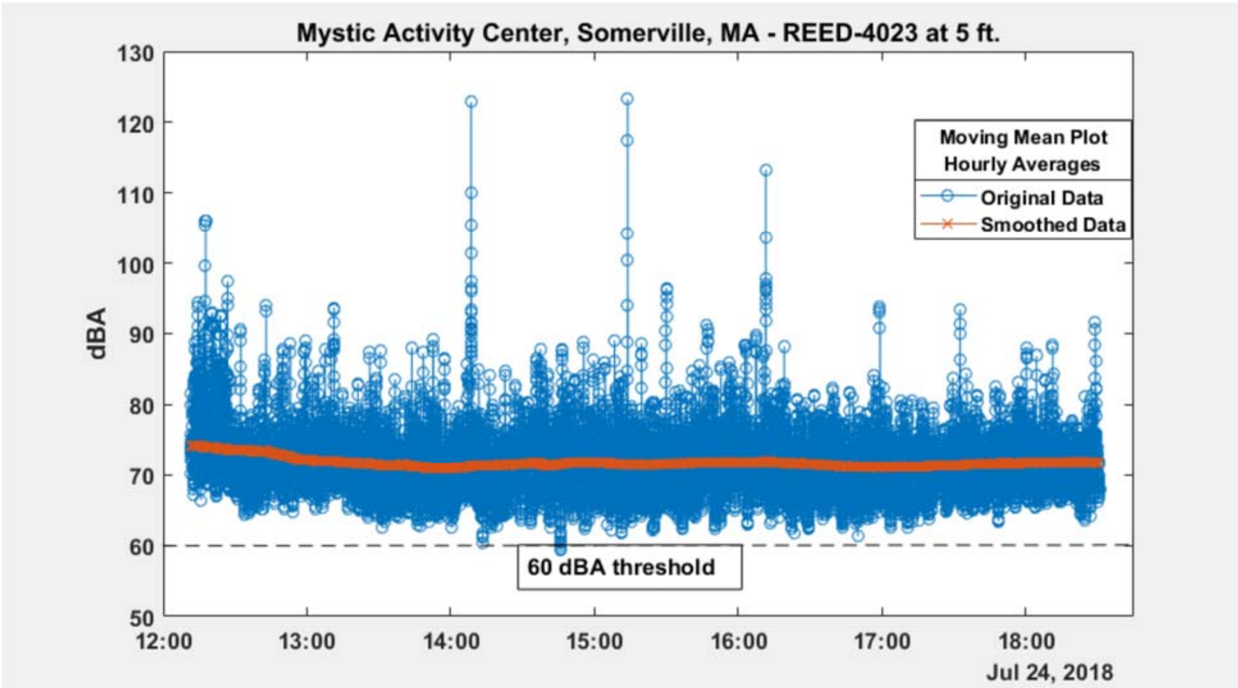


Figure 18 - Moving Mean, Hourly Average Noise Plot for 5 feet REED-4023 vs. 60 dBA threshold

<u>16 New Hampshire Ave</u>

Figs 19(a) and (b) REED-4023 SLMs Deployed at Site; View of I-93 Behind Fence at Right

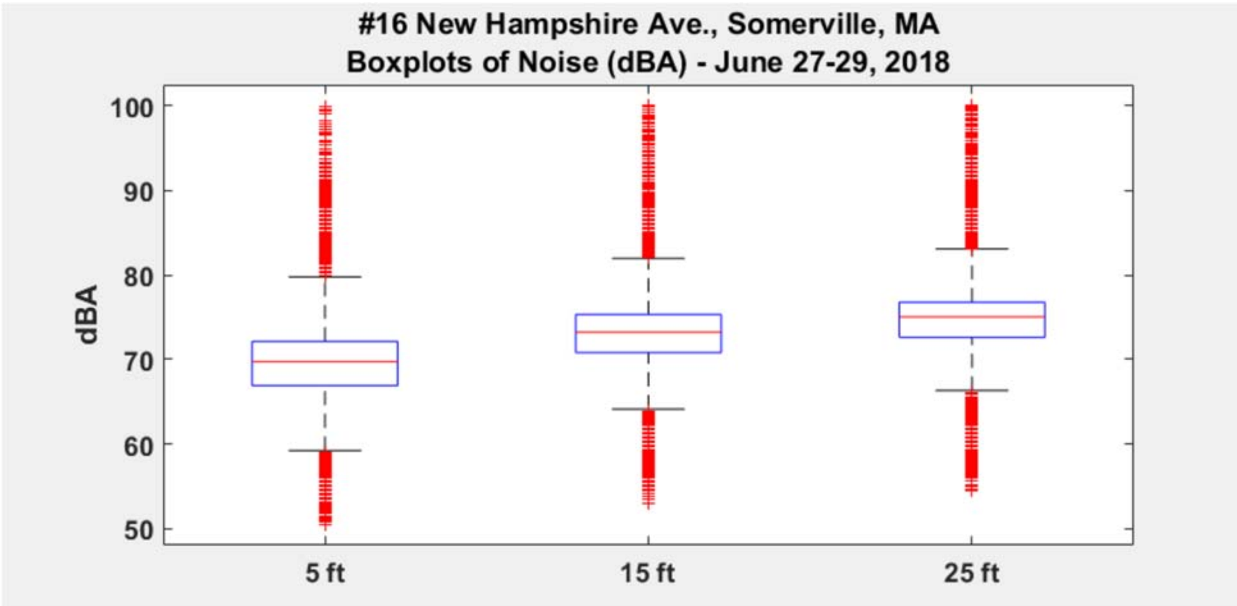
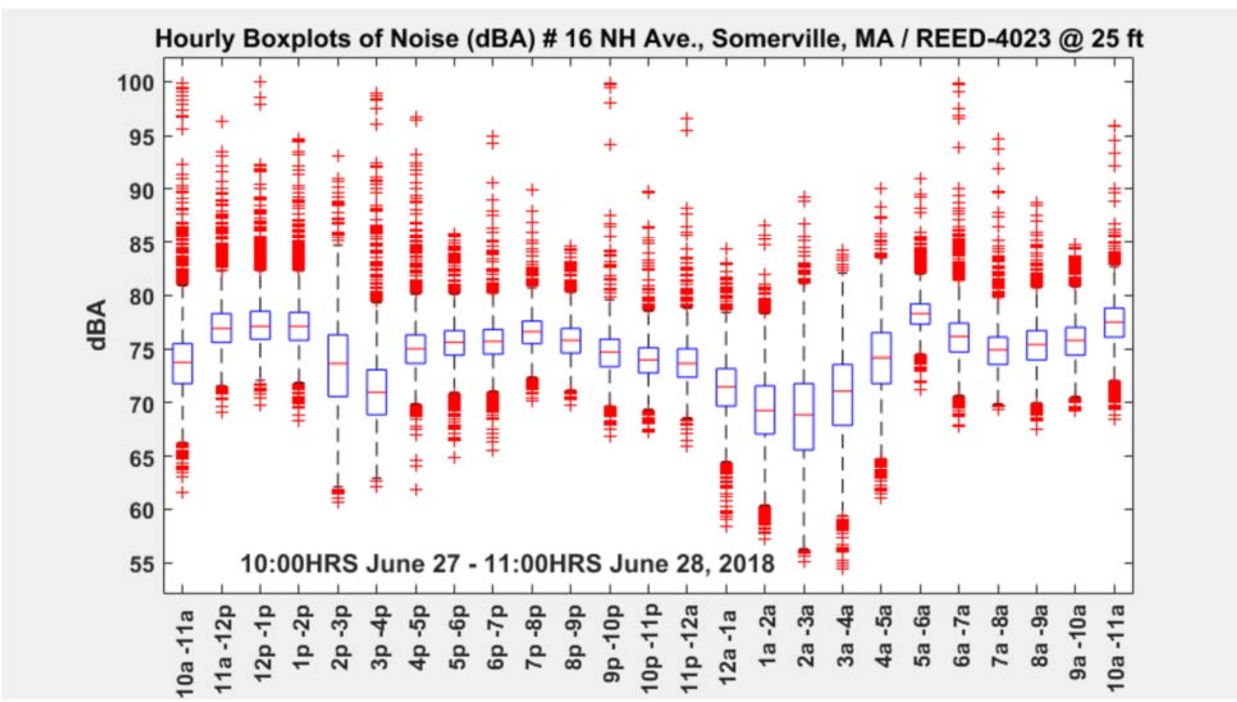
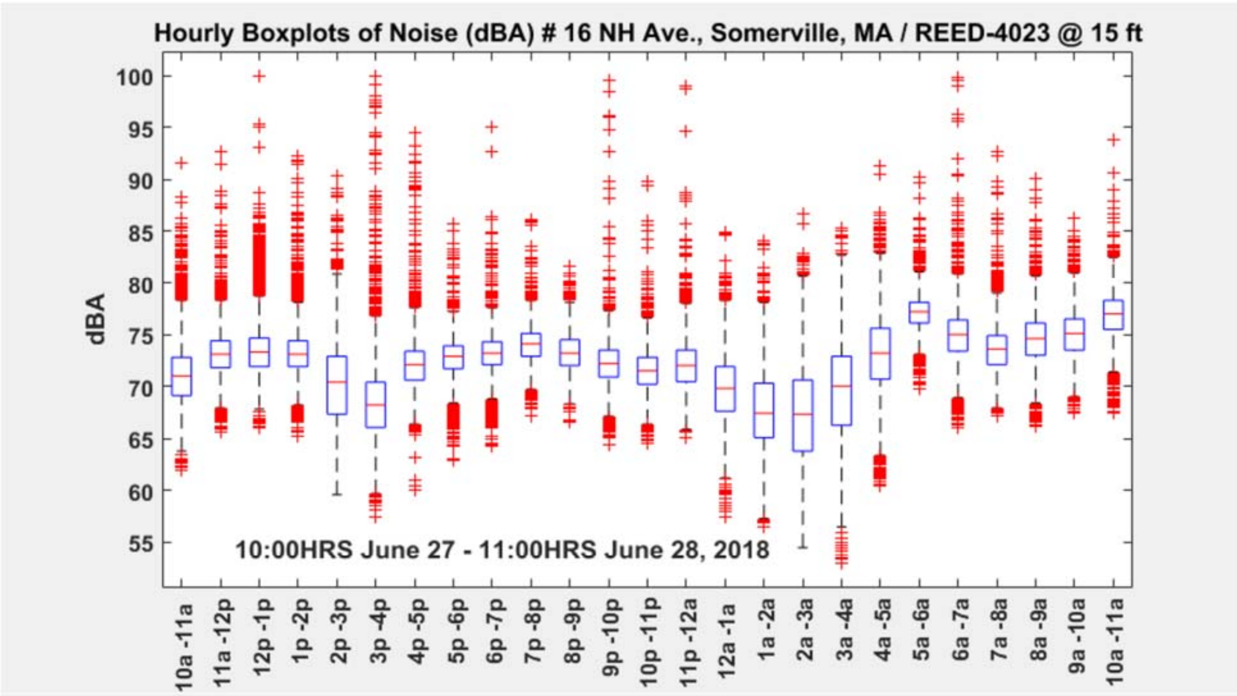
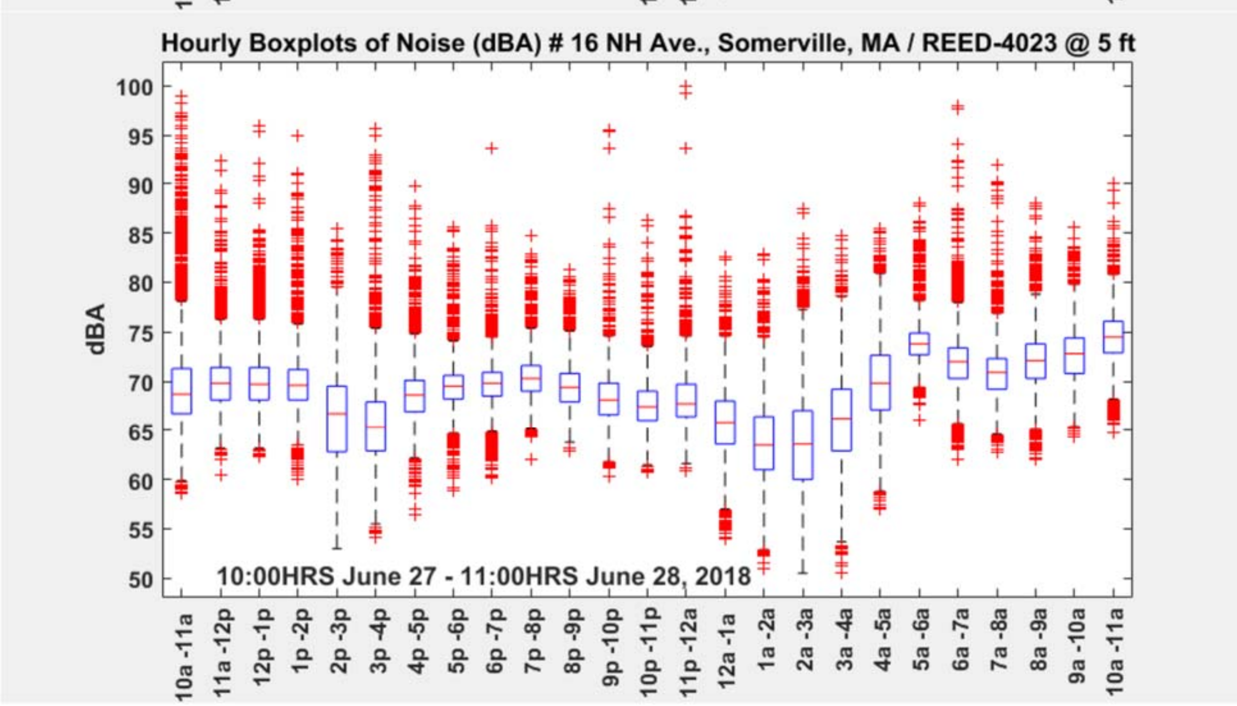


Figure 20 - Boxplots of Noise (dBA) at 5 ft, 15 ft and 25 ft (full data set)







Figures 21-23(above) - Hourly Boxplots of Noise (dBA) for 25 feet, 15 feet, and 5 feet

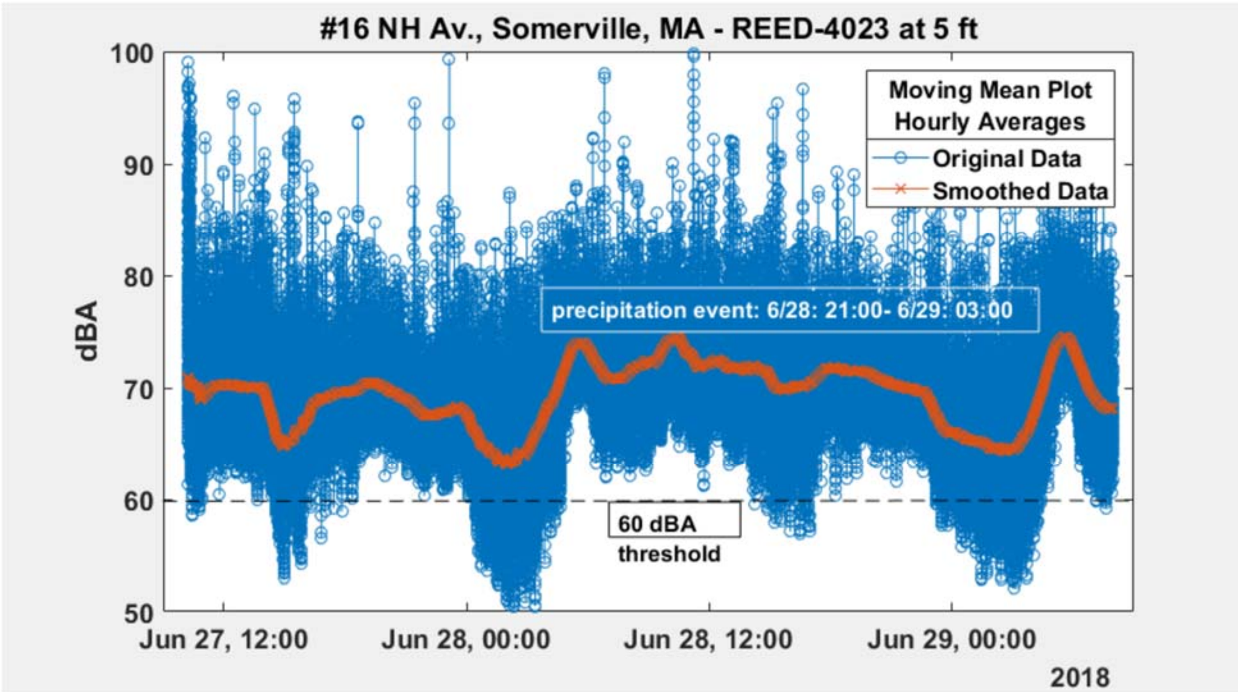


Figure 24 - Moving Mean, Hourly Average Noise Plot for 5 feet REED-4023 vs. 60 dBA threshold

#9 -11 Maine Ave

Figures 25 (a) and (b) –note: porch decks are direct exposure receptors of highway noise

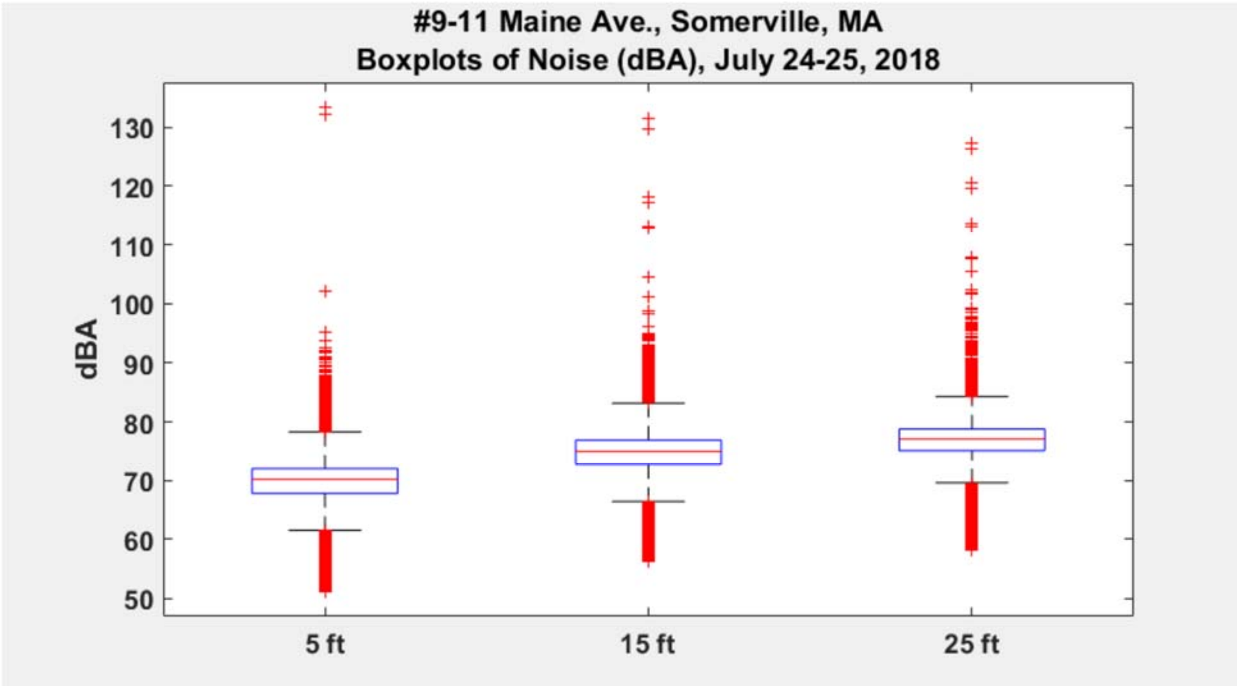
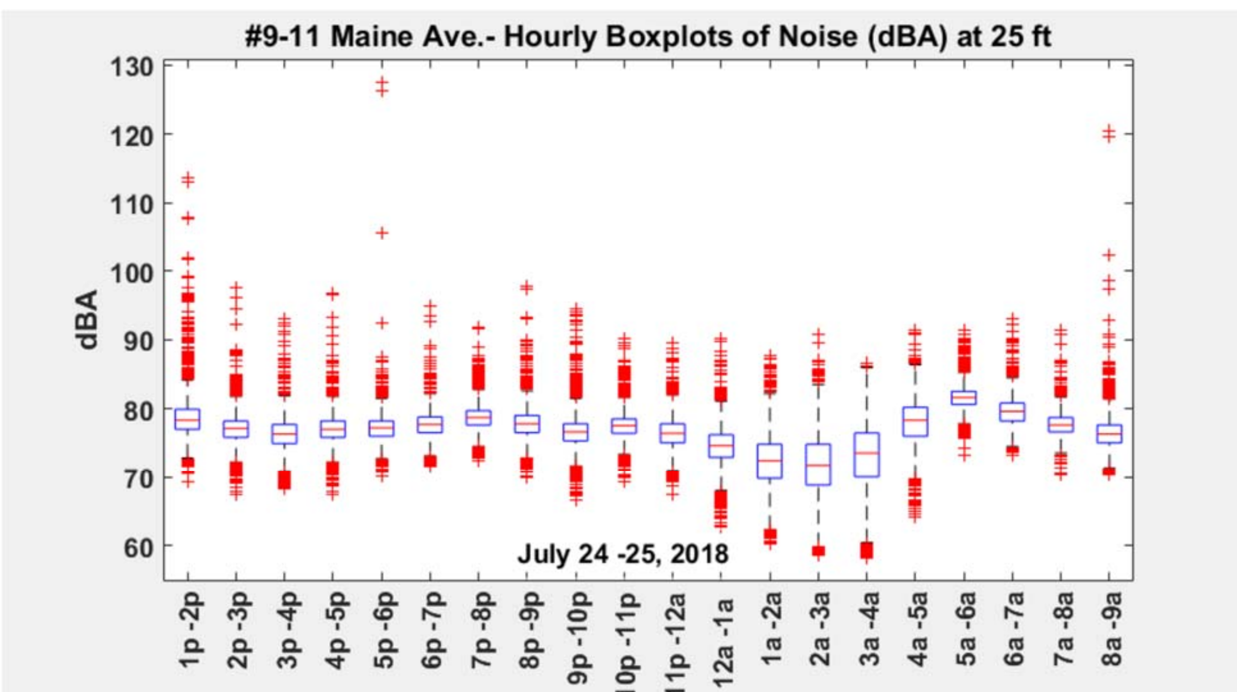
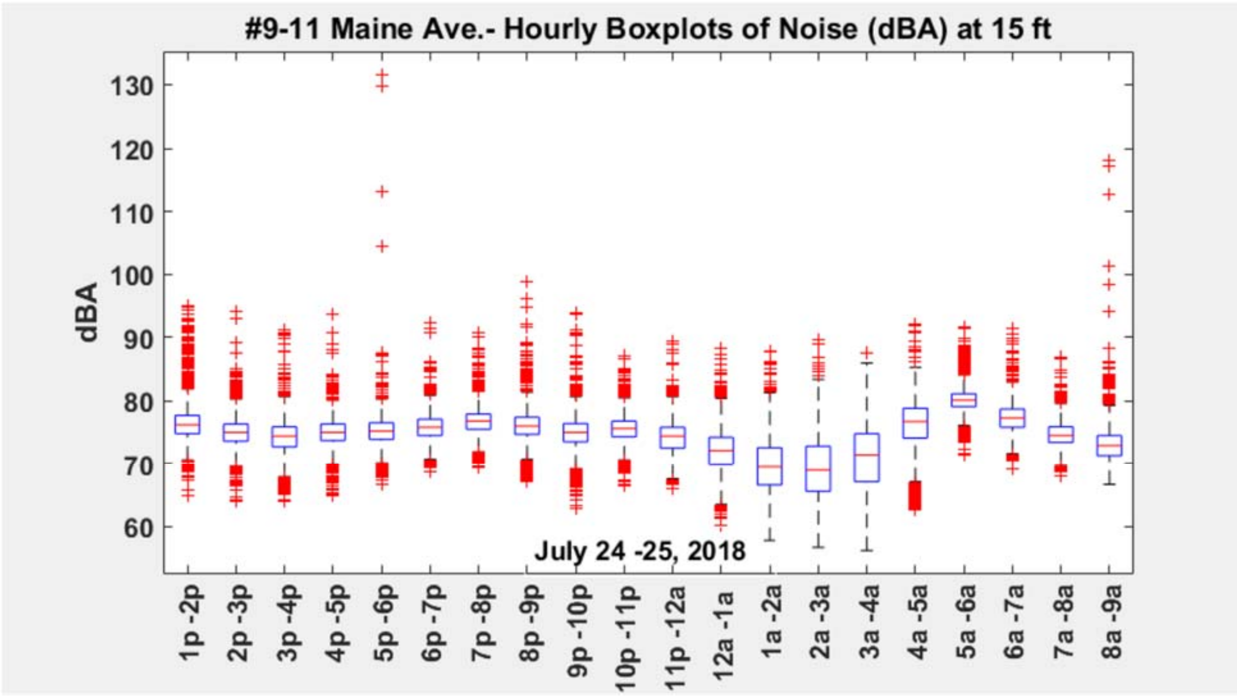
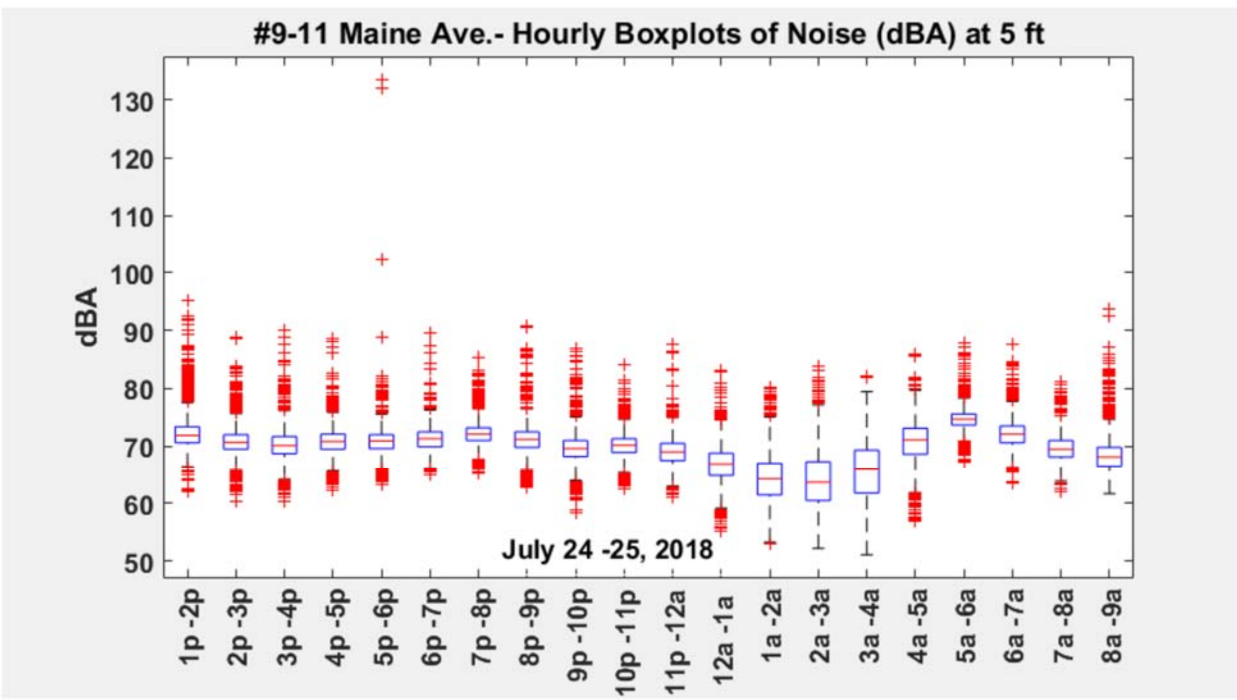


Figure 26 - Boxplots of Noise (dBA) at 5 ft, 15 ft and 25 ft (full data set)







Figs. 27-29 - Hourly Boxplots of Noise (dBA) for 25 feet, 15 feet, and 5 feet

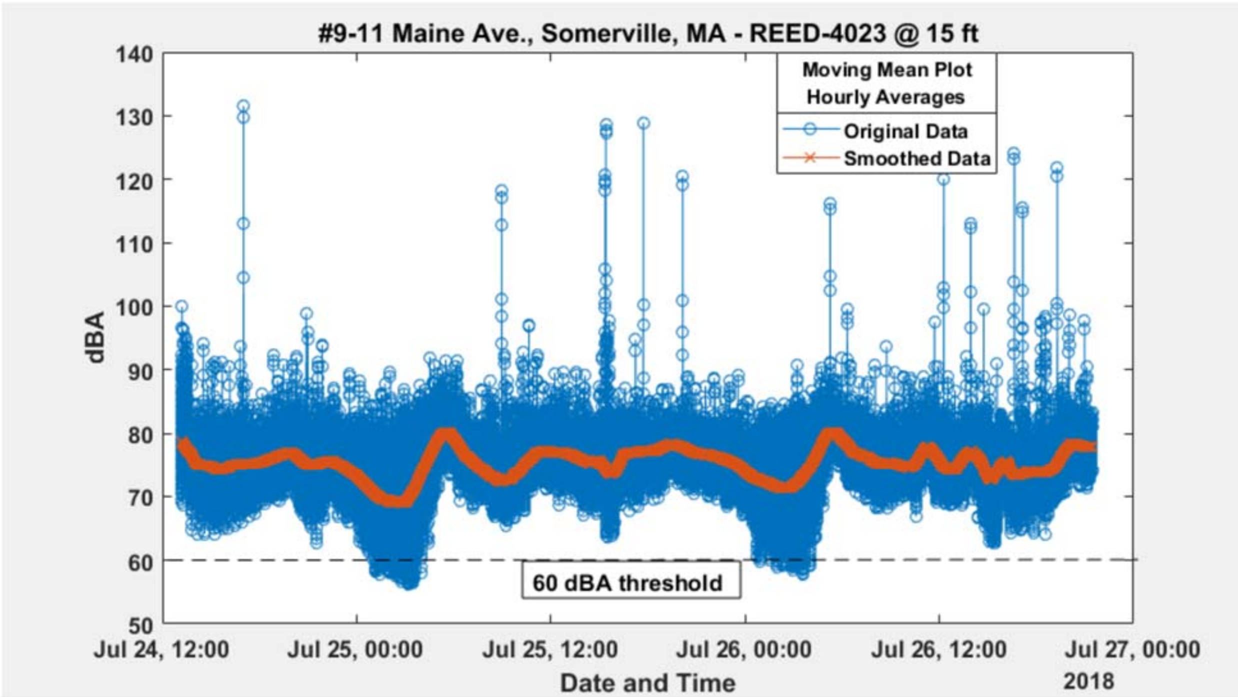


Figure 30 - Moving Mean, Hourly Average Noise Plot for 15 foot REED-4023 vs. 60 dBA threshold

<u>#14 -16 Maine Ave.</u>

Figures 31 (a) and (b) - note: highway visible in rear of photo on left

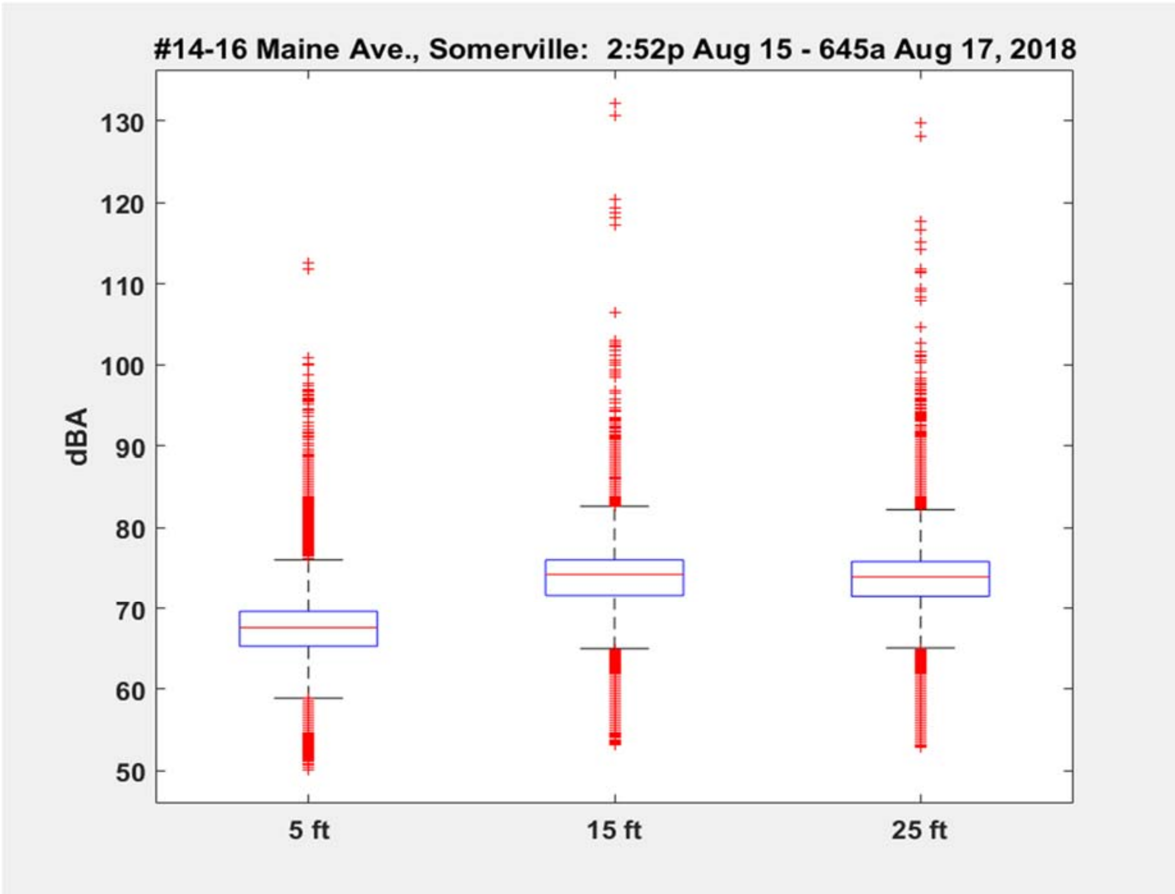
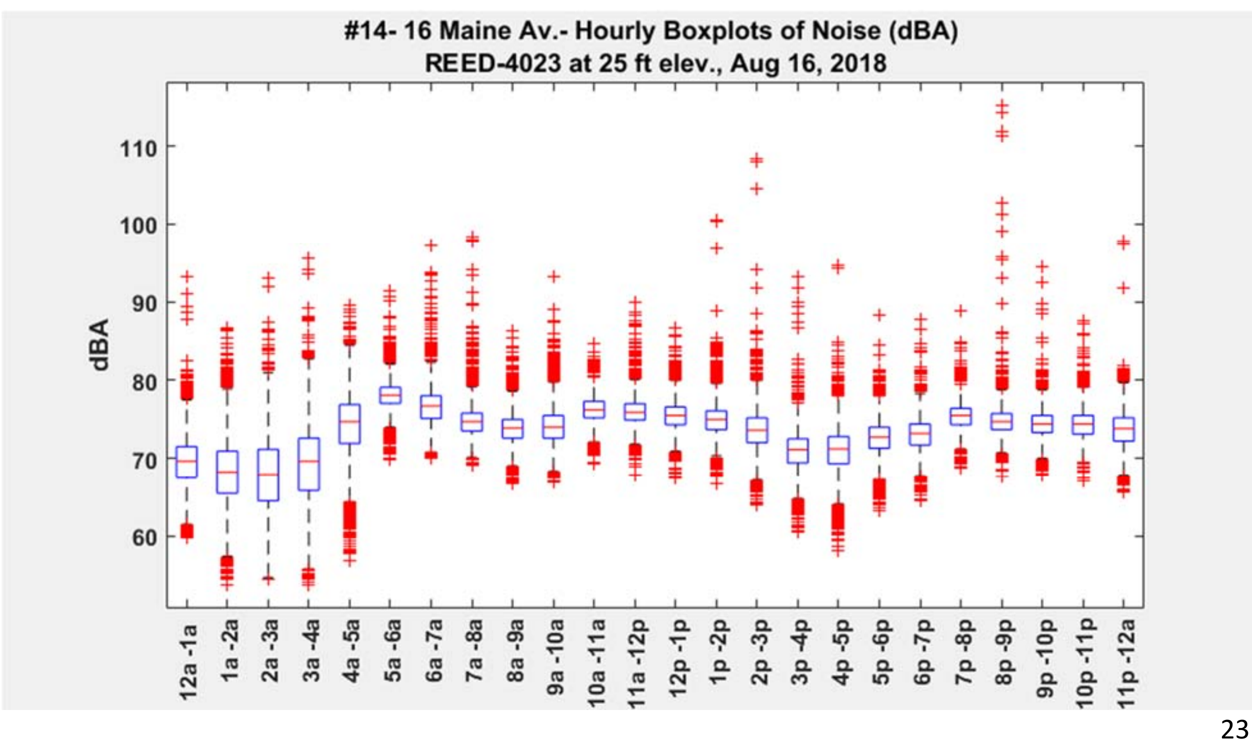
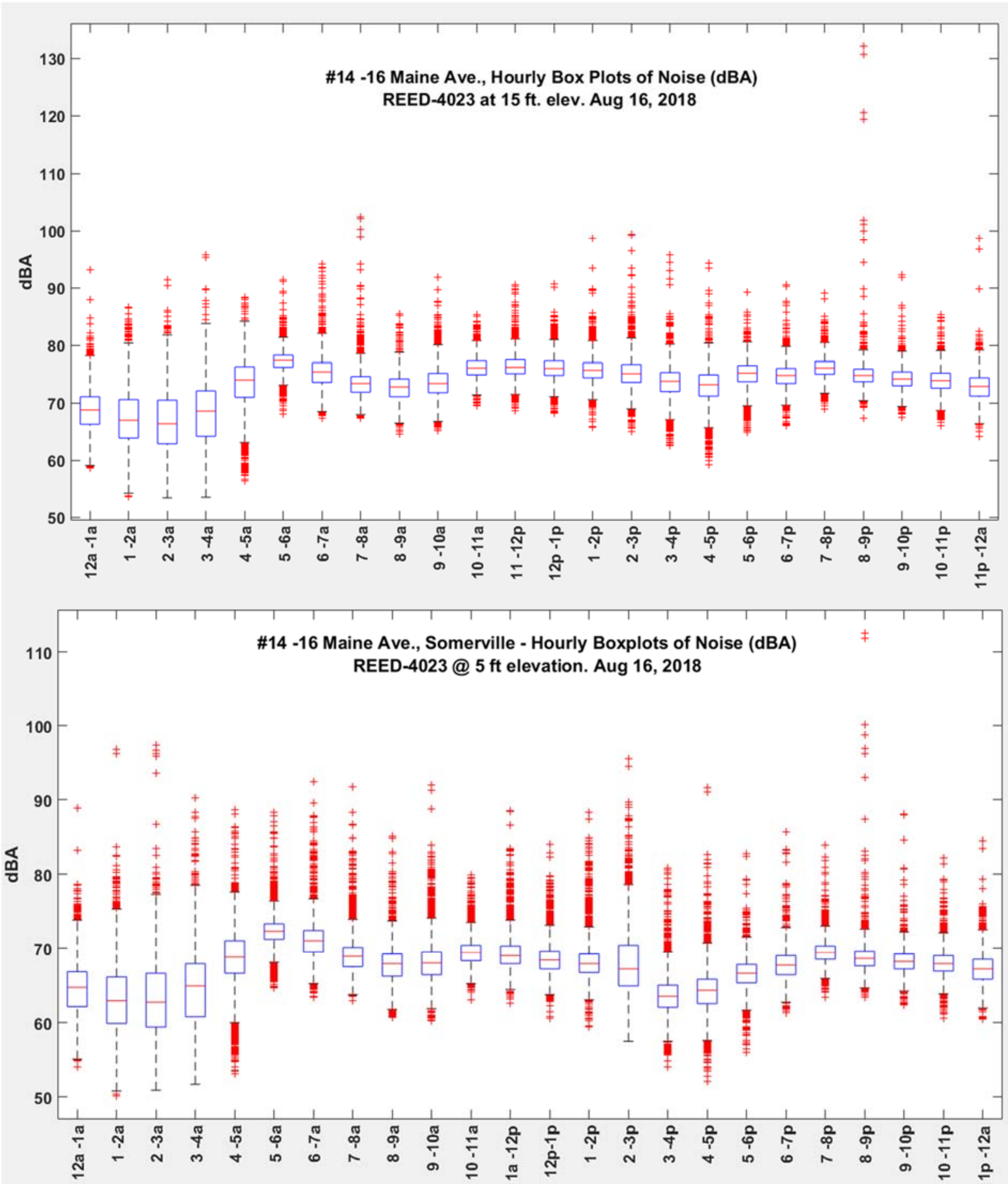


Figure 32 - Boxplots of Noise (dBA) at 5 ft, 15 ft and 25 ft (full data set)





Figs 33 -35 - Hourly Boxplots of Noise (dBA) for 25 feet, 15 feet, and 5 feet

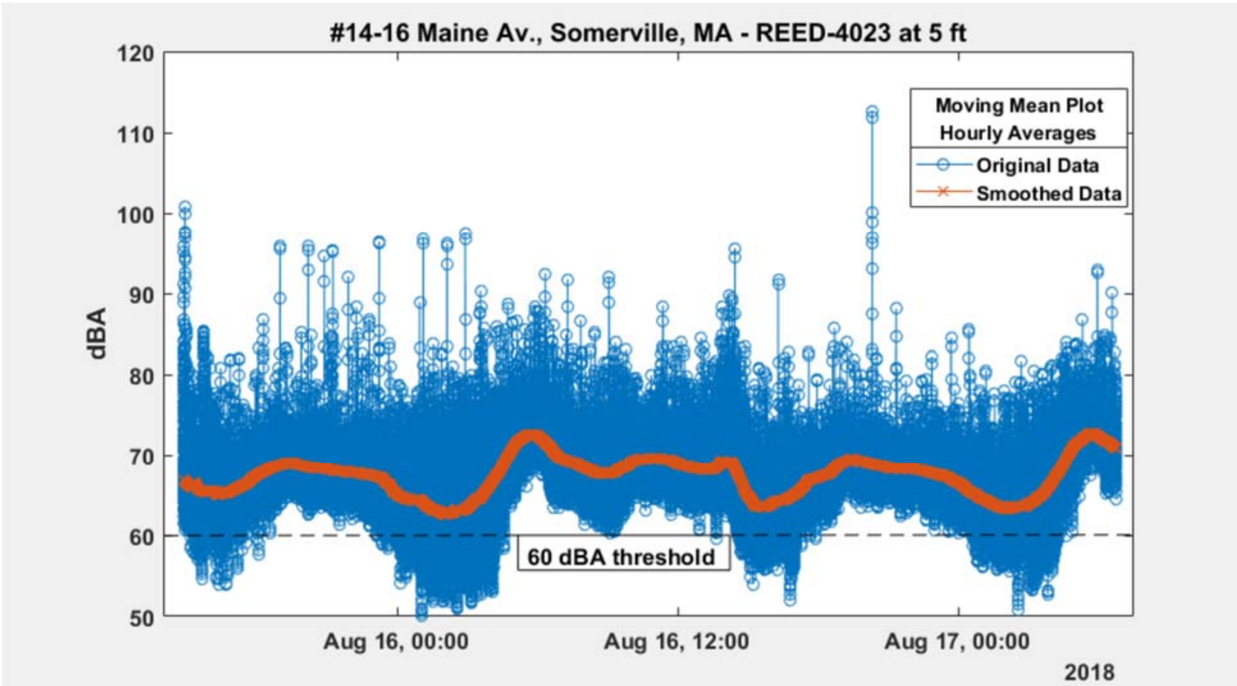


Figure 36 - Moving Mean, Hourly Average Noise Plot for 5 foot REED-4023 vs. 60 dBA threshold

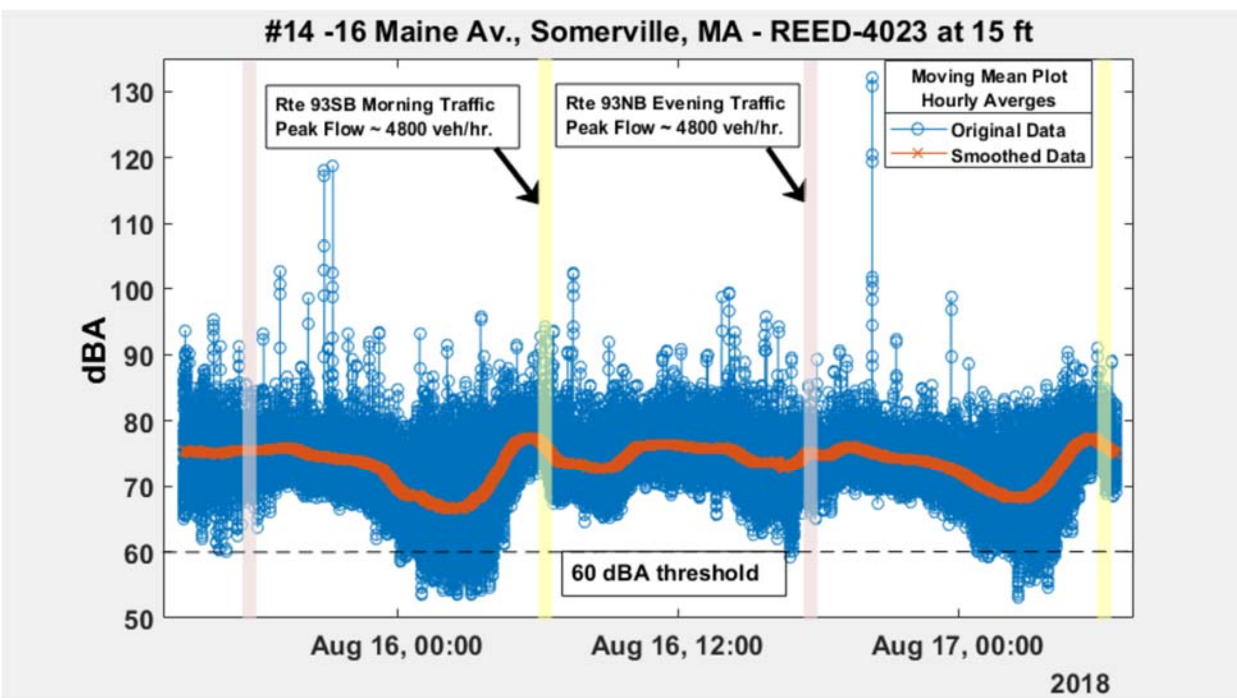


Figure 37 - Moving Mean, Hourly Average Noise Plot for 15 foot REED-4023 with peak traffic flows

#10-12 Ten Hills Road

Figures 38 (a) and (b) – note: highway noise barrier at top of photo on right, above sign

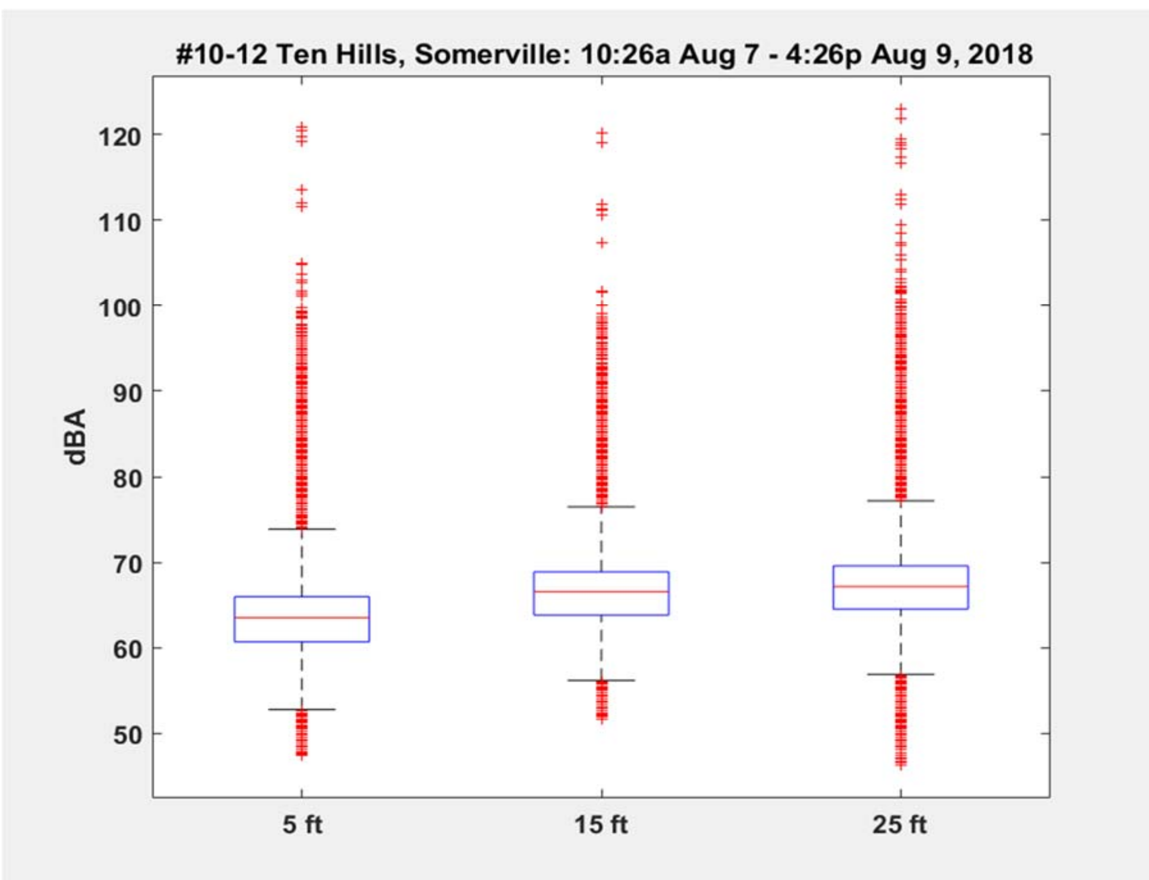
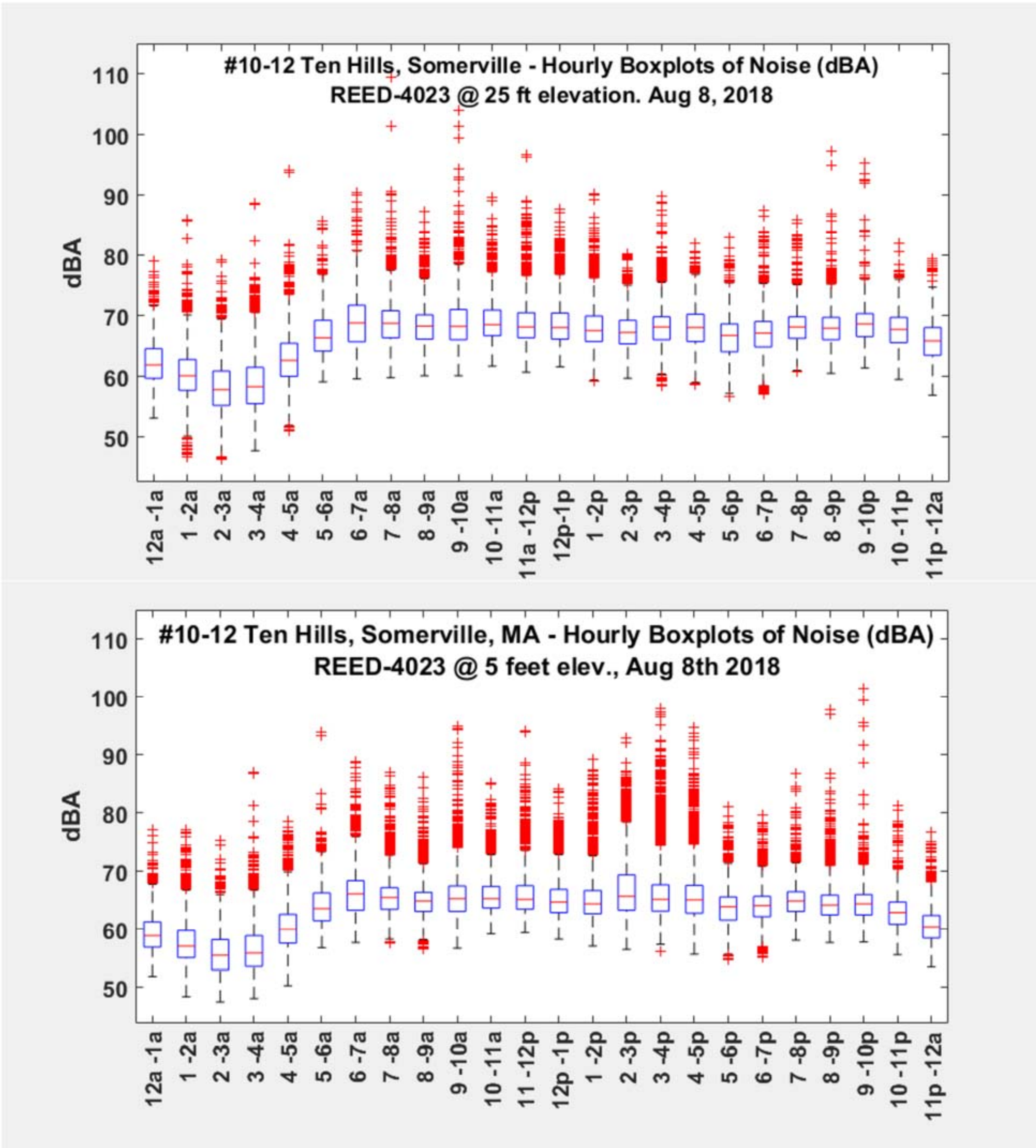


Figure 39 - Boxplots of Noise (dBA) at 5 ft, 15 ft and 25 ft (full data set)



Figures 40-41 - Hourly Boxplots of Noise (dBA) for 25 feet and 5 feet

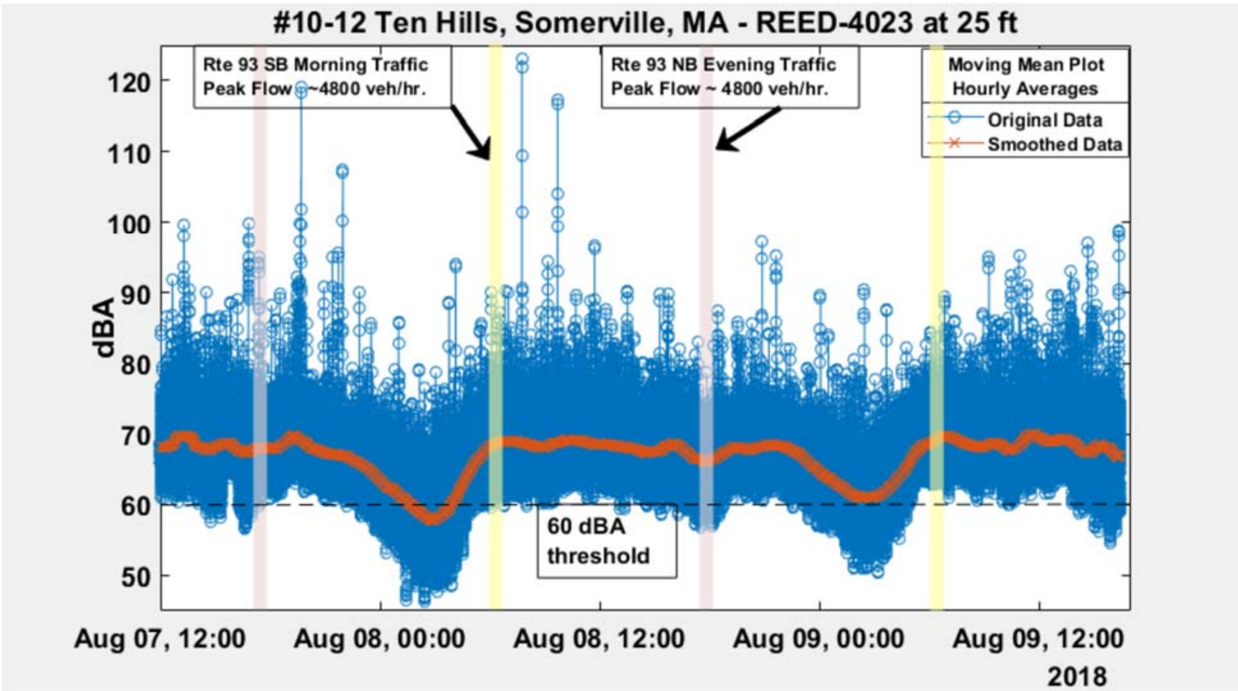


Figure 42 - Moving Mean, Hourly Average Noise Plot for 25-foot REED-4023 with peak traffic flows

<u>#50 Puritan Road</u>

Figure 43 – REED-4023 SLMs deployed at 5, 15 and 25 ft

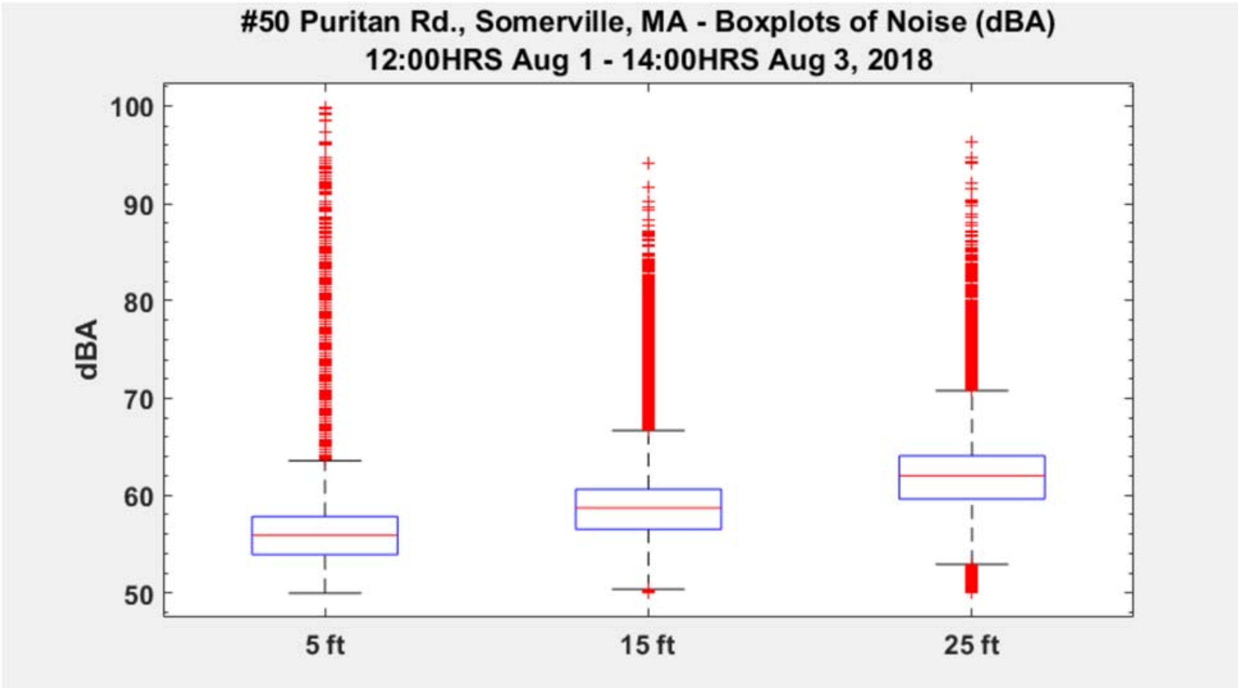
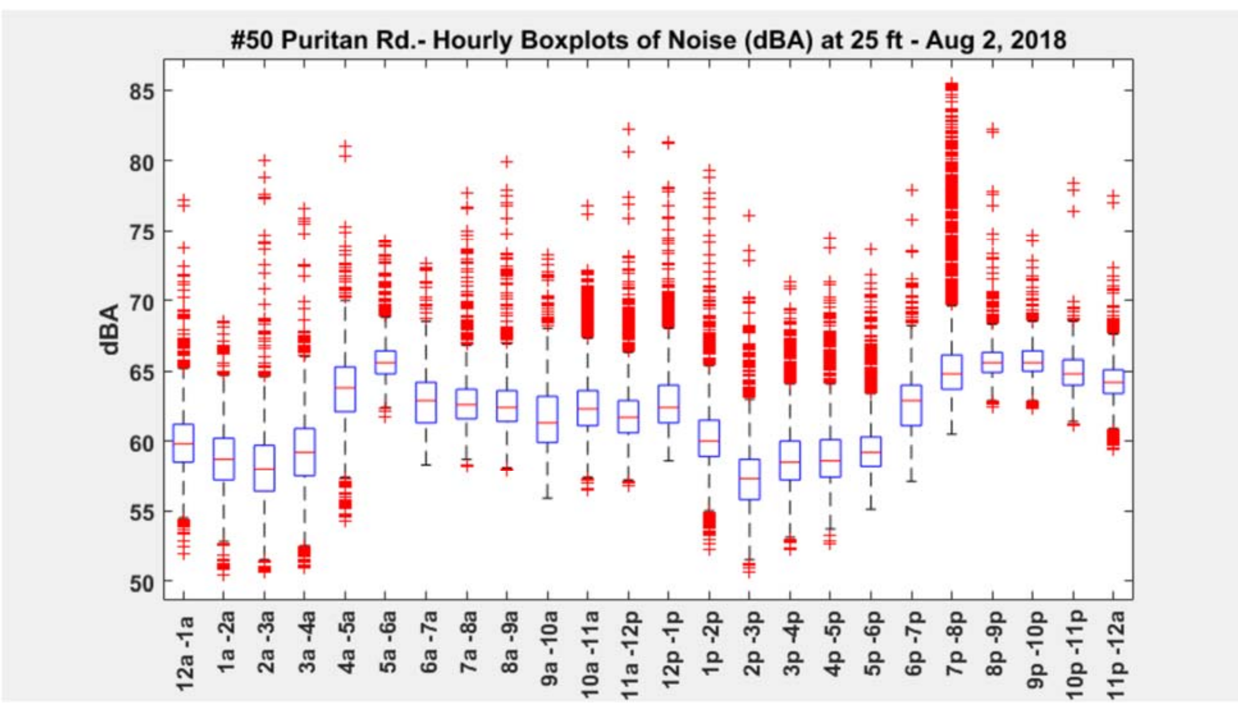
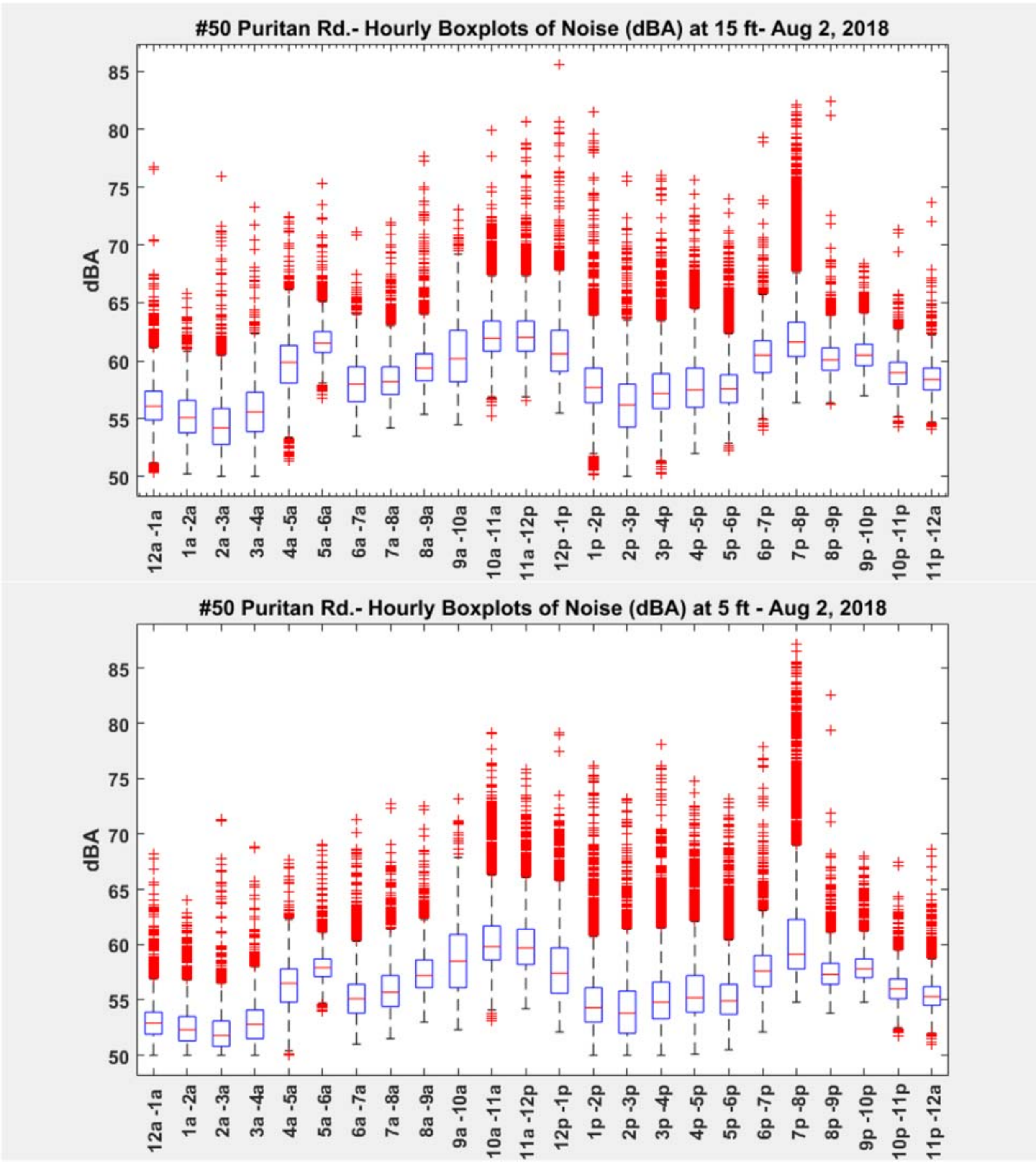


Figure 44 - **Boxplots of Noise (dBA) at 5 ft, 15 ft and 25 ft (full data set)**





Figs 45-47 (above) - Hourly Boxplots of Noise (dBA) for 25 feet, 15 feet, and 5 feet

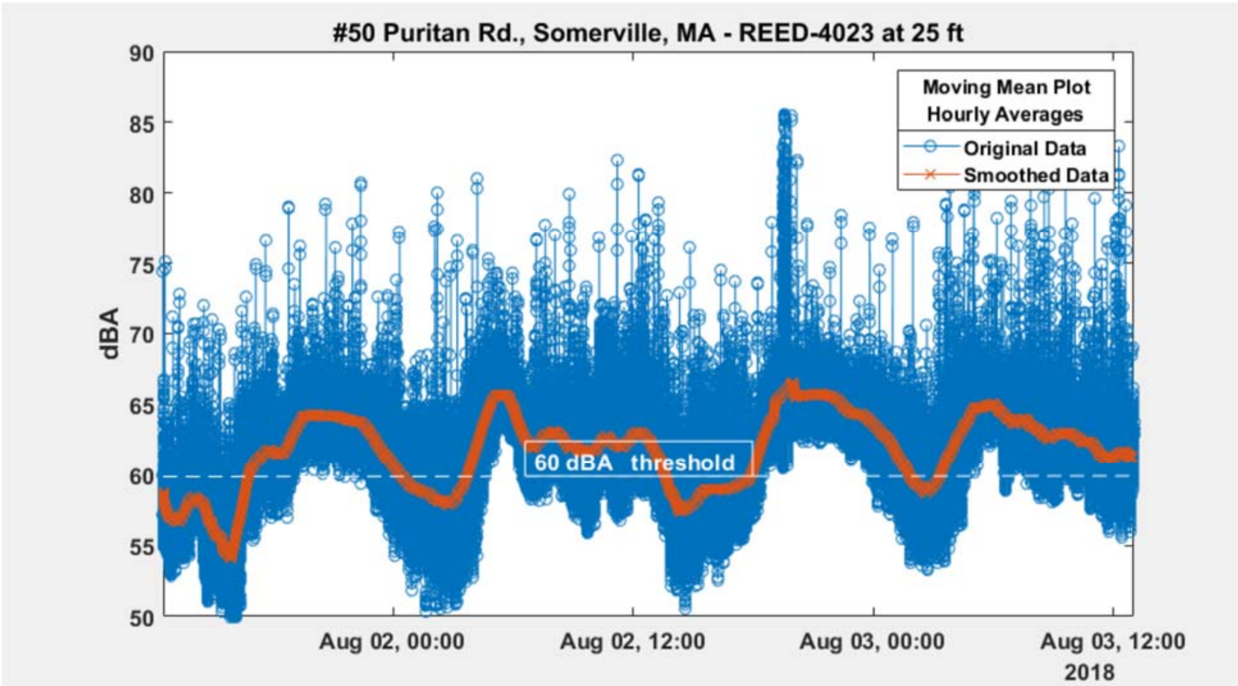


Fig 48 - Moving Mean, Hourly Average Noise Plot for 25 foot REED-4023 vs. 60 dBA threshold

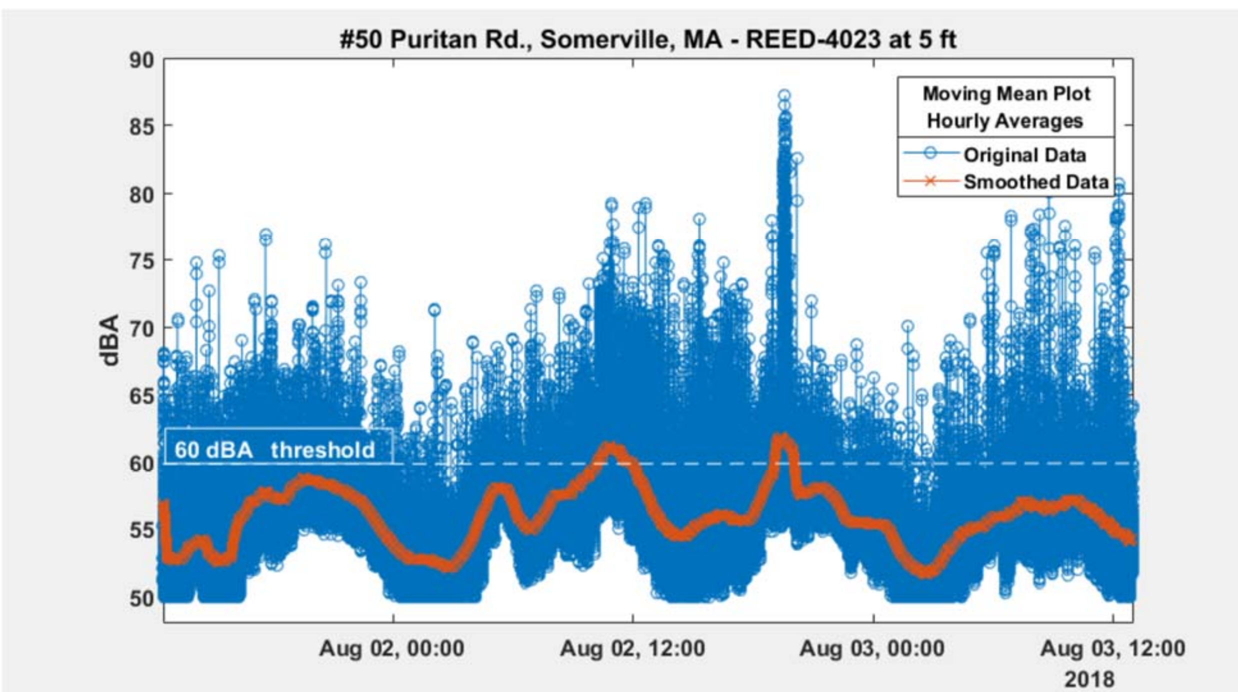


Figure 49 - Moving Mean, Hourly Average Noise Plot for 5 foot REED-4023 vs. 60 dBA threshold

Analysis

Based on the results of the noise monitoring field program of June –August 2018 the analysis provides data to assess if the Massachusetts statewide Type II Noise study of all interstates completed in 1988, which included I-93, is adequate for noise attenuation/barriers where constructed, and to assist in making recommendations for improved noise barriers and/or new barriers. Type II refers to a voluntary program that created a prioritized list of noise barrier retrofit locations. (massdot.state.ma.us/highway/Departments/EnvironmentalServices/NoiseAbatementProgram.aspx).

Per FHWA data analysis guidelines for measurement of highway-related noise, (https://www.fhwa.dot.gov/environment/noise/measurement/mhrn04.cfm#ch463) Section 4.5 Measurement Procedures (part 3), "Ambient [noise] levels should be measured and/or recorded by sampling the sound level at each receiver and at the reference microphone, with the sound source quieted or removed from the site. … If the study sound source cannot be quieted or removed, an upper limit to the ambient level using a statistical descriptor, such as L_{90}, may be used. Such upper limit ambient levels should be reported as assumed."

For this study, the L_{90} metric was used as the assumed ambient noise level, for the minimum median hour of noise data at each site (typically 2am -3am). Section 4.6.3 Ambient Adjustments specifies the following analytical approach:

Eq. (1) $$L_{adj} = 10 \times \log_{10} (10^{\{0.1L_c\}} - 10^{\{0.1L_a\}}) \quad \text{(dB)}$$

where:

- $L_{ad\,j}$ is the ambient-adjusted measured level;
- L_c is the measured level with source and ambient combined; and
- L_a is the ambient level alone.

The value of L_C in the above Eq. (1) is determined from the peak hourly average for each site (typically 5 -6am or 4 -5pm). Once the $L_{ad\,j}$ is the ambient-adjusted measured level is calculated (Eq. (1)), Sections 4.6.1(3) and (4) of FHWA data analysis guidelines specify:

> (3) Compute the mean sound level for each receiver by arithmetically averaging the levels from individual sampling periods [note: in this analysis, only the peak hour averages L_{adj} are presented]
> (4) Perform an assessment of the averaged sound levels based on study objectives.

As an additional metric for assessment of noise, this analysis calculated an aggregate noise level (i.e. - the average level, dB over a given time period) expressed as an energy mean rather than a level mean. The energy mean was calculated as:

Eq. (2) $$\text{energy mean} = 10 * \log_{10}(\text{mean}(10\text{^}(SPLi/10)) \quad \text{(dB)}$$

where:

- SPLi refers to Sound Pressure Level vector, with sample window size = 3600
- i refers to the ith sample of the 3600 sample window
- Level mean = mean(SPLi), cited here for reference only

Lastly, for determining existing noise levels per 23 CFR 772, the A-weighted sound level that is exceeded 10 percent of the time (the 90th percentile) for the period under consideration was calculated and is tabulated below in Table 2. The L10(h) is the noise level exceeded 10% of the time in the noisiest hour of the day. For FWHA Activity Categories Residential (B) and Parks/Public Uses (C), the noise abatement criteria (NAC) for hourly A-weighted sound levels (dBA) is L10(h) ≥70 dBA, measured in the exterior (outdoors).

The results of the calculations for each site are presented in Table 2, below.

Table 2 –Analysis of Somerville Noise Study Data (June –August 2018)

Site	Map key (fig 3)	Elev. REED	Min. Hrly. Avg.	Date of min. hrly avg.	Time	L(90) for min. hour	L(c) Peak Hrly Avg.	Date of max. hrly avg.	Time (Peak Hour)	L(adj) Adjusted	Energy mean	L10(h)
		(ft)	(dBA)			(dBA)	(dBA)			(dBA)	(dBA)	(dBA)
114 Moreland	M1	15	60.2	7/18/2018	2 -3a	63.8	71.7	7/17/2018	4 -5p	70.9	72.7	75.0
		5	57.9	7/17/2018	11p - 12a	72.0	73.3	7/17/2018	4 -5p	67.4	74.9	78.1
70 Mystic	M2	15	68.8	7/18/2018	1 - 2a	73.4	76.9	7/17/2018	4 -5p	74.3	77.5	79.8
		5	68.0	7/18/2018	1 -2a	72.8	76.5	7/17/2018	4 -5p	74.1	77.0	79.1
Mystic Activity	M3	25	71.5	7/24/2018	5 -6p	74.2	74.5	7/24/2018	12 - 1p	62.7	78.0	79.2
		15	72.7	7/24/2018	5 -6p	76.1	75.2	7/24/2018	12 - 1p	n/c	78.6	79.7
		5	71.3	7/24/2018	5 -6p	75.5	73.6	7/24/2018	12 - 1p	n/c	80.1	79.9
16 NH	S1	25	68.7	6/28/2018	2 -3a	74.4	78.3	6/28/2018	5 -6a	76.0	78.7	80.2
		15	67.3	6/28/2018	2 -3a	73.6	77.1	6/28/2018	5 -6a	74.5	77.6	79.0
		5	63.7	6/28/2018	2 -3a	70.7	73.9	6/28/2018	5 -6a	71.1	74.6	76.1
9 Maine	S2	25	71.7	7/25/2018	2 -3a	77.4	81.6	7/25/2018	5 -6a	79.5	82.0	83.5
		15	69.1	7/25/2018	2 -3a	75.4	80.1	7/25/2018	5 -6a	78.3	80.5	82.1
		5	63.9	7/25/2018	2 -3a	69.9	74.7	7/25/2018	5 -6a	73.0	75.1	76.5
14 Maine	S3	25	67.9	8/16/2018	2 -3a	73.8	78.1	8/16/2018	5 -6a	76.1	78.6	80.2
		15	66.8	8/16/2018	2 -3a	73.3	77.3	8/16/2018	5 -6a	75.1	77.8	79.4
		5	63.2	8/16/2018	2 -3a	69.5	72.3	8/16/2018	5 -6a	69.1	73.1	74.4
10 TenHills	T2	25	58.2	8/8/2018	2 -3a	63.8	68.9	8/8/2018	6 -7a	67.3	71.4	73.8
		5	55.8	8/8/2018	2 -3a	60.7	66.2	8/8/2018	6 -7a	64.8	68.7	70.6
50 Puritan	T1	25	57.4	8/2/2018	2 -3p	60.3	65.7	8/2/2018	5 -6a	64.2	65.9	67.2
		15	54.6	8/2/2018	2 -3a	57.7	62.4	8/2/2018	11a - 12p	60.6	63.5	65.3
		5	52.3	8/2/2018	2 -3a	54.8	60.8	8/2/2018	10a - 11a	59.5	63.1	65.9

n/a = data not available; n/c = value cannot be calculated (use energy mean and L10(h) as substitutes)

Results

The following results are organized by neighborhood, as labeled on Figure 3 of this report. Results are based on a limited data set collected during the period June – August 2018, from eight selected sites, representative of residential and mixed use receptors of highway and roadway noise.

Mystic Ave Sites

Based on data from the two heights monitored, 5 ft and 15ft, the #114 Moreland Ave site is impacted by excessive peak hour noise levels exceeding 65 dBA L_{adj} as indicated during the monitoring dates July 17-18, 2018. The 15 ft elevation L_{adj} was 70.9 dBA and the 5 ft L_{adj} was 67.4 dBA. Energy means for these elevations at peak hour were 72.7 and 74.9 dBA, respectively. L10(h) peak hour noise statistics were in excess of the 70 dBA FHWA Activity Category Residential (B) Noise Abatement Criteria (NAC) threshold for all of the Mystic Ave sites monitored, ranging from 75.0 to 79.9 dBA. Assuming the Mystic Activity Center is considered Activity Category (C), defined previously as uses of high concern, such as parks, schools, hospitals, cemeteries, etc., the L10(h) NAC threshold of 70 dBA was exceeded (Table 2). Moving mean, hourly average dBA plots (figure 9) for #114 Moreland show average hourly noise levels to be entirely above the 60 dBA threshold for the duration of monitoring (49 hours) at the 15 foot REED-4023 instrument height, selected for plotting as it is a longer duration data set than the 5 foot height (13 hours).

Noise levels at 70-80-90 Mystic Ave were analyzed for only the 5 foot and 15 foot heights, as the REED-4023 instrument at 25 feet malfunctioned. Peak hour L_{adj} noise levels exceed 74 dBA at both heights on July 17, 2018, with energy means exceeding 77 dBA. Figure 14 shows the moving mean, hourly average dBA values exceed the 60 dBA threshold at the 15 foot REED-4023 instrument height for the entirety of the monitoring period. There is little relative variability between noise data sets at either height 5 feet or 15 feet (Figure 11) for the 70-80-90 Mystic Ave site (5 ft CV = 0.0416; C15 ft V = 0.041), suggesting that highway noise is the dominant noise impacting this receptor site. Figure 10(b) illustrates the proximity of Route I-93 SB to the site.

Calculation of an accurate L_{adj} for the Mystic Activity Center was complicated by the fact that the overlapping heights data set is limited to a six-hour period: 12:11HRS to 18:31HRS July 24th, with no distinct basis for establishing a common minimum hour, such as an overnight period. Minimum hour for the Mystic Activity Center overlapping data set was determined from boxplot medians (figures 17a, b, c) to be 5 -6pm, and maximum hour 12 -1p, which suggests that local street traffic noise from Mystic Ave is more impactful than I-93 traffic noise for this site, at least for the 5 ft and 15 ft elevations. The assumed ambient level (L90 statistic) for 5 -6 pm was > 74.2 dBA for all three REED-4023 heights (5 ft, 15 ft and 25ft) and peak hourly average dBA (12p -1p) was either less than the assumed ambient value, or < 0.5 dBA, which is within instrument calibration drift. For all three meter heights, the energy mean for peak hour exceeds 78.0 dBA and the moving mean dBA for the 5 foot height exceed health-risk based and USEPA recommended noise exposure thresholds.

States Aves Sites

At each of the three States Aves sites monitored, the L10(h) peak hour noise statistics were in excess of the 70 dBA FHWA Activity Category Residential (B) Noise Abatement Criteria (NAC) threshold ranging from 74.4 to 83.5 dBA. Noise levels were excessive at the #16 New Hampshire Ave site, increasing from a median of 69.7 dBA at the 5 foot REED-4032 instrument height by approximately +2.7

dBA/10 feet (figure 20). Adjusted noise levels, L_{adj} at peak hour for each of the three instrument heights were 71.1, 74.5, and 76.0 dBA for the 5, 15 and 25 foot heights, respectively, with peak hour energy means of 74.6, 77.6, and 78.7 dBA for the 3 heights, respectively.

Figure 24 presents a moving mean, average hour plot of noise levels for the 5 foot instrument height at # 16 New Hampshire Ave. The plot indicates that all hourly averages exceed the 60 dBA health risk-based threshold, for every hour monitored (of 46 hours) June 27-29th, 2018. A precipitation event (rainfall) occurred between 21:00HRS June 28 and 03:00HRS June 29 (see precipitation plots in Appendix), sufficiently wetting the highway surface to elevate noise levels approximately + 3 to 4 dBA vs. noise levels for the same time period June 27 -28th, during dry pavement conditions. The increase is mainly due to tire noise emissions, though vehicle speeds could be a factor, although not recorded in this study.

At the #9 Maine Ave site, noise levels were excessive at all instrument heights for the duration of the monitoring period July 24th- 26th, 2018. Noise levels increased from a median of 70.2 dBA at the 5 foot REED-4032 instrument height by approximately +3.5 dBA/10 feet (figure 26). Adjusted noise levels, L_{adj} at peak hour for each of the three instrument heights were 73.0, 78.3, and 79.5 dBA for the 5, 15 and 25 foot heights, respectively, with peak hour energy means of 75.1, 80.5, and 82.0 dBA for the 3 heights, respectively. Figure 30 presents a moving mean, average hour plot of noise levels at # 9 Maine Ave for the 15 foot instrument height (selected for its longer duration data set). The plot indicates that all hourly averages exceed the 60 dBA health risk-based threshold, for every hour monitored (of 57 hours) July 24 -26th, 2018.

The third site monitored in the States Aves neighborhood is #14 -16 Maine Ave., monitored August 15 -17, 2018. Noise levels increased from a median of 67.6 dBA at the 5 foot REED-4032 instrument height to 74.2 dBA at 15 feet, an increase of approximately +6.6 dBA/10 feet (figure 32), but stabilized to 73.9 dBA at 25 feet. Adjusted noise levels, L_{adj} at peak hour for each of the three instrument heights were 69.1, 75.1, and 76.1 dBA for the 5, 15 and 25 foot heights, respectively, with peak hour energy means of 73.1, 77.8, and 78.6 dBA for the 3 heights, respectively. Figures 36 and 37 present moving mean, average hour plots of noise levels at # 14 -16 Maine Ave for the 5 foot and 15 foot instrument heights, respectively. Average hourly noise levels for both instrument heights exceed the 60 dBA threshold for the entire monitoring periods. The 15 foot moving mean plot (Fig 37) is annotated with peak traffic flows for I-93NB and SB lanes, based on traffic flow diagram schematics (see Appendix) prepared by the Boston Regional Metropolitan Planning Organization (www.ctps.org).

<u>Ten Hills Sites</u>

Sites in the Ten Hills neighborhood were monitored during the first two weeks of August 2018. The intent of monitoring at #10-12 Ten Hills Road (Figs 3, and 38) and 50 Puritan Road (Figs., 3 and 43) was to establish a background noise data set for locations buffered or partially buffered by the existing I-93 NB lane sound wall at three different heights.

#10 -12 Ten Hills Road is located at the intersection of Rte 28 and Rte I-93 in a high-traffic interchange and highway underpass. Noise levels increased from a median of 63.5 dBA at 5 feet, to 66.6 dBA at 15 feet, and 67.2 dBA at 25 feet (figure 39). Adjusted noise levels, L_{adj} at peak hour for the 5 foot and 15 foot instrument heights were 64.8 and 67.3 dBA, respectively, with peak hour energy means of

68.7 and 74.1 dBA for the 5 ft and 15 ft heights, respectively. L10(h) peak hour noise statistics were in excess of the 70 dBA FHWA Activity Category Residential (B) Noise Abatement Criteria (NAC) threshold for the #10-12 Ten Hills Road site, ranging from 70.6 (at 5 feet) to 73.8 dBA (at 25 foot monitoring elevation).

Figure 42 presents a moving mean, average hour plot of noise levels at # 10-12 Ten Hills Road 25 foot instrument height, selected to evaluate noise attenuation from the existing I-93 NB lane sound wall. The plot indicates that with the exception of the 2a -3am and 3a -4a hours August 8th, 2018, all hourly averages exceed the 60 dBA health risk-based threshold, for every hour monitored (of 54 hours) August 7 -9th, 2018. The 25 foot moving mean plot (Fig 42) is annotated with peak traffic flows for I-93NB and SB lanes, based on traffic flow diagram schematics (see Appendix) prepared by the Boston Regional Metropolitan Planning Organization (www.ctps.org).

The #50 Puritan Rd site is situated on a sloping, hilly street, approximately 120 meters (400 feet) from the existing I-93 NB lane sound wall. The 25 foot REED-4023 sound level meter was placed at the highest elevation of this property (Figure 43, upper rear porch deck), which is approximately at the same elevation (or higher) as the top of the I-93 NB lane sound wall, estimated per Google Earth maps (earth.google.com). Data analysis from #50 Puritan Road show that noise levels increased from a median of 55.9 dBA at 5 feet, to 58.7 dBA at 15 feet, and 62.0 dBA at 25 feet (figure 44). Adjusted noise levels, L_{adj} at peak hour for the 3 instrument heights were 59.5, 60.6 dBA and 64.2 dBA, respectively, with peak hour energy means of 63.1, 63.5 and 65.9 dBA for the 5 ft, 15 ft and 25 ft heights, respectively. L10(h) peak hour noise statistics were below the 70 dBA FHWA Activity Category Residential (B) Noise Abatement Criteria (NAC) threshold for the #50 Puritan Road site.

Figures 48, 49 presents moving mean, average hour plots of noise levels at #50 Puritan Road for two selected heights: the 25 foot REED-4023 instrument height and the 5 foot instrument height, selected to evaluate noise attenuation from the existing I-93 NB lane sound wall at both height and distance. The 5 foot plot (Fig 49) indicates that with the exception of the 10a -11am and 11a -12pand 7 - 8p hours August 2nd, 2018, all hourly averages are below the 60 dBA health risk-based threshold, for every hour monitored (of 53 hours) August 1 -3rd, 2018. The 25 foot moving mean plot for 50 Puritan Road (Figure 48) shows that approximately 50% of the hourly average noise levels exceed a 60 dBA threshold, suggesting that highway noise from I-93 is not fully attenuated by the existing I-93 NB lane sound wall at distance. It should be noted that the REED-4023 instruments were removed from the #50 Puritan Road site prior to the precipitation event August 3rd, 2018 (see Appendix), and that the wind direction was relatively stable from the southwest, shifting into the west, with wind speeds between 10 and 20 mph for all of August 2nd through the end of instrument deployment.

Limitations

This field study was limited in scope and subject to several limitations of both equipment and site conditions. Specific limitations of the study are summarized below:

- Access permission from property owners limited the sites monitored to FHWA Categories Residential (B) and Other (C) uses of high concern, such as parks, schools, hospitals, cemeteries, etc.
- REED-4023 Class 2 Sound Level Meter (SLM) microphones could not be “free field” mounted due to site security concerns. Solid and possibly sound-reflective materials in the

form of mounting and weatherproofing were affixed to the REED-4023 SLMs at each installation, and at some installations larger solid walls were present behind the SLMs.

- On-site meteorological data was not collected during the study, which instead relied on meteorological data from Logan International Airport (KBOS), Boston, MA. Possible local microclimatic effects from Logan Airport's direct proximity to the ocean could have biased the meteorological data analyzed for this study.
- Live traffic counts from I-93, Mystic Ave or highway on-ramps and off-ramps were not available during this field campaign. Several figures in this report are annotated with traffic flow diagram schematics ca. 2010 prepared by the Boston Regional Metropolitan Planning Organization (www.ctps.org)

Conclusions

A noise monitoring study was conducted at three Somerville, MA neighborhoods during June – August 2018 to determine impacts upon representative receptor properties (homes, community center) of roadway and highway noise. REED-4023 sound level meters (class 2) recording 1-second noise samples as A-weighted (fast) decibel levels (dBA) were deployed in the field for up to 50 continuous hours at eight sites, at three heights above ground: 5, 15 and 25 feet.

Based on the results of this field study, seven of eight sites monitored are impacted by excessive highway and roadway noise, exceeding the FHWA noise abatement criteria (NAC) for L10(h) noise levels (90th percentile) in the noisiest hour of the day. Peak noise hour was determined by analysis of hourly boxplots of noise levels (dBA) by height for each study site monitored, as illustrated in this report. For FWHA Activity Category Residential (B) and Parks/Public Uses (C), the NAC for hourly A-weighted sound levels (dBA) is L10(h) ≥70 dBA, measured in the exterior (outdoors).

Additionally, peak hour adjusted noise levels and energy mean sound levels at all sites recorded in this study exceeded the recommended 60 dBA health risk-based threshold, with one exception. At several sites, mean hourly averaged noise levels did not decrease to below 60 dBA at any time during the period monitored in this study, including overnight hours. The only locations where noise levels were not excessive or above thresholds were those sites in the Ten Hills neighborhood which benefit from an existing sound barrier wall.

Locations monitored along Mystic Ave, Somerville include #114 Moreland Ave., 70-80-90 Mystic Ave., and the Mystic Activity Center are dually impacted from local roadway noise along Mystic Ave and concurrent highway noise from I-93. L10(h) peak hour noise statistics were in excess of the 70 dB (Route 38) A FHWA Activity Category Residential (B) Noise Abatement Criteria (NAC) threshold for all of the Mystic Ave sites monitored, ranging from 75.0 to 79.9 dBA. Assuming the Mystic Activity Center is considered Activity Category (C), defined previously as uses of high concern, such as parks, schools, hospitals, cemeteries, etc. , the L10(h) NAC threshold of 70 dBA was exceeded (Table 2). Adjusted noise levels, factoring in ambient conditions, exceeded the 60 dBA health risk-based threshold for peak hour average at these three sites, with peak hour energy means ranging from 72.7 to 82.0 dBA.

In the States Aves neighborhood at all three sites monitored - #16 New Hampshire Ave, #9-11 Maine Ave., and #14 -16 Maine Ave. noise levels were excessive for the duration of the monitoring periods, At each of the three States Aves sites monitored, the L10(h) peak hour noise statistics were in excess of the 70 dBA FHWA Activity Category Residential (B) NAC threshold, ranging from 74.4 to 83.5

dBA, with adjusted noise levels ranging from 69.1 to 79.5 dBA at peak hour and energy means from 73.1 to 82.0 dBA. At no period during the study did mean hourly average noise levels in the States Aves locations decrease to below a 60 dBA threshold.

Two sites monitored in the Ten Hills neighborhood are impacted by roadway and highway noise to a lesser degree than other study sites where no noise barriers are present. At the #10-12 Ten Hills Road site L10(h) peak hour noise statistics were in excess of the 70 dBA FHWA Activity Category Residential (B) NAC threshold, ranging from 70.6 (at 5 feet) to 73.8 dBA (at 25 foot monitoring elevation). L10(h) peak hour noise statistics were below the 70 dBA FHWA Activity Category Residential (B) NAC threshold for the #50 Puritan Road site. It is notable that at these sites (#50 Puritan Road and #10-12 Ten Hill Road) the peak hourly average adjusted noise levels and energy means all exceeded the 60 dBA health risk-based threshold with one exception at #50 Puritan Road which recorded an adjusted peak hourly level of 59.5 dBA at the 5 foot elevation. The data suggests that the existing noise barrier located along I-93 North in Somerville attenuates some of the highway traffic noise in the Ten Hills neighborhood, but still left some locations above the thresholds quoted. For all other areas outside of Ten Hills, peak hour noise levels were excessive, with L10(h) levels above the 70 dBA FHWA Activity Category Residential (B) NAC threshold.

Based solely on exceedance of the L10(h) metric, this study concludes that noise levels approach or exceed the NAC threshold, confirming a traffic noise impact to the study sites. Where traffic noise impacts are identified, various noise abatement measures are typically considered to mitigate adverse impacts. The construction of a noise barrier is the mitigation measure most often associated with the concept of noise abatement.

At several sites noise levels increase with increasing height, as the REED-4023 sound level meters capture the increased intensity of both local roadway noise and combined highway noise at the higher meter elevations. The gradient in noise intensity (dBA) ranged from +2.7 dBA/10 feet to +6.6 dBA/10 feet elevation. Noise barriers can achieve -5 dB attenuation when tall enough to break the line of sight from a highway, with a barrier insertion loss goal of -10 dB (typical values are between -6 and -8 dB). An additional -1.5 dB attenuation can be achieved for every meter of barrier above the line of sight, with a theoretical total noise reduction of -20 dB (FHWA). Given these guidelines, a noise barrier constructed to a 15 foot (5 meter) height in the States Aves neighborhood could potentially attenuate highway and onramp noise -7 to -10 dB, reducing peak hour, adjusted noise levels to the 59.1 – 68.3 dBA range, below L10(h) FHWA Activity Category Residential (B) thresholds, but still above health risk-based suggested 60 dBA limits.

In the Mystic Ave neighborhood, installation of a noise barrier would need to consider noise reduction goals of either attenuating highway noise for I-93 or from local Mystic Ave. (Route 38) traffic or both. Installation of a continuous noise barrier along the length of Mystic Ave. is complicated by the numerous intersections. Other geographic and topographic conditions in the Mystic Ave. neighborhood may limit barrier installation and efficacy.

This report was written by Douglas J. Leaffer, EIT, MSCE, (Tufts 1998), PhD Candidate Civil & Environmental Engineering (Tufts), who also led the field program, with assistance from Grace Wang, MPH/MS (Tufts), and field support from David Chen, MPH-candidate (Tufts) and Wig Zamore, MS (MIT) of Somerville, MA. Neelakshi Hudda, PhD (Tufts) provided report graphics. Ellin Reisner, PhD of Somerville, MA managed and coordinated project logistics. Doug Brugge, MS, PhD, Tufts University School of Medicine directed the project’s conception.

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Code of Federal Regulations (23 CFR 772)

Federal Highway Administration regulations on Highway Traffic Noise: https://www.fhwa.dot.gov/environment/noise/

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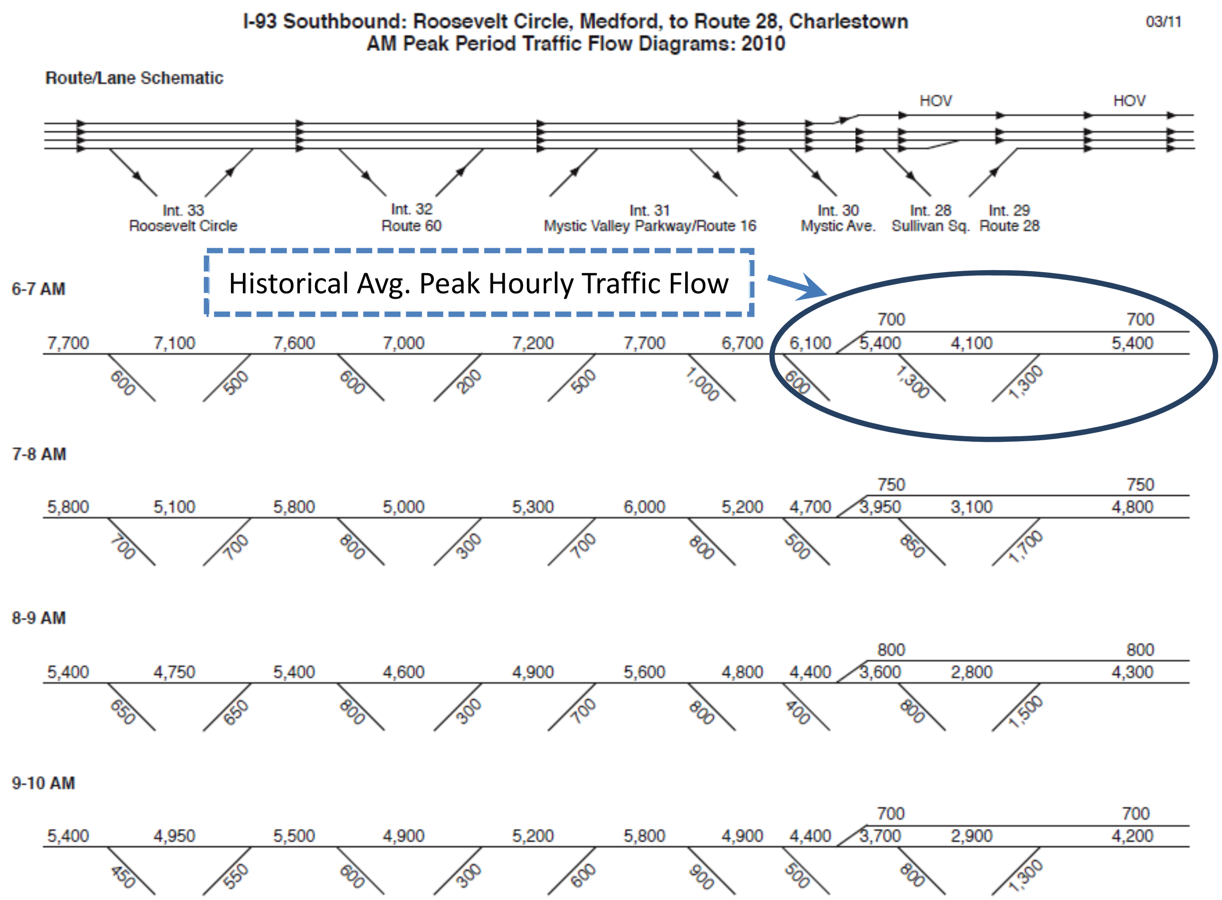
Boston Regional Metropolitan Planning Organization (www.ctps.org)

(Munzel et. al., “Environmental Noise and the Cardiovascular System,” Journal of the American College of Cardiology, 2018)

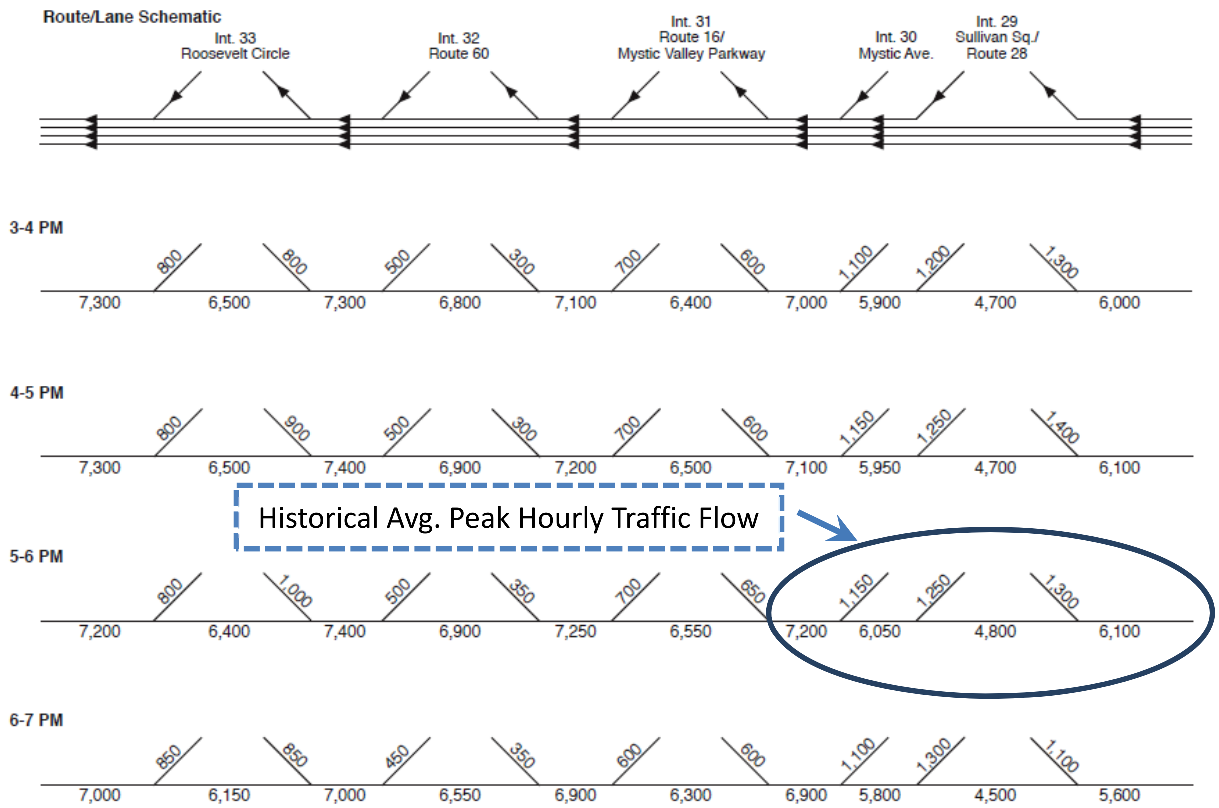
Appendix

Traffic flow diagram schematics (Boston Regional Metropolitan Planning Organization (www.ctps.org))

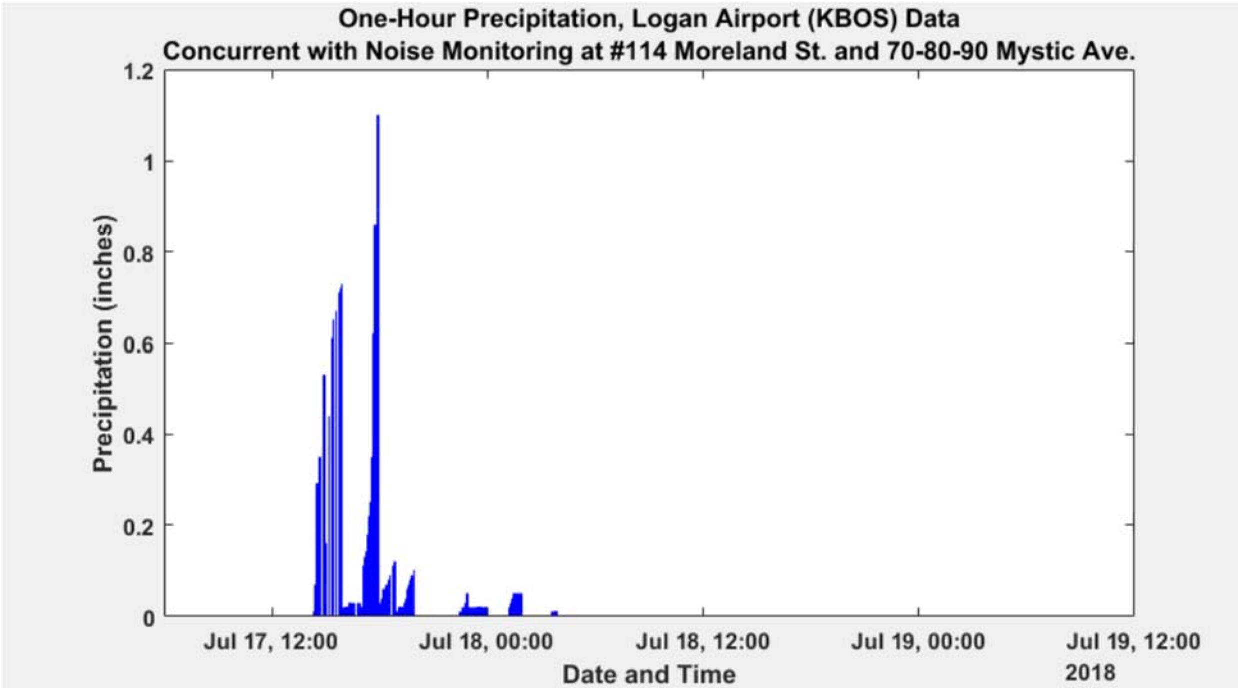


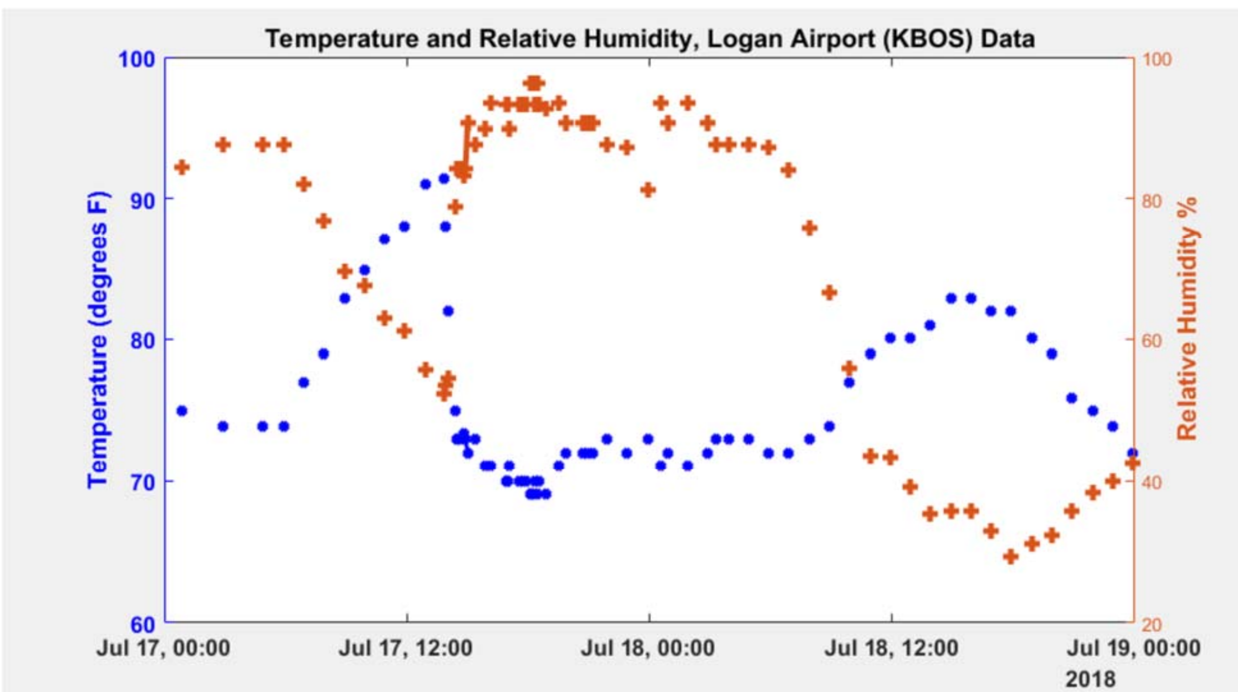
I-93 Northbound: Route 28, Somerville, to Roosevelt Circle, Medford
PM Peak Period Traffic Flow Diagrams: 2010

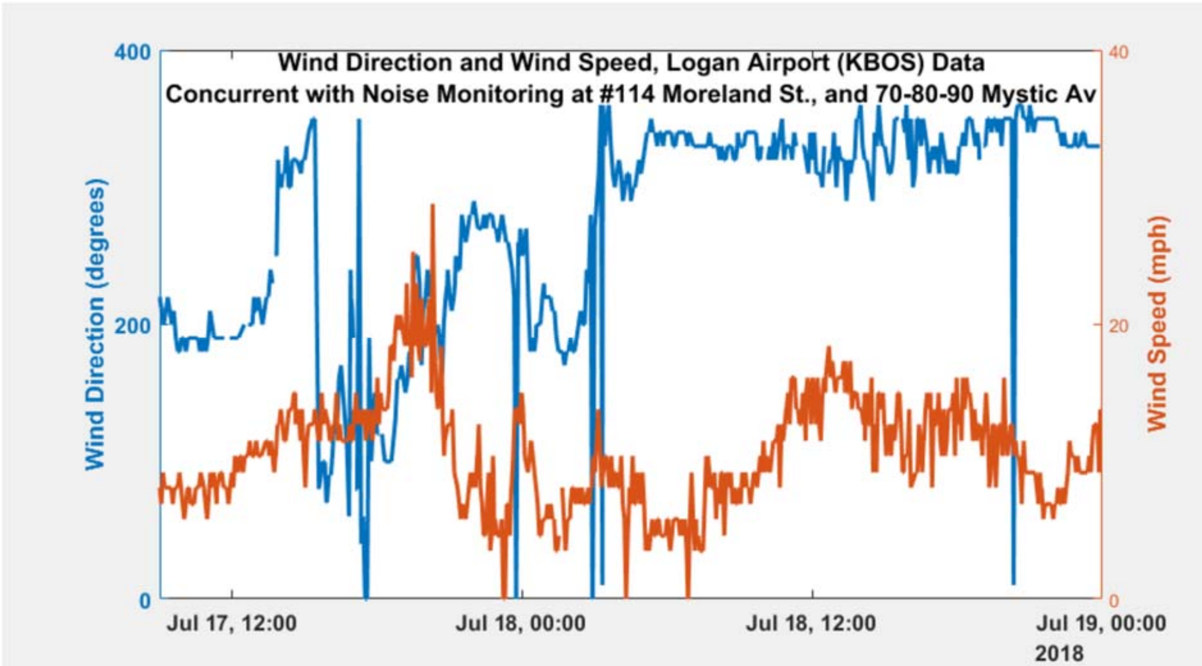
03/11

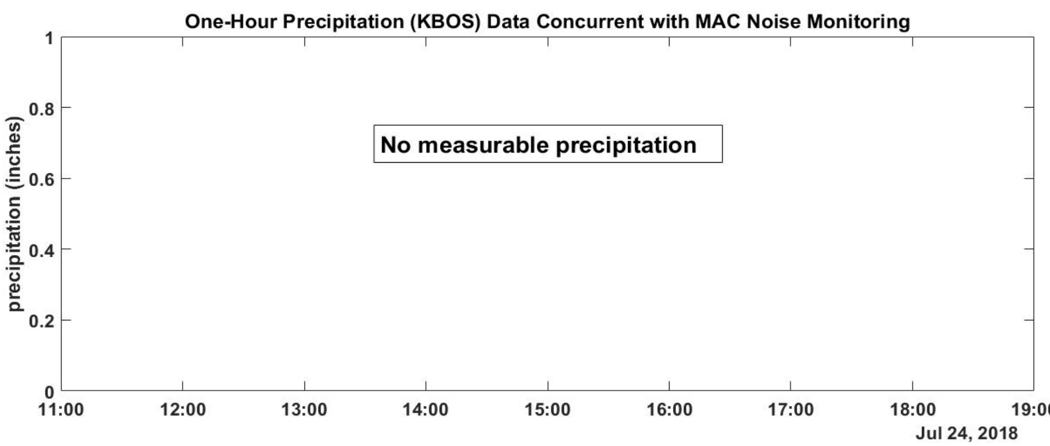


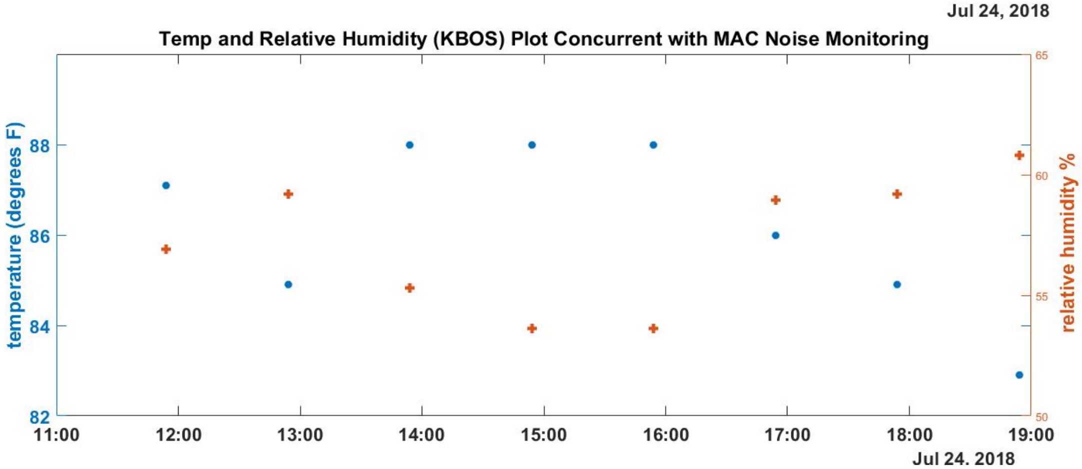
Meteorological data from Boston Logan international (KBOS) weather records:
https://mesonet.agron.iastate.edu/request/download.phtml?network=MA_ASOS

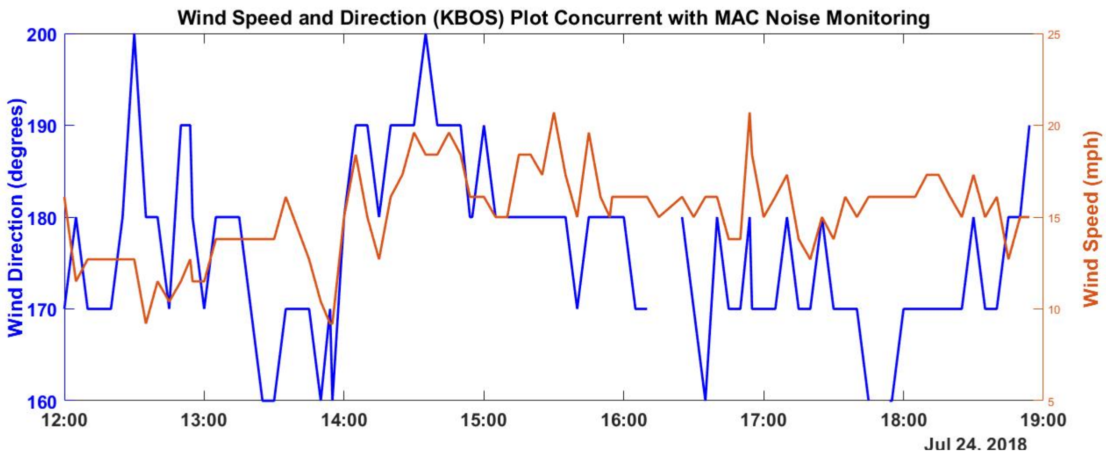


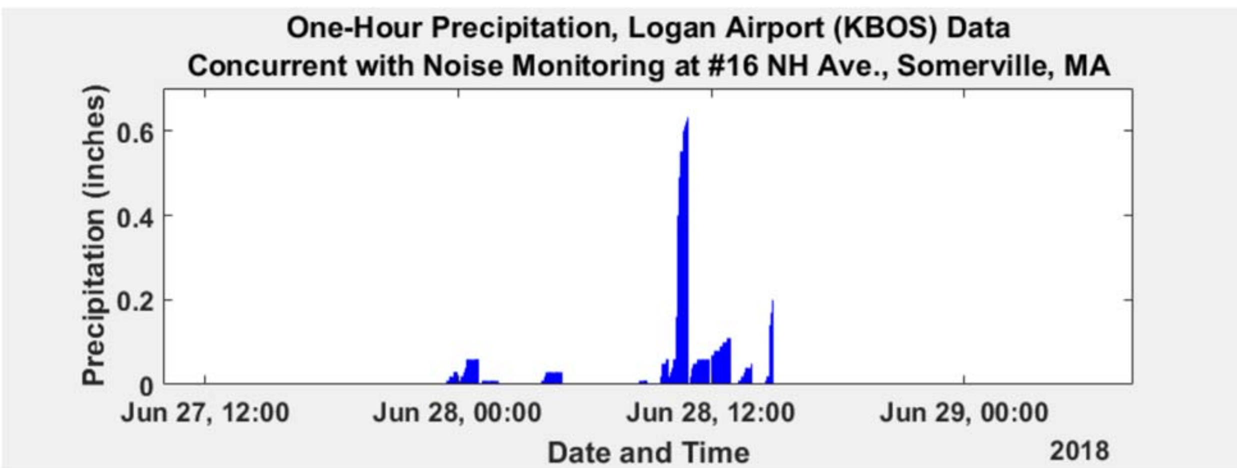


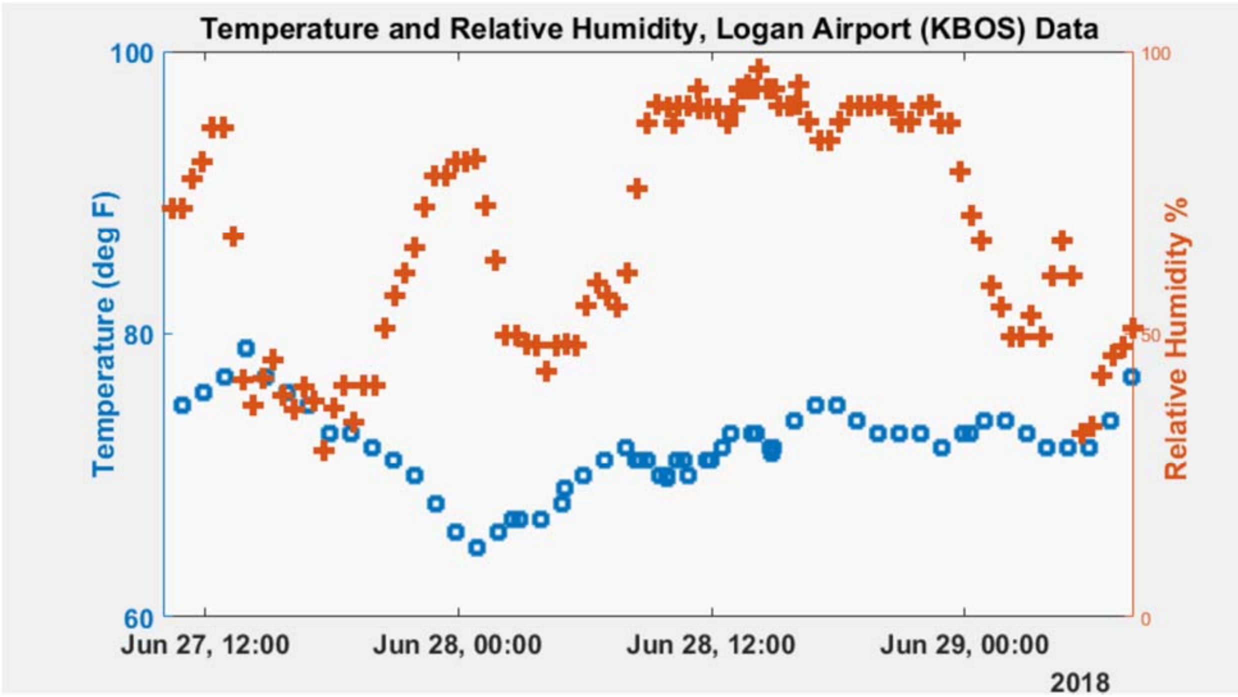

Wind Direction and Wind Speed, Logan Airport (KBOS) Data
Concurrent with Noise Monitoring at #114 Moreland St., and 70-80-90 Mystic Av
Wind Direction (degrees)
Wind Speed (mph)
400
200
0
40
20
0
Jul 17, 12:00
Jul 18, 00:00
Jul 18, 12:00
Jul 19, 00:00
2018

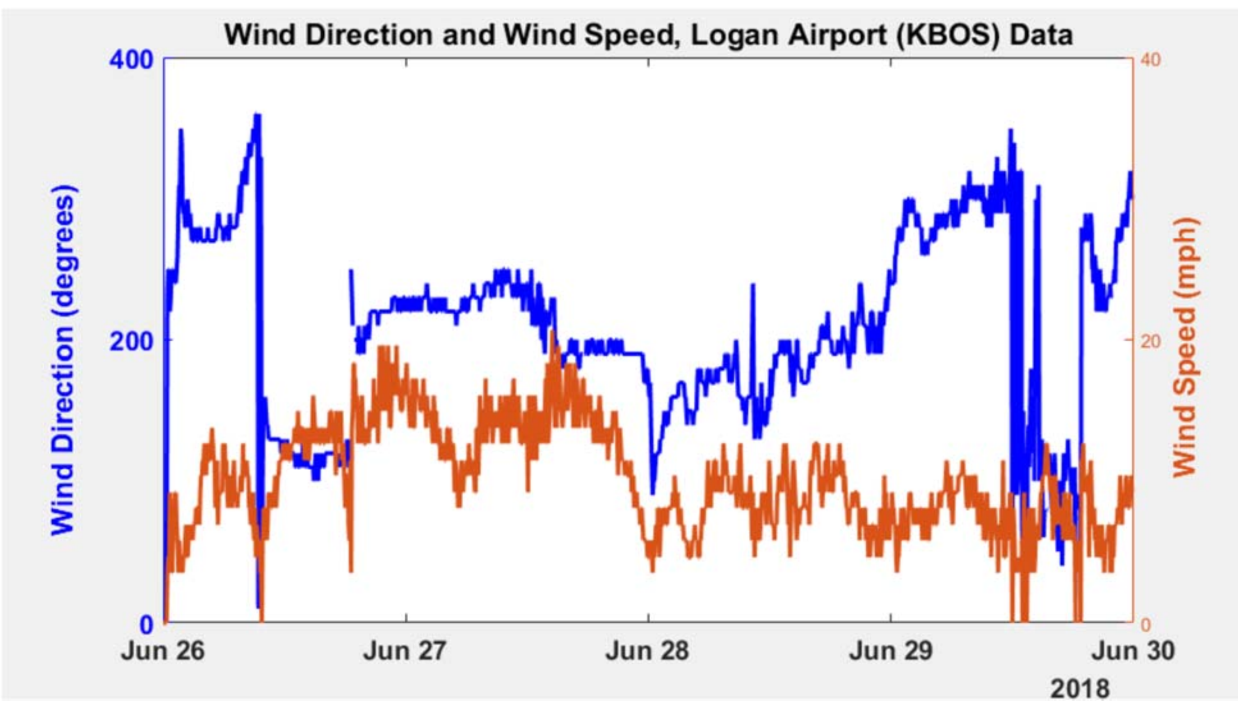

One-Hour Precipitation (KBOS) Data Concurrent with MAC Noise Monitoring
precipitation (inches)
No measurable precipitation
1
0.8
0.6
0.4
0.2
0
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
Jul 24, 2018

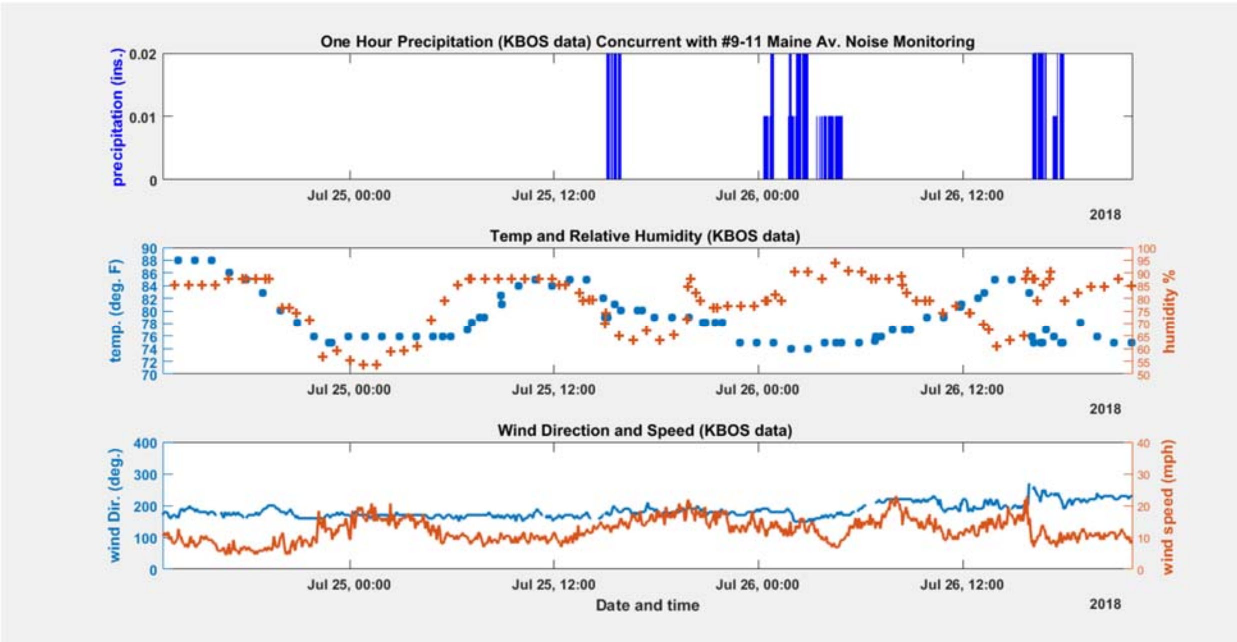

Temp and Relative Humidity (KBOS) Plot Concurrent with MAC Noise Monitoring
temperature (degrees F)
relative humidity %
88
86
84
82
65
60
55
50
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
Jul 24. 2018

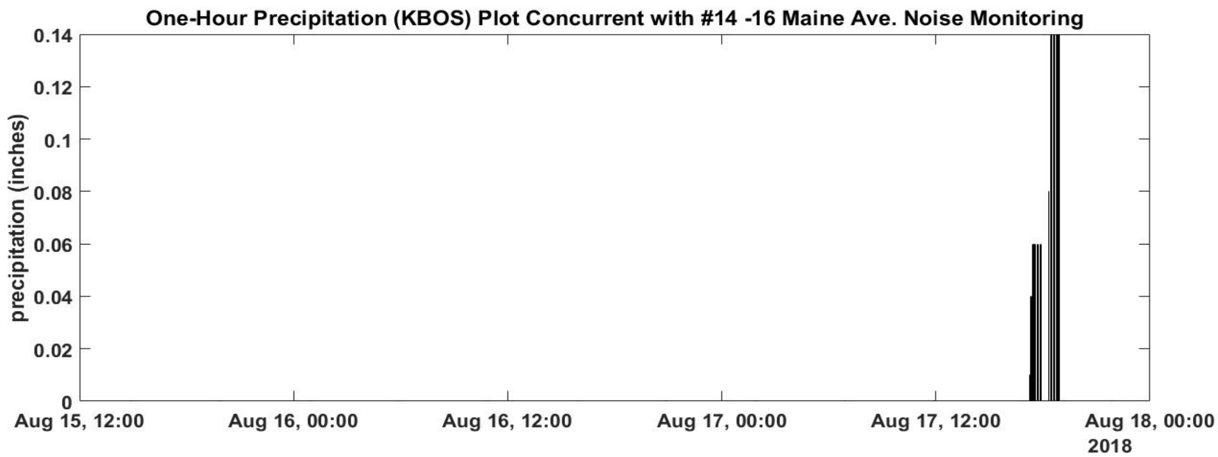

Wind Speed and Direction (KBOS) Plot Concurrent with MAC Noise Monitoring
Wind Direction (degrees)
Wind Speed (mph)
200
190
180
170
160
25
20
15
10
5
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
Jul 24, 2018

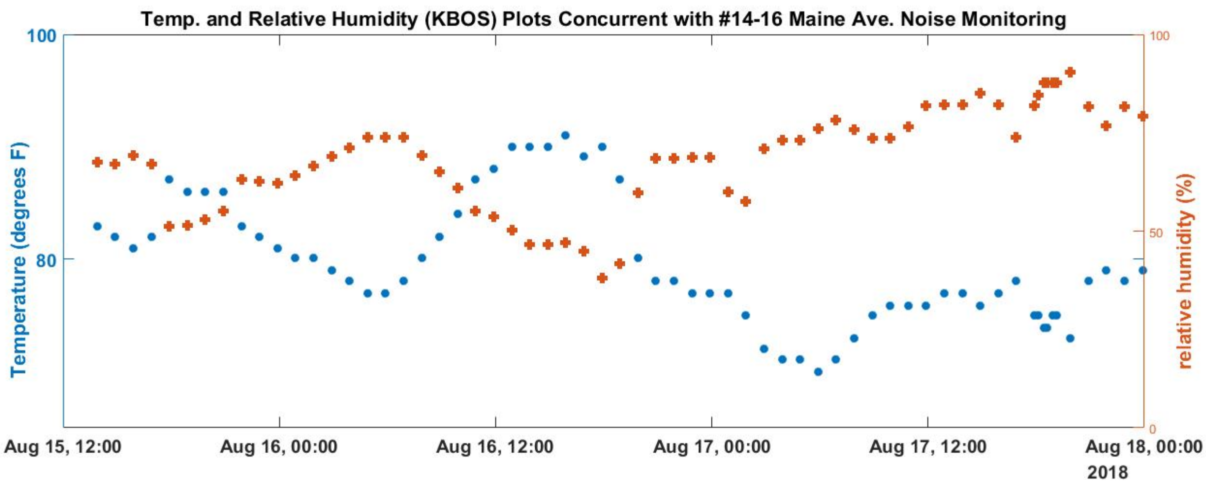

One-Hour Precipitation, Logan Airport (KBOS) Data
Concurrent with Noise Monitoring at #16 NH Ave., Somerville, MA
Precipitation (inches)
0.6
0.4
0.2
0
Jun 27, 12:00
Jun 28, 00:00
Jun 28, 12:00
Jun 29, 00:00
Date and Time
2018

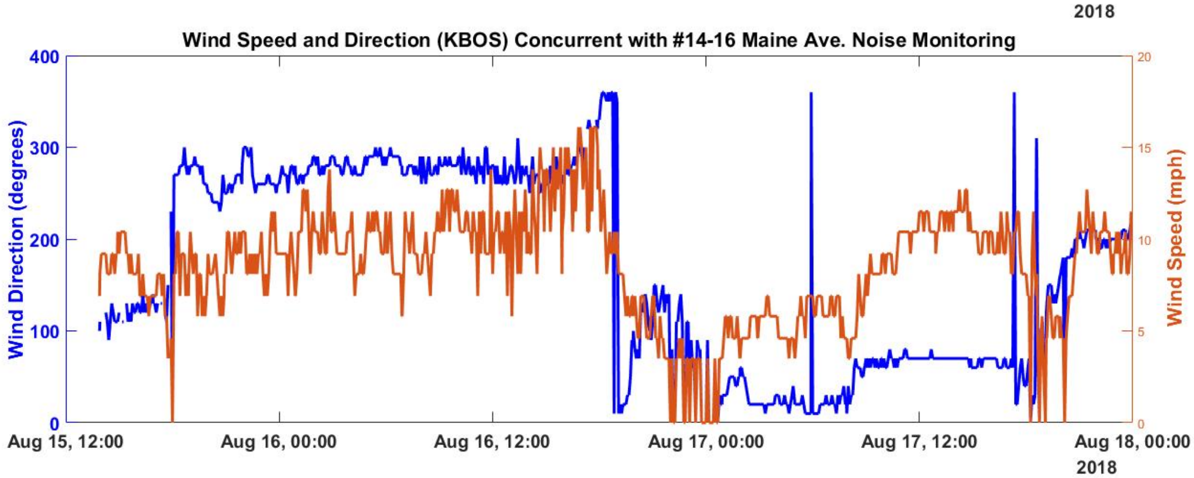

Temperature and Relative Humidity, Logan Airport (KBOS) Data
Temperature (deg F)
Relative Humidity %
100
80
60
100
50
0
Jun 27, 12:00
Jun 28, 00:00
Jun 28, 12:00
Jun 29, 00:00
2018

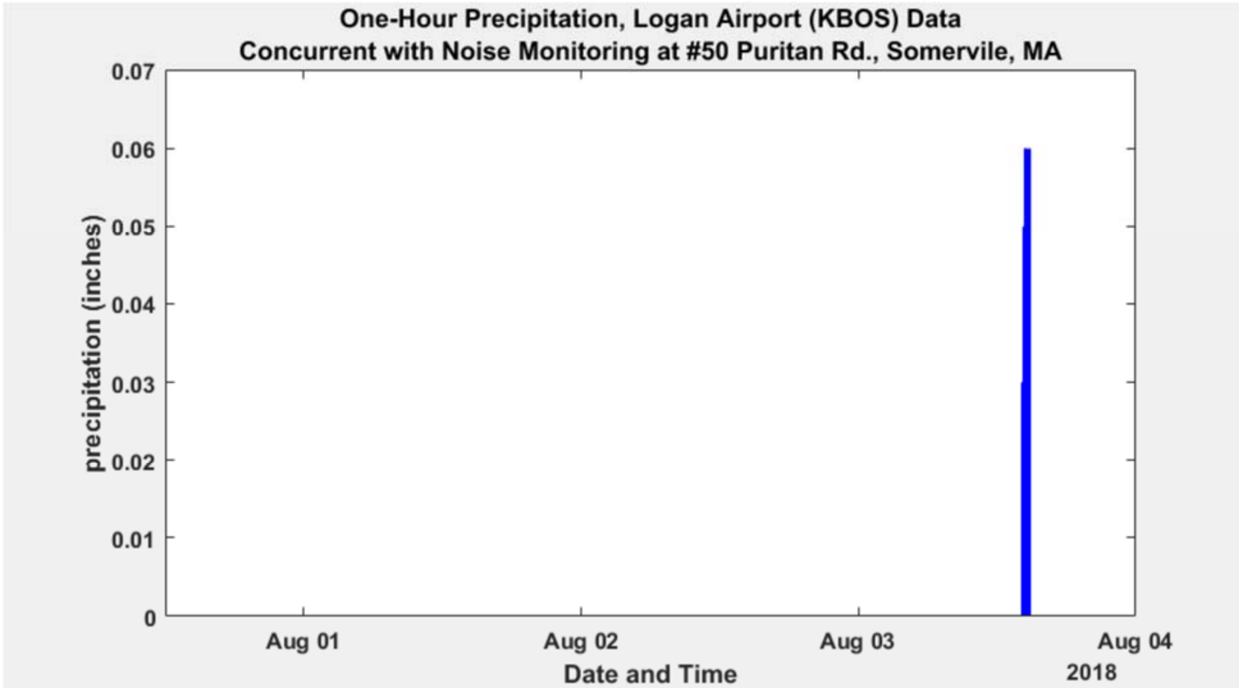

Wind Direction and Wind Speed, Logan Airport (KBOS) Data
Wind Direction (degrees)
Wind Speed (mph)
400
200
0
40
20
0
Jun 26
Jun 27
Jun 28
Jun 29
Jun 30
2018

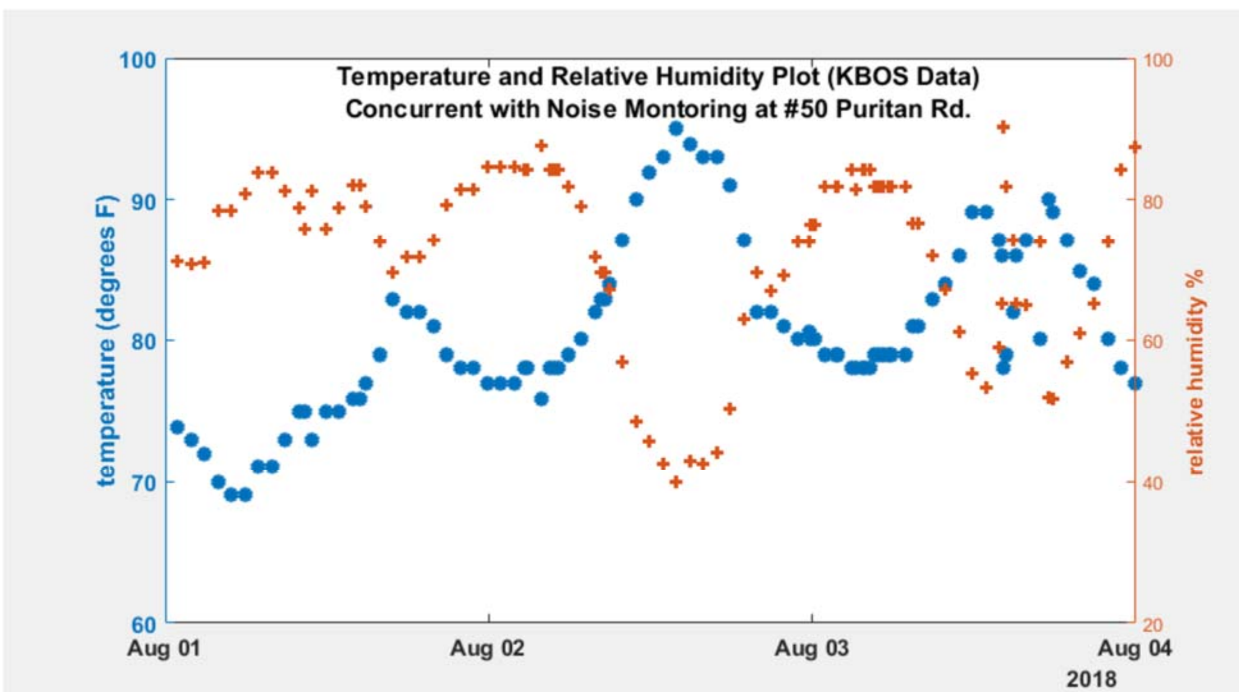

One Hour Precipitation (KBOS data) Concurrent with #9-11 Maine Av. Noise Monitoring
precipitation (ins.)
0.02
0.01
0
Jul 25, 00:00
Jul 25, 12:00
Jul 26, 00:00
Jul 26, 12:00
2018
Temp and Relative Humidity (KBOS data)
temp. (deg. F)
90
88
86
84
82
80
78
76
74
72
70
humidity %
100
95
90
85
80
75
70
65
60
55
50
Jul 25, 00:00
Jul 25, 12:00
Jul 26, 00:00
Jul 26, 12:00
2018
Wind Direction and Speed (KBOS data)
wind Dir. (deg.)
400
300
200
100
0
wind speed (mph)
40
30
20
10
0
Jul 25, 00:00
Jul 25, 12:00
Jul 26, 00:00
Jul 26, 12:00
Date and time
2018

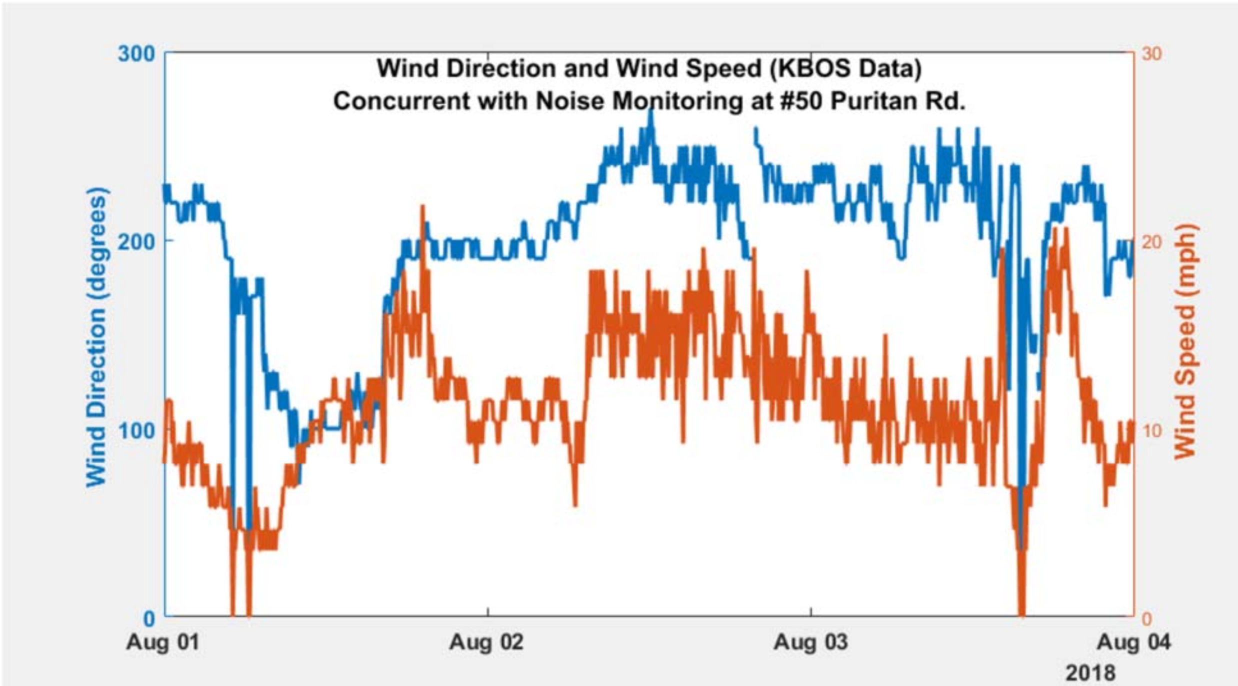

One-Hour Precipitation (KBOS) Plot Concurrent with #14 -16 Maine Ave. Noise Monitoring
precipitation (inches)
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Aug 15, 12:00
Aug 16, 00:00
Aug 16, 12:00
Aug 17, 00:00
Aug 17, 12:00
Aug 18, 00:00
2018

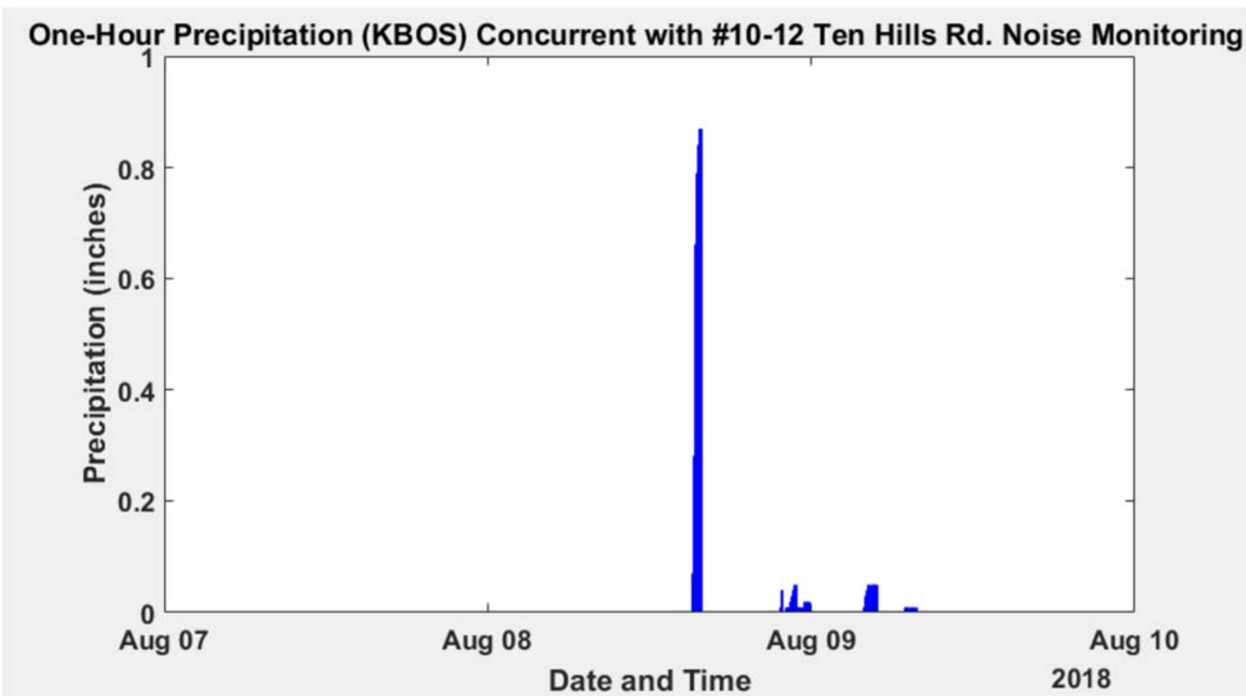

Temp. and Relative Humidity (KBOS) Plots Concurrent with #14-16 Maine Ave. Noise Monitoring
Temperature (degrees F)
100
80
relative humidity (%)
100
50
0
Aug 15, 12:00
Aug 16, 00:00
Aug 16, 12:00
Aug 17, 00:00
Aug 17, 12:00
Aug 18, 00:00
2018

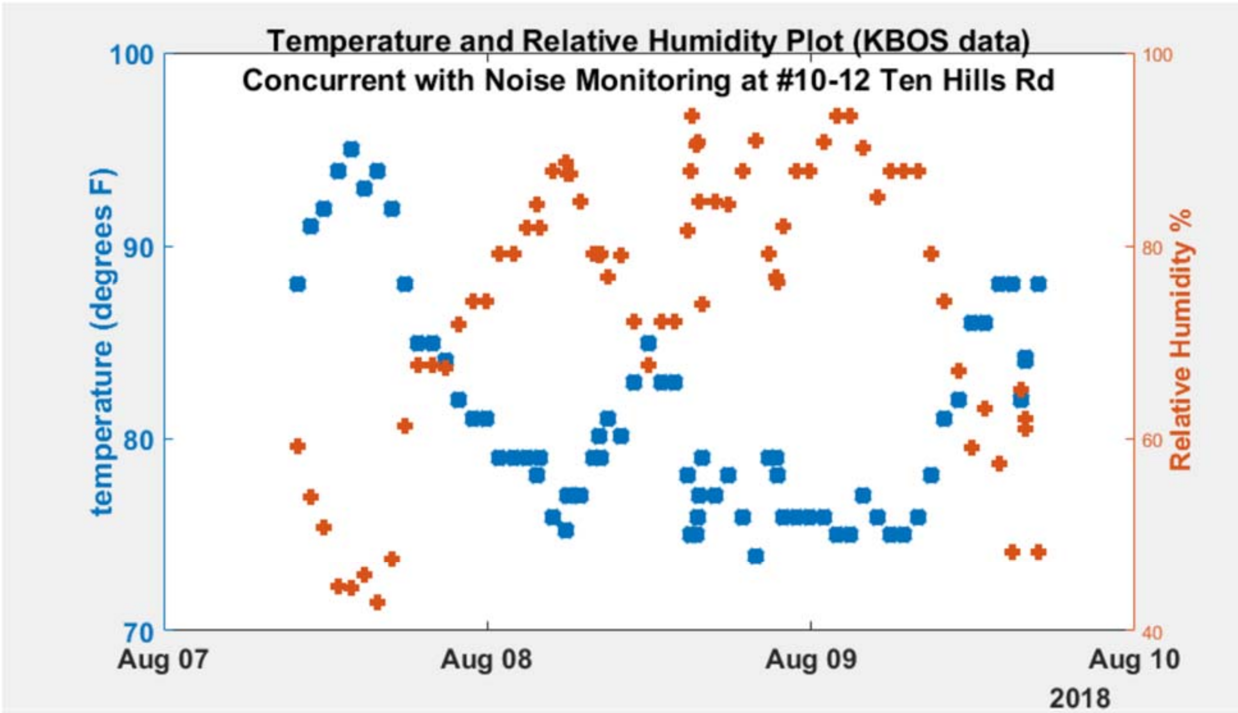

Wind Speed and Direction (KBOS) Concurrent with #14-16 Maine Ave. Noise Monitoring
Wind Direction (degrees)
400
300
200
100
0
Wind Speed (mph)
20
15
10
5
0
Aug 15, 12:00
Aug 16, 00:00
Aug 16, 12:00
Aug 17, 00:00
Aug 17, 12:00
Aug 18, 00:00
2018

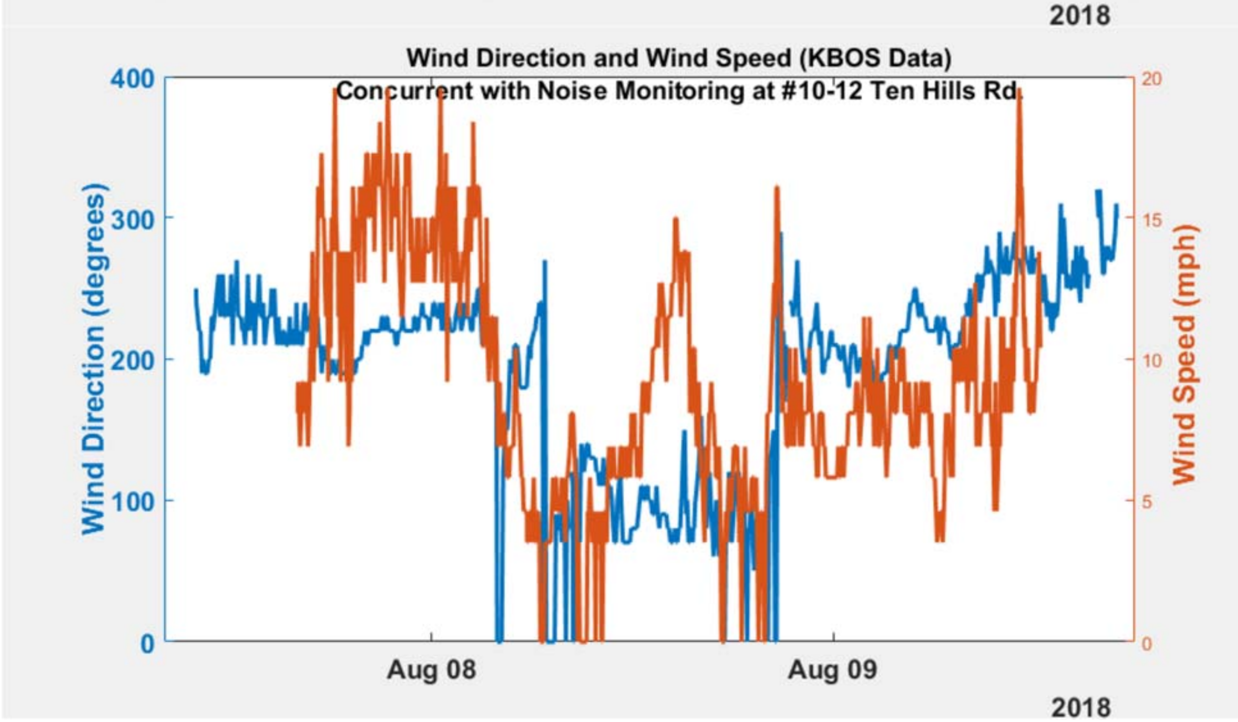

One-Hour Precipitation, Logan Airport (KBOS) Data
Concurrent with Noise Monitoring at #50 Puritan Rd., Somervile, MA
precipitation (inches)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
Aug 01
Aug 02
Aug 03
Aug 04
Date and Time
2018


Temperature and Relative Humidity Plot (KBOS Data)
Concurrent with Noise Montoring at #50 Puritan Rd.
temperature (degrees F)
100
90
80
70
60
relative humidity %
100
80
60
40
20
Aug 01
Aug 02
Aug 03
Aug 04
2018


Wind Direction and Wind Speed (KBOS Data)
Concurrent with Noise Monitoring at #50 Puritan Rd.
Wind Direction (degrees)
Wind Speed (mph)
300
200
100
0
30
20
10
0
Aug 01
Aug 02
Aug 03
Aug 04
2018


One-Hour Precipitation (KBOS) Concurrent with #10-12 Ten Hills Rd. Noise Monitoring
Precipitation (inches)
1
0.8
0.6
0.4
0.2
0
Aug 07
Aug 08
Aug 09
Aug 10
Date and Time
2018


Temperature and Relative Humidity Plot (KBOS data)
Concurrent with Noise Monitoring at #10-12 Ten Hills Rd
temperature (degrees F)
Relative Humidity %
100
90
80
70
40
60
80
100
Aug 07
Aug 08
Aug 09
Aug 10
2018


Wind Direction and Wind Speed (KBOS Data)
Concurrent with Noise Monitoring at #10-12 Ten Hills Rd.
Wind Direction (degrees)
Wind Speed (mph)
400
300
200
100
0
20
15
10
5
0
Aug 08
Aug 09
2018