Appendix A Noise Mitigation Program Implementation Plan

SkyTrain Noise Mitigation Study Phase 2
Recommendation Report and Implementation Plan
Vancouver

TransLink Ref No.: Q17-037
SLR Project No: 201.04644.00007

Appendix A

Noise Mitigation Program Implementation Plan

SkyTrain Noise Mitigation Study Phase 2

TransLink

Vancouver

Expo and Millennium Lines

SLR Project No.: 201.04644.00007

This Noise Mitigation Program Implementation Plan includes specifications, cost, resource and schedule estimates for implementation of all recommended noise mitigation measures for the Expo and Millennium Lines.

Contents:

NOISE MITIGATION PROGRAM LEAD

Recommendation:

An in-house BCRTC staff resource is required to lead the implementation of the ongoing SkyTrain Noise Mitigation Program. The responsibilities of the Noise Mitigation Program Lead would include:

1. Identifying appropriate cloud and/or network-based data analysis and visualization tools to assist with ongoing assessments and business decisions related to the noise mitigation program
2. Ongoing network wide data collection, analysis, and performance monitoring (in car noise, vibration, friction, network noise condition monitoring)
3. Coordinating rail grinding programs, scheduling grinding, rail grinding quality management
4. Liaising with the switch maintenance analyst
5. Technical support for friction modifier implementation
6. Monitoring effectiveness of TORFM implementation as it progresses
7. Responsible for coordinating or conducting annual noise compliance measurements and preparing public reports on program progress and effectiveness
8. Ongoing analysis of trends in complaints received and response to complaints
9. Point of contact for developers / those working with the Interim Guidelines for new developments

Expected resources required:

A BCRTC employee is required to lead successful implementation of the Noise Mitigation Program. This position would be a new role within BCRTC, acting as an interface or point of coordination between the multiple stakeholder groups (Capital Projects, Rollingstock, Guideway, Engineering and Maintenance) that will need to collaborate in implementing the identified noise mitigation measures.

Cost estimate:

Ongoing Noise Mitigation Program Lead salary costs as appropriate.

Additional investment may be required in cloud and/or network-based data analysis and visualization tools.

Schedule:

Commencement of this role within BCRTC should be initiated as soon as possible, to avoid delays in implementation of all other mitigation measures.

SWITCH MAINTENANCE IMPROVEMENTS

Recommendation: Monitor switch condition by measuring and analyzing axle-box acceleration through switches around the network on a weekly basis. In the first year of implementation it is recommended that additional switch passby noise data also be collected at a minimum of 20 different switches with a range of operating speeds and baseline conditions. This would improve understanding of the correlation between axle-box vibration and wayside noise, and enable development of triggers specific to each switch configuration (e.g. different speed switches would require different triggers). Longer term, it should be possible to rely on the axle-box vibration data only as a trigger for switch maintenance to minimize noise.

Prepare a bi-weekly report identifying noise status of each switch as green, orange (warning), red (above trigger). On the basis of the identified triggers, plan and undertake maintenance of switches which may include (but is not limited to):

1 Grinding to reduce impacts
2 Ensure all plates and fasteners are in good condition (no loose / pumping components)
3 Replacement of switch components
4 Replacement of switch unit

The objective of grinding maintenance is to intervene early to prevent the development of more serious defects that cannot be rectified without replacement of components. In the event that maintenance in situ is not able to remove the trigger for maintenance on the basis of noise emissions, then replacement of switch components or switches is required.

Expected resources required to implement switch maintenance improvement recommendations:

At present, switch maintenance activities focus on safe operation of the equipment. All current scheduled inspections and maintenance activities for this purpose would continue. Additional resources (additional to existing resources and additional to the Noise Mitigation Program Lead) required to maintain switches on the basis of noise emissions are as follows:

1. A full-time Engineering Analyst would be required for the first year of implementation to undertake switch noise measurements, collect axle-box vibration data, analyze and review monitoring data and report on switch acoustic condition. This would include prioritizing switches for maintenance intervention. In subsequent years it is anticipated the analyst effort may reduce to around 2 days per week, subject to investment in automating aspects of the vibration data analysis process.
2. A dedicated team of three guideway maintenance staff would be required to achieve the noise goals for switches on a full-time basis. Additional hires will be required to fill these roles long term. In the interim switch grinding should be added to the BCRTC maintenance schedule so this work can commence utilizing existing crews. Additional equipment required would be approximately 3 sets of grinding equipment per year, and dedicated fit for purpose rail-borne equipment to access work areas.

Cost estimate: Additional cost per year of improvements to switch maintenance $500K (ongoing annually) plus initial capital cost of $500K for fit for purpose rail-borne equipment.

Schedule: Subject to BCRTC budgetary approval, implementation of switch maintenance improvements could commence in 2022 by recruiting staff starting with the Engineering Analyst. Procurement of required equipment would also start in 2022 with delivery expected in 2023. The schedule for commencement of grinding by the dedicated switch maintenance crew depends on timeframe for equipment procurement.

HARDER RAIL STEEL

Recommendation:

Rail replacement program contracts for new rail acquisition are to specify high strength (premium) steel. This recommendation has been implemented by the rail replacement program commencing in 2020, ie for all future rail purchases.

In addition, it is recommended that the BCRTC rail specification be updated via the BCRTC change management process to require use of high strength steel for all future rail applications.

Expected resources required to implement harder rail steel:

Noise Mitigation Program Lead to lead change management process to update specifications in 2022. No additional resources required.

Cost estimate:

Additional cost per year of specifying high strength rail for future rail replacement is $44K (ongoing annually), based on 2020 rail steel costs. This cost is being currently being absorbed by the Rail Replacement project.

Schedule:

Implementation of harder rail steel commenced in 2020.

RAIL DAMPERS

Recommendation:

Install rail dampers at the locations shown in Figure A1 (rail damper implementation locations) following rail damper supplier instructions.

Expected resources required:

Rail dampers can be installed on 50 m of single track (two track sections) by a crew of 6 people in one night shift outside of revenue service.

The total recommended length of rail dampers is 3.2 km. A total of approximately 75 night shifts is anticipated to be required for installation throughout 2022.

Quality control inspections of rail damper installation would include noise, rail roughness and track decay rate measurements at a minimum of two locations. For each quality control check measurements should include noise and track decay rate measurements before and after installation, and rail roughness measurements at approximately the time of installation. The resources required for these spot checks are a BCRTC analyst for 3 night shifts and two half days per location (TDR, roughness, noise), and a consultant for two night shifts per location (TDR).

Cost estimate:

The cost estimate for implementation is of the identified length of rail dampers is approximately $4M, including materials, labour and equipment for installation.

Schedule:

A contract has been signed with the preferred rail damper supplier. Installation of rail dampers is scheduled throughout 2022. Rail damper installation may be delayed between Nanaimo and Broadway Stations until approximately the end of 2022, after completion of rail replacement in this area. In this event, planning is underway for rail damper installation to be completed immediately after the rail replacement to take advantage of synergies around track possessions and installed fall protection systems to install dampers efficiently.

TOP OF RAIL FRICTION MODIFIERS

Recommendation:

Implement TORFM via mounted solid-stick applicators on a minimum of 25% of the existing Mk2 and Mk3 fleet wheels, and on all future vehicles added to the fleet. Installation of applicators is not recommended on the Mk1 trains since they are being phased out of service. On Mk2 and Mk3 trains the objective is 25% coverage on all existing and new vehicles in order to achieve and maintain the long-term goal of coverage for 25% of the fleet wheels, evenly distributed across all vehicles. As new vehicles are added it is important to ensure that additional applicators are also supplied to continue to achieve the friction management goals.

In the transition period until Mk1 vehicles are phased out it may be necessary to increase applicator spring force on Mk2 and Mk3 trains while monitoring friction performance to the goals, to compensate for the lack of applicators on Mk1 trains.

Expected resources required:

TORFM implementation would be managed as a Capital Project with a TransLink Project Manager. The Noise Mitigation Program Lead would provide technical support to the TransLink Project Manager and be responsible for monitoring effectiveness of the TORFM implementation as it progresses. Installation of TORFM applicator units on existing trains and new trains would be undertaken in house in the BCRTC vehicle shop.

Cost estimate:

Assuming approval is received, an RFP is issued in 2021 and all cars are retrofitted to install new applicator units, an estimated 2022 capital cost would be approximately $600,000 for supply and install of the units. Additional capital costs of around $100,000 per year would also be incurred over five years from 2023-2027 as new vehicles are delivered and retrofitted with applicators. No capital expenditures are expected beyond 2027 based on current fleet procurement plans.

Operating costs will be approximately $500,000 per year once all the new cars have come online. Note that some of these costs are already being incurred since some FM sticks are being purchased and installed each year at present (but not sufficient quantities to be effective). Once applicators are installed on trains, refilling applicators with fresh sticks during regular vehicle inspections is not expected to require significantly increased resources.

Schedule:

Subject to TransLink Capital Project funding approval, Installation of TORFM would commence with a procurement process to identify the preferred supplier of stick applicators and consumable product. The earliest potential start date for the procurement process is Q4 2021 / Q1 2022.

ACOUSTIC RAIL GRINDING

Recommendation:

Implement the recommendations of the acoustic grinding study as appropriate based on rail steels in place around the network, starting by mapping out the grinding program following the recommended strategy and based on available grinding capacity:

- Evergreen line: Acoustic grinding
- Millennium line: A combination of standard and acoustic grinding, to be determined based on maintenance objectives, grinding capacity, rail condition before grinding and residential proximity.
- Expo line: Standard grinding for softer steels < 300 Hb, and acoustic grinding where original rails have already been replaced with harder rail steel.

Expected resources required:

In general, resources are the same as required to implement current rail grinding programs. The Noise Mitigation Program Lead would coordinate with in-house grinding crews and contract grinders as required to achieve the noise mitigation program goals in addition to all existing maintenance grinding objectives.

Cost estimate:

No additional costs have been identified for implementation of acoustic grinding for noise mitigation program purposes, beyond already budgeted costs for ongoing grinding programs which include procurement of additional BCRTC grinders.

Schedule:

Implementation of the acoustic rail grinding recommendations can commence immediately.

MONITORING AND REPORTING ON MITIGATION PROGRAM EFFECTIVENESS

Recommendation:

Undertake ongoing monitoring and verification of noise mitigation program effectiveness, and implement an annual reporting regime. Ongoing monitoring and verification involves:

- Weekly monitoring of track condition by measurement of in-car noise levels
- Weekly monitoring of track condition by measurement of axle-box vibration
- Present results as a “difference from best case condition” in visual format
- Undertake annual train passby noise measurements at 14 locations (see Appendix B) around the network to enable direct reporting of the effectiveness of the noise mitigation program and as a point of comparison for the use of vibration and in-car noise data monitoring network wide track condition
- Every two months, measure rail roughness, friction and noise at a subset of 4 locations identified to monitor performance of TORFM implementation. Analyze data in conjunction with a review of stick consumption rates, in-car noise and axlebox vibration. Identify if any adjustments are required to TORFM applicator spring rates, monitor effectiveness of implementation.
- Prepare an annual report documenting passby measurements, track condition around the network, and progress towards the noise goals.

Following commencement of implementation of all recommended mitigation measures, the annual report should include updates on whether noise goals are being met at residential facades, and include recommendations for installation of additional mitigation if required.

Expected resources required:

The Noise Mitigation Program Lead would coordinate with the Switch Maintenance Analyst and others as required to achieve the noise mitigation program monitoring goals.

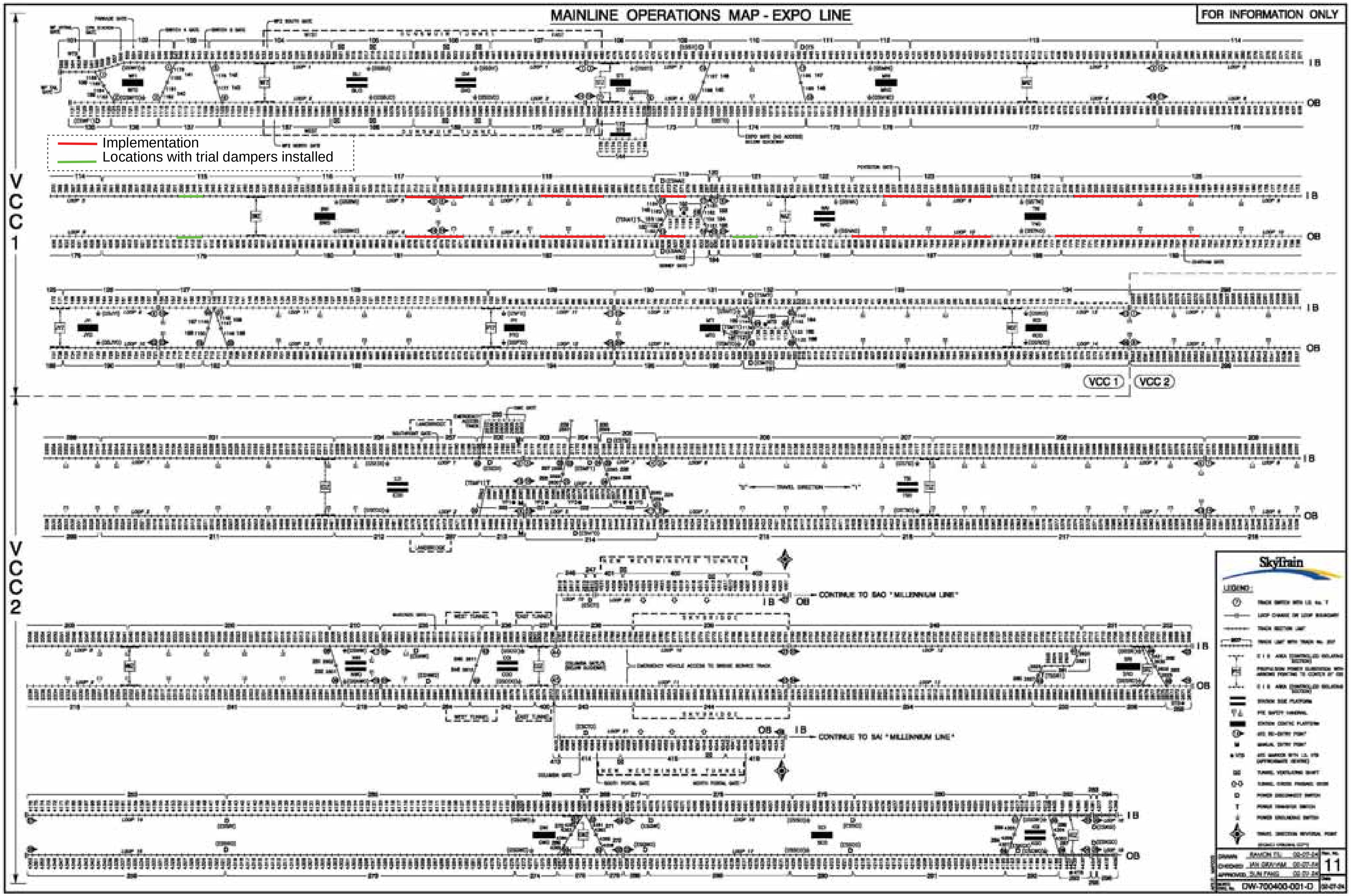
Annual train passby measurements and annual reporting on progress towards noise goals could be undertaken by either the proposed BCRTC Noise Mitigation Program Lead or an external consultant. The measurements would require one person for approximately two weeks, plus another two weeks for analysis and reporting.

The measurements of rail roughness, friction and noise at four locations to monitor performance of TORFM implementation is expected to require one to two weeks of time for one person, every two months. These measurements would be undertaken by either the proposed BCRTC Noise Mitigation Program Lead or by other existing BCRTC staff as coordinated by the BCRTC Noise Mitigation Program Lead.

Figure A1

Rail Damper Implementation Locations

RECOMMENDED RAIL DAMPER LOCATIONS



Appendix B Noise Mitigation Program Example Monitoring Report

SkyTrain Noise Mitigation Study Phase 2
Recommendation Report and Implementation Plan
Vancouver

TransLink Ref No.: Q17-037
SLR Project No: 201.04644.00007

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Memorandum

Subject:	**SKYTRAIN PASSBY NOISE MEASUREMENTS NOVEMBER 2020**
Prepared by:	**Arthur (Art) Küpper, P.Eng.** Senior Acoustical Engineer
Reviewed by:	**Briony Croft, Ph.D., P.Eng.** Principal, Acoustics

In 2018, TransLink commissioned SLR Consulting (Canada) Ltd (SLR) to undertake a SkyTrain Noise Study in response to concerns raised by residents. The Noise Study recommended investigation of the feasibility and effectiveness of various mitigation measures. Those investigations have now been completed resulting in a series of recommendations for implementation.

One recommendation relates to ongoing monitoring, including measurements of train passby noise at representative locations around the network. Repeating these measurements on an annual basis is proposed to enable direct reporting of the effectiveness of the noise mitigation program in the long term, and to provide a point of comparison for the use of in-car noise data to monitor track condition network-wide.

This memo describes train passby noise measurements completed in November 2020 as a template for future representative annual measurements to be completed under the recommended Noise Mitigation Implementation program.

1.0 NOISE MEASUREMENT DETAILS

1.1 Measurement Locations

Measurements were conducted at fourteen (14) locations as described in Table 1 and Figure 1. In this table, Track Section (TS) indicates the unique BCRTC reference to the track location, on the Inbound (IB) and Outbound (OB) tracks.

Table 1 Measurement locations

Ref.	Line	Location Description	Location GPS	TS IB	TS OB
1	Expo	Quebec Street at Expo Blvd.	49.276819°, -123.102626°	456	1021
2	Expo	N Grandview Hwy at McLean Drive	49.265648°, -123.075324°	354	919
3	Expo	East 27th Avenue at Penticton Avenue	49.246231°, -123.051346°	233	798
4	Expo	Central Park / South Burnaby Lawn Bowling Club	49.231570°, -123.016057°	111	677
5	Expo	Prenter St at Hawthorne St	49.215177°, -122.965988°	2226	2507
6	Expo	Stewardson Way – Lookout Green Space	49.203075°, -122.937470°	2083	2365
7	Expo Surrey	132 St at 112 Ave	49.205864°, -122.856536°	4132	4308
8	Expo Surrey	105 Ave at 134a St	49.193660°, -122.849596°	4069	4245
9	Millennium	N Grandview Hwy west of Slocan St	49.258231°, -123.051715°	5526	6163
10	Millennium	Lougheed Hwy at Gamma Ave	49.266144°, -122.995323°	5349	5985
11	Millennium	Lougheed Hwy at Bell Avenue	49.251475°, -122.905062°	5072	5706
12	Evergreen	North Rd at Foster Avenue	49.256629°, -122.892861°	7406	7825
13	Evergreen	Clarke St at Queens St	49.277927°, -122.858307°	7244	7664
14	Evergreen	Aberdeen Avenue at Lansdowne	49.276633°, -122.809257°	7093	7515

Figure 1 Overview of noise measurement locations

1.2 Measurement Methodology

Noise measurements were undertaken from November 9-23, 2020. Measurements generally followed the procedures described in ISO 3095:2013 *Acoustics - Railway applications – Measurement of noise emitted by railbound vehicles*. The parameters reported are the passby sound exposure level (L_{AE}), the maximum value of the sound pressure level during the passby event (L_{AFmax}), and the third octave L_{AFmax} spectrum. Passby events were excluded from analysis if two trains were present, if results were affected by noise from road or rail freight traffic, or if train speeds were unusually low.

Instrumentation used was a class 1 sound level meter and calibrator as follows:

- Larson Davis LxT2 sound level meter, S/N 0002934
- Larson Davis CAL150 calibrator, S/N 3534 (calibrated date 13 May 2019)

The microphone was attached to a 24 foot telescoping extension pole and elevated above the guideway parapet height wherever possible. The extension pole has four segments enabling measurement configurations with microphone heights above ground of 2.3m (fully collapsed), 4.0m (top segment extended), 5.7m (top two segments extended) and 7.5m (fully extended).

1.3 Overview of Recent Rail Grinding Activity

During 2020 rail grinding activity was disrupted by pandemic travel restrictions, with grinding contractors unable to complete network-wide grinding as planned in April. Rail grinding undertaken in 2020 was limited to work that could be completed in-house by BCRTC. The most recent grinding undertaken during 2020 prior to these noise measurements is shown in Table 2.

Table 2 Most Recent Rail Grinding Activity in 2020 Prior to Noise Measurements

Ref.	Line	Location Description	Track Section		Grinding Dates	
			IB	OB	IB	OB
1	Expo	Quebec Street at Expo Blvd.	456	1021	25 Aug '20	9 Mar '20
2	Expo	N Grandview Hwy at McLean Drive	354	919	n/a	n/a
3	Expo	East 27th Avenue at Penticton Avenue	233	798	28 Jul '20	19 Jul '20
4	Expo	Central Park / South Burnaby Lawn Bowling Club	111	677	19 Jan '20	2 Feb '20
5	Expo	Prenter St at Hawthorne St	2226	2507	31 Jul '20	2 Aug '20
6	Expo	Stewardson Way – Lookout Green Space	2083	2365	n/a	n/a
7	Expo Surrey	132 St at 112 Ave	4132	4308	n/a	n/a
8	Expo Surrey	105 Ave at 134a St	4069	4245	n/a	n/a
9	Millennium	N Grandview Hwy west of Slocan St	5526	6163	26 Sep '20	n/a
10	Millennium	Lougheed Hwy at Gamma Ave	5349	5985	n/a	n/a
11	Millennium	Lougheed Hwy at Bell Avenue	5072	5706	17 Aug '20	n/a
12	Evergreen	North Rd at Foster Avenue	7406	7825	7 Oct' 20	6 Oct '20
13	Evergreen	Clarke St at Queens St	7244	7664	21 Oct '20	15 Nov '20
14	Evergreen	Aberdeen Avenue at Lansdowne	7093	7515	16 Oct '20	n/a

2.0 MEASUREMENT RESULTS

Results at all measurement locations are presented in the sections below. Note that sound exposure levels (L_{AE}) for all measured passby events have been averaged logarithmically and maximum passby sound levels have been averaged arithmetically.

2.1 Location 1 – Expo Line at Quebec St. & Expo Blvd.

Measurements at Location 1 were conducted on the inbound side of the Expo line alongside the existing billboard with the microphone at a height of 7.5m above the ground. The measurement setup is shown below in Figure 2 with the microphone identified within the red circle. The average sound levels are presented in Table 3 for passbys in each direction and separated by train type.

At this location the rail replacement project replaced historical softer rails from 2003 (248 HB) with harder 330 HB rails in 2020, before these measurements were collected in November 2020.

Figure 2 Noise measurement setup – Location 1

Table 3 Passby average noise results – Location 1

Train Type	Inbound			Outbound		
	# of Passbys	L_{AFmax} (dBA)	L_{AE} (dBA)	# of Passbys	L_{AFmax} (dBA)	L_{AE} (dBA)
Total	25	83.3	89.6	22	76.2	83.6
MK 1	10	84.2	90.6	8	77.5	84.5
MK 2	6	82.7	88.9	4	75.1	82.9
MK 3	9	82.8	88.8	10	75.6	83.0

2.2 Location 2 – Expo Line at N. Grandview Hwy. & McLean Dr.

Measurements at Location 2 were conducted on the inbound side of the Expo line at a light pole with the microphone at a height of 5.7m above the ground. The measurement setup is shown below in Figure 3 with the microphone identified within the red circle. The average sound levels are presented in Table 4 for passbys in each direction and separated by train type.

At the time of these measurements rails were the original (in service 1986) softer 248HB steel. Rail replacement is scheduled for late 2021 / early 2022.

Figure 3 Noise measurement setup – Location 2

Table 4 Passby average noise results – Location 2

Train Type	Inbound			Outbound		
	# of Passbys	L_{AFmax} (dBA)	L_{AE} (dBA)	# of Passbys	L_{AFmax} (dBA)	L_{AE} (dBA)
Total	21	82.7	87.9	20	80.3	86.4
MK 1	9	84.0	89.1	10	81.4	87.5
MK 2	5	81.5	86.8	6	79.0	84.9
MK 3	7	81.8	86.7	4	79.4	84.9

2.3 Location 3 – Expo Line at E. 27th Ave. & Penticton Ave.

Measurements at Location 3 were conducted at the E. 27th Ave. at the intersection with the shared pathway. The microphone was positioned on the outbound side of the line and attached to a street sign at a height of 2.3m above the ground. The measurement setup is shown below in Figure 4 with the microphone identified within the red circle. The average sound levels are presented in Table 5 for passbys in each direction and separated by train type.

At the time of these measurements rails were the original (in service 1986) softer 248HB steel and rail replacement has not been scheduled.

Figure 4 Noise measurement setup – Location 3

Table 5 Passby average noise results – Location 3

Train Type	Inbound			Outbound		
	# of Passbys	L_{AFmax} (dBA)	L_{AE} (dBA)	# of Passbys	L_{AFmax} (dBA)	L_{AE} (dBA)
Total	21	80.5	85.4	20	88.7	93.1
MK 1	8	80.6	85.9	12	88.5	93.1
MK 2	6	80.7	85.2	5	89.9	93.4
MK 3	7	80.3	85.2	3	87.5	92.4

2.4 Location 4 – Expo Line at Central Park at the South Burnaby Lawn Bowling Club

Measurements at Location 4 were conducted in Central park at the parking lot adjacent to the South Burnaby Lawn Bowling Club. The microphone was positioned on the inbound side of the line and attached to a light pole at a height of 7.5m above the ground. The measurement setup is shown below in Figure 5 with the microphone identified within the red circle. The average sound levels are presented in Table 6 for passbys in each direction and separated by train type. Trains traveling in opposing directions regularly passed this location at near the same time and this may influence the presented equivalent (L_{AE}) sound levels. Data from simultaneous passbys are not included.

At the time of these measurements rails were the original (in service 1986) softer 248HB steel and rail replacement has not been scheduled.

Figure 5 Noise measurement setup – Location 4

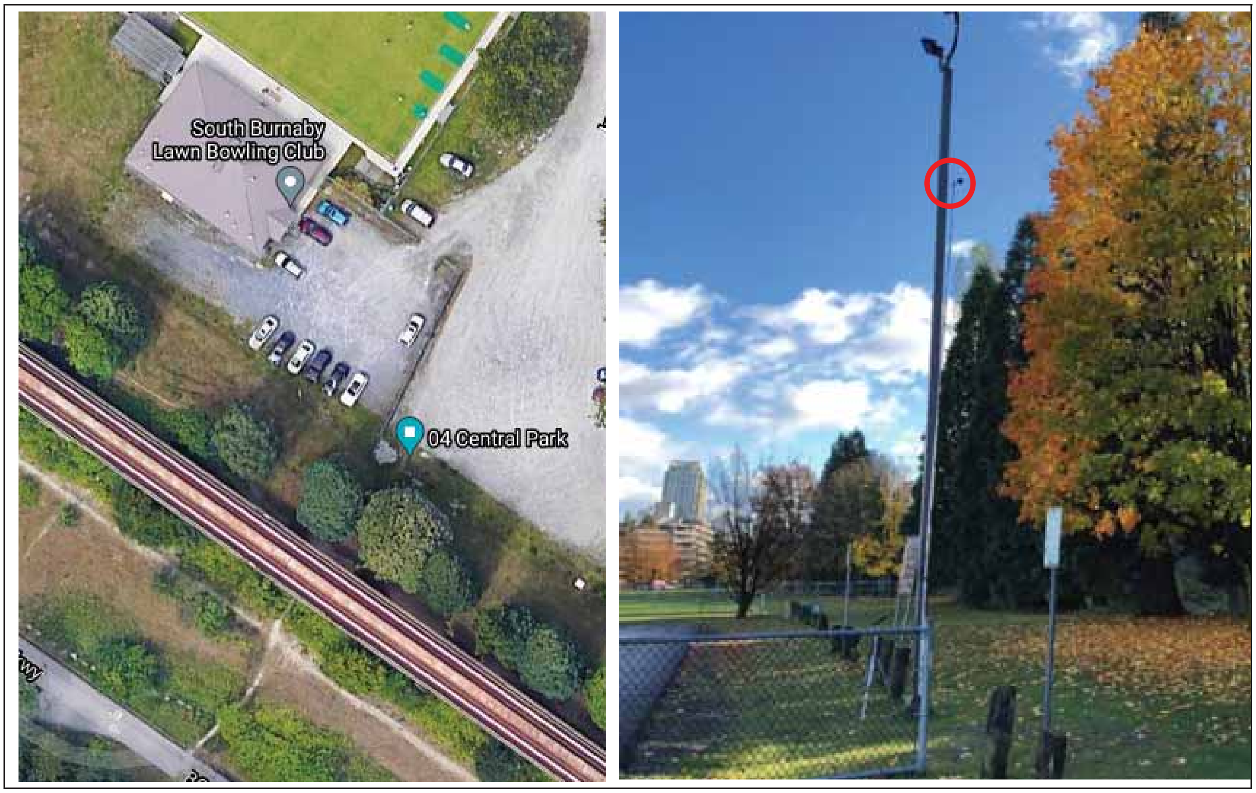


Table 6 Passby average noise results – Location 4

Train Type	Inbound			Outbound		
	# of Passbys	L_{AFmax} (dBA)	L_{AE} (dBA)	# of Passbys	L_{AFmax} (dBA)	L_{AE} (dBA)
Total	23	83.1	87.8	18	76.9	81.9
MK 1	9	84.1	88.7	10	77.6	82.5
MK 2	8	82.3	86.9	2	75.3	80.5
MK 3	6	82.9	87.5	6	76.9	81.5

2.5 Location 5 – Expo Line at Prenter St. & Hawthorne Ter.

Measurements at Location 5 were conducted on the inbound side of the line with the microphone attached to a light pole at a height of 7.5m above the ground. The measurement setup is shown below in Figure 6 with the microphone identified within the red circle. The average sound levels are presented in Table 7 for passbys in each direction and separated by train type.

At the time of these measurements rails were the original (in service 1986) softer 248HB steel and rail replacement has not been scheduled.

Figure 6 Noise measurement setup – Location 5

Table 7 Passby average noise results – Location 5

Train Type	Inbound			Outbound		
	# of Passbys	L_{AFmax} (dBA)	L_{AE} (dBA)	# of Passbys	L_{AFmax} (dBA)	L_{AE} (dBA)
Total	23	84.6	90.7	20	73.6	79.9
MK 1	9	84.8	90.7	6	74.3	80.6
MK 2	6	84.1	90.1	4	73.2	79.2
MK 3	8	84.9	91.1	10	73.4	79.6

2.6 Location 6 – Expo Line at Stewardson Way & Lookout Greenspace

Measurements at Location 6 were conducted on the inbound side of the line with the microphone attached to a light pole at a height of 7.5m above the ground. The guideway is relatively high at this location so the microphone may not have been above the parapet. The measurement setup is shown below in Figure 7 with the microphone identified within the red circle. The average sound levels are presented in Table 8 for passbys in each direction and separated by train type. Traffic noise at this location was significant. Only passbys where the maximum sound level was dominated by the train passby are included in the data below. The equivalent (L_{AE}) sound levels may include some contamination and may not be a reliable indicator of train noise for this location.

At this location the original rails (248HB installed 1986) were replaced in early 2020 outbound with 330 HB steel and late 2020 inbound with 370 HB steel. At the time of these noise measurements, the inbound track was still original rail, in poor condition. Rail replacement inbound occurred soon after the measurements.

Figure 7 Noise measurement setup – Location 6

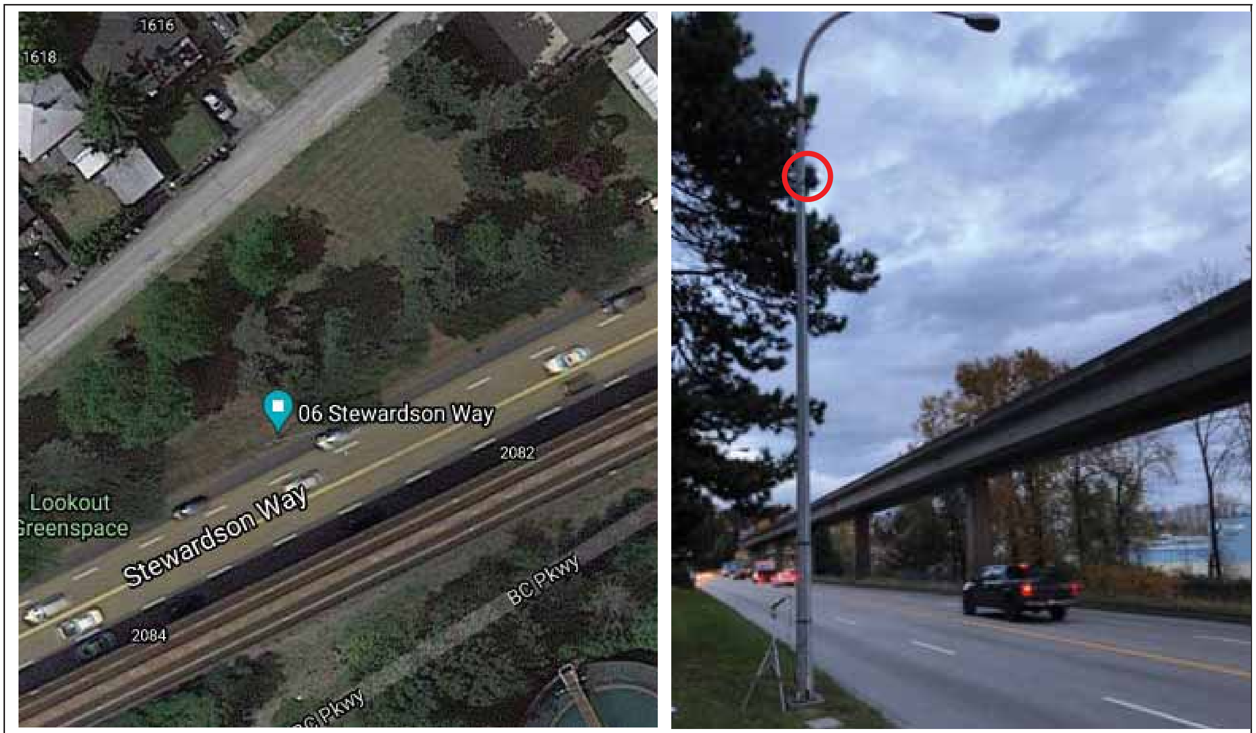


Table 8 Passby average noise results – Location 6

Train Type	Inbound			Outbound		
	# of Passbys	L_{AFmax} (dBA)	L_{AE} (dBA)	# of Passbys	L_{AFmax} (dBA)	L_{AE} (dBA)
Total	21	100.8	104.6	17	81.1	88.1
MK 1	8	101.6	105.5	5	83.1	89.6
MK 2	9	100.4	103.7	6	80.7	87.9
MK 3	4	100.3	104.1	6	79.9	86.7

2.7 Location 7 – Expo Surrey Line at 132 St. & 112 Ave.

Measurements at Location 7 were conducted on the outbound side of the line with the microphone attached to a light pole at a height of 4.0m above the ground. The measurement setup is shown below in Figure 8 with the microphone identified within the red circle. The average sound levels are presented in Table 9 for passbys in each direction and separated by train type.

At the time of these measurements rails were the original (in service 1994) 285 HB steel.

Figure 8 Noise measurement setup – Location 7

Table 9 Passby average noise results – Location 7

Train Type	Inbound			Outbound		
	# of Passbys	L_{AFmax} (dBA)	L_{AE} (dBA)	# of Passbys	L_{AFmax} (dBA)	L_{AE} (dBA)
Total	19	81.5	87.2	21	89.2	94.2
MK 1	7	82.7	88.3	7	90.2	95.4
MK 2	8	80.5	86.1	6	89.0	93.7
MK 3	4	81.4	87.1	8	88.5	93.2

2.8 Location 8 – Expo Surrey Line at 134a St. & 105 Ave.

Measurements at Location 8 were conducted on the inbound side of the line with the microphone attached to a street sign beside the parking meter at a height of 7.5m above the ground. The guideway is relatively high at this location so the microphone may not have been above the parapet. The measurement setup is shown below in Figure 9 with the microphone identified within the red circle. The average sound levels are presented in Table 10 for passbys in each direction and separated by train type. Trains traveling in opposing directions regularly passed this location at near the same time and this may influence the presented equivalent (L_{AE}) sound levels. Data from simultaneous passbys are not included.

At the time of these measurements rails were the original (in service 1994) 285 HB steel.

Figure 9 Noise measurement setup – Location 8

Table 10 Passby average noise results – Location 8

Train Type	Inbound			Outbound		
	# of Passbys	L_{AFmax} (dBA)	L_{AE} (dBA)	# of Passbys	L_{AFmax} (dBA)	L_{AE} (dBA)
Total	19	89.7	94.9	17	84.5	90.0
MK 1	9	89.6	95.1	10	85.4	90.8
MK 2	4	89.3	94.4	3	82.8	88.6
MK 3	6	90.0	95.0	4	83.5	88.4

2.9 Location 9 – Millennium Line at N. Grandview Hwy. west of Slocan St.

Measurements at Location 9 were conducted on the inbound side of the line with the microphone attached to a light pole at a height of 5.7m above the ground. The measurement setup is shown below in Figure 10 with the microphone identified within the red circle. The average sound levels are presented in Table 11 for passbys in each direction and separated by train type. All observed passbys were from Mark 2 type trains with only two cars, the only rolling stock operating on this line.

At the time of these measurements rails were the original (in service 2002) 300 HB steel.

Figure 10 Noise measurement setup – Location 9

Table 11 Passby average noise results – Location 9

Train Type	Inbound			Outbound		
	# of Passbys	L_{AFmax} (dBA)	L_{AE} (dBA)	# of Passbys	L_{AFmax} (dBA)	L_{AE} (dBA)
Total	15	79.1	83.5	16	80.4	84.0
MK 1	0			0		
MK 2	15	79.1	83.5	16	80.4	84.0
MK 3	0			0		

2.10 Location 10 – Millennium Line at Lougheed Hwy. & Gamma Ave.

Measurements at Location 10 were conducted on the inbound side of the line with the microphone attached to eastern side of a pergola at a height of 5.7m above the ground. The measurement setup is shown below in Figure 11 with the microphone identified within the red circle. The average sound levels are presented in Table 12 for passbys in each direction and separated by train type. All observed passbys were from Mark 2 type trains with only two cars, the only rolling stock operating on this line. Noise contamination from traffic and construction activities across Lougheed Hwy may influence the reported equivalent (L_{AE}) sound levels.

At the time of these measurements rails were the original (in service 2002) 300 HB steel.

Figure 11 Noise measurement setup – Location 10

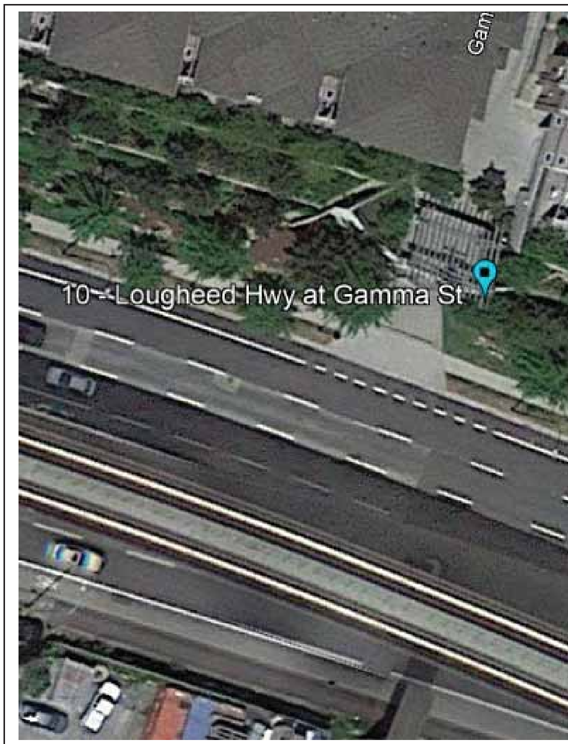


Table 12 Passby average noise results – Location 10

Train Type	Inbound			Outbound		
	# of Passbys	L_{AFmax} (dBA)	L_{AE} (dBA)	# of Passbys	L_{AFmax} (dBA)	L_{AE} (dBA)
Total	15	80.5	85.8	15	77.6	82.3
MK 1	0			0		
MK 2	15	80.5	85.8	15	77.6	82.3
MK 3	0			0		

2.11 Location 11 – Millennium Line at Lougheed Hwy. west of Bell Ave.

Measurements at Location 11 were conducted on the inbound side of the line with the microphone attached to a light pole at a height of 7.5m above the ground. The measurement setup is shown below in Figure 12 with the microphone identified within the red circle. The average (arithmetic) sound levels are presented in Table 13 for passbys in each direction and separated by train type. The measurement position was below the rail height and the Field Engineer was unable to distinguish between the Mark 2 and 3 trains with 4 cars. Noise contamination from traffic on Lougheed Hwy may influence the reported equivalent (L_{AE}) sound levels.

At the time of these measurements rails were the original (in service 2002) 300 HB steel.

Figure 12 Noise measurement setup – Location 11

Table 13 Passby average noise results – Location 11

Train Type	Inbound			Outbound		
	# of Passbys	L_{AFmax} (dBA)	L_{AE} (dBA)	# of Passbys	L_{AFmax} (dBA)	L_{AE} (dBA)
Total	19	85.2	89.2	22	78.7	83.9
MK 1 (6 cars)	1	91.3	93.8	2	78.8	83.0
MK 2 (2 cars)	12	84.4	87.9	15	78.3	82.6
MK 2/3 (4 cars)	6	85.8	89.9	5	80.1	86.6

2.12 Location 12 – Evergreen Line at North Rd & Foster Ave.

Measurements at Location 12 were conducted on the outbound side of the line with the microphone attached to a light pole at a height of 7.5m above the ground. The measurement setup is shown below in Figure 13 with the microphone identified within the red circle. The average sound levels are presented in Table 14 for passbys in each direction and separated by train type. All observed passbys were from Mark 2 type trains with only two cars, the only rolling stock operating on this line. Noise contamination from traffic on North Rd. may influence the reported equivalent (L_{AE}) sound levels. Trains traveling in opposing directions regularly passed this location at near the same time and this may also influence the presented equivalent sound levels. Data from simultaneous passbys are not included.

At the time of these measurements rails were the original (in service 2016) 350 HB steel.

Figure 13 Noise measurement setup - Location 12

Table 14 Passby average noise results – Location 12

Train Type	Inbound			Outbound		
	# of Passbys	L_{AFmax} (dBA)	L_{AE} (dBA)	# of Passbys	L_{AFmax} (dBA)	L_{AE} (dBA)
Total	11	74.6	79.6	14	81.7	85.2
MK 1	0			0		
MK 2	11	74.6	79.6	14	81.7	85.2
MK 3	0			0		

2.13 Location 13 – Evergreen Line at Clark St. & Queens St.

Measurements at Location 13 were conducted on the outbound side of the line with the microphone attached to a light pole at a height of 5.7m above the ground. The measurement setup is shown below in Figure 14 with the microphone identified within the red circle. The average sound levels are presented in Table 15 for passbys in each direction and separated by train type. All observed passbys were from Mark 2 type trains with only two cars, the only rolling stock operating on this line.

At the time of these measurements rails were the original (in service 2016) 350 HB steel.

Figure 14 Noise measurement setup - Location 13

Table 15 Passby average noise results – Location 13

Train Type	Inbound			Outbound		
	# of Passbys	L_{AFmax} (dBA)	L_{AE} (dBA)	# of Passbys	L_{AFmax} (dBA)	L_{AE} (dBA)
Total	10	76.0	81.5	14	79.6	84.7
MK 1	0			0		
MK 2	10	76.0	81.5	14	79.6	84.7
MK 3	0			0		

2.14 Location 14 – Evergreen Line at Aberdeen Ave. west of Lansdowne Dr.

Measurements at Location 14 were conducted on the inbound side of the line with the microphone attached to a light pole at a height of 5.7m above the ground. The measurement setup is shown below in Figure 15 with the microphone identified within the red circle. The average sound levels are shown in Table 16 for passbys in each direction and separated by train type. All observed events were from Mark 2 type trains with two cars, the only rolling stock operating on this line.

At the time of these measurements rails were the original (in service 2016) 350 HB steel.

Figure 15 Noise measurement setup - Location 14

Table 16 Passby average noise results – Location 14

Train Type	Inbound			Outbound		
	# of Passbys	L_{AFmax} (dBA)	L_{AE} (dBA)	# of Passbys	L_{AFmax} (dBA)	L_{AE} (dBA)
Total	9	81.6	84.0	10	82.8	85.5
MK 1	0			0		
MK 2	9	81.6	84.0	10	82.8	85.5
MK 3	0			0		

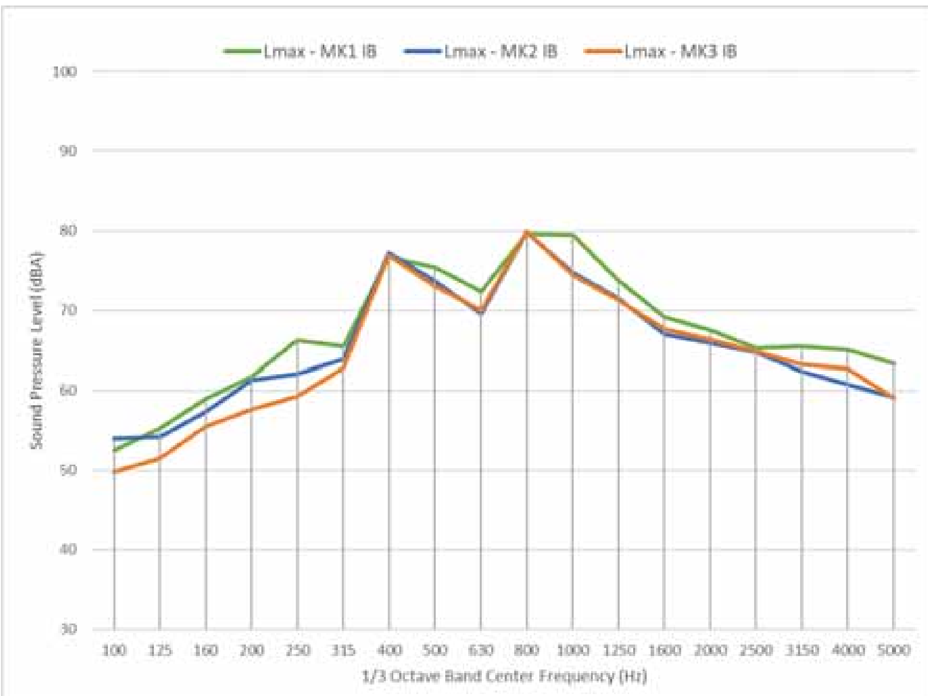
3.0 SPECTRAL SOUND PRESSURE LEVELS

The average spectral sound pressure levels measured at each location are presented in the following pages. Maximum sound levels have been averaged arithmetically across all passbys for each train type and each direction. Reported sound levels are A-weighted decibels (dBA).

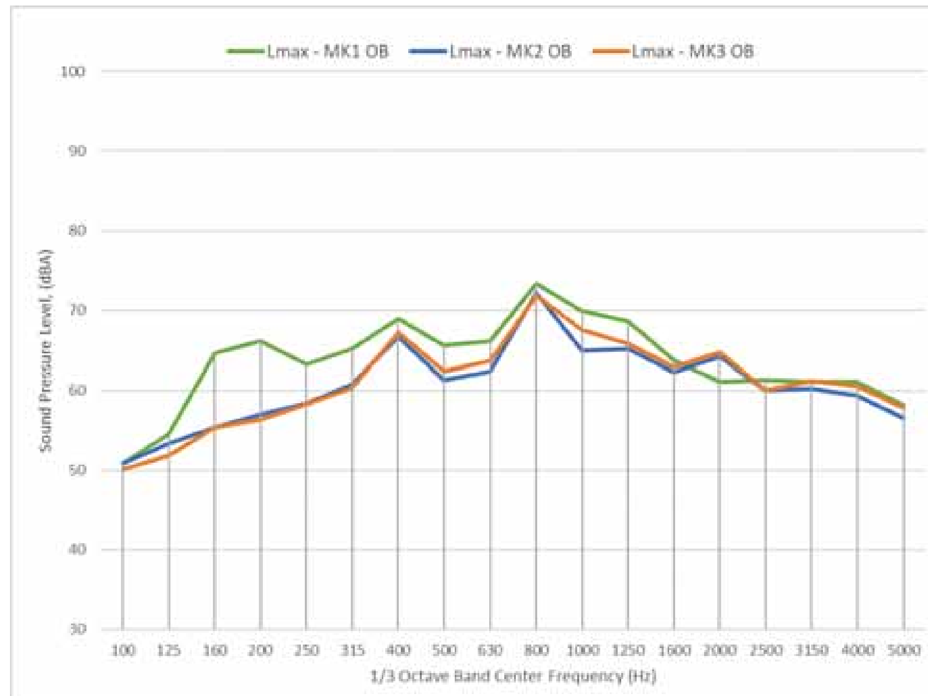
3.1 Average Spectral Sound Pressure Levels (dBA) at Location 1 – Expo Line at Quebec St. & Expo Blvd.

Parameter &	1/3 Octave Band Center Frequency (Hz)																	
Train Type	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
Lmax - MK1 IB	53	55	59	62	66	65	77	75	72	80	79	74	69	68	65	66	65	63
Lmax - MK2 IB	54	54	57	61	62	64	77	74	70	80	75	72	67	66	65	62	61	59
Lmax - MK3 IB	50	52	55	58	59	63	77	73	70	80	74	71	68	66	65	63	63	59
Lmax - MK1 OB	51	55	65	66	63	65	69	66	66	73	70	69	64	61	61	61	61	58
Lmax - MK2 OB	51	53	55	57	58	61	67	61	62	72	65	65	62	64	60	60	59	57
Lmax - MK3 OB	50	52	55	56	58	60	67	62	64	72	68	66	63	65	60	61	61	58

Lmax – Inbound Direction



Lmax – Outbound Direction

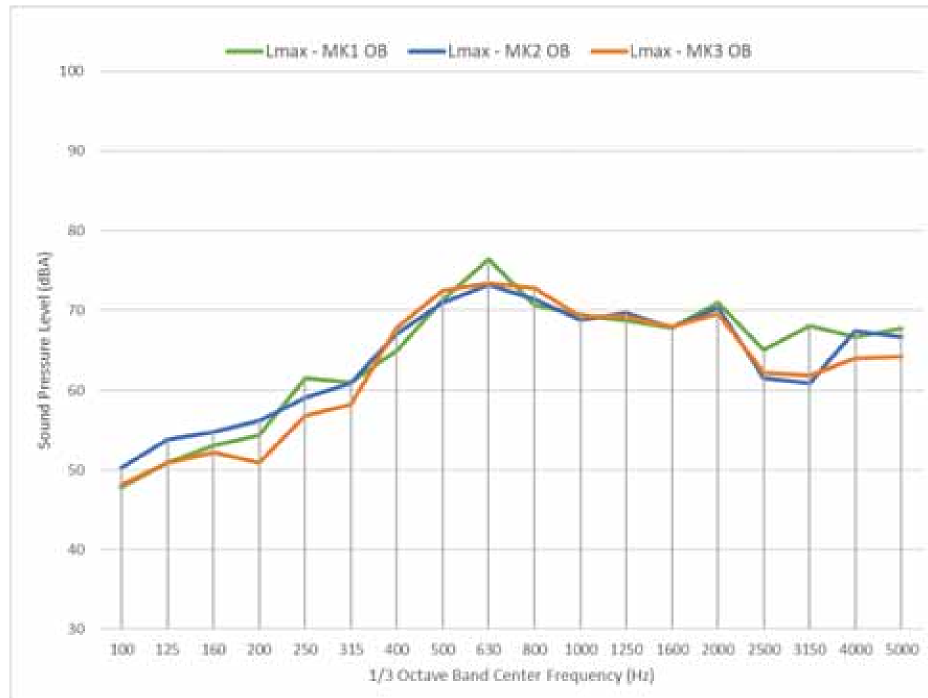


3.2 Average Spectral Sound Pressure Levels (dBA) at Location 2 – Expo Line at N. Grandview Hwy. & McLean Dr.

Parameter & Train Type	1/3 Octave Band Center Frequency (Hz)																	
	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
Lmax - MK1 IB	46	51	54	59	65	64	68	75	82	75	74	72	68	72	67	65	66	67
Lmax - MK2 IB	49	53	55	58	62	62	66	73	77	76	70	73	67	71	63	61	67	67
Lmax - MK3 IB	45	51	52	54	59	61	65	72	77	75	71	73	68	71	63	62	67	71
Lmax - MK1 OB	48	51	53	54	62	61	65	71	76	71	69	69	68	71	65	68	67	68
Lmax - MK2 OB	50	54	55	56	59	61	67	71	73	71	69	70	68	70	62	61	67	67
Lmax - MK3 OB	48	51	52	51	57	58	68	72	73	73	69	69	68	70	62	62	64	64

Lmax – Inbound Direction

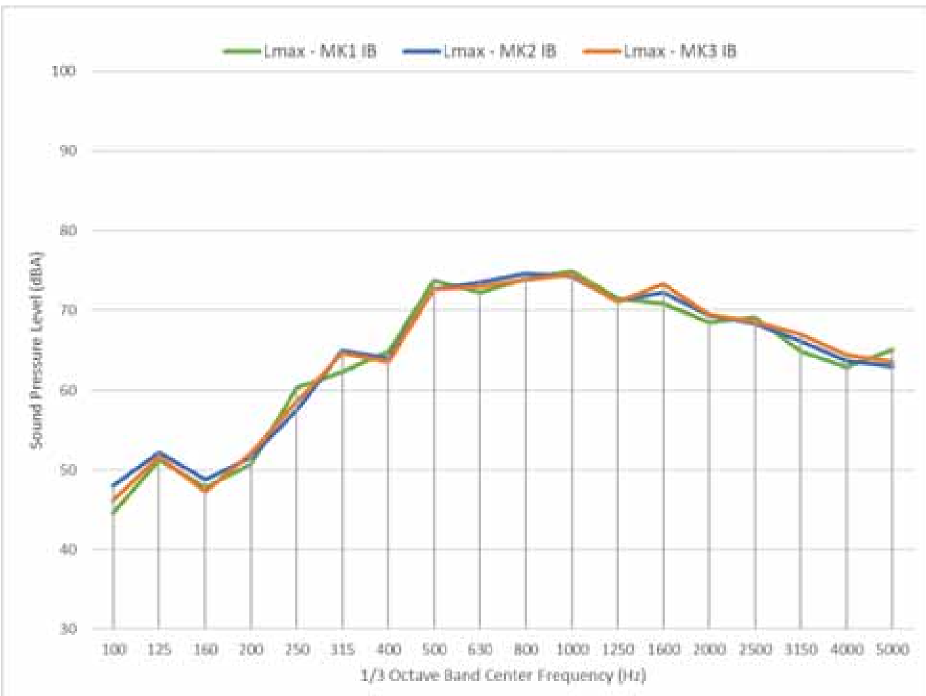
Lmax – Outbound Direction



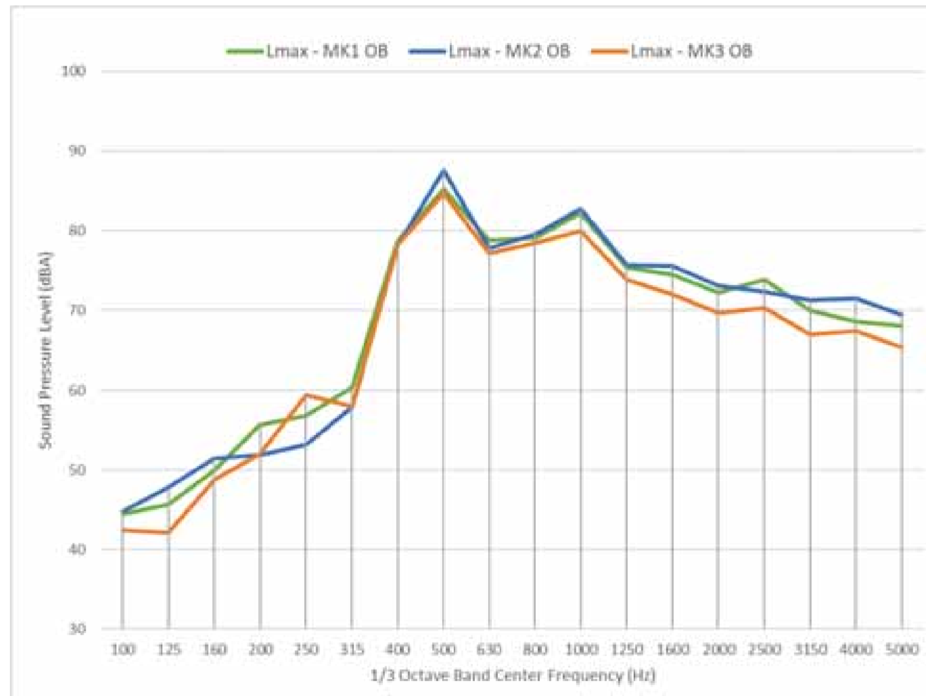
3.3 Average Spectral Sound Pressure Levels (dBA) at Location 3 – Expo Line at E. 27th Ave. & Penticton Ave.

Parameter & Train Type	1/3 Octave Band Center Frequency (Hz)																	
	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
Lmax - MK1 IB	45	51	48	51	60	62	65	74	72	74	75	71	71	68	69	65	63	65
Lmax - MK2 IB	48	52	49	52	58	65	64	73	73	75	74	71	72	69	68	66	64	63
Lmax - MK3 IB	46	52	47	52	59	65	64	73	73	74	74	71	73	69	69	67	64	64
Lmax - MK1 OB	44	46	50	56	57	60	79	85	79	79	82	75	74	72	74	70	69	68
Lmax - MK2 OB	45	48	51	52	53	58	78	88	78	80	83	76	76	73	72	71	71	69
Lmax - MK3 OB	42	42	49	52	59	58	78	85	77	78	80	74	72	70	70	67	67	65

Lmax – Inbound Direction



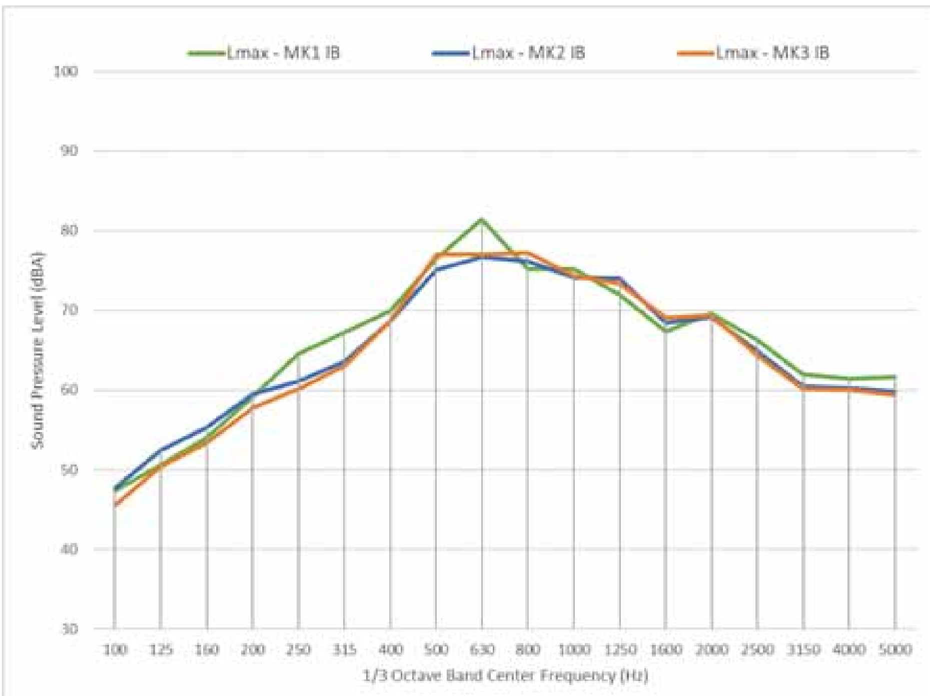
Lmax – Outbound Direction



3.4 Average Spectral Sound Pressure Levels (dBA) at Location 4 – Expo Line at Central Park at the South Burnaby Lawn Bowling Club

Parameter &	1/3 Octave Band Center Frequency (Hz)																	
Train Type	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
Lmax - MK1 IB	47	51	54	59	65	67	70	77	81	75	75	72	67	70	66	62	61	62
Lmax - MK2 IB	48	52	55	60	61	64	69	75	77	76	74	74	68	69	65	61	60	60
Lmax - MK3 IB	46	50	53	58	60	63	69	77	77	77	74	73	69	69	64	60	60	59
Lmax - MK1 OB	49	48	52	54	61	62	64	68	74	67	66	67	63	68	65	59	61	63
Lmax - MK2 OB	47	52	56	52	57	58	60	64	70	66	63	68	64	68	60	57	61	62
Lmax - MK3 OB	46	48	51	49	56	57	59	65	70	67	65	70	65	68	60	57	62	62

Lmax – Inbound Direction

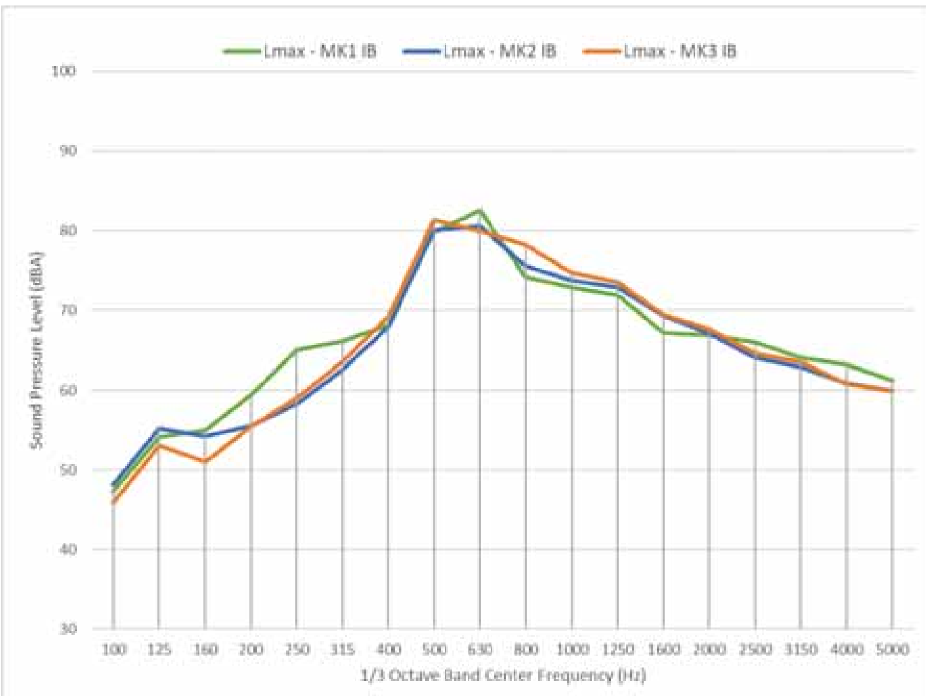


Lmax – Outbound Direction

3.5 Average Spectral Sound Pressure Levels (dBA) at Location 5 – Expo Line at Prenter St. & Hawthorne Ter.

Parameter &	1/3 Octave Band Center Frequency (Hz)																	
Train Type	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
Lmax - MK1 IB	47	54	55	59	65	66	68	80	83	74	73	72	67	67	66	64	63	61
Lmax - MK2 IB	48	55	54	56	58	62	68	80	81	76	74	73	69	67	64	63	61	60
Lmax - MK3 IB	46	53	51	55	59	63	69	81	80	78	75	73	69	68	65	64	61	60
Lmax - MK1 OB	46	49	50	54	58	60	61	67	70	63	64	66	64	65	61	61	61	61
Lmax - MK2 OB	48	51	54	53	58	57	58	65	68	62	62	66	66	65	62	58	60	57
Lmax - MK3 OB	43	46	48	51	53	55	56	65	67	64	63	66	66	65	62	58	59	57

Lmax – Inbound Direction

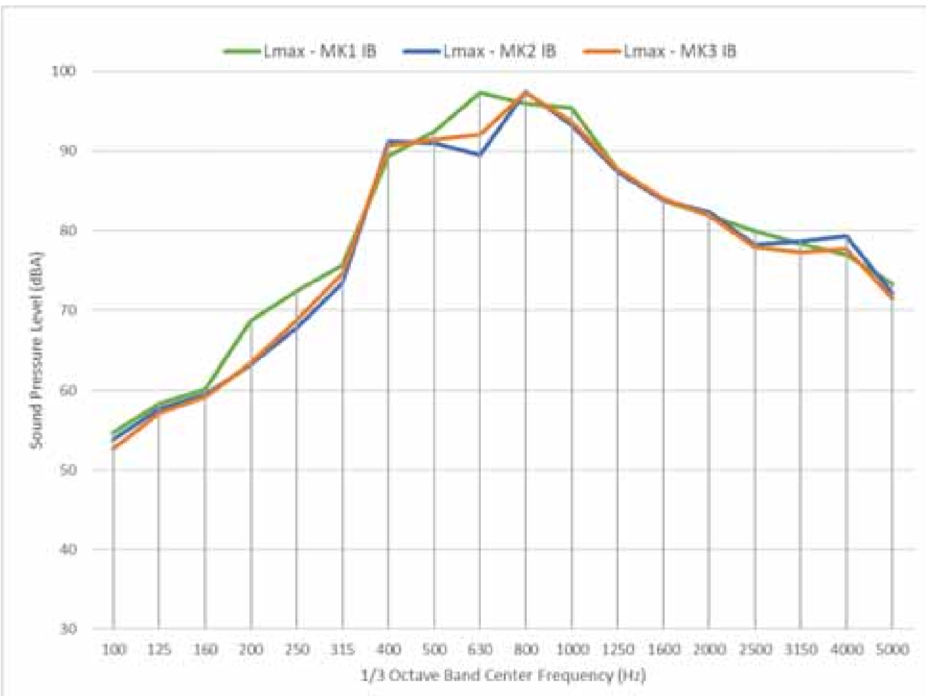


Lmax – Outbound Direction

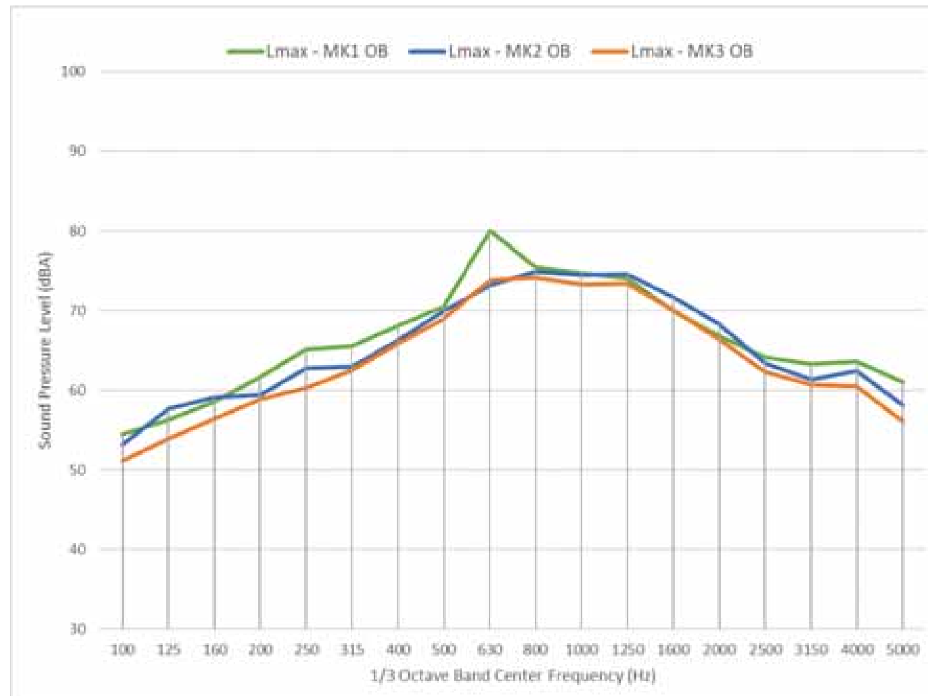
3.6 Average Spectral Sound Pressure Levels (dBA) at Location 6 – Expo Line at Stewardson Way & Lookout Greenspace

Parameter & Train Type	1/3 Octave Band Center Frequency (Hz)																	
	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
Lmax - MK1 IB	55	58	60	69	72	76	89	92	97	96	95	88	84	82	80	78	77	73
Lmax - MK2 IB	54	58	60	63	68	73	91	91	90	98	93	87	84	82	78	79	79	72
Lmax - MK3 IB	53	57	59	63	69	75	91	91	92	97	94	88	84	82	78	77	78	71
Lmax - MK1 OB	54	56	59	62	65	66	68	70	80	75	75	74	70	67	64	63	64	61
Lmax - MK2 OB	53	58	59	59	63	63	66	70	73	75	74	75	72	68	63	61	62	58
Lmax - MK3 OB	51	54	56	59	60	63	66	69	74	74	73	73	70	66	62	61	61	56

Lmax – Inbound Direction



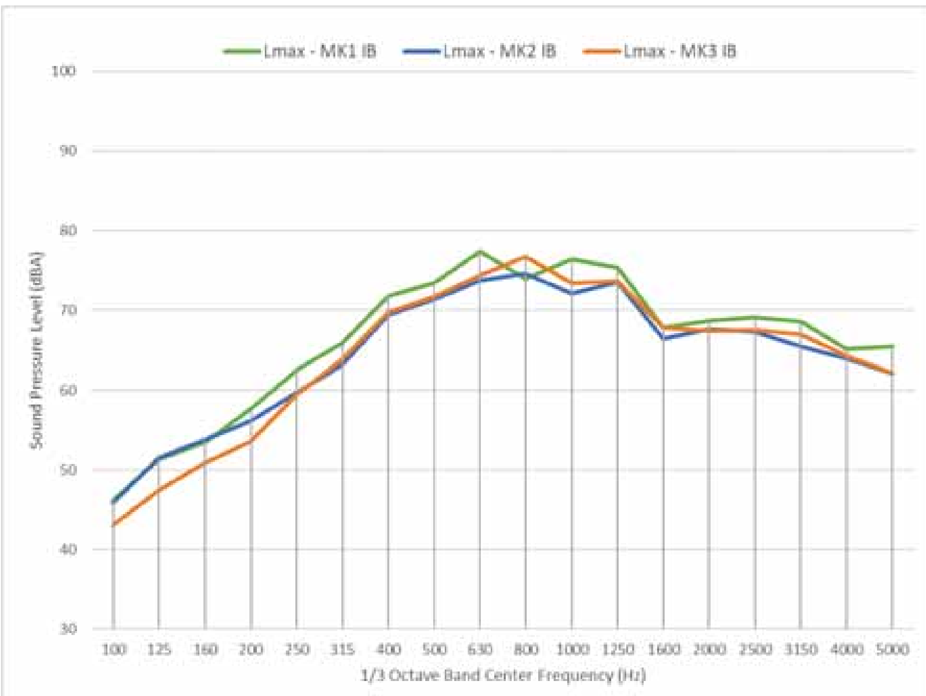
Lmax – Outbound Direction



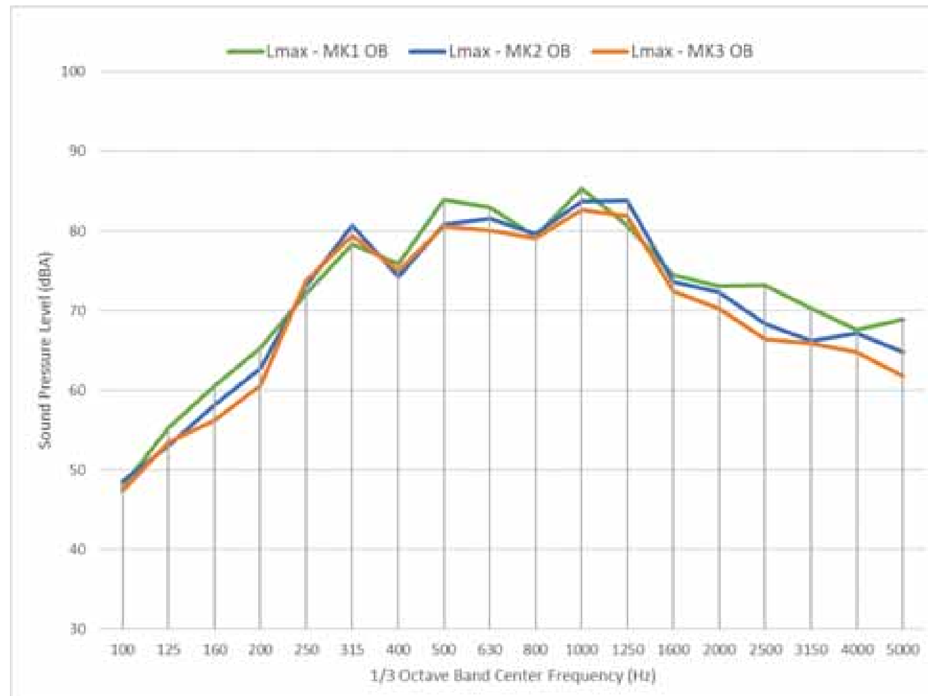
3.7 Average Spectral Sound Pressure Levels (dBA) at Location 7 – Expo Surrey Line at 132 St. & 112 Ave.

Parameter &	1/3 Octave Band Center Frequency (Hz)																	
Train Type	**100**	**125**	**160**	**200**	**250**	**315**	**400**	**500**	**630**	**800**	**1000**	**1250**	**1600**	**2000**	**2500**	**3150**	**4000**	**5000**
Lmax - MK1 IB	46	51	53	58	63	66	72	73	77	74	76	75	68	69	69	69	65	65
Lmax - MK2 IB	46	52	54	56	60	63	69	71	74	75	72	73	66	68	67	65	64	62
Lmax - MK3 IB	43	47	51	54	60	64	70	72	74	77	73	74	68	67	68	67	64	62
Lmax - MK1 OB	48	55	61	65	72	78	76	84	83	79	85	81	74	73	73	70	68	69
Lmax - MK2 OB	49	53	58	63	73	81	74	81	82	80	84	84	74	72	68	66	67	65
Lmax - MK3 OB	47	54	56	61	74	79	75	81	80	79	83	82	72	70	66	66	65	62

Lmax – Inbound Direction



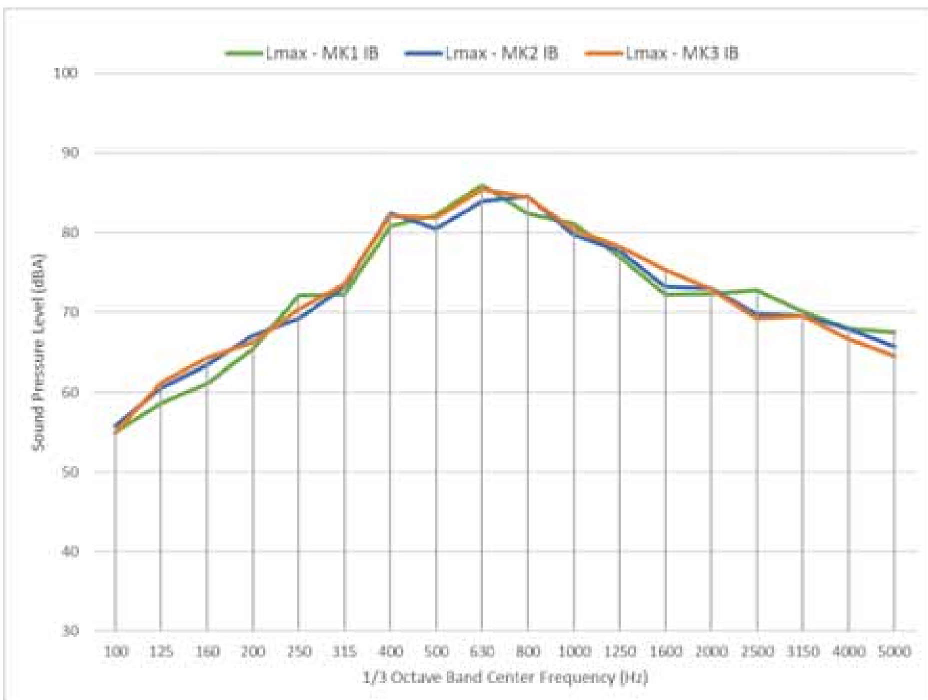
Lmax – Outbound Direction



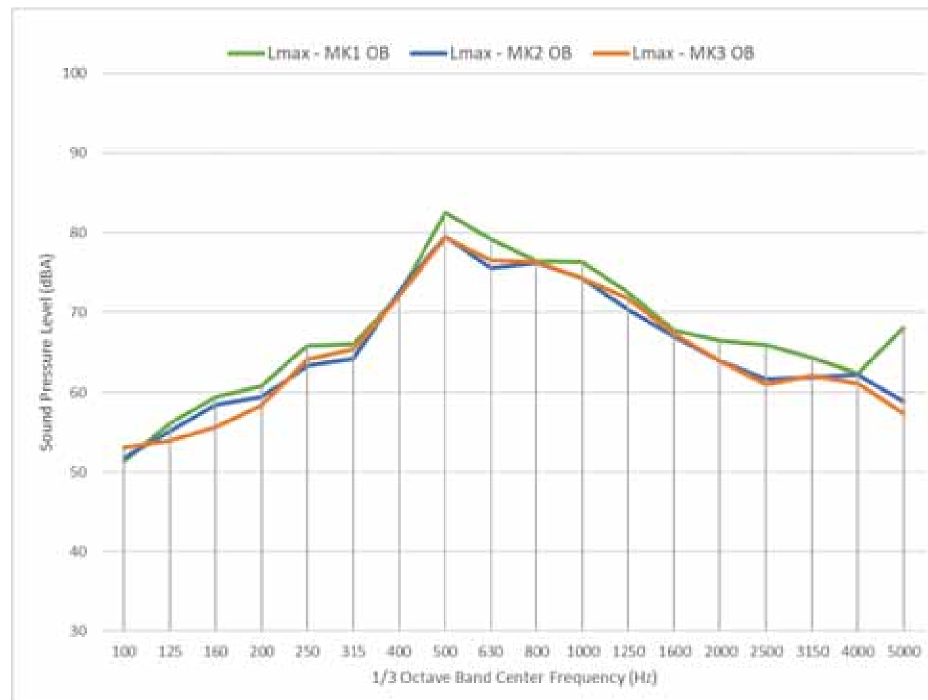
3.8 Average Spectral Sound Pressure Levels (dBA) at Location 8 – Expo Surrey Line at 134a St. & 105 Ave.

Parameter &	1/3 Octave Band Center Frequency (Hz)																	
Train Type	**100**	**125**	**160**	**200**	**250**	**315**	**400**	**500**	**630**	**800**	**1000**	**1250**	**1600**	**2000**	**2500**	**3150**	**4000**	**5000**
Lmax - MK1 IB	55	59	61	65	72	72	81	82	86	82	81	77	72	72	73	70	68	67
Lmax - MK2 IB	56	61	63	67	69	73	82	81	84	85	80	78	73	73	70	70	68	66
Lmax - MK3 IB	55	61	64	66	70	73	82	82	85	84	80	78	75	73	69	69	67	65
Lmax - MK1 OB	51	56	59	61	66	66	72	82	79	76	76	72	68	66	66	64	62	68
Lmax - MK2 OB	52	55	58	59	63	64	72	80	76	76	74	70	67	64	62	62	62	59
Lmax - MK3 OB	53	54	56	58	64	65	72	79	77	76	74	72	67	64	61	62	61	57

Lmax – Inbound Direction



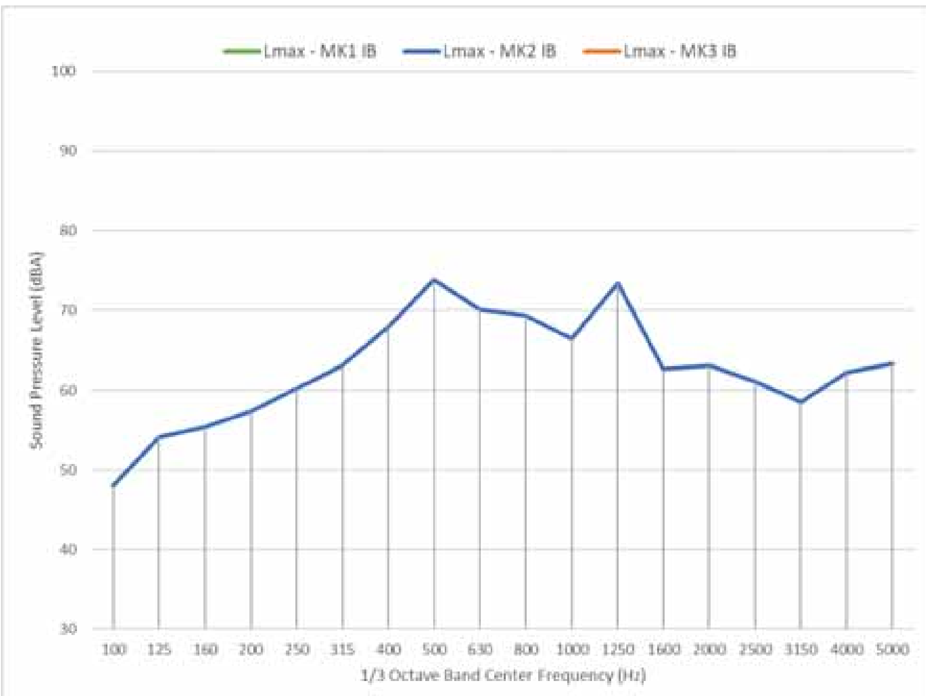
Lmax – Outbound Direction



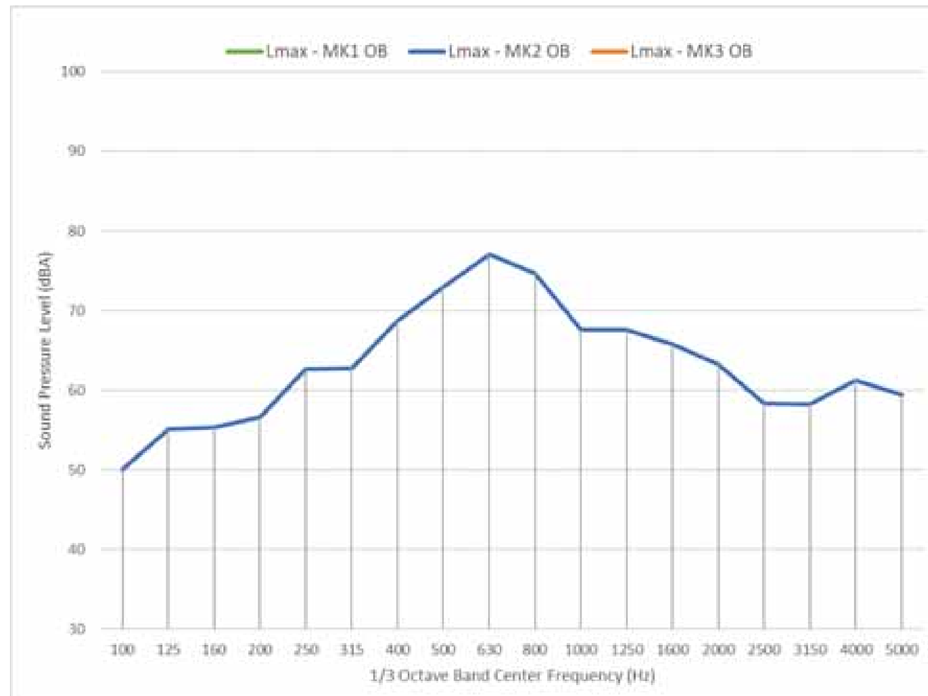
3.9 Average Spectral Sound Pressure Levels (dBA) at Location 9 – Millennium Line at N. Grandview Hwy. west of Slocan St.

Parameter &	1/3 Octave Band Center Frequency (Hz)																	
Train Type	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
Lmax - MK1 IB																		
Lmax - MK2 IB	48	54	55	57	60	63	68	74	70	69	66	73	63	63	61	59	62	63
Lmax - MK3 IB																		
Lmax - MK1 OB																		
Lmax - MK2 OB	50	55	55	57	63	63	69	73	77	75	68	68	66	63	58	58	61	59
Lmax - MK3 OB																		

Lmax – Inbound Direction



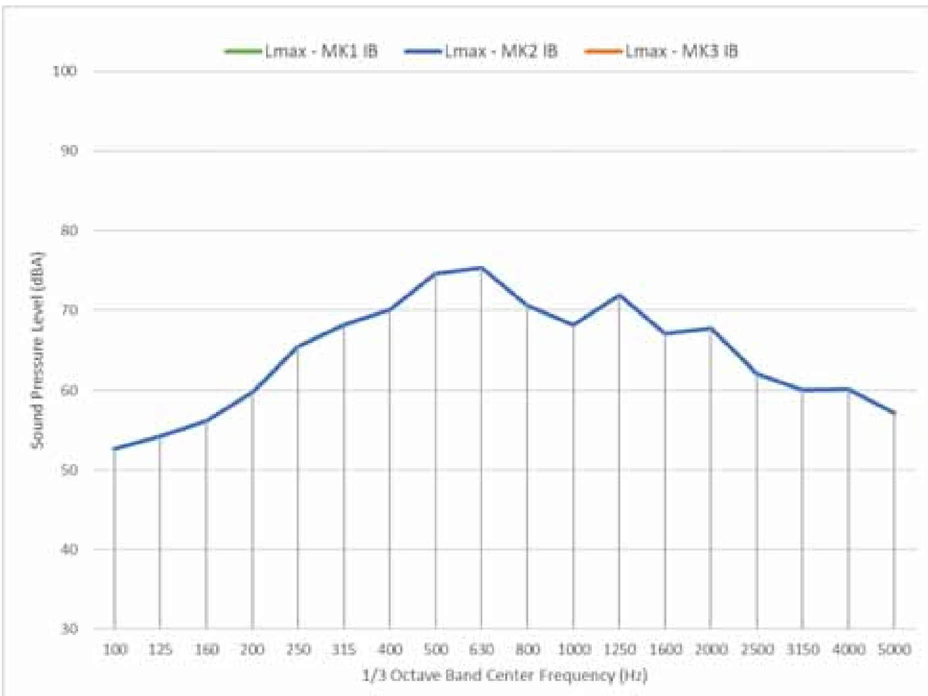
Lmax – Outbound Direction



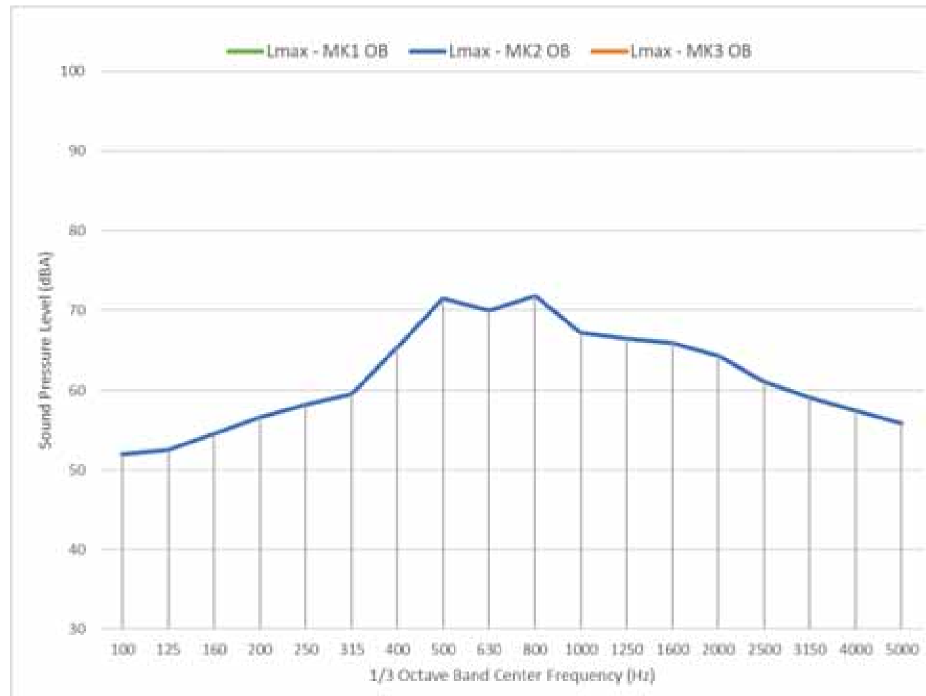
3.10 Average Spectral Sound Pressure Levels (dBA) at Location 10 – Millennium Line at Lougheed Hwy. & Gamma Ave.

Parameter & Train Type	1/3 Octave Band Center Frequency (Hz)																	
	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
Lmax - MK1 IB																		
Lmax - MK2 IB	53	54	56	60	65	68	70	75	75	71	68	72	67	68	62	60	60	57
Lmax - MK3 IB																		
Lmax - MK1 OB																		
Lmax - MK2 OB	52	53	55	57	58	59	65	71	70	72	67	66	66	64	61	59	58	56
Lmax - MK3 OB																		

Lmax – Inbound Direction



Lmax – Outbound Direction



3.11 Average Spectral Sound Pressure Levels (dBA) at Location 11 – Millennium Line at Lougheed Hwy. west of Bell Ave.

Parameter & Train Type	1/3 Octave Band Center Frequency (Hz)																	
	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
Lmax - MK1 IB (6 cars)	58	59	64	69	73	75	82	90	80	77	73	72	69	71	69	66	66	64
Lmax - MK2 IB (2 cars)	55	57	61	68	69	73	78	80	73	75	71	71	66	69	66	63	65	64
Lmax - MK3 IB (4 cars)	58	59	60	69	70	73	77	78	77	81	74	76	70	71	69	65	65	65
Lmax - MK1 OB (6 cars)	52	56	57	59	65	66	66	72	73	72	70	66	65	64	62	59	58	59
Lmax - MK2 OB (2 cars)	53	54	56	58	62	64	67	74	72	70	66	66	64	63	60	59	63	60
Lmax - MK2/3 OB (4 cars)	55	56	58	61	64	67	67	73	72	76	70	69	68	67	63	61	59	56

Lmax – Inbound Direction

Lmax – Outbound Direction

3.12 Average Spectral Sound Pressure Levels (dBA) at Location 12 – Evergreen Line at North Rd & Foster Ave.

Parameter & Train Type	1/3 Octave Band Center Frequency (Hz)																	
	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
Lmax - MK1 IB																		
Lmax - MK2 IB	51	54	56	58	66	59	63	67	63	66	66	64	62	63	63	62	60	57
Lmax - MK3 IB																		
Lmax - MK1 OB																		
Lmax - MK2 OB	51	54	56	60	61	63	69	72	68	73	73	76	68	71	68	66	67	67
Lmax - MK3 OB																		

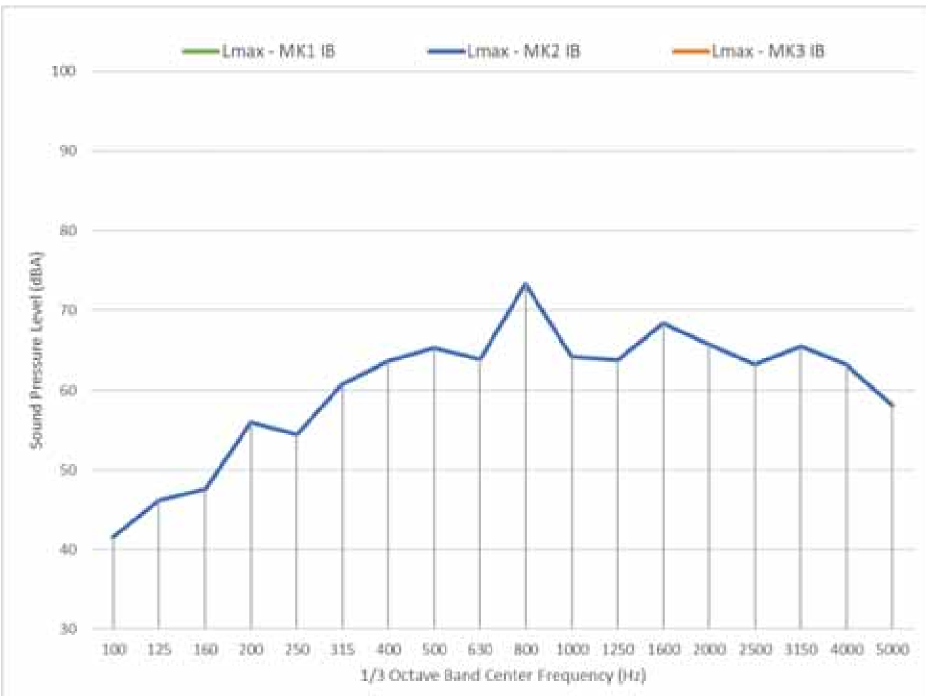
Lmax – Inbound Direction

Lmax – Outbound Direction

3.13 Average Spectral Sound Pressure Levels (dBA) at Location 13 – Evergreen Line at Clark St. & Queens St.

Parameter & Train Type	1/3 Octave Band Center Frequency (Hz)																	
	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
Lmax - MK1 IB																		
Lmax - MK2 IB	42	46	48	56	55	61	64	65	64	73	64	64	68	66	63	65	63	58
Lmax - MK3 IB																		
Lmax - MK1 OB																		
Lmax - MK2 OB	44	46	48	54	59	64	65	68	64	77	76	65	68	68	65	68	67	61
Lmax - MK3 OB																		

Lmax – Inbound Direction

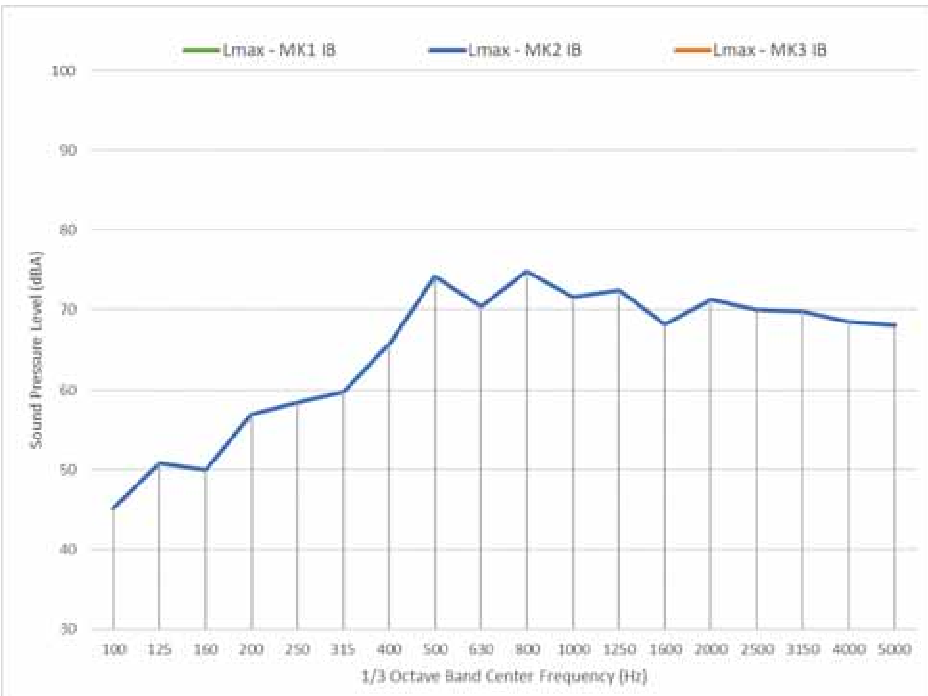


Lmax – Outbound Direction

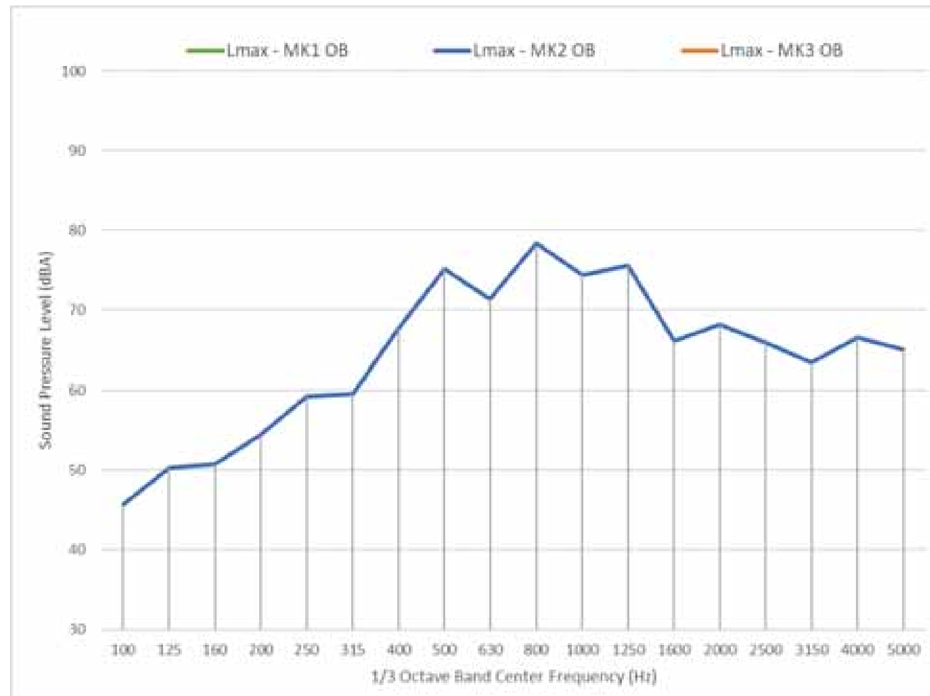
3.14 Average Spectral Sound Pressure Levels (dBA) at Location 14 – Evergreen Line at Aberdeen Ave. west of Lansdowne Dr.

Parameter &	1/3 Octave Band Center Frequency (Hz)																	
Train Type	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
Lmax - MK1 IB																		
Lmax - MK2 IB	45	51	50	57	59	60	66	74	70	75	72	72	68	71	70	70	69	68
Lmax - MK3 IB																		
Lmax - MK1 OB																		
Lmax - MK2 OB	46	50	51	54	59	60	68	75	71	78	74	76	66	68	66	63	67	65
Lmax - MK3 OB																		

Lmax – Inbound Direction



Lmax – Outbound Direction



4.0 RESULTS SUMMARY

4.1 Summary of results with speed and distance corrections

Table 17 provides an overall summary of all maximum passby noise measurement results, along with the horizontal distances from the measurement point to the track centreline and the typical train speeds at each location from the BCRTC test train data on November 5th, 2020. Summary results are the average for all train types at each location. Also shown in Table 17 is a set of results that have been corrected for speed and distance, to enable direct comparison between the results at each measurement location as if all measurements had been taken at 15 m distance and with a train speed of 80 km/h. Noting the close proximity of the measurement points to the source line, the distance correction factor applied is $10 \cdot Log_{10}$(distance/15). The speed correction factor applied is $30 \cdot Log_{10}$(speed/80), under the assumption that rolling noise is dominant.

Table 17 LAmax Results Summary with Speed and Distance

Ref.	Location Description	Distance from Track Centreline (m)		Typical Speed (km/h)		Measured Average L_{AFmax} (dBA)		L_{AFmax} (dBA) corrected to 15m		L_{AFmax} (dBA) corrected to 15m and 80 km/h	
		IB	OB	IB	OB	IB	OB	IB	OB	IB	OB
1	Quebec St. at Expo Blvd	11.2	15.3	65[1]	50	83.3	76.2	82.0	76.3	84.7	82.4
2	N Grandview Hwy at McLean Drive	20.2	24.2	80	80	82.7	80.3	84.0	82.4	84.0	82.4
3	East 27th Avenue at Penticton Avenue	18.8	14.8	70	77	80.5	88.7	81.5	88.6	83.2	89.1
4	Central Park at South Burnaby Lawn Bowling	17	21	80	80	83.1	76.9	83.6	78.4	83.6	78.4
5	Prenter St at Hawthorne St	28.1	32.1	77	79	84.6	73.6	87.3	76.9	87.8	77.1
6	Stewardson Way – Lookout Green Space	15.2	19.2	80	80	100.8	81.1	100.9	82.2	100.9	82.2
7	132 St at 112 Ave	19.4	15.0	80	80	81.5	89.2	82.6	89.2	82.6	89.2
8	105 Ave at 134a St	17.0	21.7	70	70	89.7	84.5	90.2	86.1	92.0	87.8
9	N Grandview Hwy west of Slocan St	22.7	27.2	80	80	79.1	80.4	80.9	83.0	80.9	83.0
10	Lougheed Hwy at Gamma Ave	27.9	32.6	80	80	80.5	77.6	83.2	81.0	83.2	81.0
11	Lougheed Hwy at Bell Ave.	14.0	18.6	80	80	85.2	78.7	84.9	79.6	84.9	79.6
12	North Rd at Foster Ave.	17.7	13.1	80	80	74.6	81.7	75.3	81.1	75.3	81.1
13	Clarke St at Queens St.	20.6	16	65	65	76	79.6	77.4	79.9	80.1	82.6
14	Aberdeen Avenue at Lansdowne	10.5	15.3	80	80	81.6	82.8	80.1	82.9	80.1	82.9

1. *Speeds historically 50 km/hr or 65 km/hr depending on if a go-slow order has been in place*

Maximum sound levels, corrected to 15m distance and 80 km/h speed, range from 75 dBA up to 101 dBA with a median value of 83 dBA. The clear outlier in the presented data is the inbound sound level of 101 dBA at Location 6 along Stewardson Way. Measured noise levels were significantly higher than at any other testing location indicating the track in this area was in poor condition at the time of the measurements. SLR understands that rail was replaced on the inbound track soon after these measurements were completed.

The inbound track at Location 8 on 134a Street also exhibited relatively high passby sound levels compared to other locations indicating potential poor track conditions.

The location with the lowest measured noise levels corrected to 15m distance and 80 km/h speed was on the Evergreen Line on the inbound track at Location 12 on North Road.

4.2 Summary of results alongside in-car noise levels

Table 18 provides an overall summary of all measurement results, alongside the corresponding in-car noise level measured by the BCRTC test train on November 5th, 2020. Summary results are the average for all train types at each location, distance corrected to 15 m (no speed corrections have been applied). No test train in-car noise data was collected for the Evergreen Line. While the test train travelled at the typical speed past the majority of the measurement locations, test train speeds were atypical (less than usual) at four locations as identified in Table 18, these data points cannot be compared to the external measured noise levels.

Table 18 Results Summary Alongside In-Car Noise Levels

Ref.	Location Description	Track Section		Typical Speed (km/h)		In-Car Noise Level (dBA)		Passby L_{AFmax} (dBA) corrected to 15m	
		IB	OB	IB	OB	IB	OB	IB	OB
1	Quebec Street at Expo Boulevard	456	1021	65	50	80[1]	79	82.0	76.3
2	N Grandview Hwy at McLean Drive	354	919	80	80	82	86	84.0	82.4
3	East 27th Avenue at Penticton Avenue	233	798	70	77	78[1]	80[1]	81.5	88.6
4	Central Park / South Burnaby Lawn Bowling Club	111	677	80	80	81	79[1]	83.6	78.4
5	Prenter St at Hawthorne St	2226	2507	77	79	84	83	87.3	76.9
6	Stewardson Way – Lookout Green Space	2083	2365	80	80	94	87	100.9	82.2
7	132 St at 112 Ave	4132	4308	80	80	82	83	82.6	89.2
8	105 Ave at 134a St	4069	4245	70	70	85	85	90.2	86.1
9	N Grandview Hwy west of Slocan St	5526	6163	80	80	82	88	80.9	83.0
10	Lougheed Hwy at Gamma Ave	5349	5985	80	80	85	84	83.2	81.0
11	Lougheed Hwy at Bell Avenue	5072	5706	80	80	81	84	84.9	79.6
12	North Rd at Foster Avenue	7406	7825	80	80	n/a	n/a	75.3	81.1
13	Clarke St at Queens St	7244	7664	65	65	n/a	n/a	77.4	79.9
14	Aberdeen Avenue at Lansdowne	7093	7515	80	80	n/a	n/a	80.1	82.9

1. *Test train speeds on day of measurement not representative at this location*

In-car sound levels corresponding to the measurement locations ranged from 79 dBA to 94 dBA. As for the external noise levels, the highest level in-car was measured on the in-bound track at location 6 on Stewardson Way. Generally, the in-car noise data does give a reasonable indication of track locations in poor condition. However, it is evident that relying on the in-car noise data alone may not give the full picture of external noise levels which exhibit a much higher range of results when measured externally. There is a ~25 dB difference between corrected highest and lowest external measured passby maximum level whereas the in-car data shows a range of only 15 dB at the same points. At the time of these measurements in-car data was not available for the quietest location measured externally on the Evergreen Line, however historical in-car measurements indicate that the minimum (best case) in-car noise level is 76-77 dBA at 80 km/hr.

It is concluded that ongoing external measurements at representative locations are required to supplement the in-car noise data as implementation of the recommended noise mitigation program progresses.