Beacon Hill Noise Measurement Project
Summer 2018

Beacon Hill Community Noise Team
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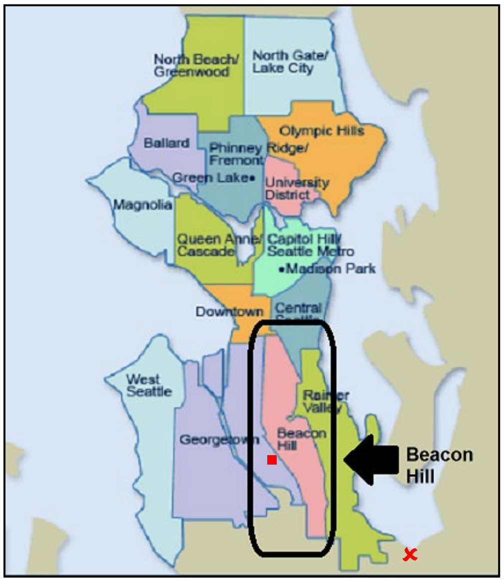
Introduction
The overarching goal of the project was to conduct Citizen Science measurements with University of Washington undergraduate student summer interns paid by El Centro de la Raza to help residents collect noise measurements. The project aimed to empower residents to collect new noise measurement data, which may benefit future follow-up activities, including collecting additional measurements, improving community awareness of noise levels, and follow-up research by others to quantify relationships to potential noise sources and health impacts.

This is the first project to collect quality assured 24 hour noise measurement data throughout Seattle's Beacon Hill neighborhood over a period of several months.

Beacon Hill Neighborhood Location

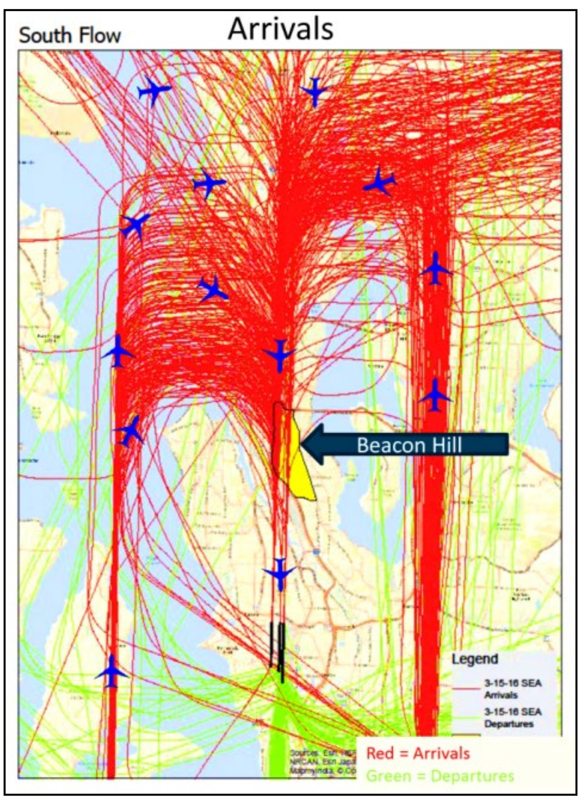


Seattle's Beacon Hill neighborhood's boundaries are approximately rectangular oriented north-south (Figure 1). From south end of the neighborhood to the north end, it is approximately 3.5 to 8.5 miles to the end of the Seattle-Tacoma International Airport runways. On Figure __, the runways of King County International Airport can be seen to the west of the Beacon Hill neighborhood. The King County airport runways are 0.25 to 0.5 miles from the Beacon Hill neighborhood (see red ▪, Fig. 1). The Renton Municipal Airport is approximately 3 – 7.5 miles to the southeast of the neighborhood (see red ×, Fig. 1). Flight paths of all three airports impact the neighborhood.

Figure 1. Seattle city limits and neighborhoods. Beacon Hill neighborhood is outlined in black.

King County International Airport's Fly Quiet map directs aircraft over the Beacon Hill neighborhood in the north, middle and south (Figure 2). MSL means the altitude of an aircraft above "mean sea level". The height of Beacon Hill is ~350 MSL. This means that in some cases aircraft will be 650 feet above the ground level of Beacon Hill.

Figure 2. Map of King County International Airport's "Fly Quiet" procedures for general aviation.



The flight paths of all incoming arrivals at Seattle-Tacoma International Airport condense to two parallel tracks directly over the Beacon Hill neighborhood as shown in Figure 3. Seventy percent of all arrivals approach the airport in this direction.

Figure 3. Arrival flight paths for Seattle-Tacoma International Airport. Beacon Hill neighborhood is outlined in yellow. Airport runways shown as two black lines center-bottom of image.

Methods

See Appendix A

Results

Noise Map. Noise measurements were collected at 52 sites. Most sites had more than 24-hours of measurements, with some having 2-3 days of measurements. Thus, in total 136 periods with 24-hour measurements were collected between April 8 – September 24, 2018.

The map in Figure 4 illustrates the 24 hour Day-Night average noise levels (LDNs) measured at BH sites. The blue lines extend from runways at Seattle-Tacoma International Airport.

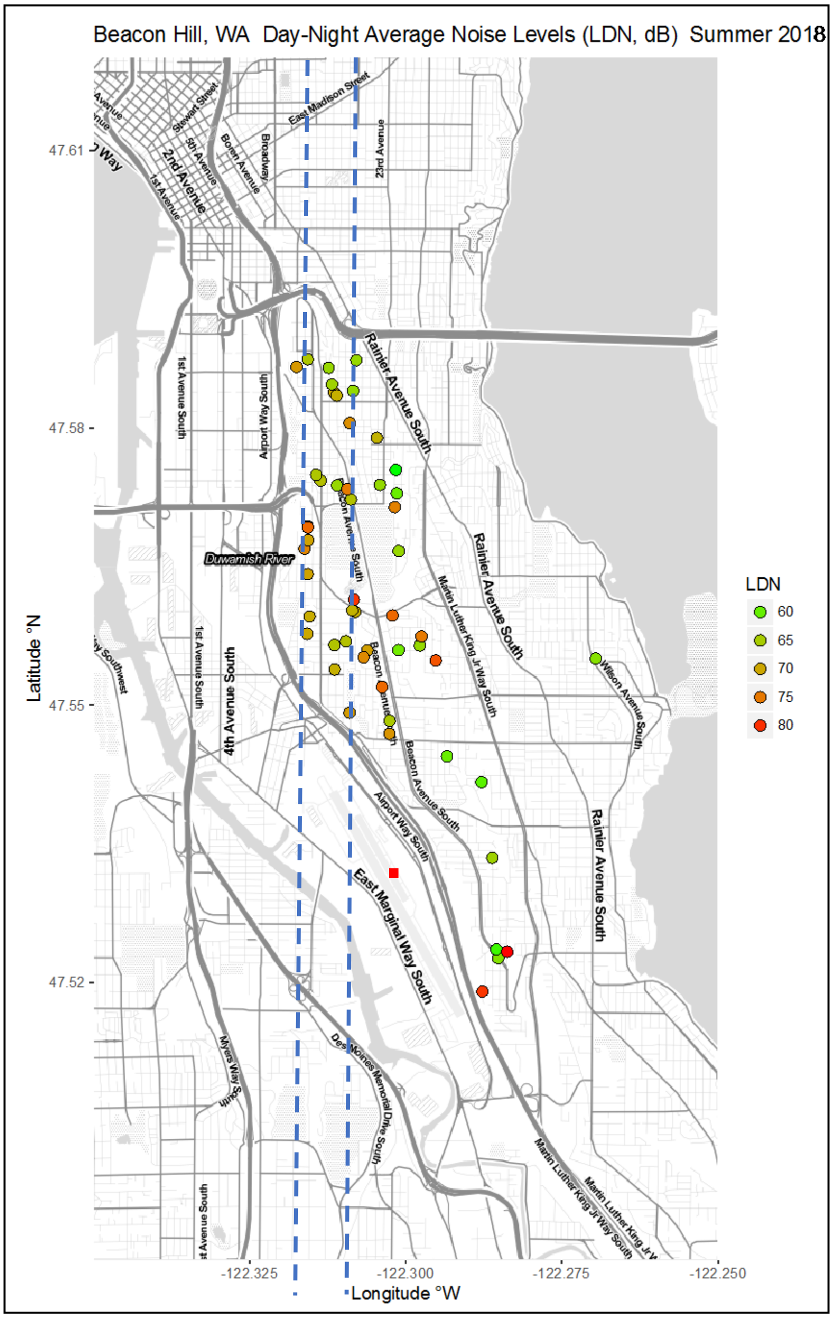


Figure 4. Day-Night 24-hour average noise levels at the study sites, April 8 – Sept 24, 2018. Blue lines extend from runways at Seattle-Tacoma International Airport which is located south. The runways of King County International Airport can be seen to the west of the Beacon Hill neighborhood as indicated by the red square ▪ .

Comparison of BH locations. Noise levels were quantified using day-night average noise levels for all 24 hour periods from all sites (Table 1, Fig 5). For each of the 52 sites when more than one 24 hour data sample existed, the average of the multiple 24 hour samples was determined (Table 2, Appendix C). The median value is the middle value of all the data; that is, one half of all the data values are above the median and one half of the data values are below the median. More than half of the 24-hour LDN_{24} measurements were above 65 dB (median 64.3, Table 1, Fig 5), with the maximum 24-hour LDN_{24} reaching 85.5 dB. Also, more than half of the 52 sites where measurements were collected had LDN_{24} measurements above 65 dB (median 68.1, Table 2). The individual data for this figure are provided in Appendix C.

Table 1. Day-Night Average Noise Levels (LDN_{24}) for all 24-hour measurements

N	Median (dB)	SD (dB)	Min (dB)	Max (dB)
136	64.3	6.5	52.2	85.5

Table 2. Day-Night Average Noise Levels for 52 sites for all 24-hour measurements

N	Median (dB)	SD (dB)	Min (dB)	Max (dB)
52	68.1	5.7	57.9	79.7

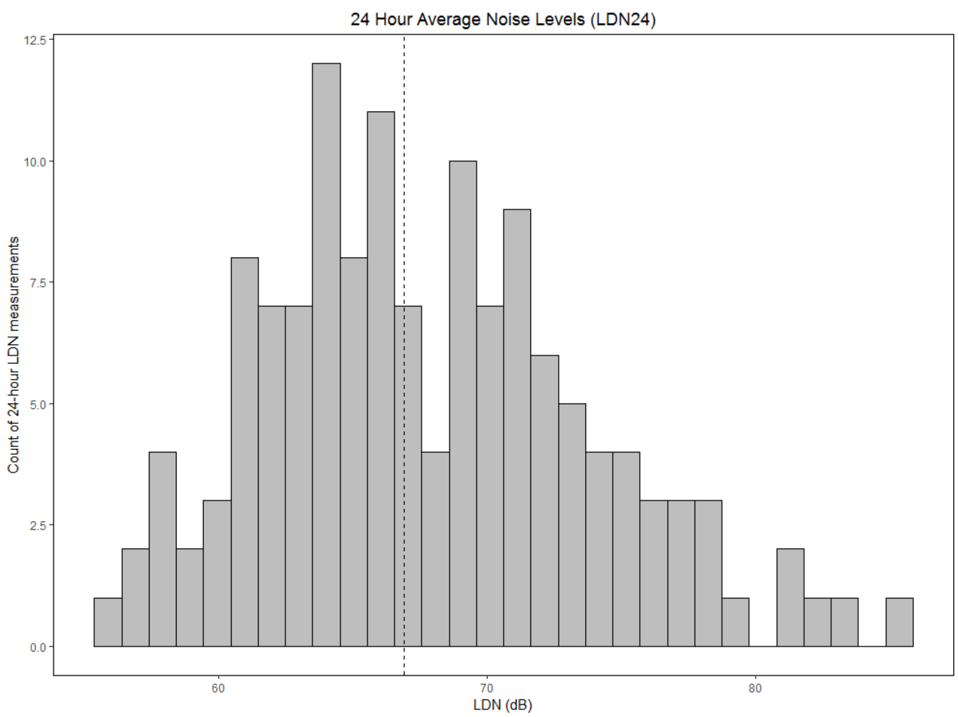


Figure 5. 24 hour Day-Night Average Noise Levels (LDN_{24}) at the 52 Beacon Hill measurement sites. The vertical dotted line indicates the median, 64.3 dB.

Figure 5 illustrates the 24-hour LDN_{24} measurements shown in Table 1, with the median of 64.3 dB indicated by the dashed line. The vertical axis is the number of measurements and the horizontal axis the LDN_{24}. The distribution was slightly skewed, with a few 24-hour measurement periods reaching noise levels higher than 80 dB LDN_{24}.

Comparisons with other locations. Publicly available measured noise data was used. The Port of Seattle Noise Monitoring System provides 24 hr LEQ data for each of its monitors on a public website (select "Airport Noise Data" at this link → https://www.portseattle.org/page/aircraft-noise-monitoring-system). 24 hr LEQ (LEQ_{24}) is the average sound level measured over 24 hours with no penalties for evening or night measurements. LEQ_{24} is the only measurement data that Port of Seattle makes publicly available. Locations of the Port of Seattle noise monitors are shown in Figure 6. LEQ_{24} values are shown in Tables 3 and 4, and Figure 7.

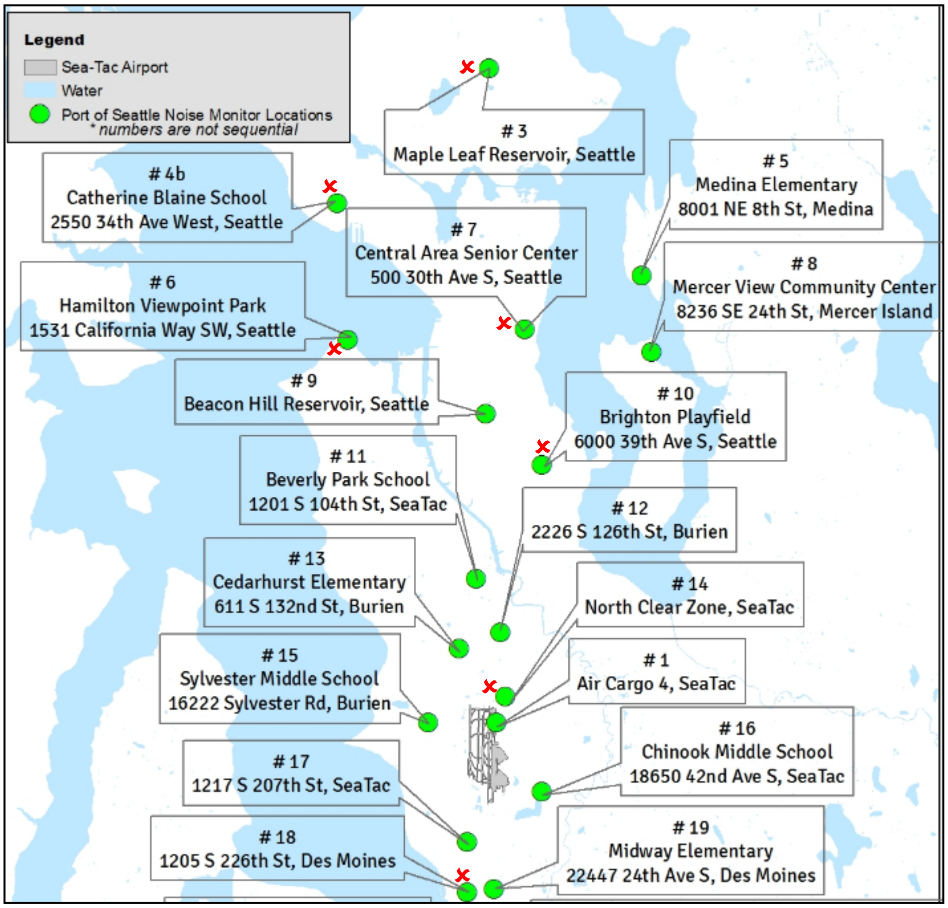


Figure 6. Fixed locations of Port of Seattle noise monitors. Locations included in Table 3 are indicated with a red × placed next to the circled location of the Port of Seattle monitor.

Table 3. LEQ_{24} values for the period April 8 – Sept 24, 2018. NMT refers to Port of Seattle monitor number. Miles indicates number of miles from the end of runways at Seattle-Tacoma International Airport.

NMT #	Name	Location of Monitor	Miles	Median LEQ_{24}	Min LEQ_{24}	Max LEQ_{24}
4b	Catherine Blaine School	2550 34th Ave S, Seattle	8	52	48	64
6	Hamilton Viewpoint Park	1531 California Way SW, Seattle	9.4	55	50	74
7	Central Area Senior Center	500 30th Ave S, Seattle	9.25	55	51	124
3	Maple Leaf Reservoir	1020 NE 82nd St, Seattle	15.5	56	51	63
10	Brighton Playfield	6000 39th Ave S, Seattle	6	56	52	82
13	Cedarhurst Elementary	611 S 132nd St, Burien	1.6	59	57	67
Field Measurements from this project	**Beacon Hill neighborhood**	**Seattle (52 locations)**	**3.5 - 8.5**	**64**	**52**	**86**
18	Des Moines WA	1205 S 226th St, Des Moines	2.25	64	62	65
14	North Clear Zone	Seatac	0.4	64	60	69

Figure 7 shows the LEQ_{24} measurements for 52 residential locations in Seattle's Beacon Hill neighborhood for the period April 8, 2018 through September 24, 2018. The vertical dotted line indicates the median value 64 LEQ_{24} with the minimum of 52 LEQ_{24} there are several LEQ_{24} values over 75 with a maximum of 86 (Table 4). The individual data for the 52 locations in this figure are provided in Appendix C. For the same time period, 24 hour LEQ results based on "LEQ Total Noise" values from the Port of Seattle "Airport Noise Data" website are shown in Table 3 and ranked by median LEQ_{24} values. Three non-Seattle sites which are located closer to the airport are included for comparison of the potential effect of distance from Seattle-Tacoma International Airport runways. The height of Beacon Hill is ~350 MSL which means residences are closer to overhead aircraft than surrounding communities which are slightly above sea level elevation and also just a few feet below the elevation of the airport runways.

Table 4. LEQ_{24} for 52 residential locations in Beacon Hill neighborhood, April 8 – Sept 24, 2018

N	Median (dB)	SD (dB)	Min (dB)	Max (dB)
136	64.3	6.5	52.1	85.5

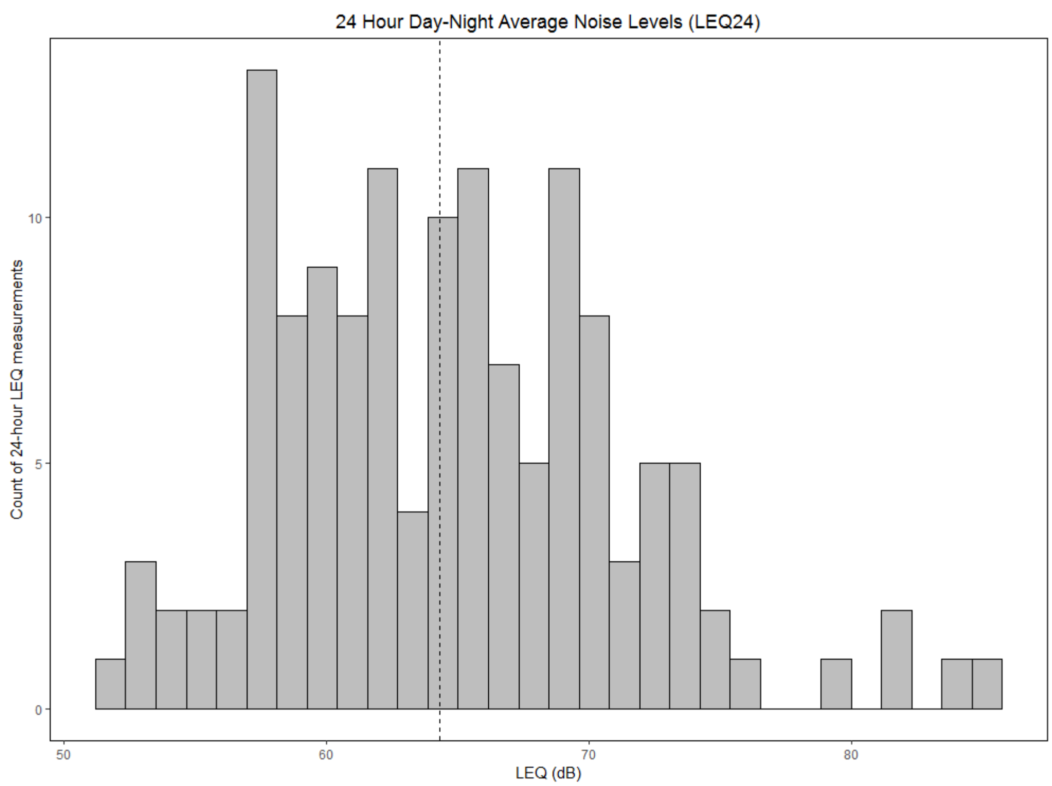


Figure 7. Beacon Hill neighborhood LEQ_{24} results based on field measurements at 52 locations. The histogram shows the frequency of occurrence of the 136 LEQ results for the period between April 8, 2018 - September 24, 2018. The vertical dotted line indicates the median value of 64.

Sources of Noise. One of the UW undergraduate student projects was to distinguish Beacon Hill neighborhood's aggregate noise versus aircraft noise based on field observations. An observational project was conducted on August 13, 2018. The methods and results are discussed in the student paper included in Appendix D. Videos for each of the nine recordings are posted on YouTube. The time of day recorded by the student's noise monitor were 12:22, 12:25, 12:26, 12:31, 12:32, 12:34, 12:35, 12.36 and 12:37 PM.

In summary, noise measured without aircraft overhead was approximately 45 to 55 dB and noise measured with aircraft overhead was 70 dB or greater. The time of day recorded by the student's noise monitor for each overhead aircraft almost exactly matched the time of day for SEL (single event level) noise recorded at Port of Seattle's noise monitor located in Jefferson Park (Table 4). The Port of Seattle noise monitor is located 2/3 miles northwest of the students' recording location.

Date/Time	Airport	Port of Seattle Noise Monitor	Flight ID	SEL
8/13/2018 12:37	SEA	SEA09	DAL2855	81
8/13/2018 12:36	SEA	SEA09	DAL1427	78
8/13/2018 12:35	SEA	SEA09	ASA484	79
8/13/2018 12:34	SEA	SEA09	JBU598	82
8/13/2018 12:32	SEA	SEA09	ASA350	81
8/13/2018 12:31	SEA	SEA09	ASA810	81
8/13/2018 12:26	SEA	SEA09	DAL1232	84
8/13/2018 12:25	SEA	SEA09	SWA1912	74
8/13/2018 12:22	SEA	SEA09	SWA2295	75

Table 4. Date, time, flight ID and SEL noise recorded by Port of Seattle at the Jefferson Park monitor (SEA09).

Another of the UW undergraduate student projects was to distinguish Beacon Hill neighborhood's aggregate noise versus other sources of noise based on field observations. An observational project was conducted on August 13, 2018. The methods and results are discussed in the student paper included in Appendix E. For this project, fifteen-minute vehicular traffic noise measurements were collected during non-peak and peak traffic periods from 2-5 pm at two Beacon Hill arterial streets, Beacon Ave S near the Light Rail station and McClellan Ave S. Fifteen minute LEQ (LEQ_{15}), the maximum and minimum dB and the type of vehicles were observed and recorded, and correlations calculated. In summary, as expected LEQ_{15} increased as the number of vehicles increased. The minimum dB recorded ranged from 45-55 dB which is the same range as observed during the student aircraft project when there were no aircraft overhead. The average LEQ_{15} for the two Beacon Hill arterial streets were 68.6 and 64.0. Visual inspection of the traffic data may suggest that buses and high numbers of car traffic within a 15 minute period are noticeable contributors to an increased LEQ_{15}.

High Noise Events. The 136 twenty-four hour noise recordings resulted in over 3,200+ hours of measurements which were collected at one second intervals and over 11 million individual sound measurements. Based on the one second noise measurements, the time of day at which 65dB was exceeded was evaluated. The hourly percentages of how many data points occurred above 65dB were determined (Figure 8). In other words, it was determined how often noise levels exceeded 65dB within a given hour of the day (on a second by second basis). For example, Figure 8 illustrates that between 3AM and 12noon, 1.2% to 17.5% of each hour is above 65dB. Noise levels exceeded 65dB more often (higher percentage of time) in afternoon and evening hours, and peaked around 12noon.

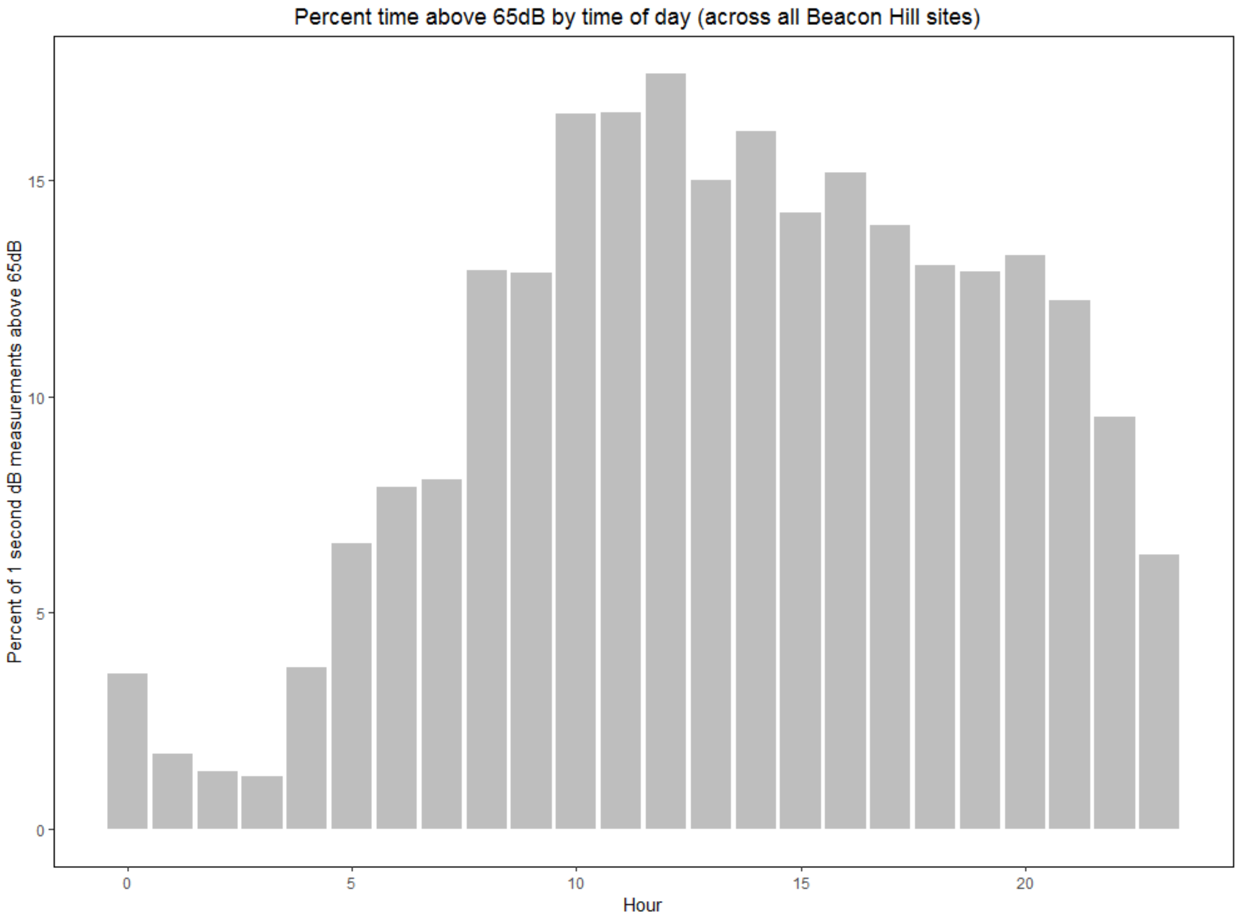


Figure 8. Percent of 1 second dB data above 65dB for each hour of a 24 day. Percentages are calculated using data from all Beacon Hill sites and all days recorded.

Discussion

The goal of this project was not to make comparisons with reference or literature noise values. There were no regulatory or policy decisions directly involved in this project. The goal was to assist and empower residents to collect 24-hour noise measurements at a limited number of neighborhood locations, and to demonstrate the ability to use these Citizen Science-collected measurements to compute standard community noise metrics that will be shared publicly.

The Beacon Hill Community Noise Team will continue to collect noise measurements as long as there are community volunteers to host a noise monitor and there are Team members to deploy the Team's three noise monitors. New noise measurements will be added to the existing data set and update the Beacon Hill noise map. These data and map are publicly available at https://beaconhillseattlenoise.org/ The Beacon Hill database has an open access license and is hosted by Open Science Framework which is an open source project management repository.

While the goal of the project was not to assess regulatory compliance, we note that Noise Control is covered in Chapter 25.08 of the Seattle Municipal Code (https://library.municode.com/wa/seattle/codes/municipal_code?nodeId=TIT25ENPRHIPR_CH25.08NOCO). General standards for noise levels within residential (55 dB), commercial (60 dB) and industrial (70 dB) land use zones within the city are provided in Section 25.08.410 of the code. One hour LEQ measurements are mentioned in the code for assessment of non-continuous noise levels and one second LEQ for a constant sound source. The Code states that during a measurement interval, Lmax may exceed the exterior sound level limits shown in subsection 25.08.410.A by no more than 15 dB. However, Section 25.08.420 mentions the need to penalize noise levels between the hours of 10pm and 7am by 10 dB, which suggests there is value in 24-hour measurements and consideration of the LDN which includes penalties for noise measured at night time. The code explicitly excludes consideration of aircraft noise per section 25.08.530.

Aircraft-specific noise is regulated by the FAA (https://www.faa.gov/about/office_org/headquarters_offices/apl/noise_emissions/airport_aircraft_noise_issues/). The FAA considers significant noise as a LDN greater than or equal to 65 dB.

Appendix A

Methods

The project took place during April through September 2018. The purpose of the project was to collect valid 24-hour noise levels for at least 34 sites in Beacon Hill. Due to the assistance of the two UW summer interns, the goal of 34 sites was exceeded and measurements from 52 sites were collected.

Community noise pollution is characterized by outdoor ambient noise levels measured in units of dB. Generally, there are three recommended quantitative metrics for community noise: the 24-hour LEQ – an average noise level assessed over a single 24-hour period; the 24-hour LDN – an average noise level assessed over a single 24-hour period with a 10 dB penalty applied to nighttime hours between 22:00 - 07:00; and the 24-hour LDEN – an average noise level over a single 24-hour period with a 10 dB penalty applied to nighttime hours like the LDN, but also a 5 dB penalty applied to the evening hours of 19:00 - 22:00. Community noise may be modeled or measured; however, measurements are more amenable to Citizen Science due to the relative ease of collecting noise measurements, as opposed to characterizing noise emissions data required for modeling.

Through the use of social media and word of mouth, volunteers signed up to have noise measurements collected at their homes. In order to engage residents from different parts of the neighborhood, we employed a grid sampling approach, in which 34 locations were selected, as best as possible, to be equally spaced across Beacon Hill. Sampling from these locations according to a grid, had an additional benefit in that it provided sites at various distances from major roads and flight paths, even if the park and southern parts of Beacon Hill did not seem to offer potential sites for measurement. Measurements were made based on volunteers' availability during the term of this project and access to appropriate measurement location at the residence. Every attempt was made to obtain measurements in available regions of the community. Given the limited resources of this project, it was not feasible to collect repeated measures over time at each site. However, additional sites were added as time allowed during the summer.

Data were collected using data-logging Type 1 noise level monitors set to measure at 1-second time-intervals, with monitors deployed over a period of no less that 24-hours at each location.

Over the course of the project period, monitors were moved from one location to another. For example, at one location measurements were collected during days in June while at a different location, measurements were collected during days in August. This means at different locations there may have been different weather and wind conditions, as well as different conditions relating to the transportation sources of noise (aircraft, vehicles, trains, ships).

Type 1 noise level monitors were operated according to the instrument operating manual. Noise levels were recorded at 1-second intervals. Monitors were calibrated prior to deployment and collected measurements at each location for a minimum of 24 hours, after which data from the monitor was downloaded, batteries recharged, monitor re-calibrated and then re-deployed to a new location. While our analyses focused on 24-hour summary measures, 1-second logged measurements provided data for other metrics including examination of temporal trends. Three monitors were used in total, with individual noise monitors identified by serial number, and each field calibrated by the team. Field logs were maintained for each noise monitor deployment. Student interns and residents worked collaboratively to deploy and pick-up noise monitors at each site.

The monitors were protected by weatherproof boxes with microphone exposed to the ambient sound outside of the box, and mounted outdoors in an undisturbed location. Location choice at a volunteer resident's home was based on field observations. As identified by the resident, the ideal location was one that was not overly influenced by any intermittent source of sound such as barking dogs, human conversation, media noise, machinery noise, etc. that would not be representative of the normal outdoor ambient noise levels. Student interns and residents worked collaboratively to contact site owners to arrange a sampling time, identify a suitable location, and deploy and pick-up monitors at each site.

Data were checked using a quality assurance process which was approved by the U.S. EPA Region 10 Quality Assurance Program manager. Measurements at sites that did not meet data completeness criteria (at least 24-hours of data per site) were not considered valid. Instruments were routinely field calibrated, and monitors that failed calibration were recalibrated or replaced. Finally, field replicate measurements were collected using two co-located monitors at a subset of monitoring sites in order to assess inter-monitor comparability. Data not meeting criteria for inter-monitor comparability ($R^2 > 0.8$) were flagged. Three sites measured during SeaFair, when the Blue Angels jets were performing were excluded from this analysis because they were deemed not representative of the general noise situation.

Appendix B

Quality Assurance Results

The noise monitoring data were checked for quality on the basis of data completeness, inter-monitor comparisons, and calibration. Complete data were collected from all sites, with at least 24-hours of 1-second noise measured at each site. Correlations between noise measurements from co-located pairs of monitors were assessed. The correlations for the double monitors were 0.98, 0.98, 0.94, 0.96, 0.98, and 0.99 (R^2 were all >0.8). Pre/post monitor calibrations did not reveal any discrepancies greater than 3 dB. Thus, all sites exceeded quality assurance levels.

Appendix C

Location, LDN and LEQ_{24} Results

Count	Site ID	Zip Code	Latitude	Longitude	LDN_{24} (dB)	LEQ_{24} (dB)
1	1	98144	47.587	-122.308	63.4	60.1
2	2	98108	47.549	-122.309	71.3	66.5
3	3	98108	47.569	-122.316	68.8	67.4
4	4	98144	47.574	-122.314	66.7	63.3
5	5	98108	47.566	-122.301	63.4	60.0
6	6	98144	47.578	-122.305	68.4	67.1
7	9	98108	47.557	-122.316	69.8	61.9
8	10	98108	47.560	-122.308	69.0	68.2
9	11	98108	47.548	-122.303	65.5	62.1
10	12	98108	47.555	-122.306	70.8	70.0
11	14	98108	47.564	-122.316	70.5	67.7
12	15	98144	47.572	-122.309	66.4	62.0
13	16	98144	47.586	-122.312	63.4	60.0
14	17	98108	47.559	-122.302	76.5	73.8
15	18	98144	47.573	-122.311	63.4	58.3
16	19	98108	47.555	-122.301	60.6	56.7
17	22	98108	47.556	-122.298	63.2	62.8
18	23	98144	47.574	-122.314	65.8	63.2
19	24	98144	47.572	-122.301	60.2	56.3
20	28	98144	47.575	-122.302	57.6	54.9
21	29	98108	47.556	-122.31	66.5	62.8
22	30	98144	47.580	-122.309	72.7	71.6
23	32	98108	47.544	-122.293	60.2	57.7
24	33	98144	47.586	-122.318	71.6	65.6
25	34	98144	47.584	-122.309	63.1	59.2
26	35	98118	47.522	-122.285	61.9	58.0
27	36	98144	47.583	-122.312	69.6	69.4
28	37	98108	47.554	-122.295	78.0	78.0
29	38	98108	47.556	-122.312	66.0	62.3
30	44	98108	47.559	-122.315	69.2	65.5
31	45	98108	47.566	-122.316	73.6	66.3
32	46	98108	47.546	-122.303	72.1	70.7
33	47	98108	47.557	-122.298	74.9	65.6
34	50	98108	47.551	-122.304	76.4	76.2
35	53	98144	47.573	-122.309	74.8	70.4

36	55	98108	47.561	-122.308	79.8	74.8
37	56	98108	47.555	-122.307	73.2	68.8
38	57	98144	47.584	-122.312	64.2	62.5
39	58	98144	47.573	-122.304	63.2	60.0
40	59	98144	47.587	-122.316	65.8	62.1
41	60	98143	47.571	-122.302	74.2	65.4
42	61	98107	47.560	-122.309	68.4	66.0
43	62	98144	47.583	-122.311	68.8	68.3
44	63	98108	47.569	-122.316	76.4	70.1
45	64	98108	47.567	-122.316	70.5	69.8
46	66	98118	47.555	-122.27	62.1	57.7
47	67	98118	47.523	-122.286	58.5	57.6
48	70	98118	47.523	-122.284	81.0	81.0
49	72	98118	47.519	-122.288	79.7	79.1
50	73	98118	47.541	-122.288	59.4	55.0
51	74	98188	47.533	-122.286	64.2	63.1
52	75	98108	47.553	-122.311	68.8	65.6

Appendix D

Aircraft Noise Case Study
Phan Su
University of Washington Undergraduate Summer Intern

Introduction

Since Beacon Hill is a residential area that lies beneath the flight paths of Seattle–Tacoma International Airport aircraft, and is directly north of the airport runways, residents are concerned about exposure to noise from the many aircraft landing or taking off. This chronic environmental stressor may cause adverse health effects among exposed residents. A study was done on residents living nearby the Orio al Serio International Airport in Northern Italy, with researchers concluding that there is a strong association between above 60 dBA noise levels, annoyance, and sleep disorders (Carugno, et al., 2018). Children can also be vulnerable to aircraft noise. The Road Traffic and Aircraft Noise Exposure and Children's Cognition and Health (RANCH) project was a cross-national study done in the Netherlands, Spain, and the UK that concluded children could have impaired cognitive development, specifically reading comprehension and recognition memory, from aircraft noise (Stansfeld, et al., 2005). Since the aircraft fly right over Beacon Hill during take-offs or landing, noise exposures may be an issue for sensitive populations such as children, elderly, and immunocompromised people that reside in the neighborhood.

The objective of this case study was to collect noise measurements specifically for commercial aircraft flying overhead at a site in Beacon Hill, and to analyze the relationship between aircraft and noise levels.

Methods

A site was selected for a series of aircraft noise measurements that conducted over the course of a 3-hour period. The site was a grassy area right by the community garden on the Chief Sealth Trail under the power lines (Figure 1). This location was selected because it is located immediately below the aircraft flightpath and away from road traffic, making it ideal for aircraft-specific noise monitoring. Being that it is an open space, aircraft were clearly visible, allowing for easy tracking of each individual aircraft flying over the measurement site.

Figure 1. Location of Aircraft Noise Measurements Shown as "Monitor". Interns (Phan and Eileen) were located slightly away from the monitor, so as to observe, but not disturb the monitoring.

The experiment was conducted on a Monday (August 13, 2018) from 9:40am-12:40pm because this tends to be peak flight hours for Sea-Tac airport. A calibrated Type 1 noise dosimeter (General DSM403SD) to collect 1-second measurements of the aircraft noise, which was placed approximately 30 feet away from where the Interns sat taking notes. The monitor was set to A weighting to accurately represent how human ears perceive sound, and fast response to capture quick changing noise levels associated with short-term aircraft flybys. A field log was used to note the geographic coordinates of the study site, and the start and end time of the measurements. The log was also used to tracking the timing of each aircraft passby events or other extraneous noise events. Other types of airplanes, such as few hydroplanes were also noted. During the last 20 minutes of the experiment, every aircraft that flew by and its noise monitor reading, were recorded in videos using a mobile phone camera.

Results

Data were analyzed and the time-series of noise levels from the last 30 minutes of the experiment is shown in Figure 2. Each peak is indicated in yellow, corresponding to field notes of when an aircraft was observed overhead. The highest dB value during each aircraft event is noted in the figure. The graph shows clear peaks of elevated noise associated with aircraft flybys. Moreover, the graph illustrates that aircraft flying over Beacon Hill produce measureable noise that was measured to reach as high as 93.4 dB during this 30-minute period. The lowest peak noise level associated with an aircraft flyby during this period was measured as 63.6 dB, which is still somewhat high since typical short-term residential noise should not be above 55 dB according to the Seattle's noise municipal code (Chapter 25.08). Additionally, the figure illustrates the frequency of (i.e., how often) noise events. During the 3-hour study period, an airplane passed by approximately every minute. There would occasionally be an approximate 3-minute break of aircraft activity, but this did not happen very often. In the graph of the last 30 minutes of monitoring, the aircraft were approximately 1-3 minutes apart. Furthermore, the aircraft were taking off from Sea-Tac airport this day and flying over Beacon Hill northward due to the wind direction. This may correspond to higher noise levels than what we might expect for landing aircraft flying over Beacon Hill. The average of the peaks in this 30-minute timespan was 74.2 dB and the 30 minute LEQ is 67.4 dB. The LEQ for the 3-hour timespan was 63.9 dB. There were also occasional hydroplanes that would fly over the site. The three peaks that are not marked/labeled in the graph were noise caused by hydroplanes. Once in a while, there were helicopters and a dog barked nearby for about a minute. Other than that, the majority of the noise produced during these three hours were from commercial aircraft flybys.

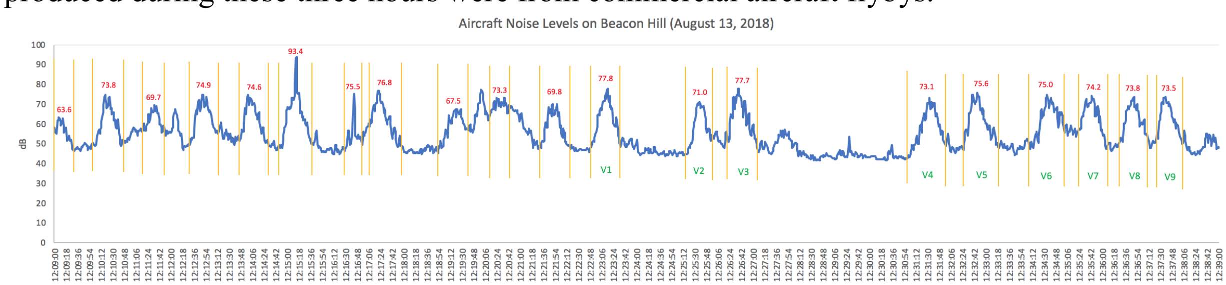


Figure 2. Time-series of noise measurements at the study site, with peak noise levels noted for each aircraft passby. Peaks denoted as V1 through V9, correspond to videos that were taken of the airplane and noise level monitor.

Links to videos taken of the aircraft flying over the site, and the corresponding noise level displayed on the screen of the noise dosimeter are provided below. Additionally, as an example, still images captured from August 13 at 12:22 PM are shown in Figure 3.

Aircraft noise Aug 13, 2018 at 12.22 PM Seattle Beacon Hill
https://youtu.be/78SznF-zKOc
Aircraft noise Aug 13, 2018 at 12.25 PM Seattle Beacon Hill
https://youtu.be/B8GRmjZi170
Aircraft noise Aug 13, 2018 at 12.26 PM Seattle Beacon Hill
https://youtu.be/tT-mFRD96JA
Aircraft noise Aug 13, 2018 at 12.31 PM Seattle Beacon Hill
https://youtu.be/3HXgPNSU9H8
Aircraft noise Aug 13, 2018 at 12.32 PM Seattle Beacon Hill
https://youtu.be/Mmh67Wozpj8
Aircraft noise Aug 13, 2018 at 12.34 pm Seattle Beacon Hill
https://youtu.be/7v5wUIQ1-8M
Aircraft noise Aug 13, 2018 at 12.35pm Seattle Beacon Hill
https://youtu.be/Bk9WnnW3SRs
Aircraft noise Aug 13, 2018 at 12.36 PM Seattle Beacon Hill
https://youtu.be/YIulccqjW0M
Aircraft noise Aug 13, 2018 at 12.37pm Seattle Beacon Hill
https://youtu.be/B9oL9NGkiX8

Figure 3. Still images from August 13 at 12:22 PM.

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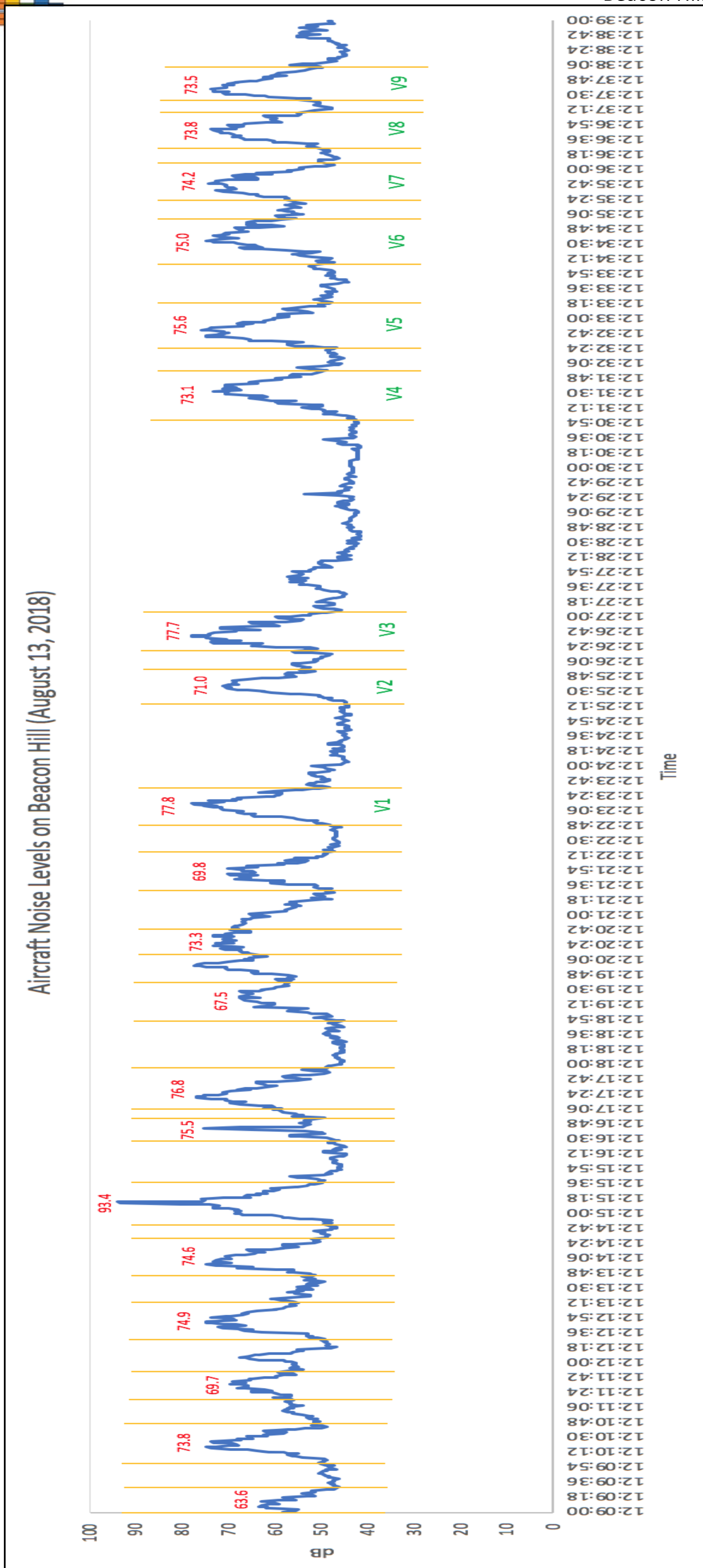


ENLARGED VERSION

Figure 2. Time-series of noise measurements at the study site, with peak noise levels noted for each aircraft passby. Peaks denoted as V1 through V9, correspond to videos that were taken of the airplane and noise level monitor.

Appendix E

Aircraft Noise Case Study

Eileen Tran
University of Washington Undergraduate Summer Intern

Introduction

While many Beacon Hill residents are concerned about noise pollution from aircraft, road traffic noise may also contribute to cumulative noise impacts. Traffic noise studies are conducted to "define areas of potential noise impact, evaluate measures to mitigate impacts and to compare various study alternates" (Highway, 2017). Traffic noise may contribute to an environmental justice issue, and may pose a threat to the health of many Beacon Hill residents.

Studies that have considered traffic noise health impacts include one study published in *Breast Cancer Research*, which studied the association between long-term noise exposure and incidence of breast cancer (Andersen, et al., 2018). The researchers found a statistically significant association between long-term noise exposure from traffic and increase of estrogen receptor-positive (ER+) breast cancer. Another study concluded that there was a positive correlation between traffic noise exposure and risk of obesity (Pyko, et al., 2015). A study published in *Environmental International* examined the effects of stress from traffic noise and found there was an association between high noise levels and use of psychotropic medication (Okokon, et al., 2018). Therefore, assessment of traffic noise, and mitigation of its impact may be important to improve the health and wellness of Beacon Hill residents.

The objective of this case study was to collect and analyze noise data from road traffic by counting traffic while simultaneously measuring noise levels at two sites in Beacon Hill.

Methods

Two sites were selected for the case study. The first site was Beacon Avenue S at the mid-block, in front of the Beacon Hill light rail station. This site was selected because it is a relatively busy street with different types of vehicles, which could potentially provide large variations in noise measurements due to varied traffic conditions. In addition, the site is not that close to freeways, which could potentially influence noise measurements. Another site, near 17th Avenue and S. McClellan Street, was also selected since it should have much less traffic for comparison.

Figure 1. Beacon Ave. S site near the Beacon Hill Light Rail Station on Beacon Ave S. Measurement location shown as yellow dot.

Figure 2. 17th Ave. and S. McClellen St. site. Measurement location shown as yellow dot.

Fifteen-minute noise measurements were collected on August 13th, 2018 during non-peak and peak traffic periods from 2-5 pm between the two sites. At each location 3 hours x 4 samples/hr were collected, resulting in 12 observations per period. Measurements were carefully collected so as to avoid bystanders, to not contaminate the noise measures. Noise measurements were collected using a calibrated Type 1 noise monitor (General DSM403SD), set to A weighting, and fast response. During noise measurements, the numbers of different types of vehicles was noted in a field log. Vehicle types included autos, trucks, buses, and motorcyclse. Minimum, maximum and LEQ_{15} dB was measured in units of decibels (dB).

Noise measurement data were used to create graphs of the relationship between vehicle counts and noise level in dB. The graphs show the correlation between traffic counts and noise levels.

Results

The mean of the 15-minute LEQs from the busier street, Beacon Ave. S, was slightly higher than the residential street. However, the data from the residential street had a higher standard deviation in LEQ_{15} compared to the busier street. This is likely due to relatively more constant traffic at Beacon Ave. S, while more varied traffic conditions at the residential street due to periods without any traffic. There were about double the amount of cars at Beacon Ave. S compared to the 17th Ave, S. McClellan St. site, and significantly more vehicles overall.

Field measurements

		15-min noise measurements (dB)			Count of Different Types of Vehicles				
Site	**Time**	**LEQ_{15}**	**Lmax**	**Lmin**	**Cars**	**Buses**	**Motorcycles**	**Medium trucks**	**Heavy trucks**
Beacon Ave. S									
	2-2:15 pm	69.1	88.7	52.8	144	7	1	1	2
	2:16-2:31 pm	67.7	83.7	52.8	126	7	0	3	1
17th Ave, S. McClellan St.									
	2:40-2:55 pm	66.5	81.4	51.9	85	0	0	0	1
	3-3:15 pm	62.2	74.2	44.8	84	0	0	1	0
Beacon Ave. S									
	3:21-3:36 pm	68.8	82	54.8	190	8	2	1	0
	3:40-3:55 pm	68.6	93.4	52.6	172	7	1	0	0
17th Ave, S. McClellan St.									
	4-4:15 pm	67.7	92.1	46.5	67	0	0	2	0
	4:15-4:30 pm	57.9	62.1	54.3	76	0	0	1	0

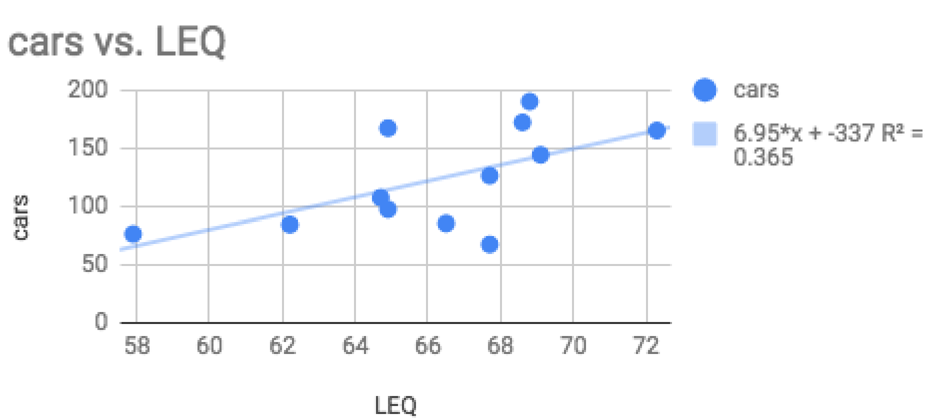
Beacon Ave. S									
	4:34-4:49 pm	64.9	73.4	51.9	167	7	0	2	0
	4:40-5:05 pm	72.3	95	54.2	165	9	2	2	1
17th Ave, S. McClellan St.									
	5:09-5:24 pm	64.9	83	46.5	97	0	0	0	0
	5:24-5:39 pm	64.7	76	45.3	107	0	1	0	0

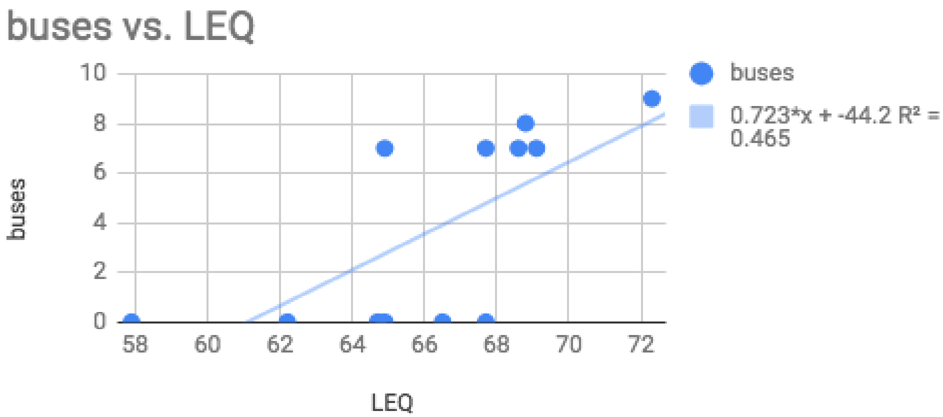
Averages from field log

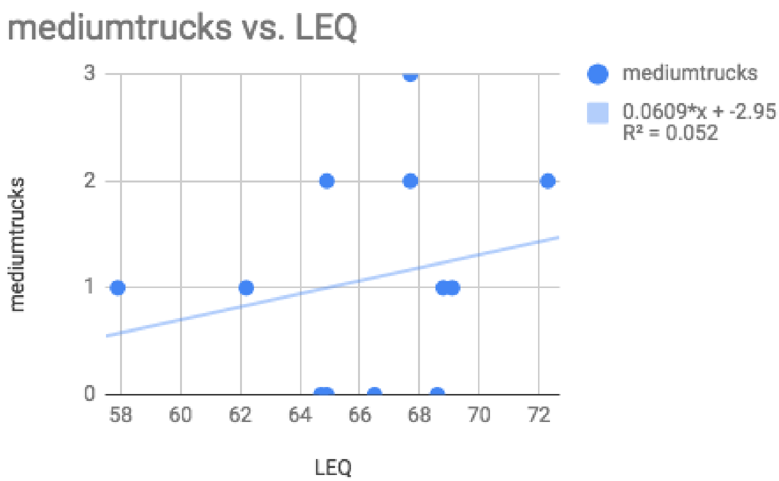
Site	**Mean of LEQ$_{15}$**	**SD of LEQ$_{15}$**	**Mean car count**	**Mean bus count**	**Mean motorcycle count**	**Mean medium truck count**	**Mean heavy truck count**
Beacon Ave. S	68.6	2.4	160.7	7.5	1.0	1.5	0.7
17th Ave, S. McClellan St.	64.0	3.5	86.0	0.0	0.2	0.7	0.2

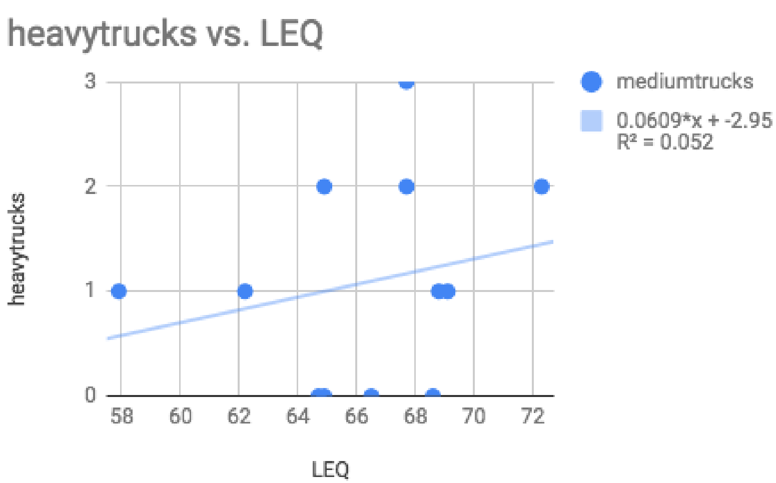
Road Traffic Analyses

The figures below illustrate the correlation between the counts of each type of vehicle and noise levels. As seen in each figure, there tends to be a positive correlation; as the number of vehicles increases, the LEQ$_{15}$ increases as well. This shows the more traffic there is, the more noise there is. There is a higher LEQ$_{15}$ from the Beacon Ave. S site in comparison to 17th Ave, S. McClellan St. due to higher traffic counts.




buses vs. LEQ
buses
0.723*x + -44.2 R² = 0.465
LEQ
10
8
6
4
2
0
58
60
62
64
66
68
70
72


mediumtrucks vs. LEQ
mediumtrucks
0.0609*x + -2.95
R² = 0.052
LEQ
3
2
1
0
58
60
62
64
66
68
70
72


heavytrucks vs. LEQ
heavytrucks
mediumtrucks
0.0609*x + -2.95
R² = 0.052
LEQ
3
2
1
0
58
60
62
64
66
68
70
72

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