Canadian Transportation Agency

Office des transports du Canada

Railway Noise Measurement and Reporting Methodology

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Summary of the Railway Noise Measurement and Reporting Methodology

The Canadian Transportation Agency is authorized, pursuant to the *Canada Transportation Act* (CTA), to resolve disputes related to noise and vibration from the construction and operation of railways under its jurisdiction.

In October 2008, the Agency published its *Guidelines for the Resolution of Complaints Concerning Railway Noise and Vibration*. The Guidelines set out the collaborative measures that parties must follow before the Agency will investigate a complaint. They also set out the elements the Agency will consider in determining whether a railway company is in compliance with the noise provisions of the CTA and the process to be followed in filing a complaint and the information to be submitted. The Guidelines can be accessed on the Agency's Web site at: www.otc-cta.gc.ca/eng/rail-complaints.

Different methods exist for the assessment of many different types of noise and in different noise environments. This *Railway Noise Measurement and Reporting Methodology* (Methodology) was prepared to guide railway companies, citizens, and municipalities conducting a railway noise assessment in the course of a noise dispute before the Agency. A complement to the Guidelines, the Methodology sets out procedures for the assessment of noise levels from existing rail installations and installations under construction. The Methodology may be used by the Agency in reviewing noise assessment submissions provided in support of cases for adjudication.

Section 1 reviews elements of sound, presents the appropriate sound descriptors for different types of sound, and describes the different types of noise associated with rail constructions and operations.

Section 2 presents three methods that have been tailored to suit the complexity of railway noise issues under dispute.

Method A is a quick and easy calculation method designed for simple situations with few noise sources.

Methods B and C are recommended for rail activities that are complex in nature with multiple noise sources. Method B focuses on using noise prediction to assess impacts while Method C uses a combination of field measurements and model predictions to assess noise.

Section 4 provides definitions of terms used in the assessment of sound.

Whether using the simplified or the most comprehensive of the three recommended methods, the assessment will follow the general pattern found in the flow chart below.

Flow Chart of Suggested Procedures for the Determination and Submission of a Railway Noise Assessment

Introduction and Background

- Identify and describe the railway noise source of dispute.
- Describe the background (ambient) sound environment (not associated with the railway operation(s) under dispute).
- Measure and analyze the existing ambient sound environment (when using Method A, ambient sound may be estimated).

↓

Assessment of Railway Activities

- Measure/predict sound levels of the railway dispute using Method A, B, or C in Section 2. General methods include an absolute assessment and/or relative change assessment.
- Include model input parameters and assumptions, and example calculations, if applicable.

↓

Assessment of Impacts

- For absolute assessment compare to ambient environment and various criteria/guidelines.
- For the relative change method compare the change from one scenario to another and report the change in sound level.
- Analyze the measurements/predictions.
- Provide a discussion on results.

↓

Conclusions and Recommendations

- Describe conclusions and recommendations based on the assessment of rail activities and their impacts.
- Depending on the recommendations, describe any mitigation proposed and the expected results.
- For any proposed mitigation, consideration should be given to their technical, financial, and operational feasibility, including operating and maintenance costs.

The noise report should clearly describe the noise receptor(s), the railway noise which is in dispute, the surrounding area, the ambient or background noise, an explanation of the prediction method used (if applicable), and all input parameters. If field measurements were taken, these should appear in tabular form in an appendix.

1.0 Introduction

In June 2007, Parliament enacted amendments to the *Canada Transportation Act* (CTA) authorizing the Canadian Transportation Agency, a quasi-judicial administrative tribunal of the federal government, to resolve complaints related to noise and vibration from the construction or operation of railways under its jurisdiction.

In October 2008, the Agency published its *Guidelines for the Resolution of Complaints Concerning Railway Noise and Vibration* (Guidelines). The Guidelines were developed to help persons, municipal administrations and railway companies to resolve railway noise and vibration issues. The Guidelines set out:

- the collaborative measures that parties must follow before the Agency conducts an investigation or a hearing into a complaint;
- the elements the Agency considers in determining whether a railway company is in compliance with the noise or vibration provisions of the CTA; and
- how to file a complaint, list the information to be submitted, as well as the process to be followed.

The Guidelines apply to railway companies that operate under federal jurisdiction as well as to public passenger service providers, including urban transit authorities. They apply to all forms of railway noise and vibration produced during the construction or operation of a railway. This includes noise from passing trains, idling locomotives, shunting, and from the compression or “stretching” of trains.

The Guidelines address noise and vibration disputes regarding existing railway operations and infrastructure under construction. They can be accessed on the Agency’s Web site at www.otc-cta.gc.ca/eng/rail-complaints.

Before conducting a noise assessment of a federally-regulated railway, the reader is directed to the Guidelines. Among other aspects, the Guidelines describe the collaborative measures that must be undertaken to satisfy the requirements of the CTA, the process for filing a rail noise complaint with the Agency, and the elements that will be used in resolving noise complaints.

For railway construction projects that require Agency approval pursuant to subsection 98(1) of the CTA, railway companies must evaluate the potential environmental impacts – including noise and vibration issues. Before authorizing the construction, the Agency must be satisfied that proposed construction will not likely create significant adverse environmental impacts.

Numerous methods exist for the assessment of noise from different sources and in different noise environments. The present *Rail Noise Measurement and Reporting Methodology* (Methodology) was prepared to guide railway companies, citizens, or municipalities conducting a noise assessment in the course of a noise investigation before the Agency. The Methodology is meant to bring clarity and consistency in the assessment of rail noise by setting out the procedures to be followed in assessing rail noise. The Agency may use the Methodology in reviewing rail noise assessments that are submitted in support of cases referred to adjudication.

Many standards and guidelines have been developed regarding noise. Municipalities and provinces have developed standards of acceptable noise levels that have been incorporated in by-laws, policies, or guidelines. The Agency may take these standards and guidelines into account in its deliberations, but is not bound by them. The Agency has not established a standard of acceptable railway noise levels but determines what is reasonable on a case-by-case basis. What is reasonable in some circumstances may not be reasonable in other circumstances.

It should be noted that train whistles, which are blown for safety reasons to warn of a train's passage, are a legal requirement of the *Canadian Rail Operating Rules* (CROR) administered by Transport Canada (TC) (TC 2008). These requirements are described in Rule 14 of the CROR which can be accessed on TC Web site at www.tc.gc.ca/rail.

1.1 Sound Basics

Sound, in its simplest form, is a succession of vibrating waves or oscillations of pressure waves (energy) transmitted in a fluid medium, such as air. These pressure waves cause the ear drum to vibrate and create the sensation of sound.

Noise is defined as unwanted sound. For example, a certain type of music can be a pleasing sound to one person and annoying noise to another person. Acousticians generally use both noise and sound interchangeably.

Sound waves are characterized by their generic properties such as frequency, wavelength, time period, amplitude (intensity), speed, and direction. Air vibrations/sounds with frequencies in the approximate range of 20 to 20,000 hertz are generally detectable by humans. The decibel (dB) is a logarithmic ratio of a value to a reference pressure level of 20 μPa.[1] However, in practice the reference level is generally left out but it is implied.

A sound level meter is the most commonly used instrument to measure sound levels. The simplest sound level meter is comprised of a microphone, a frequency-weighting filter, an energy level converter (root-mean-square, or rms detector), and a logarithmic readout. More sophisticated sound-level meters incorporate standardized octave-band or fractional-octave-band filters and provide additional metrics and analytical capabilities.

[1] 20 micropascals is the lowest sound pressure level that can be detected by an average person.

The frequency content of a sound signal can be assessed by various types of frequency analyses to determine the relative contributions of the frequency components to the total sound. The combined effects of the different frequencies on people, perceived as noise, can also be approximated by simple frequency weightings. In order to represent this weighting, a decibel symbol with a suffix for example dBA and dBC is used.

The letters “A” or “C” following the abbreviation “dB” (dBA or dBC) designate the frequency-response function that filters the sounds that are picked up by the microphone in the sound level meter. Unweighted or unfiltered sound is represented by “dB” without a suffix or “dBZ”. A frequency-response function or weighting characteristic (meaning that some frequencies are given more weight or importance than others) are used to emphasize or de-emphasize sounds of certain pitches relative to others. Humans are generally less sensitive to low frequency sounds. The A-weighting network accounts for the variation in humans by filtering out the low frequency sounds. The C-weighting is sometimes used to assess low frequency noise impacts and has nearly a flat frequency response with minimum filtering. Selection of a sound level metric and of measurement instruments generally depends upon the application.[2] Table 1 lists examples of typical noise levels perceived by the human ear.

Table 1: Typical Noise Levels*

Noise Source	Sound Level (dBA)
Jet taking off at 60 m	120
Hand-held circular saw at 1 metre	115
Jet taking off at 600m	100
Electric lawn mower at 1 metre	80-90
Hedge clippers at 1 metre	85
Coffee mill at 1 metre	75-79
Loud singing at 1 metre	75
Sewing machine at 1 metre	70-74
Passenger car 60 km per hour at 20 metres	65

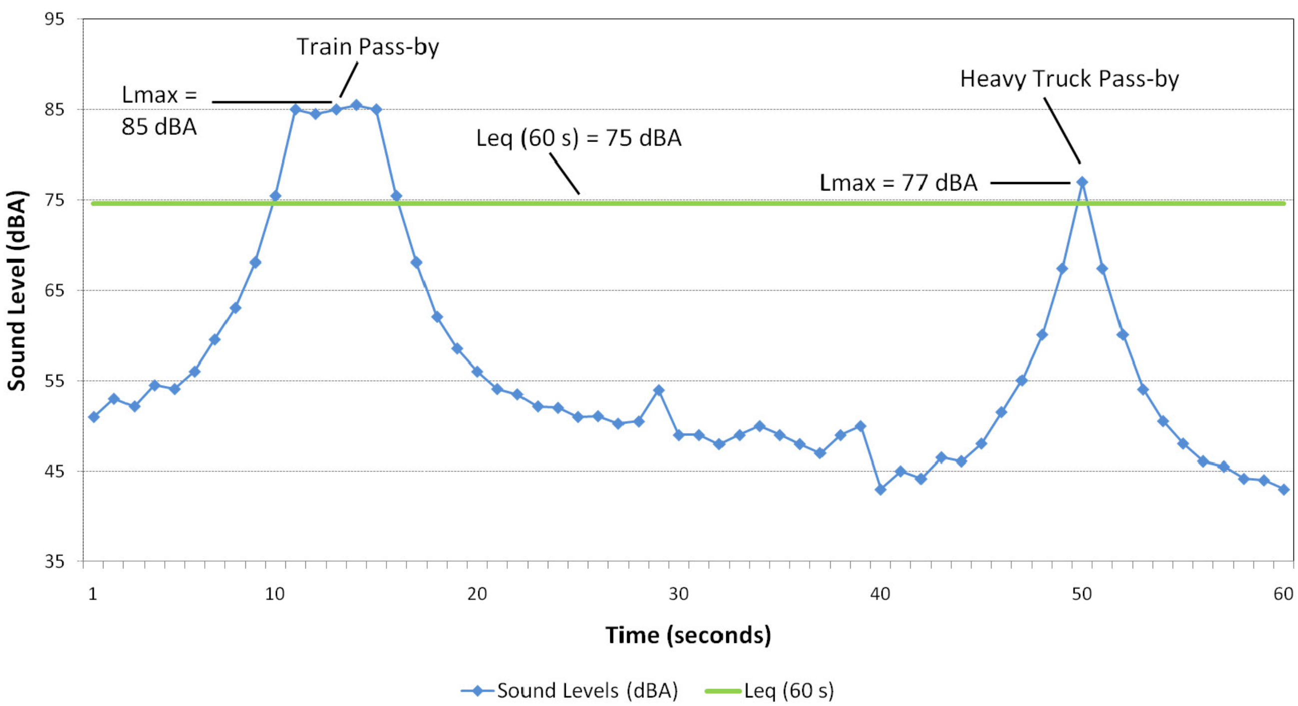
[2] The most widely accepted metric used for most types of railway sounds is the dBA as it approximates the response of human ears to railway noise.

Noise Source	Sound Level (dBA)
Hair dryer at 1 metre	58-64
Typical conversation at 1 metre	55
Hair clipper at 1 metre	50
Bedroom	35

* Source of most of these noise levels: the Canadian Centre for Occupational Health and Safety website, accessed Dec. 2010 (CCOHS 2010) and Alberta Energy Utilities Board (EUB) Directive 38: Noise Control, 2007 (EUB 2007).

The vast majority of noise standards are based on sound levels using energy equivalent sound exposure levels, in A-weighted decibels (L_{eq} values in dBA), over a defined time period. For example L_{eq} (24 h) is the sound exposure level over the entire 24-hour day. Some standards have a single-event noise descriptor based on the maximum noise level (L_{max}). The L_{eq} and L_{max} sound level concepts are illustrated in Figure 1. The graph shows a single locomotive pass-by and a heavy truck pass-by, over a 60 second period.

Figure 1: Example L_{eq} and L_{max}: L_{eq} and L_{max} Concepts



With a train pass-by, the L_{eq} (1 s) sound levels increase up to 85 dBA and during lulls of traffic the sound levels drop to 43-53 dBA. The heavy truck pass-by brings the L_{eq} (1 s) levels up to 77 dBA for a short period of time and the levels decrease to around 44-45 dBA. The L_{eq} (60 s) (energy equivalent sound exposure level over a 60 second period) is calculated to be 75 dBA. The L_{max} for the train pass-by is 85 dBA. This example demonstrates how single noise events such as a train pass-by can dominate the L_{eq} value.

To account for increased annoyance of noise during the night, the U.S. Environmental Protection Agency (U.S. EPA) developed a Day-Night sound level metric expressed as L_{dn} (EPA, 1974). The L_{dn} is similar to the L_{eq} (24 h) sound level, with an additional 10 dB penalty applied to the night hours (10 pm to 7 am). The result is an L_{dn} noise metric that is generally higher than the cumulative L_{eq} for the same 24-hour interval (provided that the night-time hourly sound levels are closer to the day-time sound levels, otherwise the penalty will not be significant).

Sound levels are based on a logarithmic scale and therefore sound levels cannot be added or subtracted directly. For example, if one locomotive generates a sound level of 80 dBA and a second identical locomotive is placed beside the first one, the combined sound level would be 83 dBA and not 160 dBA. Table 2 demonstrates a simplified method to add sound levels to an accuracy of about 1 dB.

Table 2: Simplified Decibel Addition

Numerical difference between two noise levels (dB)	Add the following number to the higher noise level
0 – 1 dB	3
2 – 3 dB	2
4 – 9 dB	1
10 dB or more	0

Generally speaking, when the difference is 10 dB or more, no adjustment is necessary because the total contribution of the lower sound level will be insignificant compared to the higher sound level.

Two other aspects of railway sound are:

- the low frequency noise[3] emitted by diesel locomotives; and
- high-level intensive impulse noise due to rail car coupling/shunting and trains with multiple rail cars stopping and starting.

Such high intensity sounds may excite structures which could be perceived as building vibration.

[3] Low Frequency Noise is sometimes referred to as LFN.

Section 4 contains further explanations of technical terms used in this document.

1.2 Types of Sound Signals

Sound signals are generally classified in the following categories:

a. steady sound levels (such as ventilation equipment associated with railway infrastructures);

b. steady, but intermittent sound levels (such as idling of trains on a main track);

c. time-varying sound (such as individual pass-bys or several pass-bys over a specific time period); and

d. impulsive sound signals that may include one or more impulses (such as train shunting, coupling, stopping, starting, etc.).

The type of sound has a bearing on how it is to be measured, what type of sound-level meter setting should be used, and what descriptors and other data should be presented. Figures 2 and 3 illustrate typical classifications of sound level events: steady, intermittent, time-varying, and impulsive sounds.

Figure 2: Typical Classifications of Sound Events – Steady, Intermittent, Time-Varying and Impulsive Sounds

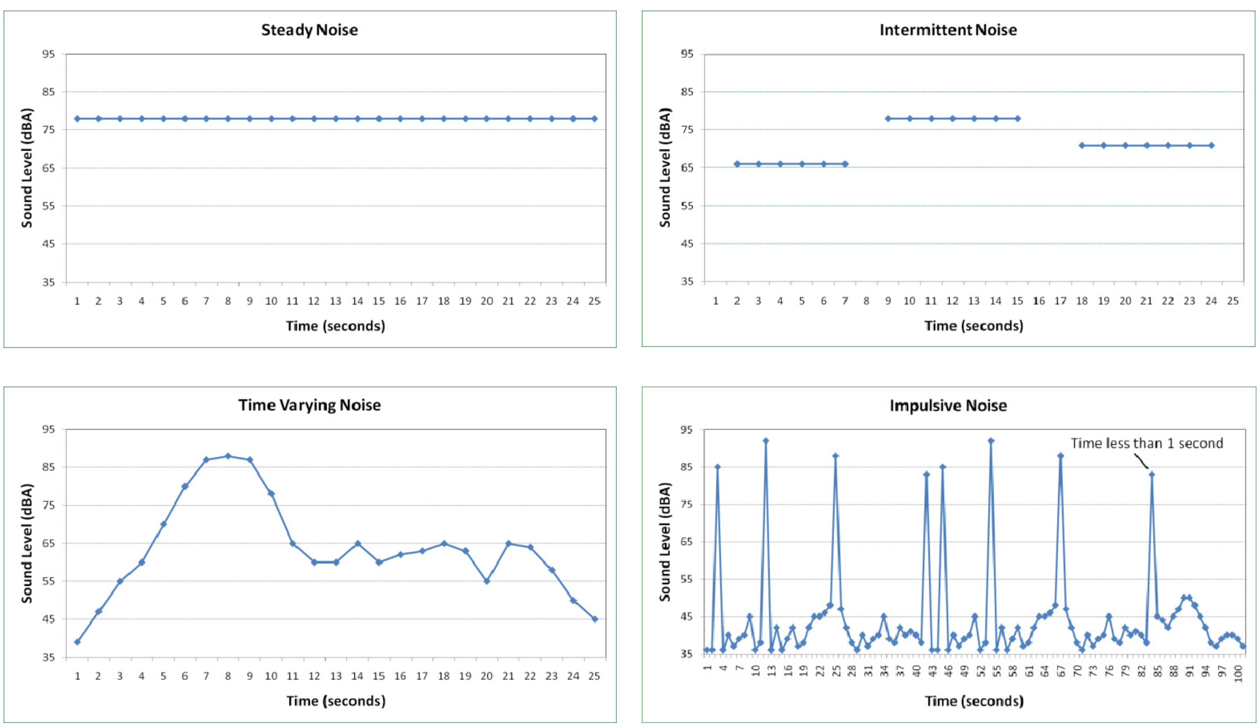
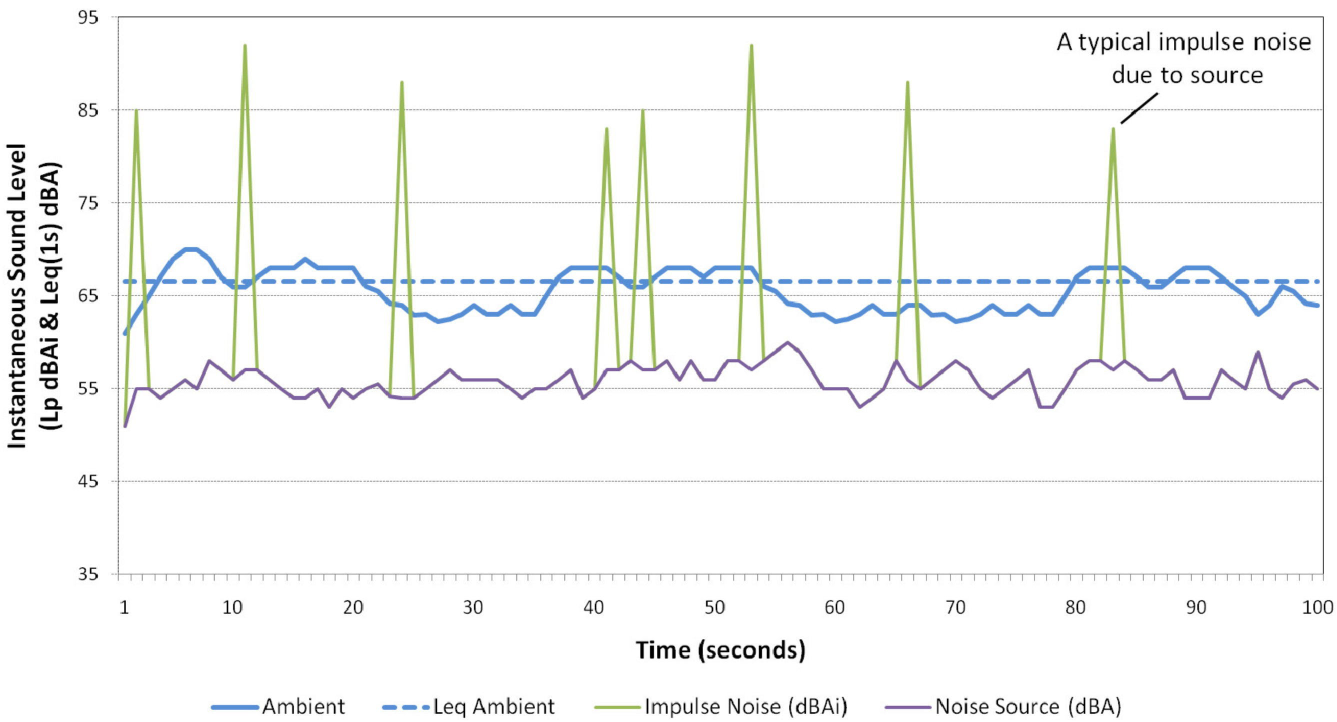


Figure 3: A Typical Time History of Impulsive Sound Signals



1.3 Sound Level Descriptors/Metrics for Non-Impulsive Sound Events

Typical sound level descriptors for non-impulsive events are summarized below:

- the A-weighted Sound Level (instantaneous) for noise measurements and prediction purposes;
- the Maximum Sound Level (L_{max}) during a single event for noise measurements and prediction purposes;
- sound Exposure Level (SEL) which describes the average sound level from a single noise event for noise measurements and prediction purposes (equivalent to L_{eq} but normalized to a time base of 1 second);
- equivalent Sound Level (L_{eq}) which is an exposure based metric (time/number of events) to describe a receiver's cumulative noise exposure from all events over a specified period of time for compliance assessment purposes (e.g. 1 hour, 16 hour day, 8 hour night or 24 hour day). This is the commonly used descriptor for impact assessment purposes;
- statistical sound levels ($L_{n\%}$) to describe the percentage of times a sound level is exceeded, for example $L_{1\%}$, $L_{10\%}$, $L_{50\%}$, $L_{90\%}$, $L_{95\%}$, etc.; and

- Day-Night sound level (L_{dn}) is average equivalent A-weighted sound level during a 24-hour day, obtained after addition of 10 decibels to sound levels in the night from 10 pm to 7 am.

1.4 Sound Level Descriptors/Metrics for Impulsive Sound Events

No consensus exists regarding the criteria for the measurement and evaluation of impulse sounds. Impulse sound refers to a sound signal of short duration (generally less than one second), particularly of high intensity, abrupt onset and rapid decay, often with a rapidly changing spectral composition.

Some railway activities produce impulsive sounds. These include: the coupling of cars when assembling a train, take-up of car slack when trains start to move or immediately prior to stopping, shunting of railway cars in rail yards and on rail sidings and repair work in railway repair shops. Figure 3 above illustrates a typical time history of impulsive noise.

To evaluate possible annoyance to the public, the following measurable impulse sound level parameters may be important: peak overpressure, rise time, time-duration, impulse noise spectrum and impulse-noise energy.

Various jurisdictions rely on different standards for measurement and assessment of impulsive noise including the use of maximum unweighted *peak* dBZ_{pk} (linear), dBC_{pk}, maximum unweighted *impulse response* $dBZ_{\mathbf{i}}$ (linear), the maximum A-weighted *impulse response* $dBA_{\mathbf{i}}$ (events may be used singularly or averaged on the basis of *logarithmic averaging*).[4] Some jurisdictions simply use the dBA metric with the meter response set to the "*fast*" response; i.e. dBZ_f. The use of any one of these metrics may be considered acceptable provided that the results are also reported in $dBA_{i.}$

Additional information on impulse sound, its measurements and adjustments, can be found in CAN/CSA-ISO 1996 (CSA 2005), ANSI standard S12.7 (R2006) (ANSI 2006).

1.5 Principal Sources of Railway Noise

The principal sources of noise from railway construction activities and railway operations are described below:

1.5.1 Construction Activities

- Motorized equipment and vehicles as well as back-up alarms.
- Manual activities including welding, hammering, dropping of metal objects, etc.

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[4] In Ontario, extensive research conducted in the late1970's led to the use of this system of measuring and reporting impulse sound signals in terms of $dBA_{\mathbf{i}}$ with the possibility of using the maximum dBAi ($L_{\mathbf{max}}$ in $dBA_{\mathbf{i}}$) level or the logarithmic averaging of a specified group of impulsive events (referred to as $L_{\mathbf{LM}}$ in dBAi)

- Telecommunication equipment and warning radios around construction areas/crews.
- Railway personnel communication (including shouting).
- Prolonged and major construction projects involving rail grade separations.
- Pile driving.
- Blasting.

1.5.2 Operational Activities

- Passing-by of trains on tangential tracks.
- Train movements on curved track sections which can generate wheel squeal.
- Extended idling of locomotives on railway lines, rail sidings, or in yards.
- Trains waiting at specific or designated locations to cross another track or waiting for a signal, an inspector, or a crew change. Whistles are sounded before train movements.
- Passage of trains over rail track discontinuities such as switches, frogs, special track work, hot boxes, dragging equipment, wheel impact detectors, joints for signalization, and at-grade intersections with roads and other rail infrastructure.
- Snow clearing equipment at switches in yards and along corridors (specifically on rail lines carrying relatively high volumes of rail traffic in proximity to at-grade road crossings).
- Audible warning devices of all types, whether mounted on the train or near at-grade road crossings.
- Rail yard operations involving trains stopping and starting, assembling of trains, shunting of cars (switching), retarders, use of signalling devices, repair work.
- Intermodal yard operations, including the transfer of containers.
- Rapid succession of commuter train traffic particularly during morning and afternoon rush hours.
- Unscheduled train operations as a result of equipment or facility malfunctions requiring changes to operations, such as the rerouting of trains.

Tracks in need of repair (loose joints, rough rail, ground settlements) can increase the noise from the activities described above. Increased rail traffic can also result in increased noise.

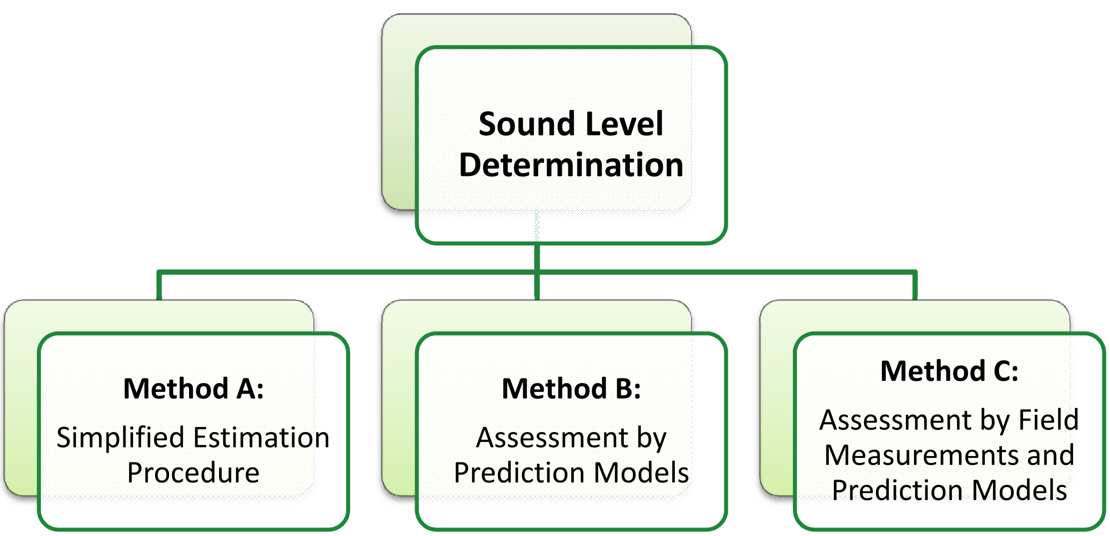
2.0 Recommended Noise Measurement and Reporting Procedures[5]

This section describes the recommended procedures for sound level assessment, measurement, and reporting. Some of the assessment procedures presented in this document require the use of specialized equipment and fairly involved technical procedures. For complex disputes that require specialized equipment and noise calculations, it is recommended that the assessment be conducted by a recognized Acoustical Specialist.

Rail noise investigations can be complex and multi-faceted in nature. In an attempt to implement a comprehensive and consistent approach for noise assessments, this document has outlined procedures for the determination of sound levels from rail activities under dispute. A flowchart shown in Figure 4 summarizes the recommended procedures. Method A is a quick and easy calculation method designed for simple situations with few noise sources. Methods B and C are recommended for rail activities that are complex in nature with multiple noise sources. Method B focuses on the use of noise predictions to assess impacts and Method C uses a combination of field measurements and model predictions to assess impacts.

When investigating a noise dispute about a specific railway operation, the preferred approach is to rely on the results of actual field measurements of the railway sound levels aided by, where deemed necessary, the use of analytical techniques. The combination of field measurements supplemented by sound level predictions will be valuable for all parties.

Figure 4: Overview of the Procedures for Sound Level Determination



[5] The recommended procedures are not intended for proposed residential development projects adjacent to existing rail facilities and for new rail vehicle sound level certification purposes.

2.1 Method A: Simplified Estimation Procedure

The Simplified Estimation Procedure is designed to provide parties with a quick and easy calculation method to predict potential noise impacts. This method is not recommended for rail activities that are complex in nature with multiple noise sources.

Step 1: Identification of Noise Receptor(s)

For measurement and determination of railway noise subject to a dispute, it is necessary to decide on the assessment location.[6] It is important that the receptor location(s) be clearly defined in any rail noise assessment and that an explanation of the land use and area zoning, including photographs of the subject area and the receptor of concern, be provided.

Receptors may include outdoor areas and/or indoor spaces in permanent residences, schools, hospitals, daycare centers, seniors' residences, and other buildings.

Step 2: Description of the Surrounding Area and Background Noise Environment

A description of the ambient or background noise (excluding the rail activity under dispute) at the noise receptor(s) must be included in the assessment. In the absence of adequate justification of background noise levels through ambient noise monitoring, the background noise may be estimated by the use of known baseline levels from areas of similar acoustical environments, previously conducted noise studies, or approximating values from Table 3 below. The estimation must include rationale to support the validity of its use. Example supporting materials include:

- a scaled area location plan identifying the noise receptor and other noise sources in the area (such as nearby industry, airplane flyovers, and a busy road or highway);
- a brief description of these nearby noise sources;
- a description of the topography and nature of the surrounding land-uses; and
- existing noise reduction measures such as an earth berm, noise wall, and upgraded windows.[7]

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[6] The number of assessment locations may be one or more locations as appropriate to support the case.
[7] If mitigation measures are in place, a noise study was likely conducted. It may be available at the municipal planning office.

Table 3: Estimation of Baseline Noise Levels

Community Type	Description [1]	Average Census Tract Population Density, Number of People Per Square Kilometre	Estimated Baseline Sound Level (dBA)		
			Ldn[2]	Leq Day[3]	Leq Night[3]
Quiet rural area	Background sounds are dominated by sounds of nature. Dwellings are more than 500 m from heavily travelled roads and/or rail lines and not subject to frequent aircraft flyovers.	27	≤ 45	≤ 45	≤ 35
Quiet suburban residential	Background sounds are dominated by sounds of nature during the night and slightly perceptible sounds from human activity during the day. Dwelling is more than 245 m away from highway.	243	50	50	40
Normal suburban residential	Sounds from human activity are audible during the day with some sounds of nature during the night. Dwelling is 120-245 m away from highway.	772	55	55	45
Urban residential	Sounds from human activity generally dominate the day and night. Dwelling is 60-120 m away from highway.	2,432	60	60	50
Noisy urban residential	Major population centre. Sounds from human activity clearly dominate during all hours of the day and night. Next to busy roads, industrial areas, rail lines, or subject to frequent aircraft flyovers. Dwelling is 30- 60 m away from highway.	7,722	65	65	55
Very noisy urban residential	Major population centre. Sounds from human activity dominate the noise environment. Next to a highway or primary rail line, or in close proximity to an airport and subject to frequent aircraft flyovers	24,324	70	70	60

[1] Highway – road with 4 or more lanes, including trucks, with a posted speed limit of 100 km/h.

[2] Ldn baseline sound levels were obtained from the Alberta Energy and Utilities Board (EUB) Directive 38 (revised February 16, 2007) and the U.S. EPA Levels document (EUB 2007, EPA 1974). The baseline level for quiet rural area was estimated from an L_{eq} night (10 pm – 7 am) sound level of 35 dBA and assuming a 10 dB difference between the day and night periods (EUB 2007, EPA 1974, FTA 2006).

[3] L_{eq} day is 7 am – 10 pm and L_{eq} night is 10 pm – 7 am. Day and night sound level estimates were obtained from the United States Federal Transit Administration – *Transit Noise and Vibration Impact Assessment Report* (FTA 2006).

Step 3: Determination of Noise Impacts from Railway Activities

Appendix A provides simplified calculations when using Method A to determine potential noise impacts. It should be noted that the Agency reviews all submitted information to develop a comprehensive understanding of the circumstances for each case.

The assessment should describe any unique characteristics of the noise, such as tonality, impulsiveness, or low frequency, which may affect how people perceive railway noise. The Agency may consider an adjustment factor to account for these characteristics.

In the absence of actual indoor field measurements or calculations, the U.S. EPA and the World Health Organization (WHO) specify outdoor-to-indoor transmission loss of 15 dB with windows partially open and 27 dB with windows fully closed (EPA 1974, WHO 1999). This approach may not be appropriate with low frequency noise.

Step 4: Conclusions and Recommendations

The assessment should include conclusions and recommendations based on the impacts of the estimated noise levels. Depending on the recommendations, the report may propose mitigation measures or not. Any mitigation measures proposed should take into consideration their technical, financial and operational feasibility.

2.2 Method B: Assessment by Prediction Models

Computerized prediction models may be preferred in situations where the:

- railway noise is difficult to measure through field investigations;
- railway noise under dispute occurs infrequently and is difficult to capture through field studies;
- receptor locations are not accessible; and
- background ambient noise levels may interfere with the measurement of the rail way noise.

There are several published noise prediction models used in different jurisdictions. When assessing railway noise, the prediction modeling should be representative of a typical situation that generated the noise dispute. The use of a worst-case scenario not representative of the typical railway activities may be refuted by the other party. If desired, the noise study could address the range of the other operational levels (e.g., low and high levels) or the corresponding upper and lower limits of specific noise events.

Generally recommended noise models for railway activities are described below. The procedures for either predicting or measuring rail noise are described in 2.2.2. The measurement and reporting procedures are described in subsection 2.4.

2.2.1 Noise Protection Model

Table 4: Generally Recommended Noise Models

Published Model	Examples of Model Applicability
STAMSON v5.03 / STEAM	Train pass-by and whistle noise
U.S. DoT – Federal Transit Authority	Train pass-bys, whistles, idling, shunting, and wheel squeal, and ancillary facilities.
ISO 9613-2	Train idling, shunting, wheel squeal, and ancillary facilities

These noise prediction models are revised periodically and the latest available version should be used.

STEAM Noise Model

STEAM,[8] *Sound from Trains Environmental Analysis Method*, (1990), a noise prediction program and component of the "Ontario Road Noise Analysis Method for Environment and Transportation" (ORNAMENT) was developed by the Ontario Ministry of the Environment (MOE 1989).

The method assumes that the sound level at the receptor is comprised of three elements: locomotive engine and exhaust noise (assumed to constitute one source), wheel-rail interaction noise, and warning signal (whistle) noise emitted when the train approaches a level crossing. The validity of the prediction method is limited to source-to-receiver distances between 15 m and approximately 500 m. For distances greater than 500 m or where topography is very irregular, the use of rail traffic noise prediction methods is not recommended.

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[8] The STEAM model yields results that are reasonably consistent with the previously developed NRC/CMHC noise model as both models were developed on the same technical platform. Field measurements and research work was conducted by NRC Canada and the Ontario Ministry of the Environment.

This prediction model is best suited for train pass-by and whistle noise. Railway activities in railway maintenance facilities, the idling of locomotives and railway yard activities are not addressed.

U.S. Department of Transport – Federal Transit Authority Noise Model

The U.S. Department of Transportation – Federal Transit Authority document *Transit Noise and Vibration Impact Assessment*, (FTA-VA-90-1003-06, May 2006), is the second edition of a guidance manual originally issued in 1995 (FTA 2006). The document presents procedures for predicting and assessing noise and vibration impacts of proposed mass transit projects including rail projects. Three levels of analyses are provided for assessing operational sound and vibration. Information is also provided on the assessment of construction noise and the presentation of the results.

The FTA manual provides guidance for prediction of the sound levels due to a variety of railway equipment and activities such as idling, shunting, special track work as well as heavy and light rail equipment. The FTA procedures rely on the use of equations and tabular data which require a technical background.

The International Organization for Standardization 9613-2 Model

The International Organization for Standardization (ISO) 9613-2:1996, *Acoustics – Attenuation of sound during propagation outdoors – Part 2: General method of calculation*, is used to calculate the attenuation of sound in an outdoor setting (ISO 1996). The algorithms take into account physical effects such as geometrical divergence, atmospheric absorption, ground effect, reflection from surfaces, and screening by obstacles. The standard relies on the use of equations which require users to have a technical background. Commercial models are available that incorporate a computerized version of the ISO Standard algorithms.

2.2.2 Additional Considerations for Rail Noise Assessment

Some guidelines and standards do not cover noise characteristics such as low frequency content, tonality, impulsiveness, or impacts from individual events. The scientific literature suggest that certain noise characteristics may affect how people perceive sounds from rail operations. Recommendations for addressing these sound characteristics follow.

Low Frequency Noise (LFN)

Many jurisdictions rely on the use of the A-weighted sound level descriptors including L_{eq} in dBA (over different time periods), L_{max} in dBA, and the statistical descriptors $L_{n\%}$ in dBA. Scientific literature and certain standards indicate that the A-weighted sound level underestimates the impact of low frequency noise (ANSI 2005, CSA 2005). Sounds with strong LFN may also result in noise-induced rattles within buildings, resulting in greater annoyance (ANSI 2005, CSA 2005). Two methods for determining if the noise under assessment is potentially a LFN generator are outlined below:

- C-weighted sound level (e.g. dBZ or dBC) is equal to or exceeds the A-weighted sound level (dBA) by approximately 20 dB; or
- ANSI indicates that sounds in the 16, 31.5 and 63-Hz octave bands greater than 70 dB may result in noise-inducted rattles.

It should be noted that the tests outlined above are indicators that further analysis may be warranted or adjustment factors to the impacted noise may need to be considered. The ANSI test is preferable for noise sources that are further away. Appropriate judgment must be used in assessing LFN. If an adjustment factor is used, rationale must be provided to support its use. ANSI provides mathematical procedures to assess LFN (ANSI 2005). The ANSI procedures are only applicable if the difference between the time-weighted C-weighted sound level exceeds the A-weight sound level by at least 10 dB. Consideration should be given to indoor criteria that have accounted for LFN. For example, some guidelines specific to railways may be 5 dB lower than criteria for road traffic noise to account for lower frequencies from rail operations.

Tonal or Impulsive Sounds

The Canadian Standards Association, ISO, U.S. EPA and the WHO indicate that tonal and impulsive noise can be annoying and disruptive to receptors (CSA 2005, EPA 1974, WHO 1999). For sounds that are audibly tonal or impulsive in nature at the receptor location, the appropriate adjustment factors should be considered. Examples of sound adjustments are shown in Appendix D. The adjustments may be added to the measured or predicted sound level, as appropriate. The acoustical specialist must use professional judgment in applying these factors. If an adjustment factor is used, rationale must be provided to support its use.

Single Events

Several railway activities, including train pass-bys, emit repetitive noises of a significant level for brief periods of time that can interfere with sleep, communications, and the well being of the residents of neighbouring properties (WHO 1999). The following metrics may be considered as part of the assessment procedures to supplement the noise assessment:

1. Maximum events sound level(s); L_{max}, in dBA.
2. Sound Exposure Level(s) due to single events; SEL, in dBA.

2.3 Method C: Assessment by Field Measurements and Prediction Models

Method C uses a combination of field measurements and model predictions to assess impacts. However an assessment based only on field measurements is acceptable provided that ambient noise and atmospheric conditions permit.

The recommended noise models are summarized in subsection 2.2.1. The measurement and reporting procedures described in 2.4 apply to Method C. Additional considerations for rail noise, such as LFN, tonal, and impulsive noise and the impact of individual noise events are discussed in subsection 2.2.2.

2.3.1 Preliminary Considerations

Measurement Equipment

Sound level meters and acoustic calibrators should meet specifications traceable to national (e.g. CSA or ANSI) and/or international standards (such as ISO). They should also be calibrated by an accredited laboratory (generally every two years for sound level meters and one to two years for calibrators). A type 1 sound level meter (a Precision Sound Level Meter with tolerances of ± 1 dB between 100 and 4000 Hz) is the preferred instrument for specific noise and impulsive events. A type 2 sound level meter (a General Purpose Sound Level Meter with tolerances of ± 1.5 dB between 100 and 1250 Hz, up to ± 3 dB at 4000 Hz), which has less stringent tolerances, may be used for investigations involving long-term noise monitoring.

The following documents are intended for the application of the present assessment method. Their latest edition (including any amendments) should be used:

- IEC 60942:2003, Electroacoustics – Sound calibrators (IEC 2003)
- IEC 61260:1995, Electroacoustics – Octave band and fractional – Octave band filters (IEC 1995).
- IEC 61672-1:2002, Electroacoustics – Sound level meters – Part 1: Specifications (IEC 2002).

The sound level meter should be field calibrated at the time of the measurements (before beginning, during prolonged sessions, and after completion of the measurements) using a sound level calibrator and in accordance with the standards above.

An Acoustic Specialist may use one or more time-synchronized sound level meters that conform to ANSI Type 1 or Type 2 specifications for sound level meters (refer to S1.4a (R2006) and ANSI S1.43 (R2007) specifications for sound level meters) to capture simultaneous sound level readings (ANSI 2006, ANSI 2007).

Weather Conditions

Environmental weather conditions can affect the assessment of background noise and rail noise in the following manner:

- Winds can increase the sound level at the microphone of a sound level meter. Wind induced noise should be at least 10 dB lower than the sounds being measured to avoid skewing the results. Wind speeds in excess of 20 km/hr can generate high ambient noise in areas that are well treed with considerable foliage.
- Relative humidity levels in excess of 90% may affect microphone performance. Excess precipitation may affect noise levels and even damage a sound level meter. The manufacturer specifications for the individual instruments should be followed.
- Traffic on wet roads can increase ambient noise and may therefore affect measurements.
- Under poor visibility (e.g., foggy conditions), train whistles may be sounded in areas where they are not normally sounded or may be sounded in addition to the routine whistles at crossings. Therefore, measurement of train activities under these conditions might not be representative of typical operating conditions.
- Under an inversion, when the temperature rises at higher altitudes (typically at night), the sound waves that would normally be directed into the atmosphere are refracted downwards. This condition can result in sound level increases of 5 to 8 dB compared to neutral atmospheric conditions. Similarly under a lapse condition, when temperature decreases at higher altitudes (typically during the daytime), the sound waves bend or refract upward resulting in sound level decreases of 5 to 10 dB compared to neutral atmospheric conditions. Wind direction and speed can also produce similar differences over large distances (AZDOT 2005).

With respect to weather conditions the following procedures should be considered:

a. Measurements should be avoided during precipitation or when the ground is wet. Measurements should also not be carried out in foggy conditions.
b. A windscreen designed to fit the specific sound level meter should be used to minimize the effect of air flow noise over the microphone.
c. Sound level meters used for long-term monitoring in inclement weather should be outfitted with an appropriate environmental protection kit to prevent bias due to atypical events and for protection from the weather. The kits typically include a wind screen, bird spikes, and desiccated chamber for high humidity environments.

d. For distances less than 40 m, the effects of atmospheric conditions on noise propagation are insignificant for the purposes of the noise assessment (ISO 1996 and ISO 2007).

e. To avoid wind-induced noise affecting measurements, wind speeds should be monitored and measurements should not be taken when they exceed 20 km/h, unless it can be clearly demonstrated that the wind-induced noise is insignificant compared to the source under measurement. Temperature, relative humidity, wind speeds, and wind direction must be provided (This data can be obtained from Environment Canada’s website, local weather station, or measured manually).

For distance setbacks greater than 40m, a record of temperature, relative humidity, wind speeds, wind direction, description of visibility, and a description of atmospheric phenomena (e.g., hail, drizzle, freezing rain, snow, ice pellets, fine hail, fog, blowing sand, etc.) should be provided. Attention should be paid to ensure that the measurement conditions are within the tolerances of the instrument (e.g., for operating temperatures typically -15° to 40° unless protected and relatively humidity typically < 90%).

Background Noise Environment

In order to present an accurate assessment of rail noise, it is important that the ambient/background sound environment be assessed. An elevated ambient noise environment could influence the noise measurements. For example, conducting measurements of an idling train adjacent to a busy highway could result in artificially high noise measurements.

Sources of ambient noise may be constant (e.g. an urban hum or noise from a distant highway) or time varying, the latter of which is more complicated for rail noise investigation (e.g. aircraft flyovers, traffic on near-by roadway).

If the noise being measured is 10 dB or greater than the background noise, then the background noise has virtually no effect. If the difference is less than 10 dB, the assessment should provide a reasonably accurate analysis of the ambient sound environment at the point of reception, during the same time period(s) when the rail noise being investigated occurs. A correction should be applied to the results to account for the influence of the ambient sound levels. Sound level meters should be equipped with the appropriate environmental kit to provide protection from adverse weather conditions.

In all cases, the report should provide adequate documentation and assessment of the ambient sound levels prevailing at the receptor locations.

2.3.2 Measurement Procedures

Construction Noise

Noise from smaller construction projects are often short lived. Noise from longer-term projects, such as the construction of grade separations, can be annoying due to its duration. Major railway construction activities with blasting and/or pile driving can generate loud impulse noise which can be disruptive and annoying at noise sensitive locations.

Careful attention should be given to predicting construction noise and to demonstrating that all reasonable measures have been considered to minimize its potential effects.

Early and continued communication between the railway company and the neighbouring community regarding the nature and duration of the construction noise can help avoid or limit disputes. The community should be kept informed of the project plans and all reasonable efforts made by the railway company to minimize construction noise.

Noise monitoring and quick responses to noise above the anticipated level or outside the agreed-upon schedules will also help relieve tensions between the railway company and the local community. The following is a summary of the sound level descriptors that should be considered in the assessment of construction noise:

- The individually measured impulse sound levels should be reported. See subsection 1.4 for additional considerations on impulsive noise.
- L_{max} at 7.5 m or 15 m for individual pieces of construction equipment. The L_{max} is the maximum sound level present in a given time period.
- L_{10} sound levels are the sound levels exceeded 10% of the time. The L_{10} values usually represent the sound levels generated when the noisiest equipment is operating.
- Hourly L_{eq} sound levels at the receptor location.

Operational Noise

1. Pass-by and Idling Noise

Pass-by and idling noise levels may be captured at a fixed reference distance from the railway tracks or at the receptor location. Sound level measurements should be conducted in the far-field. Measurements in the outdoor amenity area should be conducted 1.5 m above the ground and at least 1-2 meter from any reflective surface to avoid reflections that could contaminate readings. The report should include a description and sketch of the source and measurement location. Key distances and dimensions must be specified. The measurement results at a fixed reference distance may be extrapolated to the receptor location being assessed using standard based mathematical formula or a noise prediction model outlined in subsection 2.2.1.

For unattended measurements, the monitors should be equipped with appropriate environmental protection, as described in subsection 2.3.1 above. In addition, supplementary audio recordings (e.g., wav, mp3, video cassette recorder, digital audio tape, etc.) are required to ensure that the noise under dispute was captured without contamination from other noise.

A list of sound level descriptors, for attended and unattended measurements, is provided in Table 6.

Table 5: Sound Level Descriptors for Pass-by Measurements

Measurement Description	Sound Level Descriptors to Record	Comments
Attended	L_{eq}, SEL, L_{max}, L_{min}	Provide detailed notes on the rail activities captured in the measurement. If any other sources not related to the rail activities in dispute are audible, they should also be documented.
Unattended	L_{eq}, L_{max}, L_{min}, $L_{n\%}$ (L_1, L_{10}, L_{50}, and L_{90})	Interval times should be no greater than 20 minutes in duration. Measurements should not include other noise sources than those under assessment. If the data includes other sources (e.g. nearby highway or industry) then appropriate adjustments should be made to isolate the noise under assessment.

Sound level measurements demonstrating any unusual noise events should be included in the assessment report. Based on the measured and calculated hourly L_{eq} a daily profile of the results summarized day-by-day should be developed for the following:

- L_{eq} day (7 am – 10 pm) and L_{eq} night (10 pm – 7 am);
- L_{eq} 24 hour, dBA; and
- L_{dn}, dBA.

The results should be presented for the outdoor amenity area, at the building façade(s) and, when possible, indoors. If these locations are not accessible, measurements may be extrapolated through noise prediction modeling.

2. Train Whistling at Crossings

Train whistles are sounded for safety purposes to alert motorists, pedestrians, and railway workers of an approaching train. Whistling is a legal requirement under the Canadian Rail Operating Rules (CROR) pursuant to the Railway Safety Act (RSA) and is administered by Transport Canada (TC). Under the CROR, trains exceeding 44 mph must sound the whistle ¼ mile before the crossing, to be prolonged or repeated, until the crossing is fully occupied. Trains operating less than 44 mph must sound whistle signal to provide 20 seconds warning before entering the crossing and continue to sound the whistle until the crossing is fully occupied.

Municipalities seeking to eliminate train whistles must contact the railway company directly. More information can be found in the TC Guideline No.1, Procedures and Conditions for Eliminating Whistling at Public Crossings, which can be accessed at www.tc.gc.ca/rail.

Measurements of train whistling may be included in the noise report to demonstrate a comprehensive picture of the rail noise. TC has provision in place to eliminate whistling at certain crossings where safety prerequisites can be demonstrated.

Measurements should be taken at a distance of 30 m perpendicular from the rail line and at least 1.5 m above the ground. Recommended sound level descriptors include:

- Single event noise descriptors such as L_{max} and SEL; and
- The L_{eq} sound exposure level from the time the horn is sounded until it stops.

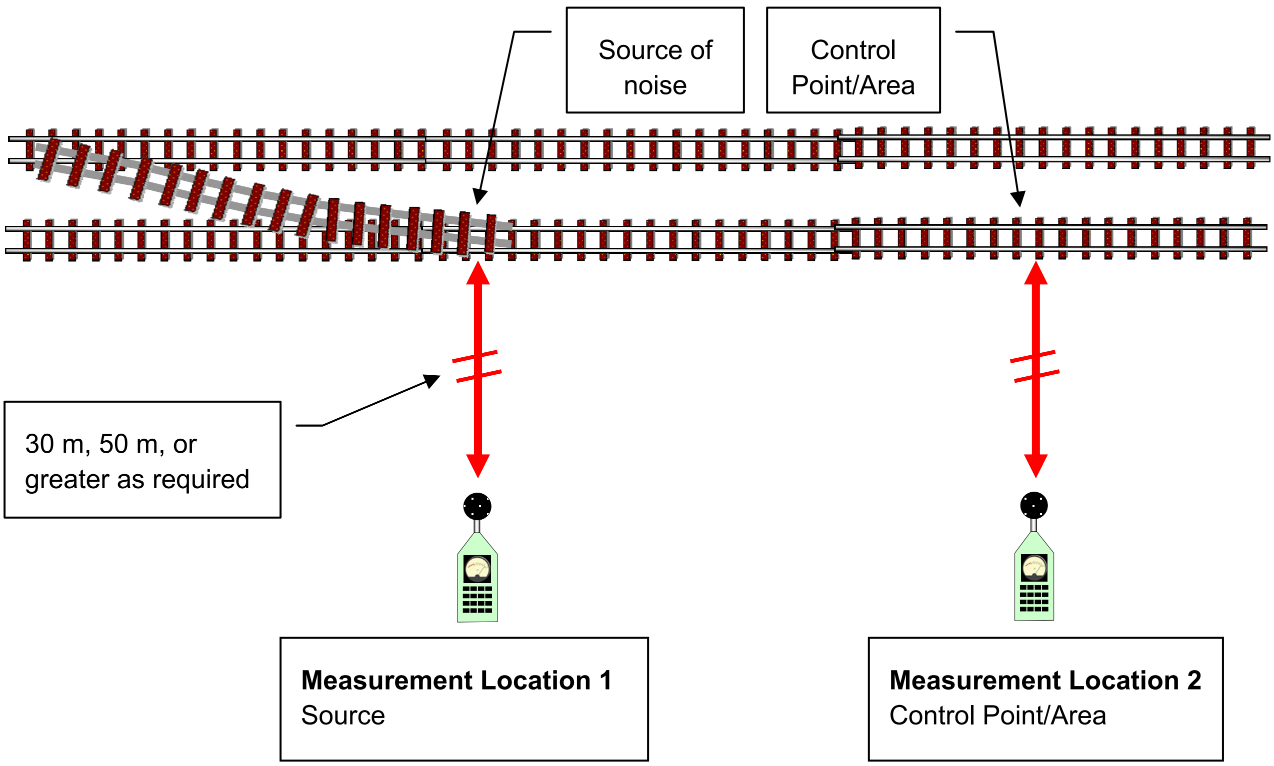
3. Control Point Measurement for Comparison Purposes

Control point measurements may be taken for comparison purposes. An illustration of the control point measurement procedure is shown in Figure 5. Measurements may be taken simultaneously or in a time-synchronized fashion at two measurement locations:

- Immediately opposite to the noise source at a predetermined distance and with a clear line of site to the source of noise.
- Immediately opposite to a “Control Point/Area” location at the same distance and with the same noise propagation characteristics (e.g., clear line of site, if possible, same ground absorption, etc.) as the noise source, but at least 4 times the distance from the sound level meter to the switch/track on either side of the location.

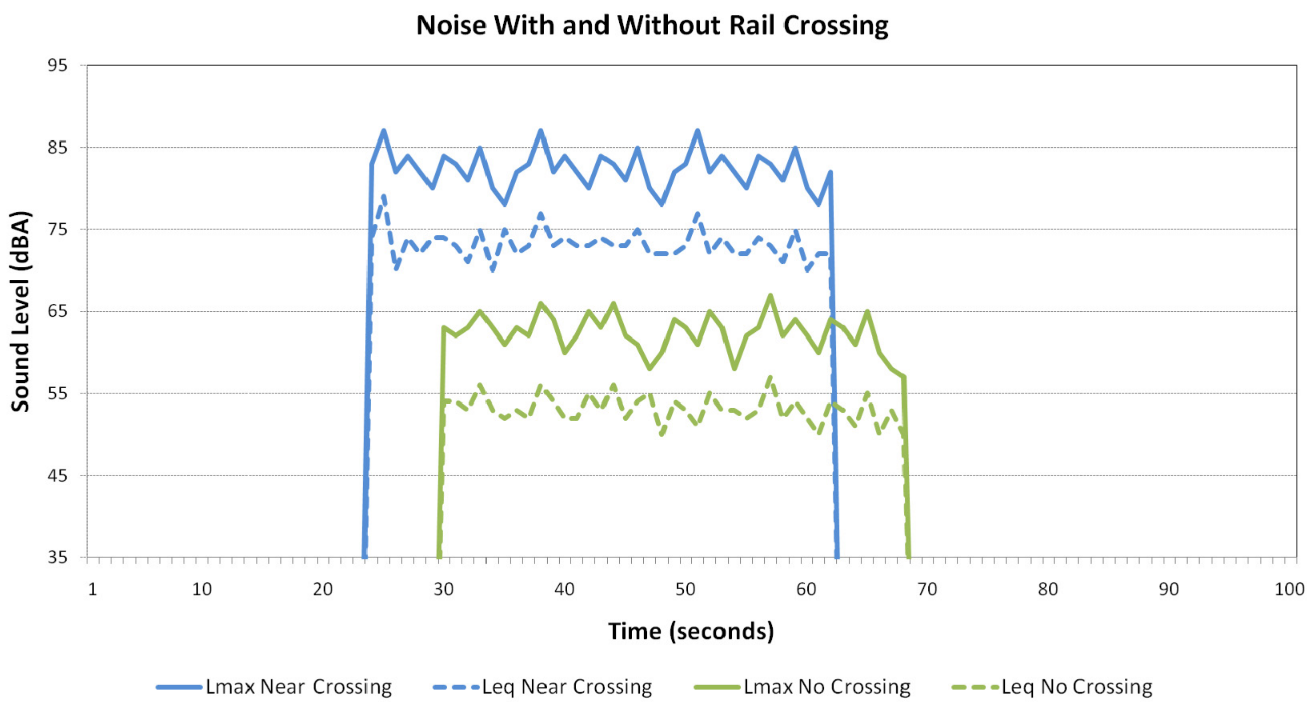
As shown in Figure 5, the measurement locations should be sufficiently far apart that the noise generated by the track discontinuity should not be audible at the “Control Point/Area” measurement location. Noise sources may include switches, intersecting rail tracks, cross-over connections.

Figure 5: Control Point Measurement Procedure



A graph illustrating results at Measurement Location 1 versus Measurement Location 2 is shown in Figure 6.

Figure 6: Example Graph of Control Point Measurement Results



Recommended sound level descriptors are listed below:

- L_{max}, dBA at each location;
- L_{eq}, dBA for each pass-by (from the time the first rail car/locomotive is opposite the measurement position until the last car passes by the measurement position). This is normally referred to as $L_{eq\ pass\text{-}by}$, dBA;
- Optional, $L_{n\%}$ levels;
- A statement of the average results for several representative pass-bys and the net differences between the two measurement locations; and
- The calculated (and/or measured) typical hourly differences between the source and the control points based on average train movements during the specified periods.

A similar procedure may be used to assess noise from jointed rail tracks to compare it with noise from continuously welded tracks. However, instead of a ‘Control Point’, one would use a “Control Area’ (i.e. a large influence area) based on selection of other nearby areas employing the continuously welded tracks. Care must be exercised in the selection of the Control Area due to the possibility of different train speeds, power settings, or ambient noise.

Jointed track

Continuously welded track

Alternatively, adjustment factors to be found in the published literature may be used to estimate the differences between different track configurations and conditions.

4. *Impulsive Sound Levels Due to Train Shunting, Car Coupling, Trains Starting/Stopping at Siding Yards and in Railway Yards*

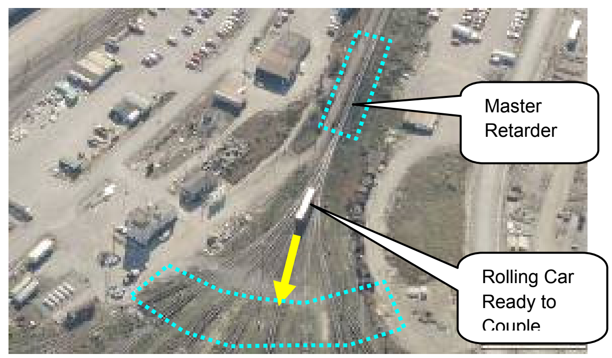
Impulse sounds from activities such as train shunting, car coupling, trains starting/stopping can sometimes be difficult to capture as not all of these activities create impulsive sound levels that can readily be measured, especially at extended distance setbacks. The random occurrence of some impulse noises can add to the challenge.

The preferred measurement location is at the specific receptor location, at the plane of the bedroom windows. If this is not possible measurements may be taken at a location closer to the source. To estimate the propagation of noise to the receptor location, a prediction model as described in subsection 2.2 may be used and adjusted as required.

While there are instruments capable of measuring impulsive sound levels in the unattended mode, it is recommended to conduct attended monitoring to capture a sufficient number of events, keeping in mind the following points:

a. The range of sound levels captured during the measurement period should be reported.
b. The individually measured impulse sound levels should be reported. See subsection 1.4 for additional considerations on impulsive noise.
c. If locomotive idling noise is clearly audible and is an element in the noise dispute, then separate hourly L_{eq} levels should be reported.
d. When measuring sound levels at distance setbacks greater than 40 m, the hourly weather data should be included. See subsection 2.3.1 on weather conditions.

5. *Noise Due to Stationary Source Facilities*



In general, stationary rail facilities can emit varying levels of noise. Facilities include railway yards, classification yards, railway sidings, intermodal terminals, bulk transfer facilities, repair shops, locomotive load test cells, sirens and switch clearing devices. When ambient noise and atmospheric conditions permit, it is recommended that sound level measurements be conducted at or near the receptor location when assessing noise from large rail facilities with multiple noise sources.

When assessing noise at such facilities, the following elements should be considered:

a. Current estimated or measured hourly L_{eq} sound levels in dBA from the facility, excluding the background ambient environment.
b. Sample frequency spectra to detect noise sources emitting tonal or cyclical noise with the use of a frequency analyzer in 1/3 Octave Bands. See subsection 2.2.3.
c. Impulse sound levels should be assessed as described in subsection 1.4.

d. The estimated or measured hourly L_{eq} due to the facility should be plotted and compared with the prevailing ambient background sound levels (e.g. due to road traffic).

e. Detailed description of facility operations and plan area drawings should be provided. The plan drawings should clearly show the location of the noise source(s) under assessment and receptor(s) of interest.

2.4 Measurement and Reporting Procedures for Methods B and C

The report should be clear, well-organized, and comprehensive with sufficient detail to permit a technical peer review. The report should be submitted in both hard copies and electronic format to the Agency.

Recommended content and format for the noise measurement reports is provided in the following Table 6. The report need not be limited to the requirements outlined below.

Table 6: Recommended Report Content and Format

Section of Report	Explanation
1) Introduction	The introduction should provide an overview of the rail noise of issue. This should include any relevant background information, details on the site location, and information on the background noise environment (excluding the source under dispute). The following items should be included: • a scaled area site plan identifying the noise sensitive receptor(s), grading (elevations), the rail activity location under dispute, and other noise sources in the area (such as nearby industry, airplane flyovers, and a busy road or highway); • a description of the surrounding topography, nature of land-uses, and existing noise reduction measures (such as a noise wall, noise berm and upgraded windows); and • photographs of the area (if possible). (Key information related to railway operations, land uses, zoning, aerial photography, etc. may be obtained from a variety of sources outlined in Appendix B.)
2) Rail Activity Description	Should include a detailed description of the railway activity under dispute and, if possible, photographs. The report should identify: • the probable noise source; • detailed description of operational and/or construction activities; • frequency of occurrence; • if the sound is steady or intermittent in nature and contains any LFN, tonal or impulsive characteristics;

Section of Report	Explanation
	• if wheel squeal is identified, the turning radius of the tracks. • for train pass-bys, provide the train speeds and volumes, number of locomotives and rail cars;[9] • track type such as jointed or continuously welded rail; • the track conditions (e.g., track corrugations, gaps, etc.), and location of any special track work (e.g., crossovers); and • the presence of existing noise mitigation measures (e.g., noise barrier, berm, etc.).
3) Noise Sensitive Receptor	• Detailed description of the noise sensitive receptor(s) such as location (including mailing address), dwelling type (e.g., single detached home), dwelling construction and number of floors (e.g., brick veneer, double glazed windows, two storey), and house ventilation details (e.g., air conditioning and heating system). The distance from the dwelling unit to the rail activity under dispute should be clearly stated in the report. • If the actual receptor heights are unknown, then the following heights may be assumed: outdoor amenity area or 1st storey receptor – 1.5m above the finished grade elevation, 2nd storey 4.5m above the 1st floor finished grade elevation, 3rd storey 7.5 m above the 1st floor finished grade elevation. • Photographs of the noise receptor. • The background noise (excluding the noise source under assessment) may be estimated from known baseline levels from areas of similar acoustical environments, previously conducted noise studies, or approximating values from Table 3. If the ambient sound environment is being estimated through noise modeling (e.g. dwelling next to a busy highway), then the details and procedures of the modeling should be included. • If the background noise was measured, the assessment should describe the sound level meter, provide a photo of the setup, an aerial photo clearly identifying the measurement location, a record of weather conditions, and any anomalies or corrections applied to the data. Additional details can be found in subsection 2.3.1. The raw data should be provided in an appendix and the results tabulated.
4) Modeled / Measured Sound Levels	This section should provide the results of sound level predictions/measurements and clearly outline the methods used to obtain them. More specifically, this section should contain: • the prediction model used (date and version); • the measurement equipment used (including date of calibration) and

[9] Can be obtained manually be conducting counts, online schedules, or calling the rail authority directly.

Section of Report	Explanation
	weather conditions at the time of measurement; a description of the background noise environment (excluding the noise source under assessment) at the time of measurement; • input modeling parameters (e.g., train type, number of locomotives, number of cars, train volumes, ground absorption coefficient, order of reflections, speeds, etc.) and the rationale for their selection. The input parameters could be organized in a table for presentation purposes. Example tables can be found in Appendix C; • source character adjustment(s) (e.g. tonal sounds) and rationale to support its use; • table of results. See subsection 2.3.2 for the appropriate sound level descriptors. Recommended sound level descriptors vary depending on the activity under assessment; and • sample calculations.
5) Assessment of Impacts	• There are two commonly used ways to assess impacts: determining change in noise levels that has initiated the dispute or comparing the absolute noise levels assessed to guidelines/criteria. The former requires a comparison of sound levels from one scenario to another (e.g. comparison of a previous year to the current year). Assessments may use both methods. • Depending on the context of the dispute, the results could be presented in the outdoor living area and/or inside the dwelling, within a noise sensitive space such as a bedroom. • In the absence of actual indoor sound measurements, indoor levels may be approximated following the method discussed in subsection 2.1 – Step 3.
6) Conclusions and Recommendations	• Describe conclusions and recommendations based on the assessment of rail activities and their impacts. • Depending on the recommendations, the report may propose noise mitigation measures. • Consideration should be given to the technical, financial, and operational feasibility of proposed mitigation measures. • Photographs or drawings of the proposed mitigation in other similar situations could be used to support the suitability of the proposed mitigation measures.
7) Appendices	• Supporting documents such as raw noise data, diagrams, sample calculations, manufacturer's specifications of equipment, etc.

3.0 More information

Canadian Transportation Agency
Ottawa, Ontario K1A 0N9
Tel: 1-888-222-2592
TTY: 1-800-669-5575
Web: **www.cta.gc.ca**
E-mail: info@otc-cta.gc.ca

For more information on the *Canada Transportation Act*, the Agency and its responsibilities, or Agency Decisions, and Orders, you can access the Agency's Web site at www.cta.gc.ca.

4.0 Definitions

Agency: The Canadian Transportation Agency

Absorb: Sound waves are converted into energy such as heat that is then captured by insulation.

Absorption: In acoustics, the changing of sound energy to heat.

Acoustic calibrator: An electro-mechanical or mechanical device that produces a sound of known frequency and sound pressure level for a field or laboratory calibration check of sound level meters or equivalent devices.

Acoustics: The body of knowledge relating to the study of sound and its properties in all media.

Airborne sound: Sound that arrives at the point of interest, such as one side of a partition, by propagation through air.

Ambient sound level (or background sound): The sound level that is present in the environment produced by acoustical sources other than the source of interest.

Amplitude: The instantaneous magnitude of an oscillating quantity such as sound pressure. The peak amplitude is the maximum value.

Attenuate: To reduce the level of an electrical or acoustical signal. Reduction in sound level.

Audible frequency range: The range of sound frequencies normally heard by the human ear. The audible range spans from 20Hz to 20,000Hz

Average sound pressure level: Of several related sound pressure levels measured at different positions or different times, or both, in a specified frequency band, ten times the common logarithm of the arithmetic mean of the squared pressure ratios from which the individual level were derived.

A-weighted sound level: A sound pressure level indicated by a measurement system that includes an A-weighting network. The resulting value is in decibels and is commonly labelled dBA.

Background sound level (or ambient sound): Ambient sound level, excluding the source under measurement.

Baffle: A moveable barrier used to achieve separation of signals from different sources. The surface or board upon which a loudspeaker is mounted.

Ballast: A layer of coarse stones supporting the sleepers on which the tracks are supported.

Beating: An audible, cyclically varying sound level, itself perhaps tonal, caused by the interaction of tones of slightly different frequency.

Decibel (dB): The logarithmic units associated with sound pressure level, sound power level, or acceleration level. For example, see definition for sound pressure level.

Decibel$_{slow}$ (dB$_s$): A decibel scale with the Sound Level Meter time response function set to read/report a sound level using the “slow” response function.

Decibel$_{fast}$ (dB$_f$): A decibel scale with the Sound Level Meter time response function set to read/report a sound level using the “fast” response function.

Diffraction: A change in the direction of propagation of sound energy in the neighborhood of a boundary discontinuity, such as the edge of a reflective or absorptive surface.

Divergence: The spreading of sound waves which, in a free field, causes sound pressure levels in the far field of a source to decrease with increasing distance from the source.

DMU (Diesel Multiple Unit): a multiple unit train set powered by diesel engines.

Equivalent sound level (denoted L_{eq} or L_{Aeq}): An A-weighted equivalent sound pressure level, thus L_{eq} dBA.

Equivalent sound pressure level (L_{eq}): The level of a steady sound having the same time integral of the squared sound pressure, in the measurement interval, as the observed sound.

$$L_{eq,T} \approx 10\log\left[\frac{1}{T}\int_{T_1}^{T_2}\left(\frac{p(t)}{P_O}\right)^2 dt\right]$$

Where

$P^{(t)}$ is the instantaneous sound pressure

P_o is the reference sound pressure 20 $_{\mu}$Pa)

$T = t_2 - t_1$ is the time interval

The determination of L_{eq} is most commonly done by periodically sampling the level during the time interval and combining these samples numerically (for example, by digital processing equipment) using the equation:

$$L_{eq,T} \approx 10log\left(\frac{1}{n}\sum_{i=1}^{n} 10^{Li/10}\right)$$

Where L_i are the levels observed at no equally spaced times during the interval T. When not otherwise qualified, L_{eq} is taken to mean equivalent A-weighted sound level, sometimes denoted by L_{Aeq}.

EMU (Electric Multiple Unit): a multiple unit train set powered by electric traction.

Fast response (denoted F after dB or dBA as required): A specific dynamic response characteristic of a sound level meter or other indicating device that conforms to ANSI Standard S1.4 or IEC Publication 651.

Flat weighting: A uniform instrument sensitivity over a specific frequency range.

Note: The acoustical or electrical conditions and frequency range within which the sensitivity of an instrument is uniform to within a given tolerance will normally be found in the information provided by the manufacturer.

Free field: An environment in which a sound wave may propagate in all directions without obstructions or reflections. Anechoic rooms can produce such an environment under controlled conditions.

Frequency: The number of complete oscillations (or cycles) per second of a periodically varying quantity, e.g., pressure, displacement, voltage. The unit is the hertz (Hz).

General purpose sound level meter: See definition for sound level meter.

Hertz: The unit of frequency, abbreviated Hz. The same as cycles per second.

Impulsive noise: Characterized by one or more short sharp peaks in the time domain, such as occurs during train shunting, coupling or hammering metal on metal.

Impulse response: A specific dynamic response characteristic of a sound level meter or other indicating device that conforms to IEC or ANSI standards.

Impulse sound level: The sound level of an impulse sound as measured with an impulse sound level meter set for "*impulse*" response.

Impulse sound level meter: A sound level meter having impulse response conforming to IEC and ANSI.

Insertion loss, IL: Of a silencer or other sound-reducing element, in a specified frequency band, the decrease in sound power level, measured at the location of the receiver, when a sound insulator or a sound attenuator is inserted in the transmission path between the source and the receiver.

Integrating sound level meter: A sound level meter capable of measuring the equivalent sound pressure level

Isolate: A dampening mechanism made a part of the assembly or system, which reduces structure borne vibrations from passing through the structure.

Joint (or rail joint): A connection between two lengths of rail, often held together by an arrangement of bolts and special steel plates (fishplates)

Ldn (Day-Night Average Level) (A descriptor that is more popular in use in the USA and partly used in Canada for some Environmental Assessments): The average equivalent A-weighted sound level during a 24-hour day, obtained after addition of 10 decibels to sound levels in the night-time from 10:00 p.m. to 7:00 a.m. *Note: CNEL and Ldn represent daily levels of noise exposure averaged on an annual or daily basis, while Leq represents the equivalent energy noise exposure for a shorter time period, typically one hour.*

Level reduction, LR: In a specified frequency band, the decrease in sound pressure level, measured at the location of the receiver, when a barrier or other sound-reducing element is placed between the source and the receiver.

Linear weighting (sometimes referred to as "Flat" weighting): this weighting factor is sometimes appended to the sound level dB as dBZ or dBF (see definition for flat weighting).

Load Cell: means a device external to the locomotive, of high electrical resistance, used in locomotive testing to simulate engine loading while the locomotive is stationary. (Electrical energy produced by the diesel generator is dissipated in the load cell resistors instead of the traction motors).

Locomotive: A powered vehicle used to draw or propel a train of carriages or cars (as opposed to a multiple unit).

Low Frequency Noise (LFN): Noise with a frequency between 16 and 63 Hz as per ANSI or between 20 and 150 Hz according to other sources and with a level in excess of 70 dB.

Maximum Sound Level, Lmax: The highest instantaneous reading a sound level meter gives over a stated period of time. The symbol for the A-frequency and weighted maximum sound level is Lmax or LAmax and it may be reported using the "*slow*" or "*fas*t" meter response depending on the application (Lmax should not be mixed with the peak value of a sound signal as the latter is related to the sound level reading response)

Measurement Period: A continuous period of time during which noise of railway yard operations is assessed, the beginning and finishing times of which may be selected before or after completion of the measurements and reported (in some cases, the measurement period is composed of several periods of time; i.e., the measurement period is the total *elapsed* time when extraneous sources are excluded/inhibited from the results)

Micropascal (1 Pascal is equal to 1,000,000 micropascal): The Pascal (symbol Pa) is the SI unit of pressure and is equivalent to one Newton per square metre.

Narrow-band sound: Sound concentrated in a narrow frequency range.

Noise reduction (NR): The difference in sound pressure level between any two points along the path of sound propagation. As an example, noise reduction is the term used to describe the difference in sound pressure levels between the inside and outside of an enclosure.

Noise sensitive receptor (receptor): A noise sensitive land use to be considered in the assessment. Receptors may include outdoor areas and/or indoor spaces in permanent residences, schools, hospitals, daycare centers, seniors' residences, and other buildings.

Octave bands: Frequency ranges in which the upper limit of each band is twice the lower limit. Octave bands are identified by their geometric mean frequency, or center frequency.

One-third octave bands: Frequency ranges where each octave is divided into one-third octaves with the upper frequency limit being 2* (1.26) times the lower frequency, identified by the geometric mean frequency of each band.

Octave: The interval between two frequencies of which the ratio is nominally 2:1 (see ANSI S1.6).

Note: For acoustical measurements the preferred frequencies are usually taken from the series 31.5, 40, 50, 63, 80, 100, 125, 160, 200, 250, 315, 400, 500, 630, 800, 1000, 1250, 1600, 2000, 2500, 3150, 4000, 5000 and 8000 Hz.

Outdoor Amenity Area: Outdoor area at ground level used for outdoor activities. The measurement/modelling location is assumed to be 3 m from the dwelling unit wall and 1.5 m above the existing ground surface. The front yard may only be considered as an OLA for special house designs and approved by the local municipality for location.

Peak particle velocity (PPV): The maximum instantaneous velocity experienced by the particles of a medium in vibratory motion.

Note: Velocity is a vector quantity and is frequently described in terms of three orthogonal components.

Peak pressure: The maximum instantaneous sound pressure during an acoustic disturbance.

Peak pressure level detector: A device capable of indicating the peak pressure occurring during an acoustic disturbance and expressing this quantity in decibels as a sound pressure level conforming to IEC Publication 651.

Percentile sound level (L_x): The sound level exceeded x% of a specified time period. When not otherwise specified, L_x is taken to mean the A-weighted sound level. Example: L_{10} is the sound level exceeded during 10% of the specified time period.

Precision sound level meter: See definition for sound level meter.

Pure tone: A sound consisting of a single frequency and having, therefore, a sinusoidal fluctuation in sound pressure.

Peak sound pressure level (LPK[nd]): Ten times the common logarithm of the square of the ratio of the largest absolute value of the instantaneous sound pressure in a stated frequency band during a specified time interval to the reference sound pressure of 20 micro pascals.

Pitch: A subjective term for the perceived frequency of a tone.

Root mean square (abbreviated RMS or rms): The square root of the arithmetic mean (average) of the squares of the original values (or the square of the function that defines the continuous waveform). It is also known as the *quadratic mean*, which is a statistical measure of the magnitude of a varying quantity such as sound.

Reflection: For large surfaces compared to the wavelength of impinging sound, sound is reflected much as light is reflected, with the angle of incidence equalling the angle of reflection.

Refraction: The bending of sound waves traveling through layered media with different sound velocities.

Sound:

a) A fluctuation in pressure, particle displacement, or particle velocity propagated in any medium; or

b) The auditory sensation that may be produced by the aforesaid fluctuation.

Sound attenuation: The reduction of the intensity of sound as it travels from the source to a receiving location. Sound absorption is often involved as, for instance, in a lined duct. Spherical spreading and scattering are other factors of attenuation.

Sound Exposure Level (denoted LAE or SEL): The level in decibels calculated as ten times the common logarithm of time integral of squared A-weighted sound pressure over a given time period or event divided by the square of the standard reference sound pressure of 20 micropascals and a reference duration of one second.

Sound level: A sound pressure level indicated by a measurement system (a sound level meter, for example) with dynamic response and weighting characteristics conforming to the requirements of ANSI Standard S1.4 or IEC Standard 651. When not otherwise qualified, the term denotes A-weighted sound level.

Sound Level Meter (SLM): An instrument consisting of a microphone, amplifier, output meter and frequency-weighting networks which is used for the measurement of sound levels.

Sound power (W): The rate of flow of acoustic energy in a specified frequency range, whether from a source, through an area, or into an absorber.

Sound power level (L_W): For airborne sound, ten times the common logarithm of the ratio of the sound power under consideration to the standard reference power of 1 pW. The quantity so obtained is expressed in decibels. When not otherwise qualified, the term denotes flat weighted sound power level.

Sound receiver/receptor: One or more observation points at which sound is evaluated or measured. The effect of sound on an individual receiver is usually evaluated by measurements near the ear or close to the body.

Sound waves: Sound waves can be thought of like the waves in water. Frequency determines the length of the waves; amplitude or volume determines the height of the waves.

Spherical divergence: Sound diverges spherically from a point source in unobstructed space

Tonal sound: A sound dominated by one or more pure tones.

Tone: A tone results in an auditory sensation of pitch.

Vibration: A perturbation in displacement, velocity, or acceleration in a solid medium.

Vibration isolation: A reduction, attained by the use of a resilient coupling, in the capacity of a system to vibrate in response to mechanical excitation.

Volume: Colloquial equivalent of sound level.

Wavelength: The distance the sound wave travels to complete one cycle. The distance between one peak or crest of a sine wave and the next corresponding peak or crest. The wave length of any sound wave may be found by dividing the speed of sound by the frequency (speed of sound at sea level is 331.4 meters/second or 1087.42 feet/second).

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Appendix A – Simplified Estimation Procedure

The Simplified Estimation Procedure is designed to:

- help identify projects that might have noise problems; and
- provide parties with a simplified calculation method to determine potential noise impacts.

Simplified calculation procedures are outlined below. Examples have also been included at the end of each section. It should be noted that sound level predictions presented to the Agency are not absolute. The Agency will consider the results as part of the case submission.

Simplified estimation procedures have been outlined for the following rail activities:

List of Rail Activities Covered in Appendix A

- Train pass-by noise
- Idling locomotive noise
- Railway crossover
- Wheel squeal on curved tracks
- Locomotive whistle noise
- Rail cars classification/shunting impulsive noise

Train Pass-by Noise

The table below is based on the following assumptions:

- the distance between the rail track and the receiver is 30 m at a height of 1.5 m above the ground;
- the sound levels are based on diesel locomotive. An adjustment factor for electric trains is provided at the end of the section;
- the rail tracks are in good condition and are continuously welded;
- all of the rail traffic is either during the day or night period; and
- predicted sound levels are based on STEAM Noise Model algorithms. Additional information on the STEAM Noise Model can be found in Section 2.2.1 of the main document.

Step 1: Single Train Pass-by Noise Level

Noise Level Prediction for Single Train Pass-by

No. of Trains Per 24 hr Time	No. of Train Locomotives	No. of Cars Per	Train Speed,	Base Sound Levels L_{eq} (16h)/L_{eq} (8h)
1	1	2	80	40/43
1	1	4	80	43/46
1	1	10	80	47/50
1	1	2	100	41/44
1	2	4	100	44/47
1	3	10	100	49/51
1	1	50	60	52/55
1	2	100	60	55/58
1	3	150	60	57/60
1	1	50	70	53/56
1	2	100	70	56/59
1	3	150	70	58/61
1	1	50	80	54/57
1	2	100	80	57/60
1	3	150	80	59/62
1	1	50	90	54/57
1	2	100	90	57/60
1	3	150	90	59/62
1	1	50	100	55/58
1	2	100	100	58/61
1	3	150	100	60/63

Note: *L_{eq}(16h) from 7am – 11pm and L_{eq}(8h) from 11pm – 7am. The sound levels are based on the assumption that all of the traffic is in the 16 hour period or 8 hour period.

Step 2: Adjustment Factor for Multiple Trains

Adjustment factors are provided to account for multiple trains. The table is based on the assumption that all trains considered are equal in sound emissions.

Adjustment for Multiple Trains

No. of Trains Per Period	Adjustment (dB)
1	+ 0
2	+ 3
3	+ 5
4	+ 6
5	+ 7
6	+ 8
7	+ 8
8	+ 9
9	+ 10
10	+ 10
15	+ 12
20	+ 13
30	+ 15
40	+ 16

Step 3: Adjustment Factor for Distances Greater Than 30 Meters

The following table provides adjustment factors for distance. The table is based on the reduction from an infinitely long line source, resulting in a sound level drop off at the rate of 3 dB per double of distance from the source. Distances beyond 100-150 m include the effect of ground absorption.

Adjustment Factor for Distance

Trains Moving Between Stations (Line Source)	
Distance From Receptors to Tracks (m)	**Sound Level Reduction (dB)**
30 *	0
40	- 1
50	- 2
60	- 3
70	- 4
80	- 5
90	- 6
100	- 7
150	- 10
200	- 12
250	- 13
300	- 14
350	- 15
400	- 16
450	- 16
500	- 17

Note: * Reference distance.

Step 4: Adjustment Factor for Electric Locomotive

The information in the literature indicates that there is a strong correlation between the sound emissions from electric powered trains to the travelling speed. As speed increases, wheel-rail noise becomes the dominant noise source. In general, electric trains tend to be approximately 2-3 dB lower than diesel trains.

Step 5: Summary of Results

Describe any unique characteristics of the noise, such as tonality, impulsiveness, or low frequency, which may affect how people perceive railway noise. The Agency may consider an adjustment factor to account for these characteristics.

Estimated Sound Level Calculation

Step	Description	Sound Level $L_{eq}(16h)$ / $L_{eq}(8h)$ (dBA)
1	Single Train Pass-by Noise Level	
2	Adjustment Factor for Multiple Trains	
3	Adjustment Factor for Distance	
4	Adjustment Factor for Electric Locomotive	
	Total:	

Example Calculation for Train Pass-by Noise

Bob Smith lives next to a busy railway. He would like to estimate the sound levels outside of his house due to train pass-bys, not including whistles.

According to Bob, there are 10 diesel freight trains that pass by his house during the night-time period (23:00-07:00). Each train is equipped with 2 locomotives and 100 cars and travels at a speed of about 60 km/h. Bob's house is approximately 100 m away from the rail track centerline.

Following Steps 1-5 above:

Estimated Sound Level Calculation

Step	Description	Sound Level (dBA)
1	Single Train Pass-by Noise Level	58
2	Adjustment Factor for Multiple Trains	+ 10
3	Adjustment Factor for Distance	- 7
4	Adjustment Factor for Electric Locomotive	None
	Total Leq(8h):	61

The $L_{eq}(8h)$ sound level at Bob's house is predicted to be 61 dBA during the night period.

Idling Locomotive Noise

The table below is based on the following assumptions:

- the sound levels are based on an idling diesel locomotive (an adjustment factor for electric trains is provided at the end of the section); and
- the locomotive is in good operating condition.

The table is based on the reduction of a point source, resulting in a sound level drop off rate of 6 dB per double of distance from the source. Distances beyond 100-150 m include the effect of ground absorption.

Step 1: Sound Levels for a Single Idling Diesel Locomotive

Base Sound Levels for Single Idling Locomotive

Distance to Idling Locomotive (m)	Base Sound Level (dBA)
15	73
20	70
25	69
30	67
35	66
40	64
45	63
50	62

Distance to Idling Locomotive (m)	Base Sound Level (dBA)
55	62
60	61
65	59
70	58
75	57
80	56
85	56
90	55

Distance to Idling Locomotive. (m)	Base Sound Level (dBA)
95	54
100	54
150	49
200	46
250	44
300	42

(Based on Sound Power Level L_w = 107 dBA)

Step 2: Adjustment for Multiple Locomotives

Adjustment factors are provided to account for multiple locomotives. The table is based on the following assumptions:

- all locomotives considered are equal in sound level; and
- the distance of each locomotive to the receptor is equal.

Number of Locomotives	Adjustment (dB)
1	0
2	+ 3
3	+ 5
4	+ 6
5	+ 7
6	+ 8
7	+ 8
8	+ 9
9	+ 10
10	+ 10

Step 3: Adjustment Factor for Time

Skip Step 3 when calculating the L_{max}.

Adjustment for Time

Idling Time in Minutes Per One Hour (Minutes)	Adjustment (dB)
60	0
50	- 1
40	- 2
30	- 3
25	- 4
20	- 5
15	- 6
10	- 8
7	- 9
6	- 10
5	- 11
4	- 12
3	- 13

Idling Time in Minutes Per One Hour (Minutes)	Adjustment (dB)
2	- 15
1	- 18

Step 4: Adjustment Factor for the Presence of Obstacles

The following table provides adjustment factors for various obstacles. When more than one adjustment factor applies, use only the largest adjustment.

Adjustment for Obstacles

Structure/Sound Barrier	Adjustment (dB)
A tall massive structure that interrupts the line-of-sight to the locomotive(s)	- 15
A two storey structure that extends beyond the source of noise	- 10
A sound barrier that is equivalent to a 2-4 storey high structure which interrupts the line-of-sight to the receptors.	- 7
A sound barrier that **just** interrupts the line-of-sight to the locomotive(s)	- 5

Step 5: Adjustment Factor for Idling Electric Locomotive

The data available on locomotive idling noise of electric trains indicate that sound level emissions are approximately 5 dB or more lower than the diesel or diesel-electric units.

Step 6: Summary of Results

Describe any unique characteristics of the noise, such low frequency noise or rattle of building elements, which may affect how people perceive railway noise. The Agency may consider an adjustment factor to account for these characteristics.

Estimated L_{eq}(1h) Sound Level Calculation

Step	Description	Sound Level L_{eq}(1h) (dBA)
1	Sound Level for a Single Idling Diesel Locomotive	
2	Adjustment Factor for Multiple Locomotives	
3	Adjustment Factor for Time	
4	Adjustment Factor for the Presences of Obstacles	
5	Adjustment Factor for Idling Electric Locomotive	
	Total:	

Estimated L_{max} Sound Level Calculation

Step	Description	Sound Level L_{max} (dBA)
1	Sound Level for a Single Idling Diesel Locomotive	
2	Adjustment Factor for Multiple Locomotives	
4	Adjustment Factor for the Presences of Obstacles	
	Total:	

Example Calculation for Idling Locomotive Noise

Bob Smith lives next to a rail yard. In the early morning hours two locomotive freight trains idle for 40-minutes before leaving for the day. He would like to estimate the sound levels outside of his house due to the idling trains.

The locomotives are positioned in the rail yard next to one another. The trains are approximately 100 m away from Bob’s house and there is an existing precast concrete acoustic barrier, 3-storeys above the ground. The barrier blocks the line of sight to the rail yard.

Estimated $L_{eq}(1h)$ Sound Level Calculation

Step	Description	Sound Level $L_{eq}(1h)$ (dBA)
1	Sound Level for a Single Idling Diesel Locomotive	54
2	Adjustment Factor for Multiple Locomotives	+ 3
3	Adjustment Factor for Time	- 2
4	Adjustment Factor for the Presences of Obstacles	- 7
5	Adjustment Factor for Idling Electric Locomotive	0
	Total:	48

Estimated L_{max} Sound Level Calculation

Step	Description	Sound Level L_{max} (dBA)
1	Sound Level for a Single Idling Diesel Locomotive	54
2	Adjustment Factor for Multiple Locomotives	+ 3
4	Adjustment Factor for the Presences of Obstacles	- 7
	Total:	50

The $L_{eq}(1h)$ and L_{max} at Bob's house are predicted to be 48 dBA and 50 dBA, respectively, due to train idling.

Railway Crossover Noise

The interaction of steel wheels and rail crossovers generate the "ka-thunk" noise, which can sometimes be audible over and above the tangential rail track noise.

Step 1: Sound Level of Cross-Over Noise

The table is based on the reduction of a point source, resulting in a sound level drop off at the rate of 6 dB per double of distance from the source. Distances beyond 100-150 m include the effect of ground absorption. A factor to estimate the L_{max} value is incorporated in Step 4.

Base Sound Levels for Crossover Noise

Distance to Crossovers (m)	Base Sound Level (dBA)	Distance to Crossovers (m)	Base Sound Level (dBA)	Distance to Crossovers (m)	Base Sound Level (dBA)
15	64	55	53	95	45
20	61	60	52	100	45
25	60	65	50	150	40
30	58	70	49	200	37
35	57	75	48	250	35
40	55	80	47	300	33
45	54	85	47		
50	53	90	46		

(Based on L_w = 98 dBA)

Step 2: Adjustment for Multiple Trains

Adjustment factors are provided to account for multiple trains. The table is based on the following assumptions:

- all trains considered have the same configurations, with the same number of locomotives and rail cars; and
- the trains are travelling at the same speed.

Adjustment for Multiple Trains

Number of Train Movements Per Hour	Adjustment (dB)
1	0
2	+ 3
3	+ 5
4	+ 6
5	+ 7
6	+ 8
7	+ 8
8	+ 9
9	+ 10

Number of Train Movements Per Hour	Adjustment (dB)
10	+ 10
10	+ 10
15	+ 12
20	+ 13
25	+ 14
30	+ 15

Step 3: Adjustment Factor for the Presence of Obstacles

The following table provides adjustment factors for various obstacles. When more than one adjustment factor applies, use only the largest adjustment.

Adjustment for Obstacles

Structure/Sound Barrier	Adjustment (dB)
A tall massive structure that interrupts the line-of-sight to the locomotive(s)	- 15
A two storey structure that extends beyond the source of noise	- 10
A sound barrier that is equivalent to a 2-4 storey high structure which interrupts the line-of-sight to the receptors.	- 7
A sound barrier that just interrupts the line-of-sight to the locomotive(s)	- 5

Step 4: Summary of Results

Estimated $L_{eq}(1h)$ Sound Level Calculation

Step	Description	Sound Level $L_{eq}(1h)$ (dBA)
1	Sound Level of Cross-Over Noise	
2	Adjustment Factor for Multiple Trains	
3	Adjustment Factor for the Presences of Obstacles	
	Total:	

Estimated L_{max} Sound Level Calculation

Step	Description	Sound Level L_{MAX} (dBA)
1	Sound Level of Cross-Over Noise	
3	Adjustment Factor for the Presences of Obstacles	
4	Adjustment Factor to Estimate L_{max}	+ 26
	Total:	

Example Calculation for Cross-Over Noise

Bob Smith lives next to a busy railway. The rail company installed a new cross-over. He would like to estimate the sound levels outside of his house due to the new cross-over.

There are 2 diesel freight trains that pass during the busiest hour of the day. Bob's house is approximately 100 m away from the cross-over and there is a large 2-storey commercial building between the tracks and his house. The commercial building interrupts the direct line of sight from his house to the cross-over.

Estimated L_{eq}(1h) Sound Level Calculation

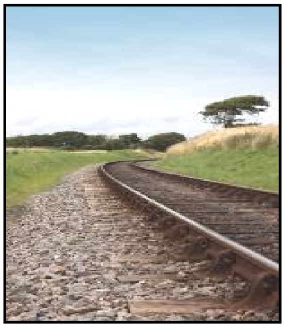
Step	Description	Sound Level Leq(1h) (dBA)
1	Sound Level of Cross-Over Noise	45
2	Adjustment Factor for Multiple Trains	+ 3
3	Adjustment Factor for the Presences of Obstacles	- 10
	Total:	38

Estimated the L_{max} Sound Level Calculation

Step	Description	Sound Level L_{max} (dBA)
1	Sound Level of Cross-Over Noise	45
3	Adjustment Factor for the Presences of Obstacles	- 10
4	Adjustment Factor to Estimate L_{max}	+ 26
	Total:	61

The L_{eq}(1h) and L_{max} sound levels at Bob's house are predicted to be 38 dBA and 61 dBA, respectively, due to the new cross-over.

Wheel Squeal on Curved Tracks



Wheel squeal occurs with the interaction of steel wheels on curved rail sections. The squeal can be particularly annoying because of the tonal nature of the noise.

The table is based on the reduction of a point source, resulting in a sound level drop off at the rate of 6 dB per double of distance from the source. Distances beyond 100-150 m include the effect of ground absorption.

Step 1: Baseline Sound Level of Wheel Squeal

Base Sound Levels for Wheel Squeal

Distance to Closest Point on Curved Track, m	Base Sound Level (dBA)	Distance to Closest Point on Curved Track, m	Base Sound Level (dBA)	Distance to Closest Point on Curved Track, m	Base Sound Level (dBA)
15	100	55	89	95	81
20	97	60	88	100	81
25	96	65	86	150	76
30	94	70	85	200	69
35	93	75	84	250	71
40	91	80	83	300	69
45	90	85	83		
50	89	90	82		

(Based on L_w = 134 dBA)

Step 2: Adjustment for Multiple Trains

Adjustment factors are provided to account for multiple trains. The table is based on the following assumptions:

- all trains considered have the same configurations, with the same number of locomotives and rail cars; and
- the trains are travelling at the same speed.

Adjustment for Multiple Trains per Hour

Number of Train Movements Per Hour	Adjustment (dB)
1	0
2	+ 3
3	+ 5
4	+ 6
5	+ 7
6	+ 8
7	+ 8

Number of Train Movements Per Hour	Adjustment (dB)
8	+ 9
9	+ 10
10	+ 10
10	+ 10
15	+ 12
20	+ 13
25	+ 14
30	+ 15

Step 3: Adjustment Factor for Time

Adjustment for Time

Pass-by Time in Minutes Per One Hour (Minutes)	Adjustment (dB)
60	0
50	- 1
40	- 2
30	- 3
25	- 4
20	- 5
15	- 6
10	- 8
7	- 9
6	- 10
5	- 11
4	- 12
3	- 13
2	- 15
1	- 18

Step 4: Adjustment Factor for the Presence of Obstacles

The following table provides adjustment factors for various obstacles. When more than one adjustment factor applies, use only the largest adjustment.

Adjustment for Obstacles

Structure/Sound Barrier	Adjustment (dB)
A tall massive structure that interrupts the line-of-sight to the locomotive(s)	- 15
A two storey structure that extends beyond the source of noise	- 10
A sound barrier that is equivalent to a 2-4 storey high structure which interrupts the line-of-sight to the receptors.	- 7
A sound barrier that just interrupts the line-of-sight to the locomotive(s)	- 5

Step 5: Summary of Results

Describe any unique characteristics of the noise, such as tonality, which may affect how people perceive railway noise. The Agency may consider an adjustment factor to account for these characteristics.

Estimated L_{eq}(1h) Sound Level Calculation

Step	Description	Sound Level Leq(1h) (dBA)
1	Baseline Sound Level of Wheel Squeal	
2	Adjustment Factor for Multiple Trains	
3	Adjustment Factor for Time	
4	Adjustment Factor for the Presences of Obstacles	
	Total:	

Estimated L_{max} Sound Level Calculation

Step	Description	L_{max} Sound Level (dBA)
1	Baseline Sound Level of Wheel Squeal	
4	Adjustment Factor for the Presences of Obstacles	
	Total:	

Example Calculation for Wheel Squeal on Curved Tracks

Bob Smith lives next to a busy railway. The section of track closest to his house is curved. During any worst-case hour there are 5 trains that pass by, each generating noticeable annoying wheel squeal. The total time it takes for 5 trains to pass Bob's house is 10 minutes. Bob is interested in estimating the sound levels outside of his house due to the wheel squeal. Bob's house is approximately 100 m away from the rail track centerline.

Estimated L_{eq}(1h) Sound Level Calculation

Step	Description	Sound Level L_{eq}(1h) (dBA)
1	Baseline Sound Level of Wheel Squeal	81
2	Adjustment Factor for Multiple Trains	+ 7
3	Adjustment Factor for Time	- 8
4	Adjustment Factor for the Presences of Obstacles	None
	Total:	80

Estimated L_{max} Sound Level Calculation

Step	Description	L_{max} Sound Level (dBA)
1	Baseline Sound Level of Wheel Squeal	81
4	Adjustment Factor for the Presences of Obstacles	none
	Total:	81

The L_{eq}(1h) and L_{max} sound levels due to wheel squeal at Bob's house are predicted to be 80 dBA and 81 dBA, respectively.

Locomotive Whistle Noise

In cases where rail operations share tracks or rights-of-way with at grade road crossings, the Federal safety rules require that locomotive whistles be sounded at public grade crossings.

The table below is based on the reduction of a point source, resulting in a sound level drop off at the rate of 6 dB per double of distance from the source. Distances beyond 100-150 m include the effect of ground absorption. A factor to estimate the L_{max} value is incorporated in Step 4.

Step 1: Baseline Sound Level of Train Whistles

Base Sound Levels for Train Whistles

Distance to the Track, m	Base Horn Sound Level, dBA
15	77
20	74
25	73
30	71
35	70
40	68
45	67
50	66
55	66
60	65
65	65
70	62
75	61
80	60
85	60
90	59
95	58
100	58
150	53
200	50
250	48
300	46

(Based on L_w = 111 dBA)

Step 2: Adjustment for Multiple Train Pass-bys

Adjustment factors are provided to account for multiple train pass-bys per hour. The table is based on the assumption that all trains considered are the same.

Adjustment for Multiple Trains

Number of Train Movements Per Hour	Adjustment, dB
1	0
2	+3
3	+5
4	+6
5	+7
6	+8
7	+8
8	+9
9	+10
10	+10
10	+10
15	+12
20	+13
25	+14
30	+15

Step 3: Adjustment Factor for the Presence of Obstacles

The following table provides adjustment factors for various obstacles. When more than one adjustment factor applies, use only the largest adjustment.

Adjustment for Obstacles

Structure/Sound Barrier	Adjustment, dB
A tall massive structure that interrupts the line-of-sight to the locomotive(s)	- 15
A two storey structure that extends beyond the source of noise	- 10
A sound barrier that is equivalent to a 2 to 4 storey high structure which interrupts the line-of-sight to the receptors.	- 7
A sound barrier that just interrupts the line-of-sight to the locomotive(s)	- 5

Step 4: Summary of Results

Estimated L_{eq}(1h) Sound Level Calculation

Step	Description	L_{eq}(1h) Sound Level (dBA)
1	Baseline Sound Level of Train Horn	
2	Adjustment Factor for Multiple Trains	
3	Adjustment Factor for the Presences of Obstacles	
	Total:	

Estimated L_{max} Sound Level Calculation

Step	Description	L_{max} Sound Level (dBA)
1	Baseline Sound Level of Train Horn	
3	Adjustment Factor for the Presences of Obstacles	
4	Adjustment Factor to Estimate L_{max}	+ 33
	Total:	

Example Calculation for Locomotive Whistle Noise

Bob Smith lives next to a busy railway. He would like to estimate the sound levels outside of his house due to whistle noise.

According to Bob, there are three freight trains that travel by his house between 1:00 am and 2:00 am. Bob's house is approximately 100 m away from the rail track centerline. Bob has built an earth berm between his house and the rail tracks. The berm just interrupts the line-of-sight to the passing trains.

Estimated L_{eq}(1h) Sound Level Calculation

Step	Description	Leq(1h) Sound Level (dBA)
1	Baseline Sound Level of Train Horn	58
2	Adjustment Factor for Multiple Trains	+ 5
3	Adjustment Factor for the Presences of Obstacles	- 5
	Total:	58

Estimated L_{max} Sound Level Calculation

Step	Description	L_{max} Sound Level (dBA)
1	Baseline Sound Level of Train Horn	58
3	Adjustment Factor for the Presences of Obstacles	- 5
4	Adjustment Factor to Estimate L_{max}	+ 33
	Total:	86

The L_{eq}(1h) and L_{max} sound levels at Bob's house are predicted to be 58 dBA and 86 dBA, respectively, due to locomotive whistle noise between 1:00 am and 2:00 am.

Rail Cars Classification/Shunting Impulse Noise

Impulse noise is created by trains stopping, starting, marshalling of rail cars or shunting of trains. Impulses can be measured independently in the field and then added logarithmically.

Step 1: Baseline Sound Level of Impulse Noise

The data in the following table is based on using impulse noise expressed in terms of dBAi. Other data using appropriate impulse noise descriptors may also be used (e.g. dBL_f) as discussed in Section 1.4 of the main document.

Base Sound Levels for Impulse Noise, dBAi

Distance to the Track (m)	Base Sound Level (dBAi)	Distance to the Track (m)	Base Sound Level (dBAi)
50	85	90	80
55	84	95	79
60	83	100	78
65	83	150	72
70	82	200	69
75	81	250	67
80	81	300	65
85	80	400	62

(Based on L_w = 111 dBA)

If it is desired to predict the impulse sound levels using the metric dBLf (unweighted dB using a fast response), the following alternate table may be used instead:

Base Sound Levels for Impulse Noise, dBZf

Distance to the Track (m)	Base Sound Level (dBZf)	Distance to the Track (m)	Base Sound Level (dBZf)
50	82	90	77
55	81	95	76
60	80	100	75
65	80	150	69
70	79	200	66
75	78	250	64
80	78	300	62
85	77	400	59

The above sound levels are based on coupling speed of 1 mph. An approximate adjustment of +3 dB should be added for every 1 mph increase in the coupling speed.

Step 2: Adjustment Factor for the Presence of Obstacles

The following table provides adjustment factors for various obstacles. When more than one adjustment factor applies, use only the largest adjustment.

Adjustments for Obstacles

Structure/Sound Barrier	Adjustment, dB
A tall massive structure that interrupts the line-of-sight to the locomotive(s)	-15
A two storey structure that extends beyond the source of noise	-10
A sound barrier that is equivalent to a 2-4 storey high structure which interrupts the line-of-sight to the receptors.	-7
A sound barrier that just interrupts the line-of-sight to the locomotive(s)	-5

Step 3: Summary of Results

Describe any unique characteristics of the noise, such as impulsiveness, which may affect how people perceive railway noise. The Agency may consider an adjustment factor to account for these characteristics.

Estimated L_{max} Sound Level Calculation

Step	Description	Sound Level (dBAi/dBZf)
1	Baseline Sound Level of Impulsive Noise	
2	Adjustment Factor for the Presences of Obstacles	
	Total:	

Example Calculation for Shunting Noise

Bob Smith lives next to a rail yard. Bob would like to estimate the impulse sound level, due to shunting activities, outside of his house.

Bob's house is approximately 100 m away from the rail track centerline. There is a noise barrier along the perimeter of the rail yard that extends approximately 3-storeys above the ground and blocks the line of sight to the rail yard.

Estimated L_{max} Sound Level Calculation

Step	Description	Sound Level (dBAi/dBZf)
1	Baseline Sound Level	78 / 75
2	Adjustment Factor for the Presence of Obstacles	- 7
	Total:	71 / 68

The shunting activities that occur in the rail yard result in an impulse noise level of approximately 71 dBA_i and 68 dBZ_f.

Appendix B – Suggestions Where Key Information Can Be Obtained

I. Data Available From the Railway Authority

- Train operational data:
  - Number of trains in specified time period(s)
  - Expected or operational train speeds
  - Type and composition of trains (cars, locomotives, etc.)
- The type of tracks in the area (jointed, welded, etc.)
- Proximity to switches and special track work
- Yard activities (may be in the form of general data only, and the investigator may have to gather more specific field data at several observation points)
- If and where train whistles are sounded

II. Data Available From the Local Municipal Authority

- Land use map for the subject area (current and future)
- Specific land use designation and zoning
- Geographic Information System (GIS) mapping which may be in the form of aerial photos to reasonably accurate scales showing property boundary outlines
- Some municipalities also maintain GIS mapping showing ground contour/spot elevations and outline of buildings and properties
- Noise study required through the municipal planning process

III. Open Source Information

- Internet-based aerial photography/mapping to reasonably accurate scales including approximate ground elevations
- Internet-based streets and building photographs and views

IV. Field Observations

- Observations of field conditions
- Observations of actual train operational data
- Other data that may be useful for noise modeling and reporting the concerns

- Specific information on the receptor's properties such as presence of barriers (berms, walls …), type of dwelling/building (light frame construction or brick veneer) and height of the building. If berms and/or barriers are observed, a noise report may be available from the municipality.

Appendix C – Example Table Layout to Present in Analysis

The following tables are examples how key information used in the assessment could be presented in the report. The information should be clear, organized, and complete with sufficient detail. Any modeling assumptions and adjustments should be stated in the report and sample calculations should be included to support the modeling results.

Example Modeling Input Tables:

Example Model Input Table 1

Train Type	Time Period	Trains per Time Period	Time Period (hours)	Loco per Train	Cars per Train	Train Speed (km/h)	Receptor Height (m)	Source-Receptor Distance (m)	Welded Rail	Soft or Hard Ground	Source Character Adjustment*	Predicted Sound Level (dBA)
Freight												
Freight												
Passenger												
Passenger												

Note: * Sound character adjustments are obtained from ANSI (2005) or ISO 1996-1:2003. See Appendix D for ISO 1996-1:2003 adjustments. The acoustical specialist must use professional judgment in applying these factors and provide a clear rationale to support their use.

Example Model Input Table 2

Train Type	Time Period*	Idling Time	Loco per Train	Cars per Train	Receptor Height (m)	Source-Receptor Distance (m)	Soft or Hard Ground	Source Character Adjustment for Low Frequency*	Predicted Sound Level (dBA)
Freight 1									
Freight 2									

Note: * Sound character adjustments are obtained from ANSI (2005). The acoustical specialist must use professional judgment in applying these factors and provide a clear rationale to support their use.

Example Field Measurement Tables:

Example Field Measurement Table 1

Time	Train Type	No of Locomotives	No of Cars	Train Speed (km/h)	Ambient Sound Environment[1,2]	Weather Conditions[1,2]

[1] Excluding the noise source under measurement.

[2] At time of the measurement.

Example Field Measurement Table 2

Time	Train Type	No of Locomotives	Idling Duration	Ambient Sound Environment[1,2]	Weather Conditions[1,2]

[1] Excluding the noise source under measurement.

[2] At time of the measurement.

Appendix D – Sound Character Adjustments

The table below describes adjustments from ISO 1996-1:2003 (CSA 2005). The adjustments may be applied to measurements or predictions of Day-Night sound levels at the noise receptor. Adjustments should only be applied if the impulsive or tonal sound characteristic is audible at the receiver. The acoustical specialist must use professional judgment in applying these factors and provide a clear rationale to support their use.

Example Adjustment Factors for Day-Night Sound Levels

Specification	Adjustment to add to Day-Night sound level (dB)
Regular Impulsive[1]	+ 5
Highly Impulsive[2]	+ 12
Prominent Tones	+ 3 to + 6

[1] ISO defines regular impulsive sound sources as “sources that are neither highly impulsive nor high-energy impulsive source sources.” Examples include slamming of car door and low-flying military aircraft.

[2] ISO defines a highly impulsive sound source as “*any source with highly impulsive characteristics and a high degree of intrusiveness*.” Example includes rail-yard shunting operations and pile driving.