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SkyTrain Noise Study
Vancouver

Noise Report and Maps

Translink Ref No. Q17-037

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SKYTRAIN NOISE STUDY
NOISE REPORT AND MAPS

VANCOUVER

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Prepared by
SLR Consulting (Canada) Ltd.
200 – 1620 West 8th Avenue
Vancouver, BC V6J 1V4

for

SOUTH COAST BRITISH COLUMBIA TRANSPORTATION AUTHORITY (TRANSLINK)
400 - 287 NELSON'S COURT
NEW WESTMINSTER, BC V3L 0E7

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Prepared by:

PROFESSIONAL PROVINCE OF Dr. B. E. CROFT # 189026 BRITISH COLUMBIA ENGINEER

28 Nov. 2018

Briony Croft, Ph.D., P.Eng.
Principal Engineer - Acoustics

Reviewed by:

PROFESSIONAL ENGINEER PASCAL EVERTON ALBERTA

28 Nov 2018

Pascal Everton, P.Eng.
Technical Discipline Manager - Acoustics

EXECUTIVE SUMMARY

A SkyTrain Noise Study has been initiated by Translink in response to noise concerns raised by residents. This Noise Report describes the study methodology, measurements undertaken, analysis, modelling and results. Noise maps are appended for each of ten study locations.

Skytrain Noise Emission Goals

Various guidelines are available indicating maximum noise levels that are typically considered acceptable from rail transit systems. Maximum SkyTrain passby noise levels of 75 dBA would generally be considered acceptable at typical residential facades with windows closed while higher noise levels would require better than average attenuation across the façade to meet internal noise goals and avoid sleep disturbance. This guideline maximum noise level of 75 dBA does not represent “no noise impact” or “no annoyance”; rather it is a balance between the adverse effects of noise and other benefits of rail transit systems to communities.

An external maximum noise level of 87 dBA is the highest that can feasibly be attenuated across a facade to minimize sleep disturbance. However, non-standard building constructions and specialist acoustic design advice would be required to effectively attenuate external façade noise at this level, if bedrooms are oriented towards the rail line.

Measured Noise Levels and Observations

Measurements and observations have been completed at 32 locations distributed around the network. The results from noise measurements conducted inside a test train while completing a full circuit of the network were also used in the analysis. This data was used to develop a noise model indicating noise exposure across all ten study areas.

The study indicates that noise levels at residential façades vary considerably. The most affected residences are exposed to maximum SkyTrain noise levels of the order of 90 dBA for typical train passby events. At locations with the greatest noise exposure, wheel/rail rolling noise is the predominant issue. There are four main factors contributing to the problem:

1. Train speed, with the highest noise levels occurring adjacent to high speed sections of track.
2. Proximity of the residence – noise attenuates with distance, so the greatest noise exposures occur close to the tracks.
3. Elevation of the residence – the highest noise levels are at locations with a direct line of sight to the tracks (i.e. overlooking or level with the guideway, without any barriers to shield the noise).
4. Track condition - rail roughness, corrugation, track defects or worn switches result in noise levels that can be upwards of 15 dB greater than corresponding levels in comparable locations with track and/or switches in good condition.

At a few locations intermittent flanging noise was observed leading to a 3-5 dB increase in noise levels for some events. However, these locations were generally low speed, and even with the flanging noise the measured overall resulting maximum levels were quieter than in other areas. Severe, sustained flanging noise or curve squeal was not observed at any locations.

The influence on noise of train type, temperature and weather conditions has been investigated. While some differences were observed, in general these factors were found to have only a minor effect on maximum SkyTrain noise levels, relative to the influence of track condition.

Noise resulting from Public Address (PA) announcements is known to be an issue affecting residents near some stations. Although measurements were taken in close proximity to several stations, no PA announcements were observed in the course of this study. It is understood that PA announcements are not made as part of regular operations (i.e. for every train arriving), but are only used when required to notify passengers of special circumstances.

Priority Areas for Consideration of Noise Mitigation

The noise contours for each study area have been overlaid with Vancouver census data from 2016 to determine the approximate population residing near the areas covered by each noise contour band. Not all people living in a census division area overlapping a noise contour band will be affected by SkyTrain noise at that maximum level. This exercise attempts to rank each of the study areas based on maximum noise levels and the relative number of people who may benefit from noise mitigation. The resulting ranking is as follows:

1. VCC – Commercial Broadway – Nanaimo: This study area has the most people potentially affected by very high noise levels. The main issues are rough rails in high speed sections of track, and also switch noise.
2. Joyce Collingwood: This study area is one of the physically smaller areas but has the next largest number of people potentially affected by very high noise levels. The primary issue is switch noise, with some areas of rough rails traversed at high speeds.
3. Edmonds – 22nd St – New West – Columbia: This area has relatively large numbers of people potentially affected by high noise levels. The main issues are rough rails, switch noise and flanging at the Surrey line junction.
4. Patterson to Metrotown, and Gilmore to Brentwood: These areas have the next largest potentially noise affected populations, but with fewer residents potentially exposed to high noise levels.
5. False Creek: Train speeds are typically lower in this area than elsewhere, so absolute maximum noise levels are less than observed elsewhere.
6. Lougheed Town Centre and Moody Centre to Inlet Centre have maximum noise levels at residences typically less than elsewhere on the network.
7. Sapperton and Lafarge Lake Douglas have relatively low numbers of people potentially affected by noise at levels above 75 dBA.

Noting that the division of the network into the above study areas is arbitrary, it is recommended that priorities for mitigation be based on noise level, independent of study area.

- First priority: residential areas with maximum noise levels above 85 dBA
- Second priority: residential areas with maximum noise levels of 80 to 85 dBA
- Third priority: residential areas with maximum noise levels of 75 to 80 dBA

Next Steps

A separate “Next Steps” report has been prepared by SLR for Translink building on the findings of this Noise Report. It identifies potential noise mitigation options, and provides details of the scope of work, resources, timeframe and budget cost required to investigate each option.

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1.0 INTRODUCTION

This study of SkyTrain noise and possible mitigation options has been initiated by Translink in response to noise concerns from residents.

Translink undertook an analysis of noise complaints submitted from 2014 to 2017. On the basis of this analysis, Translink identified ten locations (the "Study Areas") along the Expo and Millennium lines that have the highest frequency of noise complaints. These areas are listed in Table 1 and outlined in Appendix A. SLR Consulting (Canada) Ltd (SLR) has been engaged by Translink to quantify and map SkyTrain noise in these study areas, and to provide recommendations for next steps to investigate mitigation options.

Table 1 SkyTrain Noise Study Areas

Ref	Area
1	False Creek
2	VCC Station- Commercial Broadway Station – Nanaimo Station
3	Joyce Collingwood Station
4	Patterson Station to Metrotown Station
5	Edmonds Station- 22nd Street Station- New Westminster Station- Columbia Station
6	Sapperton
7	Gilmore Station- Brentwood Town Centre Station
8	Lougheed Town Centre Station
9	Moody Centre Station- Inlet Centre Station
10	Lafarge Lake- Douglas Station

1.1 Noise Study Scope

A Community Advisory Committee (CAC) formed of residents from the identified areas has provided input to and feedback on the study scope. Following a review of Translink’s database of complaints and consultation with the CAC, the agreed scope of the noise study includes examination of:

- Noise from train movements around the network, as experienced outside the trains; and
- Noise from stations and public address (PA) systems, experienced outside the stations.

In summary, this study examines noise from normal day-to-day operation of the SkyTrain as experienced by people in neighbouring communities. The primary objective is to quantify and map the maximum noise levels generated by normal operational noise sources such as train movements and station public address (PA) systems. An additional objective is to identify the approximate number of people affected by noise at various levels in different areas of the network, to assist in making recommendations for future noise mitigation priorities.

The study does not address noise experienced by passengers on the trains, except indirectly to the extent that noise levels inside the train are often related to noise generated outside the train.

The study does not address noise generated by SkyTrain maintenance activities or noise from construction of SkyTrain facilities. Both maintenance and construction are temporary in nature, will occur at varying locations and can have highly variable noise impacts depending on the specific activity. While these activities do generate noise and give rise to complaints, they are considered to be independent of the noise from normal SkyTrain operations.

This Noise Report describes the methodology applied to the operational noise study and details the measurements undertaken, analysis, modelling and results. Noise maps have been prepared for each of the study locations and are appended to this report.

A separate “Next Steps” Report has also been prepared to provide a plan for future investigation of noise mitigation options. This Next Steps report includes:

- Noise mitigation options that should be investigated
- A recommended scope of work to investigate each noise mitigation measure
- The deliverables recommended as outcomes from mitigation investigations
- An indication of the timeframe required to complete each identified task
- A budget estimate of the costs for each task

1.2 Acknowledgements

In addition to providing input to and feedback on this study, the volunteer members of the CAC provided assistance in arranging access to noise testing locations. Other members of the public also supported the study by volunteering access to their backyards and balconies to facilitate noise measurements. The time, effort, support and assistance provided by the CAC and others is gratefully acknowledged. The members of the CAC are as follows:

- Ralph Wettstein
- Chris Moore
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- Wendy Stephen
- Roland Guasparini
- Jeffery Melanson
- Linda Epplette
- Jinyi Tsai

2.0 NOISE TERMINOLOGY AND DEFINITIONS

2.1 Sound Level or Noise Level

The terms “sound” and “noise” are almost interchangeable, except that “noise” is normally used to refer to unwanted sound. Sound (or noise) consists of minute fluctuations in atmospheric pressure capable of evoking the sense of hearing. The human ear responds to changes in sound pressure over a very wide range. The loudest sound pressure to which the human ear responds is ten million times greater than the softest. The decibel (abbreviated as dB) scale reduces this ratio to a more manageable size by the use of logarithms.

The symbols SPL, L or L_P are commonly used to represent Sound Pressure Level. The symbol L_A represents A-weighted Sound Pressure Level. The standard reference unit for Sound Pressure Levels expressed in decibels is 2 x 10^{-5} Pa.

2.2 “A” Weighted Sound Pressure Level

The overall level of a sound is usually expressed in terms of dBA, which is measured using a sound level meter with an “A-weighting” filter. This is an electronic filter having a frequency response corresponding approximately to that of human hearing.

People’s hearing is most sensitive to sounds at mid frequencies (500 Hz to 4000 Hz), and less sensitive at lower and higher frequencies. Thus, the level of a sound in dBA is a good measure of the perceived loudness of that sound. Different sources having the same dBA level generally sound about equally loud.

A change of 1 dBA or 2 dBA in the level of a sound is difficult for most people to detect, while a 3 dBA to 5 dBA change corresponds to a small but noticeable change in loudness. A 10 dBA change corresponds to an approximate doubling or halving in loudness. Table 2 lists examples of typical sound pressure levels.

Table 2 Typical Sound Pressure Levels

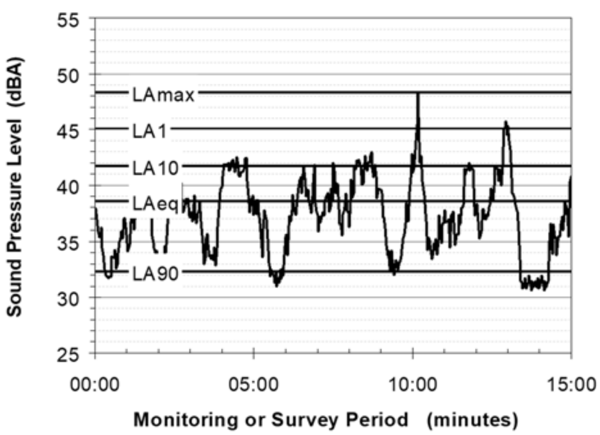
SPL (dBA)	Example	Subjective Evaluation
130	Threshold of pain	Intolerable
120	Heavy rock concert	Extremely noisy
110	Grinding on steel	
100	Loud car horn at 3 m	Very noisy
90	Construction site with pneumatic hammering	
80	Curbside of busy street	Loud
70	Loud radio or television	
60	Department store	Moderate to quiet
50	General Office	
40	Inside private office	Quiet to very quiet
30	Inside bedroom	
20	Recording studio	Almost silent

Other weightings (eg B, C and D) are less commonly used than A-weighting. Sound Levels measured without any weighting or with a flat weighting are referred to as “linear” or Z weighted respectively, with units are expressed as dB(lin), dB or dBZ.

2.3 Noise Level Descriptors

Various descriptors may be used to quantify noise that varies in level over time. Statistical exceedance levels LAN indicate the A-weighted sound pressure level exceeded for N% of a given measurement period. For example, the LA1 is the noise level exceeded for 1% of the time, LA10 the noise exceeded for 10% of the time, and so on. Figure 1 presents a hypothetical 15 minute noise survey, illustrating various noise descriptors.

Figure 1 Example Noise Time History



LA1	The noise level exceeded for 1% of the 15 minute interval.
LA10	The noise level exceed for 10% of the 15 minute interval.
LA90	The noise level exceeded for 90% of the sample period, commonly referred to as the average background level.
LAeq	The A-weighted equivalent level (average noise level), defined as the steady sound level with the same acoustical energy as the corresponding time-varying sound.
LAmax	The A-weighted maximum noise level in the measurement period, or during a train passby event or PA announcement.

In this report, statistical descriptors are used to describe the ambient noise environment (ie noise from all sources, including SkyTrain). Noise from SkyTrain operations is described using the maximum noise level descriptor (LAmax), using a fast time constant.

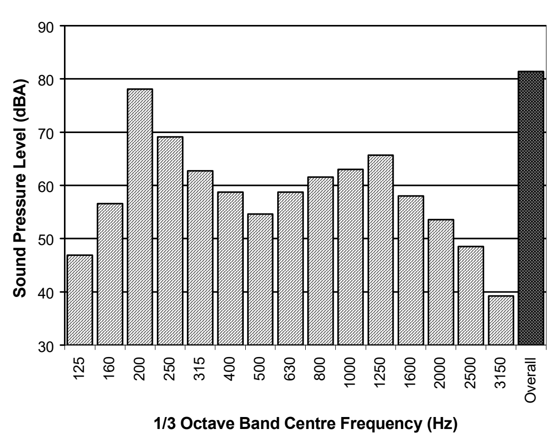
2.4 Tonality and Frequency Analysis

Tonal noise contains one or more prominent tones (i.e. distinct frequency components) and is normally regarded as more disturbing than "broad band" noise. Frequency analysis is the process used to examine the tones which make up the overall noise signal. The units for frequency are Hertz (Hz), which represent the number of cycles per second.

Frequency analysis can be narrow band (where the spectrum is divided into many bands of equal width). More commonly, analysis is undertaken in octave bands (where the centre frequency and width of each band is double the previous band), or in 1/3 octave bands.

Figure 2 shows a 1/3 octave band analysis where the noise is dominated by the 200 Hz band. The level of each individual band is less than the overall level, which is the logarithmic sum of the bands.

Figure 2 Example Noise Spectrum

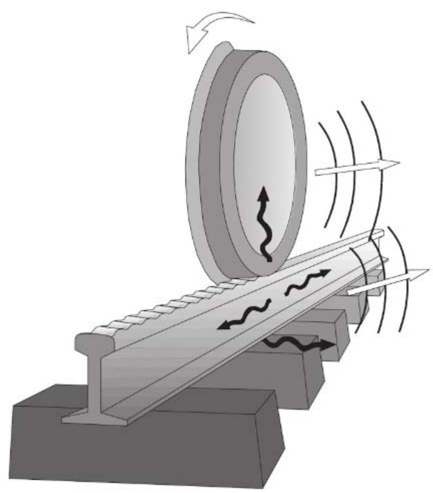


3.0 RAIL TRANSIT NOISE OVERVIEW AND GUIDELINES

3.1 Rail Transit Wheel-Rail Rolling Noise

Noise emissions from suburban electric passenger trains on surface track are predominantly caused by the rolling contact of steel wheels on steel rails. Even under ideal conditions with apparently "smooth" rail and wheels, noise occurs when the micron-scale roughness of the wheel and rail contact surfaces results in vibration of the wheels, rails and track components. These vibrating components radiate airborne noise as indicated in Figure 3.

Figure 3 Railway rolling noise mechanism



Reproduction of Figure 1-2 of *Railway Noise and Vibration Mechanisms, Modelling and Means of Control* (David Thompson, 2009).

Where track is located on a guideway, vibration is also transmitted to the structure resulting in structure-radiated noise in addition to the direct rolling noise from the track and wheels of the trains. The overall noise level experienced at any individual receiver location is then a combination of the noise radiated by the wheels, rails and guideway.

3.2 Factors Affecting Wheel-Rail Rolling Noise Level

There are a number of factors relating to the design of a rail transit system that affect the magnitude of wheel-rail rolling noise. These factors include:

- The roughness of the wheel and rail – rougher surfaces result in higher noise levels. Roughness can increase or decrease over time as the wheel and rail wear under normal traffic. Roughness can also be changed by maintenance activities such as rail grinding.
- The stiffness of the components fixing the rail to the guideway – more resilient fixings result in higher noise from the rails, but less noise from the guideway structure.
- The speed of trains – rolling noise is proportional to train speed.
- The size, design and shape of the wheel – this affects the magnitude and frequency of noise radiated from the wheel.
- The presence or absence of joints between segments of rail – joints between rail segments give rise to an impulsive "clickety-clack" noise as every wheel of the train strikes the gap in the running surface. Continuously welded rail is utilized by the SkyTrain to eliminate these discrete joints.

3.3 Other Localized Rail Transit Noise Sources

Other noise sources on electric passenger trains such as traction systems or air-conditioning units are generally insignificant in noise level when compared with the wheel rail interaction, unless the train is stationary or travelling at very low speed. These sources therefore can be significant in and near stations, when trains slow to a stop and then accelerate away.

While the SkyTrain does utilize continuously welded rails, other localized rail discontinuities such as switches, expansion joints and rail defects increase the level of wheel-rail noise as each wheel of the train passes over the discontinuity. In relation to switches, the SkyTrain uses a swing-nose design (also known as a movable point frog). This type of switch design incorporates moving parts that eliminate the gap in the rail that is traversed by wheels in a conventional switch. Swing-nose switches in good condition minimize impact noise by minimizing the discontinuity in the rolling surface. In an optimal situation, there is no increase in noise at the switch location. However, wear of the components can occur in service resulting in localized higher noise levels at switches, even with swing-nose designs.

In areas where there are tight radius curves, flanging noise or curve squeal may also increase the levels of noise emission. On rail transit systems it is also common for rail roughness to be higher on tight radius curves than on straight track sections. In some locations, this roughness can develop over time into corrugation, which is a periodic waviness along the rail. Corrugation results in locally increased rolling noise levels and a “roaring” noise characteristic. On the SkyTrain network corrugation has been observed to occur on tangent track in addition to curves.

Near stations, sounds from Public Address (PA) announcements sometimes can be heard in surrounding areas. PA sounds are considered to be noise when they are heard outside of their intended audience location.

3.4 Rail Transit Noise Emission Goals

There is no defined “noise limit” or maximum noise level criterion that is directly applicable to the original lines of the Vancouver SkyTrain, and this study does not discuss whether SkyTrain noise levels are “compliant” with any particular noise limit. Guideline maximum noise levels are discussed here to provide a context in interpreting the measured SkyTrain noise levels described in this report.

Various guidelines are available indicating maximum noise levels that are typically considered acceptable from rail transit systems. The guidelines referenced in this study include U.S. guidelines for transit system design dating from 1995 (US guidelines are commonly referenced in setting design goals for Canadian transit projects) and World Health Organization (WHO) noise guidelines dating from 1999 relating indoor night-time maximum noise levels to sleep disturbance.

Noise level goals applied to rail transit systems worldwide do not represent “no impact”. These goals necessarily weigh the adverse community noise impacts against the wider benefits to societies of providing public transit, including health benefits of transit. Transit noise goals are commonly derived with reference to majority annoyance responses. “Low” and even “moderate” noise annoyance are often considered acceptable by policymakers when weighing noise impacts against the wider benefits of transit in urban areas. In addition, in any population some people will be more sensitive to noise than others. A maximum rail transit noise level that is acceptable for one individual may result in high annoyance for another individual.

This study examines outdoor L_{Amax} (maximum noise level, fast response) from individual passby events. The L_{Amax} parameter has been selected rather than L_{Aeq} based (equivalent average) noise parameters because it enables direct comparison of maximum SkyTrain noise levels around the network, independent of the number or length of trains. The L_{Amax} passby noise level is a useful parameter to use as a baseline for investigation of SkyTrain noise mitigation options, which is the overall objective of this study. Translink identified maximum A-weighted noise level as the descriptor of interest in defining the scope of work of this study.

3.4.1 U.S. Transit Noise Guidelines (Current and Historical)

The U.S. Federal Transit Administration's *Transit Noise and Vibration Impact Assessment* is a guideline for assessing the operational noise impacts of new rail transit projects. This guideline was first released in 1995, with updated versions released in 2006 and in September 2018. The 2006 version has been commonly applied in Canada, for example it was used in the planning stages of the Evergreen Extension. This U.S. guideline uses L_{Aeq} based (equivalent average noise level) parameters to assess project impacts and mitigation requirements considering noise level and the number of train passbys during the daytime and night-time periods. This average noise level assessment approach is commonly used to assess new projects, because average daytime and night-time noise level can be used as an indicator of potential long-term health effects of noise.

Around the time of construction of the original SkyTrain, goals for maximum outdoor airborne wayside noise from train operations were included in American Public Transit Association (APTA) design guidelines. The U.S. Transit Cooperative Research Program *Report 23 Wheel/Rail Noise Control Manual* (James T. Nelson, 1997) summarizes historical APTA maximum noise level goals; these are reproduced in Table 3. Note that more recent guidelines do not differentiate between single family and multi-family dwellings. These historical APTA maximum noise level goals for residential areas range from 70 dBA up to 85 dBA, with less stringent goals applied to residences in commercial or industrial areas, or on highway corridors. For average density urban or suburban residential areas, the passby maximum noise level goal was 75 dBA.

Table 3 APTA Historical Guidelines for Maximum Noise from Train Operations

Community Area Category	Area Description	Single Event Maximum Noise Level Design Goal (dBA)		
		Single Family Dwellings	Multi-Family Dwellings	Commercial Buildings
I	Low density residential	70	75	80
II	Average density residential	75	75	80
III	High Density Residential	75	80	85
IV	Commercial areas	80	80	85
V	Industrial areas / highway corridors	80	85	85

3.4.2 WHO Recommendations Relating to Maximum Noise and Sleep Disturbance

WHO reviews of noise impacts on health dating from 1980 through to 2018 predominantly concentrate on average noise level parameters and health implications of overall long-term noise exposure from all noise sources. Some WHO guidelines do provide information on indoor night-time maximum noise levels linked to sleep disturbance. Sleep disturbance is a key concern for people living near the SkyTrain.

The WHO's Guidelines *for Community Noise* (1999) set a maximum indoor noise level goal of 45 dBA that should not be exceeded more than 10-15 times a night. To convert this goal to an external façade noise level requires an adjustment based on attenuation across a typical façade and an assumption as to whether windows are open or closed.

In 2009 WHO published *Night Noise Guidelines for Europe*. This guideline relates sleep quality to a maximum internal noise level of 42 dBA, without limiting the number of noise events per night. If windows are to be left open, WHO suggest a 15 dB reduction from outside to inside giving an external maximum noise goal of 57 dBA. For closed windows, WHO states a typical reduction is 30 dB or more depending on glazing and insulation, with up to 45 dB of attenuation achievable with the most comprehensively attenuated facades. The external maximum noise goal would then be 72 dBA to 87 dBA, depending on the attenuation achieved by the façade.

A maximum noise level of 57 dBA is frequently and regularly exceeded by many different night-time noise sources in urban residential areas – a normal passenger car driving by on a local street would often generate noise above this level at residential facades. For this reason, it is clear that closing of windows is likely to be required at many residential urban locations to avoid sleep disturbance, although this has obvious disadvantages if relying on open windows for ventilation.

For the Evergreen Extension Environmental Impact Assessment, a 30 dB adjustment was used assuming windows were closed to derive an external maximum noise level goal of 75 dBA from the 1999 WHO guidelines. This noise level was taken to represent a moderate maximum noise impact to residences. Noise mitigation was to be considered (subject to feasibility) for locations with maximum predicted noise levels above this threshold, but predicted maximum noise levels were generally not above 75 dBA at existing residential locations assessed.

A vehicle exterior maximum noise criterion of 75 dBA has also been used by Translink in specifications for procurement of new rail vehicles. In this context, the 75 dBA maximum noise level goal is applicable at 15 m from the track centre line of a guideway with parapet wall, with a train travelling on continuous, smooth mainline track at 80 km/h.

In summary, an external 75 dBA maximum passby noise level is an indicative threshold that may be used as a reference for typical acceptability of SkyTrain noise levels at residential facades, assuming typical façade construction and closed windows. At locations where external maximum noise levels are higher than this, increased attenuation of noise by the façade is likely to be required to achieve internal noise goals. With reference to the WHO discussion of the potentially achievable façade attenuation, external maximum noise levels of 87 dBA are the highest noise level that could feasibly be attenuated across a facade to minimize sleep disturbance. This maximum noise level therefore represents a reference upper bound for SkyTrain noise. Note that non-standard building constructions and specialist acoustic design advice are required to attenuate external façade noise at this level, if bedrooms are oriented towards the rail line.

4.0 SKYTRAIN SYSTEM DESCRIPTION

The SkyTrain system commenced operations in 1986 and has undergone several expansions since. The system is comprised of roughly 60 km of standard gauge double track fully automated guideway on two lines, the Expo Line and the Millennium Line (which includes the Evergreen Extension). The system has 39 stations and runs up to 21 hours per day, seven days a week.

4.1 SkyTrain Track Description

Most of the system is built on elevated guideway; however, there are sections of tunnel and at-grade track. Relative to other rail transit systems, the SkyTrain alignment is characterized by some sections of steep grades (6%) and tight curves as low as 70 m radius. Track is slab track, meaning the rails are directly fastened to the deck of the guideway without any ballast. The rails are AREMA standard 115RE rails supported by the Delkor Alt1 RF191-01 baseplate fastening system. This fastener has a specified static vertical stiffness between 18 kN/mm and 35 kN/mm, which is highly resilient.

The *Handbook of Railway Vehicle Dynamics* (edited by S. Iwnicki, 2006) states that slab tracks "are generally found to be noisier than conventional ballasted track, typically by 3 to 5 dB. This can be attributed to two features of such tracks. Firstly, they tend to be fitted with softer rail fasteners in order to introduce the resilience normally given by the ballast. Second, they have a hard sound-reflecting surface, whereas ballast has an absorptive effect. The latter affects the overall noise by 1 to 2 dB."

The guideway structure predominantly consists of concrete box girders, although some areas incorporate steel beams supporting concrete spans. The structure-radiated noise from concrete and composite concrete / steel guideways is inherently less than that from steel structures. Even so, at locations close to and below the guideway, where the line of sight to the rails is blocked, the structural component of noise may dominate over rolling noise. The amount of shielding provided by the structure depends on the relative geometry of the viaduct structure and the nearby buildings. Figure 4 shows an example cross section of the guideway structure and track from the Evergreen Extension, a similar arrangement is utilised in tangent dual track sections of the Millennium line.

The guideway cross section varies in special trackwork sections (at switches), at stations, around curves, in single track sections and when track is at grade or in tunnel. However, for the purpose of this noise study the dimensions of the critical deck elements are relatively consistent everywhere. These critical elements are the width of the deck either side of the track centrelines, and the height of the parapets on each side of each track. While the primary purpose of these parapets is to support the power rails, they also act as low barriers and provide some shielding of wheel-rail rolling noise.

Figure 5 shows an example cross section of the guideway structure and track from the Expo Line. On this line a dual box girder arrangement is used throughout. Again, the dimensions of the deck and parapets are reasonably consistent along the length of the Expo Line.

Throughout the Expo and Millennium Lines including the Evergreen Extension, the parapet height above top of rail is of the order of 280-340 mm (determined by scaling from drawings provided by Translink). The inside edges of these parapets are typically located a minimum of 1295 mm either side of the track centreline.

Figure 4 Example guideway and track cross section – Millennium and Evergreen

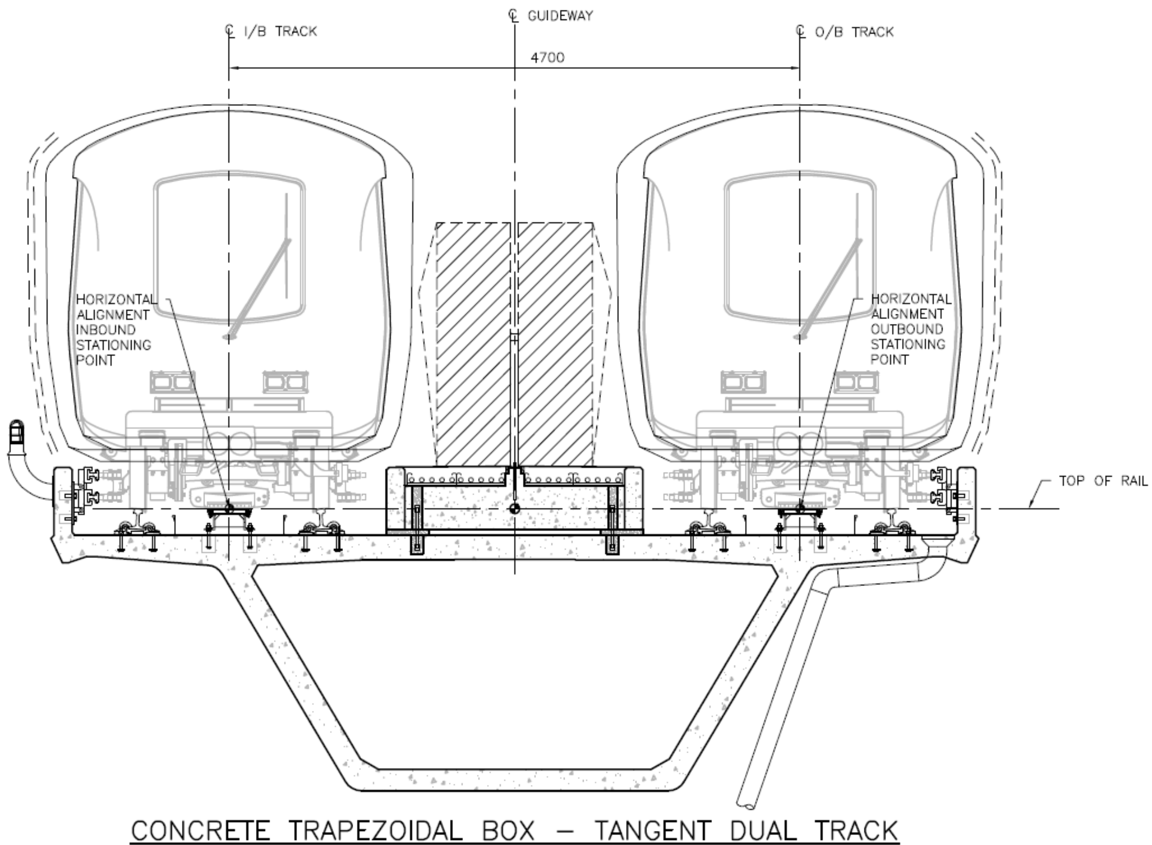
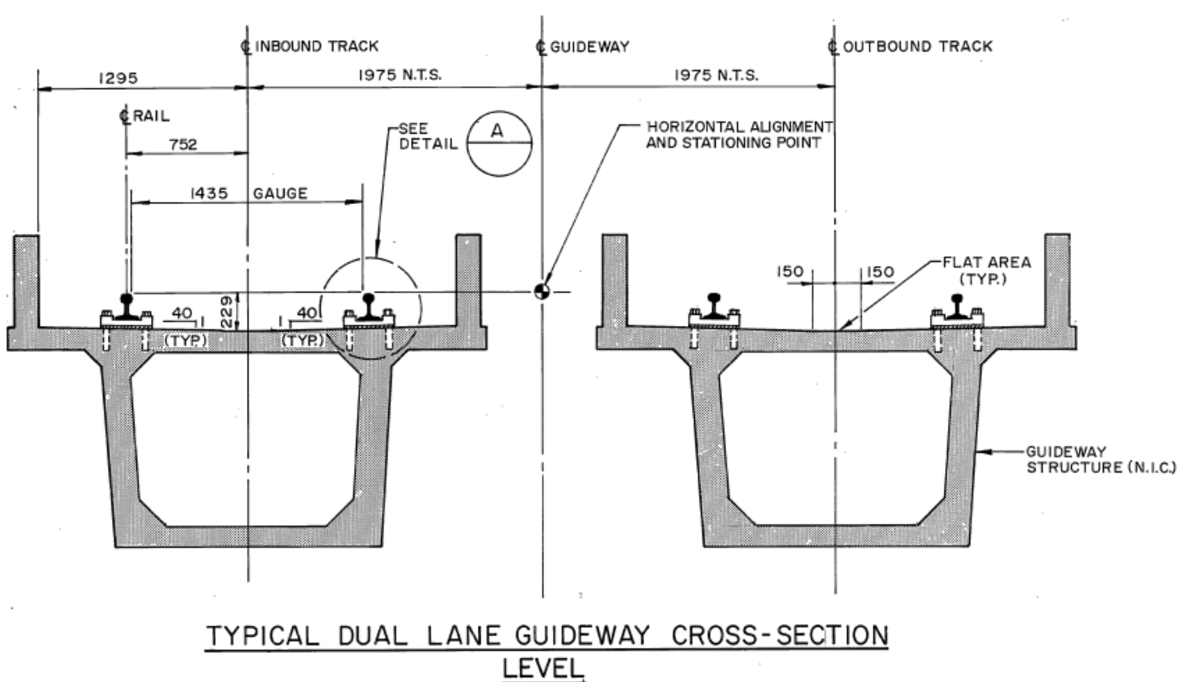


Figure 5 Example guideway and track cross section – Expo



4.2 SkyTrain Rolling Stock Description

The SkyTrain currently operates a fleet of 286 vehicles of three types, Mark (MK) I, II and III. The original fleet of MK I vehicles entered service in 1986, with additional batches purchased in 1991 (16 vehicles) and 1994 (20 vehicles). The first 60 MK II vehicles entered service in 2001/2002, joined by 48 additional vehicles in 2009. The first 28 MK III vehicles entered service in 2017, with additional vehicles to be added in 2018/2019.

All vehicle types use a linear induction propulsion system, with two linear induction motors mounted on the underside of each vehicle with a nominal air gap of 12 mm to the reaction rail installed between the running rails. Traction power is supplied via power rails mounted on the inside of the guideway parapets.

All vehicle types utilize steering wheelsets which minimize the likelihood of curve squeal. All vehicle types use solid steel wheel designs. An alternative composite resilient wheel design was initially utilized for MK I trains, but this wheel design was phased out. Cost was a factor in the change in addition to operations and maintenance issues with the resilient wheels.

The typical operating configuration of these vehicles is as follows:

- MK I trains operate in 6 car or 4 car sets on the Expo Line only
- MK II trains operate in 2 car or 4 car sets on both the Expo and Millennium Lines
- MK III trains operate in 4 car sets on the Expo Line only

During the noise study, MK I trains were most commonly observed in 6 car formations. MK II cars on the Millennium Line were only observed in 2 car sets, while on the Expo Line a mix of 2 and 4 car sets were observed with 4 car sets much more common.

Table 4 provides an overview of dimensions of the three train types as relevant to this noise study (train length, weight, number and size of wheels). The MK II and MK III trains are almost identical in these parameters and use the same wheel design.

Table 4 SkyTrain Rolling Stock Descriptors

Parameter	Value		
	MK I	MK II	MK III
Vehicle Length (end car)	12.7 m	17.35 m	17.35 m
Vehicle Length (middle car)	12.7 m	16.7 m	16.7 m
Operational consist options (cars per train)	2,4,6	2,4	4
Overall train lengths	25.4 m, 50.8 m, 76.2 m	34.7 m, 68.1 m	68.1 m
Distance centre to centre of trucks	7.94 m	12.0 m	12.0 m
Truck axle centre spacing	1.7 m	1.9 m	1.9 m
Wheel diameter (new)	0.460 m	0.585 m	0.585 m
Wheel diameter (worn, minimum)	0.440 m	0.549 m	0.549 m
Wheel gauge (back to back flanges, new)	1.386 m	1.372 m	1.372 m
Nominal weight per car (empty)	15 tonnes	21.5 tonnes	21.3 tonnes

The maximum normal operating speed of the SkyTrain is 80 km/h, with a catch-up speed of 90 km/h. The maximum acceleration rate is 1.3 m/s^2, and the maximum deceleration rate is 1.0 m/s^2.

5.0 MEASUREMENTS TO CHARACTERIZE EXISTING NOISE

5.1 Overview of Measurement Methodology

The existing ambient noise environment varies around the SkyTrain network, as would be expected from the wide range of commercial, urban, residential and industrial land uses within the study area. The noise from the SkyTrain also varies, with factors such as train speed, rail surface condition and the presence of switches affecting noise emissions at the source. The measurement distance and elevation relative to the guideway is another factor that influences the measured noise level.

The measurement methodology used in this study combined attended measurements and observations of SkyTrain noise with longer term monitoring of ambient noise and specific measurements inside the BCRTC test train. All measurements were undertaken using calibrated Class 1 Sound Level Meters, details of equipment used are provided in Appendix B.

5.1.1 Method for Attended Measurements of SkyTrain Noise

Operator-attended measurements were used to determine existing SkyTrain noise levels and the contributing noise sources. At each location, attended measurements and observations were made over a period of up to two hours. Measurements of each train passby were made generally in accordance with the procedures described in International Standard *ISO 3095:2013 Acoustics – Railway applications – Measurement of noise emitted by railbound vehicles*.[1]

Each measurement commenced as the noise from the train emerged above the background and concluded after the train had passed. Notes were collected on the train type, number of cars, direction of travel (inbound/outbound) or if two trains passed at the same time. Additional notes identified trains that deviated from the typical speed at that location (faster or slower than normal), and any noise from other sources that was observed with the potential to contaminate the results. Results were excluded from the analysis if (for example) a truck or motorcycle passing at the same time as the train may have affected the measured maximum noise level.

With a service frequency of a train each way every 3 or 6 minutes, most 2-hour measurements captured 40 to 80 train passby events of a mix of types. At some measurement locations on the Evergreen Extension the service frequency during the measurements was less than that elsewhere on the network, however since all trains observed on this line were a consistent type and length the 2-hour period was sufficient to characterize passby noise.

Attended measurements were undertaken at 32 representative locations distributed throughout the study areas as shown in Appendix A. Table 5 provides a summary of the measurement locations. These were selected to include curved track, inclined track, straight (tangent) track, switches and locations near stations. The measurement locations were selected in consultation with the CAC, who also assisted in arranging access to many of the locations. The elevation relative to the tracks varied between locations, with some overlooking the guideway, some approximately level with the guideway deck and other locations below deck level.

[1] This standard is intended for type testing of individual vehicles on a specific test track at defined speeds, measurement distances and elevations. Strict adherence to all aspects of the standard is therefore not possible for measurements on an operating system. ISO 3095 has been used as a guide to measurement parameters, instrumentation requirements, measurement time period and data processing.

Table 5 Attended Measurement Location Summary

Area	Ref	Address	Elevation Details[1]	Comments
False Creek	1a	1088 Quebec St	L8	Switch, tangent track
	1b	688 Abbott St	L26	Station
	1c	Creekside Park	Ground below deck	Control location, switch
VCC – Commercial Broadway - Nanaimo	2a	Woodland Dr bridge sidewalk	Above Millennium line, below Expo deck	Tangent track
	2b	2360 Commercial Dr	Rooftop slightly below deck	Curve
	2c	3250 Commercial Dr	Ground below deck	Curve
	2d	3974 Gladstone St	Level with deck	Tangent inclined track
Joyce Collingwood	3a	5380 Oben St	L17	Switch
	3b	Vanness near Ruby	Guideway deck level	Tangent track, barriers on guideway edge
Patterson to Metrotown	4a	6152 Kathleen Ave	L4	Tangent track
	4b	4333 Central Blvd	Sidewalk, below deck	Tangent track
Edmonds - 22nd Street - New West - Columbia	5a	Prenter St (east end)	Ground, below deck	Curve
	5b	6837 Station Hill Dr	L25	Station, curve, tangent
	5c	2311 London St	Ground, below deck	Curve
	5d	Grimston Park	Ground, level with deck	Control location, slight curve and incline
	5e	426 14th St	Ground below deck	Tangent inclined track
	5f	892 Carnarvon St	L21	Station
	5g	420 Carnarvon St	L4	Station
	5h	610 Victoria St	L16	Tunnel portal
	5i	312 Carnarvon St	L3	Tunnel portal and switch
Sapperton	6a	69 Jamieson Ct	L5	Tangent track
Gilmore - Brentwood	7a	4788 Brentwood Dr	Patio level with deck	Slight curve
	7b	2088 Madison Ave	L9	Switch and tangent track
	7c	Gilmore near Dawson	Ground, below deck	Station, curve
Lougheed Town Centre	8a	3771 Bartlett Ct	L22	Station, switches
	8b	Salish Ct	Ground, below deck	Tangent track, barriers on guideway edge
	8c	Perth Ave at North Rd	Ground, below deck	Tangent track
Moody Centre – Inlet Centre	9a	301 Capilano Rd	Ground, below deck	Tangent track
	9b	Golden Spike Ln	Bridge above tracks	Tangent track
	9c	Dewdney Trunk Rd	Ground above deck	Tangent track
Lafarge Lake - Douglas	10a	1188 Pinetree Way	L42	Curve near station
	10b	1169 Pinetree Way	Rooftop above deck	Curve near station

Note 1: Building floor of measurement or approximate microphone height relative to guideway deck

Measurements at 30 locations were undertaken in predominantly calm, dry conditions in March and April of 2018. All measurements were taken outside (e.g. on balconies or sidewalks) and had a line of sight to the guideway (except where obscured by station structures). For a detailed description of each measurement location see Appendix B.

Two of the 32 locations were designated as "Control" locations. At these locations, measurements were repeated in different conditions including rain, cold, snow, warm and hot weather, between February and June of 2018. The objective of these measurements was to identify noise variations under different conditions in a controlled manner.

5.1.2 Method for Unattended Monitoring of Ambient Noise

Unattended ambient noise measurements were undertaken at a subset of 9 of the 30 locations used for attended SkyTrain noise measurements, plus one additional location[2]. Measurements were taken using self-contained noise monitoring kits, left unattended for a minimum of 24 h at each location.

This type of noise monitoring captures noise from all sources in the environment, not just the SkyTrain. At some locations, road traffic or other noise sources contribute to the ambient noise environment. These measurements enable review of the SkyTrain noise contribution relative to ambient noise from all sources during the daytime and night-time. Table 6 summarizes the unattended measurement locations, for a full description of each see Appendix B.

Table 6 Unattended Measurement Location Summary

Area	Ref	Address	Main Ambient Noise Sources
False Creek	1a	1088 Quebec St	SkyTrain, road traffic
VCC – Commercial Broadway - Nanaimo	2d	3974 Gladstone St	SkyTrain, distant traffic
Joyce Collingwood	3a	5380 Oben St	SkyTrain, distant traffic
Patterson to Metrotown	4a	6152 Kathleen Ave	SkyTrain, distant traffic
Edmonds - 22nd Street - New West - Columbia	5b	6837 Station Hill Dr	SkyTrain, distant traffic
	5h	610 Victoria St	SkyTrain, road traffic
Gilmore - Brentwood	7b	2088 Madison Ave	SkyTrain, road traffic
Lougheed Town Centre	8a	3771 Bartlett Ct	SkyTrain, road traffic, construction
Moody Centre – Inlet Centre	9d	2525 Quay Place	SkyTrain, distant traffic
Lafarge Lake - Douglas	10a	1188 Pinetree Way	SkyTrain, road traffic

5.1.3 Method for Test Train Noise Measurements

As part of their regular system monitoring, BCRTC measure noise inside a test train which completes a circuit of the complete network once a week. The data collected each week is the overall noise level inside the vehicle as it varies with time and vehicle position around the network. BCRTC use the noise data as one tool to prioritize locations requiring maintenance.

For this study, supplementary measurements including spectral information (noise level vs frequency) were collected for one of the regular test train circuits using a sound level meter capable of frequency analysis. The objective of these measurements is to understand how noise varies around the network with speed and rail roughness. The spectral test train noise and speed time history has also been used to inform the development of the train reference noise levels in the noise model, which leads to the maps of noise around the network.

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[2] The attended measurement locations in the Moody Centre / Inlet Centre area were not secure for unattended monitoring, so a residential backyard was used for unattended measurements in this area.

5.2 Measured SkyTrain Maximum Noise Levels

Table 7 summarizes the measured maximum noise levels from train passby events on each track at each location. This table shows results for the single noisiest train type measured at each location. Full results are in Appendix B. The influence of train type on noise level is discussed in Section 5.5.

Table 7 Summary of SkyTrain Maximum Noise Levels by Location

Area	Ref	Address	Inbound Passby LAmax		Outbound Passby LAmax	
			Average	Maximum	Average	Maximum
False Creek	1a	1088 Quebec St	77	79	81	83
	1b	688 Abbott St	75	76	77	78
	1c	Creekside Park	74	76	80	81
VCC – Commercial Broadway - Nanaimo	2a	Woodland Dr (Expo)	74	78	84	87
	2a	Woodland Dr (Millennium)	84	86	87	88
	2b	2360 Commercial Dr	82	86	79	80
	2c	3250 Commercial Dr	82	85	74	80
	2d	3974 Gladstone St	81	82	77	79
Joyce Collingwood	3a	5380 Oben St	90	92	80	81
	3b	Vanness Ave	76	78	80	81
Patterson to Metrotown	4a	6152 Kathleen Ave	68	70	76	78
	4b	4333 Central Blvd	88	90	82	83
Edmonds - 22nd Street - New West - Columbia	5a	Prenter St	73	74	64	66
	5b	6837 Station Hill Dr	68	71	71	74
	5c	2311 London St	78	79	72	75
	5d	Grimston Park	76	78	74	76
	5e	426 14th St	81	82	77	78
	5f	892 Carnarvon St	77	78	71	74
	5g	420 Carnarvon St	75	77	75	77
	5h	610 Victoria St	73	75	74	75
	5i	312 Carnarvon St	74	78	77	78
Sapperton	6a	69 Jamieson Ct	74	76	74	75
Gilmore - Brentwood	7a	4788 Brentwood Dr	84	89	77	82
	7b	2088 Madison Ave	81	83	83	85
	7c	Gilmore Ave	69	74	63	67
Lougheed Town Centre	8a	3771 Bartlett Ct	67	70	63	67
	8b	Salish Ct	66	70	67	69
	8c	Perth Ave	79	83	72	75
Moody Centre – Inlet Centre	9a	301 Capilano Rd	73	74	61	62
	9b	Golden Spike Ln	87	91	83	92
	9c	Dewdney Trunk Rd	76	77	75	78
Lafarge Lake - Douglas	10a	1188 Pinetree Way	69	71	69	70
	10b	1169 Pinetree Way	78	79	77	77

Note: This summary shows results for the single noisiest train type at each location. For control locations, results are for the noisiest train type in the noisiest scenario. For full results see Appendix B.

The maximum passby noise level measurements indicate a wide range of noise levels, as expected considering the locations have different elevations, distances from the tracks, train speeds and track features. In general, the noise levels measured at each location for a single train type were very consistent. The difference between the average L_{Amax} noise level and the single loudest individual event measured was typically 1-2 dB only. This consistency reflects the automated nature of the system – almost all trains were travelling at the same speed past the same location.

At locations where the difference between average and maximum noise level is greater, the maximum noise level was generally due to a specific feature of an event that was intermittent. An example of this is location 5i, where some (but not all) train passby events included noise from the wheel flange rubbing on the side of the rail, as the train moved through the switches at this location. Occasional intermittent flanging noise was also observed on the inbound track at location 2b.

At the majority of locations, the trains on the nearest track to the measurement point produced higher maximum noise levels, and differences in noise between the two tracks could be attributed to geometry. However, at several residential locations there was a noticeable difference in the noise between the two tracks, with higher noise levels generated by the more distant track:

- At 1a (1088 Quebec) trains on the outbound track were travelling faster through the switch than trains on the inbound track and were 4 dB louder on average. There may also be some differences in the wear condition of the switch on the inbound and outbound tracks.
- At 2d (3794 Gladstone) trains of the same type on the inbound track were 4 dB louder on average than the nearer outbound trains, although speeds were similar. The difference at this location can be attributed to roughness or corrugation of the inbound track.
- At 3a (5380 Oben) inbound trains through the switch inbound were 10 dB louder on average than trains of the same type (and same speed) moving past the switch in the outbound direction. At this location, the difference is predominantly due to a worn switch requiring maintenance attention.

5.3 SkyTrain Night-Time Noise Emergence above Background

When considering the potential for sleep disturbance it is useful to consider the difference between the night-time background noise level (L_{A90}) and the typical SkyTrain maximum noise level. Table 8 provides a comparison based on the noisiest track direction for the locations where longer-term noise measurements were completed. Full results of the 24-hour noise monitoring are provided in Appendix B.

The emergence of SkyTrain noise above background depends strongly on measurement location relative to tracks and other noise sources such as main roads and will be different for other residential locations in the same area.

Table 8 SkyTrain Night Noise Emergence above Background

Area	Ref	Address	Minimum Night-time Background Level L_{A90} (dBA)	SkyTrain Average Maximum Level[1] (dBA)	Maximum Emergence above Background (dBA)
False Creek	1a	1088 Quebec St	46	81	35
VCC – Commercial Broadway - Nanaimo	2d	3974 Gladstone St	39	81	42
Joyce Collingwood	3a	5380 Oben St	40	90	50
Patterson to Metrotown	4a	6152 Kathleen Ave	42	76	34
Edmonds - 22nd Street - New West - Columbia	5b	6837 Station Hill Dr	45	71	26
	5h	610 Victoria St	49	74	25
Gilmore - Brentwood	7b	2088 Madison Ave	52	83	31
Lougheed Town Centre	8a	3771 Bartlett Ct	50	67	17
Moody Centre – Inlet Centre	9d	2525 Quay Place	37	60	23
Lafarge Lake - Douglas	10a	1188 Pinetree Way	43	69	26

Note 1: Average SkyTrain LAmax passby noise level for train movements in the noisier track direction. Measured noise levels are specific to the measurement location and elevation – impacts at other residences will be different.

The 24-hour noise monitoring results confirm that night-time background noise levels are variable around the network. The locations with the highest night-time background noise levels (7b, 8a) were close to Lougheed Highway. The locations with the lowest night-time background noise levels (9d, 2d, 3a) were located distant from any major roads. If sleep disturbance can be correlated to maximum passby noise level and night-time emergence above background, then the most affected measurement locations are 3a and 2d. Both these locations have relatively low night-time background noise levels, and relatively high maximum train noise levels, resulting in train noise emerging around 40 to 50 dB above the minimum night-time background level.

5.4 Discussion of the Influence of Temperature and Weather on Noise Levels

The influence of weather and temperature on measured noise levels was investigated at two locations (1c, 5d) where measurements were repeated over a four-month period in various meteorological conditions. Table 9 shows a summary of the control measurements with reference to the average maximum noise level measured at each location for each scenario.

For this analysis, it is assumed that the mix of train types was sufficiently similar for all scenarios to enable a direct comparison. No adjustments have been made to the measured level to account for any differences in rail roughness or switch condition over the course of the control measurements.

Table 9 Summary of Control Measurements and Scenarios

Location	Date	Scenario	No. Passbys[1]	Inbound Average LAmax (dBA)	Outbound Average LAmax (dBA)
1c – Creekside Park (switch, below guideway deck)	10 Feb 2018	Cold - 5°C	51	72	80
	24 Feb 2018	Snow - 0°C	39	69	74
	30 May 2018	Warm - 18°C	52	72	78
	19 June 2018	Hot - 27°C	75	73	79
5d – Grimston Park (slight curve and incline, level with guideway deck)	10 Feb 2018	Cold – 0 to 5°C	62	74	73
	18 Feb 2018	Cold / thin snow 0°C	68	75	74
	24 Feb 2018	Snow - 0°C	39	71	69
	29 Mar 2018	Light rain - 6°C	50	75	70
	30 May 2018	Warm - 17°C	53	72	70
	19 June 2018	Hot - 26°C	51	73	72

Note 1: This summary is for individual train passbys, excluding events with two trains passing simultaneously. All train types are included.

Overall, only one of the scenarios measured showed a potentially noticeable noise difference attributable to weather. Measurements undertaken with 15 cm of fresh snow all showed lower noise levels than measurements in other conditions. This difference is as expected, attributed to the absorptive characteristic of ground covered by fresh snow.

All other measurements across a temperature range of over 20 degrees were within +/-1 dB at Creekside Park, and within +/- 2 dB at Grimston Park. While more variation in noise levels was observed at Grimston Park, there were no clear trends with temperature or weather. For example, light rain resulted in the highest noise levels from the inbound track, but the lowest noise levels from the outbound track. The data does not suggest noise levels are consistently higher in hotter weather. Overall, the measured variation in maximum noise levels would be difficult for most people to detect.

5.5 Discussion of the Influence of Train Type

The attended measurements categorised each passby event on the basis of train type. The data collected indicates that there are sometimes differences in maximum noise levels from the different train types, but that these differences are not consistent across all locations. Due to the low number of MKIII trains currently in service and their design similarities with the MKII trains, this review concentrates on establishing differences between the MKI trains and the newer types.

5.5.1 Train Type Influence-Locations Below Guideway Deck

Several measurement locations were at ground level, below the guideway deck without a direct line of sight to the rails. At these locations (1c, 2c, 4b and 5c) there was no clear difference in the typical passby LAmax noise levels across the most common train types. At some locations and in some directions the newer trains were slightly louder than the MKI trains, by up to 2 dB. At other locations or for other track directions, the MKI trains were similar to or slightly louder than the newer train types, by around 1 dB.

At locations below the guideway deck, structure radiated noise is likely to be a factor in the overall noise level. Since the MK1 trains have smaller wheels and a lower unsprung mass[3] than the newer train types it is possible they result in slightly less energy transmitted into the guideway structure, and hence slightly lower structure radiated noise levels than the MKII or MKIII trains. However, differences in maximum noise level of the order of 1 to 2 dB as measured are considered to be marginal and would be difficult for most people to detect.

5.5.2 Train Type Influence-Station Locations

Even though train speeds were relatively low at the measurement locations near stations, traction noise was not always the dominant contributor to the overall maximum noise level. At several of the station locations, wheel/rail rolling noise or noise from switches on train approach or departure from the station was the source of the highest maximum noise level.

At Columbia station, measurements taken at location 5g (420 Carnarvon St) overlooking the opening in the station roof enabled a comparison of traction noise from different train types. At this location, the MKI train types had average L_{Amax} noise levels that were around 1 dB louder than the other train types. While this difference in noise level is considered almost negligible, the MKI trains also exhibit a distinctly tonal whining noise when coming to a stop. This tonal characteristic means that the different train types are clearly detectable by ear, and it is likely that the MKI train types could cause more annoyance at locations near stations than the newer train types.

5.5.3 Train Type Influence-Locations with Switches

At locations with switches, MKI trains were observed to be slightly louder than the newer train types. Often the difference was only 1-2 dB in average L_{Amax} noise level, however at location 1a (1088 Quebec) the MKI trains in the inbound direction were 3-4 dB louder than the newer train types. In the outbound direction at this location MKI trains were 1-2 dB louder than other types, as seen at other locations. Noise data collected from the control location in Creekside Park (opposite 1088 Quebec) saw a similar pattern for the first measurement with MKI trains notably louder than the newer trains. The difference in noise between train types was less pronounced for subsequent control measurements, but still up to 3 dB. At this control location MKI trains on the outbound track were 1 dB or less louder on average than the newer train types, a marginal difference.

Noting the differences in wheel design, it is possible that different train types produce differing magnitude of impact noise as switches wear over time. Another factor related to train type at switches is that the MKI trains with typically six cars (24 axles) per trainset will result in 50% more impacts through a worn switch than the MKII or MKIII train types, which have 4 longer cars and only 16 axles per trainset. While this does not necessarily increase the numeric maximum noise level during the passby, it may be a contributing factor in the perception of MKI trains being louder than the newer train types.

[3] Unsprung mass is the mass of all components located in the bogie below the primary vehicle suspension. It affects the dynamic interaction of the vehicle with the track, and is a factor in the amount of vibration energy transmitted into the guideway structure as a train passes by.

5.5.4 Train Type Influence-Overlooking or to side of Guideway

At locations where measurements were taken overlooking the guideway or to the side, there was a general trend of MKI trains being 1 to 2 dB noisier in terms of average L_{Amax} passby noise level. This difference was not universal. At two locations the difference was greater, up to 4 dB (2b, 2d), while at some locations MKI trains were observed to produce similar or slightly lower maximum noise levels to the newer train types (3b, 4a).

At the Grimston Park Control location (combining all measurements excluding rain and snow), MKI trains inbound were 1 dB louder on average than the newer train types. MKI trains outbound were 1 dB louder on average than MKII trains, but very similar to MKIII trains.

Overall it is concluded that the newer trains are typically somewhat quieter in terms of maximum passby noise levels than the older MKI trains, however the difference at locations overlooking the tracks is typically only 1 to 2 dB. At some locations, track features such as curves and possibly the line of roughness seen by the wheels of each type also leads to some differences in noise emissions. Overall, the measured variation in maximum noise levels between different train types would be difficult for most people to detect.

5.6 In-Car Noise Measurement Results

Noise levels measured inside a train completing a full circuit of the network have been investigated to understand how noise varies around the network with speed and rail roughness. As described in Section 3.2, there are a number of factors relating to the design of a rail transit system that affect the magnitude of wheel-rail rolling noise. These include the roughness of the rails, the roughness of the wheels, the stiffness of the rail fasteners, the design of the wheels, and the speed of the trains. By taking measurements inside a vehicle, several of these factors are controlled or set to a constant value, enabling a comparative investigation of the influence of the remaining variables. In the test train circuit, the wheel design and wheel roughness is constant throughout. Also, since the SkyTrain network uses the same rail fasteners everywhere, this factor is controlled. The remaining factors influencing rolling noise are train speed and rail roughness. While noise levels measured inside the train are not directly comparable to noise outside the train (due to the attenuation provided by the vehicle body) the relative influence of speed and rail roughness on the overall noise level is expected to be similar both inside and outside the train.

Rolling noise levels increase with speed following a relationship of the form

$$L_P = L_{p0} + N.\log_{10}\left(\frac{V}{V_o}\right)$$

where L_{p0} is the sound level at a reference speed V_0. The "speed exponent" N has a typical value of 30.[4]

To examine the influence of speed and rail roughness, sections of the network with track in tunnels have been excluded from the analysis (since noise levels are increased inside tunnels). In addition, the analysis considers only the original Expo and Millennium Lines. For the Evergreen Extension, BCRTC does not yet correlate in-car noise data to track section or train

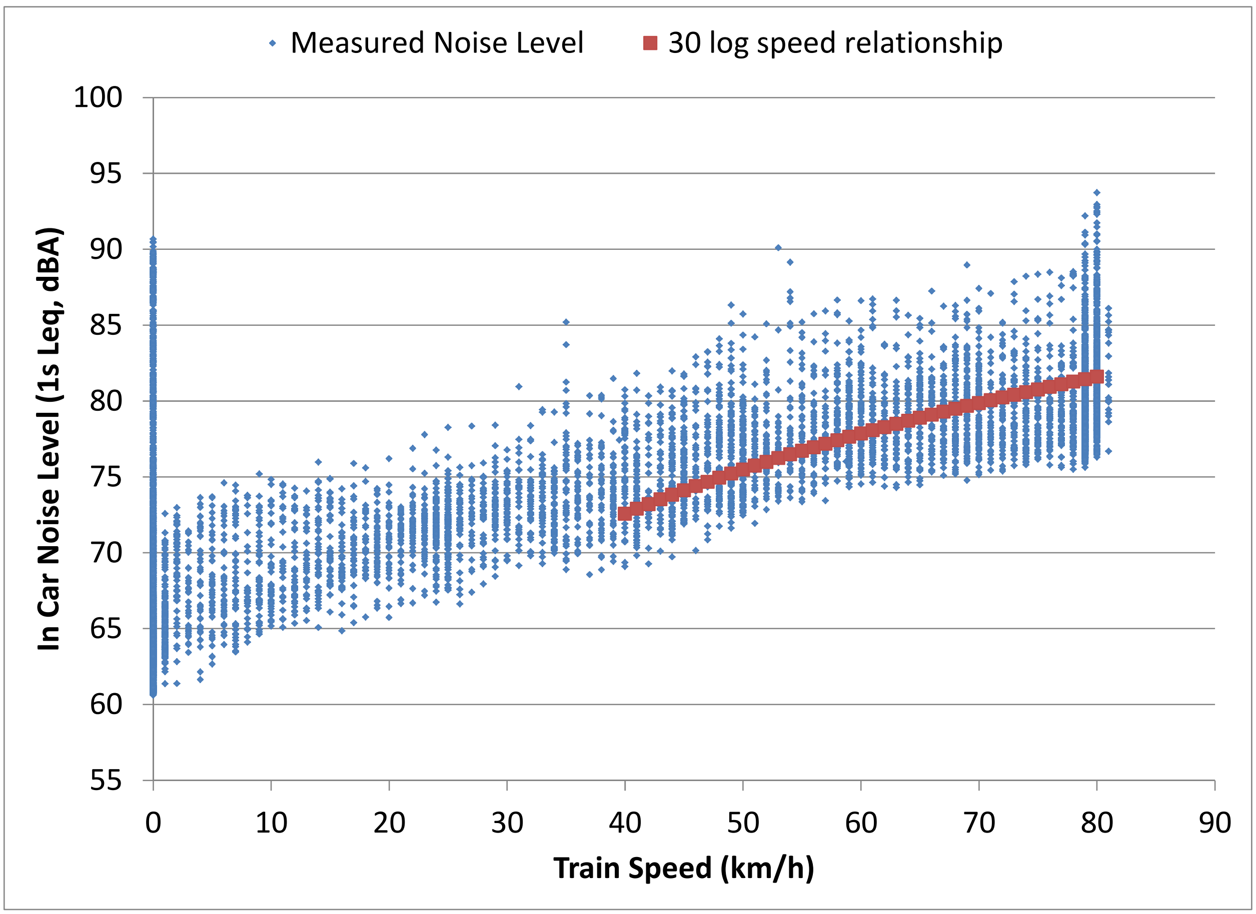
[4] *Railway Noise and Vibration Mechanisms, Modelling and Means of Control* (David Thompson, 2009)

speed. The remaining data points collected can be plotted to show the relationship between train speed and in-car noise level, as shown in Figure 6. Also shown in this figure is the expected typical relationship between speed and rolling noise level, based on a logarithmic speed exponent of 30 and the measured average in car sound level of 81.6 dBA at 80 km/h.

A high level examination of the data points in Figure 6 indicates firstly that there is a wide range of noise levels at zero speed, from 61 dB up to 91 dBA. This range covers the time period with the train stopped at a station, and includes doors opening and closing, PA announcements, traction and auxiliary systems. There is a minimum in-car noise level present at very low speeds and while stationary of 61 dBA. This minimum background noise level is due to auxiliary systems, is present at all times, and does not reflect rolling noise.

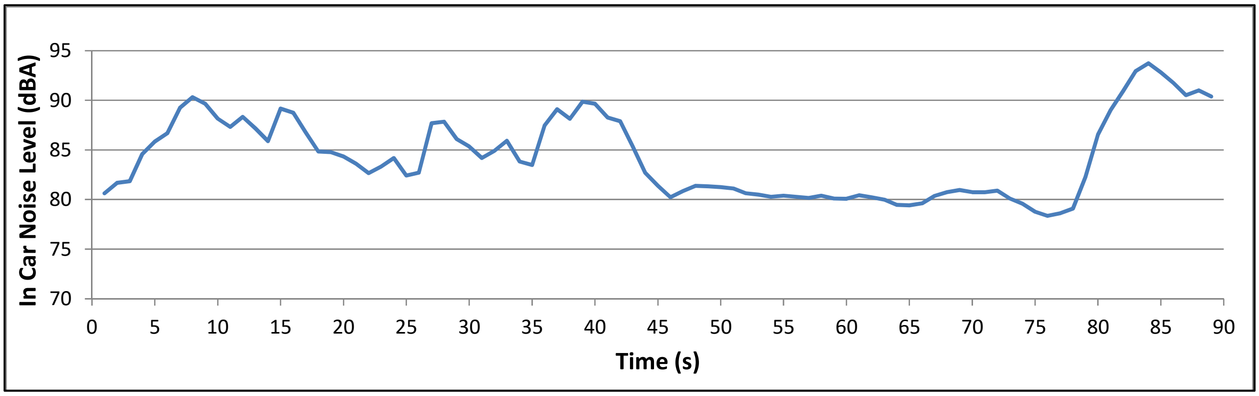
At train speeds of around 40 km/h and higher, rolling noise is expected to be dominant with no auxiliary sources contributing. Therefore, data collected at speeds of around 40 km/h and higher are most useful for examining the influence of rail roughness and speed on rolling noise.

Figure 6 In-Car Noise Level vs Speed



At the maximum normal operating speed of 80 km/h, there remains a large variation in noise levels, from 77 dBA up to 93 dBA. This difference in noise level at a constant speed indicates the range of variation in noise around the network due to variation in rail roughness and track condition, including the presence of defects on the rail head, or worn switches. It is clear from this data that rail roughness and track condition can result in differences in rolling noise level of the order of 15 dB or more in the highest speed sections of track. To further illustrate this difference, in-car noise levels measured over a 90 second period travelling at consistent 80 km/h speed are plotted in Figure 7. In this 90 second period (over a section of outbound track between Main St – Science World and Broadway), corrugated track was observed leading to in-car noise levels of up to 90 dBA. For a period around the 1-minute mark, the noise level dropped back to around 80 dBA or even less, before increasing again to 94 dBA.

Figure 7 In-Car Noise Level Example Variation at 80 km/h



5.7 Discussion of Public Address System Noise

Although measurements were taken in close proximity to several stations, no PA announcements were observed as part of this study. It is understood that PA announcements are not made for every train arrival or departure but are only used when required to notify passengers of special circumstances.

PA maximum noise levels on Level 4 of 420 Carnarvon Street overlooking Columbia Station have been measured previously by others. BKL[5] reported maximum PA noise levels up to 83 dBA, with the highest noise events attributed to feedback during an announcement made by the station attendant via a platform telephone handset or via radio. Announcements made by other means including those generated from the SkyTrain operations centre were typically lower in volume, up to 77 dBA L_{Amax}. With reference to the maximum noise levels measured in this study due to trains arriving and departing, 77 dBA L_{Amax} from PA announcements is similar to the maximum noise level due to trains. Announcements by the station attendant including feedback are sometimes louder than the maximum noise level due to trains.

5.8 Summary of Measured Noise Levels and Observations

Noise measurements and observations have been completed at 32 locations distributed around the network. The analysis of the data collected has led to the following conclusions:

1. Maximum SkyTrain noise levels of 75 dBA would generally be considered acceptable (with windows closed) while higher noise levels would require better than average attenuation across the façade to meet internal noise goals and avoid sleep disturbance.

[5] BKL memorandum to Translink. *Columbia Station Public Address (PA) System Baseline Noise Measurement,* September 15, 2017.

2. An external maximum noise level of 87 dBA is the highest noise level that could feasibly be attenuated across a facade to minimize sleep disturbance.
3. Noise levels measured at residential facades vary considerably, but the most affected residences are exposed to maximum SkyTrain noise levels that are 90 dBA or higher for average train passby events.
4. At most locations with the greatest noise exposure there are two main factors contributing to the problem. The first is train speed, with the highest noise levels occurring adjacent to high speed sections of track. The second is track condition, with rail roughness or worn switches resulting in noise levels up to 15 dB higher than corresponding noise levels in sections with track and or switches in good condition.
5. At a few locations some intermittent flanging noise was observed leading to a 3-5 dB increase in maximum noise levels. However, severe flanging was not observed anywhere. Curve squeal was also not observed – this is attributed to the vehicle design incorporating steering wheelsets.
6. Other factors such as train type, temperature and weather conditions were found to have a relatively minor effect on maximum noise levels.

6.0 SKYTRAIN NOISE MODELLING AND MAPPING

It is not feasible to measure the noise from the SkyTrain at every residential location around the network. Instead, noise modelling is used to identify maximum noise levels throughout all the identified study areas. The noise model is validated by the measurements at representative locations and used to generate noise maps. Noise modelling software SoundPLAN Version 8.0 has been used to calculate railway maximum noise levels across each of the study areas for this project. Of the train noise prediction models available within SoundPLAN, the Nord2000 algorithm has been used.

6.1 Overview of Model Inputs

6.1.1 Speeds, Source Noise Levels and Condition Corrections

Typical train speed information for each track 25 m track section on the original Expo and Millennium Lines has been provided by Translink and verified by comparison with test train speeds. For the Evergreen Extension this information was not available, instead typical acceleration and deceleration profiles for Mark II trains were determined from elsewhere on the Millennium Line and attributed to the Evergreen Line centred on each station location. Between Evergreen Line stations, the maximum speed of 80 km/h was assumed.

The source noise level input data used in modelling the Vancouver SkyTrain have been derived from the measurements. The reference source noise levels are summarized in Appendix C along with other technical parameters used in the noise model. Noting the variation in rolling noise with rail surface condition around the network, a rail surface condition correction has been included. This surface correction has been derived from the test train in-car noise data and attributed to the corresponding 25 m track section in the model. At some locations where surface condition was good, this correction is a negative addition to the reference source levels. At locations with corrugation or worn switches, the correction is a positive addition resulting in a localized increase in noise level.

For the Expo Line, reference source levels based on MKI trainsets have been used since this rolling stock was marginally louder than newer trains at locations overlooking the guideway deck. For the Millennium Line, MKII reference source levels have been used.

6.1.2 Track Alignment, Ground Terrain and Buildings

Track alignments, track elevations, ground terrain, building footprints and heights were extracted from open source GIS data including aerial imagery, ground contours and LiDAR (Light Detection and Ranging) data where available. For areas within the municipalities of New Westminster and Port Moody LiDAR was not available. Track elevations in these areas have been estimated with reference to site observations, typical guideway heights above ground, known maximum guideway gradients and known locations of tunnel portals.

In New Westminster building footprints were available but not building heights. The height of high-rise buildings immediately adjacent to the tracks was estimated, with other buildings at greater distances assumed to be typical two storey residential buildings with a height of 10 m. In Port Moody, neither building footprints nor heights were available. Here building footprints have been generated from aerial imagery for the first few rows of buildings adjacent to the railway, with heights estimated. Port Moody areas set further back from the railway were represented in the model as a “volume attenuation area” to simulate noise attenuation through a typical built up urban area, without representing individual buildings in the model.

6.2 Model Validation

A comparison of measured average vs modelled maximum noise levels has been undertaken as shown in Table 10. The comparison is made between the model and the average measured maximum noise level for the noisiest track at each location. A positive difference indicates the model is over-predicting noise relative to the average measured passby maximum noise level. A negative difference indicates the model is under-predicting noise. For noise modelling, a difference between predictions and measurements of +/- 3 dB is considered acceptable, while agreement of +/- 2 dB is considered very good.

Table 10 Noise Model Results vs Measured Maximum Noise Levels

Area	Ref	Address	Measured Passby average LAmax (dBA)	Modelled Passby LAmax (dBA)	Difference (dBA)
False Creek	1a	1088 Quebec St	81	82	1
	1b	688 Abbott St	77	77	0
	1c	Creekside Park	80	79	-1
VCC – Commercial Broadway - Nanaimo	2a	Woodland Dr	87	89	2
	2b	2360 Commercial Dr	82	82	0
	2c	3250 Commercial Dr	82	81	-1
	2d	3974 Gladstone St	81	82	1
Joyce Collingwood	3a	5380 Oben St	90	89	-1
	3b	Vanness Ave	80	81	1
Patterson to Metrotown	4a	6152 Kathleen Ave	76	77	1
	4b	4333 Central Blvd	88	81	-7

Table 10 Noise Model Results vs Measured Maximum Noise Levels

Area	Ref	Address	Measured Passby average LAmax (dBA)	Modelled Passby LAmax (dBA)	Difference (dBA)
Edmonds - 22nd Street - New West - Columbia	5a	Prenter St	73	76	3
	5b	6837 Station Hill Dr	71	72	1
	5c	2311 London St	78	78	0
	5d	Grimston Park	76	79	3
	5e	426 14th St	81	83	2
	5f	892 Carnarvon St	77	77	0
	5g	420 Carnarvon St	75	75	0
	5h	610 Victoria St	74	75	1
	5i	312 Carnarvon St	77	77	0
Sapperton	6a	69 Jamieson Ct	74	75	1
Gilmore - Brentwood	7a	4788 Brentwood Dr	84	82	-2
	7b	2088 Madison Ave	83	82	-1
	7c	Gilmore Ave	69	71	2
Lougheed Town Centre	8a	3771 Bartlett Ct	67	65	-2
	8b	Salish Ct	67	66	-1
	8c	Perth Ave	79	79	0
Moody Centre – Inlet Centre	9a	301 Capilano Rd	73	73	0
	9b	Golden Spike Ln	87	89	2
	9c	Dewdney Trunk Rd	76	76	0
Lafarge Lake - Douglas	10a	1188 Pinetree Way	69	67	-2
	10b	1169 Pinetree Way	78	80	2

Note: This summary shows results for the single noisiest train type and nosiest track direction at each location. A positive difference indicates the model is overpredicting relative to the average measured passby maximum noise level. A negative difference indicates the model is underpredicting noise.

The comparison between modelled maximum noise level and measured maximum noise level as shown in Table 10 indicates that the model results are generally in very good agreement with measurements. Model results at 29 of the 32 locations are within +/- 2 dB of the measured results. At two locations the agreement is + 3 dB, indicating the model is acceptable but slightly conservative at these locations.

At one location the agreement is poor with the model under-predicting noise by 7 dB. This location (4b) is relatively close to the guideway at ground level. Note that Location 4a is very close to the same track section but is elevated relative to the guideway - at this elevated location the model predictions correspond very well to measurements indicating that the direct noise radiated from the track is reasonably well represented by the model.

A review of the in-car noise data and a comparative investigation of the noise at a geometrically similar measurement location has been undertaken in an attempt to understand the discrepancy at 4b. Measurement location 2c is very similar to location 4b. Each of these locations is a similar distance from the guideway, below the guideway deck, with train speeds of 80 km/h. Inbound trains produce the highest noise levels at both locations, and the measured inbound in-car noise levels were similar (80 dBA vs 81 dBA) indicating similar source noise levels at both locations. Despite these similarities, the measured noise levels at location 4b were 6 dB higher than those at location 2c. In the absence of other explanations, it is concluded that the structure radiated noise component may be higher than typical at location 4b. No adjustments have been made to the model to compensate for this discrepancy. Overall, the model is considered to be an adequate representation of maximum SkyTrain noise levels around the network and is suitable for the purpose of mapping noise levels.

6.3 Model Results

The noise model results are provided in two sets of noise maps for each of the study areas in Appendices D and E.

Appendix D shows the noise impacts at 20 m above ground level. This elevation represents noise impacts at the most affected locations overlooking the guideway deck, for example around the 6th level of a multi-storey building. At this level, the guideway parapets typically do not provide significant shielding of noise to overlooking receivers. Noise at higher elevations would begin to decrease again, noting that noise attenuates with distance (i.e. height) above the guideway. In interpreting the noise maps at 20 m elevation, note that the noise levels shown are not representative of impacts at ground or lower height buildings.

Appendix E shows maximum noise levels at an elevation of 5 m above ground level. This elevation is representative of noise impacts at locations below the guideway deck, for example at the second storey window level of a typical detached house.

7.0 PRIORITIES FOR CONSIDERATION OF NOISE MITIGATION

7.1 Noise vs Population

The noise contours for each study area have been overlaid with block level Vancouver census data from 2016 to determine the approximate population in the areas corresponding to each noise contour band in each of the study areas, as shown in Table 11. This analysis has been undertaken for the 20 m elevation contours only. This analysis does not distinguish between noise impacts at different building facades, or at other building heights. The numbers of people identified is the sum of the population in each census division that overlaps in any way the noise contour of interest.

Not all people living in a census division area overlapping a noise contour band will be affected by SkyTrain noise at this maximum level. For example, noise impacts will be much less in an apartment oriented away from the rail line than in an apartment facing the rail line. Some census division areas may be overlapped by more than one contour band. The numbers shown in Table 11 do not indicate the actual number of noise affected people in each area, which will be considerably less than shown.

This exercise has been undertaken in an attempt to determine a relative ranking of each of the study areas, based on the number of people who may benefit from noise mitigation. In reviewing the results, note that each study area is a different size. For example, Study Area 5 (Edmonds to Columbia) is considerably larger than Study Area 1 (False Creek). This affects the number of people identified within each noise contour in each study area and hence the ranking.

Table 11 Population of Census Blocks Overlapping 20 m Noise Contours

Study Area	Population within noise contour – 20 m elevation[1]			
	75 dBA	80 dBA	85 dBA	90 dBA
False Creek	10	6	1	0
VCC – Commercial Broadway - Nanaimo	37	21	9	3
Joyce Collingwood	20	13	6	2
Patterson to Metrotown	18	11	3	0
Edmonds - 22nd Street - New West - Columbia	43	24	8	1
Sapperton	2	1	0	0
Gilmore - Brentwood	19	11	4	0
Lougheed Town Centre	8	4	0	0
Moody Centre – Inlet Centre	7	4	1	0
Lafarge Lake - Douglas	3	1	0	0

Note 1: Noise contour areas are overlapping – people counted from blocks overlapping the 90 dBA contour are also counted for all other noise contours. Population estimates are expressed as thousands. Population numbers reflect the combined effect of the physical size of each study area and the magnitude of noise emissions. The numbers shown **do not** indicate the number of noise affected people in each area, which will be less than shown.

The resulting ranking of noise study areas based on the number of people who may benefit from noise mitigation is as follows. Note that this ranking does not constitute a recommendation for prioritisation of mitigation, since there are limitations to determining priorities on the basis of arbitrarily sized discrete study areas. Recommended priorities for noise mitigation are discussed in Section 7.2.

1. VCC – Commercial Broadway – Nanaimo: This study area has the highest number of people potentially affected by very high noise levels both above 85 dBA and above 90 dBA. Even with windows closed and extremely good façade attenuation, noise at this level is likely to cause sleep disturbance. The high noise levels are primarily attributed to sections with rough rails in high speed sections of track, and partially to switch noise.
2. Joyce Collingwood: This study area is one of the physically smaller areas but has the second highest number of people potentially affected by very high noise levels above 90 dBA. The primary issue is switch noise, with some areas of rough rails traversed at high speeds.
3. Edmonds – 22nd St – New West – Columbia: This area has relatively high numbers of people potentially affected by noise above 85 dBA. The main issues are rough rails, switch noise and flanging at the Surrey line junction. This is also a large study area.
4. Patterson to Metrotown, and Gilmore to Brentwood – these areas have the next greatest potentially noise affected populations, but with less prevalence of residents exposed to noise levels above 80 dBA.
5. False Creek – This study area is smaller than some others which is a factor in the lower number of potentially affected residents. Another factor is that train speeds are typically lower in this area than elsewhere, so absolute maximum noise levels are less than observed elsewhere.
6. Lougheed Town Centre and Moody Centre to Inlet Centre have maximum noise levels typically less than elsewhere on the network, and relatively low numbers of people potentially affected by noise at levels above 80 dBA.
7. Sapperton and Lafarge Lake Douglas have relatively low numbers of people potentially affected by noise at levels above 75 dBA.

7.2 Discussion of Priorities for Noise Mitigation

While it is possible to rank the study areas based on the number of people who may benefit from noise mitigation, determining priorities for noise mitigation on the basis of the population of the study areas is not recommended. The noise study areas are arbitrary, having been determined initially from complaint density and being of variable physical area. Noise impacts vary considerably at different locations within each study area, for example the areas affected by increased noise from sections of rough rails can be highly localized. In addition, the population density analysis that has been undertaken is limited by the resolution of the census divisions.

It is recommended that priorities for future noise mitigation be determined based on noise level in specific affected areas, regardless of study area. Any residential areas with measured or modelled maximum noise levels above 85 dBA should be categorized as the first priority for consideration of mitigation. This is based on the upper limit (with windows closed) 87 dBA WHO criterion for sleep disturbance, with a 2 dB factor to account for model uncertainty.

Relative to the most noise affected locations, residential areas with maximum noise levels of 80 dBA to 85 dBA are suggested as a second priority for consideration of mitigation, and areas with maximum noise levels of 75 to 80 dBA as the third priority.

8.0 CONCLUSION

Measurements and observations have been completed at 32 locations distributed around the network. The results from noise measurements conducted inside a test train while completing a full circuit of the network were also used in the analysis. This data was used to develop a noise model and the appended noise maps indicating noise exposure across ten study areas.

The study indicates that noise levels at residential façades vary considerably. The most affected residences are exposed to maximum SkyTrain noise levels of the order of 90 dBA for typical train passby events. At locations with the greatest noise exposure, wheel/rail rolling noise is the predominant issue. There are four main factors contributing to the problem:

1. Train speed - the highest noise levels occurring at high speed sections of track.
2. Proximity – the greatest noise exposures occur close to the tracks.
3. Elevation – the highest noise levels are at locations overlooking the guideway.
4. Track condition - rail roughness, corrugation, track defects or worn switches result in noise levels that can be upwards of 15 dB greater than corresponding levels in comparable locations with track and/or switches in good condition.

The influence on noise of train type, temperature and weather conditions has been investigated. While some differences were observed, in general these factors were found to have only a minor effect on maximum SkyTrain noise levels, relative to the influence of track condition.

Census data from 2016 has been reviewed in conjunction with the noise maps to rank the study areas on the basis of noise level and population. However, since the division of the network into noise study areas is arbitrary it is recommended that priorities for noise mitigation be based on specific noise affected areas, regardless of study area, such as:

- Residential areas with measured or modelled maximum noise levels above 85 dBA are recommended as the first priority for consideration of mitigation. This is based on the upper limit (with windows closed) 87 dBA WHO criterion, with a 2 dB factor to account for model uncertainty.

- Residential areas with maximum noise levels of 80 to 85 dBA are the second priority for consideration of mitigation
- Residential areas with maximum noise levels of 75 to 80 dBA are the third priority for consideration of mitigation.

A separate “Next Steps” report has been prepared by SLR for Translink building on the findings of this Noise Report. It identifies potential noise mitigation options, and provides details of the scope of work, resources, timeframe and budget cost required to investigate each option.

9.0 STATEMENT OF LIMITATIONS

This report has been prepared and the work referred to in this report has been undertaken by SLR Consulting (Canada) Ltd. (SLR) for Translink, hereafter referred to as the “Client”. It is intended for the sole and exclusive use of Translink. The report has been prepared in accordance with the Scope of Work and agreement between SLR and the Client. Other than by the Client and as set out herein, copying or distribution of this report or use of or reliance on the information contained herein, in whole or in part, is not permitted unless payment for the work has been made in full and express written permission has been obtained from SLR.

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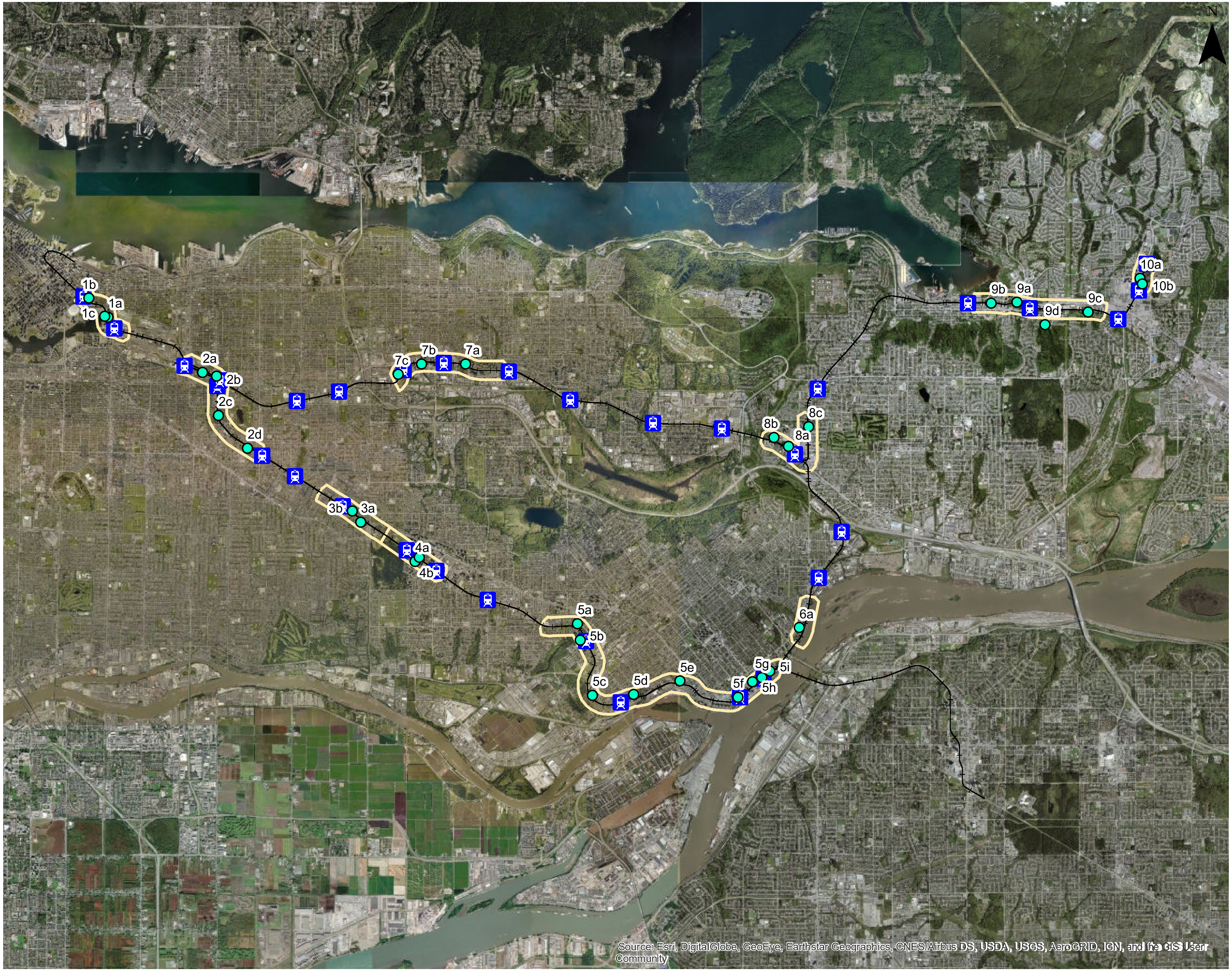
APPENDIX A
Study Areas and Measurement Locations

SkyTrain Noise Study Vancouver
Noise Report and Maps
SLR Project No.: 201.04644.00003



LEGEND

- Noise Measurement Location
- Skytrain Stations
- Track
- Noise Contour Calculation Area

0 1 2 4 Kilometers

SCALE: 1:80,000
WHEN PLOTTED CORRECTLY AT 11 x 17
NAD 1983 UTM Zone 10N

NOTES

This map is for conceptual purposes only and should not be used for navigational purposes.

Basedata:

SKYTRAIN

TRANSLINK NOISE MAPPING

STUDY AREA AND NOISE MEASUREMENT LOCATIONS

October 26, 2018	Rev **0.0**	Figure No.
Project No. 201.04644.00003		**A**

SLR
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APPENDIX B
Noise Measurements Description and Results

SkyTrain Noise Study Vancouver
Noise Report and Maps
SLR Project No.: 201.04644.00003

Noise Monitoring Location Descriptions

Noise Measurement Location:	**1a – 1088 Quebec Street**
Sound Level Meter: B&K 2270	Serial No: 2808472
Calibrator: B&K 4231	Serial No: 2326528

Measurements were taken on a Level 8 balcony of 1088 Quebec Street, overlooking the SkyTrain between Stadium – Chinatown Station and Main Street – Science World Station. Road traffic noise (SPL typically around 60 to 70 dBA) and the SkyTrain were observed as the main sources contributing to the ambient noise environment. The track adjacent to the measurement location is a 300 meter straight section incorporating a switch (crossover). Trains on the outbound track travelled at higher speeds through the switch, were noticeably louder than inbound trains, and dominated the maximum noise level even during simultaneous passbys. Inbound trains approached the switch at low speed then accelerated over the switch. Speed variation between individual trains was observed giving some variability in noise. MK I trains were noticeably louder through the switch than MK II and MK III.

A total of 80 events were observed at this location. Of these, 5 have been excluded from the analysis due to the influence of noise from sources other than the SkyTrain.

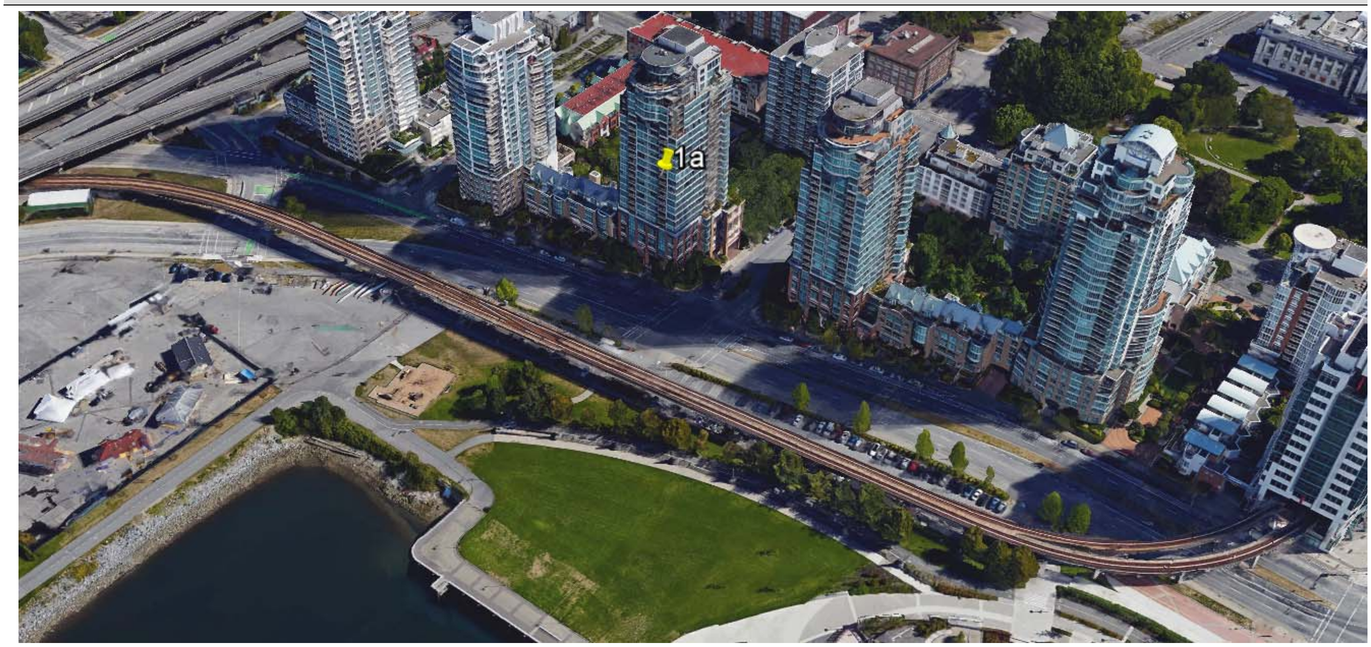
View to tracks

Attended Noise Measurement Results

Date: 20/03/2018 **Start Time:** 8:30 am Conditions: Overcast to partly cloudy, no wind, 5°C

Track	**Train Type**	**No. of Events**	**Sound Pressure Level (dBA)**	
			Average LAFmax[1]	**Maximum LAFmax**
Inbound	MK I	16	77	79
	MK II	11	73	79
	MK III	5	74	76
Outbound	MK I	15	81	83
	MK II	14	79	80
	MK III	3	80	80
Train on both tracks	Various	11	80	82
Combined	All	75	78	83

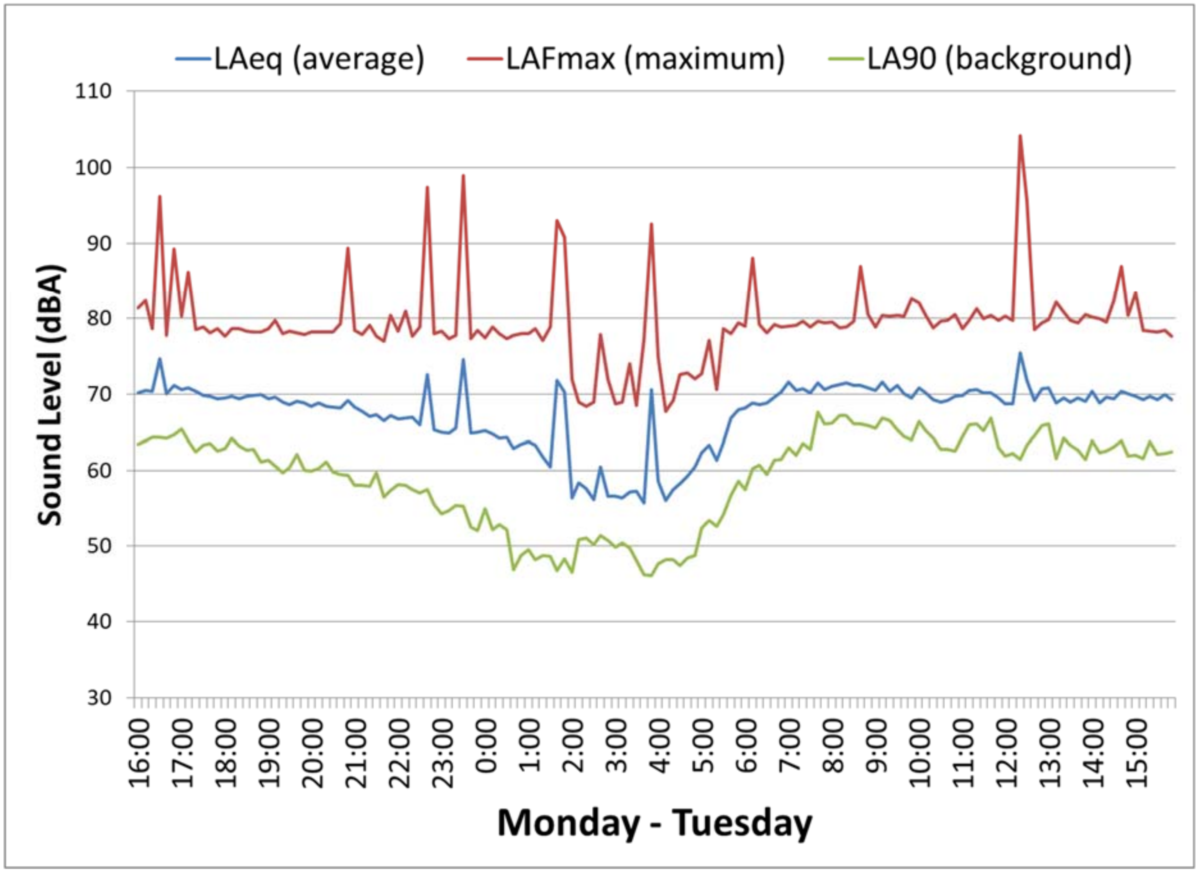
Noise Measurement Location



Note 1: Arithmetic Average

Unattended Noise Measurement Results: 1a – 1088 Quebec Street		
Start Date: 16/04/2018	Sound Level Meter: Larson Davis 824	Serial No: 824A0301

Measured sound level time history (10 minute increments):



Notes:

SkyTrain hours of operation are between 5:00 am and 1:30 am (with some variation depending on location).

The typical maximum noise level in any 10 minute period is around 80 dBA and is clearly correlated to SkyTrain hours of operation – the attended measurements found similar SkyTrain maximum noise levels. Sources other than the SkyTrain are responsible for isolated peaks in the maximum noise level time history that are considerably different from this typical level.

At this location, the minimum background L90 noise level in any 10 minute period was 46 dBA during the night-time. The highest background L90 noise level was 68 dBA, during the morning peak period.

The difference between SkyTrain maximum noise level and the background noise level is typically around 20 dBA during the daytime and 30-35 dBA during the night-time, at times of first and last services.

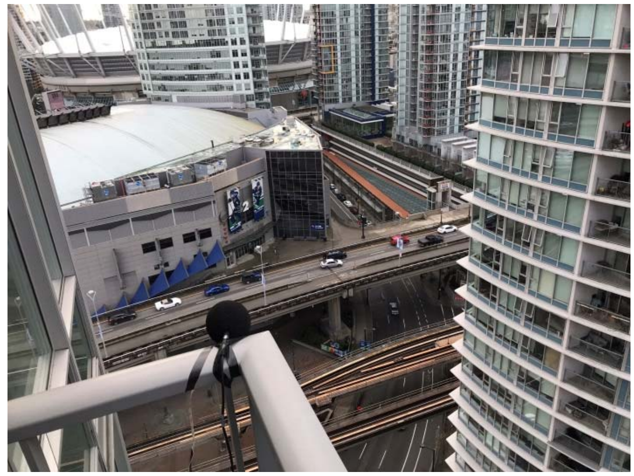
Noise Monitoring Location Descriptions

Noise Measurement Location:	1b – 688 Abbott Street
Sound Level Meter: B&K 2270	Serial No: 2808472
Calibrator: B&K 4231	Serial No: 2326528

Measurements were taken on a Level 26 balcony of 688 Abbott Street, overlooking the SkyTrain near Stadium – Chinatown Station. Road traffic (SPL typically around 62 to 68 dBA), occasional sirens and the SkyTrain were observed as the main sources contributing to the ambient noise environment. The track adjacent to the measurement location is the station approach with a switch on the outbound track. Trains on the outbound track accelerating through the switch were somewhat louder than inbound trains. Inbound trains were also observed to be passing over a track discontinuity of some kind, although this was not visible from the measurement location.

A total of 73 events were observed at this location. Of these, 2 have been excluded from the analysis due to the influence of noise from sources other than the SkyTrain.

View to Tracks

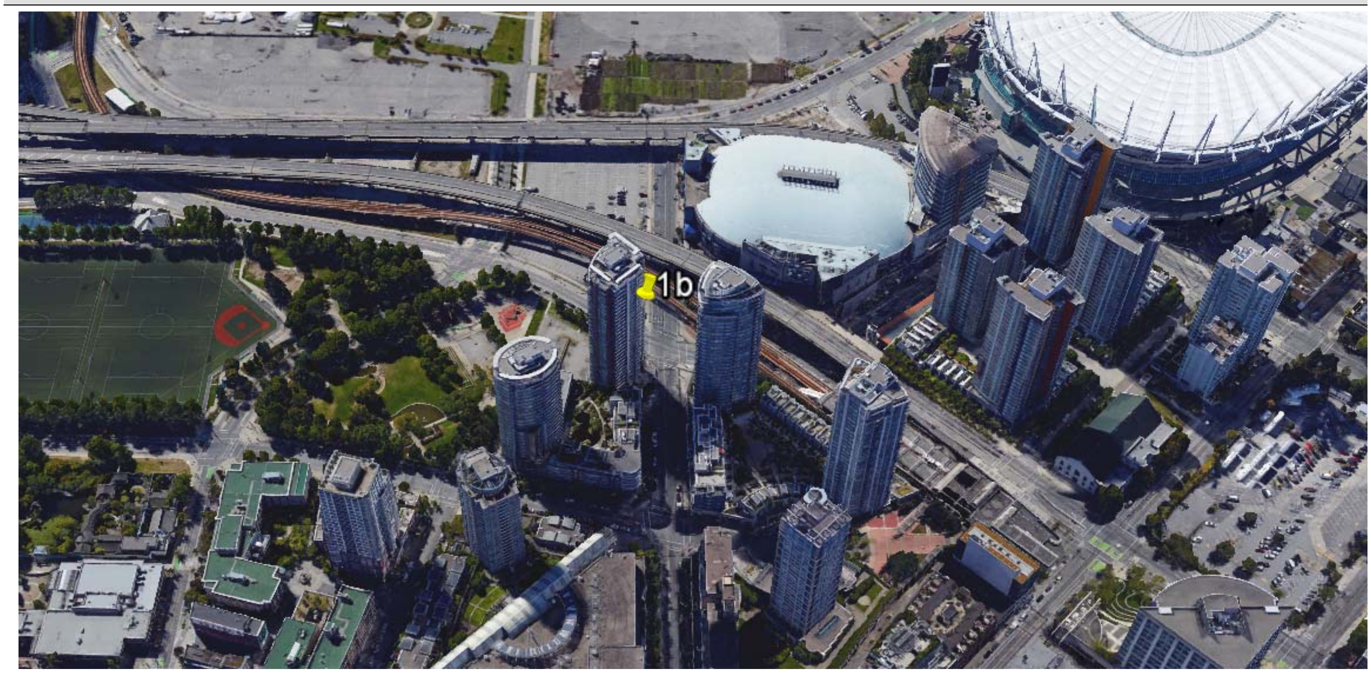


Attended Noise Measurement Results

Date: 22/03/2018 **Start Time:** 5:45 pm Conditions: Overcast to partly cloudy, occasional breeze, 5°C

Track	Train Type	No. of Trains	Sound Pressure Level (dBA)	
			Average LAFmax[1]	Maximum LAFmax
Inbound	MK I	17	75	76
	MK II	10	76	76
	MK III	4	75	76
Outbound	MK I	21	77	78
	MK II	6	75	75
	MK III	6	76	77
Train on both tracks	Various	7	77	78
Combined	All	71	76	78

Noise Measurement Location



Note 1: Arithmetic Average

Noise Measurement Location:	1c – Creekside Park (Control)
Sound Level Meter: B&K 2270	Serial No: 2808472
Calibrator: B&K 4231	Serial No: 2326528, 1795340

This location in Creekside Park was used as a control location to measure noise over several months in various conditions.

The track adjacent to the measurement location is a 300 meter straight section incorporating a switch (crossover). Trains on the outbound track travelled at higher speeds through the switch, were noticeably louder than inbound trains, and dominated the maximum noise level during simultaneous passbys. Inbound trains approached the switch at low speed then accelerated over the switch. Speed variation between individual trains was observed giving some variability in noise.

The reported results for each scenario at this control location exclude simultaneous passby events and events influenced by noise from sources other than the SkyTrain. Results are reported for each measurement scenario, namely cold weather, cold with snow, warm weather and hot weather.

View to Tracks

Noise Measurement Location

Attended Noise Measurement Results – Scenario 1 Cold Weather

Date: 10/02/2018 **Start Time:** 7:00 am Conditions: Overcast to partly cloudy, no wind, 5°C

Track	Train Type	No. of Trains	Sound Pressure Level (dBA)	
			Average LAFmax[1]	Maximum LAFmax
Inbound	MK I	17	74	75
	MK II	5	69	71
	MK III	2	69	69
Outbound	MK I	18	80	81
	MK II	7	80	81
	MK III	2	80	80
Combined	All	51	76	81

Attended Noise Measurement Results – Scenario 2 Snow				
Date: 24/02/2018	**Start Time:** 7:15 am		Conditions: Calm, 0°C, 15 cm of fresh snow	
Track	**Train Type**	**No. of Trains**	**Sound Pressure Level (dBA)**	
			Average LAFmax[1]	**Maximum LAFmax**
Inbound	MK I	10	70	71
	MK II	9	67	72
	MK III	1	69	69
Outbound	MK I	9	74	75
	MK II	9	73	74
	MK III	1	73	73
Combined	All	39	71	75

Attended Noise Measurement Results – Scenario 3 Warm				
Date: 30/05/2018	**Start Time:** 3:40 pm		Conditions: Sunny, 18°C, light breeze	
Track	**Train Type**	**No. of Trains**	**Sound Pressure Level (dBA)**	
			Average LAFmax[1]	**Maximum LAFmax**
Inbound	MK 1	10	73	75
	MK 2	9	72	75
	MK 3	6	70	71
Outbound	MK 1	15	78	79
	MK 2	7	78	79
	MK 3	5	78	78
Combined	All	52	75	79

Attended Noise Measurement Results – Scenario 4 Hot				
Date: 19/06/2018	**Start Time:** 3:45 pm		Conditions: Sunny, 27°C, calm to light breeze	
Track	**Train Type**	**No. of Trains**	**Sound Pressure Level (dBA)**	
			Average LAFmax[1]	**Maximum LAFmax**
Inbound	MK 1	22	74	76
	MK 2	9	72	73
	MK 3	5	71	71
Outbound	MK 1	19	79	80
	MK 2	12	79	80
	MK 3	8	78	79
Combined	All	75	76	80

Note 1: Arithmetic Average

Noise Monitoring Location Descriptions

Noise Measurement Location:	2a – Woodland Drive Bridge
Sound Level Meter: B&K 2270	Serial No: 2808472
Calibrator: B&K 4231	Serial No: 2326528

Measurements were taken from the eastern sidewalk of the bridge, with the microphone placed on the edge of the bridge directly above the outbound Millennium Line track in the cutting. Measurements were also taken of trains on the elevated Expo Line guideway.

Noise from other sources such as road traffic and freight trains was observed only intermittently. Both Expo and Millennium lines are tangent track with no noticeable joints or track defects. Trains on the Expo line are higher speed than on the Millennium Line, this combined with the location of the Millennium track in cutting mean noise impacts to residences would be greater from the Expo line.

A total of 89 events were observed at this location. Of these, 2 have been excluded from the analysis due to the influence of noise from sources other than the SkyTrain.

View to Tracks

Attended Noise Measurement Results

Date: 23/03/2018 **Start Time:** 10:45 am Conditions: Overcast to partly cloudy, no wind, 5°C

Track	Train Type	No. of Trains	Sound Pressure Level (dBA)	
			Average LAFmax[1]	Maximum LAFmax
Inbound Millennium	MK II	13	84	86
Outbound Millennium	MK II	17	87	88
Inbound Expo	MK I	18	74	75
	MK II	9	74	78
	MK III	2	72	72
Outbound Expo	MK I	14	84	85
	MK II	9	83	87
	MK III	2	83	83
Train on both tracks	Various	3	86	87
Combined	All	87	81	88

Noise Measurement Location

Note 1: Arithmetic Average

Noise Measurement Location:	2b – 2360 Commercial Dr
Sound Level Meter: B&K 2270	Serial No: 2808472
Calibrator: B&K 4231	Serial No: 2326528

Measurements were taken at the edge of the rooftop carpark above St Augustine's at 2360 Commercial Drive. Short-term maximum noise levels from road traffic were often similar to rail noise levels, including occasional horns, trucks and buses. Measurements were taken of trains on the elevated Expo Line tracks only, on the curve into and out of the station. Millennium Line trains were in cutting and not visible. At this location, measurements were abbreviated to the duration of the train passby only (Tp as defined in ISO 3095) to avoid the influence of road traffic.

Mild intermittent flanging and curve noise characteristics were observed for a few passby events, particularly inbound MK I trains and contributed to the highest maximum noise levels for those events.

A total of 82 events were observed at this location. Of these, 9 have been excluded from the analysis due to the influence of noise from sources other than the SkyTrain.

View to Tracks

Attended Noise Measurement Results

Date: 21/03/2018 **Start Time:** 2:00 pm Conditions: Overcast to partly cloudy, calm, 7°C

Track	Train Type	No. of Trains	Sound Pressure Level (dBA)	
			Average LAFmax[1]	Maximum LAFmax
Inbound	MK I	21	82	86
	MK II	11	79	81
	MK III	6	79	80
Outbound	MK I	13	79	80
	MK II	14	77	78
	MK III	5	76	78
Train on both tracks	Various	3	83	86
Combined	All	73	79	86

Noise Measurement Location

Note 1: Arithmetic Average

Noise Measurement Location:	**2c – 3250 Commercial Drive**
Sound Level Meter: B&K 2270	Serial No: 2821599
Calibrator: B&K 4231	Serial No: 1795340

The 3250 Commercial Drive measurement was situated in the Croatian Cultural Centre parking lot, below guideway deck level and adjacent to a curve. The measurement position has acoustic line of sight of the inbound track and an obstructed view of the outbound track.

60 events were measured and all were included in the analysis, with none influenced by noise from sources other than the SkyTrain.

View to Tracks

Attended Noise Measurement Results

Date: 20/03/2018 **Start Time:** 10:30 am Conditions: Mild wind, overcast, 7°C

Track	**Train Type**	**No. of Trains**	**Sound Pressure Level (dBA)**	
			Average LAFmax[1]	**Maximum LAFmax**
Inbound	MK I	11	81	82
	MK II	10	82	85
	MK III	2	79	82
Outbound	MK I	21	74	80
	MK II	9	75	76
	MK III	1	70	70
Train on both tracks	Various	6	81	83
Combined	All	60	78	85

Noise Measurement Location

Note 1: Arithmetic Average

Noise Monitoring Location Descriptions

Noise Measurement Location:	**2d - 3174 Gladstone**
Sound Level Meter: B&K 2270	Serial No: 2808472
Calibrator: B&K 4231	Serial No: 2326528

Measurements were taken on the rear porch of 3174 Gladstone St, elevated at first floor level. At this location the track is straight but inclined with outbound trains travelling uphill.

Impact noise from the switch to the west of the measurement point was noticeable for trains travelling inbound. Noise attributed to rail corrugation was also observed.

A total of 70 events were observed at this location. All were included in the analysis with none influenced by noise from sources other than the SkyTrain.

View to Tracks

Attended Noise Measurement Results

Date: 20/03/2018 **Start Time:** 9:45 am Conditions: Overcast to partly cloudy, no wind, 5°C

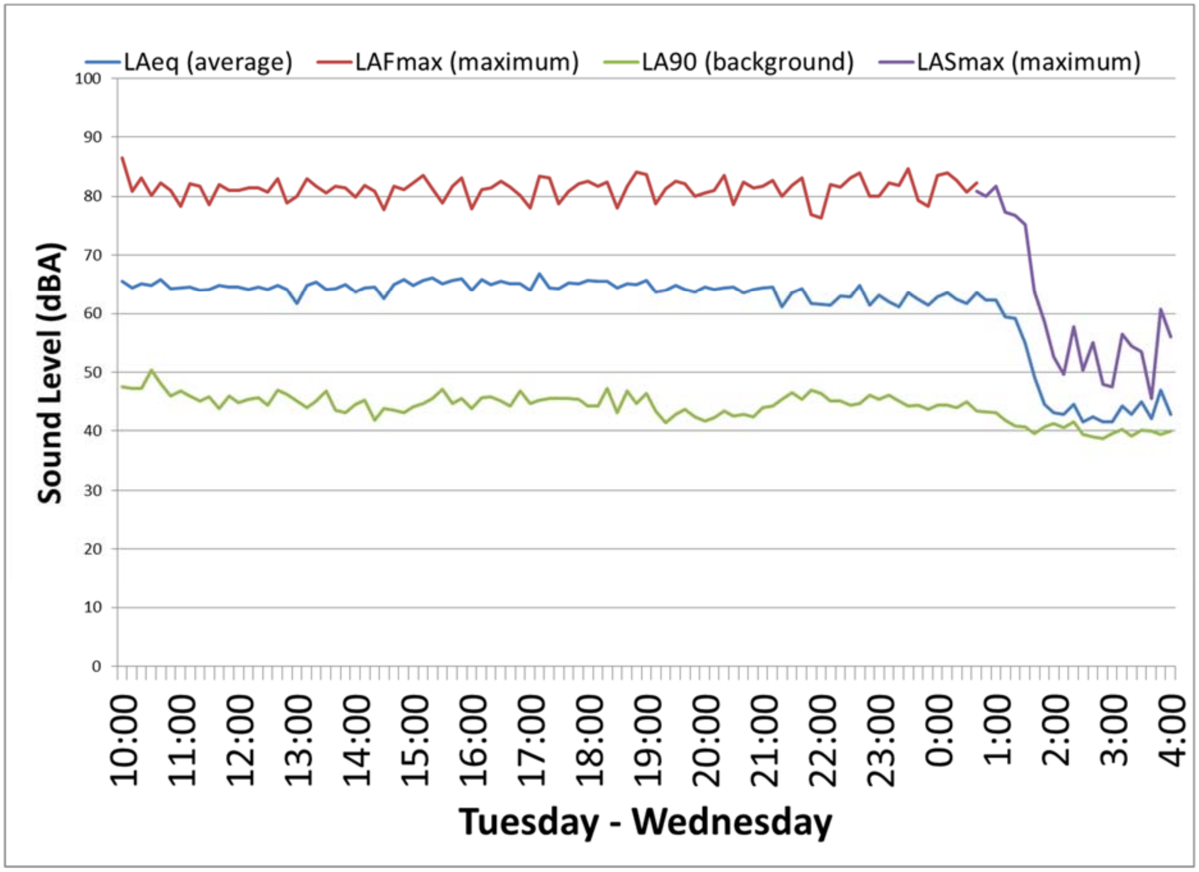
Track	**Train Type**	**No. of Trains**	**Sound Pressure Level (dBA)**	
			Average LAFmax[1]	**Maximum LAFmax**
Inbound	MK I	18	81	82
	MK II	13	77	82
	MK III	2	76	77
Outbound	MK I	18	77	79
	MK II	11	76	78
	MK III	5	70	73
Train on both tracks	Various	3	80	82
Combined	All	70	77	82

Noise Measurement Location

Note 1: Arithmetic Average

Unattended Noise Measurement Results: 2d - 3174 Gladstone			
Start Date:	20/03/2018	Sound Level Meter: Larson Davis 824	Serial No: 824A0342

Measured sound level time history (10 minute increments):



Notes:

SkyTrain hours of operation are between 5:00 am and 1:30 am (with some variation depending on location). At this location, the selected noise logger memory settings resulted in only 16 hours of data collected, and collection of slow response maximum noise levels only during the last few hours of monitoring. This is considered sufficient given the consistency of the noise data during times of SkyTrain operation.

The typical maximum noise level in any 10 minute period is around 80 to 82 dBA and is clearly correlated to SkyTrain hours of operation – the attended measurements found similar SkyTrain maximum noise levels. Sources other than the SkyTrain do not contribute significantly to the ambient noise environment at this location, as indicated by the relatively flat, consistent noise time history during SkyTrain hours of operation.

At this location, the minimum background L90 noise level in any 10 minute period was 39 dBA during the night-time. The highest background L90 noise level was 50 dBA, during the morning.

The difference between SkyTrain maximum noise level and the background noise level is typically around 38 dBA during the daytime and up to 42 dBA during the night-time, at times of first and last services.

Noise Monitoring Location Descriptions

Noise Measurement Location:	**3a – 5380 Oben**
Sound Level Meter: B&K 2270	Serial No: 2808472
Calibrator: B&K 4231	Serial No: 2326528

Measurements were taken on a Level 17 balcony of 5380 Oben Street. Distant road traffic noise and a nearby air conditioning unit were relatively low level with SPL typically around 60 to 62 dBA.

The SkyTrain was the main source contributing to the ambient noise environment. The track adjacent to the measurement location is a straight section incorporating a switch (crossover). Trains on the inbound track were typically 10 dB louder through the switch than outbound trains, a considerable difference indicating a need for corrective maintenance of the switch inbound.

A total of 51 events were observed at this location. All were included in the analysis with none influenced by noise from sources other than the SkyTrain.

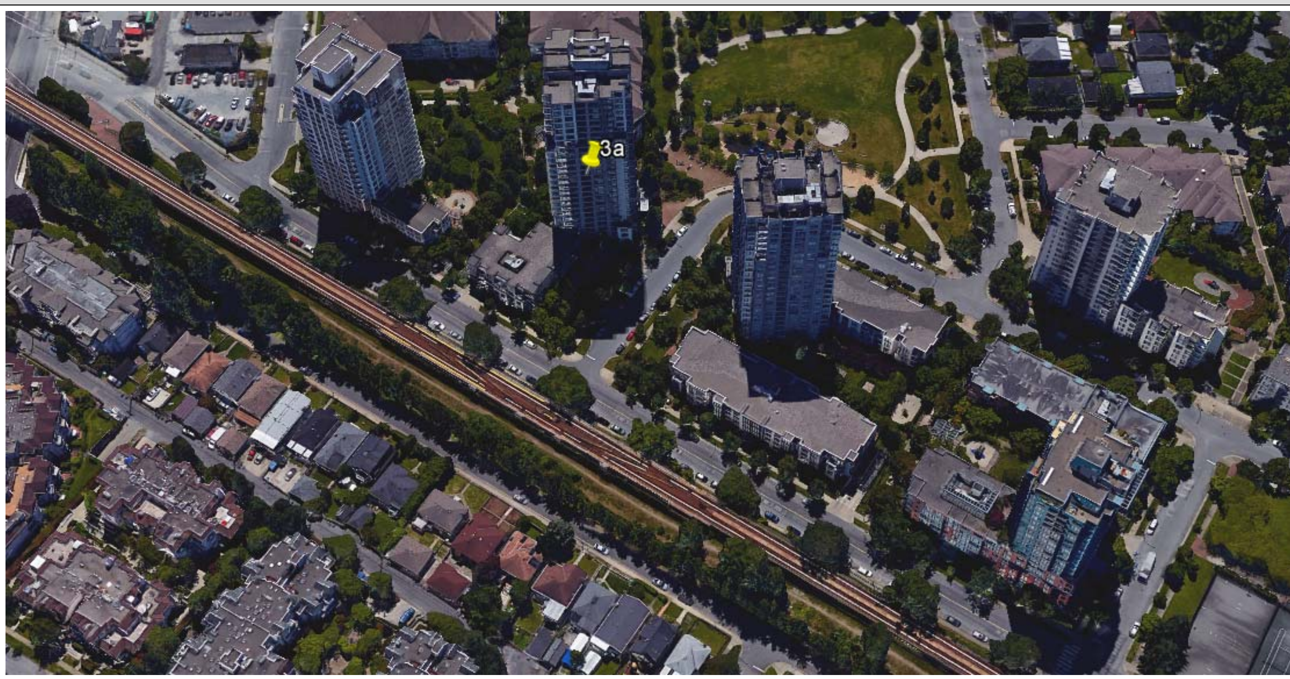
View to Tracks

Attended Noise Measurement Results

Date: 28/03/2018 **Start Time:** 1:00 pm Conditions: Overcast to partly cloudy, calm, 9°C

Track	**Train Type**	**No. of Trains**	**Sound Pressure Level (dBA)**	
			Average LAFmax[1]	**Maximum LAFmax**
Inbound	MK I	16	90	92
	MK II	9	90	90
	MK III	2	89	89
Outbound	MK I	13	80	81
	MK II	8	79	80
	MK III	2	78	79
Train on both tracks	Various	1	90	90
Combined	All	51	85	92

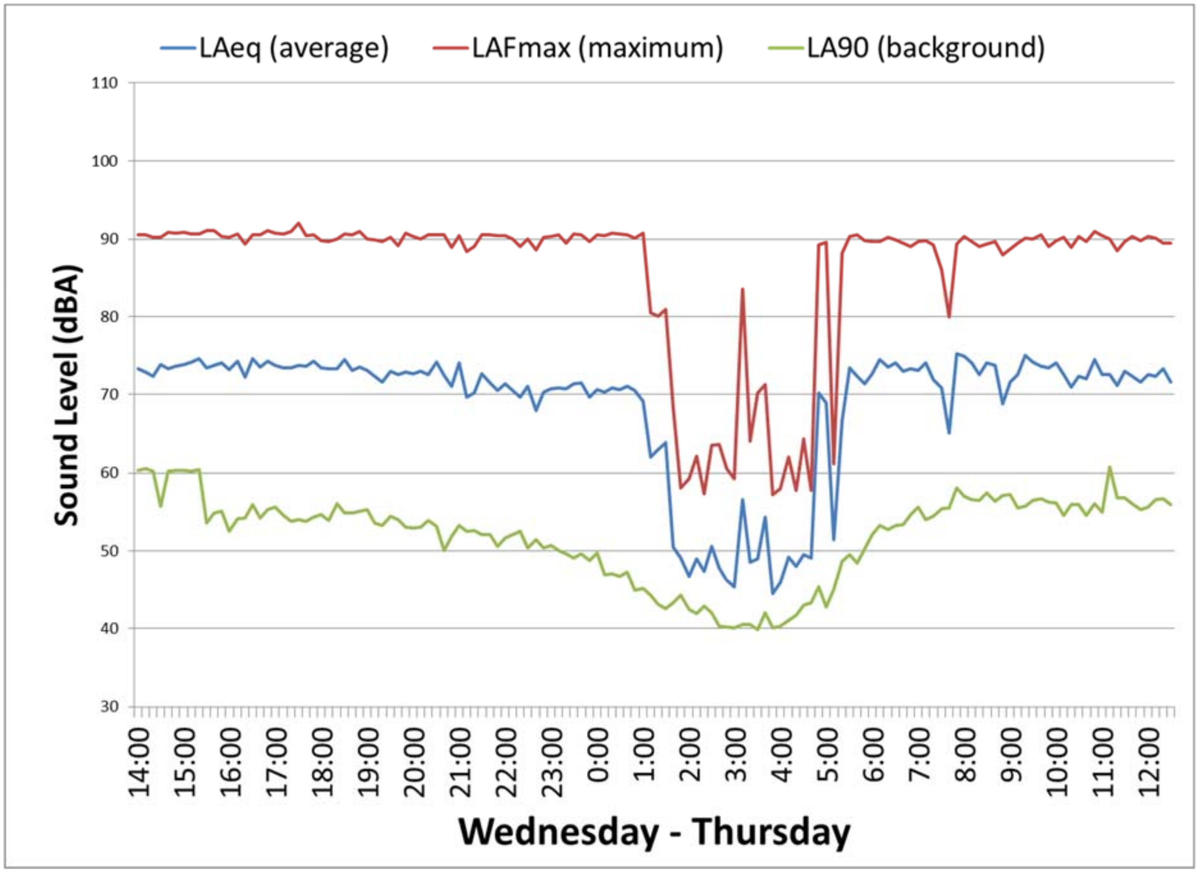
Noise Measurement Location



Note 1: Arithmetic Average

Unattended Noise Measurement Results: 3a – 5380 Oben			
Start Date:	28/03/2018	Sound Level Meter: Larson Davis 824	Serial No: 824A0301

Measured sound level time history (10 minute increments):



Notes:

SkyTrain hours of operation are between 5:00 am and 1:30 am (with some variation depending on location).

The typical maximum noise level in any 10 minute period is around 90 dBA and is clearly correlated to SkyTrain hours of operation – the attended measurements found similar SkyTrain maximum noise levels. Sources other than the SkyTrain do not contribute significantly to the ambient noise environment at this location, as indicated by the relatively flat, consistent noise time history during SkyTrain hours of operation.

At this location, the minimum background L90 noise level in any 10 minute period was 40 dBA during the night-time. The highest background L90 noise level was 60 dBA, and attributed to operation of an air conditioning unit.

The difference between SkyTrain maximum noise level and the background noise level is typically around 35 dBA during the daytime and around 48 dBA during the night-time, at times of first and last services.

Noise Measurement Location:	3b – Vanness Ave & Ruby St
Sound Level Meter: B&K 2270	Serial No: 2821599
Calibrator: B&K 4231	Serial No: 1795340

Measurements were taken on an embankment adjacent to a tangent section of track, with the microphone approximately level with the guideway deck height. The measurement location is approximately 220 m to the west of a switch.

At this location, the guideway is fitted with low noise barriers which increase the height of the parapet and increase shielding of wheel/rail rolling noise.

A total of 50 events were observed at this location. All were included in the analysis with none influenced by noise from sources other than the SkyTrain.

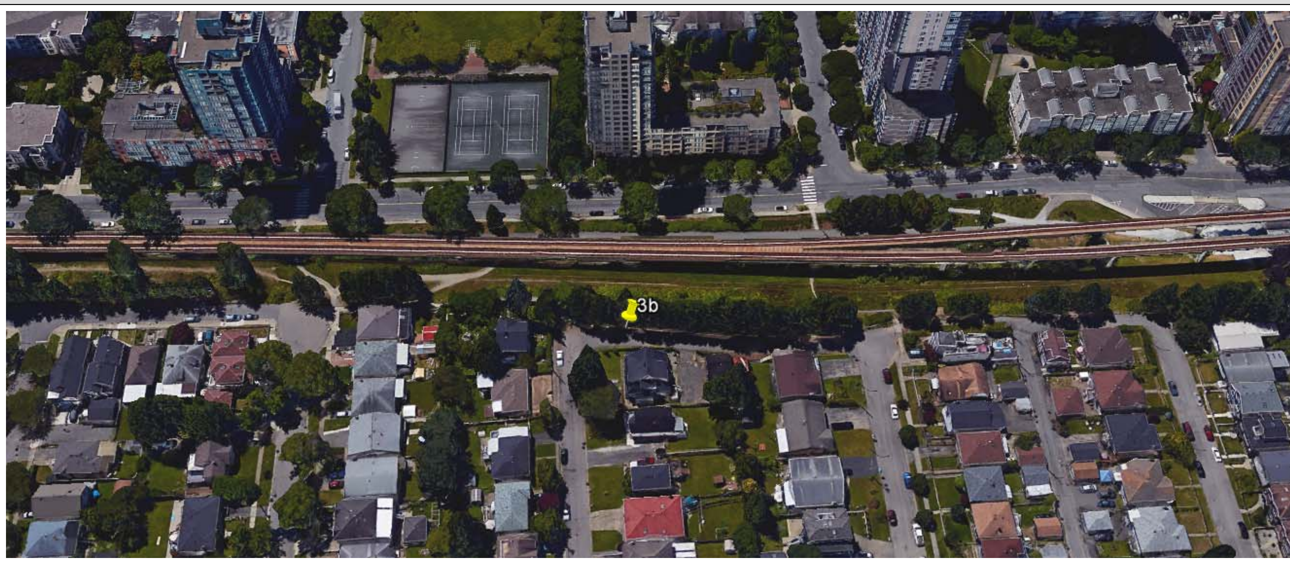
View to Tracks

Attended Noise Measurement Results

Date: 28/03/2018 **Start Time:** 11:30 am Conditions: Partly cloudy, occasional wind gust, 9°C

Track	Train Type	No. of Trains	Sound Pressure Level (dBA)	
			Average LAFmax[1]	Maximum LAFmax
Inbound	MK I	16	73	77
	MK II	7	76	78
	MK III	2	74	75
Outbound	MK I	13	80	80
	MK II	10	80	81
	MK III	2	80	80
Train on both tracks	Various	-	-	-
Combined	All	50	77	81

Noise Measurement Location



Note 1: Arithmetic Average

Noise Monitoring Location Descriptions

Noise Measurement Location:	**4a – 6152 Kathleen**	**View to Tracks**
Sound Level Meter: B&K 2270	Serial No: 2808472	
Calibrator: B&K 4231	Serial No: 2326528	

Measurements were taken on a Level 4 balcony of 6152 Kathleen Avenue. This location is on the western side of the building, with line of sight to track to the west but no direct propagation path from the nearest track segment to the north.

Reflected noise off neighbouring high rise buildings was a noticeable feature of the noise at this location. At the time of the measurements, the inbound track had recently been ground.

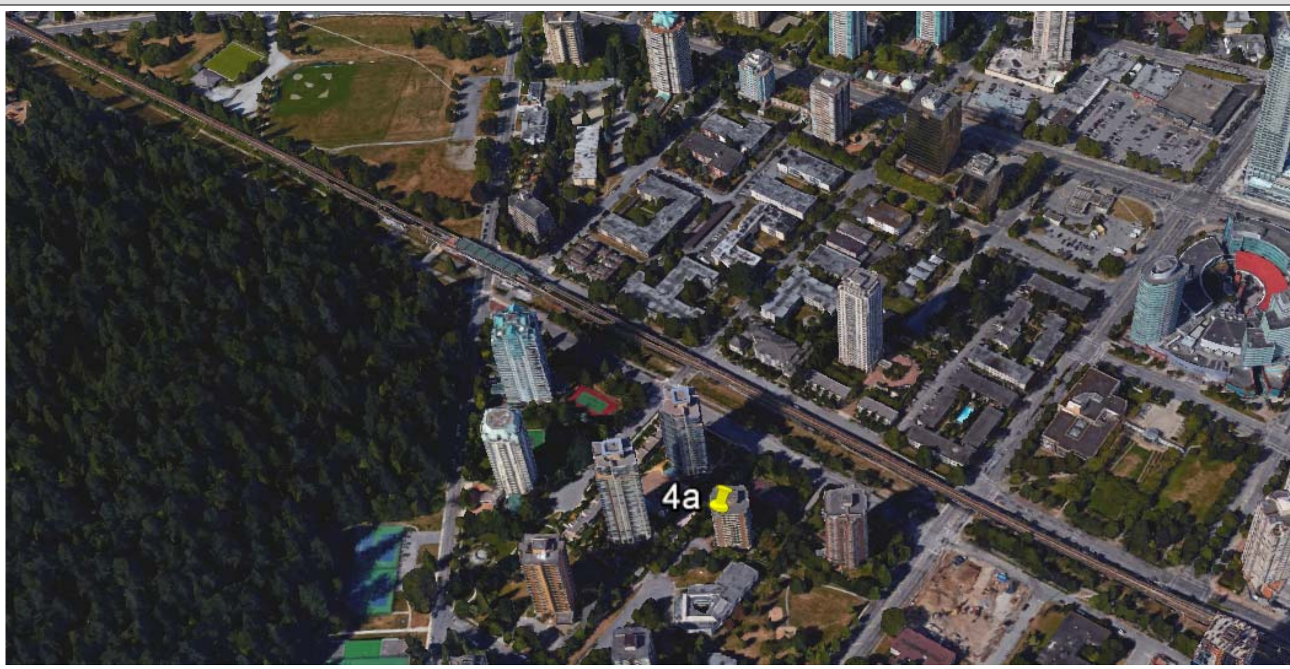
A total of 60 events were observed at this location. Of these, 1 has been excluded from the analysis due to the influence of noise from sources other than the SkyTrain.

Attended Noise Measurement Results

Date: 20/03/2018 **Start Time:** 2:00 pm Conditions: Cloudy, calm, 6°C

Track	**Train Type**	**No. of Trains**	**Sound Pressure Level (dBA)**	
			Average LAFmax[1]	**Maximum LAFmax**
Inbound	MK I	17	68	70
	MK II	7	66	67
	MK III	5	66	67
Outbound	MK I	15	75	77
	MK II	8	76	76
	MK III	3	76	78
Train on both tracks	Various	9	74	77
Combined	All	59	72	78

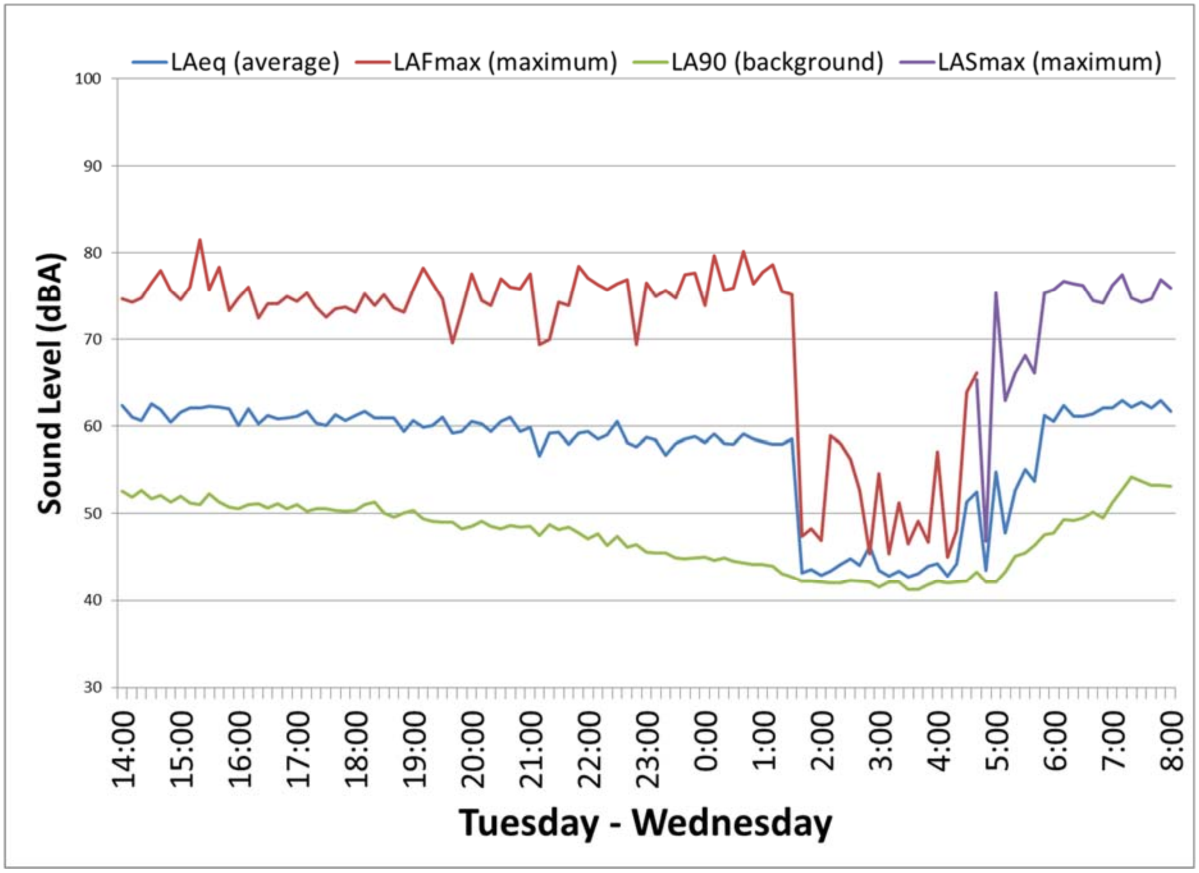
Noise Measurement Location



Note 1: Arithmetic Average

Unattended Noise Measurement Results: 4a – 6152 Kathleen		
Start Date: 20/03/2018	Sound Level Meter: Larson Davis 824	Serial No: 824A1093

Measured sound level time history (10 minute increments):



Notes:

SkyTrain hours of operation are between 5:00 am and 1:30 am (with some variation depending on location). At this location, the selected noise logger memory settings resulted in only 16 hours of data collected, and collection of slow response maximum noise levels only during the last few hours of monitoring. This is considered sufficient given the consistency of the noise data during times of SkyTrain operation.

The maximum noise level in any 10 minute period varies between 70 to 80 dBA and is correlated to SkyTrain hours of operation – the attended measurements found SkyTrain maximum noise levels up to 76 dBA. There is more variation in maximum noise level at this location than at others, possibly as a result of the complex propagation path including various reflections from neighbouring buildings.

At this location, the minimum background L90 noise level in any 10 minute period was 42 dBA during the night-time. The highest background L90 noise level was 54 dBA, during the morning peak period.

The difference between SkyTrain maximum noise level and the background noise level is typically around 28 dBA during the daytime and up to 38 dBA during the night-time, at times of first and last services.

Noise Monitoring Location Descriptions

Noise Measurement Location:	4b – 4333 Central BLVD
Sound Level Meter: B&K 2270	Serial No: 2821599
Calibrator: B&K 4231	Serial No: 1795340

The measurement was situated on the sidewalk by the driveway of 4333 Central Boulevard, below guideway deck level. Street traffic and distant construction sounds were noticed in the ambient noise environment.

In this area the track is straight with no switches. This location was almost directly opposite the tracks from location 4a.

A total of 51 events were observed at this location. Of these, 2 have been excluded from the analysis due to the influence of noise from sources other than the SkyTrain.

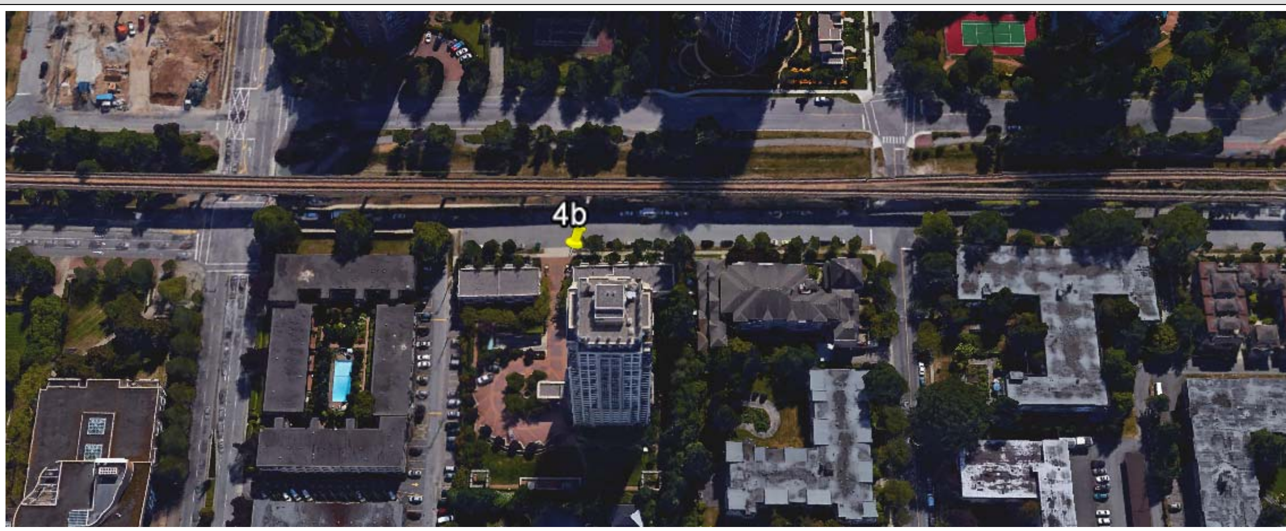
View to Tracks

Attended Noise Measurement Results

Date: 20/03/2018 **Start Time:** 2:30 pm Conditions: Overcast to partly cloudy, calm, 8°C

Track	Train Type	No. of Trains	Sound Pressure Level (dBA)	
			Average LAFmax[1]	Maximum LAFmax
Inbound	MK I	13	88	90
	MK II	5	87	88
	MK III	4	87	87
Outbound	MK I	11	79	80
	MK II	6	81	82
	MK III	4	82	83
Train on both tracks	Various	6	88	90
Combined	All	49	84	90

Noise Measurement Location



Note 1: Arithmetic Average

Noise Measurement Location:	**5a – Prenter Street**	**View to Tracks**
Sound Level Meter: B&K 2270	Serial No: 2821599	
Calibrator: B&K 4231	Serial No: 1795340	
Measurements were taken in an open area north of Prenter Street (near Rumble St) at ground level, approximately level with the guideway deck. The track adjacent to the measurement location is curved. Noise sources observed in addition to the SkyTrain were a workshop to the north and occasional road traffic noise. A total of 50 events were observed at this location. Of these, 3 have been excluded from the analysis due to the influence of noise from sources other than the SkyTrain.		

Attended Noise Measurement Results

Date: 21/03/2018 **Start Time:** 9:30 am Conditions: Overcast to partly cloudy, calm, 6°C

Track	**Train Type**	**No. of Trains**	**Sound Pressure Level (dBA)**	
			Average LAFmax[1]	**Maximum LAFmax**
Inbound	MK I	7	73	74
	MK II	5	72	73
	MK III	1	73	73
Outbound	MK I	7	64	66
	MK II	3	62	63
	MK III	3	62	63
Train on both tracks	Various	21	73	76
Combined	All	47	70	76

Noise Measurement Location

Note 1: Arithmetic Average

Noise Measurement Location:	5b – 6837 Station Hill Drive
Sound Level Meter: B&K 2270	Serial No: 2808472
Calibrator: B&K 4231	Serial No: 1795340

Measurements were taken on a balcony of Level 25 of 6837 Station Hill Drive. Ambient noise levels were due to distant traffic with SPLs around 52-58 dBA. A lawn mower generated SPLs around 55-59 dBA, varying depending on its proximity. Maximum SkyTrain noise levels as reported were largely unaffected, although note other parameters collected incidentally may have been influenced by noise from this activity.

A large length of track is visible and audible at this location, and as a result most measurements were influenced by more than one train. A section of corrugated track was audible to the north, adjacent to Prenter Street at Hawthorne St – maximum noise levels from the train in this area were often higher than from trains on the curve.

A total of 40 events were observed at this location. Of these, 1 has been excluded from the analysis due to the influence of noise from sources other than the SkyTrain.

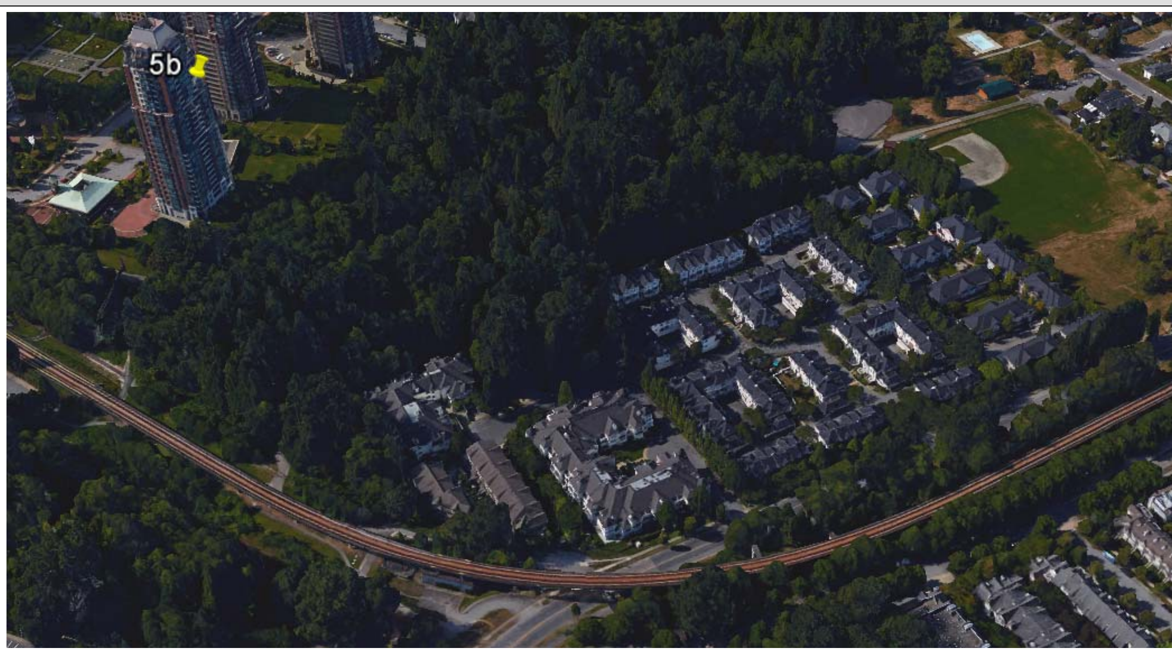
View to Tracks

Attended Noise Measurement Results

Date: 18/04/2018 **Start Time:** 1:00 pm Conditions: Partly cloudy, calm, 11°C

Track	Train Type	No. of Trains	Sound Pressure Level (dBA)	
			Average LAFmax[1]	Maximum LAFmax
Inbound	MK I	6	68	71
	MK II	1	66	66
	MK III	0	-	-
Outbound	MK I	4	71	74
	MK II	2	67	68
	MK III	0	-	-
Train on both tracks	Various	26	70	73
Combined	All	39	69	74

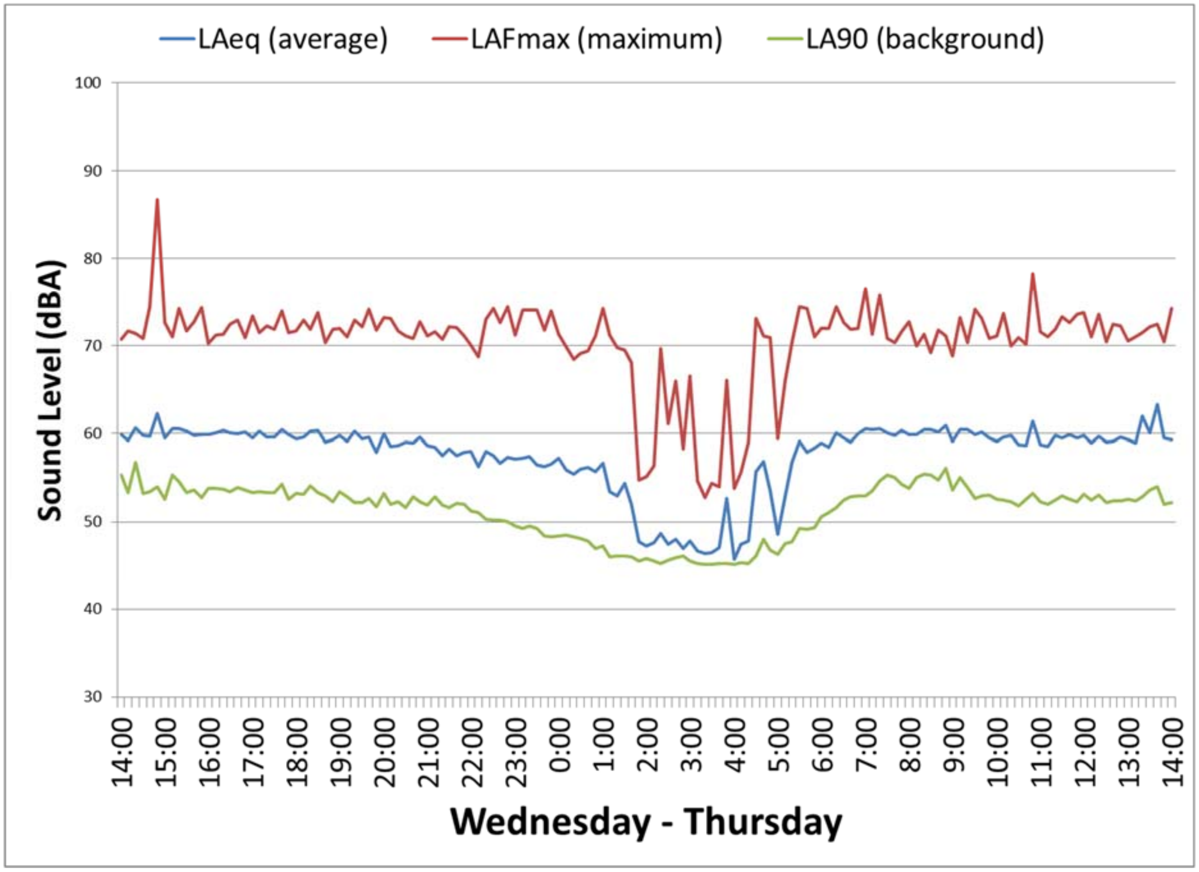
Noise Measurement Location



Note 1: Arithmetic Average

Unattended Noise Measurement Results: 5b – 6837 Station Hill Drive			
Start Date:	18/04/2018	Sound Level Meter: Larson Davis 824	Serial No: 824A0342

Measured sound level time history (10 minute increments):



Notes:

SkyTrain hours of operation are between 5:00 am and 1:30 am (with some variation depending on location).

The typical maximum noise level in any 10 minute period is 70 to 74 dBA and is clearly correlated to SkyTrain hours of operation – the attended measurements found similar SkyTrain maximum noise levels. Sources other than the SkyTrain are responsible for isolated peaks in the maximum noise level time history that are considerably different from this typical level.

At this location, the minimum background L90 noise level in any 10 minute period was 45 dBA during the night-time. The highest background L90 noise level was 56 dBA, during the morning peak period.

The difference between SkyTrain maximum noise level and the background noise level is typically around 20 dBA during the daytime and up to 30 dBA during the night-time, at times of first and last services.

Noise Measurement Location:	5c – 2311 London Street	View to Tracks
Sound Level Meter: B&K 2270	Serial No: 2821599	
Calibrator: B&K 4231	Serial No: 1795340	

Measurements were taken by the sidewalk near 2311 London Street, below guideway deck level.

Train passbys on the outbound track were observed to include an impact noise characteristic possibly due to a defect or discontinuity in the rail running surface. Trains on the inbound track were noticeably louder than on the outbound track and had a roaring or “thunderous” characteristic potentially due to corrugation linked to the relatively tight curve at this location. Low noise barriers are in place at this location increasing the height of the regular guideway parapet.

A total of 54 events were observed at this location. Of these, 1 has been excluded from the analysis due to the influence of noise from sources other than the SkyTrain.

Attended Noise Measurement Results

Date: 24/03/2018 **Start Time:** 4:30 pm Conditions: Partly cloudy, 6°C

Track	Train Type	No. of Trains	Sound Pressure Level (dBA)	
			Average LAFmax[1]	Maximum LAFmax
Inbound	MK I	16	75	76
	MK II	8	77	78
	MK III	2	78	79
Outbound	MK I	17	72	75
	MK II	7	72	73
	MK III	3	72	72
Train on both tracks	Various	-	-	-
Combined	All	53	74	79

Noise Measurement Location

Note 1: Arithmetic Average

Noise Measurement Location:	5d – Grimston Park (Control)	View to Tracks
Sound Level Meter: B&K 2270	Serial No: 2808472	
Calibrator: B&K 4231	Serial No: 2326528, 1795340	

This location in Grimston Park was used as a control location to measure noise over several months in various conditions.

The track adjacent to the measurement location is a predominantly straight section on a slight incline, with inbound trains travelling uphill.

The reported results for each scenario at this control location exclude simultaneous passby events and events influenced by noise from sources other than the SkyTrain. Results are reported for each measurement scenario, namely cold weather, cold with a light dusting of snow, cold with about 15 cm of fresh snow, rain, warm weather and hot weather.

Noise Measurement Location

Attended Noise Measurement Results – Scenario 1 Cold

Date:	10/02/2018	**Start Time:**	9:45 am	Conditions:	Clear, calm, frosty, 0 - 5°C

Track	Train Type	No. of Trains	Sound Pressure Level (dBA)	
			Average LAFmax[1]	Maximum LAFmax
Inbound	MK I	15	74	78
	MK II	12	73	76
	MK III	1	73	73
Outbound	MK I	19	72	75
	MK II	13	73	76
	MK III	2	72	73
Combined	All	62	73	78

Attended Noise Measurement Results – Scenario 2 Cold, Some Snow				
Date: 18/02/2018	**Start Time:**	9:00 am	Conditions:	Calm, 0°C, up to 2 cm dusting of snow
Track	**Train Type**	**No. of Trains**	**Sound Pressure Level (dBA)**	
			Average LAFmax[1]	**Maximum LAFmax**
Inbound	MK I	18	75	78
	MK II	6	75	77
	MK III	9	74	77
Outbound	MK I	21	74	76
	MK II	5	72	74
	MK III	9	74	74
Combined	All	68	74	78

Attended Noise Measurement Results – Scenario 3 15-20 cm Fresh Snow				
Date: 24/02/2018	**Start Time:**	9:30 am	Conditions:	Calm, 0°C, 15-20 cm of fresh snow
Track	**Train Type**	**No. of Trains**	**Sound Pressure Level (dBA)**	
			Average LAFmax[1]	**Maximum LAFmax**
Inbound	MK I	9	71	74
	MK II	3	72	78
	MK III	8	70	72
Outbound	MK I	9	69	70
	MK II	2	70	70
	MK III	8	71	71
Combined	All	39	70	78

Attended Noise Measurement Results – Scenario 4 Rain				
Date: 29/03/2018	**Start Time:**	1:30 pm	Conditions:	Overcast, light rain, no wind, 6°C
Track	**Train Type**	**No. of Trains**	**Sound Pressure Level (dBA)**	
			Average LAFmax[1]	**Maximum LAFmax**
Inbound	MK I	16	76	77
	MK II	5	74	75
	MK III	3	75	77
Outbound	MK I	15	70	72
	MK II	8	70	71
	MK III	3	70	71
Combined	All	50	73	77

Attended Noise Measurement Results – Scenario 5 Warm				
Date: 30/05/2018	**Start Time:**	12:45 pm	Conditions:	Calm to light breeze, 17°C, cloudy
Track	**Train Type**	**No. of Trains**	**Sound Pressure Level (dBA)**	
			Average LAFmax[1]	**Maximum LAFmax**
Inbound	MK 1	15	73	75
	MK 2	7	72	75
	MK 3	2	72	72
Outbound	MK 1	16	71	75
	MK 2	8	70	71
	MK 3	4	70	71
Combined	All	52	71	75

Attended Noise Measurement Results - Scenario 6 Hot				
Date: 19/06/2018	**Start Time:**	12:00 pm	Conditions:	Sunny, 26 °C, light breeze
Track	**Train Type**	**No. of Trains**	**Sound Pressure Level (dBA)**	
			Average LAFmax[1]	**Maximum LAFmax**
Inbound	MK 1	11	73	75
	MK 2	6	73	76
	MK 3	8	73	78
Outbound	MK 1	16	72	74
	MK 2	5	71	72
	MK 3	5	71	73
Combined	All	51	72	78

Note 1: Arithmetic Average

Noise Monitoring Location Descriptions

Noise Measurement Location:	5e – 14th Street New West
Sound Level Meter: B&K 2270	Serial No: 2821599
Calibrator: B&K 4231	Serial No: 1795340

Measurements were taken on the north-east side of 14th Street (opposite 426 14th Street), slightly below guideway deck level.

Track in this area is straight with no observed noise-increasing features.

Noise sources other than the SkyTrain had levels ranging from 52 dBA up to 70 dBA and included road traffic and freight trains.

A total of 50 events were observed at this location. Of these, 2 have been excluded from the analysis due to the influence of noise from sources other than the SkyTrain.

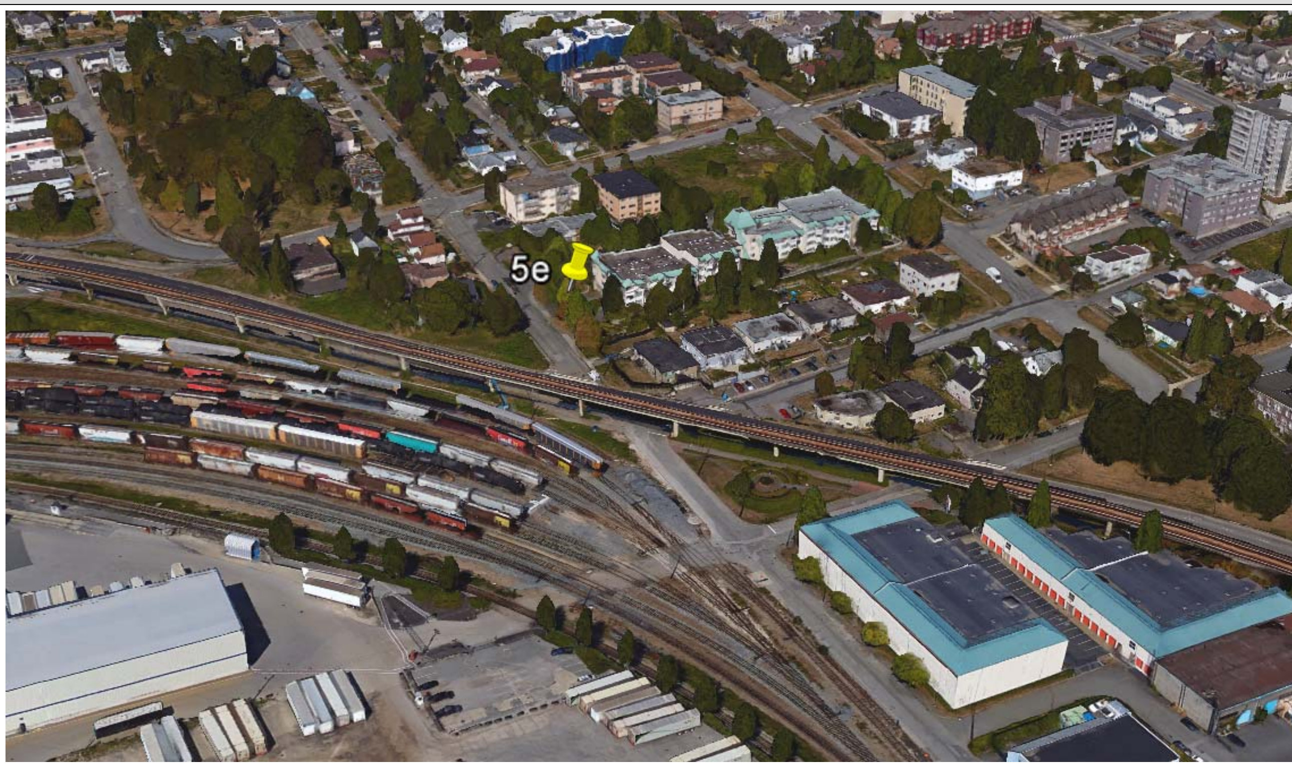
View to Tracks

Attended Noise Measurement Results

Date: 21/03/2018 **Start Time:** 12:00 pm Conditions: Scattered clouds, calm, 10°C

Track	Train Type	No. of Trains	Sound Pressure Level (dBA)	
			Average LAFmax[1]	Maximum LAFmax
Inbound	MK I	15	81	82
	MK II	7	81	81
	MK III	2	80	81
Outbound	MK I	14	76	78
	MK II	9	77	78
	MK III	2	77	78
Train on both tracks	Various	-	-	-
Combined	All	48	79	82

Noise Measurement Location



Note 1: Arithmetic Average

Noise Monitoring Location Descriptions

Noise Measurement Location:	5f – 892 Carnarvon
Sound Level Meter: B&K 2270	Serial No: 2808472
Calibrator: B&K 4231	Serial No: 2326528

Measurements were taken on a Level 21 balcony of 892 Carnarvon Street, above the opening in the roof of New Westminster Station. Road traffic, birds, freight trains and sirens were observed in the ambient noise environment, with SPL typically around 56 to 64 dBA but sometimes up to 70 dBA. No PA noise was observed despite the location above the station. Train type identification was not possible at this location as the view to the tracks was obscured.

Inbound trains were heard to be passing over a running surface discontinuity in the tunnel shortly after departing the station; this was observed from the platform to be a switch although not visible from the measurement location.

A total of 48 events were observed at this location. Of these, 3 have been excluded from the analysis due to the influence of noise from sources other than the SkyTrain.

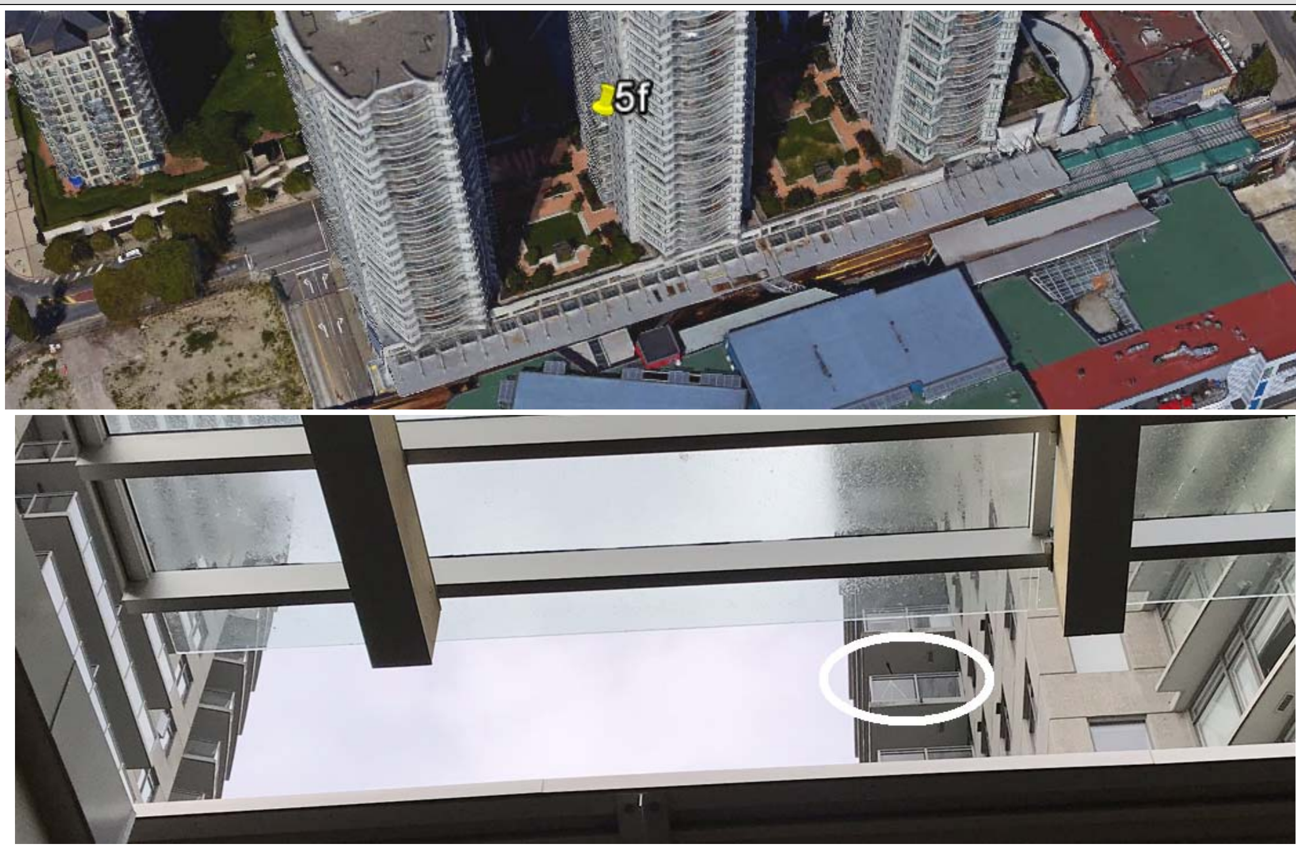
View to Tracks

Attended Noise Measurement Results

Date: 24/03/2018 **Start Time:** 4:00 pm Conditions: Overcast, calm, 5°C

Track	Train Type	No. of Trains	Sound Pressure Level (dBA)	
			Average LAFmax[1]	Maximum LAFmax
Inbound	(No sight)	24	77	78
Outbound	(No sight)	20	71	74
Train on both tracks	Various	1	76	76
Combined	All	45	74	78

Noise Measurement Location



Note 1: Arithmetic Average

Noise Monitoring Location Descriptions

Noise Measurement Location:	5g – 420 Carnarvon
Sound Level Meter: B&K 2270	Serial No: 2808472
Calibrator: B&K 4231	Serial No: 2326528

Measurements were taken on a Level 4 balcony of 420 Carnarvon Street, overlooking the opening in the roof of Columbia Station.

At this location, each train "passby" was divided into an arrival and a departure event. Inbound trains departing the station were on average 7 dB louder in maximum noise level than arriving trains, while outbound trains were on average 4 dB louder when arriving at the station than when departing, although the single noisiest event outbound was a departing MK I train. The noise level of train auxiliary systems when stopped at the station was typically 58 to 59 dBA.

Inbound trains departing the station were heard to be passing over a track discontinuity; inspection of the track from the platform shows a defect on the running rail as shown in the image below.

No PA system announcements were observed in the 2 hour period.

A total of 100 "events" were observed at this location and all have been included in the analysis.

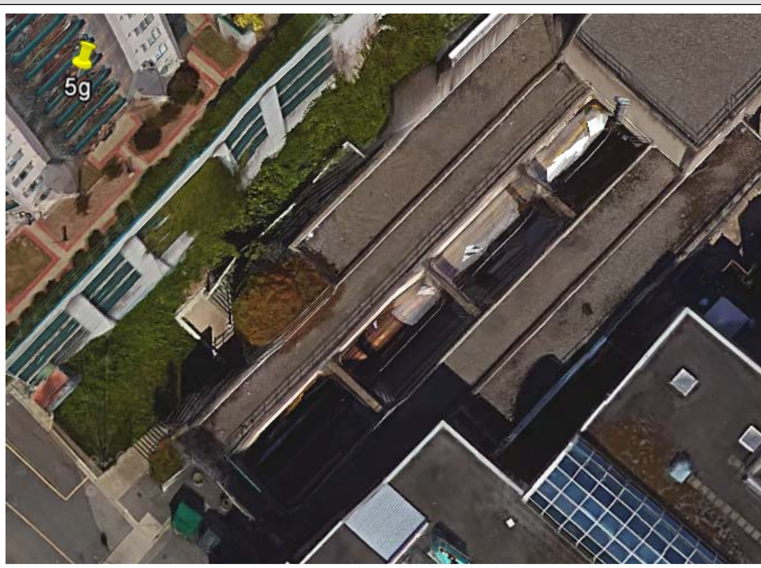
View to Tracks

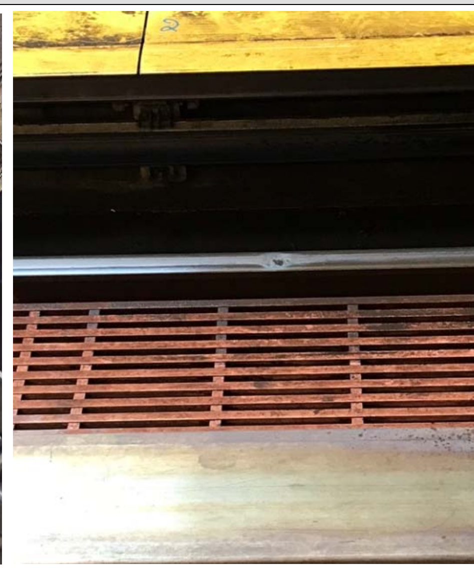
Attended Noise Measurement Results

Date: 27/03/2018 **Start Time:** 4:00 pm Conditions: Partly cloudy, no wind, 10°C

Track	Train Type	No. of Events (Train arrival or departure)	Sound Pressure Level (dBA)	
			Average LAFmax[1]	Maximum LAFmax[2]
Inbound	(No sight)	29	72	77
Outbound	MK I	33	73	77
	MK II	11	72	76
	MK III	7	72	76
Train on both tracks	Various	20	75	77
Combined	All	100	73	77

Noise Measurement Location and Observed Track Defect





Note 1: Arithmetic Average, includes train arrivals and departures as separate events

Note 2: Maximum LAFmax values are due to trains departing inbound, and trains arriving outbound

Noise Monitoring Location Descriptions

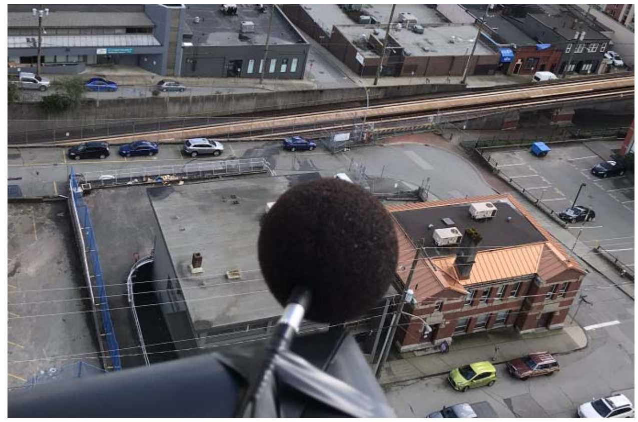
Noise Measurement Location:	5h – 610 Victoria Street
Sound Level Meter: B&K 2270	Serial No: 2808472
Calibrator: B&K 4231	Serial No: 2326528

Measurements were taken on a Level 16 balcony of 610 Victoria Street, north of the tunnel portal west of Columbia Station. Road traffic at 56 to 65 dBA and freight trains were observed as the main sources contributing to the ambient noise environment in addition to the SkyTrain.

Outbound trains were observed to be slightly noisier than inbound trains, and the highest noise levels were observed before the trains entered the tunnel.

A total of 66 events were observed at this location. Of these, 1 has been excluded from the analysis due to the influence of noise from sources other than the SkyTrain.

View to Tracks

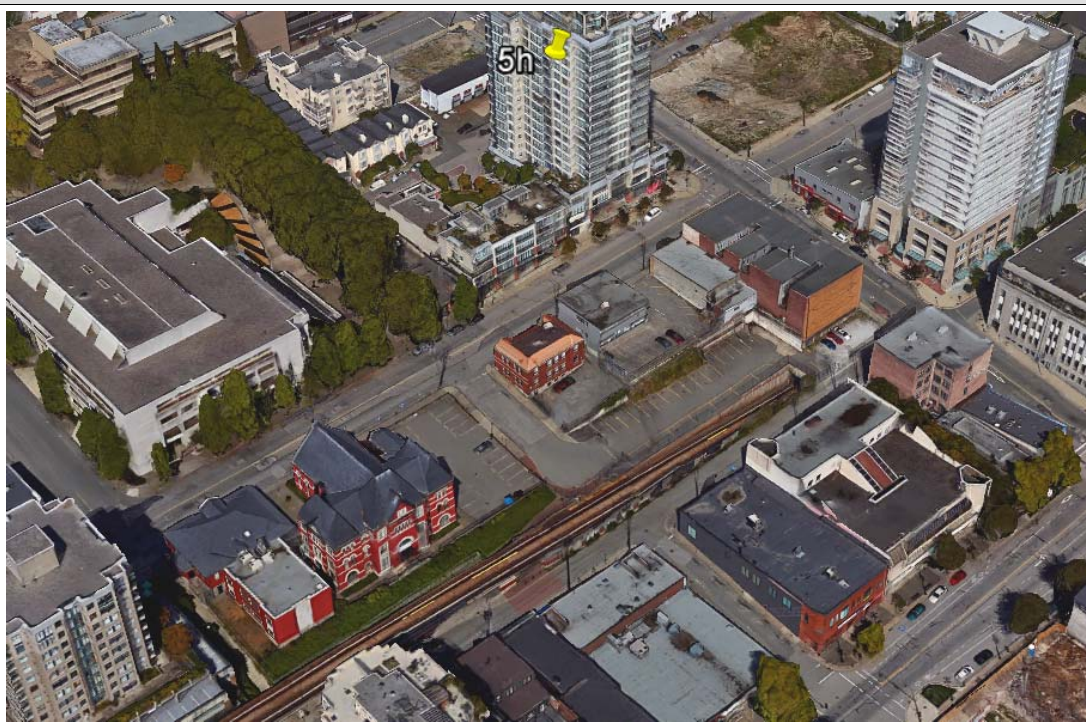


Attended Noise Measurement Results

Date: 12/04/2018 **Start Time:** 2:45 pm Conditions: Partly cloudy to increasingly sunny, calm, 14°C

Track	Train Type	No. of Trains	Sound Pressure Level (dBA)	
			Average LAFmax[1]	Maximum LAFmax
Inbound	MK I	19	73	75
	MK II	9	72	75
	MK III	2	72	72
Outbound	MK I	20	74	75
	MK II	10	73	75
	MK III	5	73	75
Train on both tracks	Various	1	74	74
Combined	All	66	73	75

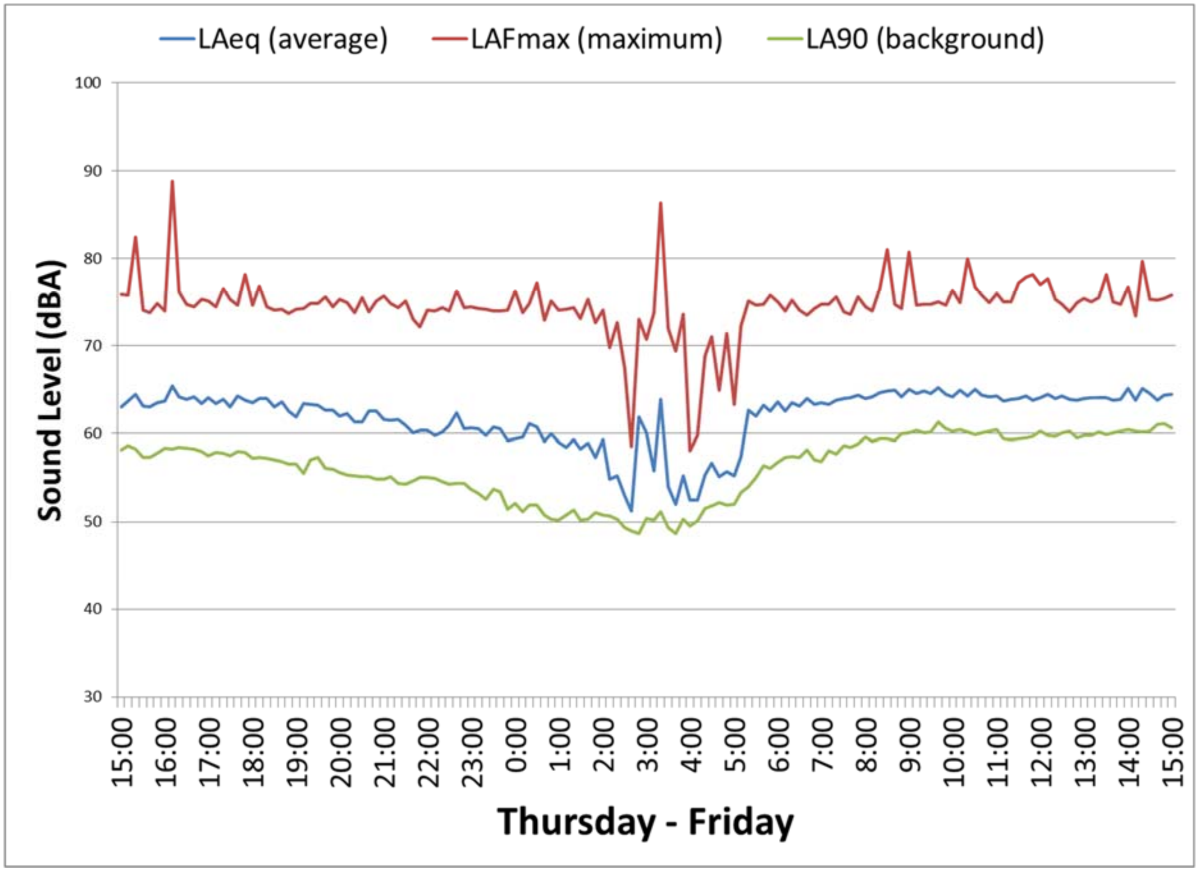
Noise Measurement Location



Note 1: Arithmetic Average

Unattended Noise Measurement Results: 5h – 610 Victoria Street		
Start Date: 12/04/2018	Sound Level Meter: Larson Davis 824	Serial No: 824A0342

Measured sound level time history (10 minute increments):



Notes:

SkyTrain hours of operation are between 5:00 am and 1:30 am (with some variation depending on location).

The typical maximum noise level in any 10 minute period is around 75 dBA and is generally correlated to SkyTrain hours of operation – the attended measurements found similar SkyTrain maximum noise levels. Sources other than the SkyTrain are responsible for isolated peaks in the maximum noise level time history that are considerably different from this typical level. In particular, the peak in noise levels occurring at around 3:20 am was due to freight train noise, in particular whistles.

At this location, the minimum background L90 noise level in any 10 minute period was 49 dBA during the night-time. The highest background L90 noise level was 60 dBA, during the daytime.

The difference between SkyTrain maximum noise level and the background noise level is typically around 15 dBA during the daytime and up to 25 dBA during the night-time, at times of first and last services.

Noise Measurement Location:	5i – 312 Carnarvon	View to Tracks
Sound Level Meter: B&K 2270	Serial No: 2808472	
Calibrator: B&K 4231	Serial No: 2326528	

Measurements were taken on a Level 3 balcony of 312 Carnarvon Street, near the tunnel portal east of Columbia Station, and adjacent to the turnout (switch) for trains routed to Surrey. Road traffic at 58 to 65 dBA was observed as the main source contributing to the ambient noise environment in addition to the SkyTrain.

Inbound trains from Production Way – University (“Main” in table below) were not visible and noise levels were similar to ambient except when flanging noise was present. Outbound trains to Production Way travelled slowly over the switch, minimizing impact noise. Both inbound and outbound Surrey trains were higher speed and noisier. Some flanging noise was observed.

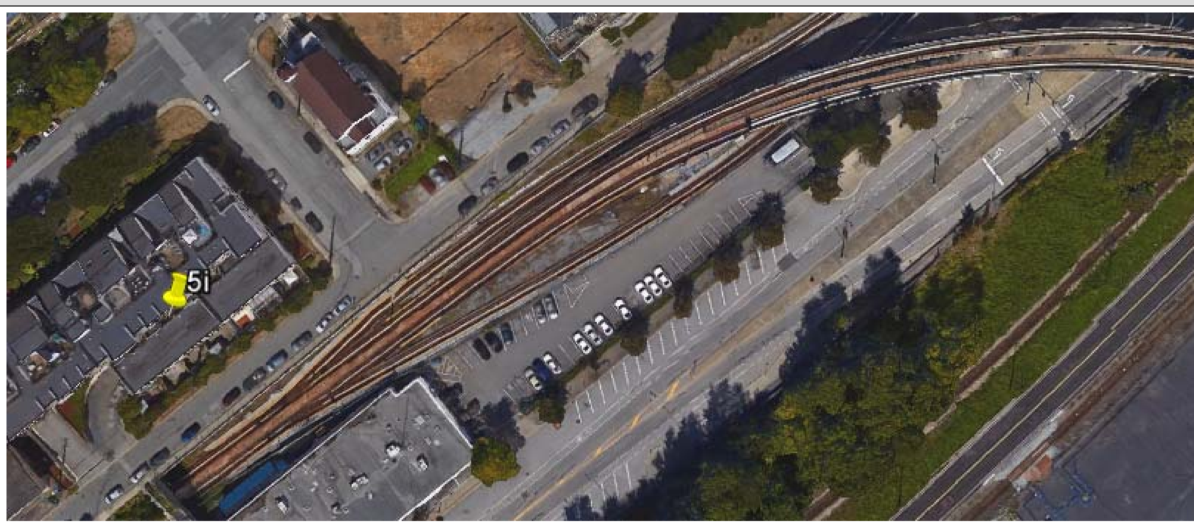
A total of 50 events were observed at this location. All were included in the analysis with none influenced by noise from sources other than the SkyTrain.

Attended Noise Measurement Results

Date: 27/03/2018 **Start Time:** 1:30 pm Conditions: Scattered clouds, calm, 9°C

Track	Train Type	No. of Trains	Sound Pressure Level (dBA)	
			Average LAFmax[1]	Maximum LAFmax
Inbound Main	(No sight)	8	68	78
Outbound Main	MK I	13	69	76
	MK II	2	68	69
	MK III	-	-	-
Inbound Surrey	MK I	4	74	75
	MK II	3	72	73
	MK III	2	73	73
Outbound Surrey	MK I	6	77	78
	MK II	-	-	-
	MK III	1	74	74
Train on both tracks	Main	2	75	76
Train on both tracks	Surrey	10	75	77
Combined	All	50	72	78

Noise Measurement Location



Note 1: Arithmetic Average

Noise Measurement Location:	**6a – 69 Jamieson Court**	**View to Tracks**
Sound Level Meter: B&K 2270	Serial No: 2808472	
Calibrator: B&K 4231	Serial No: 2326528	

Measurements were taken on a Level 5 balcony of 69 Jamieson Court. Road traffic and birds contributed to ambient noise in addition to the SkyTrain with SPL typically around 50 to 60 dBA.

The track adjacent to the measurement location is tangent track with no noticeable localized noise affecting features.

Partway through the measurement at this location light rain began falling. There was no noticeable effect on the measured SkyTrain noise levels although ambient road traffic noise levels did increase slightly with wet roads.

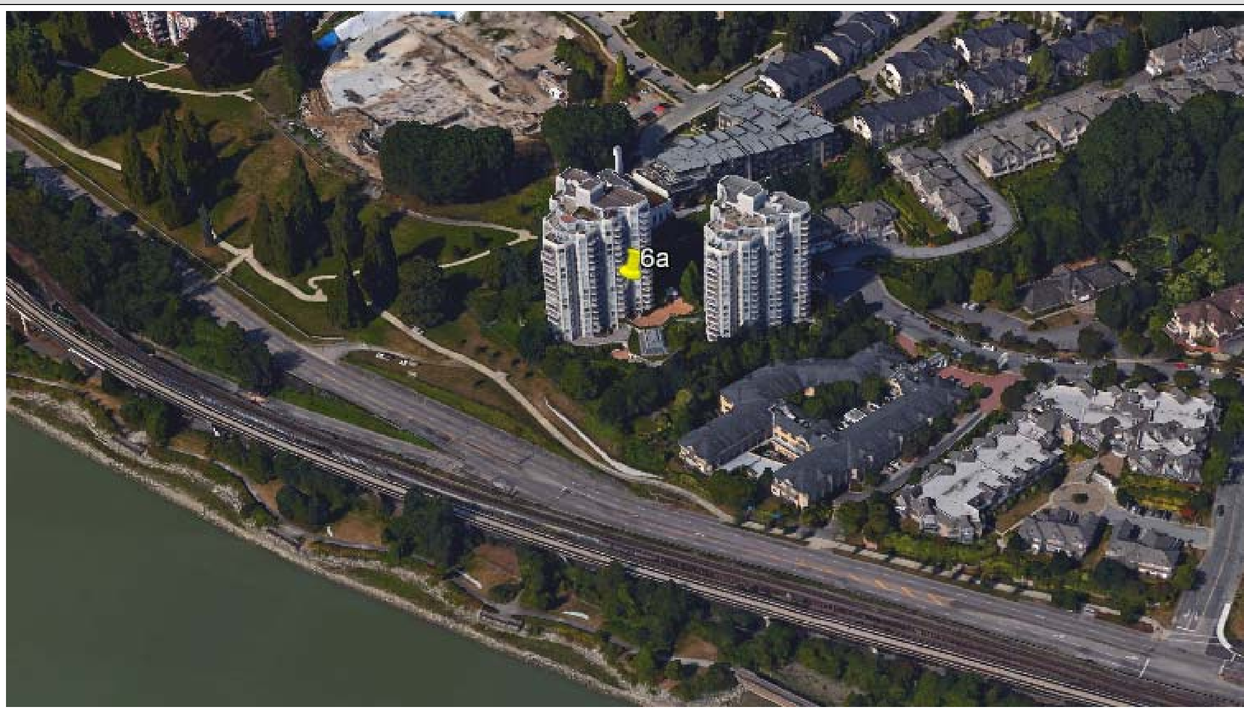
A total of 40 events were observed at this location and all were included in the analysis.

Attended Noise Measurement Results

Date: 24/03/2018 **Start Time:** 9:30 am Conditions: Overcast, calm, periodic light rain, 4°C

Track	**Train Type**	**No. of Trains**	**Sound Pressure Level (dBA)**	
			Average LAFmax[1]	**Maximum LAFmax**
Inbound	MK I	13	74	76
	MK II	5	72	74
	MK III	3	72	73
Outbound	MK I	10	74	75
	MK II	5	73	73
	MK III	4	72	74
Train on both tracks	Various	-	-	-
Combined	All	40	73	76

Noise Measurement Location



Note 1: Arithmetic Average

Noise Measurement Location:	**7a – 4788 Brentwood**	**View to Tracks**
Sound Level Meter: B&K 2270	Serial No: 2808472	
Calibrator: B&K 4231	Serial No: 2326528	

Measurements were taken on the outside edge of a patio at 4788 Brentwood Street, overlooking Lougheed Highway and near SkyTrain guideway deck level.

Road traffic noise and nearby construction noise was observed to be variable, with minimum SPLs of 60-65 dBA, and higher SPLs of 72 to 81 dBA particularly due to heavy vehicles. Maximum SkyTrain noise levels were largely unaffected although it is noted that other parameters (collected incidentally) may have been influenced by these other noise sources.

No localized SkyTrain noise affecting features were observed although some increased roughness or corrugation of the inbound track is possible, trains in this direction were noticeably louder than outbound trains.

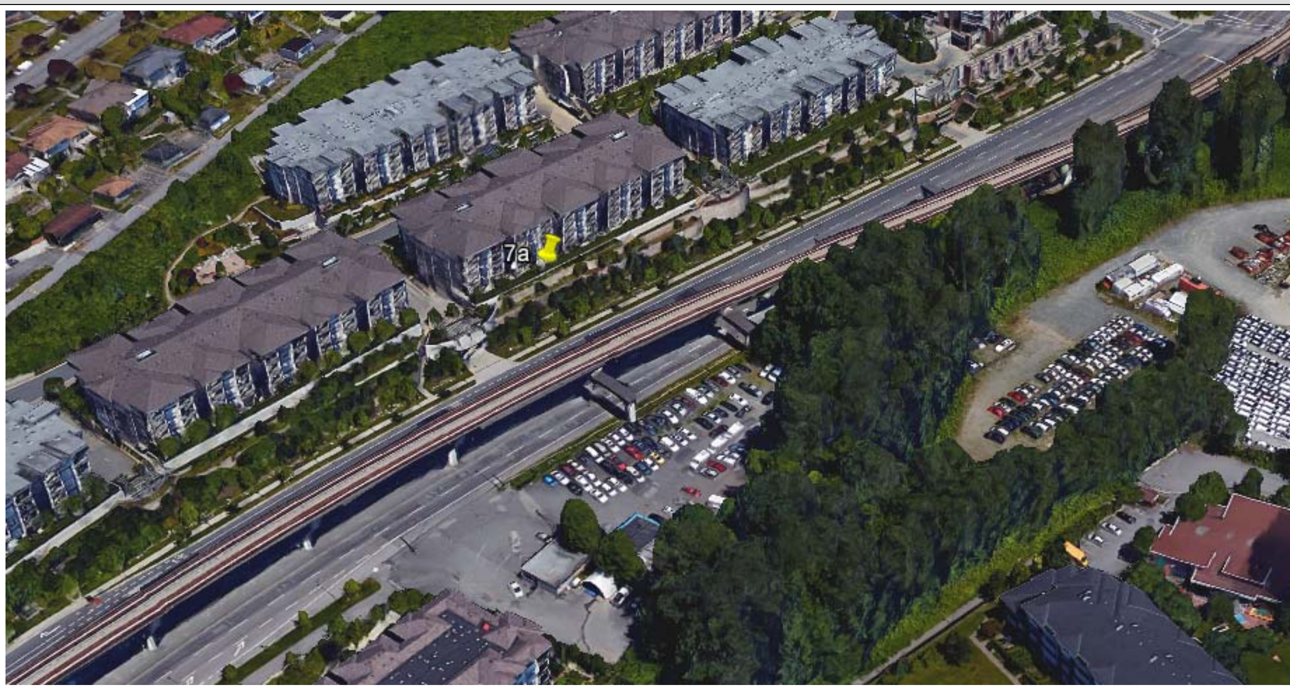
A total of 40 events were observed at this location. Events clearly affected by road traffic noise were filtered out by the operator so that all measured events have been included in the analysis.

Attended Noise Measurement Results

Date: 28/03/2018 **Start Time:** 10:20 am Conditions: Overcast to sunny, light breeze, 7°C

Track	**Train Type**	**No. of Trains**	**Sound Pressure Level (dBA)**	
			Average LAFmax[1]	**Maximum LAFmax**
Inbound	MK II	21	84	89
Outbound	MK II	19	77	82
Train on both tracks	Various	-	-	-
Combined	All	40	81	89

Noise Measurement Location



Note 1: Arithmetic Average

Noise Monitoring Location Descriptions

Noise Measurement Location:	7b – 2088 Madison	View to Tracks
Sound Level Meter: B&K 2270	Serial No: 2808472	
Calibrator: B&K 4231	Serial No: 2326528	

Measurements were taken on a Level 9 balcony of 2088 Madison Street, overlooking the SkyTrain and Lougheed Highway. Road traffic (SPL typically around 62 to 73 dBA) and the SkyTrain were observed as the main sources contributing to the ambient noise environment. The track adjacent to the measurement location is tangent track with a switch nearby to the west. Switch impact noise was noticeable in the noise characteristic, but did not increase maximum noise levels as much as has been observed near switches elsewhere.

Noise from road traffic noise and some lawn mowing activity was also observed during the measurements. Maximum SkyTrain noise levels as reported were largely unaffected, although note other parameters collected incidentally may have been influenced by noise from these other sources.

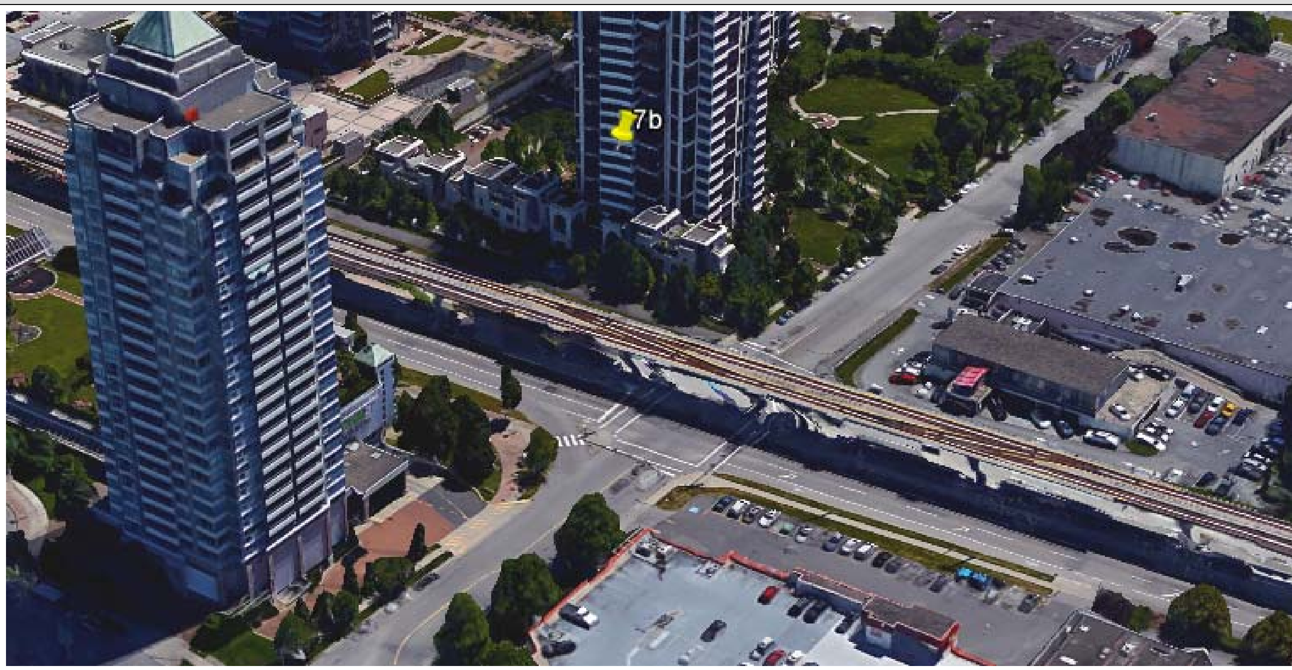
A total of 44 events were observed at this location. Of these, 3 have been excluded from the analysis due to the influence of noise from sources other than the SkyTrain.

Attended Noise Measurement Results

Date: 28/03/2018 **Start Time:** 8:30 am Conditions: Overcast to partly cloudy, light breeze, 7°C

Track	Train Type	No. of Trains	Sound Pressure Level (dBA)	
			Average LAFmax[1]	Maximum LAFmax
Inbound	MK II	20	81	83
Outbound	MK II	21	83	85
Train on both tracks	Various	-	-	-
Combined	All	41	82	85

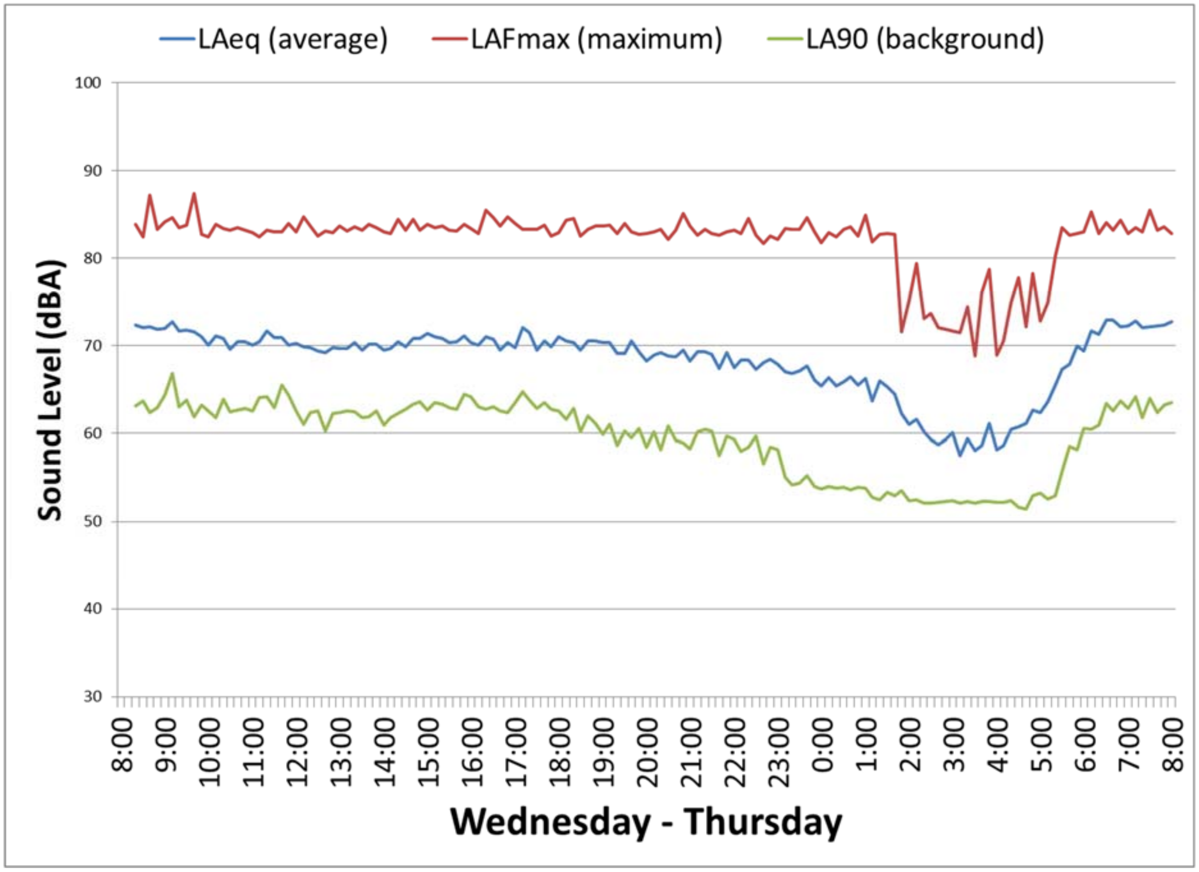
Noise Measurement Location



Note 1: Arithmetic Average

Unattended Noise Measurement Results: 7b – 2088 Madison		
Start Date: 28/03/2018	Sound Level Meter: Larson Davis 824	Serial No: 824A1093

Measured sound level time history (10 minute increments):



Notes:

SkyTrain hours of operation are between 5:00 am and 1:30 am (with some variation depending on location).

The typical maximum noise level in any 10 minute period is around 83 to 85 dBA and is clearly correlated to SkyTrain hours of operation – the attended measurements found similar SkyTrain maximum noise levels. Sources other than the SkyTrain are responsible for isolated peaks in the maximum noise level time history during the night-time. While this location is on a busy road, maximum noise levels are typically due to SkyTrain rather than road traffic.

At this location, the minimum background L90 noise level in any 10 minute period was 52 dBA during the night-time. The highest background L90 noise level was around 65 dBA, during the daytime.

The difference between SkyTrain maximum noise level and the background noise level is typically around 22 dBA during the daytime and up to 30 dBA during the night-time, at times of first and last services.

Noise Monitoring Location Descriptions

Noise Measurement Location:	7c – Gilmore near Dawson
Sound Level Meter: B&K 2270	Serial No: 2808472
Calibrator: B&K 4231	Serial No: 1795340

Measurements were taken at ground level in the Gilmore Pump Station lot, across Gilmore Avenue from 4188 Dawson St. Road traffic (SPL typically around 59 to 62 dBA), birds and the SkyTrain were observed as the main sources contributing to the ambient noise environment. The track adjacent to the measurement location is curved track with relatively low speeds observed near the station. Noise from outbound trains was shielded by the guideway structure; inbound trains were therefore notably louder. Some intermittent flanging noise was observed around the curve and the highest maximum noise level observed was due to flanging.

A total of 42 events were observed at this location. Of these, 8 have been excluded from the analysis due to the influence of noise from sources other than the SkyTrain.

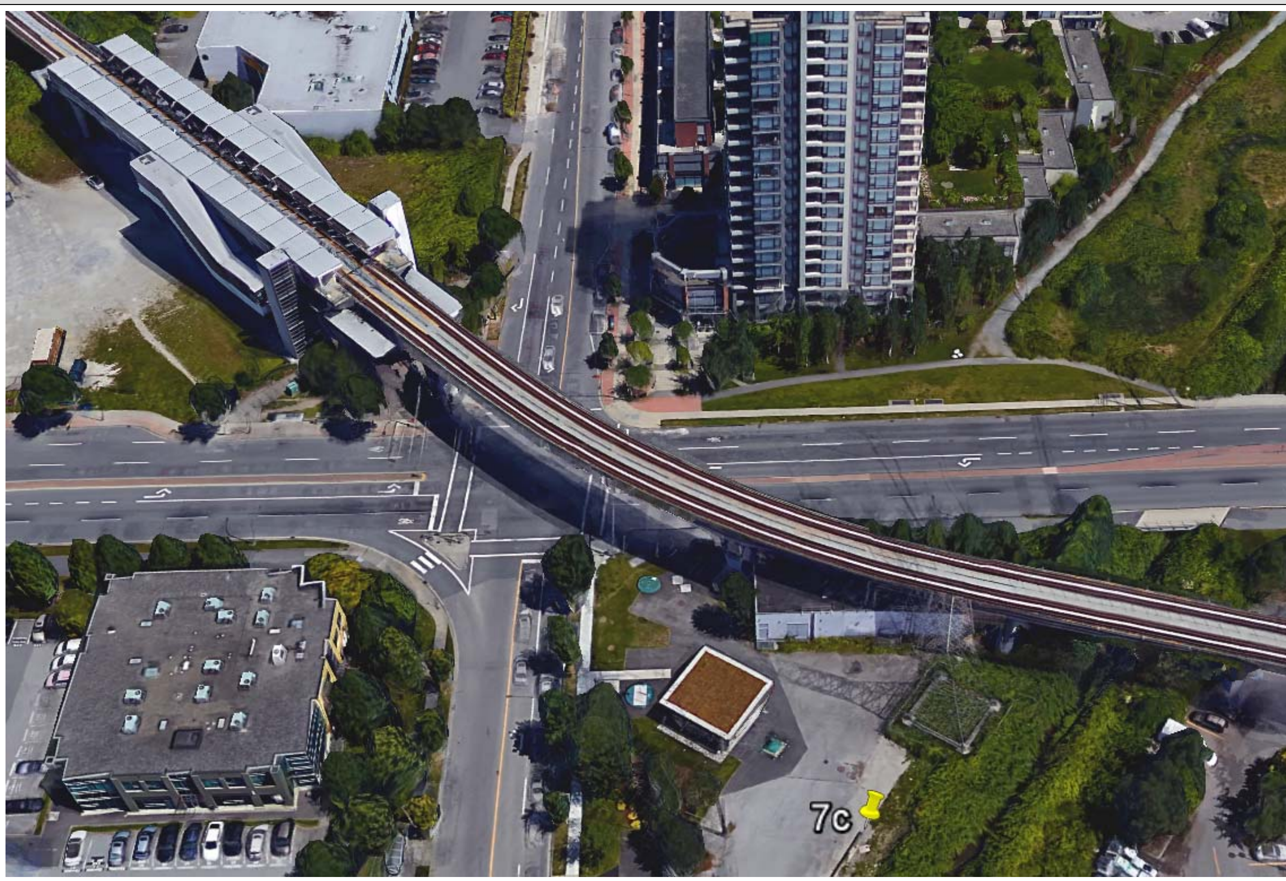
View to Tracks

Attended Noise Measurement Results

Date: 18/04/2018 **Start Time:** 8:00 am Conditions: Sunny, calm, 10°C

Track	Train Type	No. of Trains	Sound Pressure Level (dBA)	
			Average LAFmax[1]	Maximum LAFmax
Inbound	MK II	18	69	74
Outbound	MK II	12	63	67
Train on both tracks	Various	4	71	74
Combined	All	34	67	74

Noise Measurement Location



Note 1: Arithmetic Average

Noise Measurement Location:	8a – 3771 Bartlett
Sound Level Meter: B&K 2270	Serial No: 2808472
Calibrator: B&K 4231	Serial No: 1795340

Measurements were taken on a balcony of Level 22 of 3771 Bartlett Court overlooking Lougheed Station. Ambient noise levels were due to traffic with SPLs typically around 58-60 dBA, but up to 70 dBA associated with heavy vehicles or motorbikes. Intermittent construction activity in the nearby mall generated SPLs around 64-68 dBA. Ambient noise is likely to have contributed to the measured SkyTrain noise levels for some measurements.

Trains on the outbound track were observed to be quieter than those on the inbound track due to the switches on the inbound track, where some flanging noise was observed.

A total of 63 events were observed at this location. Of these, 15 have been excluded from the analysis due to the influence of noise from sources other than the SkyTrain.

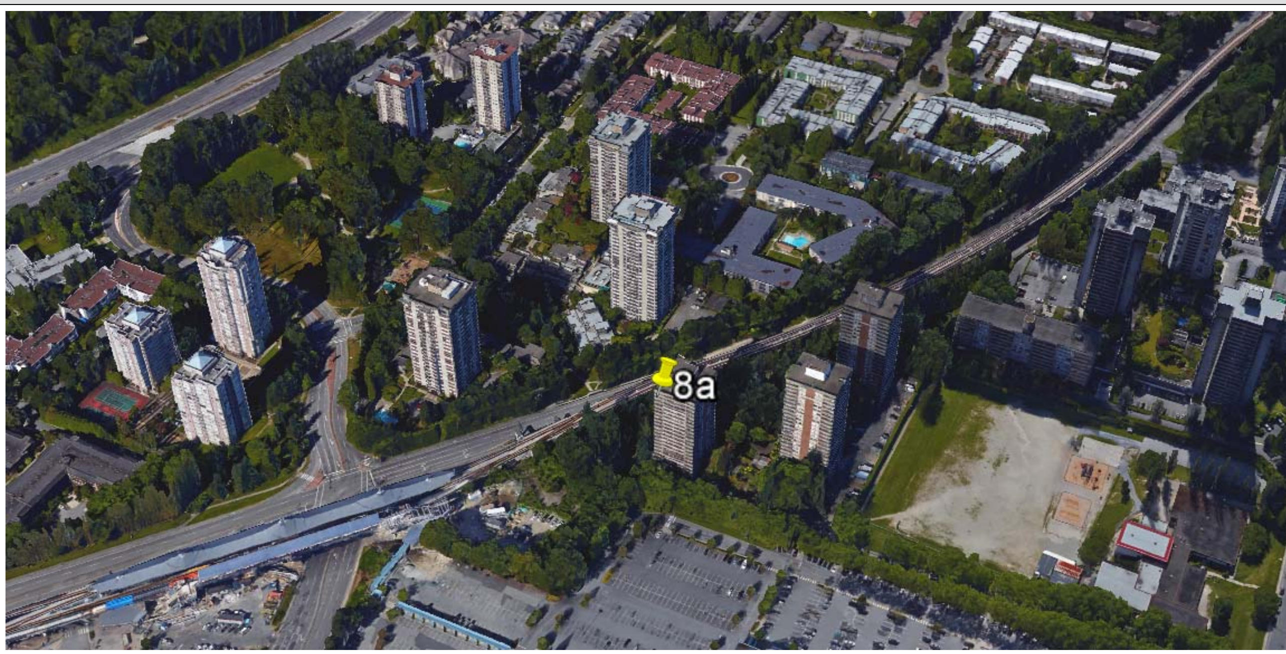
View to Tracks

Attended Noise Measurement Results

Date: 17/04/2018 **Start Time:** 3:00 pm Conditions: Overcast, calm, 11°C

Track	Train Type	No. of Trains	Sound Pressure Level (dBA)	
			Average LAFmax[1]	Maximum LAFmax
Inbound	MK I	3	69	70
	MK II	19	67	70
	MK III	1	69	69
Outbound	MK I	1	68	68
	MK II	20	63	67
	MK III	1	67	67
Train on both tracks	Various	3	69	70
Combined	All	48	66	70

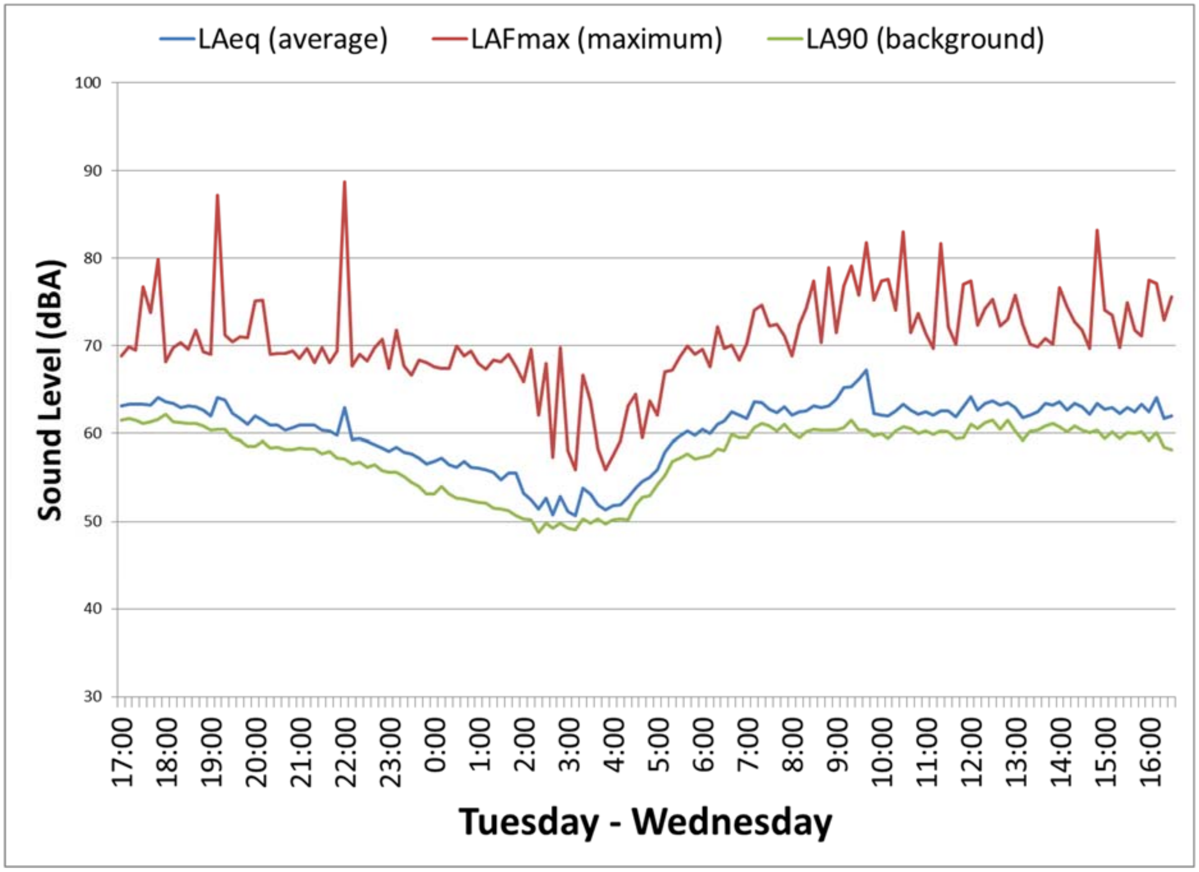
Noise Measurement Location



Note 1: Arithmetic Average

Unattended Noise Measurement Results: 8a – 3771 Bartlett			
Start Date:	16/04/2018	Sound Level Meter: Larson Davis 824	Serial No: 824A1093

Measured sound level time history (10 minute increments):



Notes:

SkyTrain hours of operation are between 5:00 am and 1:30 am (with some variation depending on location).

The typical maximum noise level in any 10 minute period is variable and not clearly correlated to SkyTrain hours of operation. SkyTrain maximum noise levels were around 70 dBA and this maximum noise level is most clearly seen during the evening and night-time period. Sources other than the SkyTrain at this location include construction and road traffic, these other sources are responsible isolated peaks in the maximum noise level time history that are considerably different from the typical SkyTrain level.

At this location, the minimum background L90 noise level in any 10 minute period was 50 dBA during the night-time. The highest background L90 noise level was 61 dBA, during the evening peak period.

The difference between SkyTrain maximum noise level and the background noise level is typically around 10 dBA during the daytime and up to 20 dBA during the night-time, at times of first and last services.

Noise Monitoring Location Descriptions

Noise Measurement Location:	8b – Salish Court
Sound Level Meter: B&K 2270	Serial No: 2821599
Calibrator: B&K 4231	Serial No: 1795340

Measurements were taken in a car park off Salish Court. Road traffic and birds with SPL around 56 to 70 dBA were observed as the main other sources contributing to the ambient noise environment.

The track adjacent to the measurement location is a large radius curve and low noise barriers are in place increasing the height of the guideway parapet.

A total of 63 events were observed at this location. Of these, 6 have been excluded from the analysis due to the influence of noise from sources other than the SkyTrain.

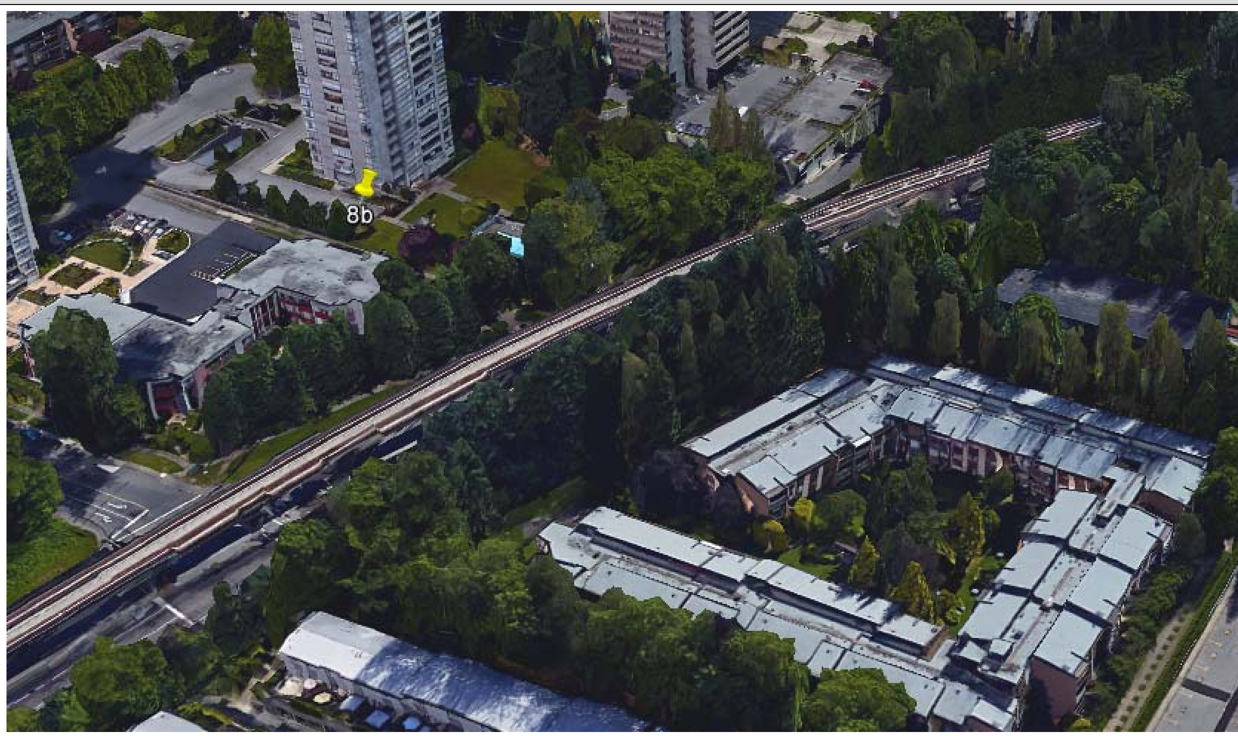
View to Tracks

Attended Noise Measurement Results

Date: 28/03/2018 **Start Time:** 8:40 am Conditions: Overcast, calm, 9°C

Track	Train Type	No. of Trains	Sound Pressure Level (dBA)	
			Average LAFmax[1]	Maximum LAFmax
Inbound	MK I	6	66	69
	MK II	21	66	70
	MK III	1	65	65
Outbound	MK I	8	67	69
	MK II	15	63	69
	MK III	3	68	69
Train on both tracks	Various	3	69	72
Combined	All	57	66	72

Noise Measurement Location



Note 1: Arithmetic Average

Noise Measurement Location:	8c – North Road
Sound Level Meter: B&K 2270	Serial No: 2821599
Calibrator: B&K 4231	Serial No: 1795340

The North Road measurement was situated at the end of Perth Avenue, at ground level below the guideway deck. Track in this area is tangent track with no noticeable localized features affecting noise level.

Street traffic resulted in variable ambient noise levels ranging from 50 to 70 dBA, up to 75 dB in some cases.

Light rain began falling soon after commencing measurements at this location and resulted in increased road traffic noise levels. Maximum SkyTrain noise levels are not expected to have been significantly affected.

The train frequency was relatively low during this measurement completed on a Saturday. A total of 18 events were observed at this location, all 2-car MK II trains. Of these, 3 have been excluded from the analysis due to the influence of noise from sources other than the SkyTrain.

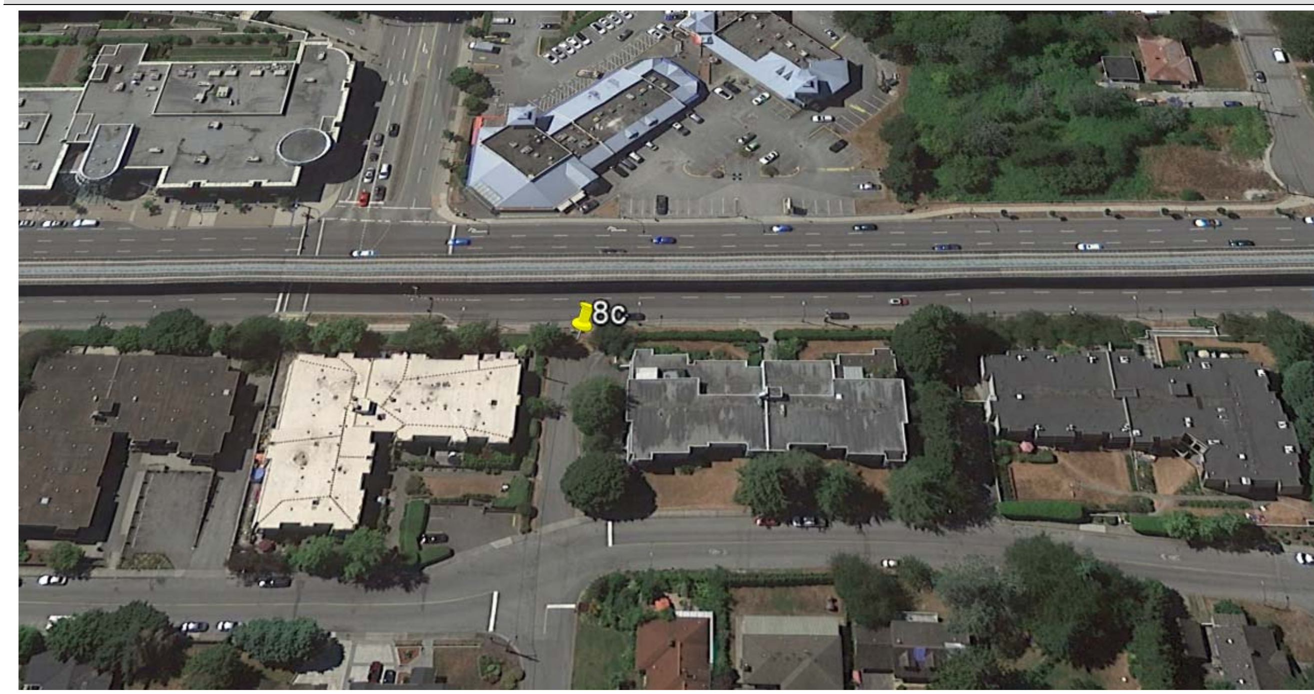
View to tracks

Attended Noise Measurement Results

Date: 24/03/2018 **Start Time:** 9:45 am Conditions: Light rain, 4°C

Track	Train Type	No. of Trains	Sound Pressure Level (dBA)	
			Average LAFmax[1]	Maximum LAFmax
Inbound	MK II	10	79	83
Outbound	MK II	5	72	75
Train on both tracks	-	-	-	-
Combined	All	15	77	83

Noise Measurement Location



Note 1: Arithmetic Average

Noise Measurement Location:	9a – 301 Capilano	View to Tracks
Sound Level Meter: B&K 2270	Serial No: 2821599	
Calibrator: B&K 4231	Serial No: 1795340	

Measurements were taken at ground level at the rear of 301 Capilano Road.

Track in this location is tangent track with no localized features observed to affect SkyTrain noise.

Ambient noise levels between SkyTrain passbys were typically around 50 dBA, sometimes a little higher with construction noise and bird calls.

A total of 41 events were observed at this location. Of these, 5 have been excluded from the analysis due to the influence of noise from sources other than the SkyTrain.

Attended Noise Measurement Results

Date: 28/03/2018 **Start Time:** 2:45 pm Conditions: Partly cloudy, light breeze, 10°C

Track	Train Type	No. of Trains	Sound Pressure Level (dBA)	
			Average LAFmax[1]	Maximum LAFmax
Inbound	MK II	16	73	74
Outbound	MK II	17	61	62
Train on both tracks	MK II	3	73	74
Combined	All	36	67	74

Noise Measurement Location

Note 1: Arithmetic Average

Noise Monitoring Location Descriptions

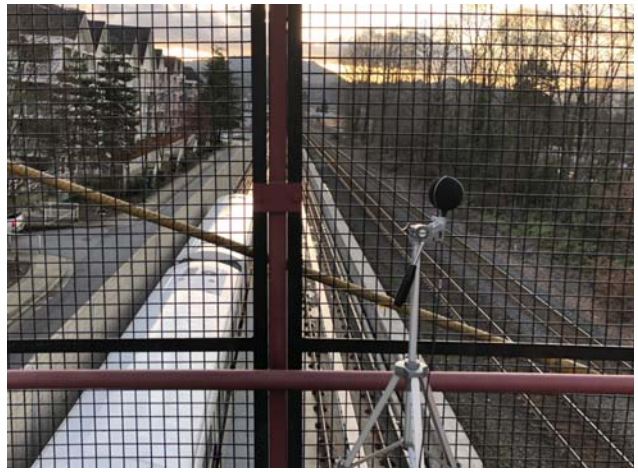
Noise Measurement Location:	9b – Golden Spike Lane
Sound Level Meter: B&K 2270	Serial No: 2821599
Calibrator: B&K 4231	Serial No: 1795340

Measurements were taken on a pedestrian overbridge above the tracks to the east of Moody Centre Station. Ambient road traffic SPLs were typically around 55 dBA. Maximum noise levels from freight trains were observed to be up to around 90 dBA. Noticeable vibration was generated by pedestrian traffic on the bridge structure, however this did not affect the maximum passby noise levels.

The tracks running underneath the measurement location are straight with no localized features affecting SkyTrain noise.

A total of 40 events were observed at this location. Of these, 1 has been excluded from the analysis due to the influence of noise from sources other than the SkyTrain.

View to Tracks

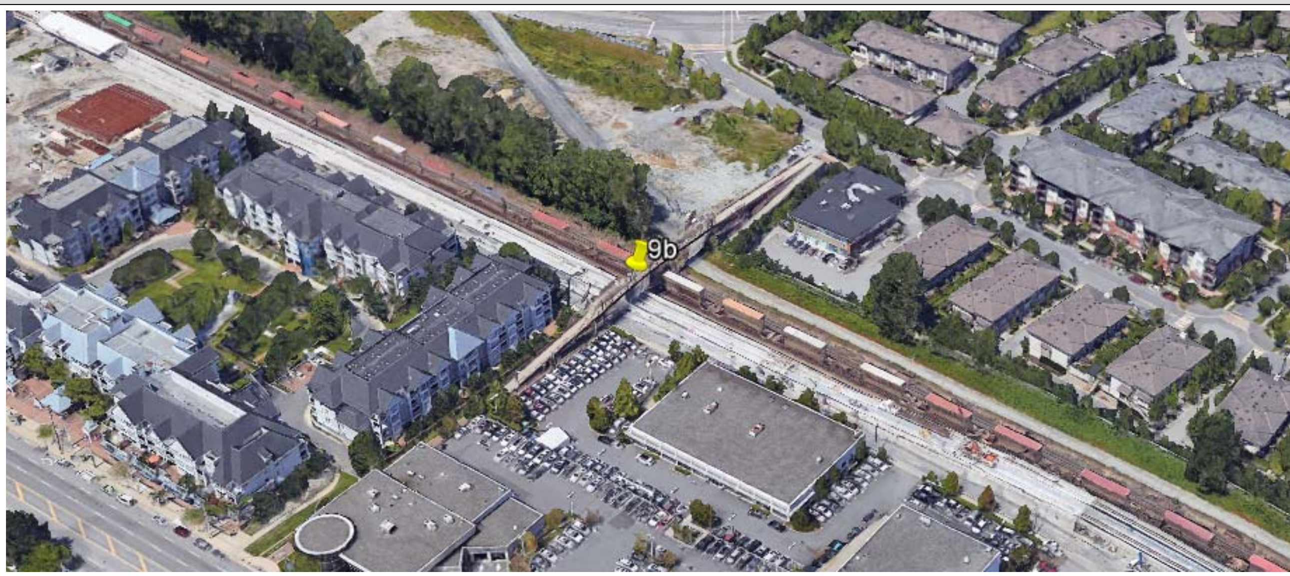


Attended Noise Measurement Results

Date: 27/03/2018 **Start Time:** 6:00 pm Conditions: Mostly sunny, light breeze with mild gusts, 14°C

Track	Train Type	No. of Trains	Sound Pressure Level (dBA)	
			Average LAFmax[1]	Maximum LAFmax
Inbound	MK II	17	87	91
Outbound	MK II	21	83	92
Train on both tracks	Various	1	87	87
Combined	All	39	85	92

Noise Measurement Location



Note 1: Arithmetic Average

Noise Measurement Location:	**9c – Dewdney Trunk Road**	**View to Tracks**
Sound Level Meter: B&K 2270	Serial No: 2821599	
Calibrator: B&K 4231	Serial No: 1795340	

Measurements were taken to the side of Dewdney Trunk Road in a location with line of sight to the SkyTrain. The microphone was situated above guideway deck level.

Track in this location is tangent track. SkyTrain noise was observed to be louder along the inbound line to the west of measurement location, while passing a series of switches near the operations and maintenance centre.

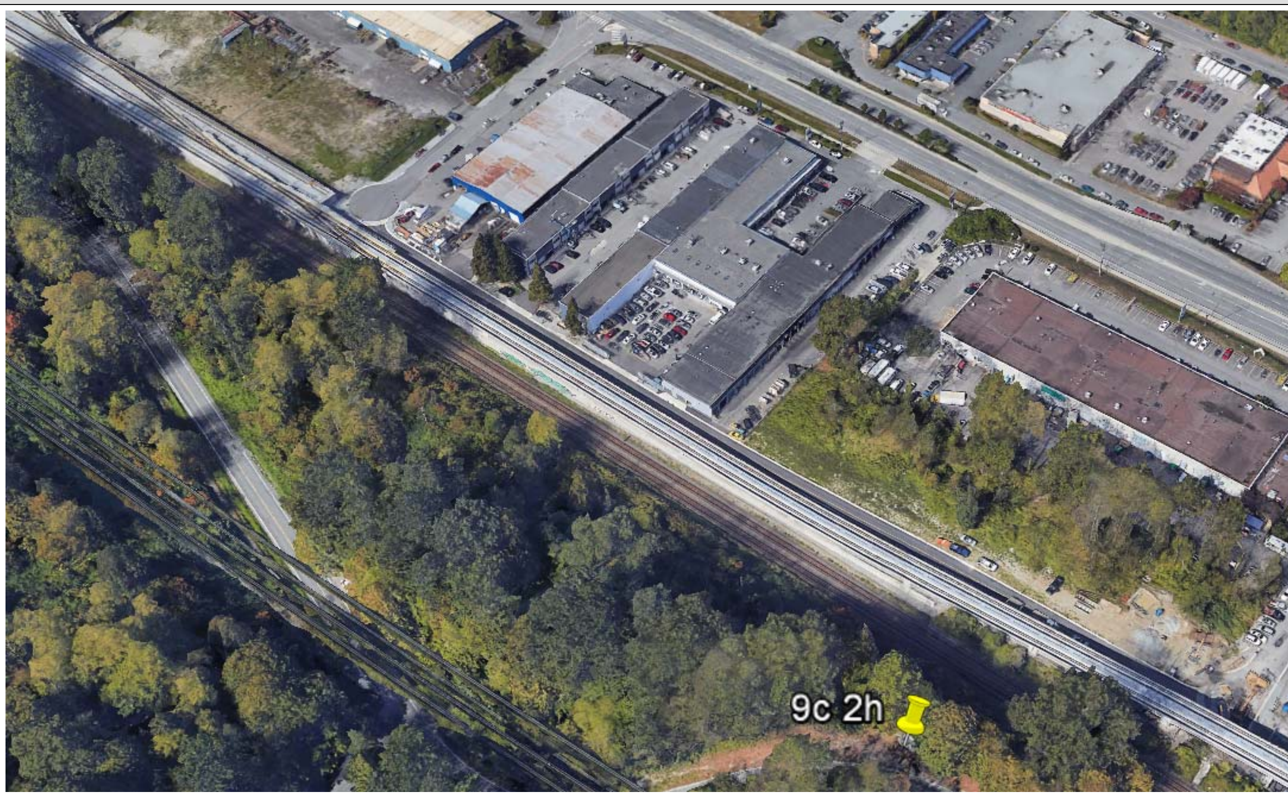
Ambient noise sources in addition to the SkyTrain included some industrial noise, freight trains, and road traffic on Dewdney Trunk Road.

A total of 40 events were observed at this location. Of these, 5 have been excluded from the analysis due to the influence of noise from sources other than the SkyTrain.

Attended Noise Measurement Results

Date: 27/03/2018	**Start Time:** 4:15 pm		Conditions: Sunny to partly cloudy, light breeze, 13°C	
Track	**Train Type**	**No. of Trains**	**Sound Pressure Level (dBA)**	
			Average LAFmax[1]	**Maximum LAFmax**
Inbound	MK II	18	76	77
Outbound	MK II	15	75	78
Train on both tracks	MK II	2	77	78
Combined	All	35	76	78

Noise Measurement Location



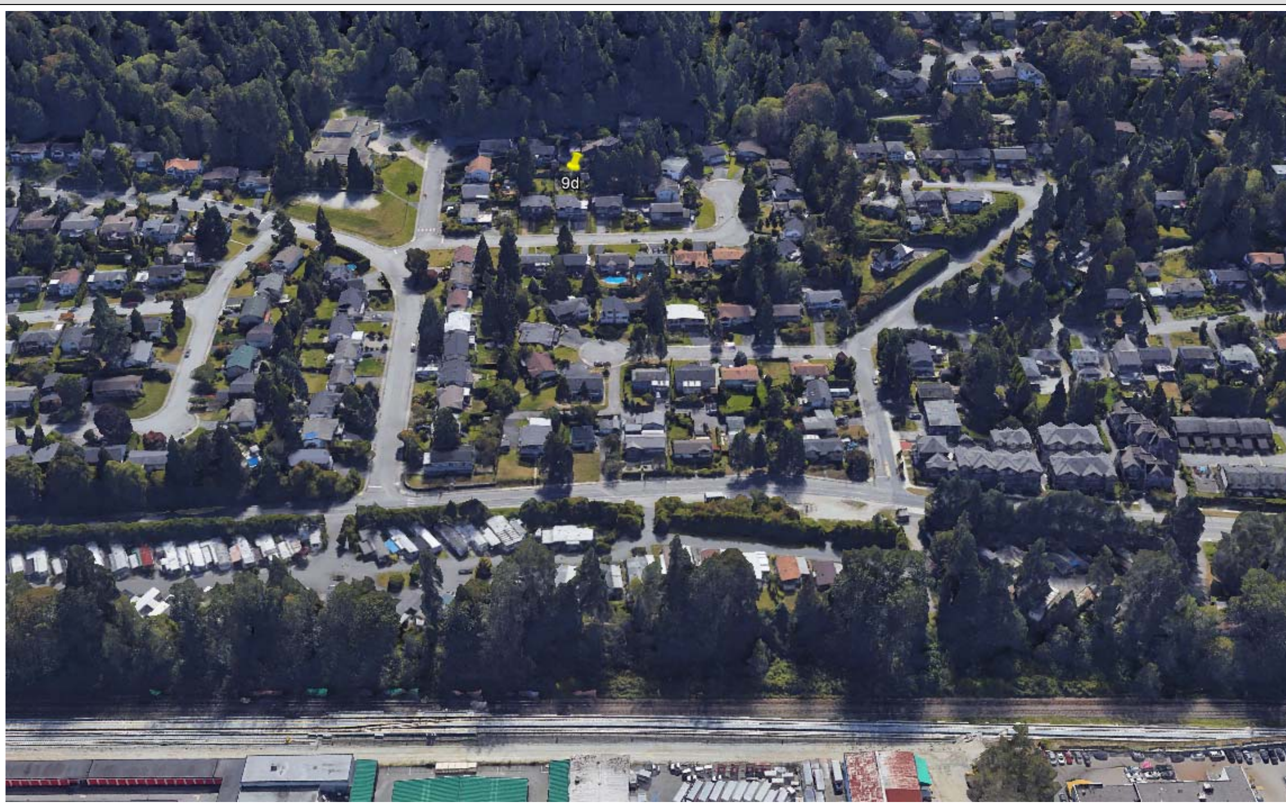
Note 1: Arithmetic Average

Noise Measurement Location:	9d – 2525 Quay Place	View to Tracks
Calibrator: B&K 4231	Serial No: 1795340	

The attended measurement locations in the Moody Centre / Inlet Centre area were not secure for unattended monitoring, so this residential backyard was used for unattended measurements in this area. Attended measurements of individual SkyTrain passbys were not taken at this location due to the lack of line of sight to the tracks; instead a 15 minute attended observation was conducted.

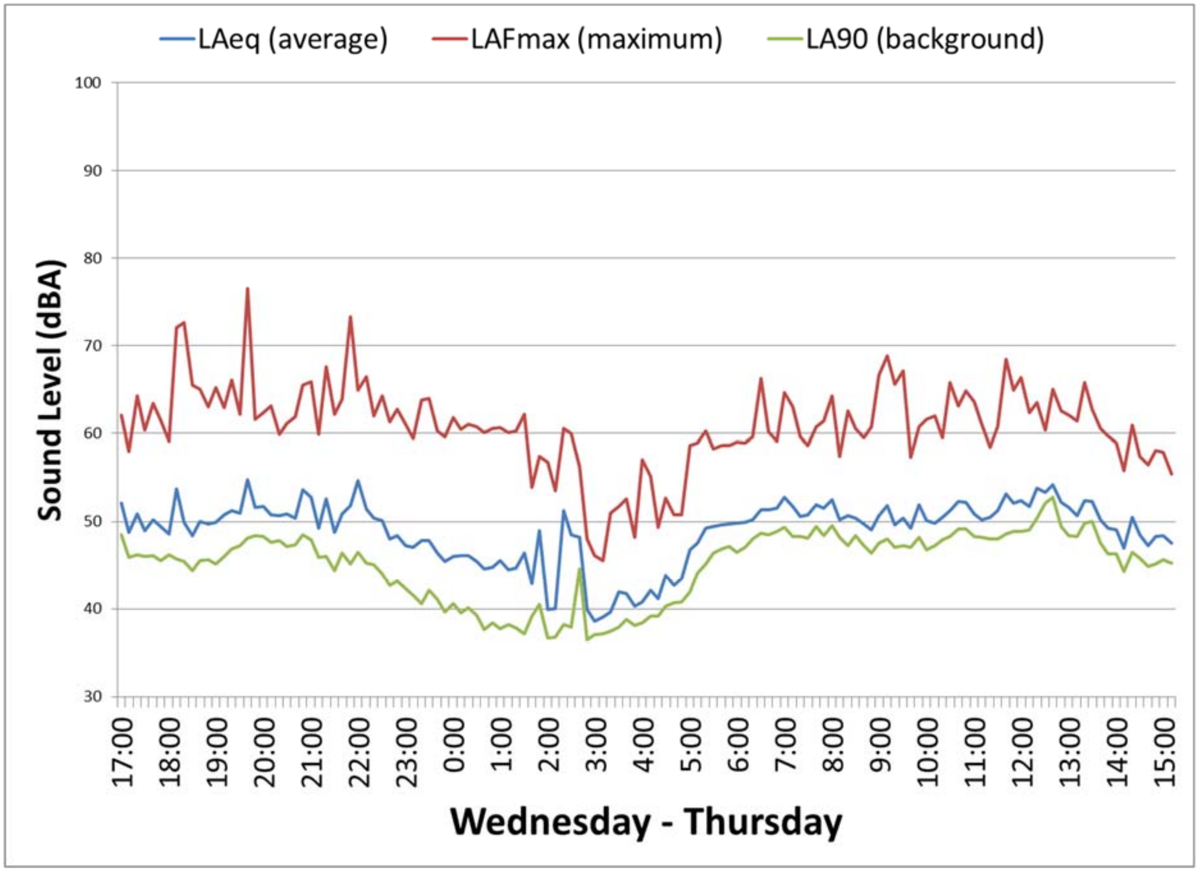
SkyTrain noise was observed to generate maximum noise levels around 60 dBA. Distant road traffic noise was typically around 50 dBA, and the daytime background noise level was around 45 dBA. Other noise sources included local neighbourhood noise.

Noise Measurement Location



Unattended Noise Measurement Results: 9d – 2525 Quay Place		
Start Date: 28/03/2018	Sound Level Meter: Larson Davis 824	Serial No: 824A0342

Measured sound level time history (10 minute increments):



Notes:

SkyTrain hours of operation are between 5:00 am and 1:30 am (with some variation depending on location).

The typical maximum noise level in any 10 minute period is variable and not solely correlated to SkyTrain hours of operation. SkyTrain maximum noise levels were around 60 dBA and this maximum noise level is most clearly seen during the night-time period before 1:00 am. Sources other than the SkyTrain at this location include road traffic, birds and neighbourhood noise, these other sources are responsible isolated peaks in the maximum noise level time history that are considerably different from the typical SkyTrain level.

At this location, the minimum background L90 noise level in any 10 minute period was 37 dBA during the night-time. The highest background L90 noise level was 52 dBA, during the daytime.

The difference between SkyTrain maximum noise level and the background noise level is typically around 12 dBA during the daytime and up to 23 dBA during the night-time, at times of first and last services.

Noise Monitoring Location Descriptions

Noise Measurement Location:	10a – 1188 Pinetree Way
Sound Level Meter: B&K 2270	Serial No: 2808472
Calibrator: B&K 4231	Serial No: 2326528

Measurements were taken on a Level 42 balcony 1188 Pinetree Way, overlooking the tracks between Lincoln Station and Lafarge-Lake Douglas Station. Road traffic dominated ambient noise levels with SPLs typically around 54 to 61 dBA. Maximum noise levels during train passbys were sometimes less than 10 dB above the ambient level. The maximum level was measured as the train was adjacent to the measurement location. In the inbound direction, the maximum noise was due to rolling noise, in the outbound direction some traction noise was also noticeable.

No noticeable impact noise was observed from the switches on the approach to Lafarge-Lake Douglas Station.

A total of 42 events were observed at this location. Of these, 1 has been excluded from the analysis due to the influence of noise from sources other than the SkyTrain.

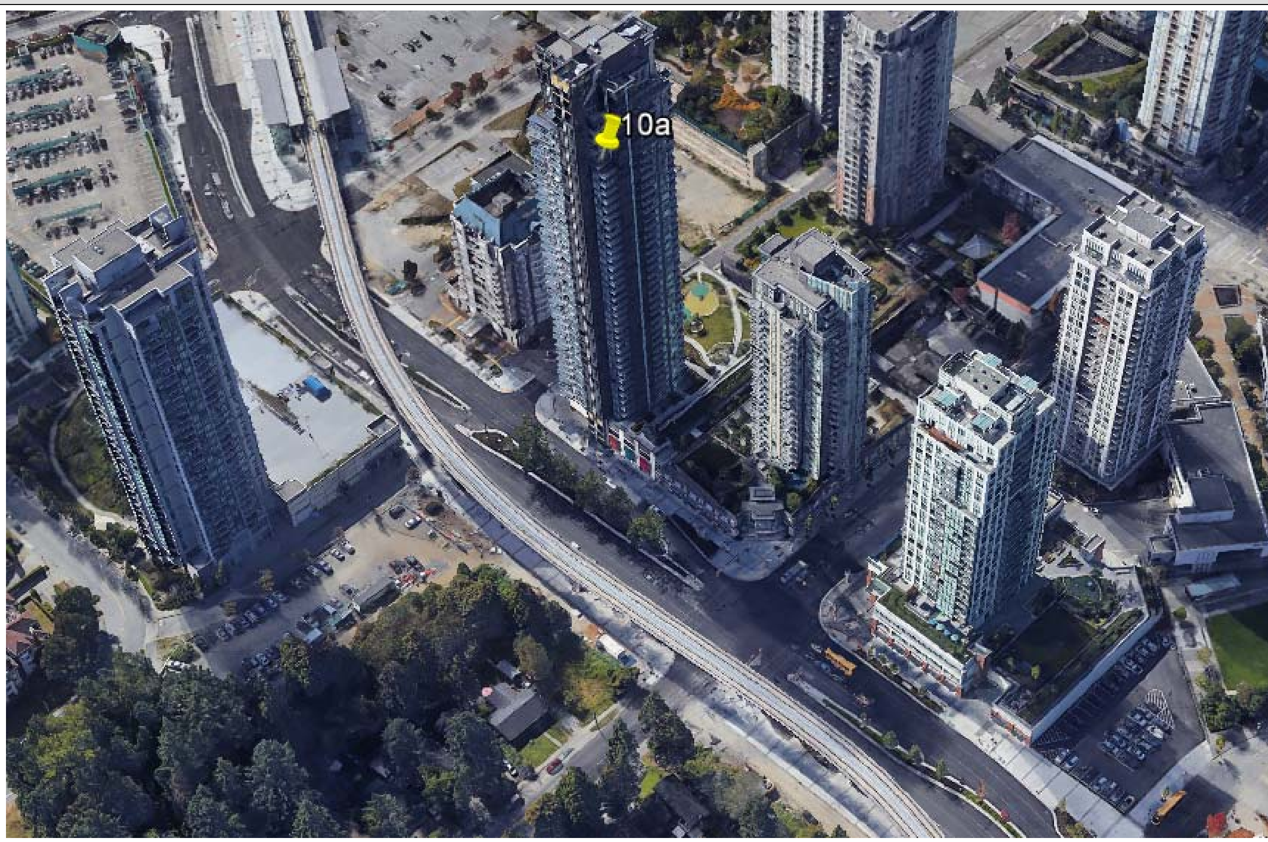
View to Tracks

Attended Noise Measurement Results

Date: 23/03/2018 **Start Time:** 5:30 pm Conditions: Overcast to partly cloudy, low wind, 5°C

Track	Train Type	No. of Trains	Sound Pressure Level (dBA)	
			Average LAFmax[1]	Maximum LAFmax
Inbound	MK II	21	69	71
Outbound	MK II	20	69	70
Train on both tracks	MK II	-	-	-
Combined	All	41	69	71

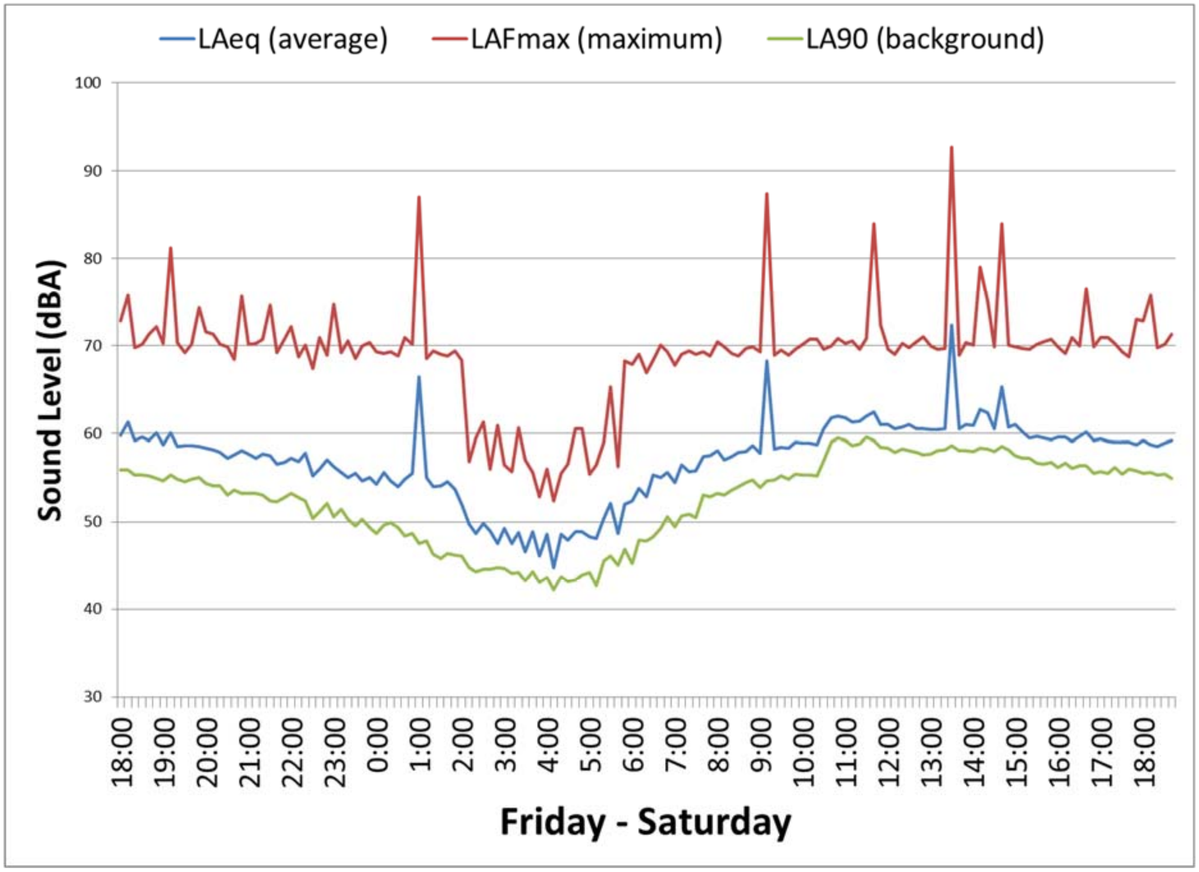
Noise Measurement Location



Note 1: Arithmetic Average

Unattended Noise Measurement Results: 10a – 1188 Pinetree Way			
Start Date:	23/03/2018	Sound Level Meter: Larson Davis 824	Serial No: 824A0301

Measured sound level time history (10 minute increments):



Notes:

SkyTrain hours of operation are between 5:00 am and 1:30 am (with some variation depending on location).

The typical maximum noise level in any 10 minute period is around 70 dBA and is clearly correlated to SkyTrain hours of operation – the attended measurements found similar SkyTrain maximum noise levels. Sources other than the SkyTrain are responsible for isolated peaks in the maximum noise level time history that are considerably different from this typical level.

At this location, the minimum background L90 noise level in any 10 minute period was 43 dBA during the night-time. The highest background L90 noise level was 59 dBA, during the daytime.

The difference between SkyTrain maximum noise level and the background noise level is typically around 15 dBA during the daytime and up to 25 dBA during the night-time, at times of first and last services.

Noise Measurement Location:	**10b – 1169 Pinetree (Roof)**
Sound Level Meter: B&K 2270	Serial No: 2808472
Calibrator: B&K 4231	Serial No: 2326528

Measurements were taken on the edge of the rooftop carpark at 1169 Pinetree Way, above guideway deck level (approximately at SkyTrain vehicle roof level). Ambient noise levels were due to an exhaust fan on the carpark roof with SPLs around 55-58 dBA. Intermittent road traffic noise had SPLs around 65-70 dBA.

Noise levels were observed to be relatively low given the close proximity to the tracks. There was no impulsive noise; rolling noise was very consistent for all trains. Train speeds were relatively low due to the proximity of the station.

A total of 42 events were observed at this location. Of these, 0 have been excluded from the analysis due to the influence of noise from sources other than the SkyTrain.

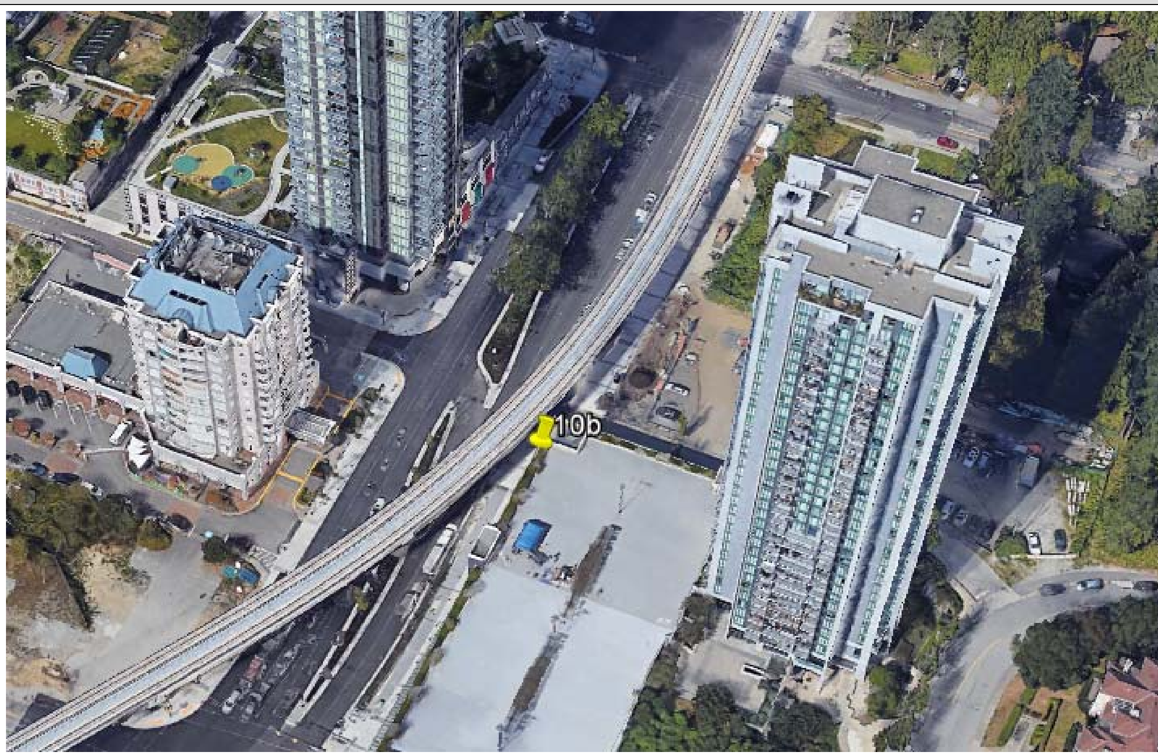
View to Tracks

Attended Noise Measurement Results

Date: 23/03/2018 **Start Time:** 3:30 pm Conditions: Overcast to partly cloudy, no wind, 5°C

Track	**Train Type**	**No. of Trains**	**Sound Pressure Level (dBA)**	
			Average LAFmax[1]	**Maximum LAFmax**
Inbound	MK II	21	78	79
Outbound	MK II	21	77	77
Train on both tracks	Various	0	-	-
Combined	All	42	77	79

Noise Measurement Location



Note 1: Arithmetic Average

APPENDIX C
Noise Model Parameters

SkyTrain Noise Study Vancouver
Noise Report and Maps
SLR Project No.: 201.04644.00003

Appendix C - Noise Modeling Parameters

SkyTrain Noise Study – Noise Mapping

Noise Modeling Software

SoundPLAN , version 8.0

Standards

Nord2000 Rail: Jonasson & Storeheier Nord 2000. New Nordic Prediction Method for Rail Traffic Noise

Air absorption: ISO 9613-1 Calculation of the absorption of sound by the atmosphere

Source Emission Heights

Source	Height (m) MK I	Height (m) MK II
1	0.01	0.01
2	0.23	0.3
3	0.46	0.58

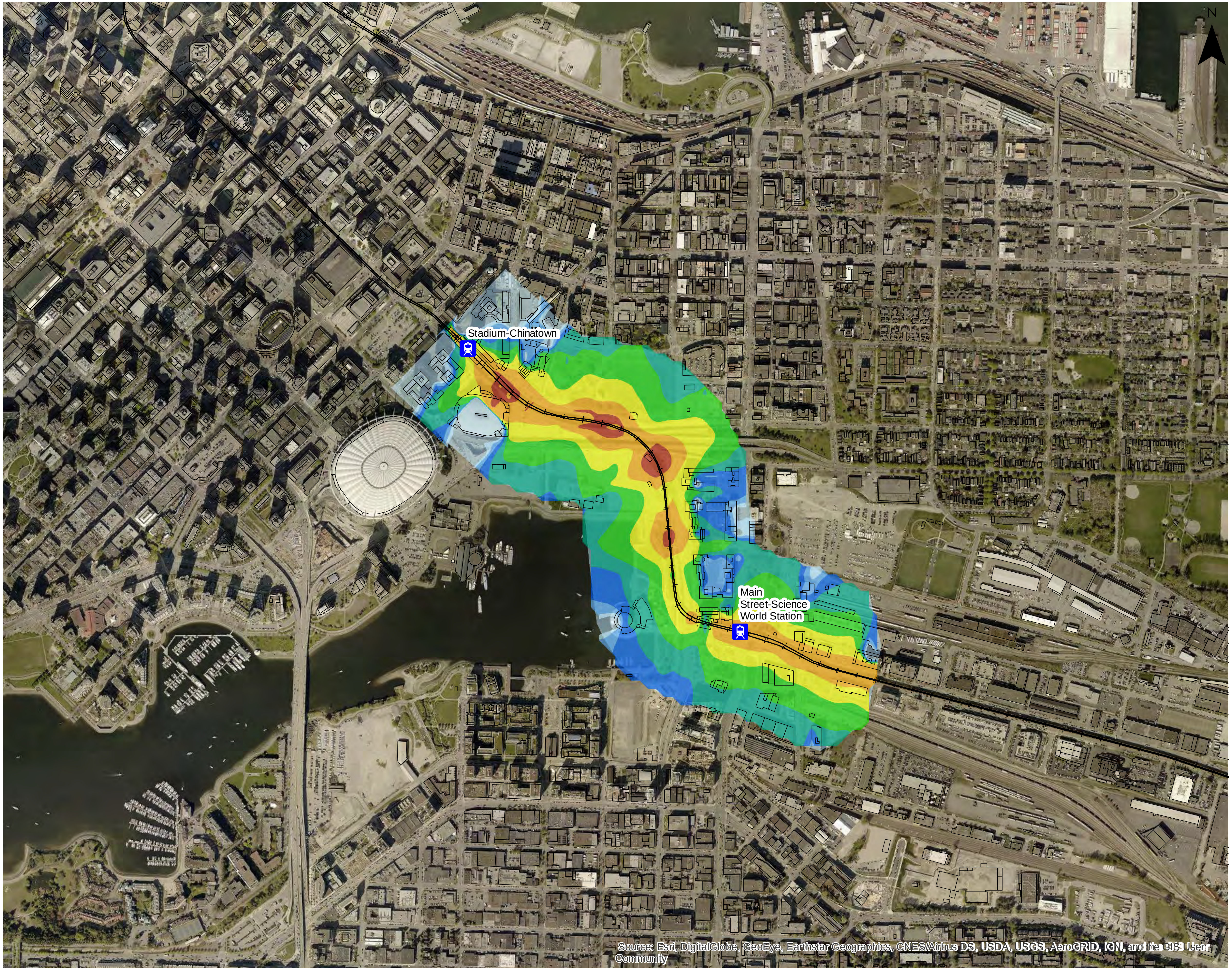
Train Reference Noise Emission Constants

Frequency (Hz)	MK I		MK II	
	a	b	a	b
125	0.2	83.8	0.2	86.1
160	6.9	85.4	6.9	86.8
200	13.1	90.4	13.1	91.0
250	11.3	94.2	11.3	93.1
315	10.1	94.6	10.1	93.5
400	33.9	98.1	33.9	97.4
500	42.7	101.4	42.7	101.8
630	14.4	98.4	14.4	96.5
800	18.4	97.1	18.4	97.9
1000	30.1	99.1	30.1	96.8
1250	30.0	97.1	30.0	96.4
1600	25.6	90.5	25.6	91.8
2000	11.7	88.0	11.7	91.5
2500	18.0	88.5	18.0	83.1
3150	19.1	82.2	19.1	81.7
4000	24.0	82.2	24.0	80.5
5000	23.4	80.8	23.4	78.8
6300	25.0	75.7	25.0	74.8
8000	25.3	70.6	25.3	71.2
10000	23.5	65.7	23.5	65.2

Ground Parameters	
Ground factor	G=0 (hard ground)
Impedance class:	Nord2000 Class D
Effective flow resistivity:	σ=200 kNs/m^4
Roughness class:	N: Nil +/- 0.25m
Meteorological Parameters	
Temperature:	15^{o}C
Air Pressure:	1013.3 mbar
Relative humidity:	70%
Propagation conditions:	Neutral (zero wind and temperature gradients)
Other Calculation Parameters	
Reflection order:	2
Maximum reflection distance to receiver:	200 m
Maximum reflection distance to source:	100 m
Search radius:	500 m
Allowed tolerance (per individual source):	0.5 dB
Grid noise map calculation spacing:	20 m

APPENDIX D
Noise Level Maps 20 m Elevation

SkyTrain Noise Study Vancouver
Noise Report and Maps
SLR Project No.: 201.04644.00003



LEGEND

- Skytrain Stations
- Track
- Building Outline

Maximum Noise Level (dBA)

- < 55
- 55 - < 60
- 60 - < 65
- 65 - < 70
- 70 - < 75
- 75 - < 80
- 80 - < 85
- 85 - < 90
- > 90

Contours show typical maximum train passby noise level (LAmax) at 20m elevation above ground

0 125 250 500 Meters

SCALE: 1:9,000
WHEN PLOTTED CORRECTLY AT 11 x 17
NAD 1983 UTM Zone 10N

NOTES
This map is for conceptual purposes only and should not be used for navigational purposes.
Basedata:

SKYTRAIN

TRANSLINK NOISE MAPPING

NOISE CONTOURS FOR STUDY AREA 1 - FALSE CREEK AT 20M ELEVATION

November 26, 2018	Rev 0.0	Figure No.
Project No. 201.04644.00003		1B

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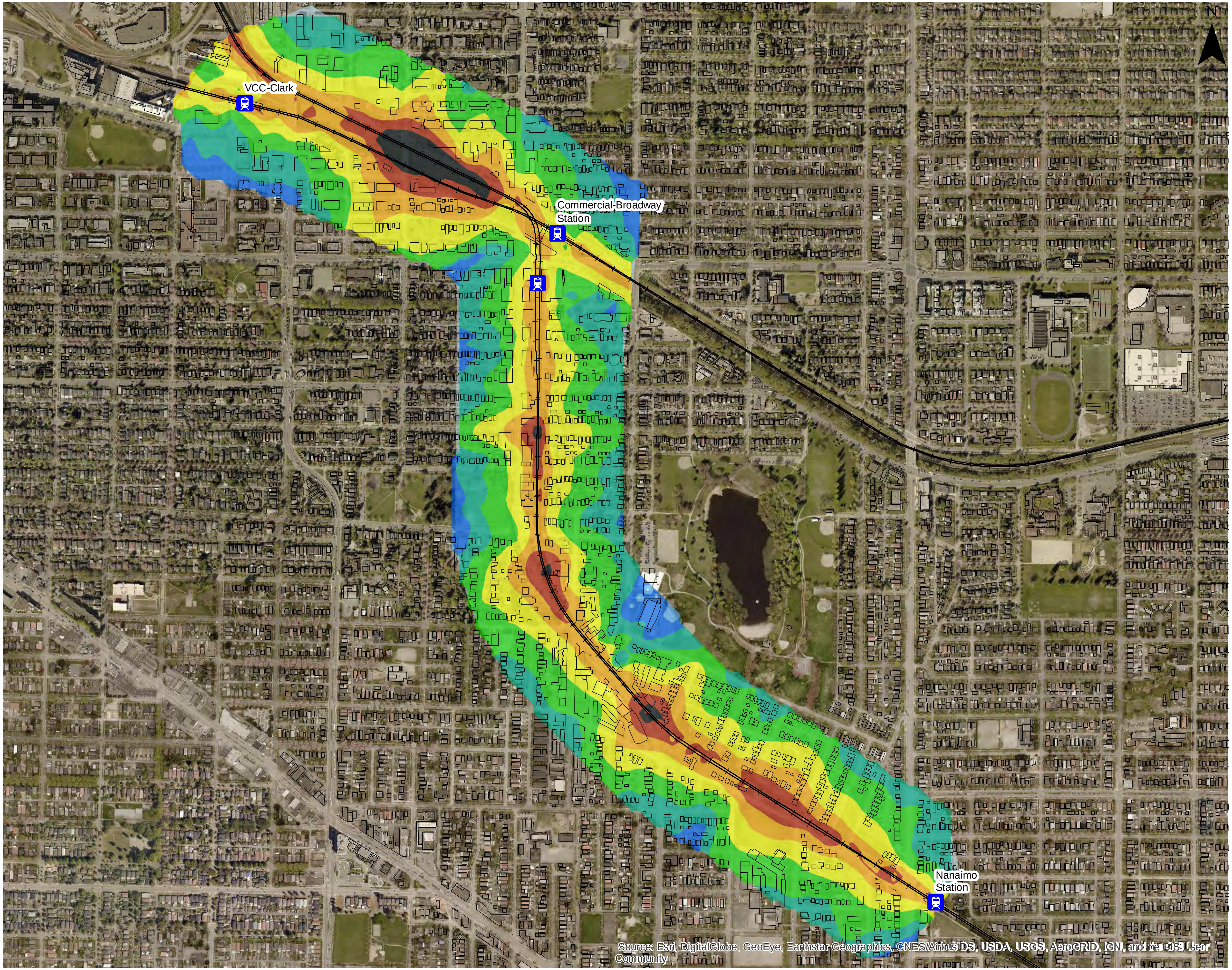

LEGEND

- Skytrain Stations
- Track
- Building Outline

Maximum Noise Level (dBA)

- < 55
- 55 - < 60
- 60 - < 65
- 65 - < 70
- 70 - < 75
- 75 - < 80
- 80 - < 85
- 85 - < 90
- > 90

Contours show typical maximum train passby noise level (LAmax) at 20m elevation above ground

0 125 250 500 Meters

SCALE: 1:9,000
WHEN PLOTTED CORRECTLY AT 11 x 17
NAD 1983 UTM Zone 10N

NOTES
This map is for conceptual purposes only and should not be used for navigational purposes.
Basedata:

SKYTRAIN

TRANSLINK NOISE MAPPING

NOISE CONTOURS FOR STUDY AREA 2 - VCC - COMMERCIAL BROADWAY – NANAIMO AT 20M ELEVATION

November 26, 2018	Rev 0.0	Figure No.
Project No.	201.04644.00003	2B

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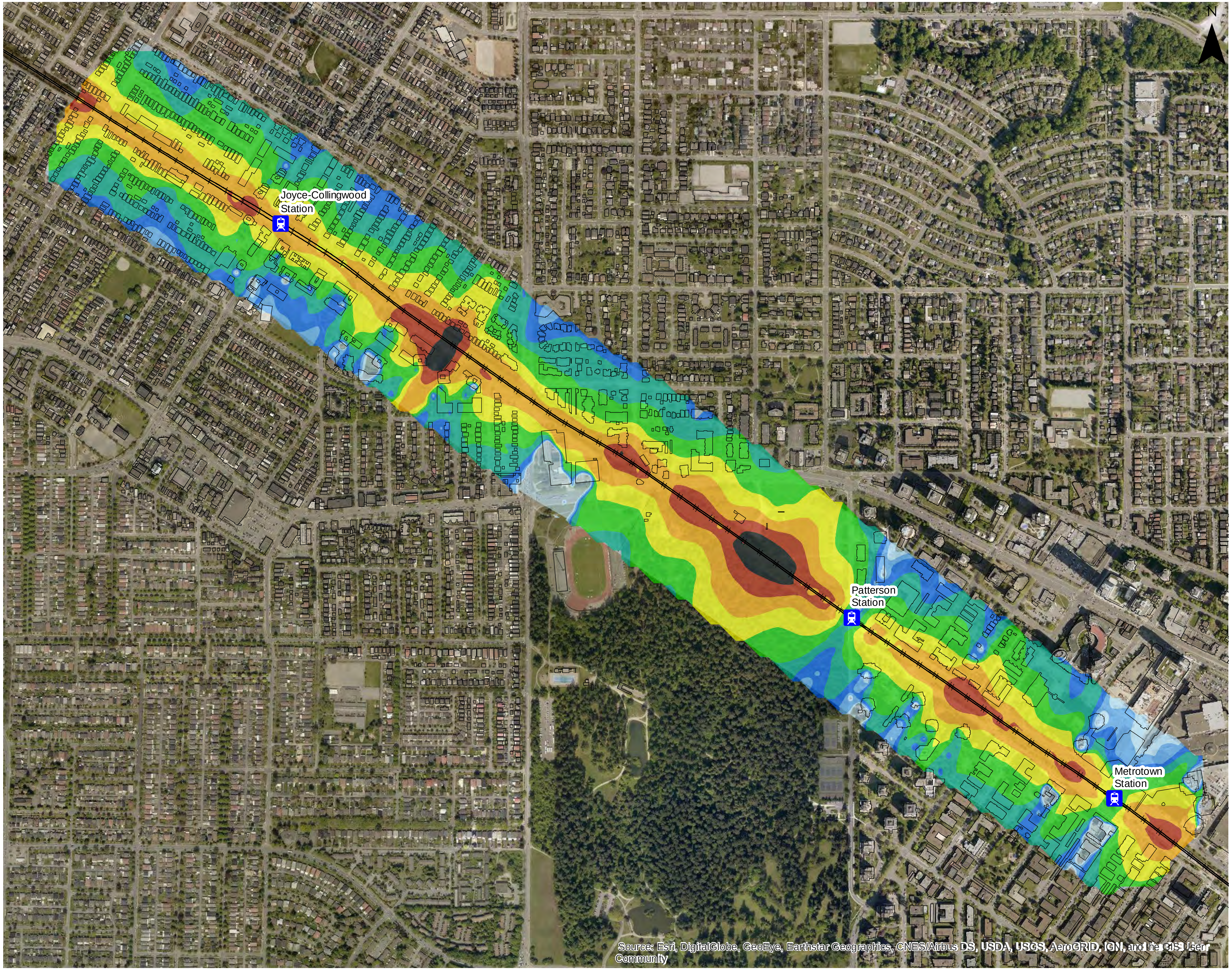

LEGEND

- Skytrain Stations
- Track
- Building Outline

Maximum Noise Level (dBA)

- < 55
- 55 - < 60
- 60 - < 65
- 65 - < 70
- 70 - < 75
- 75 - < 80
- 80 - < 85
- 85 - < 90
- > 90

Contours show typical maximum train passby noise level (LAmax) at 20m elevation above ground

0 125 250 500 Meters

SCALE: 1:9,000
WHEN PLOTTED CORRECTLY AT 11 x 17
NAD 1983 UTM Zone 10N

NOTES

This map is for conceptual purposes only and should not be used for navigational purposes.

Basedata:

SKYTRAIN

TRANSLINK NOISE MAPPING

NOISE CONTOURS FOR STUDY AREAS 3 AND 4 - JOYCE COLLINGWOOD AND PATTERSON TO METROTOWN AT 20M ELEVATION

November 26, 2018	Rev	0.0	Figure No.
Project No.	201.04644.00003		**3B**

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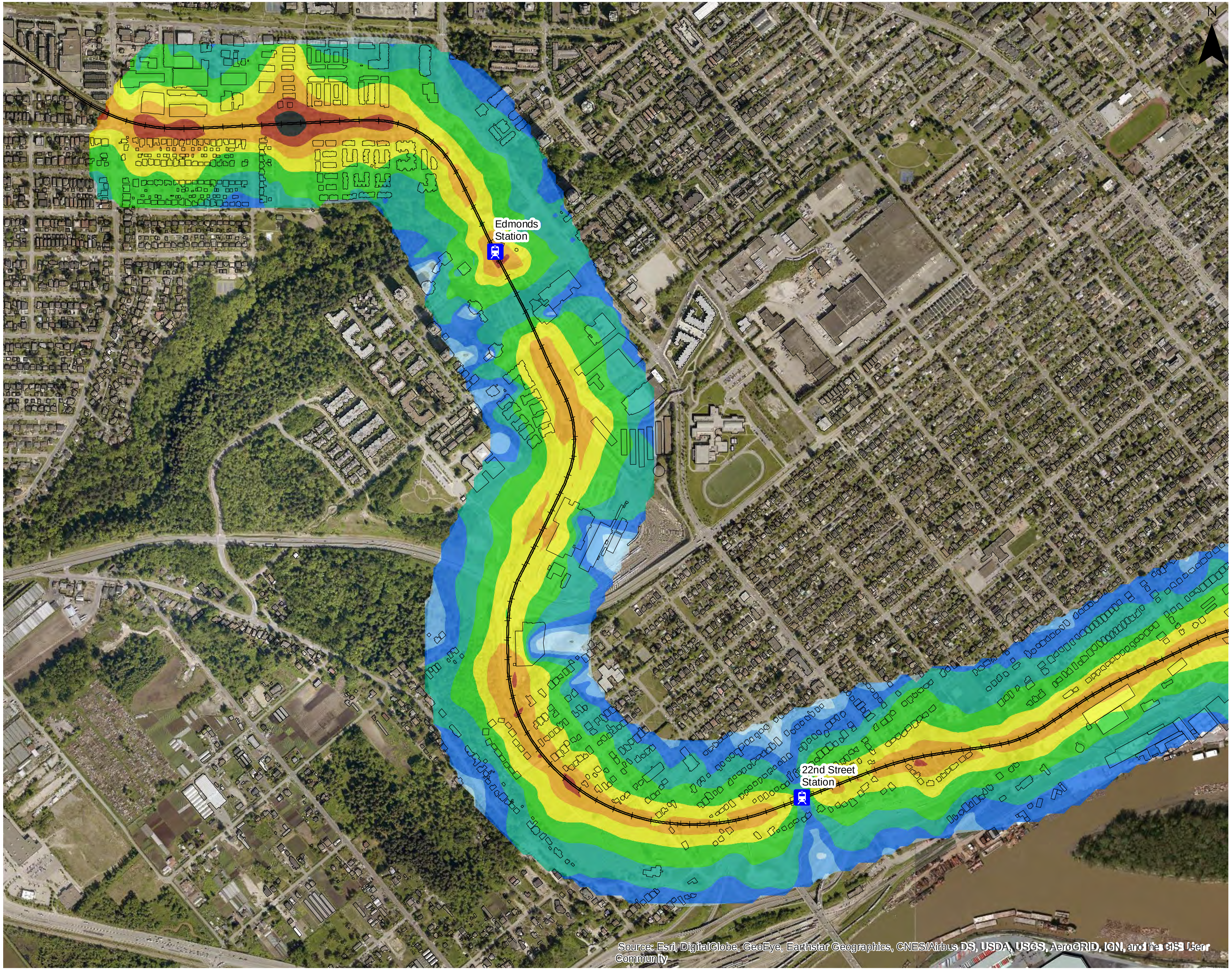

LEGEND

Skytrain Stations

Track

Building Outline

Maximum Noise Level (dBA)

- < 55
- 55 - < 60
- 60 - < 65
- 65 - < 70
- 70 - < 75
- 75 - < 80
- 80 - < 85
- 85 - < 90
- > 90

Contours show typical maximum train passby noise level (LAmax) at 20m elevation above ground

0 125 250 500 Meters

SCALE: 1:9,000
WHEN PLOTTED CORRECTLY AT 11 x 17
NAD 1983 UTM Zone 10N

NOTES

This map is for conceptual purposes only and should not be used for navigational purposes.

Basedata:

SKYTRAIN

TRANSLINK NOISE MAPPING

NOISE CONTOURS FOR STUDY AREA 5 - EDMONDS TO COLUMBIA (SHEET 1 OF 2) AT 20M ELEVATION

November 26, 2018	Rev 0.0	Figure No.
Project No. 201.04644.00003		4B

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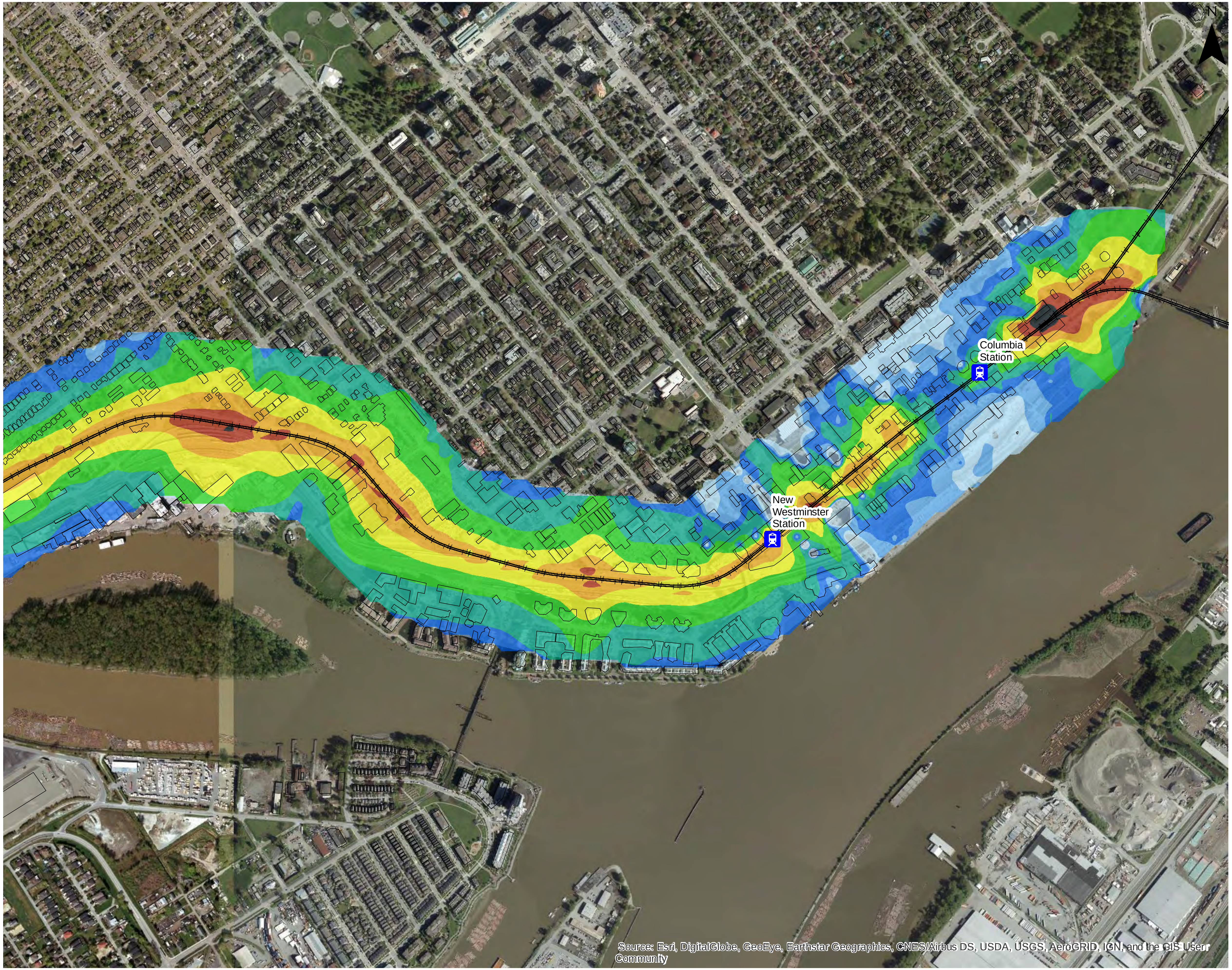

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LEGEND

Skytrain Stations

Track

Building Outline

Maximum Noise Level (dBA)

< 55

55 - < 60

60 - < 65

65 - < 70

70 - < 75

75 - < 80

80 - < 85

85 - < 90

> 90

Contours show typical maximum train passby noise level (LAmax) at 20m elevation above ground

0 125 250 500 Meters

SCALE: 1:9,000
WHEN PLOTTED CORRECTLY AT 11 x 17
NAD 1983 UTM Zone 10N

NOTES

This map is for conceptual purposes only and should not be used for navigational purposes.

Basedata:

SKYTRAIN

TRANSLINK NOISE MAPPING

NOISE CONTOURS FOR STUDY AREA 5 - EDMONDS TO COLUMBIA (SHEET 2 OF 2) AT 20M ELEVATION

November 26, 2018	Rev 0.0	Figure No.
Project No. 201.04644.00003		5B

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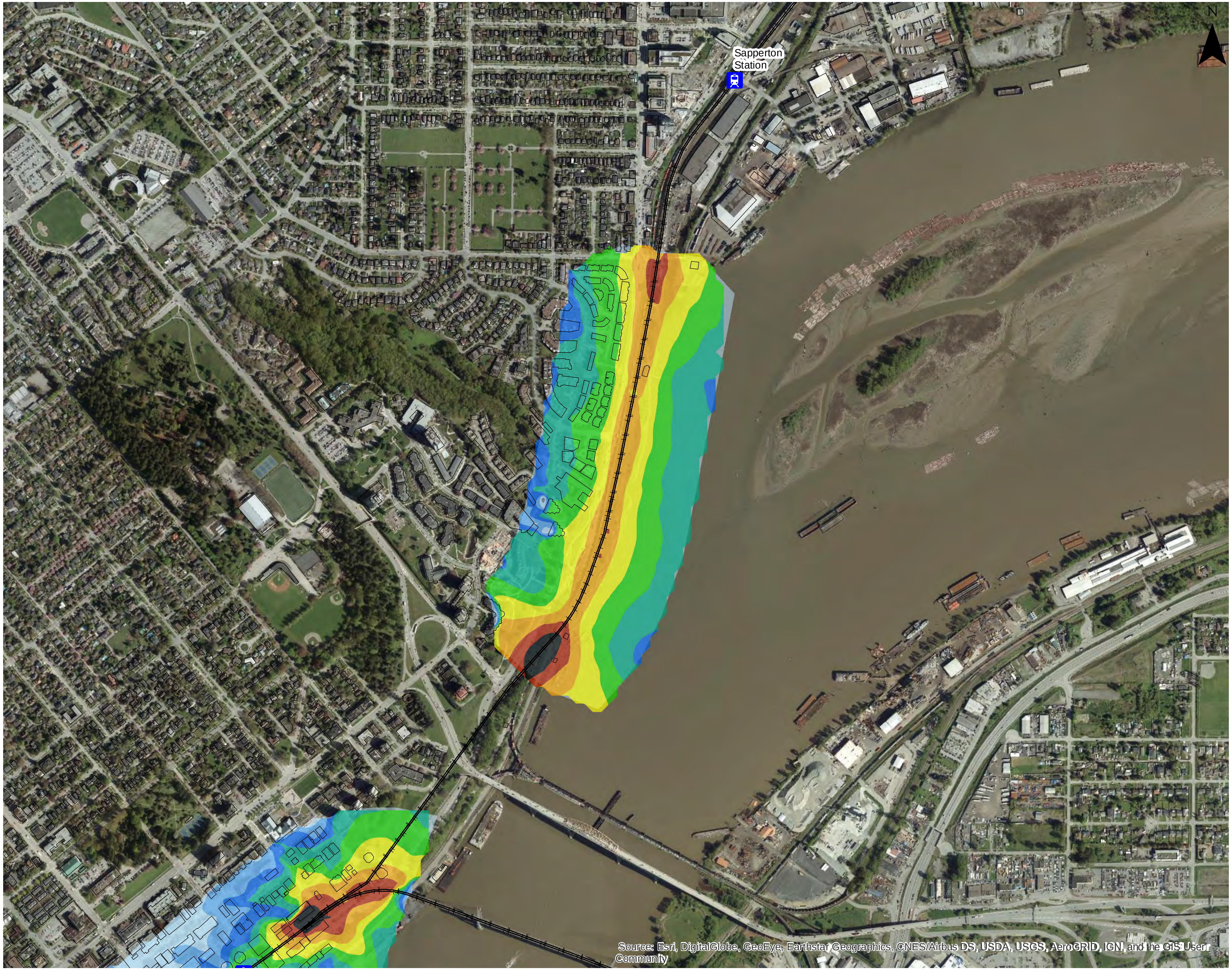

LEGEND

Skytrain Stations

Track

Building Outline

Maximum Noise Level (dBA)

< 55

55 - < 60

60 - < 65

65 - < 70

70 - < 75

75 - < 80

80 - < 85

85 - < 90

> 90

Contours show typical maximum train passby noise level (LAmax) at 20m elevation above ground

0 125 250 500 Meters

SCALE: 1:9,000
WHEN PLOTTED CORRECTLY AT 11 x 17
NAD 1983 UTM Zone 10N

NOTES

This map is for conceptual purposes only and should not be used for navigational purposes.

Basedata:

SKYTRAIN

TRANSLINK NOISE MAPPING

NOISE CONTOURS FOR STUDY AREAS 6 - SAPPERTON AT 20M ELEVATION

November 26, 2018	Rev	0.0	Figure No.
Project No.	201.04644.00003		6B

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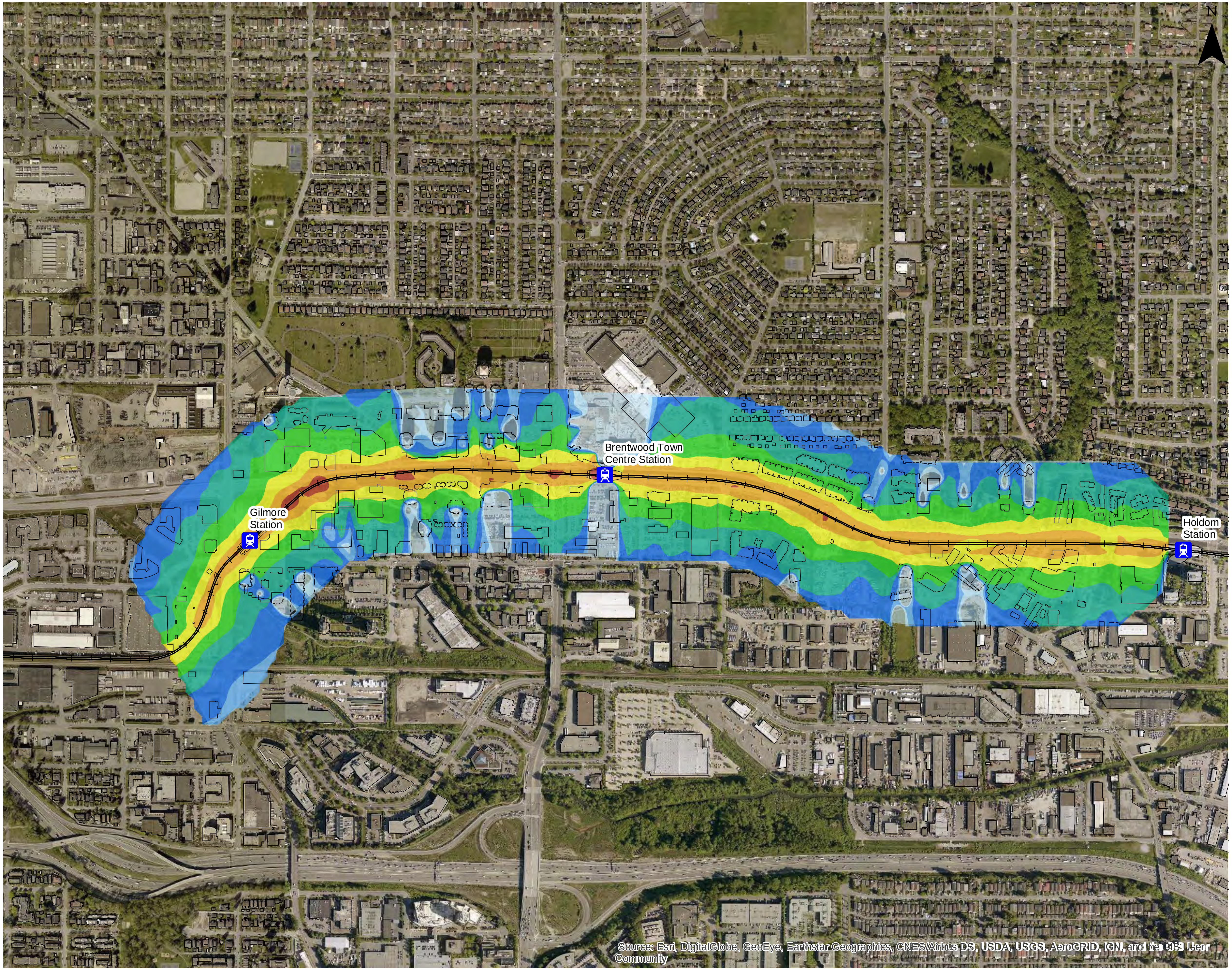

LEGEND

- Skytrain Stations
- Track
- Building Outline

Maximum Noise Level (dBA)

- < 55
- 55 - < 60
- 60 - < 65
- 65 - < 70
- 70 - < 75
- 75 - < 80
- 80 - < 85
- 85 - < 90
- > 90

Contours show typical maximum train passby noise level (LAmax) at 20m elevation above ground

0 125 250 500 Meters

SCALE: 1:9,000
WHEN PLOTTED CORRECTLY AT 11 x 17
NAD 1983 UTM Zone 10N

NOTES

This map is for conceptual purposes only and should not be used for navigational purposes.

Basedata:

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TRANSLINK NOISE MAPPING

NOISE CONTOURS FOR STUDY AREA 7 GILMORE - BRENTWOOD TOWN CENTRE AT 20M ELEVATION

November 26, 2018	Rev	0.0	Figure No.
Project No.	201.04644.00003		7B

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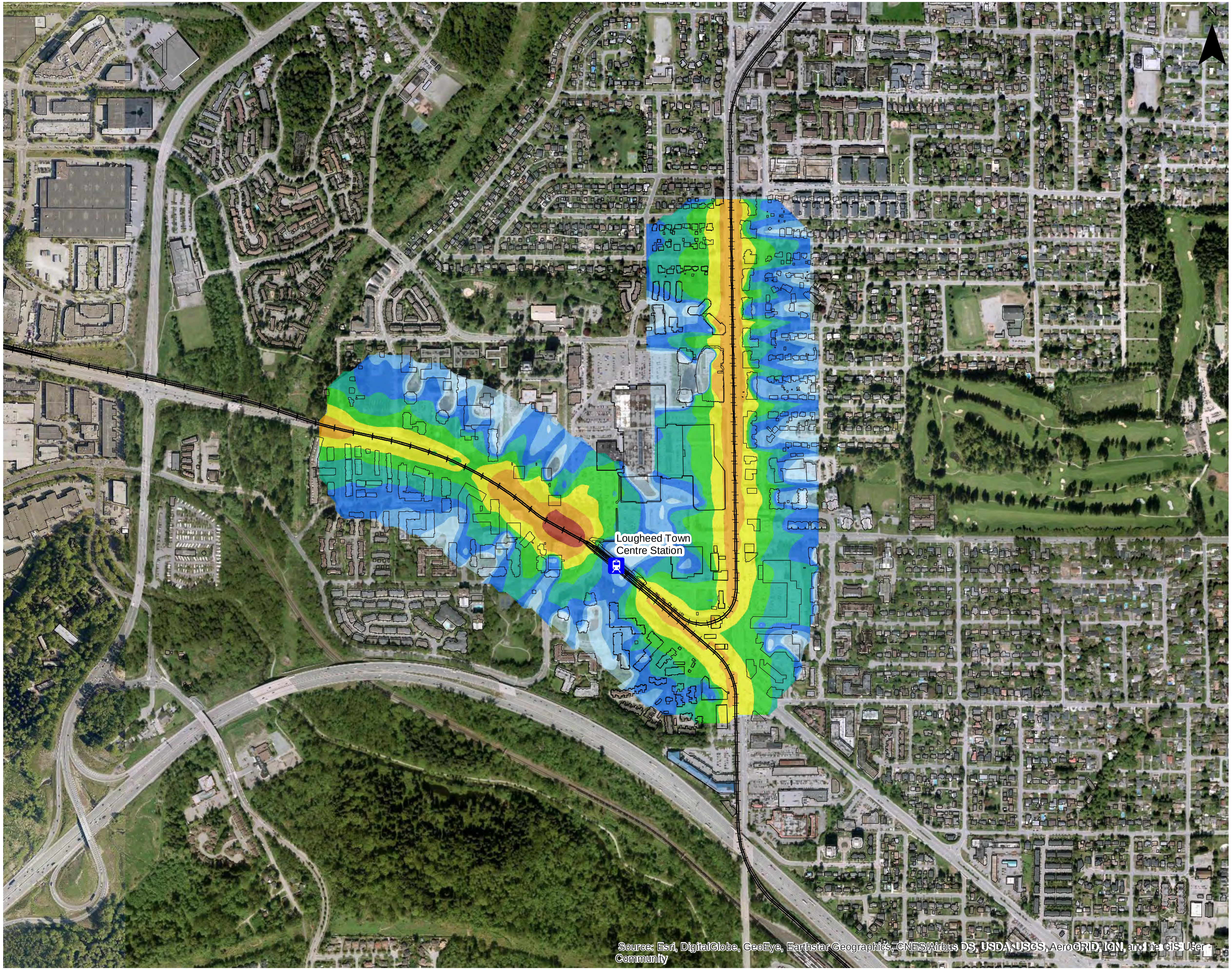

LEGEND

- Skytrain Stations
- Track
- Building Outline

Maximum Noise Level (dBA)

- < 55
- 55 - < 60
- 60 - < 65
- 65 - < 70
- 70 - < 75
- 75 - < 80
- 80 - < 85
- 85 - < 90
- > 90

Contours show typical maximum train passby noise level (LAmax) at 20m elevation above ground

0 125 250 500 Meters

SCALE: 1:9,000
WHEN PLOTTED CORRECTLY AT 11 x 17
NAD 1983 UTM Zone 10N

NOTES

This map is for conceptual purposes only and should not be used for navigational purposes.

Basedata:

SKYTRAIN

TRANSLINK NOISE MAPPING

NOISE CONTOURS FOR STUDY AREA 8 - LOUGHEED TOWN CENTRE AT 20M ELEVATION

November 26, 2018	Rev	0.0	Figure No.
Project No.	201.04644.00003		8B

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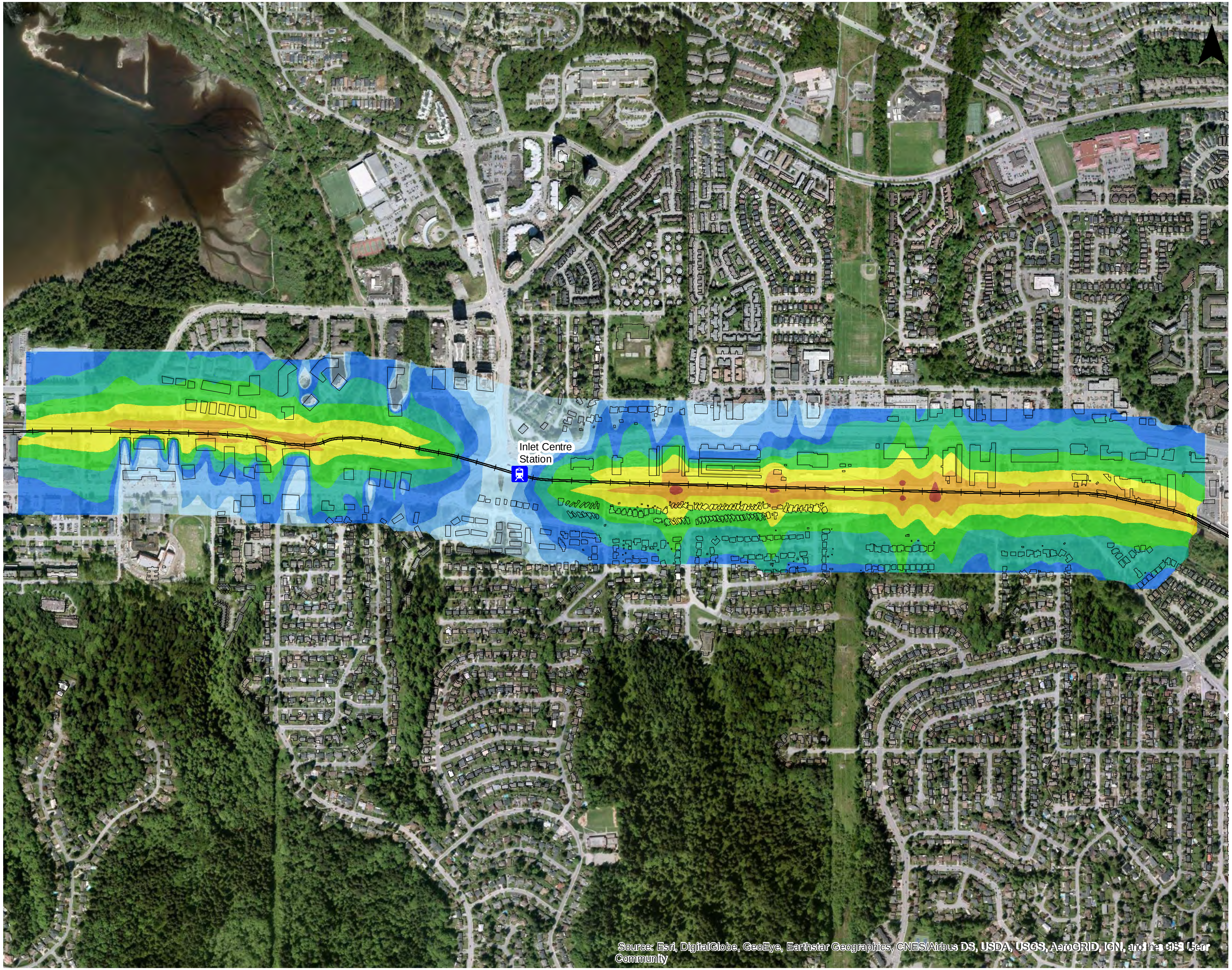

LEGEND

- Skytrain Stations
- Track
- Building Outline

Maximum Noise Level (dBA)

- < 55
- 55 - < 60
- 60 - < 65
- 65 - < 70
- 70 - < 75
- 75 - < 80
- 80 - < 85
- 85 - < 90
- > 90

Contours show typical maximum train passby noise level (LAmax) at 20m elevation above ground

0 125 250 500 Meters

SCALE: 1:9,000
WHEN PLOTTED CORRECTLY AT 11 x 17
NAD 1983 UTM Zone 10N

NOTES

This map is for conceptual purposes only and should not be used for navigational purposes.

Basedata:

SKYTRAIN

TRANSLINK NOISE MAPPING

NOISE CONTOURS FOR STUDY AREA 9 - MOODY CENTRE - INLET CENTRE AT 20M ELEVATION

November 26, 2018	Rev 0.0	Figure No.
Project No. 201.04644.00003		9B

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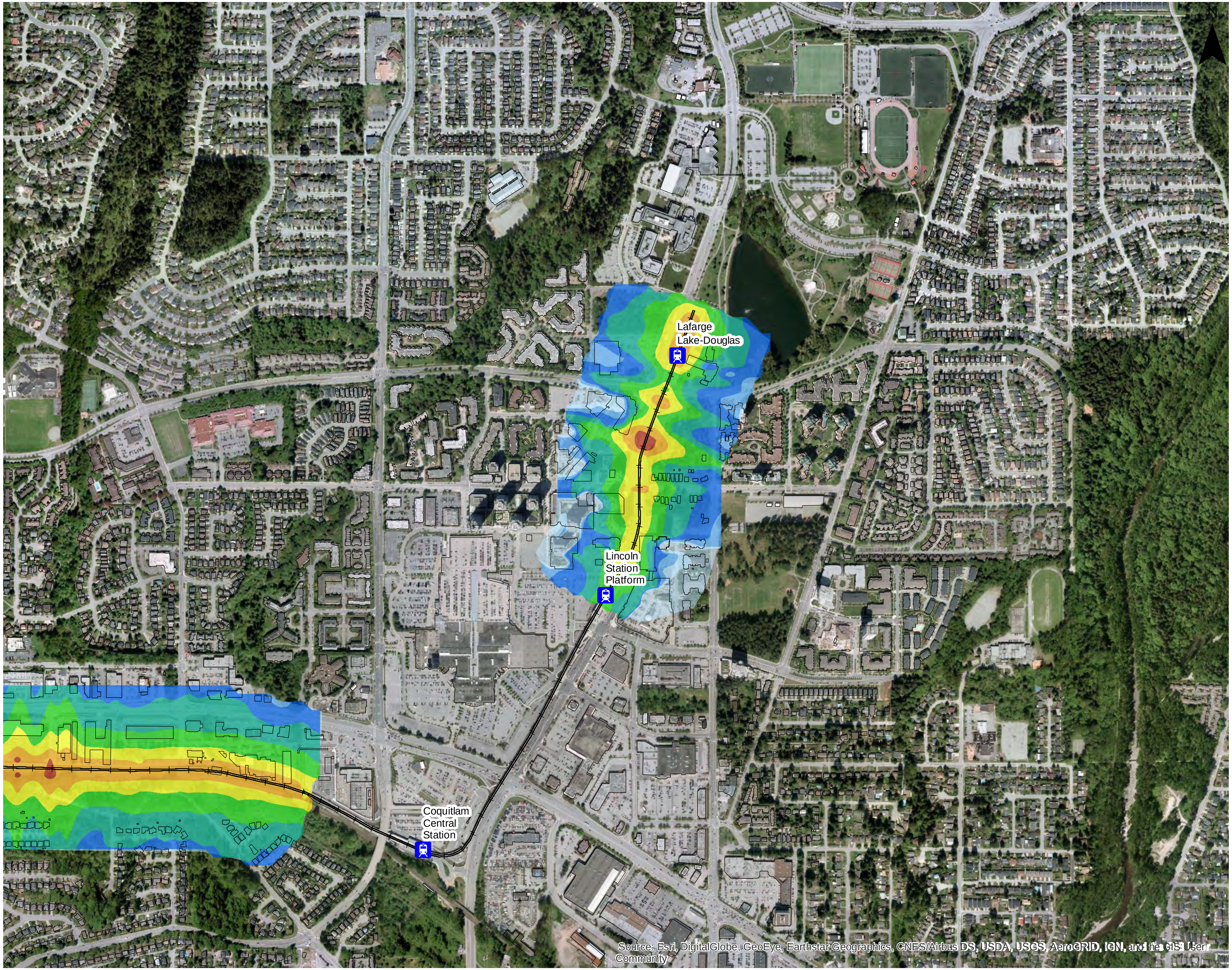

LEGEND

- Skytrain Stations
- Track
- Building Outline

Maximum Noise Level (dBA)

- < 55
- 55 - < 60
- 60 - < 65
- 65 - < 70
- 70 - < 75
- 75 - < 80
- 80 - < 85
- 85 - < 90
- > 90

Contours show typical maximum train passby noise level (LAmax) at 20m elevation above ground

0 125 250 500 Meters

SCALE: 1:9,000
WHEN PLOTTED CORRECTLY AT 11 x 17
NAD 1983 UTM Zone 10N

NOTES

This map is for conceptual purposes only and should not be used for navigational purposes.

Basedata:

SKYTRAIN

TRANSLINK NOISE MAPPING

NOISE CONTOURS FOR STUDY AREA 10 - LAFARGE LAKE DOUGLAS AT 20M ELEVATION

November 26, 2018	Rev	0.0	Figure No.
Project No.	201.04644.00003		10B

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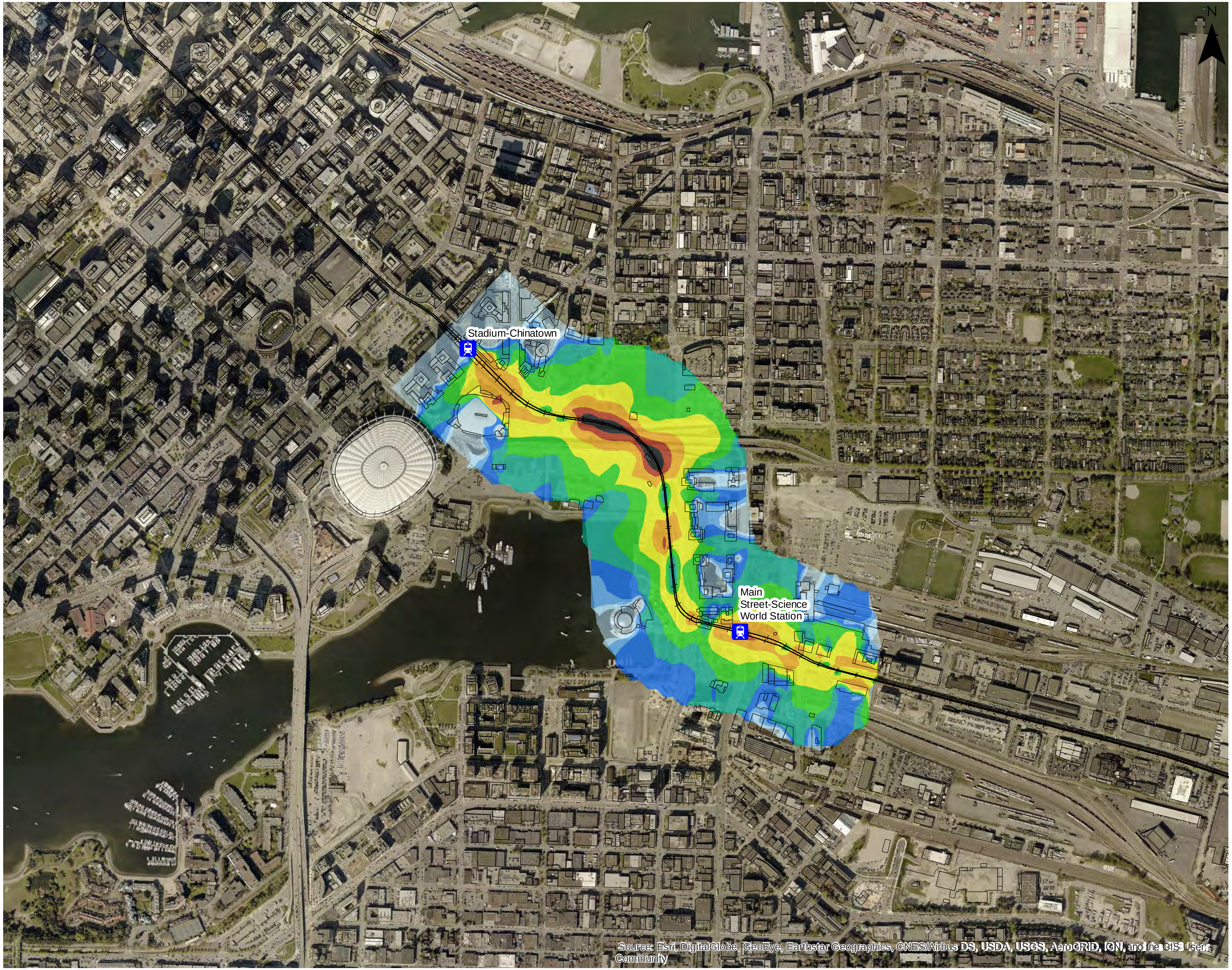
APPENDIX E
Noise Level Maps 5 m Elevation

SkyTrain Noise Study Vancouver
Noise Report and Maps
SLR Project No.: 201.04644.00003



LEGEND

Skytrain Station

Track

Building Outline

Maximum Noise Level (dBA)

- < 55
- 55 - < 60
- 60 - < 65
- 65 - < 70
- 70 - < 75
- 75 - < 80
- 80 - < 85
- 85 - < 90
- > 90

Contours show typical maximum train passby noise level (LAmax) at 5m elevation above ground

0 125 250 500 Meters

SCALE: 1:9,000
WHEN PLOTTED CORRECTLY AT 11 x 17
NAD 1983 UTM Zone 10N

NOTES

This map is for conceptual purposes only and should not be used for navigational purposes.

Basedata:

SKYTRAIN

TRANSLINK NOISE MAPPING

NOISE CONTOURS FOR STUDY AREA 1 - FALSE CREEK AT 5M ELEVATION

November 26, 2018	Rev	0.0	Figure No.
Project No.	201.04644.00003		1

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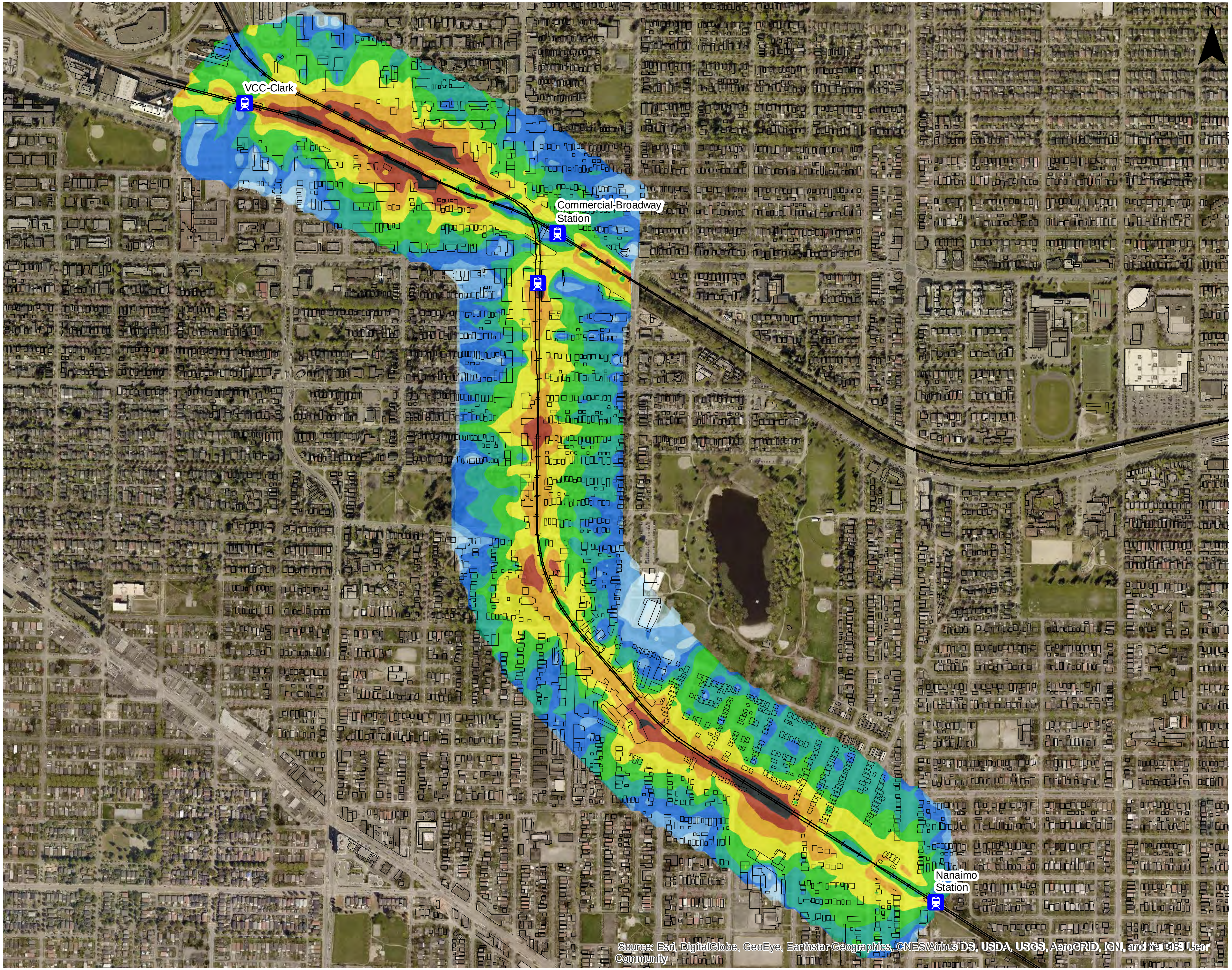

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LEGEND

Skytrain Station

Track

Building Outline

Maximum Noise Level (dBA)

- < 55
- 55 - < 60
- 60 - < 65
- 65 - < 70
- 70 - < 75
- 75 - < 80
- 80 - < 85
- 85 - < 90
- > 90

Contours show typical maximum train passby noise level (LAmax) at 5m elevation above ground

0 125 250 500 Meters

SCALE: 1:9,000
WHEN PLOTTED CORRECTLY AT 11 x 17
NAD 1983 UTM Zone 10N

NOTES

This map is for conceptual purposes only and should not be used for navigational purposes.

Basedata:

SKYTRAIN

TRANSLINK NOISE MAPPING

NOISE CONTOURS FOR STUDY AREA 2 - VCC - COMMERCIAL BROADWAY – NANAIMO AT 5M

November 26, 2018	Rev	0.0	Figure No.
Project No.	201.04644.00003		2

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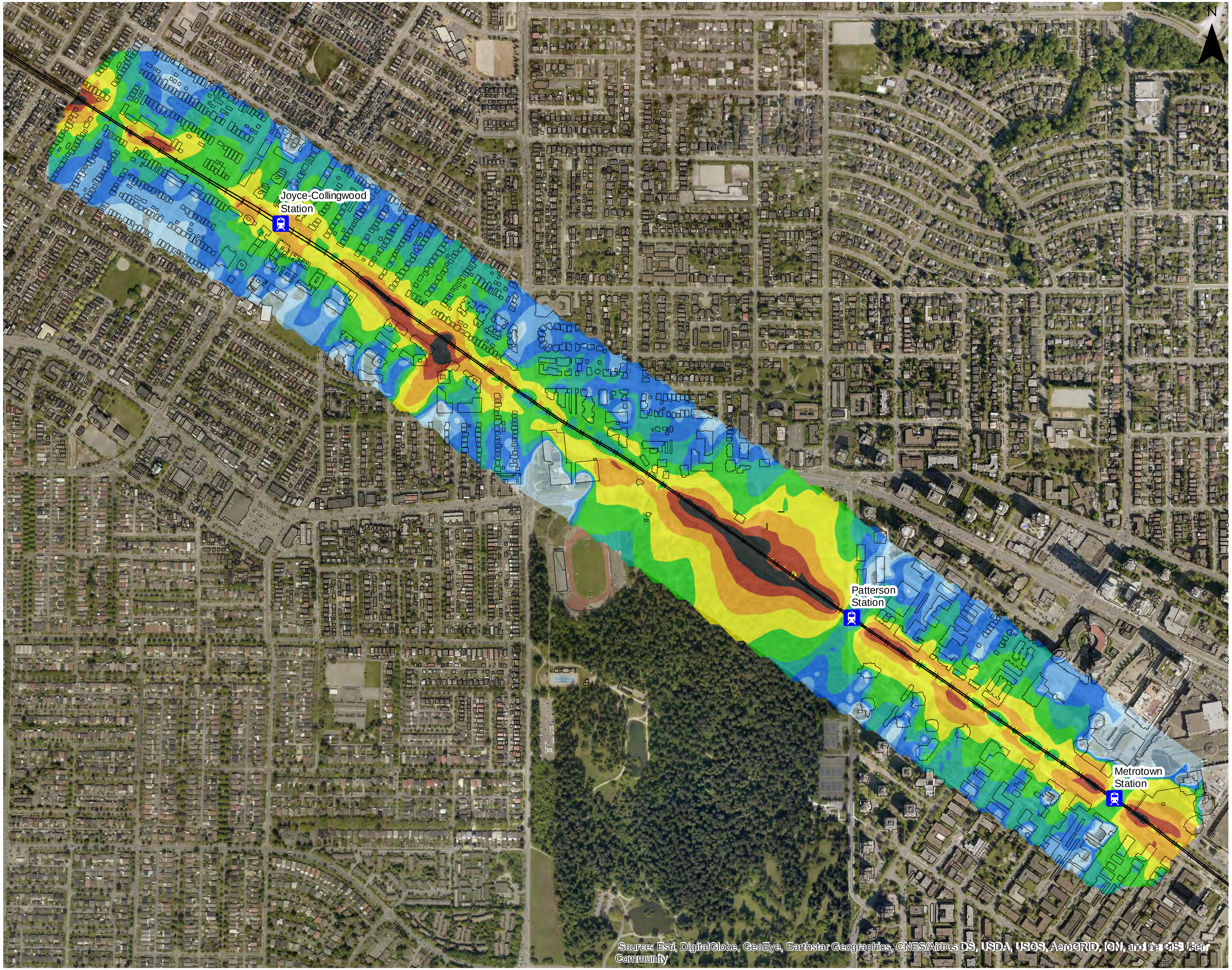

LEGEND

Skytrain Station

Track

Building Outline

Maximum Noise Level (dBA)

- < 55
- 55 - < 60
- 60 - < 65
- 65 - < 70
- 70 - < 75
- 75 - < 80
- 80 - < 85
- 85 - < 90
- > 90

Contours show typical maximum train passby noise level (LAmax) at 5m elevation above ground

0 125 250 500 Meters

SCALE: 1:9,000
WHEN PLOTTED CORRECTLY AT 11 x 17
NAD 1983 UTM Zone 10N

NOTES

This map is for conceptual purposes only and should not be used for navigational purposes.

Basedata:

SKYTRAIN

TRANSLINK NOISE MAPPING

NOISE CONTOURS FOR STUDY AREAS 3 AND 4 - JOYCE COLLINGWOOD AND PATTERSON

November 26, 2018	Rev **0.0**	Figure No.
Project No.	201.04644.00003	**3**

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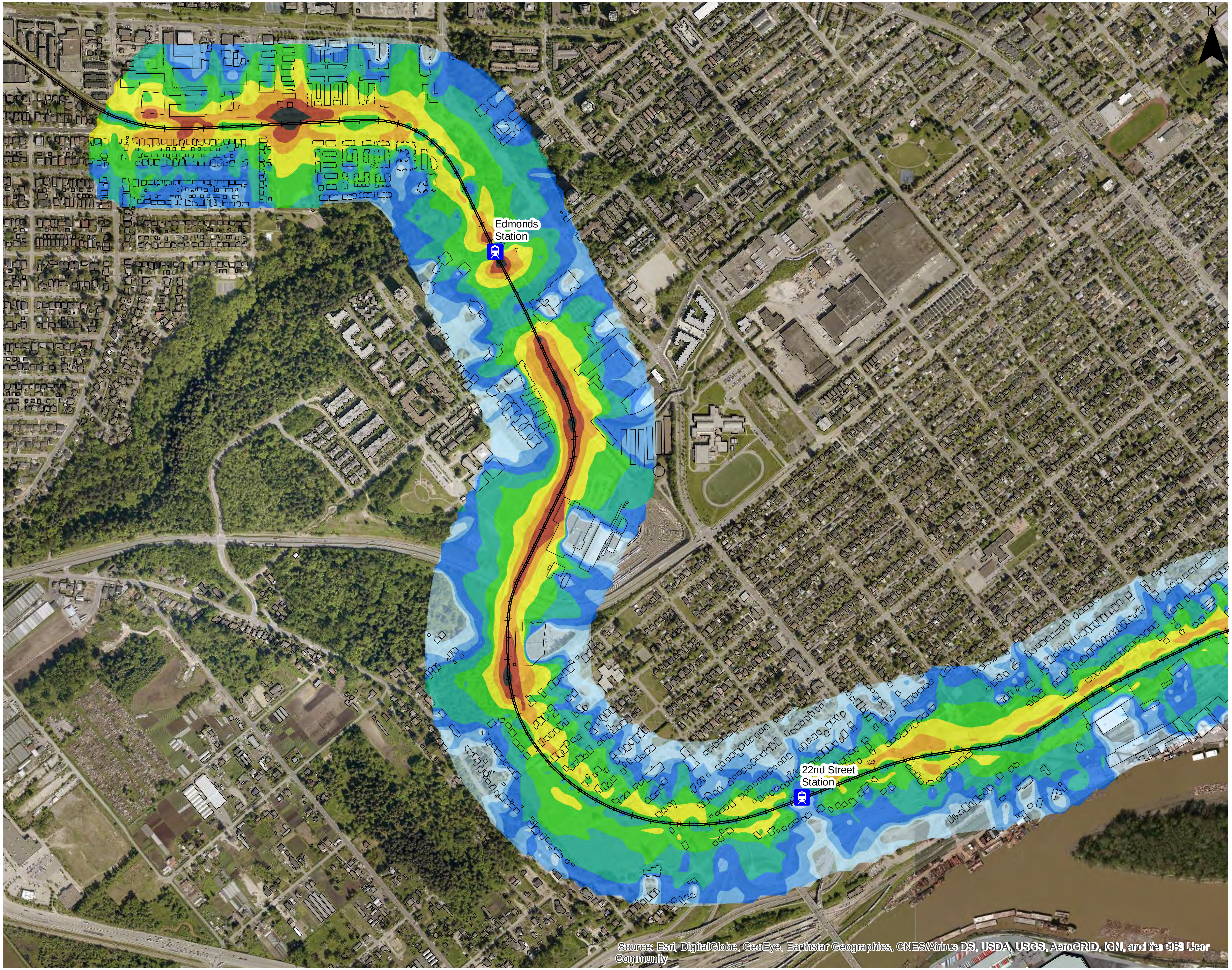

LEGEND

Skytrain Station

Track

Building Outline

Maximum Noise Level (dBA)

- < 55
- 55 - < 60
- 60 - < 65
- 65 - < 70
- 70 - < 75
- 75 - < 80
- 80 - < 85
- 85 - < 90
- > 90

Contours show typical maximum train passby noise level (LAmax) at 5m elevation above ground

0 125 250 500 Meters

SCALE: 1:9,000
WHEN PLOTTED CORRECTLY AT 11 x 17
NAD 1983 UTM Zone 10N

NOTES

This map is for conceptual purposes only and should not be used for navigational purposes.

Basedata:

SKYTRAIN

TRANSLINK NOISE MAPPING

NOISE CONTOURS FOR STUDY AREA 5 - EDMONDS TO COLUMBIA (SHEET 1 OF 2) AT 5M ELEVATION

November 26, 2018	Rev	0.0	Figure No.
Project No.	201.04644.00003		4

SLR
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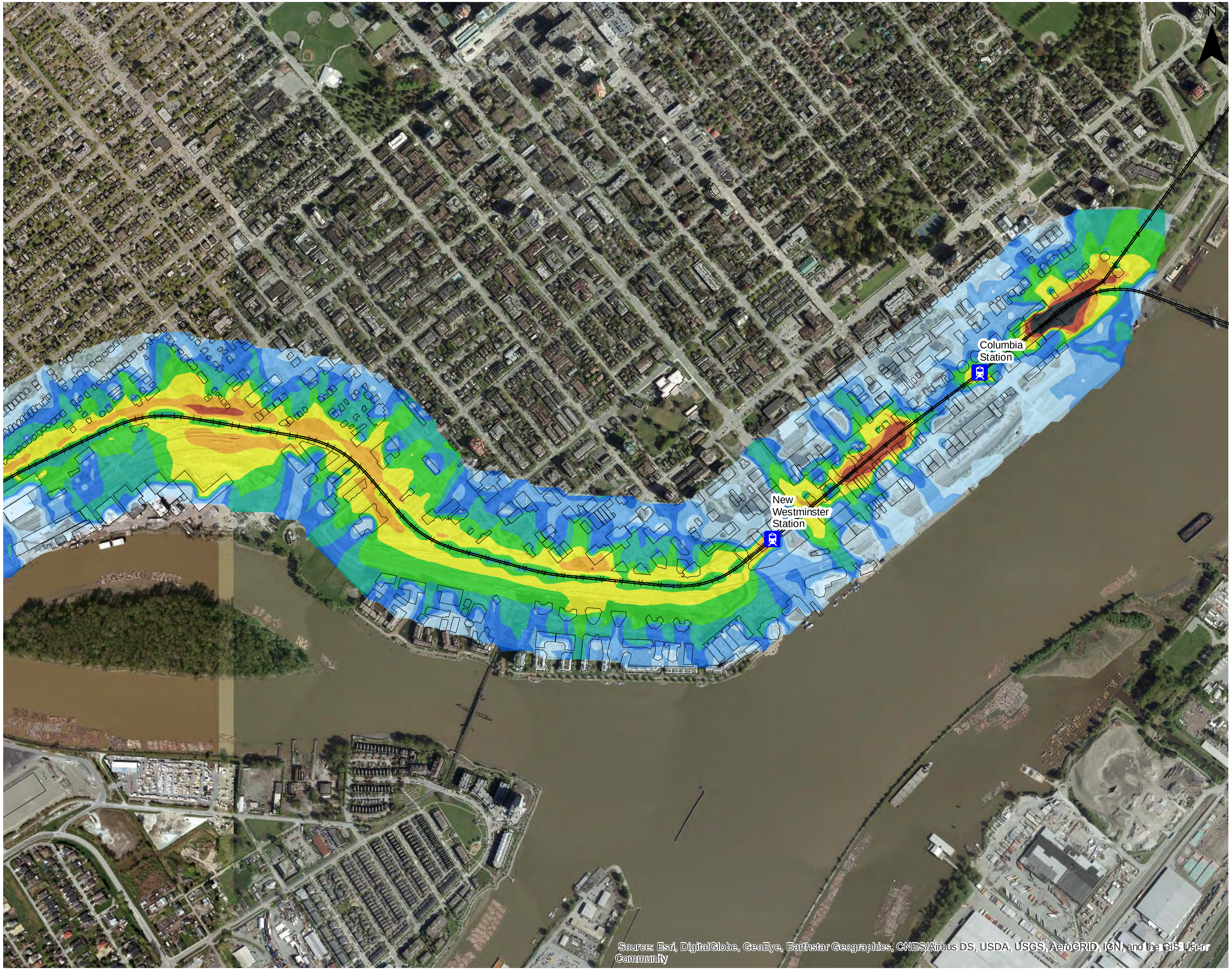

LEGEND

- Skytrain Station
- Track
- Building Outline

Maximum Noise Level (dBA)

- < 55
- 55 - < 60
- 60 - < 65
- 65 - < 70
- 70 - < 75
- 75 - < 80
- 80 - < 85
- 85 - < 90
- > 90

Contours show typical maximum train passby noise level (LAmax) at 5m elevation above ground

0 125 250 500 Meters

SCALE: 1:9,000
WHEN PLOTTED CORRECTLY AT 11 x 17
NAD 1983 UTM Zone 10N

NOTES

This map is for conceptual purposes only and should not be used for navigational purposes.

Basedata:

SKYTRAIN

TRANSLINK NOISE MAPPING

NOISE CONTOURS FOR STUDY AREA 5 - EDMONDS TO COLUMBIA (SHEET 2 OF 2) AT 5M ELEVATION

November 26, 2018	Rev 0.0	Figure No. 5
Project No.	201.04644.00003	

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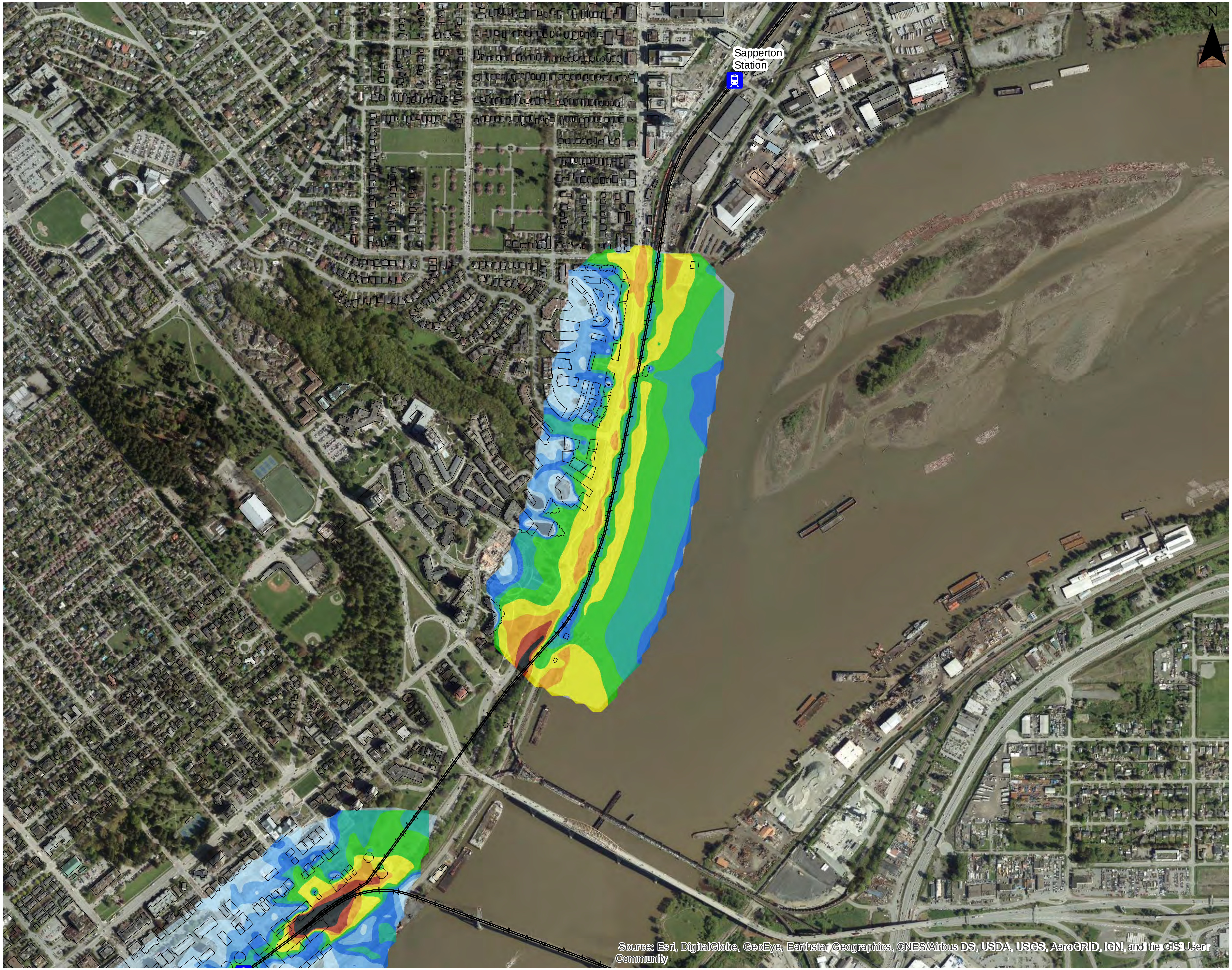

LEGEND

Skytrain Station

Track

Building Outline

Maximum Noise Level (dBA)

- < 55
- 55 - < 60
- 60 - < 65
- 65 - < 70
- 70 - < 75
- 75 - < 80
- 80 - < 85
- 85 - < 90
- > 90

Contours show typical maximum train passby noise level (LAmax) at 5m elevation above ground

0 125 250 500 Meters

SCALE: 1:9,000
WHEN PLOTTED CORRECTLY AT 11 x 17
NAD 1983 UTM Zone 10N

NOTES

This map is for conceptual purposes only and should not be used for navigational purposes.

Basedata:

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TRANSLINK NOISE MAPPING

NOISE CONTOURS FOR STUDY AREAS 6 - SAPPERTON AT 5M ELEVATION

November 26, 2018	Rev	0.0	Figure No. 6
Project No.	201.04644.00003		

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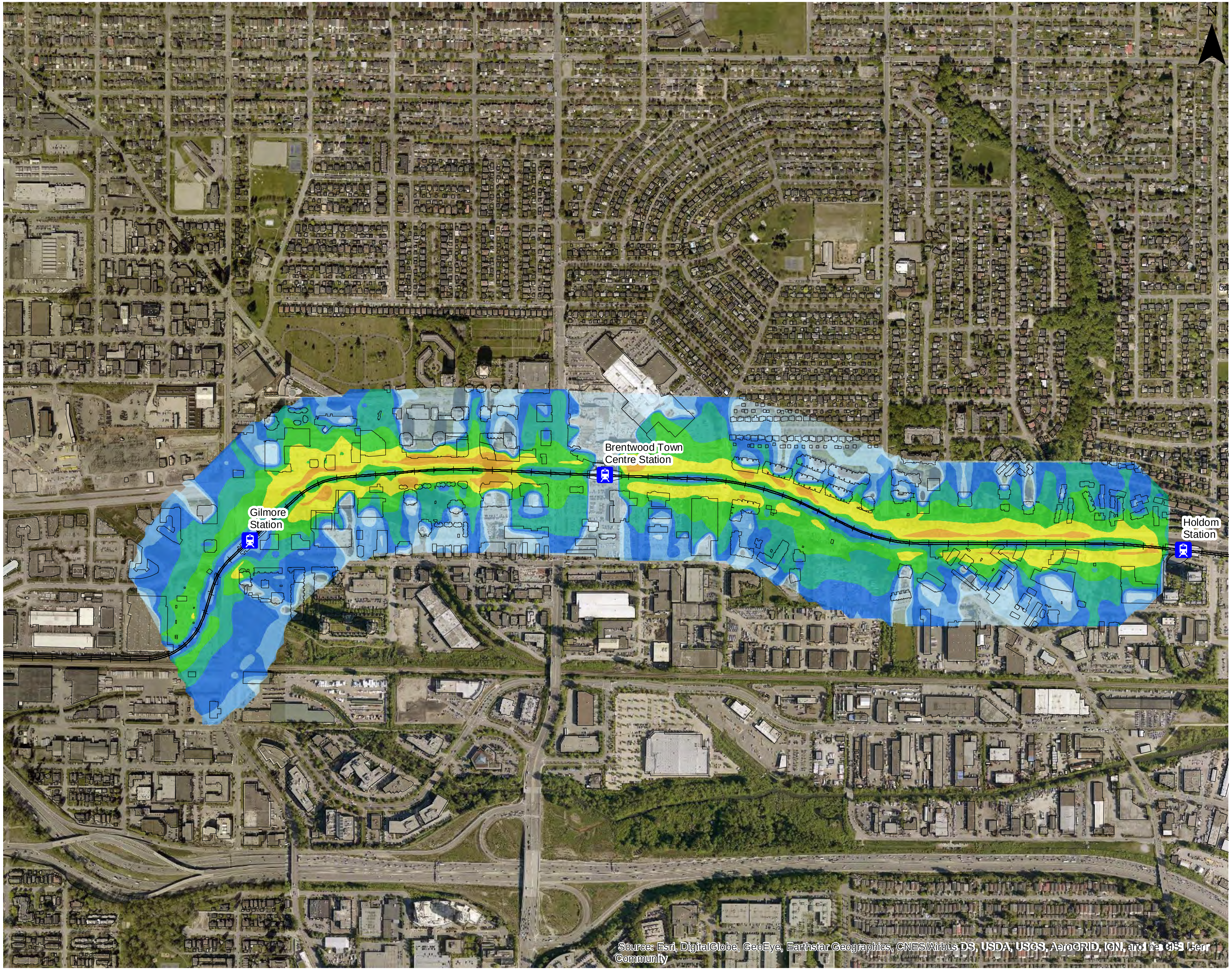

LEGEND

- Skytrain Station
- Track
- Building Outline

Maximum Noise Level (dBA)

- < 55
- 55 - < 60
- 60 - < 65
- 65 - < 70
- 70 - < 75
- 75 - < 80
- 80 - < 85
- 85 - < 90
- > 90

Contours show typical maximum train passby noise level (LAmax) at 5m elevation above ground

0 125 250 500 Meters

SCALE: 1:9,000
WHEN PLOTTED CORRECTLY AT 11 x 17
NAD 1983 UTM Zone 10N

NOTES

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Basedata:

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TRANSLINK NOISE MAPPING

NOISE CONTOURS FOR STUDY AREA 7 GILMORE - BRENTWOOD TOWN CENTRE AT 5M ELEVATION

November 26, 2018	Rev	0.0	Figure No.
Project No.	201.04644.00003		7

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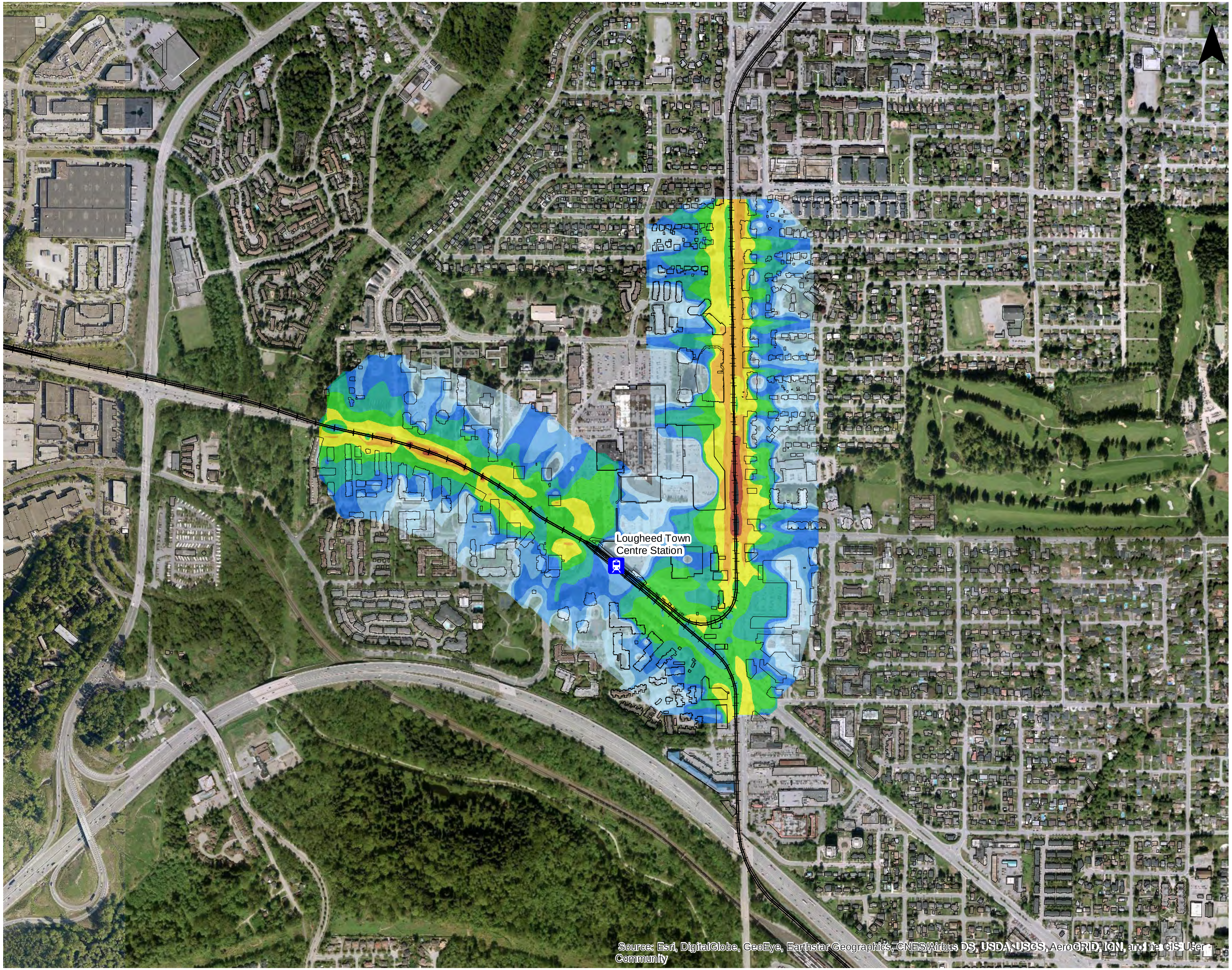

N

LEGEND

Skytrain Station

Track

Building Outline

Maximum Noise Level (dBA)

< 55

55 - < 60

60 - < 65

65 - < 70

70 - < 75

75 - < 80

80 - < 85

85 - < 90

> 90

Contours show typical maximum train passby noise level (LAmax) at 5m elevation above ground

0 125 250 500 Meters

SCALE: 1:9,000
WHEN PLOTTED CORRECTLY AT 11 x 17
NAD 1983 UTM Zone 10N

NOTES

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Basedata:

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TRANSLINK NOISE MAPPING

NOISE CONTOURS FOR STUDY AREA 8 - LOUGHEED TOWN CENTRE AT 5M ELEVATION

November 26, 2018	Rev	0.0	Figure No.
Project No.	201.04644.00003		8

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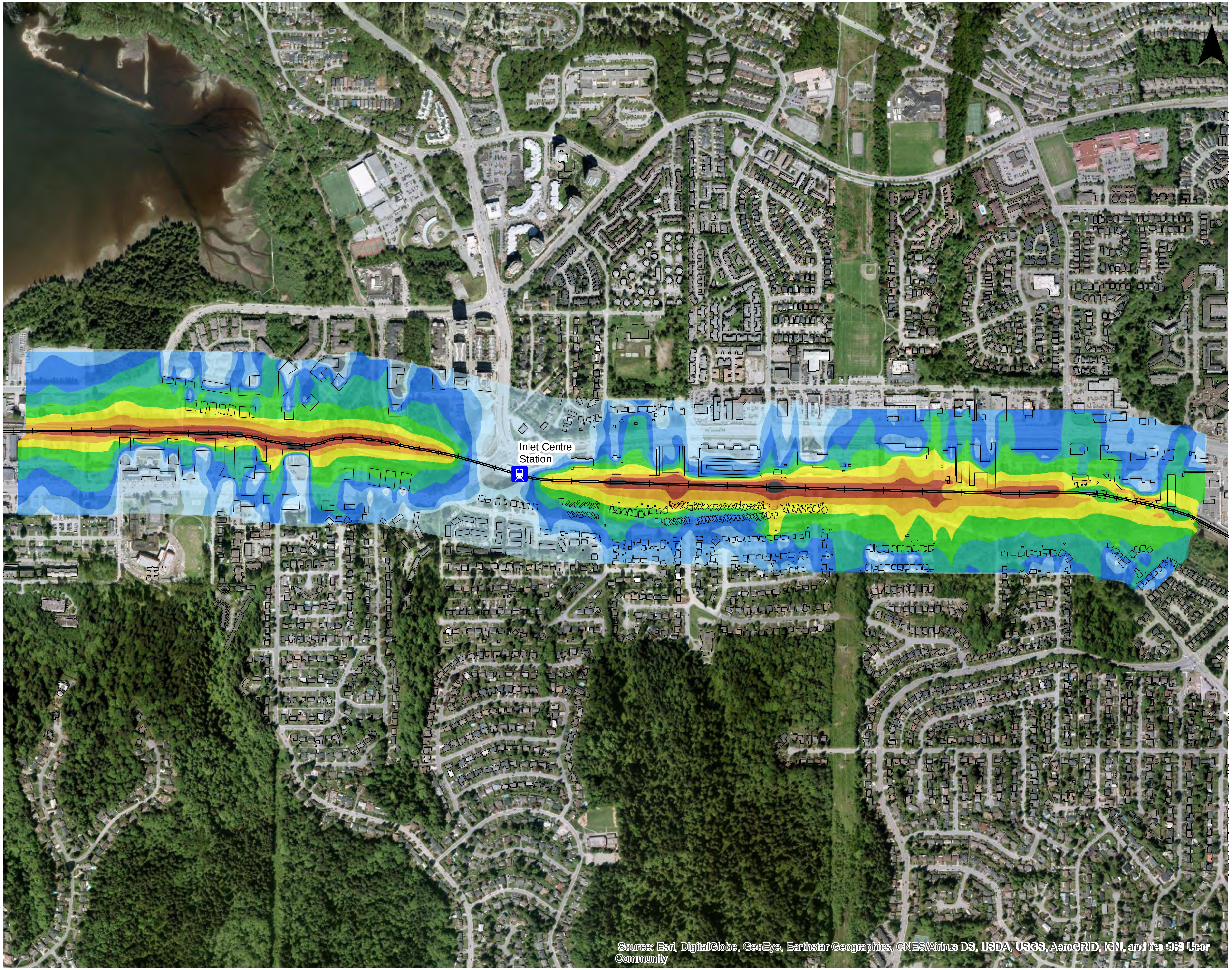

LEGEND

Skytrain Station

Track

Building Outline

Maximum Noise Level (dBA)

- < 55
- 55 - < 60
- 60 - < 65
- 65 - < 70
- 70 - < 75
- 75 - < 80
- 80 - < 85
- 85 - < 90
- > 90

Contours show typical maximum train passby noise level (LAmax) at 5m elevation above ground

0 125 250 500 Meters

SCALE: 1:9,000
WHEN PLOTTED CORRECTLY AT 11 x 17
NAD 1983 UTM Zone 10N

NOTES

This map is for conceptual purposes only and should not be used for navigational purposes.

Basedata:

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TRANSLINK NOISE MAPPING

NOISE CONTOURS FOR STUDY AREA 9 - MOODY CENTRE - INLET CENTRE AT 5M ELEVATION

November 26, 2018	Rev	0.0	Figure No.
Project No.	201.04644.00003		9

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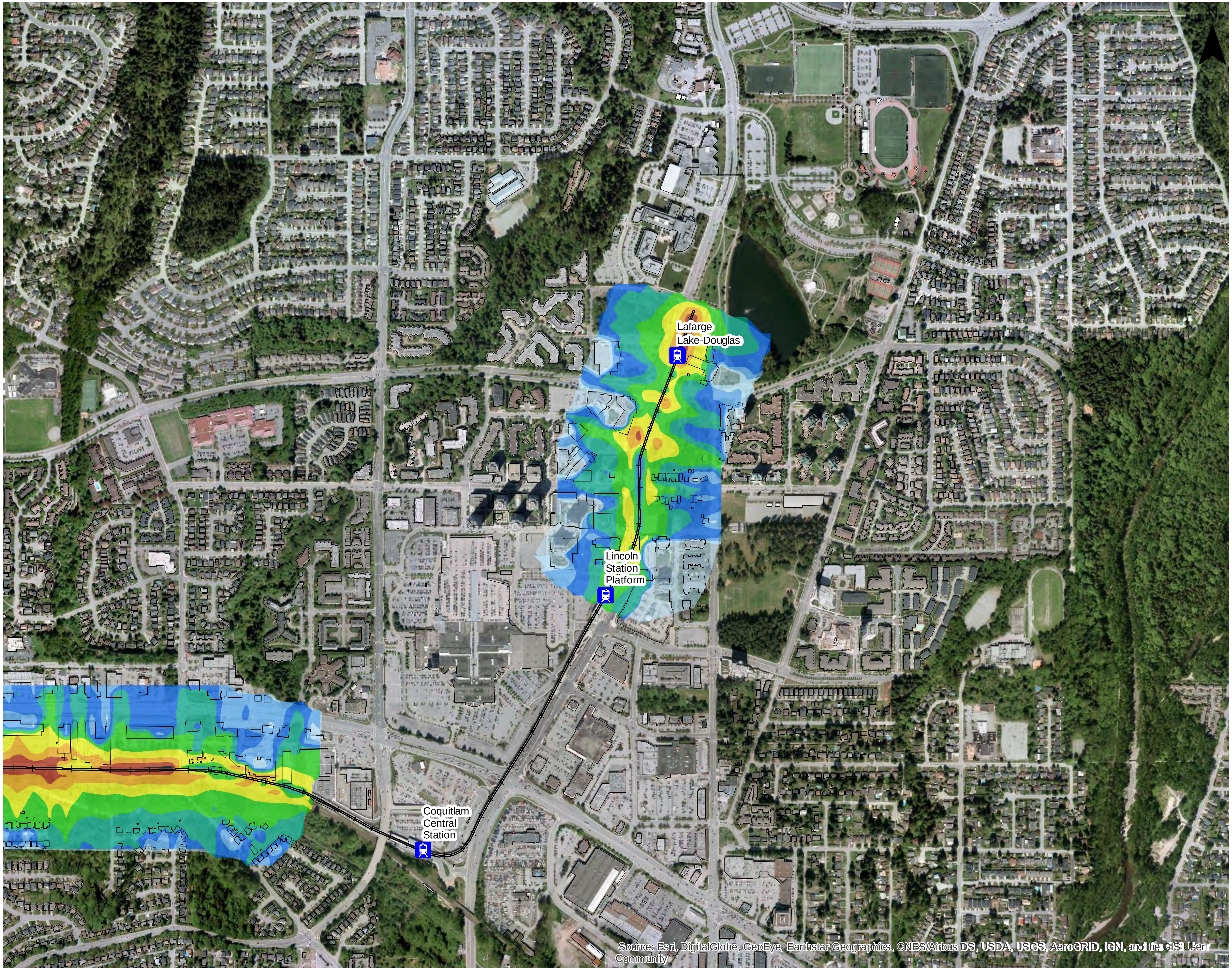

LEGEND

- Skytrain Station
- Track
- Building Outline

Maximum Noise Level (dBA)

- < 55
- 55 - < 60
- 60 - < 65
- 65 - < 70
- 70 - < 75
- 75 - < 80
- 80 - < 85
- 85 - < 90
- > 90

Contours show typical maximum train passby noise level (LAmax) at 5m elevation above ground

0 125 250 500 Meters

SCALE: 1:9,000
WHEN PLOTTED CORRECTLY AT 11 x 17
NAD 1983 UTM Zone 10N

NOTES

This map is for conceptual purposes only and should not be used for navigational purposes.

Basedata:

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TRANSLINK NOISE MAPPING

NOISE CONTOURS FOR STUDY AREA 10 - LAFARGE LAKE DOUGLAS AT 5M ELEVATION

November 26, 2018	Rev	0.0	Figure No.
Project No.	201.04644.00003		10

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global environmental solutions

Calgary, AB
1185-10201 Southport Rd SW
Calgary, AB T2W 4X9
Canada
Tel: (403) 266-2030
Fax: (403) 263-7906

Edmonton, AB
6940 Roper Road
Edmonton, AB T6B 3H9
Canada
Tel: (780) 490-7893
Fax: (780) 490-7819

Grande Prairie, AB
10015 102 Street
Grande Prairie, AB T8V 2V5
Canada
Tel: (780) 513-6819
Fax: (780) 513-6821

Kamloops, BC
8 West St. Paul Street
Kamloops, BC V2C 1G1
Canada
Tel: (250) 374-8749
Fax: (250) 374-8656

Kelowna, BC
200-1475 Ellis Street
Kelowna, BC V1Y 2A3
Canada
Tel: (250) 762-7202
Fax: (250) 763-7303

Markham, ON
200 - 300 Town Centre Blvd
Markham, ON L3R 5Z6
Canada
Tel: (905) 415-7248
Fax: (905) 415-1019

Nanaimo, BC
9-6421 Applecross Road
Nanaimo, BC V9V 1N1
Canada
Tel: (250) 390-5050
Fax: (250) 390-5042

Ottawa, ON
43 Auriga Drive, Suite 203
Ottawa, ON K2E 7Y8
Canada
Tel: (613) 725-1777
Fax: (905) 415-1019

Prince George, BC
1586 Ogilvie Street
Prince George, BC V2N 1W9
Canada
Tel: (250) 562-4452
Fax: (250) 562-4458

Regina, SK
1048 Winnipeg Street
Regina, SK S4R 8P8
Canada
Tel: (306) 525-4690
Fax (306) 525-4691

Saskatoon, SK
620-3530 Millar Avenue
Saskatoon, SK S7P 0B6
Canada
Tel: (306) 374-6800
Fax: (306) 374-6077

Toronto, ON
36 King Street East, 4th Floor
Toronto, ON M5C 3B2
Canada
Tel: (905) 415-7248
Fax: (905) 415-1019

Vancouver, BC (Head Office)
200-1620 West 8th Avenue
Vancouver, BC V6J 1V4
Canada
Tel: (604) 738-2500
Fax: (604) 738-2508

Victoria, BC
6-40 Cadillac Avenue
Victoria, BC V8Z 1T2
Canada
Tel: (250) 475-9595
Fax: (250) 475-9596

Winnipeg, MB
1353 Kenaston Boulevard
Winnipeg, MB R3P 2P2
Canada
Tel: (204) 477-1848
Fax: (204) 475-1649

Whitehorse, YT
6131 6th Avenue
Whitehorse, YT Y1A 1N2
Canada
Tel: (867) 689-2021

Yellowknife, NT
Unit 44, 5022 49 Street
Yellowknife, NT X1A 3R8
Canada
Tel: (867) 765-5695