The Effect of Freight Trains on Noise Pollution in the British Columbia Lower Mainland

April 30, 2015

Abstract

On August 21st 2014, Port Metro Vancouver approved an increase of US thermal coal train traffic along the BNSF rail line enroute to Fraser Surrey Docks. As a result of the anticipated increase in U.S. thermal coal trains, health concerns have been expressed by our community partner, Communities and Coal, a group of citizens in the communities surrounding the BNSF rail line (Delta, White Rock, Crescent Beach and Surrey). In order to address these concerns, current noise pollution data was collected at four different sites along the BNSF rail line in 24-hour time intervals from the time period of November 2014 to March 2015 using an EXTECH Sound Level Data Logger. Each site was monitored twice. The observed equivalent continuous sound levels (L_{eq-16} and L_{eq-24}) for all sites and trials are seen to exceed the 55 dBA noise guidelines (Canada Mortgage and Housing, 1981). Thus, it is likely that increases in train traffic will further escalate the sound levels beyond the current guidelines.

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Course: ENVR 400
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Author Biographies

Maruska Giacchetto

Maruska, an effective communicator and listener, brought fieldwork experience to the team. She acquired this from coursework as well as her NSERC experience working on a Greenhouse Gas analysis project, involving water sample collection. She is excellent with time-management, is goal-oriented, and has experience with several computer programs such as Excel, R, and GIS.

Vivian (XiuXiu) Jiang

Vivian brought critical thinking and research skills to the project. Her experience doing a co-op in China working with environmental impact assessments, has given her a great deal of knowledge on air pollution (with a focus on total volatile organic compounds - TVOCs), chemical industrial production, real estate development, agricultural reclamation, and municipal infrastructure projects. Vivian's wide range of knowledge is also supplemented by the following skills: basic graphic design, research, and basic MATLAB and Excel skills.

Kelsey McDougall

Kelsey is a goal-oriented, organized, and responsible individual with an interest in how environmental factors affect human health. She brought her knowledge of atmospheric science, meteorology, and social based geography to this project, as well as her experience with fieldwork.

Mina Phaisaltantiwongs

Mina brought a positive attitude and strong work ethic, as well as knowledge from various coursework such as air pollution meteorology and atmospheric science to the project. In addition, she was capable of analyzing and visually representing environmental data and brought experience in project management and project presentation to the team.

Introduction

Port Metro Vancouver in 2014 approved the development of a Direct Transfer Coal Facility at Fraser Surrey Docks to handle up to four million metric tonnes of coal, implying an anticipated increase in freight train traffic along the Burlington Northern Santé Fe (BNSF) rail line (Port Metro Vancouver, 2014). The project was approved despite over 1,700 people signing a petition against the expansion of US Thermal coal traffic (Port Metro Vancouver, 2014).

Consequently, a group of citizens in the communities surrounding the BNSF railway has expressed concerns over health, property damage and environmental effects that could be caused by an increased in air, noise, and water pollution. These citizens formed a group called Communities and Coal and approached UBC Environmental Science 400 students for an assessment on current noise pollution from train traffic in the affected communities: White Rock, Surrey, and Delta. This research project will aid our community partner by gathering data that can be used for future comparisons after the construction of the Direct Transfer Coal Facility.

The impacts of trains travelling through residential areas can have significant health impacts on the surrounding communities (Babisch, 2005) and thus, is the main focus of our project for the Communities and Coal society. Noise pollution can be the cause of various health problems such as: headaches, insomnia, irritation, displaced aggression, discomfort, and raised blood pressure and heart rate due to arousal from sleep as trains pass (Zannin and Bunn, 2014; Dzhambov and Dimitrova, 2014; Sforza et al., 2004). Growth in train traffic has lead to increased noise pollution affecting residents in nearby homes and thus, increased concerns over these health issues (Port Metro Vancouver, 2014).

This project aims to investigate current noise pollution in several lower BC mainland communities (Delta, White Rock, and Crescent Beach/Surrey) from train traffic along the BNSF railway in the anticipation of increased train traffic by: 1) Comparing collected noise pollution data with existing noise guidelines; 2) Predicting the impact on noise levels as the number of trains per day increases; and 3) Determining the areas affected by the train traffic noise attenuation with distance and land use type.

Methods

Current noise pollution data was collected at four different sites along the BNSF railway (White Rock, Burns Bog, and two Crescent Beach sites, see Table 1) for two trials each, both of a 24-hour duration. The noise pollution monitoring occurred during various days of the week between November 2014 and March 2015. An EXTECH Sound Level USB Datalogger (Model 407760) with a basic accuracy of ± 1.4 dBA was used in order to collect the noise pollution data. The instrument was set up within approximately 40m of the train tracks. Monitoring only occurred on days without precipitation, for equipment protection, and to ensure that noise from precipitation events was not included in the results.

Table 1: A Summary of the noise pollution monitoring sites, dates monitored, and approximate distance from the tracks. See Appendix A for site selection criteria.

Site	Trial	Date Monitored	Approximate Horizontal Distance From Tracks (m)	Description of Factors Between the Tracks and Equipment
Crescent Beach #1	1	November 15, 2014	39.06	Road, Trees
	2	December 14, 2014		
White Rock	1	November 14, 2014	16.21	Nothing
	2	December 13, 2014		
Burns Bog	1	January 13, 2015	37.65	Pathway, Trees
	2	January 20, 2015		
Crescent Beach #2	1	January 30, 2015	30.29	Pathway, Trees
	2	March 1, 2015		

The approximate horizontal distance from the tracks was estimated using the ruler function in Google Earth.

In addition to monitoring the noise pollution, a trail camera was set up nearby so that photos could be taken for identifying the types of trains passing by. In particular, this was useful for distinguishing between freight trains and passenger trains.

Background Information: Noise

Sound is a succession of vibrating waves or oscillations of pressure energy transmitted in a fluid medium, such as air. The decibel (dB) is a logarithmic ratio of an actual sound pressure to a reference pressure level (P_0) of 20 µPa, which is the lowest sound pressure level that can be detected by an average person (see Appendix B, Equation 1) (Alberta Energy and Utilities Board, 2007). The A-weighted decibel (dBA) is the most common sound level used, as it does not capture low frequency sounds that cannot be detected by the human ear (Canadian Transportation Agency, 2011). In this experiment, all noise levels are presented in A-weighted decibels (dBA).

Equivalent continuous sound levels (L_{eq}) describe how sound varies over time. L_{eq} is presented as a single decibel value that takes into account the total sound energy over the period of time of interest (see Appendix B, Equation 1). Of particular importance to this paper are the L_{eq-24}, the sound exposure level over 24-hours, and L_{eq-16}, the sound exposure level over the daytime hours (07:00 to 23:00) (SS Wilson Associates, 2006). This paper also presents L_{eq} values where train noises have been removed from the data (i.e. $L_{eq\text{-}24\text{-}no\ trains}$ and $L_{eq\text{-}16\text{-}no\ trains}$).

L_{dn} is the day-night average sound level, which is the average of hourly L_{eq} values for 15 daytime hours (07:00 and 22:00) and the 9 nighttime hours (22:00 to 07:00). The nighttime hours are given an additional 10 dBA penalty. This penalty is added to account for the fact that noise is more disturbing at residential locations during these hours (Miedema, H., & Oudshoorn, C., 2001).

Three levels of government are responsible for different types of noise abatement. The federal government is responsible for aircraft and manufacturing noise. The federal government has been responsible to assess and create standards for those industries. Provincial governments are responsible for highway noise abatement. Provincial and federal governments are both responsible for industrial noise. Finally, municipality governments, under the supervision of the provincial government, are authorized to create noise by-laws. However, municipal by-laws are harder to enforce. Obtaining measurements is not an easy task and therefore most municipalities have suggestive regulations on noise levels (Canada Mortgage and Housing Corporation, 1981). For instance, the maximum recommended acceptable level of rail traffic noise in dwellings and in outdoor recreation areas in British Columbia is 55 dBA, as seen in Table 2 (Canada Mortgage and Housing Corporation, 1981). This corresponds to an indoor noise level of 40 dBA. Therefore, it is recommended to have nighttime outside average noise level lower than the recommended acceptable level. This 55 dBA recommended is confirmed in other locations across Canada as seen in the Federation of Canadian Municipalities and the Railway Association of Canada Noise Control Guideline (2013).

Table 2: Noise level and typical reactions from regular sound sources: Canada Mortgage and Housing Corporation (1981).

Sound Source	**Noise Level (dBA)**	**Typical Reaction**	**CMHC Requirements**		
			Categories	**dBA**	**Maximum in Specific Area**
Maximum Acceptable	135	Painful	Unacceptable		
Military Jet	130	Limit amplified speech	Unacceptable		
Jet Takeoff at 50m	120	Maximum vocal effort	Unacceptable		
Freight train at 15m	95	Very annoying/ hearing damage if continuous for 8hours	Unacceptable		
Heavy truck / busy city street	90	Annoying	Unacceptable		
Heavy traffic at 15m	80-70	Telephone use difficult	Unacceptable without adequate insulation	-75-	
Light traffic at 15m	60-50	Intrusive	Normally acceptable	-55-	Outdoor park (55 dBA)

Results

Monitoring Results

Table 3 shows a summary of the data collected over the different trials. Our results show that both L_{eq-16} and the L_{eq-24} levels exceed the guideline limit for all sites and trials (Figure 2). The L_{eq-16} sound levels are in the range of 7 to 20 dBA above the standard. The L_{eq-24} sound levels are 5 to 14 dBA above the guideline. As observed in figure 2A at Crescent Beach 1 trial 1 the $L_{eq-16-no\ train}$ is lower than the guideline, and all other trials exceed the suggested noise guideline. The $L_{eq-24-no\ train}$ (figure 2B) has two trial days that are slightly lower than the suggested guideline level (Crescent Beach 1 Trial 1, and Crescent Beach 2 Trial 2).

Table 3: Summary of the data collected over the different trials. All data is reported in dBA.

Sites	Trial Number	L_{eq-16}	L_{eq-24}	Min	Max	No Trains L_{eq-16}	No Trains L_{eq-24}
White Rock	1	68.4	64.9	19.1	101.1	61.1	57.2
	2	69.9	67.6	15.0	109.0	63.0	58.7
Crescent Beach 1	1	74.6	70.0	20.3	111.4	53.5	50.5
	2	74.4	68.2	27.9	109.5	60.6	57.0
Burns Bog	1	62.8	60.4	28.2	91.6	60.6	56.6
	2	62.1	59.1	19.8	89.0	59.7	56.5
Crescent Beach 2	1	75.3	70.6	40.1	111.6	67.4	63.1
	2	72.6	69.5	19.3	109.7	58.2	53.9

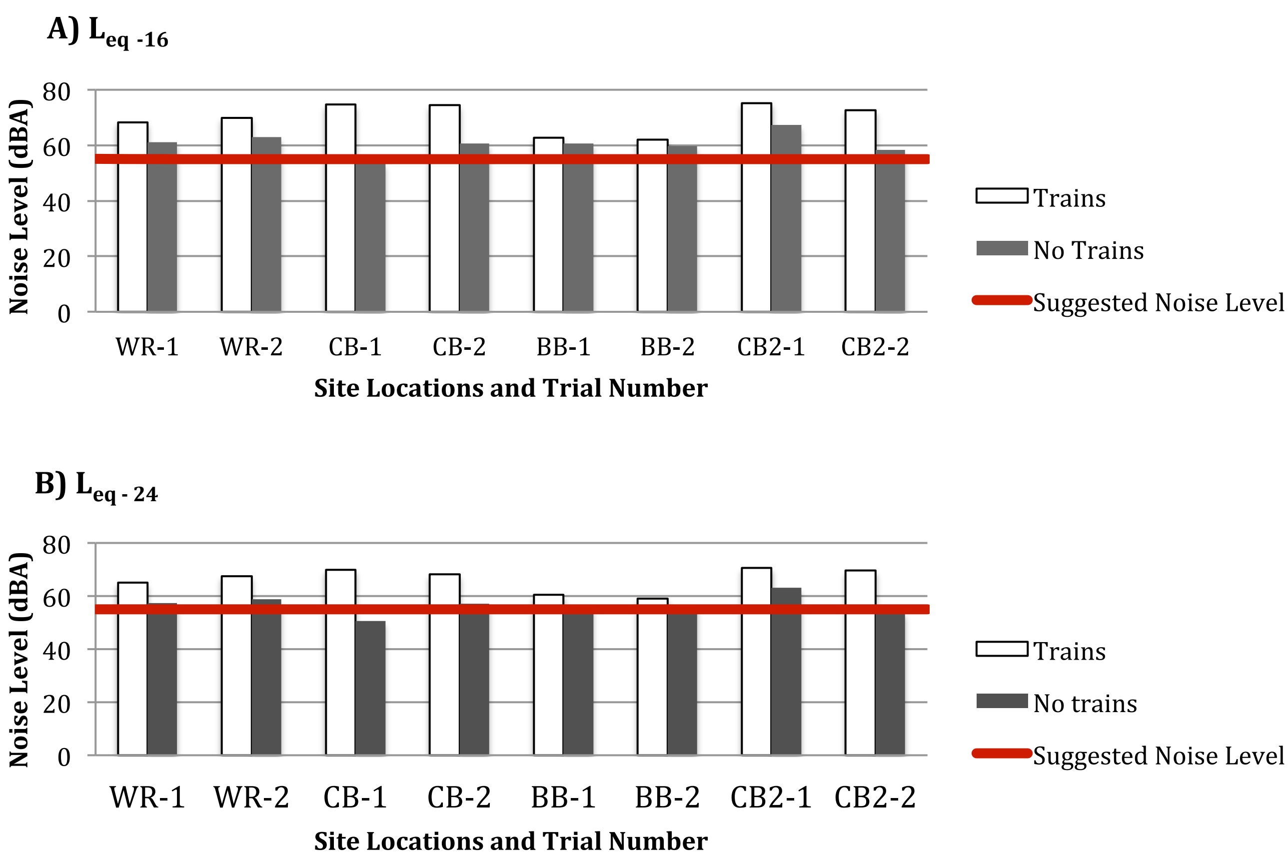


Figure 2: Equivalent Continuous Sound Levels for: a) for a time period of 16 hours (07:00-23:00), $L_{eq\text{-}16\,h}$ (dBA); b) a time period of 24 hours, $L_{eq-24\,h}$ (dBA), for each monitoring trial at each site (White Rock, Crescent Beach 1, Burns Bog, and Crescent Beach 2). This graph includes L_{eq} calculations for both trains and no trains. Also shown is the noise guideline of 55 dBA as outlined in the Canada Mortgage and Housing Corporation (1981).

Noise Attenuation Results

The noise attenuation was calculated based on equations from Canada Mortgage and Housing (1981) and are dependent on whether the ground type is classified as soft or hard (see Appendix B). The maximum noise levels are associated with hard ground while the minimum noise levels are associated with soft ground (Canada Mortgage and Housing, 1981). Based on the calculation method, the noise attenuation buffer is fixed at a 450m distance from the train track. The minimum distance across all sites at which the noise attenuation is seen to be below the suggested guideline is found at 90m from the track (Burns Bog) for the $L_{eq\text{-}24}$ and 112m from the track (Burns Bog) for the $L_{eq\text{-}16}$. At some sites the noise attenuation is higher than the guideline even at the end of the 450m buffer. No barriers were accounted for in these calculations, thus, the attenuation graphs shown in Figure 3 and 4 are overestimates of the actual noise levels at these sites.

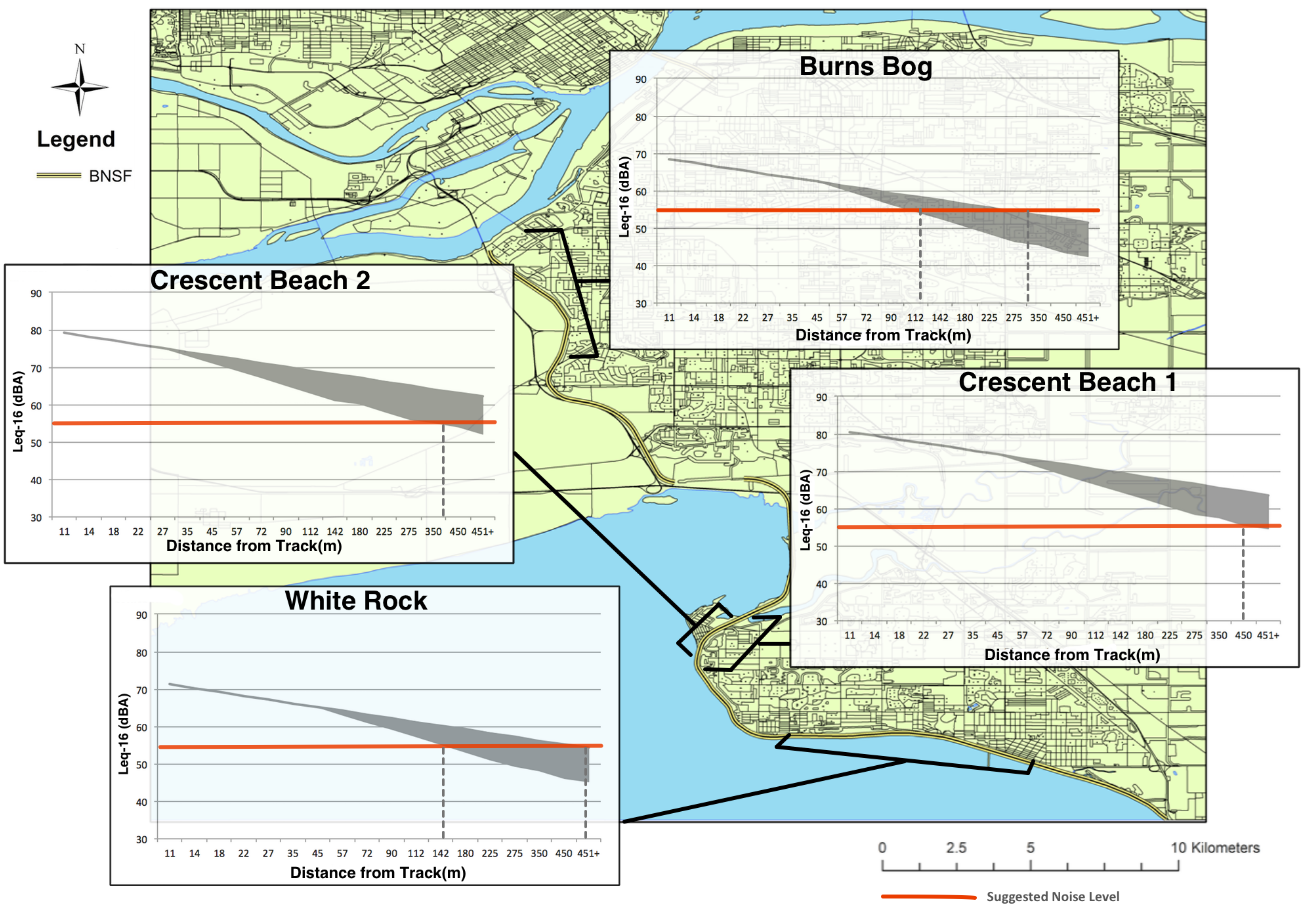


Figure 3: $L_{eq\text{-}16}$ (dBA) noise attenuation at the four different sites along the BNSF rail line. The dotted lines represent the distance at which the suggested guideline is met. Map obtained from DMTI (2013).

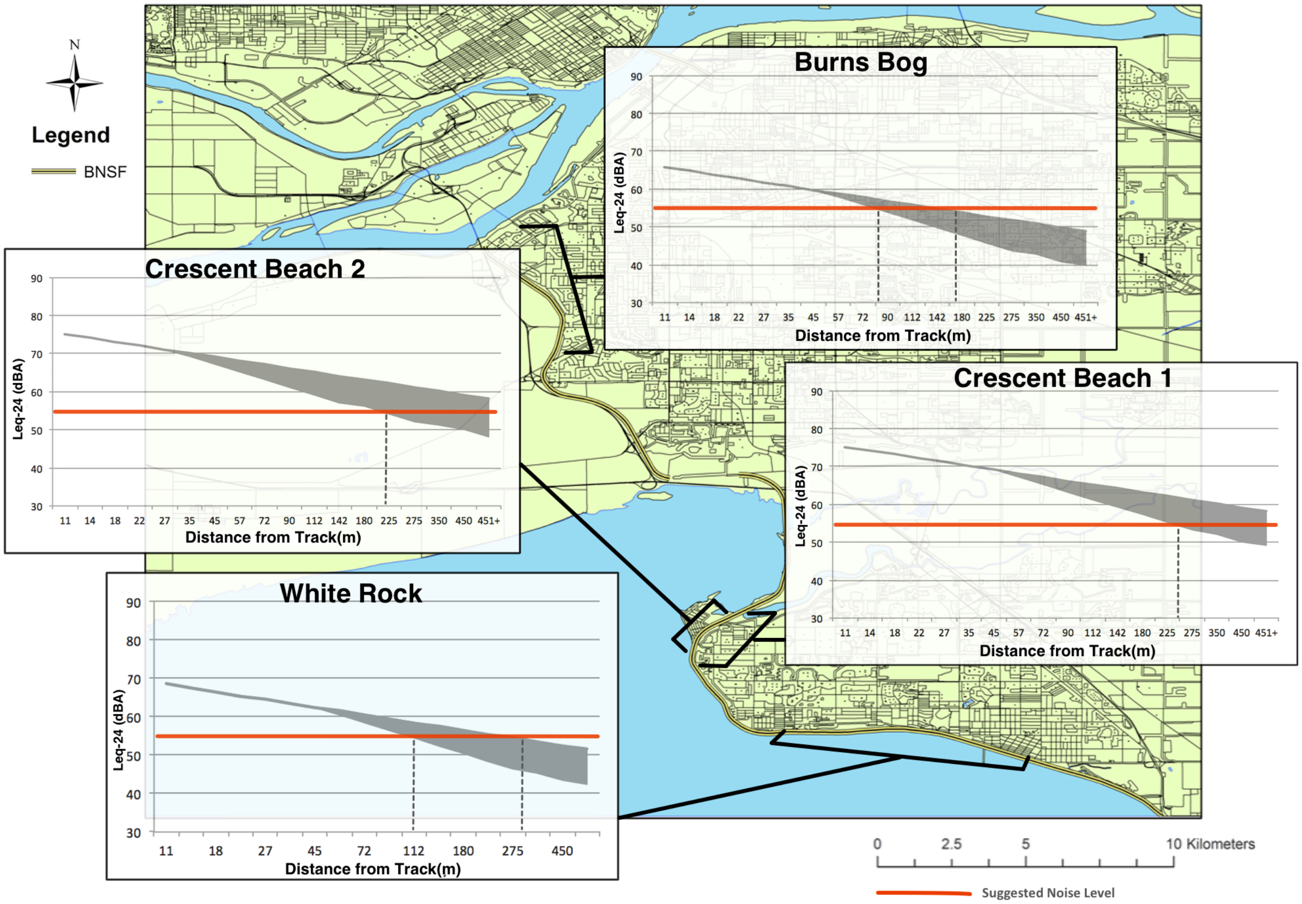
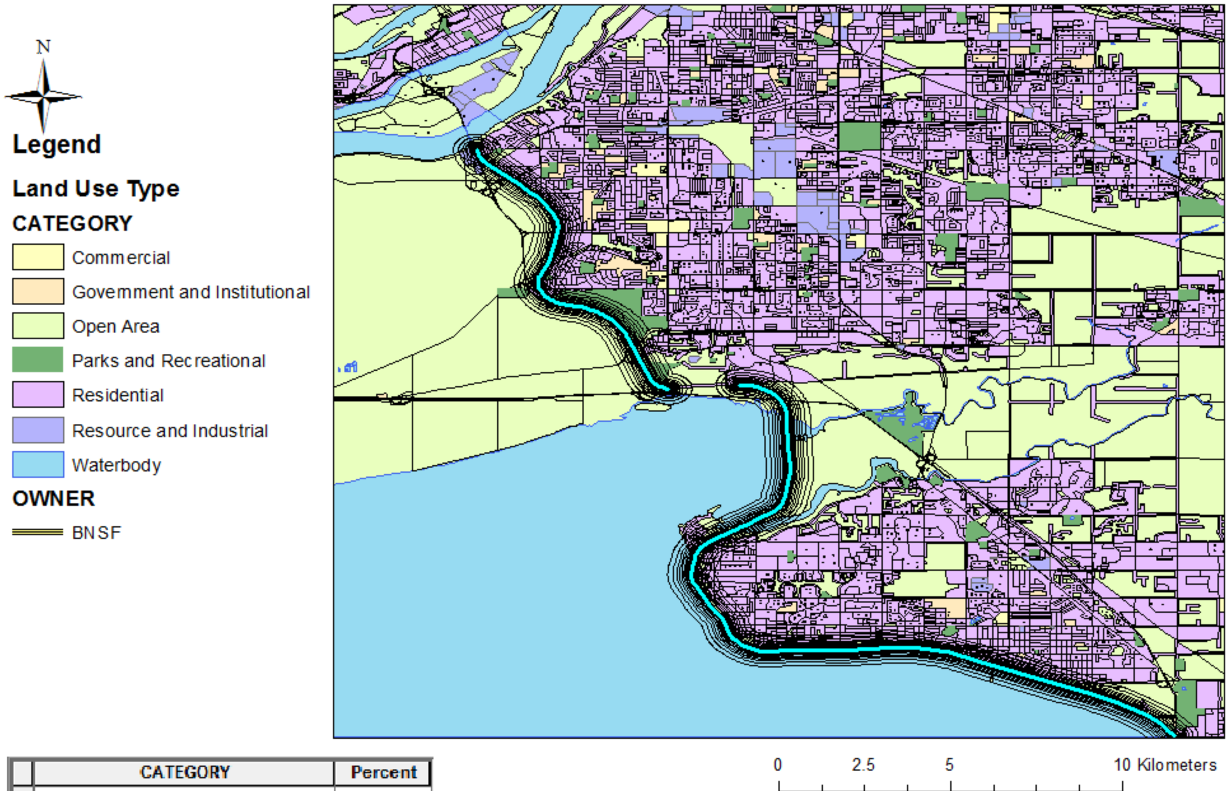


Figure 4:$L_{eq\text{-}24}$ (dBA) noise attenuation at the four different sites along the BNSF rail line. The dotted lines represent the distance at which the suggested guideline is met. Map obtained from DMTI (2013).

Present Implications

Currently, all $L_{eq\text{-}16}$ and $L_{eq\text{-}24}$ exceeded the recommended 55 dBA. According to Canada Mortgage and Housing Corporation (1981), these levels of noise correspond to a category of unacceptable (refer Table 2). Further investigation should be considered in these communities as a result of the anticipated increase in U.S. thermal coal trains. As Figure 5 shows the current noise levels are crucial to take into account because within 450m of the track 33% of land use area is found to be residential. Within these residential areas lie certain sensitive functions such as educational facilities and healthcare centers (Figure 6). The analysis showed that Ocean Cliff Elementary School and Buena Vista Rest Home fall within 450m of the track.



CATEGORY	Percent
Commercial	0
Government and Institutional	1
Open Area	34
Parks and Recreational	5
Residential	33
Resource and Industrial	7
Waterbody	21

Figure 5: Land use type falling within a 450m noise attenuation buffer of the BNSF rail line. GIS data obtained from DMTI (2013).

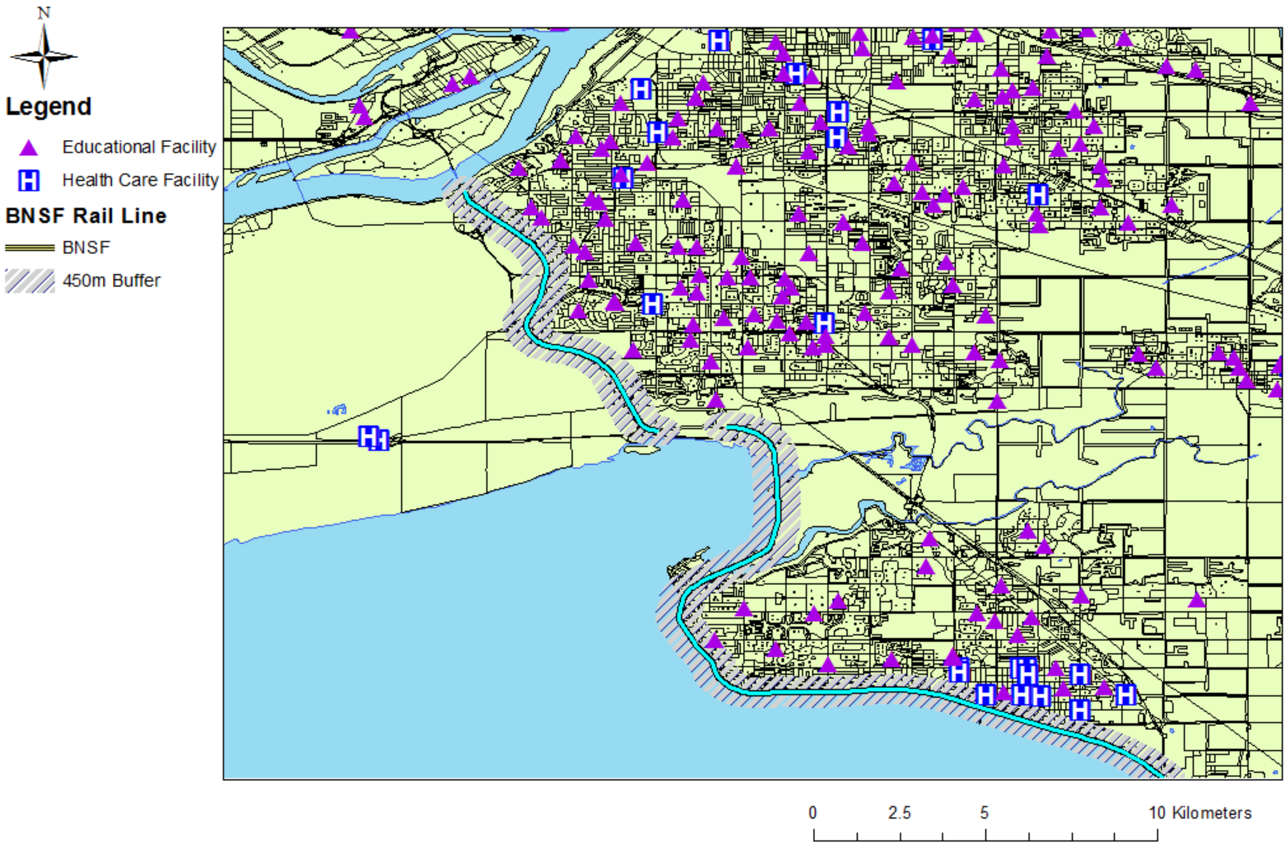


Figure 6: Educational facilities and healthcare centers in the lower BC mainland depicted with the BNSF rail line and a 450m attenuation buffer. GIS data obtained from DMTI (2013).

Specifically, the noise generated by train is associated with the engine, the whistle and the friction created by the wheel on the rail. Train whistles are required to sound as a warning 400m before a target is reached (Canada Mortgage and Housing Corporation, 1981). The propagation of the noise from those sources is very different and further investigation should be done in the lower Mainland in order to assess and evaluated the impact of each component separately.

Health Canada (2010) suggests that studies undergo analyses on the percentage of a population that are annoyed when operational sounds are within the range of 45-75 dBA. This project uses equations presented by Miedema and Oudshoorn (2001) to calculate the percentage of the population that would either be lightly annoyed, annoyed, or highly annoyed near railways from L_{dn} values. We used these equations to identify the annoyance impact on the surrounding populations in the affected communities. Annoyance can cause sleep interference, and overall impacts on health (Zannin and Bunn, 2014). Sleep interference depends specifically on the rapid change in noise level, not on the exact sound level itself (i.e. from a background noise dBA level to a train passing by). Nighttime indoor maximum levels range from 25-35 dBA (Canada Mortgage and Housing Corporation, 1981).

This project methodology does not allow for the comparison of annoyance levels to a baseline noise environment (i.e. a control area with no train traffic), therefore it is not possible to adequately predict health effects through Health Canada's method (2010). It is possible to predict health effects if, when compared to a baseline noise environment, there is a 6.5% difference in percent of highly annoyed individuals. If this is observed, Health Canada (2010) suggests that mitigation measures to limit noise are implemented. The noise from railways may be reduced by the presence of a barrier. However trees are not considered as a significant protection as it provides no significant shielding. For instance, to obtain a reduction of 10 dBA, it is recommended to have a barrier of 5 kg/m^2 and 10 kg/m^2 for greater attenuation (Canada Mortgage and Housing Corporation, 1981).

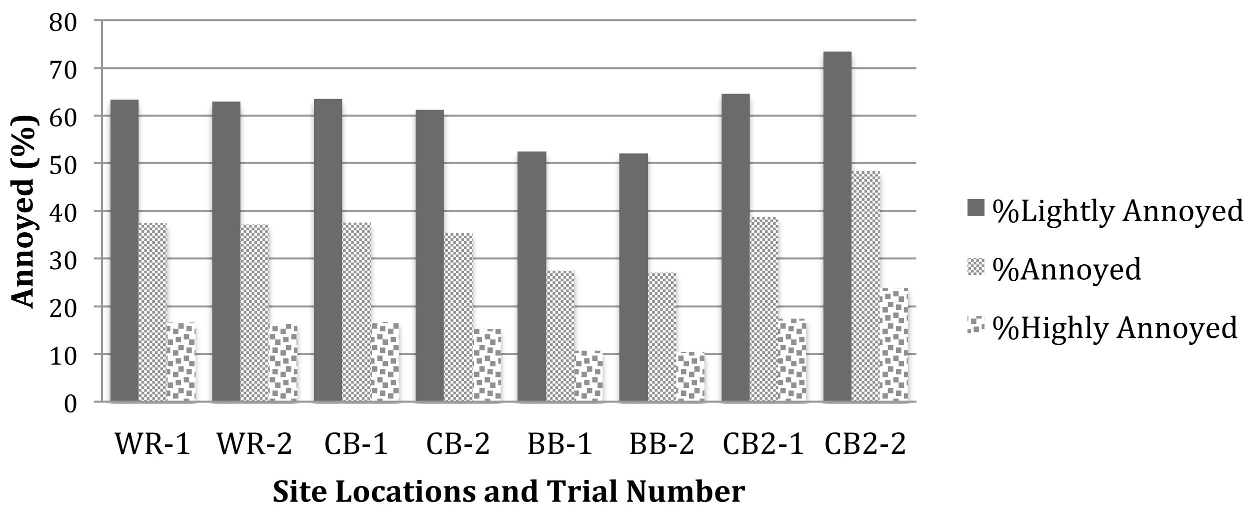
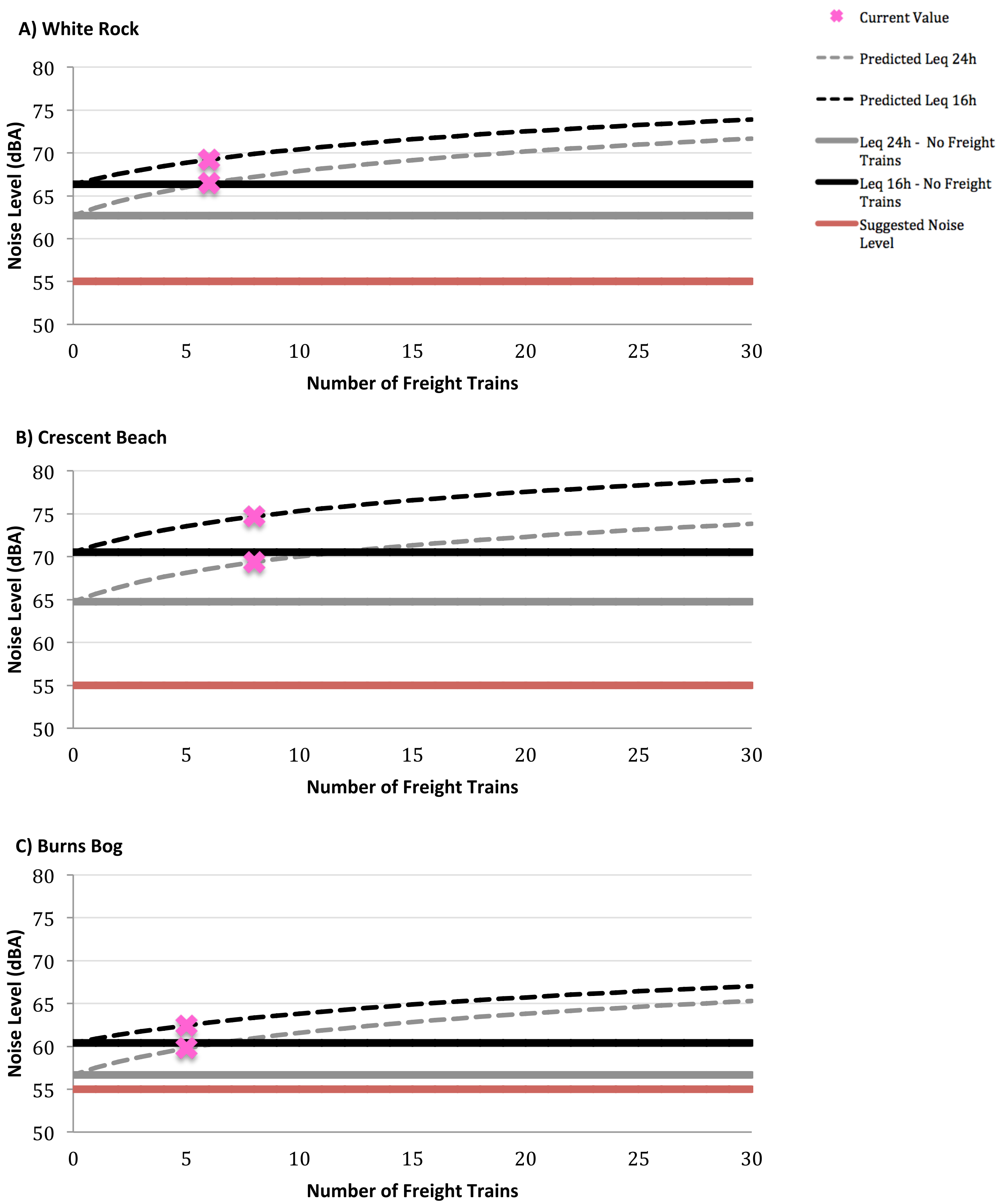


Figure 5: Percentage of the population that would be Lightly Annoyed, Annoyed, or Highly Annoyed for the different trial days at the specific distances of monitoring for each site. This calculation was off of the L_{dN} values (see Appendix B).

Based on our annoyance analysis, Figure 5, at all sites over 50% of the population would be lightly annoyed, over 25% would be annoyed and over 10% of the population would be highly annoyed with the current sound levels being emitted from the tracks. A survey was conducted in the different communities, out of the 20 individuals who responded the percentage of response that indicated that trains affect their lifestyle and sleep was approximately 30% and 20% respectively. These percentages are similar to that of the population that would be annoyed (see Appendix C).

Future Implications

Figure 6 shows the prediction of the impact of increasing number of freight trains on noise levels (see Appendix B for methods). It should be noted that our methodology assumed that passenger train traffic and average background noise levels stayed constant. Our results show that as the number of freight trains increases, the noise levels increased at a diminishing rate. With an increase in freight train traffic, we see that noise levels exhibit a larger difference from the suggested guidelines. This is of particular concern as the calculated L_{eq-16} and L_{eq-24} hours are already exceeding the 55 dBA guidelines.


A) White Rock
B) Crescent Beach
C) Burns Bog
Noise Level (dBA)
80
75
70
65
60
55
50
0
5
10
15
20
25
30
Number of Freight Trains
Current Value
Predicted Leq 24h
Predicted Leq 16h
Leq 24h - No Freight Trains
Leq 16h - No Freight Trains
Suggested Noise Level

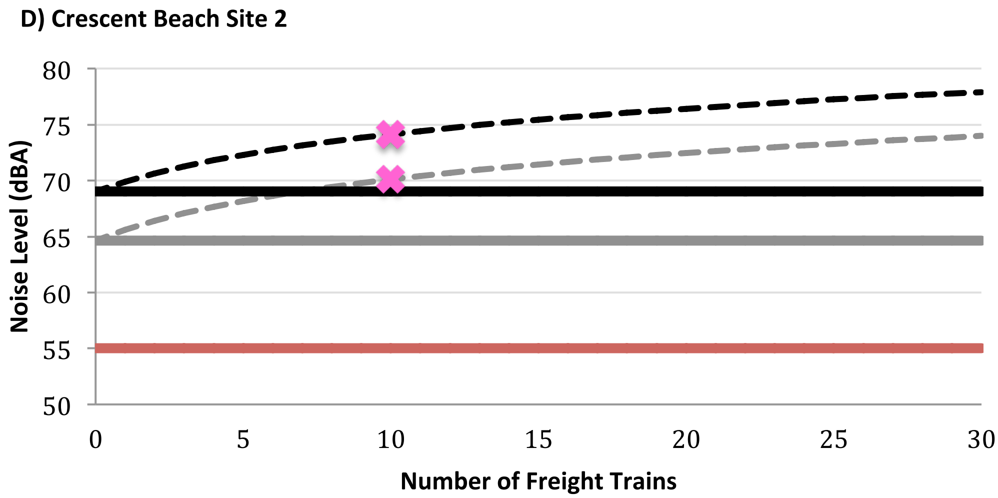


Figure 6: Predictions on the effect of increasing the number of freight trains at four different sites (A- White Rock, B- Crescent Beach, C- Burns Bog, and D- Crescent Beach Site 2) on the overall noise level (either $L_{eq\text{-}16}$ or $L_{eq\text{-}24}$). See Appendix B for the methods.

Limitations

This project has four main limitations associated with the methods and data. Firstly, the number of trial days and site locations is limited and do not extend into the summer months. Secondly, the railway companies do not provide information on train schedules or cargo contents of the freight trains, making predictions of future train traffic and noise level increases difficult to assess. Thirdly, there was difficulty in matching nighttime pictures with the type of train due to picture quality, however Burns Bog Trial 1 and Crescent Beach 2 Trial 1 do not have this difficulty due to volunteer train observers. Lastly, a complete assessment of the ground type and barriers at each location were not taken into account in our calculations of noise level. Therefore, the accurate attenuation cannot be provided.

Conclusion and Future Recommendations

Our project provides evidence to support the conclusion that at all of the sites, the equivalent continuous sound level (L_{eq}) for 16-hour and 24-hour periods are exceeding the recommended standards of 55 dBA in British Columbia (1981). Therefore, an increase in U.S thermal coal is likely to further contribute to regulation exceedance.

We suggest that future research include a longer time span of observation on noise pollution and more trials at each site in the BC Lower Mainland in order to ensure statistical significance. Also, we highly recommend further monitoring on the coal train traffic through the affected communities as the Direct Transfer Coal Station will be built at Fraser Surrey Docks. As well, we would also like to recommend that noise attenuation studies be performed and that sound levels be measured from different distances at the sites. This is recommended as the noise attenuation calculations in this report were overestimates that did not include for barriers.

Furthermore, it would be beneficial to investigate the affects of acute exposure to the maximum sound levels versus the chronic exposures from long-term average noise levels.

In addition, it would be highly interesting to study and measure noise levels experienced by the individuals inside of their homes. This would provide further understanding of whether house infrastructure is an adequate barrier for the sound levels emitted from the train and to assess health impacts caused by the sound levels individuals experience within their homes.

Finally, we recognize that our study focuses primarily on human health, thus we would like to suggest that an ecological impact health study be performed. The purpose of this would be to determine how increases in noise levels would affect the wildlife in the surrounding area. Of particular importance, attention should focus on birds specifically as there is a bird sanctuary located at Crescent Beach. This is an area of interest expressed by our community partner.

Acknowledgments

We would like to thank our professors and advisors, Tara Ivanochko and Sara Harris, for their expertise. To Murray Hodgson for his input into the analysis of our data. To Rajiv Bhatia, Ian McKendry, and the UBC EOAS department for providing us with equipment. Last, but not least, to our community partner Stephanie Smith for her passion about the project, and to her group of volunteers for lending us the use of their backyards.

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Appendix

Appendix A: Site Selection Criteria

Site Selection Criteria:
Four sites were selected during a site survey visit, based on the following criteria:

- Land use considerations (i.e. is the land being used for sensitive functions such as residences, schools, parks and open spaces, churches, health care facilities, with an emphasis on residential areas)
- Secure access to monitoring location
- Proximity of monitoring site to the rail line (within ~1000 feet or 300 meters)
- Presence of noise sources that produce significant levels of background or intermittent noise (e.g. freeways; construction sites)
- Consideration of community partner priority and preferences for locations

Appendix B: Noise Pollution Data Analysis Methods

Noise Pollution Data Analysis Methods

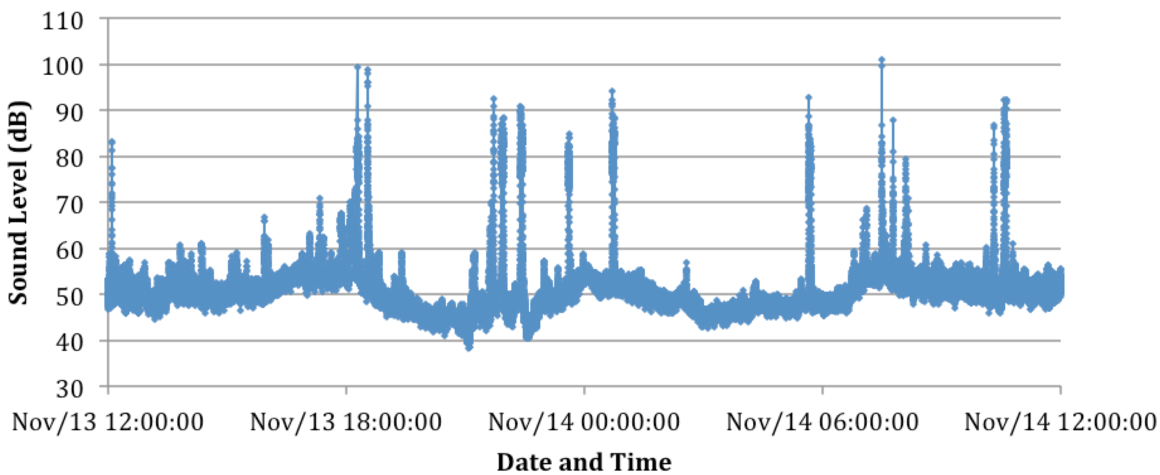
The sound level data was collected in 1 second intervals during a 24 hour time period for 8 different days. We formatted all the raw data into excel files for each day, plotted them into graphs (see Figure B-1), identified the time that sound peaks presented in each day, and we compared these time intervals with pictures taken by a trail camera to identify the passage time of all trains. We used the images to distinguish passenger trains and freight trains for each day. Then, we did statistical analysis on train durations (see Figure B-2)

For all noise pollution data when undergoing any calculations on the decibel level, a conversion to sound pressure level must first be calculated (see Equation 1).

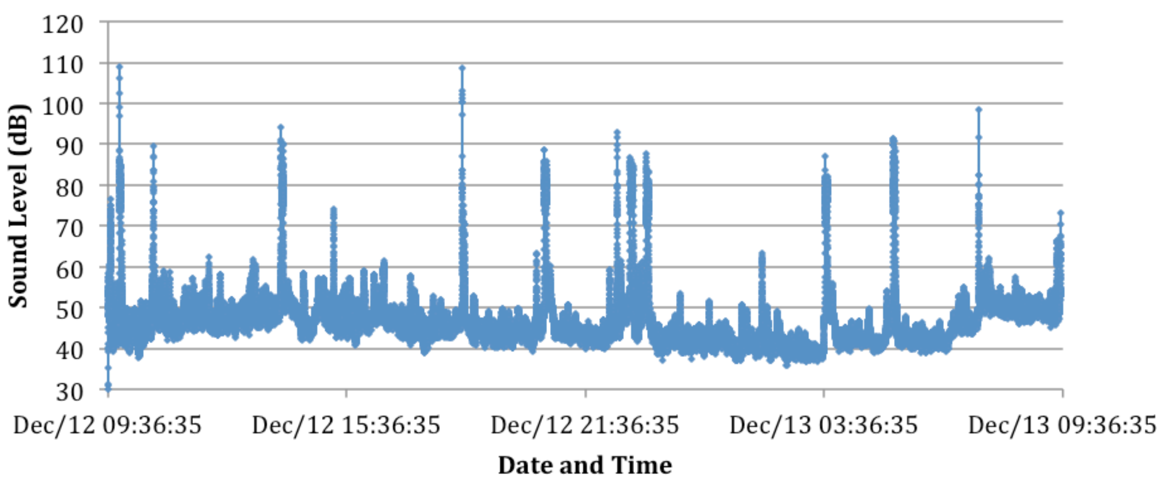
Equation 1: $L_{dB} = 10 \log_{10}(\frac{P_1}{P_0})$ (Alberta Energy and Utilities Board, 2007)

Raw Data

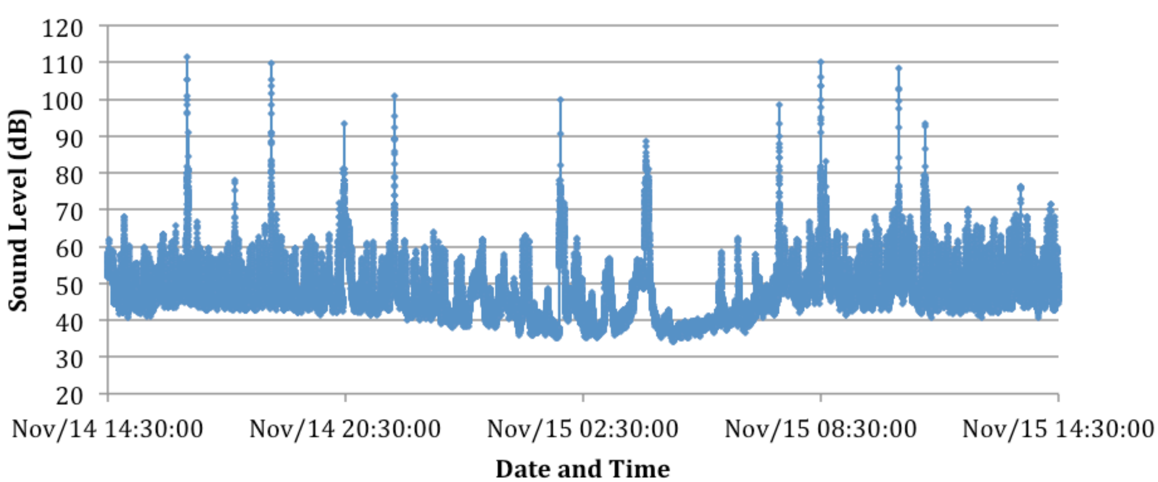
A) White Rock – Trial 1



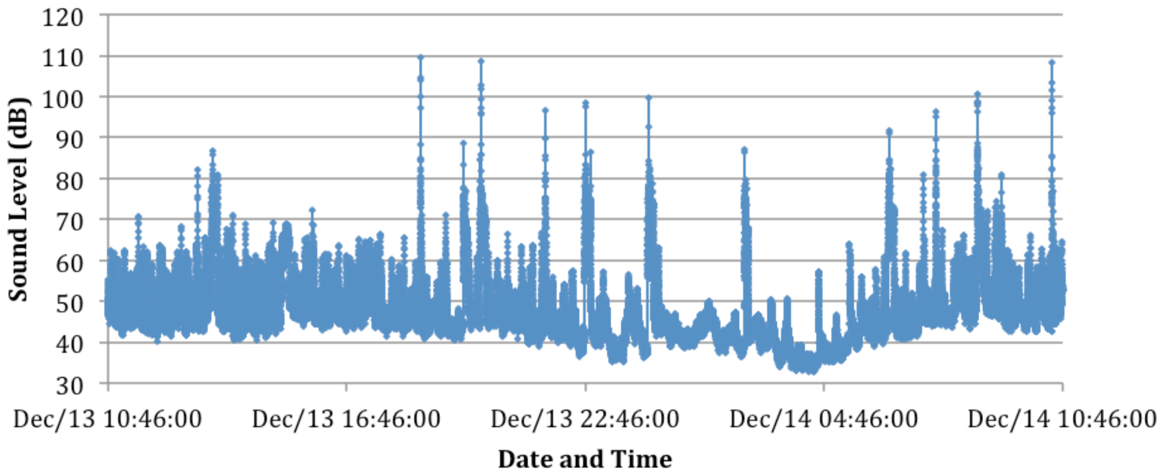
B) White Rock – Trial 2



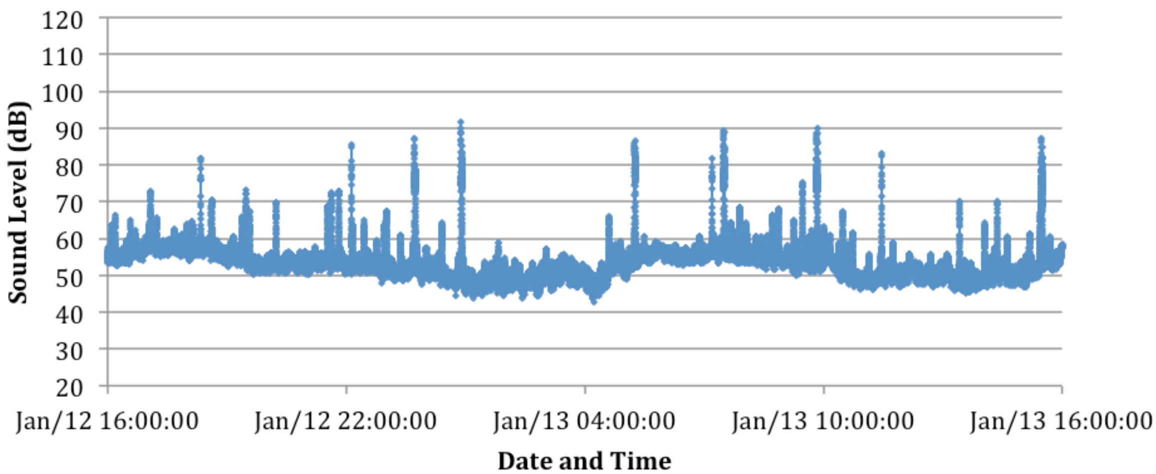
C) Crescent Beach – Trial 1



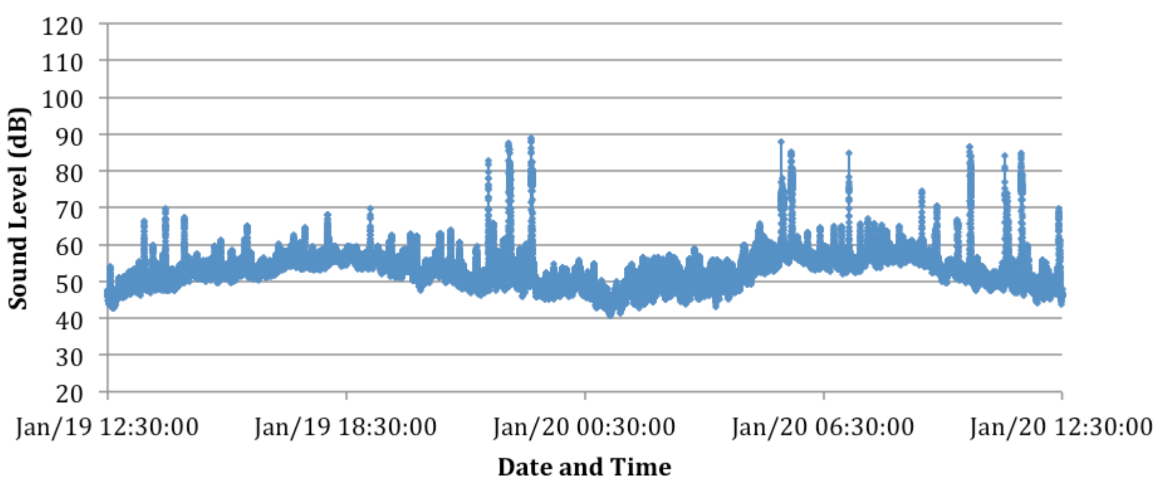
D) **Crescent Beach – Trial 2**



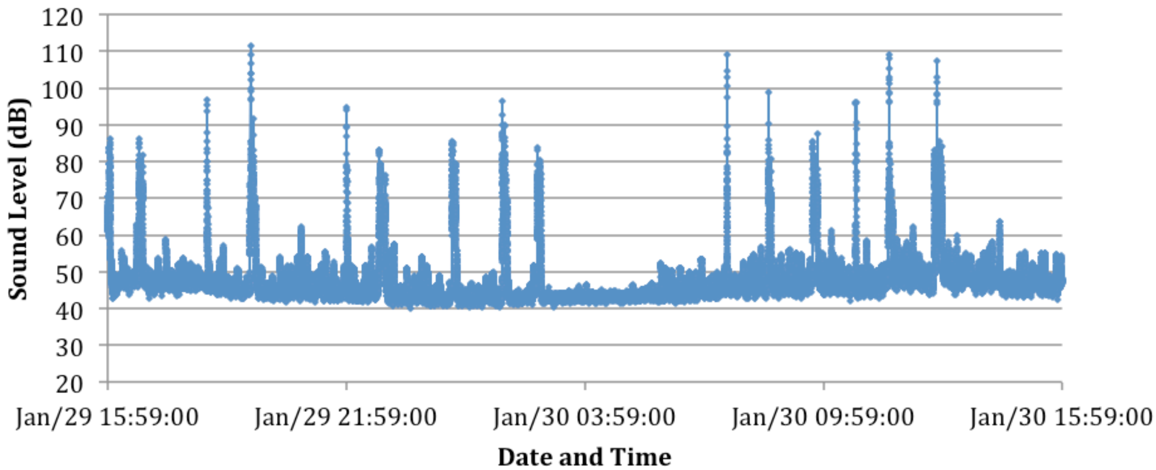
E) **Burns Bog – Trial 1**



F) **Burns Bog – Trial 2**



G) Crescent Beach Site 2 – Trial 1



H) Crescent Beach Site 2 – Trial 2

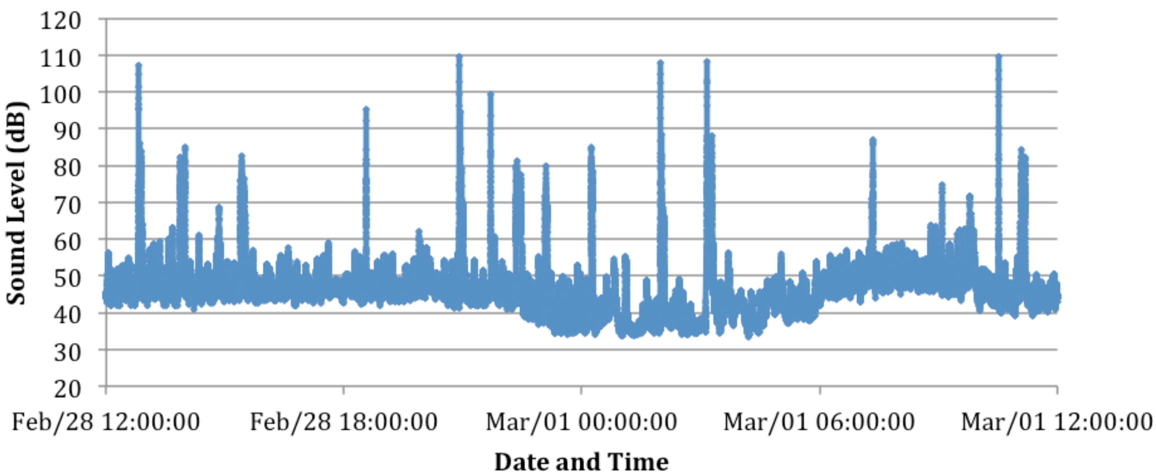


Figure B-1: Raw noise pollution data for each site and trial.

Duration

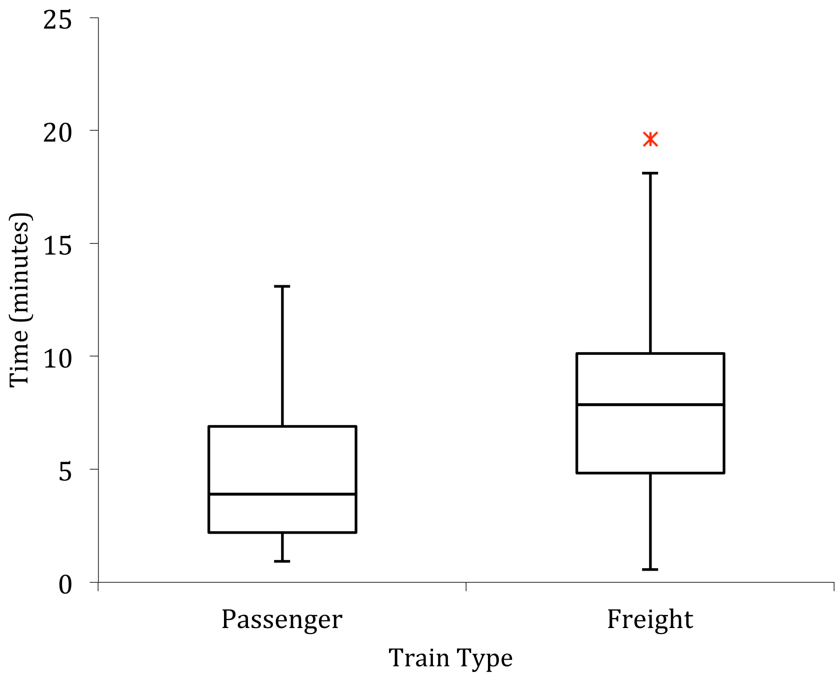


Figure B-2: Box plot for the train duration (minutes) for passenger and freight trains. The mean duration value for passenger trains was 3.9 minutes and 7.9 minutes for freight trains. The red x signifies an outlier.

Average Noise

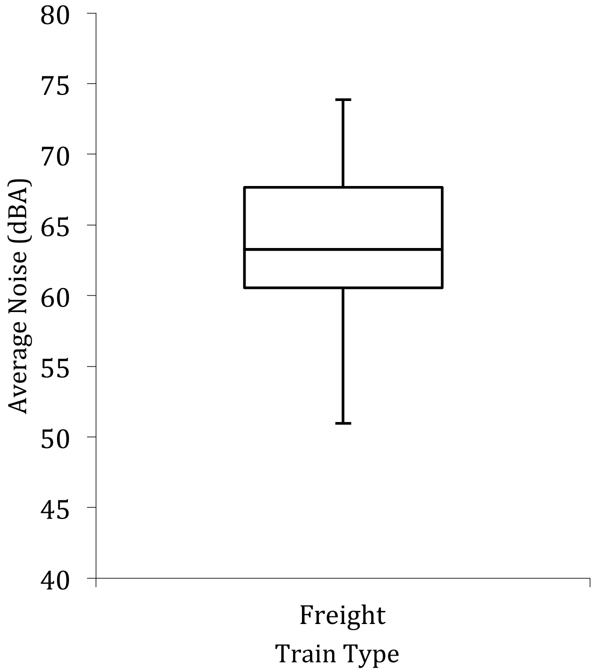


Figure B-3: Box plot for the average noise emitted by freight trains calculated across all trials. The mean value was 63.3 dBA.

L_{eq} Calculation

Due to the large quantity of sound data and the complexity of calculations, we decided to use MATLAB to do the data analysis. First, we calculated $L_{eq\text{-}24}$ and $L_{eq\text{-}16}$ for all days (using Equation 2, and the values f_i= 1/86400 s and f_i= 1/57600s, respectively). $L_{eq\text{-}24}$ was calculated for the entire day, while $L_{eq\text{-}16}$ was calculated from 07:00 to 23:00. For our data sets the hours in which data was collected is not constant, therefore for example for Trial 1 at the White Rock site in order to calculate the $L_{eq\text{-}16}$ we used the hours from 12:00 to 23:00 from November 14th and 07:00 to 11:59 on November 15th.

Next, we calculated the $L_{eq\text{-}24\ no\ trains}$ and $L_{eq\ \text{-}16\ no\ trains}$ for all days. This was done by averaging the data 30 minutes to 2 minutes before and after the passing of each train (identified via pictures or volunteers). These averages were then used to replace the original sound level (L_i) recorded during the train passing. The L_{eq} values were then determined using the same method as when calculating the $L_{eq\text{-}24}$ and $L_{eq\text{-}16}$.

Equation 2: $L_{eq} = 10\log\left(\sum_{i=1}^{n} f_i \times 10^{L_i/10}\right)$ (Alberta Energy and Utilities Board, 2007)

L_i = the sound levels observed at any spaced times during the interval T

F_i = fraction of total time in the constant level L_i is present

L_{dn} Calculations

L_{dn} was calculated based off the hourly L_{eq} values (see Equation 3). In order to calculate hourly L_{eq} values Equation 2 was used, however instead of using a 24-hour period, 1 hour (f_i = 1/3600) was used. This was then repeated for every hour in the 24-hour period, and for every different trial day. An L_{day} value was then calculated to determine the day equivalent level, this was done by averaging the sound pressure levels from the hours from 07:00 to 22:00, then converting back to dBA. Then the L_{night} value was then calculated for the hours between 22:00 and 07:00, using the same method.

Equation 3: $L_{dn} = 10\times \log_{10}(\left(\frac{15}{24}\right)\times 10^{\frac{L_{day}}{10}} + \left(\frac{9}{24}\right)\times 10^{\frac{L_{night}+10}{10}})$ (Miedema and Oudshoorn, 2001)

%A, %LA, %HA Calculations

Using the calculated L_{dn} values for each site the percentage a population that would be annoyed, lightly annoyed, or highly annoyed was calculated. These values were based off of equations presented by Miedema and Oudshoorn (2001) specifically for railway noise - see Equations 4, 5 and 6.

Equation 4: $\%LA = -3.343\times 10^{-4}(L_{dn} - 32)^3 + 4.918\times 10^{-2}(L_{dn} - 32)^2 + 0.175(L_{dn} - 32)$

Equation 5: $\%A = 4.552\times 10^{-4}(L_{dn} - 37)^3 + 9.400\times 10^{-3}(L_{dn} - 37)^2 + 0.212(L_{dn} - 37)$

Equation 6: $\%HA = 7.158\times 10^{-4}(L_{dn} - 42)^3 - 7.774\times 10^{-3}(L_{dn} - 42)^2 + 0.163(L_{dn} - 42)$ (Miedema and Oudshoorn, 2001)

Noise Attenuation

Noise attenuation for up to 450m from the railway tracks was calculated based off of Canada Mortgage and Housing (1981), using Table B-1. Effective heights were calculated by determining the source and receiver heights. The source height is the height of the train, which is assumed to be a constant 4 m (Canada Housing and Mortgage, 1981). The receiver height was calculated by adding the elevation change and the height at which the microphone was set up. The elevation was calculated using Google Earth from the train track to where the microphone was set up.

Table B-1: Noise attenuation (in dBA) for a horizontal distance from source to receiver at an effective height. Table obtained from Canada Mortgage and Housing (1981, p.45, Table 4.4).

Effective Total Height Above Ground (metres)	HORIZONTAL DISTANCE IN METRES FROM SOURCE TO RECEIVING POINT																	
	up to 11	11 to 14	15 to 18	19 to 22	23 to 27	28 to 35	36 to 45	46 to 57	58 to 72	73 to 90	91 to 112	113 to 142	143 to 180	181 to 225	226 to 275	276 to 350	351 to 450	451 or over
	Correction in dB if acoustically "soft" surface																	
58.0 or over	+5	+4	+3	+2	+1	0	−1	−2	−3	−4	−5	−6	−7	−8	−9	−11	−13	−15
45.1 to 57.0	+5	+4	+3	+2	+1	0	−1	−2	−3	−4	−5	−6	−7	−8	−10	−12	−14	−16
36.1 to 45.0	+5	+4	+3	+2	+1	0	−1	−2	−3	−4	−5	−6	−7	−9	−11	−13	−15	−17
28.1 to 36.0	+5	+4	+3	+2	+1	0	−1	−2	−3	−4	−5	−6	−8	−10	−12	−14	−16	−18
22.1 to 28.0	+5	+4	+3	+2	+1	0	−1	−2	−3	−4	−5	−7	−9	−11	−13	−15	−17	−19
18.1 to 22.0	+5	+4	+3	+2	+1	0	−1	−2	−3	−4	−6	−8	−10	−12	−14	−16	−18	−20
14.1 to 18.0	+5	+4	+3	+2	+1	0	−1	−2	−3	−5	−7	−9	−11	−13	−15	−17	−18	−20
11.1 to 14.0	+5	+4	+3	+2	+1	0	−1	−2	−4	−6	−8	−10	−12	−14	−16	−17	−19	−21
9.1 to 11.0	+5	+4	+3	+2	+1	0	−1	−3	−5	−7	−9	−11	−13	−15	−17	−18	−20	−21
7.1 to 9.0	+5	+4	+3	+2	+1	0	−2	−4	−6	−8	−10	−12	−14	−16	−17	−19	−20	−22
5.6 to 7.0	+5	+4	+3	+2	+1	−1	−3	−5	−7	−9	−11	−13	−14	−16	−18	−19	−20	−22
4.1 to 5.5	+5	+4	+3	+2	0	−2	−4	−6	−8	−10	−12	−14	−15	−17	−18	−20	−21	−23
2.6 to 4.0	+5	+4	+3	+1	0	−2	−4	−6	−8	−10	−12	−14	−16	−18	−19	−21	−22	−24
up to 2.5	+5	+4	+3	+1	−1	−3	−5	−7	−9	−11	−13	−15	−17	−19	−21	−22	−23	−25
	Correction in dB if acoustically "hard" surface																	
All Heights	+5	+4	+3	+2	+1	0	−1	−2	−3	−4	−5	−6	−7	−8	−9	−10	−11	−12

Noise Projection Calculations

For the projection calculations we used the average $L_{eq\text{-}total}$ value (see equation 2) that incorporates the background noise, the freight train noise and the passenger train noise, then subtracted the average $L_{eq\text{-}no\ freight}$ which only incorporates the background noise and passenger train noise. To subtract these two L_{eq} values from each other they must be first converted to sound pressure levels (i.e. $10^{(Leq/10)}$). The average L_{eq} values were calculated for each site by averaging the two different trial days. Next this difference was divided by the average amount of trains that passed by at each respective site over the two different trial days. This provides a value that is the overall impact on L_{eq} due to the passing of one averaged freight train, respective for each site. Lastly, this value was multiplied by the number of predicted trains (0-30) and added to the $L_{eq\text{-}no\ freight}$ values.

Appendix C: Survey Questionnaire and Results

Earth, Ocean and Atmospheric Sciences

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Consent Form

The Effect of Coal Trains on Noise and Air Pollution in the British Columbia Lower Mainland: A Partnership with Communities and Coal

Who is conducting the study?

Principal Investigator: Sara Harris, Earth, Ocean and Atmospheric Sciences, Senior Instructor Phone: 604-822-9651 *Co-Investigators:* Undergraduate students in the Faculty of Science at The University of British Columbia (UBC): Mina Phaisaltantiwongs, Kelsey McDougall, Xiuxiu Jiang, Maruska Giacchetto Phone: 1-778-215-5552

The study is being conducted in conjunction with the Communities and Coal Society, a group of lower Mainland residents concerned about coal train traffic.

Why are we doing this study?

This study will help us evaluate the affect of noise pollution from Coal trains and how it affects citizens in the surrounding communities. This questionnaire will take about 15 minutes to complete.
Metro Vancouver has approved the Fraser Surrey Docks project, involving the construction of a direct transfer coal facility in British Columbia, which will receive about 8 million metric tons of thermal coal. The coal is currently transported from the United States via trains passing through British Columbian communities such as White Rock, South and North Surrey and Delta.

How is the study done?

We will give you a questionnaire to answer. If the questionnaire is completed, it will be assumed that 1) you have given consent to participate AND 2) that you are 19 years of age or older. Some of the questions we ask may seem personal. You do not have to answer any question if you do not want to. There is no compensation for the completion of the survey.

What will happen to the study results?

The results of this study will be shared with the Communities and Coal Society. There are no immediate benefits to participating, but, in the future, others may benefit from what we learn. Participants' privacy is ensured by keeping the questionnaire anonymous. All completed questionnaires will be kept in a secure location.

Questions?

If you have any questions or concerns about what we are asking of you, please contact the principal investigator or the co-investigators. The names and telephone numbers are listed above. If you have any concerns or complaints about your rights as a research participant and/or your experiences while participating in this study, contact the Research Participant Complaint Line in the UBC Office of Research Services at 604-822-8598 or if long distance e-mail RSIL@ors.ubc.ca or call toll free 1-877-822-8598.

Earth, Ocean and Atmospheric Sciences

UBC

THE UNIVERSITY OF BRITISH COLUMBIA

Questionnaire

The Effect of Coal Trains on Noise and Air Pollution in the British Columbia Lower Mainland: A Partnership with Communities and Coal

If the questionnaire is completed, it will be assumed that consent has been given

Questions:

1) Do the trains affect your health in any way?

2) Do the trains affect your or sleep schedule?

3) Have you noticed any change in the frequency of the trains?

4) Are you aware of the content transported by the freight train? If so, what do they contained?

5) Do trains interfere with your lifestyle in any significant way?

6) Have you noticed any changes on animal behaviours?

Les effets de train de charbon sur la pollution sonore et qualité de l'air dans le Lower Mainland de la Colombie-Britannique: En partenariat avec Communities and Coal

Si le questionnaire est complété, consentement sera assumé

Questions:

1) Est-ce que les trains affectent votre sante physique. SI oui, comment?

2) Est-ce que les trains dérangent votre sommeil? Si oui, expliquer

3) Avez-vous remarqué une différence dans la fréquence des trains?

4) Savez-vous ce que contiennent les trains de marchandises? SI oui, que contiennent-ils?

5) Est-ce que les trains affectent votre vie d'une certaine façon? Si oui, expliquer

6) Avez-vous noté une différence dans l'agissement de la faune?

Survey Methods

A survey was conducted to identify if current train traffic is affecting the health or lifestyle of citizens living in the surrounding communities. Twenty surveys were conducted in total: seven surveys were distributed at White Rock and Crescent Beach each and six surveys were distributed at Burns Bog. The surveys were approved by the UBC Behavioural Research Ethics Board (BREB).

Survey Results and Implications

The survey results (Figure C-1) showed that while the majority of responses indicated that the trains were not affecting health, sleep schedule, or lifestyle, some individuals in these communities were concerned about these issues. The citizens who showed concern for the trains in the survey, indicated that they noticed an increase in the frequency of trains. When the citizens were asked if they were aware of the contents of the trains, it was interesting to note that one citizen had actually counted 168 railcars filled with coal and that another citizen felt that the communities should be informed about the contents of the rail cars. When asked if the trains interfere with their lifestyle in any way, it was shown that of the individuals who responded “yes” concerns included noise, safety, and access to recreational spaces (such as community gardens or beaches).

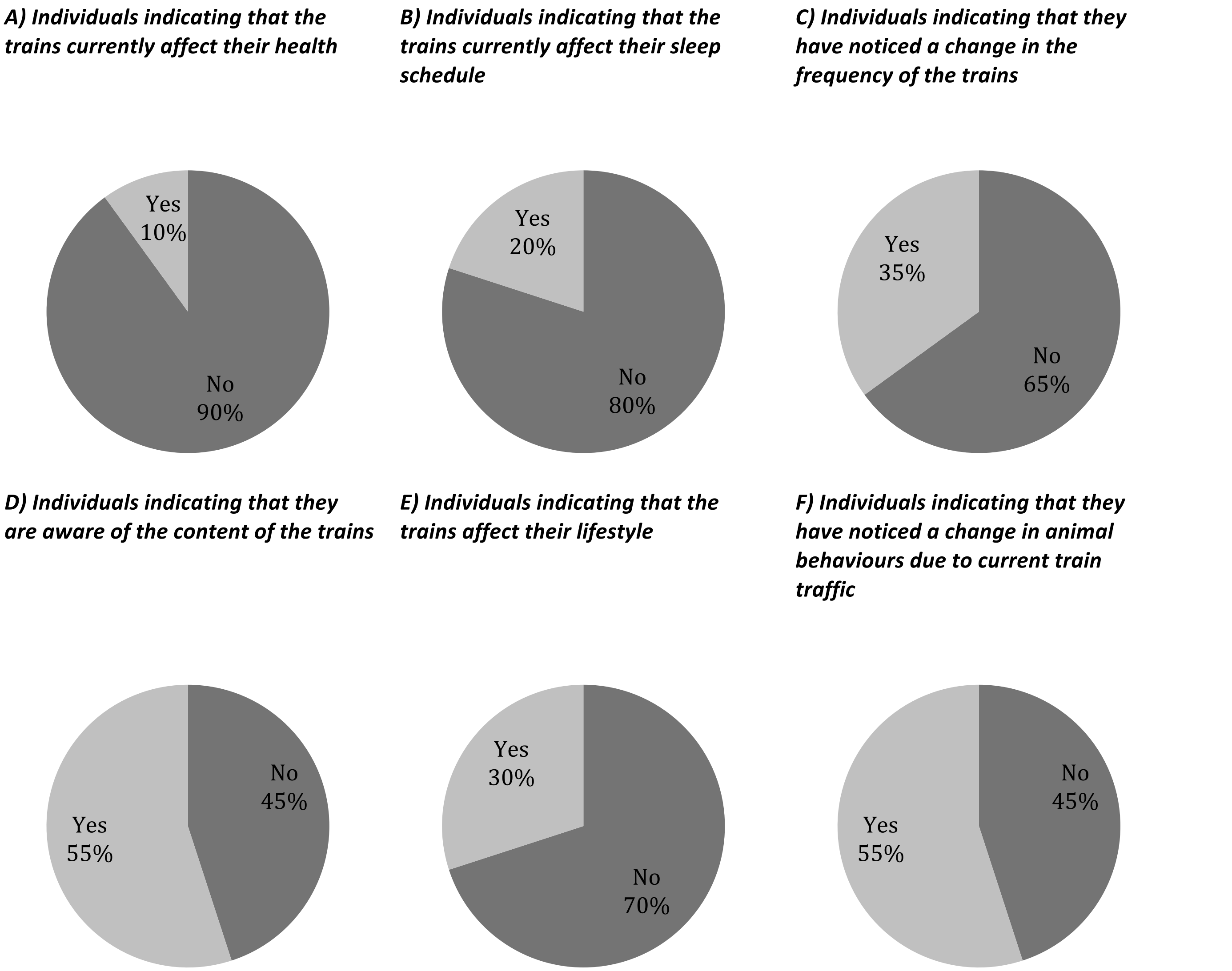

Figure C-1: Summary table of survey responses.