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Guidance for Evaluating Human Health Impacts in Environmental Assessment:

NOISE

Canada

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To obtain additional information, please contact:

Health Canada
Address Locator 0900C2
Ottawa, ON K1A 0K9
Tel.: 613-957-2991
Toll free: 1-866-225-0709
Fax: 613-941-5366
TTY: 1-800-465-7735
Email: publications@hc-sc.gc.ca

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Any questions or comments on this document may be directed to:
Environmental Assessment Program, Ottawa, Ontario K1A 0K9
Email: ead@hc-sc.gc.ca

1 ACRONYMS

ACRONYM	MEANING
%HA	percent highly annoyed
%HSD	percent highly sleep disturbed
ANSI	American National Standards Institute
CEAA 2012	*Canadian Environmental Assessment Act*, 2012
CSA	Canadian Standards Association
CTA	Canadian Transportation Agency
dB	decibel
dBA	A-weighted decibels
dBZ	Z-weighted decibels
EA	environmental assessment
EIS	environmental impact statement
ERCB (EUB)	Energy Resources Conservation Board, Alberta (formerly Energy and Utilities Board)
FA	federal authority
Hz	hertz
ISO	International Organization for Standardization
Ld	daytime sound level
Ldn	day-night sound level
Leq	equivalent continuous sound level
Ln	night-time sound level
LAeq	A-weighted equivalent continuous sound level
LAmax	maximum A-weighted sound level
LSA	local study area
MNL	mitigation noise level
NIHL	noise-induced hearing loss
RA	responsible authority
REDA	*Radiation Emitting Devices Act*
RSA	regional study area
SEL	sound exposure level
WHO	World Health Organization
US EPA	United States Environmental Protection Agency

2 PURPOSE OF THIS DOCUMENT

This document provides generic guidance on predicting health risks related to levels and/or types of sound predicted in federal environmental assessments (EAs) of proposed major resource and infrastructure projects (such as mines, dams, pipelines and other projects). It presents the principles, current practices and basic information Health Canada looks for when it reviews the environmental impact statement (EIS) or other reports submitted by project proponents as part of the EA process.

It was prepared for the benefit of proponents and their consultants and to support an efficient and transparent project review process. The foundational information described here should be supplemented appropriately with additional information relevant to specific projects.

The guidance was also prepared for responsible authorities (RAs) and stakeholders to the EA process to communicate our normal areas of engagement and our priorities within these areas to help ensure that sufficient evidence is available to support sound decisions.

As part of its review, Health Canada may suggest that an RA, review panel or others collect information not specifically described here in order to assess the health effects of specific projects. As the guidance provided here is generic and designed to support EA under multiple jurisdictions, the scope of our review will also necessarily be amended according to specific jurisdictional requirements.

Health Canada updates guidance documents periodically and, in the interest of continuous improvement, accepts comments and corrections at the following address: ead@hc-sc.gc.ca

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3 INTRODUCTION AND CONTEXT

Health Canada provides expertise to assist RAs, review panels and/or other jurisdictions leading environmental assessments to determine whether there are potential health risks associated with proposed projects and how to prevent, reduce or mitigate them.

Health Canada brings to bear its expertise in health risks associated with air quality, water quality, radiation, noise and country foods when it reviews and provides comments on information submitted by proponents in support of proposed projects. Health Canada also provides guidance to help stakeholders, including responsible authorities, review panels and affected communities, better understand how to conduct health assessments for proposed major resource projects.

This document concerns the assessment of health risks associated with noise. It contains information on the division of roles and responsibilities for issues related to noise at various levels of government in Canada, health effects associated with noise, indicators of these effects, and steps in Health Canada's preferred approach to assessing noise-related health effects.

Appendix A contains a Glossary that defines the technical terms used throughout.

Appendix B contains a checklist of noise impacts that can be used to verify that the essential components of a noise-related health assessment are completed.

Appendices C through H contain additional technical and supplementary information related to noise assessment in EAs.

4 ROLES AND RESPONSIBILITIES WITH RESPECT TO NOISE

In Canada, noise is managed by different levels of government. Federal examples include Transport Canada (aircraft noise), the Canadian Transportation Agency (rail noise), and Employment and Social Development Canada (specifically the Labour Program: occupational noise in workplaces under federal jurisdiction). Health Canada has a regulatory role via the *Radiation Emitting Devices Act* (REDA), which controls the sale of devices that create an unnecessary noise hazard or do not comply with regulatory standards. Outside of these specific federal mandates, noise may be regulated directly through provincial and territorial legislation and guidelines, or through municipal by-laws, which may apply broadly or only to specific project types or sectors. Few or many different criteria may be used to establish noise guidelines, which may include, but not be limited to, noise impacts on sleep, hearing and high annoyance.

In the context of environmental assessments, one of Health Canada's roles concerning noise exposure is to review acoustical assessments for scientific validity and potential risks to human health from project-related changes in environmental noise. This role is fulfilled via leadership in science, research, participation in national and international bodies that develop standards (Canadian Standards Association (CSA) and the International Organization for Standardization [ISO]) and participation in the development of guidelines (World Health Organization [WHO]) for noise and human health.

Health Canada's scientists conduct, evaluate and remain current on domestic and international scientific research pertaining to the human health impacts of noise. Their expertise regarding the potential human health effects of noise is made available to responsible authorities conducting assessments of projects subject to EA legislation. The responsibility for determining the significance of these effects rests with the RAs, review panels or other jurisdictions conducting assessments.

Health Canada does not enforce noise thresholds or standards, but can make available information and knowledge acquired from Canadian and international sources regarding the potential adverse human health effects of noise—based on the type of community (e.g. urban, suburban or quiet rural areas). When noise levels have the potential to induce adverse human health effects, Health Canada may make available information or knowledge on mitigation measures. When mitigation measures are to be implemented, appropriate mitigation strategies based on all applicable guidelines should be considered. Health Canada encourages proponents to consult with other government authorities to determine which enforceable standards for noise exist for specific regions.

4.1 HEALTH CANADA'S APPROACH TO NOISE ASSESSMENTS IN ENVIRONMENTAL ASSESSMENTS

Noise is a somewhat special type of change to the environment, as it is an energy added to the air in the form of acoustical waves. Below the exposure threshold of biological damage to the ear, noise can also cause potential health impacts, such as sleep disturbance and/or cause long-term high annoyance, an indicator of potential health impacts. These impacts depend on the interference of the noise with what one is trying to do (e.g. sleep, concentrate or communicate) and the expectation of peace and quiet during such activities (e.g. in a quiet rural area or during Indigenous spiritual ceremonies).

Human response to noise varies among individuals and according to the specific situation. Response to noise can be characterized using different methodologies and endpoints, and may be affected by several factors. These factors include how noise moves from source to receptor, how it is measured, and what behavioural/physiological and/or psychological changes it evokes in humans.

A particular standard or guideline may not cover all possible considerations or the inherent variability in noise characterization. Several approaches to assessing noise impacts exist, and these various approaches often rely on different noise guidelines and/or regulations that may not be easily reconciled. For example, a guideline may be established to protect against hearing loss, but consideration of additional human health endpoints, such as sleep disturbance, may also be warranted. Some guidelines and/or regulations are based on limiting absolute noise levels, whereas others emphasize the relative change in the noise environment.

This document provides general information on Health Canada's preferred methodology for various human health endpoints used to determine these potential impacts. The prediction of potential impacts is necessary to understand the nature, extent and severity of human health effects that may occur due to noise generated during various stages of a proposed project. These calculations also serve to evaluate the feasibility of the project proponent's planned mitigation measures in reducing human health effects and whether a specific mitigation measure is expected to achieve the desired result. Health Canada reviews the methodology and calculations provided in the noise assessment, as well as the subsequent discussion of potential noise-related impacts on health, for accuracy and completeness. This information may be complementary to the applicable regulations, EIS guidelines or requirements of other jurisdictions.

Depending upon the nature of the project, the responsible authority, review panel or other jurisdiction conducting the EA may want to consider the assessment of noise impacts (specifically, sleep disturbance) on off-duty workers residing in or near the project area. Note that occupational exposure is typically under provincial or territorial jurisdiction, and Health Canada does not review this information in the context of EAs. Also, Health Canada does not possess information or knowledge on the impacts of noise on wildlife or ecosystems.

5 IMPACTS ASSOCIATED WITH NOISE

In reviewing an EA, Health Canada emphasizes only those endpoints that have demonstrated a reasonable causal relationship between noise exposure and adverse human health effects. In the context of an environmental assessment, the associations that have been reported between noise exposure and hearing loss, sleep disturbance, interference with communication, noise complaints and a high level of annoyance are particularly relevant (WHO 1999, 2011). The information and knowledge that Health Canada makes available is based on the following: the modelled changes between the existing and predicted daytime and night-time sound levels (for construction, operation and decommissioning activities); predicted noise-level changes at specific receptor locations (see Appendix G) where people are or will be present; the characteristics of the noise (e.g. impulsive or tonal); and/or the type of community (e.g. urban, suburban or quiet rural area).

5.1 NOISE-INDUCED HEARING LOSS

There is no known risk of permanent hearing loss associated with sound levels below 70 A-weighted decibels (dBA), regardless of the exposure duration. However, as sound levels increase, the duration of daily exposure becomes an important risk factor for hearing loss. The time period before damage occurs shortens as the average sound level increases (WHO 1999; Health Canada 2012).

Hearing loss impacts are not typically considered in EAs because project-related sound levels rarely reach these high levels at the locations of impacted receptors. However, noise-induced hearing loss (NIHL) may be a concern when project activities such as blasting, pile driving and jack hammering are expected. When considering impulsive noise, Health Canada suggests following the WHO recommendation to avoid hearing loss resulting from impulsive noise exposure and that peak sound pressures not exceed 140 Z-weighted decibels (dBZ) for adults and 120 dBZ for children (WHO, 1999).

5.2 NOISE-INDUCED SLEEP DISTURBANCE

Sleep disturbance encompasses the following: difficulty falling asleep; awakenings; curtailed sleep duration; alterations of sleep stages or depth; and increased body movements during sleep. The effects of sleep disturbance have been shown to include, but are not limited to: increased fatigue; irritability; and decreased concentration and performance. These effects are generally experienced in the days subsequent to significant disturbances in sleep. Ongoing disturbed sleep has been reported to be linked to a wide variety of health effects, including, but not limited to cardiovascular effects, mental health and accidents (WHO 2009; Zaharna and Guilleminault 2010).

The guidelines and recommendations of the WHO (1999, 2009) regarding sleep disturbance should be considered in the EA. In particular, WHO guideline levels should not be exceeded for quiet rural areas and susceptible populations, such as those in hospitals, or convalescent or senior homes. For estimating the likelihood of sleep disturbance on any given night, the WHO's *Guidelines for Community Noise* (1999) report a threshold for sleep disturbance as being an indoor sound level of no more than 30 dBA LAeq for continuous noise, during the sleep period. For individual noise events, the WHO has stated: "*For a good sleep, it is believed that indoor sound pressure levels should not exceed approximately 45 dBA LAmax more than 10–15 times per night....*" Health Canada recognizes that in many cases, people will want to keep windows at least partially open, depending on the season. Unless specified otherwise, it is assumed by Health Canada that an outdoor-to-indoor transmission loss with windows at least partially open is 15 dBA (United States Environmental Protection Agency [US EPA] 1974; WHO 1999). Fully closed windows are assumed to reduce outdoor sound levels by approximately 27 dBA (US EPA 1974).

More recently, the WHO has published night-time noise guidelines that are intended to protect the public, including the most vulnerable groups, from adverse health effects associated with sleep disturbance due to night-time noise. The recommended annual average is 40 dBA Ln outdoors (WHO 2009). As this is an annual average, there may be times when the sound level is above and below 40 dBA; however, there should be no long-term impact on health if the annual average does not exceed 40 dBA.

Consistent with the view expressed above, when care facilities, including hospitals, nursing homes, daycare centres and homes for the elderly, are identified as receptors that could be impacted by project-related noise, it is a good practice to consult with these facilities to determine whether certain sensitivities to sleep disturbance exist during the day. Should any such sensitivities be noted, the threshold level for sleep disturbance specified in the WHO's Guidelines (1999, 2009) may be used to assess the severity of potential impacts on these receptors. Where there is interest in estimating the prevalence of sleep disturbance—expressed as the percentage self-reported highly sleep disturbed (%HSD)—Miedema and Vos (2007) have published dose-response relationships for estimating %HSD by road, rail and aircraft noise.

5.3 INTERFERENCE WITH SPEECH COMPREHENSION

To maintain good speech comprehension, the recommended sound levels vary, depending on whether the noise from project activities is measured (or estimated) indoors or outdoors. For good speech comprehension, speech levels should exceed that of background noise by 15 dB. The same difference is also desirable for music or television listening. Normal indoor speaking levels are typically 55 to 58 dBA (Levitt and Webster 1991), which is in line with the US EPA 1974 recommendation that indoor background noise levels should not exceed 40 dBA to achieve 100% sentence intelligibility. According to the WHO (1999), speech in relaxed conversation is 100% intelligible in background noise levels of about 35 dBA, and can be understood fairly well in background levels of 45 dBA. Therefore, Health Canada holds the view that background noise levels (i.e. noise due to project activities as measured indoors) be maintained below 40 dBA to sustain adequate speech comprehension.

People generally tend to speak in a louder voice when outdoors, where the separation between speakers is typically larger than indoors. In outdoor environments where distances of up to two metres exist between speakers, US EPA 1974 suggests that 95% sentence intelligibility is acceptable, and recommends a background noise level of 55 dBA outdoors (i.e. 60 dBA with a 5-dBA margin of safety). To sustain good outdoor speech comprehension, background outdoor noise levels for continuous noise should be kept below 55 dBA.

When a school is identified as a potentially impacted receptor, it is suggested that the EA address the special sensitivity of this type of receptor to daytime noise. The WHO recommends an ideal background noise level of 35 dBA in the classroom (WHO 1999). This level is the threshold below which no impacts are expected. This recommendation is based especially on speech interference, but also on the impacts of disturbing message communication and the extraction of information (e.g. speech comprehension and reading), and annoyance.

5.4 INDICATORS OF POTENTIAL HUMAN HEALTH EFFECTS

Health Canada holds the view that certain community reactions to project-related noise represent potential indicators of adverse health; that is, if the noise is experienced over a long period of time, it could potentially increase one's risk of developing health effects. In the context of noise exposure, two of the most common community reactions are complaints and annoyance.

5.4.1 Noise Complaints

Many municipal policies concerning noise are based on the resolution of complaints. Noise-related complaints can be an indicator of human health effects and are used, in US EPA 1974, to help identify sound levels that would protect public health and well-being. Summarizing the US EPA document, Michaud *et al.* (2008) state that a "no reaction" response corresponded to a normalized outdoor day-night sound level (Ldn) of 55 dBA for the intruding noise. They also state that sporadic complaints can occur in communities when this noise level exceeds 55 dBA or widespread complaints, at a level exceeding 58 dBA. Michaud *et al.* (2008) discussed the divergence between "sporadic complaints" and "widespread complaints," when the normalized Ldn of the intruding noise (i.e. project noise) reached 62 dBA. Based on this work, Health Canada uses a normalized Ldn of 62 dBA when it considers effects related to widespread complaints. When project sound levels are greater than a normalized 75 dBA Ldn level, complaints can be expected to include strong appeals to authorities to stop noise. Reliance on noise complaints may only provide a partial indication of a noise problem (Michaud *et al.* 2008) and when possible, the estimated magnitude of complaints should be supplemented with other measures, such as the calculated change in the percentage of highly annoyed (%HA) in an average community and/or estimated impacts on sleep.

5.4.2 Long-term High Annoyance

Annoyance can be described as the effect of noise that most people are aware of. The consideration of community annoyance due to noise is useful; the %HA can be thought of as an aggregate indicator of assorted noise effects, present to varying degrees, which are creating a negative effect on the community and which may not be measurable when considered as separate negative effects.

High annoyance has been widely used as one way to estimate a community response to noise levels. High annoyance is an endpoint that is not directly measured but has been synthesized from self-reported annoyance in numerous large, community-based surveys. Although individual reaction varies greatly, the reported change in %HA among an average community in reaction to certain sound levels provides usable exposure-response relationships (Michaud *et al.*, 2008). Thus, the calculated %HA provides information on how an average community responds to a noise level. Health Canada uses the change in %HA as an appropriate indicator of noise-induced human health effects from exposure to project operational noise (see Section 6.3.2) and to long-term construction noise (see Section 6.3.1) exposure.

There have been more than 50 years of social and socio-acoustic research that either directly or indirectly studied the impact of noise on community annoyance. These studies have consistently shown that an increase in noise level is associated with an increase in the percentage of the community indicating that they are highly annoyed. The relationship between noise levels and high annoyance is stronger than any other self-reported measure, including complaints. Canadian research on road-traffic noise also shows that respondents highly annoyed by traffic noise are significantly more likely to perceive their annoyance as having a negative impact on their health (Michaud *et al.* 2008).

To assess the impacts of noise from projects using this indicator, the project-related change in the sound environment and the related increase in %HA are evaluated. Using the dose-response relationship between noise levels and annoyance, as per ISO 1996-1:2003, one can calculate the percentage of a typical community that would report being "highly annoyed," expressed as %HA. The %HA increases exponentially as sound levels increase. Due to the non-linear nature of the relationship between noise and %HA, there can be a substantial increase in the %HA, with relatively small changes in the noise environment—in situations where the initial baseline noise level is high. In other words, the higher the initial noise level, the more the annoyance will increase when there is an increase from the baseline noise level. In general, this dose-response relationship may be a useful tool in characterizing and quantifying average community response to noise levels and changes in noise levels.

Health Canada prefers the use of the dose-response relationship only for long-term noise exposure considerations in EAs, and holds the view that %HA be calculated only for receptors exposed to long-term project noise (more than one year). It is important to emphasize that these annoyance responses are not applicable to a particular individual or group, but represent an average community. Appendix F presents the methodology for obtaining variables used in the equations to calculate %HA. Health Canada prefers that the increase in %HA per representative receptor (i.e. a group of residences in similar geographic proximity to the noise source) be evaluated and not the average increase in %HA for all receptors—which could underestimate the project-related impact on community annoyance.

Noise mitigation measures should be considered when a change in the calculated %HA at any given receptor location exceeds 6.5%. The ISO method does not characterize the nature of the increase in terms of severity of impact. However, the U.S. Federal Transit Administration describes a long-term increase of more than 6.5%HA as representing a severe project-related noise impact (Hanson *et al.* 2006). This increase is based in part on the historical acceptability in the U.S. of no more than a 5-dBA increase in Ldn in an urban residential environment (not immediately adjacent to heavily travelled roads and industrial areas). Further justification for using an increase of 6.5%HA as a criterion for a severe noise-related impact may be found in Michaud *et al.*, 2008, and Hanson *et al.*, 2006. ISO 1996-1:2003 notes that research has shown that there is a greater expectation for, and value placed on, "peace and quiet" in quiet rural areas, which may be equivalent to up to 10 dB in noise. Unless specified otherwise in an EA, this expectation is assumed by Health Canada to be equivalent to an adjustment of 10 dB (ISO 1996-1:2003).

Note that the change in %HA is only one potential indicator of noise-related human health effects and that all possible human health endpoints may be considered in an assessment. In situations where baseline noise levels exceed an Ldn of 77 dBA , and project noise levels alone exceed an Ldn of 75 dBA, it may be too difficult to meet the WHO guidelines for sleep disturbance and vulnerable populations (see Section 5.2). It may also be too difficult to reduce these environmental noise levels to meet the levels suggested in Section 5.3, regarding adequate speech comprehension indoors for residents. Therefore, Health Canada holds the view that mitigation of project noise be applied if it exceeds an Ldn of 75 dBA, even if the change in %HA does not exceed 6.5%. For example, if project noise alone exceeds an Ldn of 75 dBA, it may be that the levels noted in Sections 5.2 and 5.3 are not achievable in typical residences, even in situations where the highest level of outdoor-to-indoor transmission loss is achieved. In situations like this, project noise should be cautiously mitigated to a level below an Ldn of 75 dBA, which includes a consideration of uncertainty in predictions.

6 AN APPROACH FOR ASSESSING THE HEALTH IMPACTS OF NOISE

The approach preferred by Health Canada for noise assessment involves obtaining the best possible characterization of the acoustical exposure that may impact potential noise receptors. This description includes sound level and duration, and noise characteristics, such as whether the noise is tonal, impulsive, highly impulsive, etc. (see Appendix B).

To obtain the highest-quality data in acoustical studies, acoustical assessments should be completed by professional and properly trained consultants, using equipment and methods that are recognized as the industry standard for acoustical measurements. Occasionally, limitations may exist in the technology and expertise available for some projects. Whenever uncertainty exists in the selection of appropriate monitoring equipment or in the application of standard techniques for noise characterization in EAs, government authorities are encouraged to consult Health Canada for assistance or additional guidance.

The main steps in assessing the potential health impacts of changes in noise associated with a project are the following:

- Identify people (receptors) who may be affected by the project-related noise;
- Determine the existing (baseline) noise levels at representative receptors, by measurement or estimation;
- Predict project-related changes in noise levels for each phase of the project (construction, operation and decommissioning) and describe the sound characteristics;
- Compare predicted noise levels to relevant guidelines and/or standards;
- Identify and discuss the potential human health impacts associated with predicted changes in noise levels;
- Consider mitigation measures, their implementation, and any residual effects, after the measures are implemented;
- Consider community consultation and prepare a complaints-resolution plan; and
- Consider the need for monitoring of noise levels.

6.1 IDENTIFICATION OF HUMAN RECEPTORS IN PROJECT AREAS

It is important to identify and describe all existing and reasonably foreseeable human receptors in the area that may be influenced by project-related noise—including a description of how the receptors were identified (e.g. recent land use maps, verification in person). The characterization of potential receptors typically includes the distance(s) to the project's local study area (LSA) and regional study area (RSA) for each receptor, and map(s) illustrating modelled noise levels from the project at receptor locations in the study area. While sound levels at one receptor site are typically averaged over time, it is not appropriate to assess noise impacts using the average increase in sound levels across receptor locations because sound level ranges, and therefore noise impacts, may be different at different locations.

Health Canada prefers that noise assessments identify and describe any particular receptors that may have a heightened sensitivity to noise exposure (e.g. Indigenous Peoples, schools, child care centres, hospitals). Specifically note in the EA documentation if receptors with heightened sensitivity are not present in the study area. A list of commonly encountered receptors and related characteristics is provided in Appendix G.

When identifying receptor sites at which noise impacts will be assessed, it is a good practice to consider and note the following:

- how the sites are representative of potentially impacted receptors;
- any receptors who have rented dwellings or land; and
- any receptors who live outside Canada that may be impacted by a project, where applicable.

If any local receptors that may be influenced by project noise are not being assessed in the EA, provide a rationale for this exclusion. If no human receptors are (or will be) present in the local or regional study area during the construction, operation or decommissioning phases of the project, no further assessment with respect to noise is necessary.

It is important to identify and describe any receptors in rural areas that could be considered to have a greater expectation of "peace and quiet" (i.e. quiet rural areas). Health Canada considers a "quiet rural area" to be a rural area with Ldn due to human-made sounds to be below 45 dBA. For areas with the most stringent permissible noise levels, provincial regulatory criteria may also be used to define "quiet rural areas," provided these areas are adequately described.

Due to the expected heightened sensitivity to noise, baseline levels in quiet rural areas are adjusted by adding 10 dB (ISO 1996-1:2003, ANSI, 2005). This 10 dB adjustment also applies to the predicted project noise levels for all phases of the project (i.e. construction, operation and decommissioning) in determining percent highly annoyed (%HA). The effect of this +10 dB adjustment in quiet rural areas is to produce a greater change in %HA than would occur with unadjusted noise levels. The exponential relationship between %HA and noise levels, as discussed in Section 5.4.2, produces increasingly larger changes in %HA for equal increases in project noise, compared to the baseline level.

An example follows:

If the initial baseline noise level is 45 dBA and the project-related noise level is 55 dBA, the unadjusted change in %HA would be 3.01 (using equations in Appendix F). When the +10 dB adjustment to both baseline and project-related noise is applied in a quiet rural area, the baseline rating level used to calculate the %HA becomes 55 dBA and the project-related noise rating level becomes 65 dBA in the calculation of %HA. At these rating levels, the resulting change in %HA is 9.79. Therefore, a 10-dBA project-related noise increase from a baseline of 45 dBA in a quiet rural area will result in exceeding the suggested mitigation level of 6.5%, while a 10-dBA increase in project-related noise from a baseline of 45 dBA in a more urbanized area would not exceed this level.

6.2 ASSESSMENT OF BASELINE NOISE

Baseline noise levels that are determined by measurement or estimation can be applied to noise impact assessments for all project phases (construction, operation and decommissioning). Health Canada prefers that measured or valid estimated baseline noise levels for both daytime (Ld) and night-time (Ln) at all representative receptor locations be assessed and reported in the EA. It is a good practice to clearly indicate whether sound levels are measured or estimated, and to identify the exact location of the baseline measurement (e.g. outdoors at the building facade, or on the lower level, upper level, property line, etc.).

6.2.1 Measuring Baseline Noise

When baseline measurement is conducted, Health Canada prefers that the measurement be completed in accordance with ISO 1996-2:2007 at each representative receptor, and that the reports include the dates and hours used to characterize these measurements. Sounds that are not generated by human activity (e.g. ocean, wind and animal noises) should not be included in determining a baseline sound level. Wind and rain can also create false signals in the microphone used to measure sound levels. As a result, sound is not measured in the presence of precipitation or when wind speeds exceed 14 km/hr, unless an appropriate wind screen is used.

To minimize uncertainty of the validity of measured baseline-sound-level data, Health Canada suggests that the EA report provides the following information:

- the number of hours or days used for measurement, and a rationale for why the reported sound levels can be considered representative;
- an estimate of seasonal differences and any differences between the weekend and weekday baseline noise levels;
- where applicable, any differences due to weather conditions;
- all noise sources that contribute significantly to the baseline, by type (e.g. traffic, aircraft, trains, industrial); and
- a characterization of each noise type described in the assessment using descriptors such as continuous, intermittent, regular impulsive, highly impulsive, high-energy impulsive, and continuous tonal and intermittent tonal.

6.2.2 Estimating Baseline Noise

Although the standard approach for baseline sound determinations is direct measurement, there may be situations where baseline measurement data are not available. In such cases alternative approaches to estimating baseline levels exist. One conservative (i.e. most protective) approach is to consider a reasonable worst-case scenario and assume Ldn baselines of 35 dBA for rural areas and 45 dBA for urban/suburban areas. However, defaulting to these lower baseline sound levels may result in greater values obtained for change in %HA when calculating noise effects for construction lasting more than one year or for operational noise. Note that the estimate of an Ldn of 45 dBA for urban/suburban areas does not consider the inherent variability in baseline noise estimates based on population density, proximity to busy roads or adjacent industrial activity.

The use of alternative approaches to estimating baseline noise may yield higher baseline estimates than the reasonable worst-case scenario described above. To adequately review the reliability of such estimates, Health Canada prefers that sufficient supporting rationale is provided in the EA, particularly where the accuracy of the selected estimation approach decreases (see below).

Other approaches to estimating baseline noise in order of decreasing accuracy may include the following:

- predictions based on computer models whose inputs, algorithms and outputs are based on accepted standards;
- manual calculation procedures based on well-accepted models or standards;
- the use of known baseline levels from areas with very similar acoustical environments (e.g. very similar types of baseline noise sources, distances from sources to receptors, meteorological conditions, shielding, etc.); and/or
- approximate values from Table 6.1 (see below).

Table 6.1 describes the estimation of baseline noise levels, based on a qualitative description of community characteristics and an average census-based population density (ERCB Directive 038, 2007). If this method (based on US EPA 1974 and ERCB 2007) is used in a noise assessment, provide a rationale to support the validity of its use.

Table 6.1: Estimation of Baseline Noise Levels Using Qualitative Descriptions and Population Densities of Average Types of Communities

Community Type (Qualitative Description)	Average Census Tract Population Density, Number of People Per Square km	Estimated Baseline Sound Level[1], Ldn (dBA)
Quiet rural dwelling units more than 500 m from heavily travelled roads and/or rail lines and not subject to frequent aircraft flyovers	28	≤45[2]
Quiet suburban residential remote from large cities, industrial activity and trucking	249	48–52
Normal suburban residential not located near industrial activity	791	53–57
Urban residential not immediately adjacent to heavily travelled roads and industrial areas	2493	58–62
Noisy urban residential near relatively busy roads or industrial areas	7913	63–67
Very noisy urban residential	24,925	68–72

1. Note that a range of values is provided and that selection of the appropriate estimated value would typically be based on the precautionary principle in the absence of adequate justification for a higher baseline. All day-night sound level (Ldn) values, except those of the quiet rural area community type, are based on the US EPA levels document (US EPA 1974).

2. The quiet rural area (Ln = 35 dBA) estimated baseline noise level and population density were obtained from ERCB Directive 038 (revised Feb 16, 2007). The difference between Ld and Ln was obtained from ERCB and US EPA, and was approximated as 10 dBA. As such, quiet rural areas are considered to be less than or equal to 45 dBA Ldn.

6.3 ASSESSMENT OF PROJECT-RELATED NOISE

It is a good practice to document the criteria used to review the human health impacts of project-related noise and to characterize the potential for change in the sound environment due to any project activity, including construction, operation and decommissioning. In the noise assessment, it is important to compare predicted noise levels during construction and operation to the baseline noise levels at each representative receptor, as this will clearly demonstrate the predicted changes in noise levels experienced by each receptor. Health Canada suggests that the type of measurements used and the uncertainty associated with any sound-level monitoring, modelling or estimates be provided for all reported data.

It is important to consider that human health effects related to noise may be evaluated by a variety of endpoints and indicators, as discussed in Section 5. Health Canada holds the view that the evaluation of each potential noise-induced human health effect by one method alone is not necessarily representative of all possible human health effects related to noise exposure. For example, when using %HA as an indicator in a noise impact assessment, the change in %HA of receptors exposed to long-term noise may not exceed 6.5%, but these receptors may experience sleep disturbances due to an exceedance of the WHO indoor sleep-disturbance threshold limits discussed in Section 5.2. When changes in the sound environment have been characterized, Health Canada suggests that a discussion of the severity of these changes and how they impact human health be included in the noise assessment. Such an evaluation would typically describe all appropriate endpoints or indicators used to address potential impacts on human health, as described in this guidance. Alternative approaches to this evaluation may be acceptable, provided they are supported by adequate scientific justification.

In some cases, a less extensive assessment may be warranted. If noise levels at all receptors are not expected to approach the US EPA's mitigation noise levels (see Section 6.4.2) or to result in a change in %HA exceeding 6.5%, as discussed in Section 5.4.2, Health Canada suggests that a scientifically sound rationale be provided in the EA—to confirm that noise levels will be well below the level where human health effects may occur (see Section 5) and that this rationale has been provided in place of a complete noise impact assessment.

The results and conclusions of the noise assessment should be clearly documented in the EA. Health Canada suggests that the conclusion include a discussion of whether mitigation measures and/or follow-up monitoring is warranted.

The following sections discuss the assessment of project-related construction noise of short-and long-term durations, as well as project operational noise.

6.3.1 Assessing Construction Noise

Noise from construction activities has the potential to negatively impact nearby receptors and is often the loudest source of project-related noise. Predicted construction noise levels for both daytime (Ld) and night-time (Ln) at all representative receptor locations should be reported in the EA. To permit a proper comparison of noise levels, the units, averaging times and other measurement parameters (including the uncertainty associated with any of the measurements) should be the same as those used in establishing the baseline.

The method for determining effects related to construction noise depends on the duration of the construction activities as follows:

i. Short-Term Construction Noise Exposure (<1 year)

Health Canada suggests using the US EPA (1974) methodology that provides mitigation noise levels (MNLs) and associated adjustments for community types, to determine if adverse effects are likely and if mitigation is suggested. This methodology is discussed in Section 6.4.2, **Mitigating Short-Term Construction Noise Exposure (<1 year)**. Consideration should also be given to potential impacts on sleep, where adverse impacts are reported to begin when sound levels inside bedrooms exceed 30 dBA for continuous noise sources and 45 dBA LAmax for discrete noise events (WHO 1999). With an estimated 15 dBA outdoor-to-indoor transmission loss, the equivalent outdoor levels should be 45 dBA and 60 dBA, respectively.

ii. Long-Term Construction Noise Exposure (≥ 1 year)

Health Canada suggests that construction noise lasting longer than 1 year be assessed as operational noise. This approach allows for an evaluation of the change in %HA at each receptor, in accordance with ISO 1996-1:2003. Appendix F describes the methodology and equations related to calculating the change in %HA for projects. The appropriate adjustments (see Appendix E) may be applied to the A-weighted calculated or measured noise levels. This method of assessing construction noise is essentially identical to that of assessing operational noise, as discussed in Section 6.3.2 below. Also, potential impacts on sleep should be considered when construction activities may occur at night-time (as noted above in short-term construction).

There may be insufficient information concerning construction activities to permit an assessment of their potential impacts at the EA stage. Conservative assumptions based on similar projects and/or planned activities are often used in estimating noise levels and calculating impacts due to construction. An example of this estimation technique is to assume that all equipment is operating simultaneously for a 12-hour period, even though actual impacts are expected to be lower. In these cases, Health Canada suggests providing as much information as possible on construction activities, schedules, equipment use and any assumptions used, in addition to an explanation of why a more detailed assessment is not possible.

It is a good practice to include a description of construction noise as it relates to exposure duration, rather than construction activity duration. The difference in these perspectives becomes apparent when considering the impacts of construction noise related to road projects. As a road project progresses, noise exposure continually varies from receptor to receptor as the geographic location of the construction equipment changes.

6.3.2 Assessing Project Operational Noise

Predicted operational noise levels for both daytime (Ld) and night-time (Ln) at all representative receptor locations should be reported in the EA. To permit a proper comparison of noise levels, the units, averaging times and other measurement parameters (including the uncertainty associated with any of the measurements) should be the same as those used in establishing the baseline.

As discussed previously, the determination of %HA is a widely accepted indicator of the human health effects of long-term noise exposure. Similar to comments in Section 6.3.1 ii above, the assessment of project operational noise may include an evaluation of the change in %HA at each receptor site, in accordance with ISO 1996-1:2003. Appendix F describes the methodology and equations related to calculating the change in %HA for projects. The appropriate adjustments (see Appendix E) may be applied to the A-weighted calculated or measured noise levels. If noise from project operations may occur at night-time, the assessment of operational noise should also consider potential impacts on sleep.

Modelling sound levels (using appropriate software) is one method that is commonly used to estimate present or future operational sound levels. In the assessment, clearly identify the model(s) used and justify their suitability. Specific models may be selected on a site-by-site basis. Health Canada prefers that any assumptions used be conservative (i.e. reasonable worst-case scenario) and be adequately described in the assessment.

If project-related noise levels are provided without being added to the baseline sound levels, this must be clearly indicated. In assessing impacts on human health, the baseline and project noise are added together, as their sum represents what noise effects the receptors will actually experience. Other changes in the sound environment may also be characterized. If project-related operational noise includes audible tonal or impulsive noise (including regular impulsive, highly impulsive and high-energy impulsive types of noise [ISO 1996-1:2003] [e.g. blasting]), appropriate adjustments as presented in Appendix E can be made. Refer to ISO 1996-2:2007 for additional guidance on describing or measuring tonal and impulsive noise. These adjustments apply only when the noise under consideration is audible at receptor sites. In situations where more than one source characteristic adjustment is applicable (e.g. impulsive or tonal), only the higher of the adjustments is used. However, all time-of-day adjustments and the quiet rural area adjustment are to be added to the highest of the applicable source adjustments.

6.4 MITIGATION

Noise management and noise monitoring plans, including complaint resolution plans, are often incorporated as part of the EA's Environmental Management Plan. When health effects from project-related noise are possible, Health Canada prefers that a noise management plan detailing the actions that will be taken to minimize human health impacts due to project noise (mitigation measures) be developed and included in the EA. Special consideration should be given to mitigation measures for construction noise that occurs at night, in order to minimize impacts on sleep (i.e. avoiding tonal or impulsive noise sources at night).

Due to the inherent uncertainty in both predicted and/or measured project noise, additional information should be provided to demonstrate that exceedances of the MNL or a 6.5% change in %HA are unlikely. Proposals for specific mitigation measures to limit noise at receptors where this uncertainty exists should be provided in the EA.

Health Canada prefers that any noise mitigation measures proposed for the project be described in sufficient detail to permit Health Canada to adequately review the measures' impacts on achieving noise reduction. When describing possible mitigation or other noise management measures, identify the conditions or circumstances under which various mitigation measures will be applied or implemented.

As it is more effective to use source controls, Health Canada prefers that mitigation measures be applied to the source rather than the receptor site, where this is technically feasible. It should be noted that some estimates discussed in Section 5.2 (e.g. noise attenuation by closed windows or enclosed balconies) may not achieve the desired level of noise reduction, due to variability in construction techniques. While fully-closed windows are assumed to typically reduce outdoor sound levels by 27 dBA (US EPA 1974), the type of enclosures that surround the windows or the presence of ventilation ducts may result in an outdoor-to-indoor noise transmission loss that is lower than 27 dBA.

6.4.1 Community Consultation

Developing a community consultation plan can be helpful when projects propose noisy work occurring outside of normal working hours or extended work that produces high levels of noise (such as rock hammering or pile driving). The consultation process may assist in establishing feasible mitigation measures by targeting receptors that have the greatest potential for human health-related effects resulting from noise disturbance. Previous experience in assessing community reaction to noise impacts following community consultation has demonstrated that in these cases, a community is more likely to be understanding and accepting of noise, and more likely to make appropriate adjustments to limit noise exposure. This has been noted particularly when the information provided during the consultation process is accurate and does not attempt to understate the likely noise level, and when commitments made by the proponent to limit noise during specific hours are respected.

The EA should specify whether community consultation with respect to noise has occurred, and whether any human health concerns have been expressed by potentially impacted receptors.

The comments or recommendations received during the consultation process may provide an indication of which project elements are likely to trigger the greatest level of opposition, particularly where noise issues are identified. Informing the public about project plans early in the process is encouraged, as this may provide additional options for mitigation measures, or at the very least, provide the opportunity to discuss the mitigation measures under consideration. It is a good practice to undertake community consultation prior to the creation of work schedules (e.g. continuous versus specific construction times) and to discuss the preferred means of informing the public of the time and duration of noisy activities. When construction delays or other problems result in extended construction schedules, Health Canada suggests that a plan for community consultation be implemented and that this consultation process be described in the EA, where applicable. When a project proponent deems it to be manageable, it may be preferable to consult with residents individually.

When the community receives information about expected changes in sound levels through a consultation process, and feels that concerns with respect to noise may be addressed and resolved, the incidence of noise-related complaints is frequently reduced. Health Canada suggests that this approach be considered in managing both minor and major public concerns related to project-related noise. For more information, refer to ERCB Directive 38 (2007). For information specific to rail projects, refer to the Canadian Transportation Agency's *Guidelines for the Resolution of Complaints Over Railway Noise and Vibration* (2008).

6.4.2 Mitigating Short-Term Construction Noise Exposure (<1 year)

Health Canada often suggests mitigation measures to the authority conducting the EA, when the predicted construction noise level (construction lasting less than one year) exceeds the suggested mitigation noise level (MNL). To avoid widespread complaints regarding construction noise at receptor sites, where the exposure duration is less than one year at any given representative receptor site, the basic suggested MNL is 47 dBA (US EPA 1974). This value has been derived from the data presented in Figure D-7 and Table D-7 in US EPA 1974. The basic MNL is applicable for receptors in quiet suburban or rural areas, assuming that all of the construction noise is tonal and/or impulsive.

In order to determine whether mitigation is advisable, consider the following:

1. Use the data in Table 6.1 to characterize the community type based on average census tract population densities and community qualitative descriptions. Validating the community type may be accomplished by monitoring or calculating baseline noise levels.
2. Use the data in Table 6.2 to identify the applicable correction factors for the relevant community type and additional corrections (e.g. construction duration, presence of tonal or impulsive noise, and whether windows are open), and then calculate the suggested construction noise (less than one year) MNL.
3. If the predicted construction noise levels exceed the suggested MNL for construction phase (less than one year), the authority conducting the EA should consider noise mitigation measures.

Table 6.2: Calculating Suggested Mitigation Noise Level (MNL) for Construction Noise (Based on US EPA 1974)

Suggested Basic MNL 47 dBA Ldn* *Suggested MNL for various scenarios*		
Community Description	***Applied Correction Factors***	***Suggested MNL***
Quiet suburban or rural	+0 dB	47 dBA Ldn
Normal suburban	+5 dB	52 dBA Ldn
Urban residential	+10 dB	57 dBA Ldn
Noisy urban	+15 dB	62 dBA Ldn
Very noisy urban	+20 dB	67 dBA Ldn
Additional Corrections If applicable, add any or all of the following corrections:		
Construction duration less than two months	+10 dB	
Winter (or windows always closed)	+5 dB	
Negligible tonal or impulsive noise[§]	+5 dB	

* Due to backup alarms, slamming tailgates, etc., construction noise normally contains both tonal and impulsive components. For the suggested basic MNL, the reasonable worst-case scenario is used and all of the construction noise is assumed to be due to tonal and/or impulsive noise.

§ When the contribution from tonal and/or impulsive noise may be negligible, +5 dB may be added to the suggested basic MNL. Health Canada prefers that a rationale be provided if this adjustment is applied.

Table 6.3 presents an example of how to establish a mitigation noise level (MNL). The final MNL is obtained through the application of several possible correction factors, as shown in Table 6.3. Calculated MNLs for other construction projects may vary, depending on the applicable correction factors specific to the project type, season and location.

Table 6.3: An Example of Applying Corrections to Establish a Suggested MNL for a Project in a Very Noisy Urban Community

Description	Applied Correction	Suggested MNL
Basic MNL	0 dB	47 (dBA) Ldn
Project occurs in a very noisy urban community	+20 (dB) Ldn	67 (dBA) Ldn
Construction duration is less than two months	+10 (dB) Ldn	77 (dBA) Ldn
Noise contains negligible tonal or impulsive noise	+5 (dB) Ldn	82 (dBA) Ldn
Project occurs during winter or in proximity to residences where windows cannot be opened	+5 (dB) Ldn	87 (dBA) Ldn
Final MNL		87 (dBA) Ldn

Widespread complaints tend to occur when the suggested MNLs in Table 6.2 are exceeded (US EPA 1974). Therefore, Health Canada suggests the use of quieter technology or other mitigation measures, rather than lengthening construction duration (e.g. lowering the noise by having fewer pieces of equipment running at a time, thereby extending construction duration) to achieve a reduction in human health-related noise impacts.

Some examples of quiet technology and procedures are the following:

- vibratory pile driving or boring, instead of impulsive pile driving; and
- ambient-sensitive backup alarms, signal workers, machinery turning circles, and side loading/unloading trucks to reduce the impact of backup alarms.

If acceptable levels cannot be obtained with quieter technology, community consultation (as discussed in Section 6.4.1) is preferred, in order to seek consensus on construction operations (e.g. no activity during night-time or weekend hours). Some commonly applied construction noise mitigation measures and considerations for noise reduction are described in Appendix H.

6.4.3 Mitigating Long-Term Construction Noise (≥ 1 year)

Health Canada suggests that mitigation be implemented when noise levels during long-term construction result in a greater than 6.5% increase in %HA. If the change in %HA exceeds 6.5%, even when implementing quieter technology and construction methods as described in Appendix H, community consultation is important to establish mutually agreeable work schedules and is an acceptable means of informing the public of the time and duration of noisy activities.

Communication with potentially impacted residents is especially important when construction must occur outside daytime hours. Residents' concerns about blasting or other noisy activities can often be addressed through community consultation. Some flexibility among impacted residents may exist regarding construction noise levels, if demonstrable mitigation measures are used. Community consultation can be useful to determine whether the ability to avoid long periods of construction would result in greater community acceptance.

In addition to the consultative process, it is a good practice to consider technically and economically feasible mitigation measures (see Appendix H), in an attempt to reduce noise levels to levels that keep the change in %HA below 6.5% and protect against sleep impacts. In some cases, monitoring and working with the impacted community may address community reactions.

6.4.4 Mitigating Blasting Noise

Noise due to blasting has unique characteristics. Therefore, Health Canada holds the view that for blasting during short-term construction (< 1 year), limits on the number of blasts should be implemented irrespective of other noise levels due to background sources or construction activities. Noise effects due to blasting can be assessed in several ways. One approach for blasting exposures lasting less than one year is to use the US EPA 1974 criterion for sonic booms. The rationale for this approach stems from the findings of Schomer *et al.* (1997), whose research indicates that blasts and sonic booms create similar levels of annoyance for equal peaks.

According to US EPA (1974), little or no public annoyance is expected to result from any number of daytime sonic booms per day, if their measured or predicted peak value is below 125-10 log N dB. In this case, dB is interpreted as meaning Z-weighting (dBZ). Health Canada prefers that the US EPA's sonic boom criterion be used as a blasting MNL for blasting that lasts less than one year.

Table 6.4 presents an example of the assessment technique of establishing an MNL based on a representative number of blasts.

Table 6.4: Mitigation Noise Levels Related to Number of Blasts

Number of Daytime Blasts (N)	Blasting MNL (125-10 log N) (dBZ)
10	115
25	111
50	108
100	105

Health Canada suggests following the recommendations in ISO 1996-1:2003, as described in Appendix E and Appendix F of this guidance document, for blasting of duration of more than one year (≥ 1 year),

6.4.5 Mitigating Operational Noise

As with long-term construction noise, Health Canada considers high annoyance with noise generated during a project's operational phase to be an indicator of human health effects. If the change in %HA exceeds 6.5% or the suggested target values noted in Section 6.3.2 for project operational noise, Health Canada suggests that possible mitigation measures target the source, the propagation from source to receptor site and/or the receptor site itself. These measures include, but are not limited to the following:

- reducing noise output, such as using quieter machinery where technically and economically feasible;
- implementing physical barriers, including noise walls, berms (artificial ridges or embankments) and windows with high soundproofing; and
- in some cases, changing project design (e.g. changing the proposed placement of an access road).

In general, implementing mitigation measures that further reduce noise impacts is encouraged.

6.5 ASSESSMENT OF RESIDUAL IMPACTS

An assessment of the residual impacts of a project may include discussion of potential noise impacts arising from the project, after all proposed mitigation and management measures have been applied. It is a good practice for this discussion to include characterizing final sound levels at representative receptor locations—in the same manner as is done in establishing the baseline and predicted sound levels—in addition to discussing the potential impacts that may be expected due to these changes.

Mitigating adverse noise effects can at times be technically challenging and costly. The severity of potential impacts on human health caused by noise is only one of many factors that may be considered in making an overall noise assessment of the project. When mitigation measures are judged to be not technically or economically feasible, a detailed discussion justifying the exclusion of these measures may be helpful in addressing potential concerns with respect to residual impacts of project-related noise. In such cases, the community consultation process discussed in Section 6.4.1 may offer alternative options for limiting complaints arising from excessive noise.

6.6 SOUND LEVEL MONITORING

The periodic monitoring of sound levels at representative receptor locations can be used to verify predictions made during the EA process. This monitoring is particularly important when predicted noise levels approach the level where adverse human health effects are considered likely and mitigation measures become necessary. If the uncertainty related to predicted sound levels is large and the resulting impacts are more severe than expected, monitoring is considered particularly useful. It is also helpful to describe in the EA any commitments to evaluate the need for additional mitigation measures, if actual project-related noise levels are higher than predicted or if community reaction is stronger than expected.

If post-project monitoring is not being undertaken when predicted noise levels are close to the suggested mitigation-measure levels, Health Canada holds the view that the EA documentation should include a rationale explaining why monitoring is not considered appropriate.

7 ASSESSMENT OF CUMULATIVE EFFECTS

If the proposed project is in a region where there are other proposed or ongoing development projects that may contribute to noise levels, an assessment of cumulative effects is an important consideration. In attempting to predict sound levels from the project when contributions from other sources are possible, Health Canada suggests that these sources be included in the modelling to establish potential cumulative effects.

In selecting a baseline for a cumulative effects assessment, the pre-project baseline is the most appropriate comparison for noise-related human health impacts, as this comparison is predictive of the absolute change in the noise environment, when all project and additional noise sources are considered.

For guidance on assessing cumulative effects, consult the Canadian Environmental Assessment Agency's website for up-to-date guidance materials: **www.ceaa.gc.ca**

8 FOLLOW-UP PROGRAMS

Under CEAA 2012, a “follow-up program” means a program to:

a. Verify the accuracy of the environmental assessment of a designated project; and

b. Determine the effectiveness of any mitigation measures.

It may be appropriate to consider a follow-up program for noise if there is uncertainty about (not a comprehensive list):

- Modelling of project construction and/or operational noise; and/or
- Whether proposed mitigation measures (e.g. the use of novel technologies or materials) will be effective.

For further and up-to-date information on follow-up programs, contact the Canadian Environmental Assessment Agency, Canadian Nuclear Safety Commission or National Energy Board, as appropriate.

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Note: *Effective June 17, 2013, the ERCB has been succeeded by the Alberta Energy Regulator (AER). No changes have been made to Directive 038 by the AER, and the Directive continues to contain references to the ERCB. When a new edition of the Directive is issued, the ERCB references will be revised. The Directive may also contain references to the former Energy Utilities Board (EUB), which had been realigned to the ERCB on January 1, 2008.*

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APPENDIX AI **GLOSSARY**

TERM	DEFINITION
Acoustics	The interdisciplinary science that deals with the study of sound, ultrasound and infrasound (all mechanical waves in gases, liquids and solids).
Ambient sensitive backup alarms	Alarms that warn workers that a vehicle is backing up. These alarms increase or decrease in volume based on background noise levels to maintain a readily noticeable tone to workers, while reducing community noise annoyance. The alarms work best on small equipment such as backhoes and trucks. Note: The Construction Safety Association of Ontario notes that alarms offer the greatest benefit when traffic is limited to only one or two vehicles. The warning effect of the alarm is greatly reduced when it becomes part of the background noise on-site.
Annoyance	A state, or adverse reaction, that may be referred to as being annoyed, disturbed, bothered, (or dissatisfied). *Noise annoyance:* A degree of annoyance measured by a subject's response to an annoyance questionnaire as part of a social survey on noise and annoyance. *High annoyance:* A degree of noise annoyance with a minimum cut-off of 71–73 on a scale of 0 to 100 (7–10 if the ISO-recommended scale of 0–10 is used) or the top two categories (very or extremely) of an adjectival scale. (ISO/TS 15666:2003[1])
Average community	A community that would yield the same reaction to noise as that obtained from social surveys on noise in a large number of communities around the world (Michaud *et al.* 2008).
Berm	An artificial ridge or embankment used to shield receptors from intruding noise.
Community	An agglomeration of residents whose reaction to noise is being measured. (For the complaint assessment method using US EPA 1974 only, see the Michaud *et al.* 2008, and US EPA 1974 references). *Very noisy urban residential community:* day-night sound level (Ldn) typical range 68–72 dBA, average 70 dBA; no qualitative characterization. *Noisy urban residential community:* Ldn typical range 63–67 dBA, average 65 dBA; qualitative characterization: near relatively busy roads or industrial areas. *Urban residential community:* Ldn typical range 58–62 dBA, average 60 dBA; qualitative characterization: not immediately adjacent to heavily travelled roads and industrial areas. *Normal suburban community:* Ldn typical range 53–57 dBA, average 55 dBA; qualitative characterization: not located near industrial activity. *Quiet suburban or rural community:* Ldn typical range 48–52 dBA, average 50 dBA; qualitative characterization: remote from large cities, industrial activity and trucking.

1 ISO (2003). ISO/TS 15666:2003 Acoustics – Assessment of noise annoyance of social and socio-acoustic surveys. **www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=28630**

TERM	DEFINITION
Decibel	A logarithmic unit of measurement that expresses the magnitude of a physical quantity (pressure, power or intensity) relative to a specified or implied reference level. Since it expresses a ratio of two quantities with the same unit, it is a dimensionless unit. The decibel is useful for acoustics and confers a number of advantages, such as the ability to conveniently represent very large or small numbers, and a logarithmic scaling that roughly corresponds to the human perception of sound. The decibel symbol is often qualified with a suffix, which indicates which reference quantity or frequency weighting function has been used. An example of this is dBA and is discussed in Appendix D.
Environmental noise	Also called community noise, refers to non-occupational noise. The main sources of community noise include road, rail and air traffic, industries, construction and public work. In the context of this document, environmental noise refers almost always, if not entirely, to the above. In a more general context, the term may also refer to neighbourhood noise and indoor sources; primarily ventilation systems, home appliances and neighbours (e.g. in apartments). (Adapted from WHO 1999.)
Equivalent continuous sound level Leq (t)	A sound level obtained from energy averaging over a specified time interval (t). This level is obtained using an integrating averaging sound level meter, which determines the mean of the square of the sound pressure over a specified time interval (t), and expresses the result in decibels. *Day-night sound level (Ldn, also referred to as DNL):* An equivalent continuous sound level taken over 24 hours, with the night-time (10 p.m. to 7 a.m.) contributions adjusted by +10 dB. (This is a type of rating level because of the night-time adjustments.) The night-time adjustment (or addition of 10 dB to the night-time period) is used to account for the expected increased annoyance due to noise-induced sleep disturbance and the increased residential population at night relative to daytime, by a factor of 2–3. US EPA 1974 suggests that in quiet areas, the night-time levels naturally drop by about 10 dB and this level of adjustment has been used with success in the U.S. *Daytime sound level (Ld):* An equivalent continuous sound level taken over 15 hours from 7 a.m. to 10 p.m. (In some jurisdictions, the start of daytime hours can be as early as 6 a.m. and the end of daytime hours can be as late as 11 p.m.) *Night-time sound level (Ln):* An equivalent continuous sound level taken over 9 hours from 10 p.m. to 7 a.m. (In some jurisdictions, the start of night can be as late as 11 p.m. As well, in some jurisdictions, the end of night can be as early as 6 a.m.) *Day-night rating level ($L_R$dn):* A day-night sound level to which an adjustment has been added. *Daytime rating level (L_Rd):* A daytime sound level to which an adjustment has been added. *Night-time rating level (L_Rn):* A night-time sound level to which an adjustment has been added. *LAeq (t):* An A-weighted equivalent continuous sound level in the denoted time interval. *LAeq (24):* An A-weighted equivalent continuous sound level for a specified 24-hour time interval. *LAeq (1):* An A-weighted equivalent continuous sound level for a specified 1-hour time interval.

TERM	DEFINITION
Frequency weighting	A relative value applied to the spectrum of a sound in each defined frequency interval. *A-weighting (dBA):* A weighting of the frequencies in a sound that approximates the response of the human ear to frequencies in moderately loud sounds (sound pressure levels in the range of 45-65 dBA). *C-weighting (dBC):* A weighting of the frequencies in a sound that approximates the response of the human ear to frequencies in very loud sounds. It emphasizes the low frequencies of a sound much more than the A-weighting. *G-weighting (dBG):* A frequency weighting used for infrasound measurements. It is defined in ISO 7196 as 0 dB at 10 Hz. Between 1 and 20 Hz (the highest weighted frequency), the weighting approximates a straight line with a slope of 12 dB/octave. *Z-weighting (dBZ):* A frequency weighting defined in International Electrotechnical Commission (IEC) 61672-1:2002 with 0 dB weighting from 10 Hz to 20 kHz, within tolerances defined in the standard.
Infrasound	Like **Sound** but with frequency content below 20 Hz.
Maximum A-weighted sound level (LAmax)	The maximum value of the sound pressure level during a noise event, measured with a sound level meter using a Fast Time Weighting. This level can be applied to pass-by noise from transportation noise sources and impulsive noise events.

TERM	DEFINITION
Noise	Unwanted sound. *Low-frequency noise:* Noise with frequency content in the range of 20-200 Hz. Where it produces a 16, 31.5 or 63 Hz octave band sound-pressure level of more than 65, 65 or 70 dBZ, respectively, low frequency noise can be associated with the introduction of noticeable vibrations and rattles in some structures (e.g. as from a nearby idling locomotive). *Tonal noise:* Noise containing prominent (audible) tones such as backup alarms on trucks. Here "tones" refers to tonal sound, defined in ISO 19961:2003 as sound characterized by a single frequency component or narrow-band components that emerge audibly, **at the receptor position**, from the total sound. If the audibility is in dispute, ISO 1996-2:2007 contains a (rather complex) method for analyzing a spectrum to determine audible tonality. *High-energy impulsive noise:* Impulsive noise from any high-energy impulsive sound source, including any explosive source in which the equivalent mass of TNT (trinitrotoluene) exceeds 50 g, or sources with comparable characteristics and degrees of intrusiveness. Internationally agreed upon examples are listed in ISO 1996-1:2003 and include sonic booms, blasting, quarry and mining explosions, demolition or industrial processes that use high explosives, explosive industrial circuit breakers and military ordnance (e.g. armour, artillery, mortar fire, bombs, and the explosive ignition of rockets and missiles). *Highly impulsive noise:* Impulsive noise from any noise source with highly impulsive characteristics and a high degree of intrusiveness. Internationally agreed upon examples of sources are listed in ISO 1996-1:2003 and include impact pile driving, small arms firing, hammering on metal or wood, nail guns, drop-hammering, drop forging, punch pressing, pneumatic hammering, pavement breaking, or metal impacts in rail-yard shunting operations. *Regular impulsive noise:* Impulsive noise from sources that are neither highly impulsive nor high-energy impulsive. Internationally agreed upon examples of these sources are listed in ISO 1996-1:2003 and include slamming car doors and truck tailgates.
Normalized Ldn	A calculated day-night sound level that is used to determine the potential for widespread complaints. The normalized Ldn is obtained from the measured value and the addition of various corrections in dB (US EPA 1974).
Octave band	A section (band) of a sound spectrum where the ratio of the maximum to minimum frequency in the band is 2. Nominal centre frequencies (in Hz) of noise octave bands have been standardized as 16, 31.5, 63, 125, 250, 500, 1000, 2000, 4000, 8000, and 16000.
Sentence intelligibility	The ability to recognize key words in a sentence using full concentration in a laboratory setting. Due to redundancy in normal conversation, all words in the sentence may not have been understood.
Signal workers or Signallers	People who signal to a vehicle operator to ensure his or her awareness of other people. Signallers also warn workers that vehicles are backing up.

TERM	DEFINITION
Sleep disturbance	Any of: (i) interfering with falling asleep, (ii) shortening sleep stage duration, (iii) lessening perceived quality of sleep, (iv) awakening people from sleep, or (v) increasing body movements (motility) during sleep. *Awakenings:* A transient or indeterminate end of sleep. Awakenings can be measured: (i) behaviourally, by a subject pushing a button upon finding that they are aware of awakening, (ii) when a certain threshold of body movement (motility threshold) is exceeded from a previous low level of body movement (sleep), and (iii) by an objectively defined change in brain wave pattern measured by an electroencephalograph (EEG) (Michaud *et al.* 2008). *Percent awakenings due to noise:* Awakenings attributed to noise events divided by the total number of awakenings multiplied by 100 (normally the totals are taken for all subjects in the study). *Sleep stage:* a stage of sleep with a well-defined brain wave pattern measured with an EEG. There are 5 stages of sleep. Sleep stage is also related to muscle activity and eye movements.
Sound exposure level (SEL)	The 1-second equivalent continuous sound level that would be measured if the total energy in a noise event occurred during that one second. This level can be applied to pass-bys of transportation noise sources and impulsive noise events. Note: The equivalent continuous sound level for an extended time period that contains a number of noise events can be obtained by energy averaging the SEL values over the time period.
Time weighting	*Fast weighting:* A time constant of 0.125 second in a sound-level meter used to smooth the square of the measured sound pressure prior to the expression of the sound pressure level in decibels. *Slow weighting:* A time constant of 1 second used to smooth the square of the measured sound pressure prior to the expression of the sound pressure level in decibels.
Transmission loss	In environmental noise, the ratio of the sound energy striking a wall (e.g. the outside of a residence) relative to the transmitted sound energy (e.g. into a living room or bedroom), expressed in decibels.
Vibratory pile driving or boring	A pile driving system that does not rely on an impact hammer but on a rapidly vibrating hammer that transfers its vibrational energy to the pile to drive it in.
Wind screen	A screen, commonly a porous sphere or an egg-shaped structure of open cell foam, to protect a microphone's protective grid from turbulence produced by the passage of wind. For a given wind speed, the lower the frequency of noise to be reduced, the larger the windscreen that is needed.

APPENDIX BI **NOISE IMPACTS IN EA CHECKLIST**

This checklist is beneficial in verifying that the main components of a noise impact assessment are completed. It is useful to include this checklist as an index in an environmental assessment (EA) to identify the locations of the key components of a noise impact assessment, especially if the information is found in multiple sections of the EA documentation.

OVERALL (THROUGHOUT THE EA)	
✓	***Item***
	1. In addition to the construction phase, are all other project phases, including operation, decommissioning and abandonment, included in the EA?
	2. When modelling techniques are used to estimate present (baseline) or future (construction and operational) sound levels, are these techniques and any assumptions documented and appropriately justified?
	3. Is information provided that describes any tonal, regularly impulsive, highly impulsive or high-energy impulsive noise that is audible at receptors during the construction, operation and decommissioning project phases?
	4. Does the EA avoid statements relating to the perceptibility or whether changes in noise are noticeable based solely on decibel levels?

RECEPTOR IDENTIFICATION AND CHARACTERIZATION		
✓	***Item***	***Section in EA***
	5. Are all currently impacted receptors (including Indigenous Peoples) and potential reasonably foreseeable future receptors, clearly identified?	
	6. Is information on all noise-sensitive receptors in the area (including any foreseeable future receptors) and on distances of receptors from the project, included?	
	7. Are maps identifying receptor locations relative to the project site, including noise contour diagrams, provided?	
	8. Is justification provided for any excluded receptors (if applicable)?	
	9. Are receptors identified in "quiet rural areas" assigned a +10 dB adjustment (if applicable)?	
	10. Is a description provided of any community consultation that may have occurred concerning noise impacts, including any human health concerns expressed by potential receptors?	

IMPACTS ASSOCIATED WITH NOISE				
✓	***Item***			***Section in EA***
	11. Does the outdoor annual average for night-time (Ln) exceed 40 dBA?	☐ No	☐ Yes	
	12. Do indoor night-time sound levels (or sound levels when nearby receptors are expected to be sleeping) exceed 30 dBA Leq from continuous noise sources at any representative receptors?	☐ No	☐ Yes	
	13. Are more than 10–15 night-time individual noise events above 45 dBA LAmax indoors predicted at any representative receptor?	☐ No	☐ Yes	
	14. Is an evaluation of the severity of residual impacts (post-mitigation) on sleep disturbance included?			
	15. Is any interference with daytime speech comprehension (indoor sound levels greater than or equal to 40 dBA or outdoor sound levels greater than 55 dBA) predicted?	☐ No	☐ Yes	
	16. Is an evaluation of the severity of residual impacts (post-mitigation) on speech comprehension provided in the EA?			

ASSESSMENT OF BASELINE NOISE LEVELS		
✓	***Item***	***Section in EA***
	17. Are measured or valid estimates of baseline noise levels provided, including any uncertainties for both daytime (Ld) and night-time (Ln) at receptors?	
	18. When measured baseline noise levels are provided, are the hours during which the measurements were obtained and the exact locations of the measurements provided?	
	19. Is a rationale provided explaining why the baseline is considered representative, including the days, weather conditions and any seasonal variations when monitoring occurred?	
	20. Are all noise sources that contribute to the baseline identified (see Appendix E including a description of the specific noise character(s), and appropriate adjustments made?	
	21. When baseline noise is estimated, are the estimation method and a rationale for using this method provided?	
	22. Is a calculation of baseline percent highly annoyed (%HA) at receptors provided?	
ASSESSMENT OF CONSTRUCTION NOISE LEVELS		
✓	***Item***	***Section in EA***
	23. Are valid estimates (predictions) of construction noise levels provided for both daytime (Ld) and night-time (Ln) at receptors, including any uncertainties?	
	24. Are the duration of construction activities impacting each receptor and the method of noise assessment (based on the construction duration) provided?	
	25. Are construction noise-related impacts and a noise management plan (if applicable) included?	
	26. Are construction noise levels estimated or modelled for each receptor, and are appropriate adjustments identified? (See Appendix E)	
	27. When construction noise levels are expected to approach a suggested mitigation noise level (MNL), are mitigation measures and a noise management plan provided?	
	28. If an assessment of construction noise impacts is not conducted because the noise levels are predicted to be below the level for widespread complaints at all receptors, is a rationale provided?	
	29. When construction noise is expected to last longer than 1 year at any given receptor, is an evaluation of the change in %HA (from baseline) at these receptors provided? Are all applicable adjustments identified in estimating %HA?	
MITIGATION MEASURES		
✓	***Item***	***Section in EA***
	30. Are predicted future (operation) daytime (Ld) and night-time (Ln) sound levels provided for all receptors, using the same parameters that were used to establish the baseline (e.g. units and averaging times)? Are appropriate adjustments identified? (See Appendix E)	
	31. Is an evaluation of the change in %HA (from baseline) at each receptor provided for operational noise?	
	32. Are the results and conclusions of the operational noise assessment clearly documented?	

SSS				
✓	*Item*			*Section in EA*
	33. If applicable, is a discussion of whether mitigation measures or follow-up monitoring are warranted included?			
	34. When noise is expected to approach suggested mitigation levels either during project construction or operations, is a discussion of planned or conditional mitigation measures included?			
	35. Is a residual impacts assessment discussing noise impacts following mitigation included?			
	36. When low-frequency noise is emitted, is information describing impacts of any anticipated effects (e.g. rattling) and related mitigation measures included?			
	37. After all of the noise mitigation measures are applied, does the calculated change in %HA (from baseline) at any of the representative receptors exceed 6.5%?	☐ No	☐ Yes	
	38. Is information provided on how the noise-related complaints will be addressed, including a description of a complaint resolution process?			

ASSESSMENT OF CUMULATIVE EFFECTS		
✓	*Item*	*Section in EA*
	39. When other ongoing or reasonably foreseeable future projects in the region may contribute to noise levels, is a cumulative effects assessment included?	

APPENDIX C| **NOISE CHARACTERISTICS**

C.1 TONAL AND IMPULSIVE NOISE

Tonal (e.g. backup alarms on trucks) and impulsive noise (e.g. hammering on metal) are often perceived as annoying and may have a high potential to disturb receptors (US EPA 1974, ISO 1996-1:2003, ANSI 2005, WHO 1999). Therefore, providing information on tonal, regular impulsive, highly impulsive or high-energy impulsive project noise that is audible at receptors is suggested. This characterization of noise is also important in selecting the appropriate corrections and adjustments in the calculation of noise impacts for construction and operational noise.

As described in ISO 1996-1:2003, regular impulsive noise is sometimes characterized as intrusive but not as intrusive as highly impulsive noise. Examples of regular impulsive noise include the slamming of car doors, outdoor ball games, such as football, soccer or basketball, and church bells. Very fast pass-bys of low-flying military aircraft may also fall under this category.

Impulsive noise sources that have a high degree of intrusiveness may be characterized as either highly impulsive (defined in ISO 1996-1:2003) or high-energy impulsive, as described in ISO 1996-1:2003. For details on these noise types, see Appendix A.

ISO 1996-1:2003 recommends making a +5 dB adjustment to tonal and regular impulsive noise sources and a +12 dB adjustment to highly impulsive noise sources. The expected contribution of project noise and details on how tonality and impulsiveness were accounted for are important elements of the noise assessment. See Appendix F for more information.

C.2 LOW-FREQUENCY NOISE

Noise occurring at frequencies below 100 to 200 Hertz (Hz) is generally defined as low-frequency noise. Low-frequency noise is commonly not well perceived by the human ear but may induce vibrations in buildings that may be perceptible or cause a “rattle” in these environments. Research indicates that annoyance related to noise is greater when low-frequency noise is present (ISO 1996-1:2003) and one of the main reasons is the annoyance caused by rattles (Schomer and Neathammer 1987; Schomer and Averbuch 1989). As sound environments are usually characterized using A-weighted decibel levels (dBA) that reflect the frequencies most audible to the human ear, the impacts of low-frequency noise may need to be assessed separately.

Guidance for low-frequency sound (or infrasound) in the 16-63 Hz octave bands stems from the ANSI standard on environmental sound regarding noise assessment and the related prediction of long-term community response (ANSI 2005). Where standards or acceptable procedures for the measurement of these frequencies exist, it is suggested that the EA include a description of the potential impacts and any mitigation measures concerning the effects of these frequencies.

The ANSI standard concerns essentially continuous sounds with strong low-frequency content. To prevent rattles from low-frequency noise and the associated annoyance from this effect, ANSI indicates that the (energy) sum of the sound levels in the 16-, 31.5- and 63-Hz octave bands be less than 70 dBZ. If this 70-dBZ "rattle criterion" is exceeded, Health Canada may suggest the implementation of feasible mitigation measures. ANSI 2005 indicates that there is evidence that noise-induced rattles are very annoying, and this annoyance may be independent of the number or duration of events.

Additionally, ANSI 2005 provides a more sophisticated mathematical procedure for assessing %HA when low-frequency noise is present. Health Canada prefers using this procedure when the C-weighted Ldn exceeds the A-weighted Ldn by more than 10 dB. This is further outlined in Appendix D of ANSI 2005.

C.3 PERCEPTIBILITY

The typical threshold for an increase in sound level that is considered to be "barely perceptible" by the human ear in a controlled laboratory setting varies from 1 to 5 dBA, depending on the sound pressure level and frequency of the sound. In community noise applications, a 5-dBA reduction in highway noise by a barrier is accepted as the minimum that will be clearly noticeable. These findings cannot be broadly generalized in the context of assessing community noise impacts.

Changes to the characteristics of the sound from baseline (e.g. a change in frequency, changes in sound modulation, increased impulsiveness, or a shift in noise from the daytime to being more at night) may be perceived and may cause noise to be more noticeable, even if the absolute equivalent continuous sound level (in dBA) is not substantially increased. Consult ANSI S12.9-2005/Part 4, clause A.1.3 for further information.

It is important to consider that people respond to sound characteristics that do not necessarily appreciably increase the sound level. Therefore, in the context of an EA, it is suggested that statements relating to perceptibility or whether changes in noise are noticeable based solely on decibel levels be avoided, as these statements may be misleading.

APPENDIX DI **INTRODUCTION TO NOISE**

SOUND AND NOISE

Sound is defined as mechanical vibrations travelling through the air or other media.

Noise is most simply defined as unwanted sound.

Sound is measured using a calibrated microphone to determine the rapid cyclical changes in pressure (force per unit area) of the sound wave from the normal atmospheric pressure of about 101,000 pascals (Pa). As the human ear is sensitive to sound waves over a very wide range of maximum changes in sound pressure, for convenience, this range is compressed by using a logarithmic scale, and the resulting sound unit used is called a "decibel" (dB). A logarithmic scale is non-linear; as one moves up the scale, the same change in decibels represents a larger and larger increase in sound pressure. This means that decibels cannot be added or averaged in the same way as other linear measurements such as distance or weight.

D.1 SOUND PERCEPTION

Perception of sound is not related to sound level in decibels in a linear manner. For example, a 10-dB increase is the median change in sound level at 1 kHz, which is perceived as being twice as loud. A typically cited threshold for an increase in sound level that is often stated as being "barely perceptible" by the human ear varies from 3 to 5 dB (see Appendix B). This threshold is often used in EAs, which may state that residual sound increases lower than this threshold will not be perceptible; however, a difficulty with this approach is that humans also perceive and respond to changes in sound characteristics other than loudness. Examples of these characteristics include frequency, sound modulation, impulsiveness and tonality, which are described in Appendix A.

D.2 WEIGHTING

People do not perceive all sound frequencies equally, and as such, decibel levels are modified (weighted) according to the frequencies present in the sound. The modified levels are termed "A-weighted" and are reported as dBA rather than dB. The A-weighting reduces the contribution from low and high frequencies to capture the mid-frequency range to which the average human ear is most sensitive. Note that low-frequency noise is de-emphasized by A-weighting as its impacts are not perceived as well by the human ear. However, these low frequencies are factors that can induce rattles and vibrations that can be heard and felt. There are other ways to weight decibels, such as C-, G- and Z-weighting. C-weighting is applicable in the EA context to assess the %HA from exposure to frequent blasting (a high-energy impulsive noise) or, potentially, other project noise sources in which low-frequency noise dominates.

D.3 ADDING DECIBELS

Sounds often need to be added together to determine sound (or adjusted sound) levels (expressed in decibels) for use in EAs. The known/measured/predicted values characterizing the sound are also normally expressed as sound levels in decibels. To add sounds, the starting sound levels Li are changed to mean square sound pressures, $10^{0.1Li}$ which are added, and then the sum is changed back to decibels. Some rapid estimations are particularly useful, e.g. if sounds with 2 equal sound levels are added, the final value will be very nearly 3 dB greater than the starting values.

D.4 AVERAGING DECIBELS

In calculating an average sound level over a certain time period, the measured sound pressure at each time is squared and then averaged over time (mean square sound pressure). The mean square sound pressure is then converted to decibels. Occasional loud sound events (e.g. a bird landing on a microphone) may inappropriately influence an average. Events unrelated to the assessment are, after being identified, commonly excluded from the calculation of average sound pressure level.

D.5 MEASUREMENTS ASSOCIATED WITH SOUND LEVELS REPORTED IN EAS

In the context of noise impact assessment, sound levels are typically reported in average decibel level over a defined time period. In some cases, a specific time weighting is also applied to the average, most commonly as a penalty for night-time sound levels before averaging, to account for the additional potential for disturbance during these hours. The measurement used to describe the sound level indicates the duration and time of day of the sound, and whether any weighting was applied. The following describes the **A-weighted metrics** most commonly presented in EAs:

Ldn (also termed DNL): indicates that the sound was averaged over 24 hours with 10 dBA added to night-time sound levels. The standard night-time hours for this measurement are 10:00 p.m. to 7:00 a.m. Tables 6.2 and 6.3 show Ldn used in the calculation of suggested Mitigation Noise Levels for construction noise exposure less than 1 year.

Ld: average daytime level (standard hours 7 a.m. to 10 p.m. although this varies between 6 a.m. and 11 p.m. in some jurisdictions, such as Ontario).

Ln: average night-time level (10:00 p.m. to 7:00 a.m.).

Leq (24): indicates that the sound was averaged over 24 hours without any adjustment applied.

Leq (1): indicates that the sound was averaged over 1 hour.

Leq (1 hour max): indicates that the average sound level of the worst hour (as measured by a provincial inspector) in a 24-hour period is being reported.

APPENDIX EI SOUND SOURCES AND SOUND CHARACTER

Appendix F Determination of Percent Highly Annoyed (%HA), lists equations that show how to obtain %HA values from daytime and night-time rating levels. The rating levels can be estimated from the application of adjustments to the applicable daytime (Ld) and night-time (Ln) sound levels for the noise environments with and without the project. The Ld and Ln are obtained by an appropriate combination of predictions and measurements.

The values of the daytime rating levels $L_R d_i$ and the night-time rating levels $L_R n_i$ for any applicable noise source are obtained by applying adjustments to the sound levels that are energy-averaged to obtain Ld and Ln for the given (i-th) noise source. Adjustments may pertain to a particular type of source or to a particular character of the noise from a source or to the receiver characteristics.

When adjustments to project or baseline noise are necessary, Health Canada prefers that adjustments be made by following ISO 1996-1:2003. Details of how to apply adjustments are given in Section 6 of ISO 1996-1:2003, in particular for situations where noise sources of specific character are audible and either distinguishable from noise from other sources, or indistinguishable from noise from other sources. Furthermore, this section of the ISO standard indicates how to determine the rating level from combined sources.

With respect to receptor characteristics, an adjustment is made for a “quiet rural area,” where a noise receptor (or group of receptors) has a greater expectation for and value placed on “peace and quiet”. ISO notes that a +10 dB adjustment should be applied in this situation. In the absence of further information, Health Canada will assume that receptors with a LAeq (7 a.m.–10 p.m.) of 45 dBA or less and a LAeq (10 p.m.–7 a.m.) of 35 dBA or less are in a quiet rural area, and warrant a +10 dB adjustment in the calculation of the change in %HA.

For **air traffic** sources of noise, Health Canada prefers that a +5 dB adjustment be applied.

For **rail traffic**, Health Canada prefers that either a -5 dB (note this is a negative adjustment) or 0 dB adjustment be applied, as applicable. The -5 dB rail traffic adjustment is not applicable to long diesel trains, or to trains operating at speeds in excess of 250 km/hr. These specific adjustments fall within the ranges given in ISO 1996-1:2003.

Road traffic noise and industrial-type noise (including construction noise for the purposes of this guidance) have a 0 dB adjustment, as specified in the ISO standard. The 0 dB adjustment for industry/construction noise applies to only two types of sound levels: (i) from noise sources which are not audibly tonal at the receptor and (ii) from non-impulsive sources.

Certain **other noise sources**, as per ISO 1996-1:2003, are considered regular impulsive (+5 dB adjustment), highly impulsive (+12 dB adjustment) or high energy impulsive. (The rating level is based on the C-weighted sound level and can be obtained from Appendix B of ISO 1996-1:2003.) Tonal sound is also addressed in the ISO standard. Health Canada prefers that a +5 dB adjustment be applied to noise which is audibly tonal at the receptor. This value falls within the range specified in the standard.

As per ISO 1996-1:2003, if more than one adjustment applies for the source type or character of a given **single sound source**, only the largest adjustment is applied. However, time period adjustments are always added to the otherwise adjusted levels. Also, the adjustment for receiver characteristics in a quiet rural area is added to any other adjustments.

ISO 1996-1:2003 also explicitly states that adjustments for tonal character should only be applied when the "sound is audibly tonal at the receiver location". The standard also indicates that adjustments for impulsive source character should only be applied to "impulsive sound sources that are audible at the receiver location." The subtle distinction made in ISO 1996-1:2003 between audibly tonal versus audible sources may only be relevant in consideration of high energy impulsive noise. At long distances, high energy impulsive artillery fire can change from an impulse to a rumble without substantially affecting the magnitude of the required adjustment. For more common sources, a source is still impulsive even if it loses the high frequencies at long distances (e.g. ISO 1996-1:2003 identifies the predominantly low-frequency car door slam as regular impulsive).

E.1 EXAMPLES

Aircraft noise: Although an aircraft can create prominent tones during aircraft noise events, which would normally get a +5 dB adjustment, the adjustment for the air traffic type is also +5 dB. Therefore all the air traffic noise receives a +5 dB adjustment.

Shunting of rail cars: The **sound sources** which are identified as highly impulsive in ISO 1996-1:2003 are the "metal impacts in rail-yard shunting operations." Thus, only the sound level during the time that the metal impacts are audible should receive the +12 dB adjustment; not the rest of the noise associated with the shunting activity. The noise due to the engine and motion of the rail cars during shunting is separate from the impact noise and is thus a separate component with a 0 dB adjustment.

Rail wheel squeal: There are times at the receptor when the noise from the train is audibly tonal, due to wheel squeal, and the +5 dB adjustment applies. However, for that portion of time where the sound is no longer audibly tonal at the receptor, the noise from the train receives either 0 or -5 dB adjustment for source type.

APPENDIX F | **DETERMINATION OF PERCENT HIGHLY ANNOYED (%HA)**

INTRODUCTION

Appendix F presents the methodology and equations for calculating (the change in) percent highly annoyed (%HA): using Ld and Ln to calculate rating levels L_Rd and L_Rn; and using rating levels in the equations below to determine %HA. These calculations are applicable to projects where the construction phase ≥ 1 year's duration, and for projects in the operational phase.

Note: Rating levels are an intermediate step in the calculations of %HA, but are generally not reported in an EA. Health Canada prefers the reporting of various details about Ld, Ln and the adjustments applied.

Refer to Section 5.4 for a discussion about complaints and %HA, and consult Appendix A for definitions.

CALCULATION OF BASELINE, CONSTRUCTION ≥ 1 YEAR DURATION, AND OPERATION DAYTIME (7 A.M.–10 P.M.) AND NIGHT-TIME (10 P.M.–7 A.M.) RATING LEVELS

Energy summation of applicable daytime rating levels will result in a daytime rating level which can be used to calculate %HA.

Daytime rating level

$$(L_R d) = 10 \log_{10} [\sum_i 10^{(0.1 L_R d_i)}] \qquad \text{(F1)}$$

For a quiet rural area, the daytime rating level

$$(L_R d) = 10 + 10 \log_{10} [\sum_i 10^{(0.1 L_R d_i)}] \qquad (\text{F1}_{\text{quiet rural area}})$$

Where $L_R d_i$ = any applicable daytime rating level and a quiet rural area is considered an area where a noise receptor (or group of receptors) has a greater expectation for and value placed on "peace and quiet". In the absence of further information, Health Canada will assume that receptors with a LAeq[2] (7 a.m.–10 p.m.) of 45 dBA or less and a LAeq (10 p.m.–7 a.m.) of 35 dBA or less are in a quiet rural area and warrant a +10 dB adjustment.

The same calculation (using Equations F1 or $\text{F1}_{\text{quiet rural area}}$) is also applicable to determine the night-time rating level (L_Rn) needed to calculate %HA.

2 LAeq is an A-weighted equivalent of continuous sound level in the denoted time period.

CALCULATION OF %HA

The rating level used to calculate %HA is the day-night rating level ($L_R dn$). In general, to calculate the relevant change in %HA values due to the project noise, $L_R dn$ values are needed for baseline, construction ≥ 1 year, and operation. The energy summation of baseline and construction $L_R dn$ values ($L_R dn_{(baseline\ and\ construction)}$) is needed for the construction phase. The energy summation of baseline and operation $L_R dn$ values ($L_R dn_{(baseline\ and\ operation)}$) is needed for the operation phase. $L_R dn$ is a 24-hour energy averaged rating level in which the contribution from the night-time rating level is artificially increased by 10 dB and is calculated using Equation E2.

$$L_R dn = 10 \log_{10} [((15 \times 10^{(0.1 \times L_R d)}) + (9 \text{ x } 10^{(0.1 \times (L_R n + 10))}) \ / \ 24] \qquad \text{(F2)}$$

$$L_R dn_{(baseline\ and\ construction)} = 10 \log_{10} (10^{(0.1 \times construction\ L_R dn)} + 10^{(0.1 \times baseline\ L_R dn)}) \qquad \text{(F3a)}$$

$$L_R dn_{(baseline\ and\ operation)} = 10 \log_{10} (10^{(0.1 \times operation\ L_R dn)} + 10^{(0.1 \times baseline\ L_R dn)}) \qquad \text{(F3b)}$$

The %HA is calculated using Equation F4:

$$\%HA = 100 \ / \ [1 + e^{(10.4 - 0.132 * L_R dn)}] \qquad \text{(F4)}$$

The %HA (baseline), %HA (baseline and construction), %HA (construction), %HA (baseline and operation) and %HA (operation) can be obtained by substituting the appropriate $L_R dn$ into Equation F4.

The **change in %HA for project construction** is calculated by subtracting %HA (baseline) from %HA (baseline and construction).

The **change in %HA for project operation** is calculated by subtracting %HA (baseline) from %HA (baseline and operation).

Table F.1 is a worked example showing the project noise levels (i.e. construction phase [≥ 1 year] or during the operational phase) that would result in a change of 6.5%HA from the baseline to project scenario. Use this table as a reference to check calculations carried out for a specific project. This table presents rating levels, but note that rating levels are not commonly reported in an EA as they are an intermediate step in calculating %HA (see above).

The table ranges from a baseline of 20 dB (i.e. quiet rural area) up to a project level of 75 dB.

Table F.1: Worked example showing baseline and project rating levels associated with a 6.5% increase in %HA due to a project's noise.

			Change in %HA between baseline and project equals 6.5%	
$L_R$dn baseline (dB)	$L_R$dn project (dB)	total $L_R$dn (dB)	%HA baseline (%)	%HA project (%)
< 20	58.6	58.6	0.0	6.5
35	58.9	59.0	0.3	6.8
42	59.4	59.5	0.8	7.3
46	59.9	60.1	1.3	7.8
48	60.2	60.5	1.7	8.2
50	60.6	61.0	2.2	8.7
52	61.1	61.6	2.8	9.3
53	61.3	61.9	3.2	9.7
55	61.9	62.7	4.1	10.6
56	62.2	63.1	4.7	11.2
57	62.5	63.6	5.3	11.8
58	62.8	64.1	6.0	12.5
59	63.2	64.6	6.8	13.3
60	63.6	65.2	7.7	14.2
61	64.0	65.8	8.7	15.2
62	64.5	66.4	9.8	16.3
63	64.9	67.1	11.1	17.6
64	65.4	67.8	12.4	18.9
65	65.9	68.5	13.9	20.4
66	66.5	69.2	15.6	22.1
67	67.0	70.0	17.4	23.9
68	67.6	70.8	19.4	25.9
69	68.3	71.7	21.6	28.1
70	68.9	72.5	23.9	30.4
71	69.6	73.4	26.3	32.8
72	70.3	74.3	29.0	35.5
73	71.1	75.2	31.8	38.3
74	71.9	76.1	34.7	41.2
75	72.8	77.0	37.8	44.3
76	73.7	78.0	40.9	47.4
77	74.6	79.0	44.1	50.6

APPENDIX GI IDENTIFICATION AND CHARACTERIZATION OF SOME COMMON RECEPTOR LOCATIONS

RECEPTOR LOCATION	CHARACTERIZATION	COMMENTS/ CONSIDERATIONS
Commercial premises	Retail stores, offices, research facilities and laboratories	Noise effects during business hours
Daycare centres	Highly sensitive receptors (children)	Noise effects considered during occupied periods
Entertainment establishments	Film and television studios, theatres, restaurants, etc.	Noise effects during periods of operation
Hospitals	Highly sensitive receptors (sick people)	Noise effects over a 24-hour period
Industrial premises	Factories and other industrial plants	Potential for additive noise in cumulative effects assessment
Places of worship and cemeteries	Churches, mosques, synagogues, temples, locations where Indigenous Peoples' cultural or religious ceremonies occur, etc.	Noise effects during religious services, meetings or processions
Recreation areas: *Active*	Parks and sports grounds	Noise effects considered during occupied periods
Recreation areas: *Passive*	Outdoor grounds used for hunting, fishing, teaching, etc.; includes locations where Indigenous Peoples may hunt, fish or gather country foods	Noise effects considered during activity periods
Residences: *Permanent*	Urban, suburban and rural locations containing houses, mobile homes and/or multilevel dwellings	Noise effects over a 24-hour period with particular emphasis on night-time noise levels
Residences: *Seasonal*	Cottages, campgrounds and RV parks; includes Indigenous hunting and fishing cabins, and seasonal camping places	Noise effects considered during occupied periods
Schools	Education facilities from pre-school to universities; highly sensitive receptors	Noise effects during regular hours of operation, which may include evenings and the possibility of schools being used during summer
Seniors' residences	Highly sensitive receptors (elderly)	Consideration of noise effects over a 24-hour period with particular emphasis on night-time noise levels
Workers' living quarters[3]	Locations may be on or off the project site	Mitigation measures in the design of temporary living quarters for workers to limit noise

3 Occupational exposure and health issues are typically under provincial or territorial jurisdiction, and Health Canada does not review this information in the context of EAs.

APPENDIX HI COMMONLY APPLIED CONSTRUCTION NOISE MITIGATION MEASURES AND CONSIDERATIONS FOR NOISE REDUCTION

The measures below have been adapted from the New South Wales Interim Construction Noise Guideline (July 2009), Department of Environment and Climate Change, New South Wales, Australia. Available at: **www.epa.nsw.gov.au/noise/constructnoise.htm**

GENERAL MITIGATION MEASURES

- Regularly train workers and contractors to use equipment in ways that minimize noise.
- Ensure that site managers periodically check the site, nearby residences and other sensitive receptors for noise problems so that solutions can be quickly applied.
- Include in tenders, employment contracts, subcontractor agreements and work method statements, clauses that assure the minimization of noise and compliance with directions from management to minimize noise.
- Avoid the use of radios and stereos outdoors and the overuse of public address systems where neighbours can be affected.
- Avoid shouting, and minimize talking loudly and slamming vehicle doors.
- Keep truck drivers informed of designated vehicle routes, parking locations, acceptable delivery hours and other relevant practices (e.g. minimizing the use of engine brakes and periods of engine idling).

NIGHT-TIME MITIGATION MEASURES

- Avoid the use of equipment that generates impulsive noise.
- Minimize the need for reversing alarms.
- Avoid dropping materials from a height.
- Avoid metal-to-metal contact on equipment.
- If possible, schedule truck movements to avoid residential streets.
- Avoid clustering of equipment near residences and other sensitive receptors.
- Ensure that periods of respite are provided in the case of unavoidable maximum noise level events.

CONSULTATION AND NOTIFICATION

- The community is more likely to be understanding and accepting of project noise if related information is provided and is frank, and does not attempt to understate the likely noise level, and if commitments are respected.

NOTIFICATION BEFORE AND DURING CONSTRUCTION

- Provide advance notification to people concerning construction duration, defining activities that are expected to be noisy and their expected duration, what noise mitigation measures are being applied, and when noise respite periods will occur.
- For night-time work, receptors may be informed in two stages: two weeks prior to construction and then two days before commencement.
- Provide information to neighbours before and during construction through media such as letterbox drops, meetings or individual consultation. In some areas, the need to provide notification in languages other than English may be considered. A website may also be established for the project.
- Use a site information board at the front of the site with contact details, hours of operation and regular information updates.
- Facilitate contact with people to ensure that everyone can see that the site manager understands potential issues, that a planned approach is in place, and that there is an ongoing commitment to minimize noise.

WORK SITE AND EQUIPMENT

- In terms of both cost and results, controlling noise at the source is one of the most effective methods of minimizing the noise impacts from any construction activities.

QUIETER METHODS

- Examine and implement, where feasible and reasonable, alternatives to rock-breaking work methods, such as hydraulic splitters for rock and concrete, hydraulic jaw crushers, chemical rock and concrete splitting, and controlled blasting, such as penetrating cone fracture.
- Consider alternatives to diesel and gasoline engines and pneumatic units, such as hydraulic or electric-controlled units, where feasible and reasonable. When there is no electricity supply, consider using an electrical generator located away from residences.
- Examine and implement, where feasible and reasonable, alternatives to transporting excavated material from underground tunnelling off-site at night-time. (e.g. stockpile material in an acoustically treated shed during the night and load out the following day).

QUIETER EQUIPMENT

- Examine different types of machines that perform the same function and compare the noise level data to select the least noisy machine (e.g. rubber-wheeled tractors can be less noisy than steel-tracked tractors).
- Pneumatic equipment is traditionally a problem. Consider selecting super-silenced compressors, silenced jackhammers and damped bits, where possible.
- When renting (or purchasing) equipment, select quieter pieces of machinery and construction equipment, where feasible and reasonable. As well, select the most effective mufflers, enclosures and low-noise tool bits and blades. Always seek the manufacturer's advice before making modifications to any equipment to reduce noise.
- Reduce throttle settings and turn off equipment when it is not being used.
- Examine and consider implementing, where feasible and reasonable, the option of reducing noise from metal chutes and bins by placing damping material in the bin.

EQUIPMENT MAINTENANCE

- Regularly inspect and maintain equipment to ensure that it is in good working order, including the condition of mufflers.
- For machines with enclosures, verify that doors and door seals are in good working order and that the doors close properly against the seals.
- Return any leased equipment that is causing noise that is not typical for the equipment. The increased noise may indicate the need for repair.
- Ensure that air lines on pneumatic equipment do not leak.

SITE MITIGATION MEASURES

- Barriers and acoustic sheds are most suited to long-term fixed works, as in these cases, the associated cost is typically outweighed by the overall time savings.

WORK SITE LOCATION

- Place as much distance as possible between the machinery or equipment, and residences and other sensitive receptors.
- Restrict areas in which mobile equipment can operate, so that they are away from residences and other sensitive receptors at particular times.
- Locate site vehicle entrances away from residences and other sensitive receptors.
- Carry out noisy fabrication work at another site (e.g. within enclosed factory premises) and then transport products to the project site.

ALTERNATIVES TO REVERSING ALARMS

- Avoid the use of reversing alarms by designing the site layout to avoid reversing, such as by including drive-through for parking and deliveries.
- When applicable legislation permits, consider less annoying alternatives to the typical "beeper" alarms. Examples include smart alarms that are adjustable in volume depending on the ambient level of noise, and multi-frequency alarms that emit noise over a wide range of frequencies.

MAXIMIZE SHIELDING

- Re-use existing structures rather than demolishing and reconstructing.
- Use full enclosures, such as large sheds, with good seals fitted to doors to control noise from night-time work.
- Use temporary site buildings and material stockpiles as noise barriers.
- Schedule the construction of permanent walls so that they can be used as noise barriers as early as possible.
- Use natural landform as a noise barrier. Place fixed equipment in cuttings or behind earth berms.
- Take note of large reflecting surfaces on- and off-site that might increase noise levels, and avoid placing noise-producing equipment in locations where reflected noise will increase noise exposure or reduce the effectiveness of mitigation measures.

PROVIDE RESPITE PERIODS

- Consult with schools to ensure that noise-generating construction works in the vicinity are not scheduled to occur during examination periods, unless other acceptable arrangements (such as relocation) can be made.
- When night work near residences cannot be feasibly or reasonably avoided, restrict the number of nights per week and/or per calendar month that the work is undertaken.

WORK SCHEDULING

- Schedule noisy work during periods when people are least affected.

SCHEDULE ACTIVITIES TO MINIMIZE NOISE IMPACTS

- Organize work to be undertaken during the recommended standard hours, where possible.
- If the construction site is in the vicinity of a sports venue, consider scheduling work to avoid times when there are special events.

- When work outside the recommended standard hours is planned, avoid scheduling it on Sundays or public holidays.
- Schedule work when neighbours are not present (e.g. outside business hours or on weekends, when commercial neighbours, college students and school students may not be present).
- Schedule noisy activities around times of high background noise (i.e. when local road traffic or other local noise sources are active) where possible, to provide masking or to reduce the amount that the construction noise intrudes above the background noise.

DELIVERIES AND ACCESS

- Nominate an off-site truck parking area away from residences for trucks arriving prior to gates opening and schedule deliveries only during specified periods.
- Optimize the number of vehicle trips to and from the site. Movements can be organized to amalgamate loads rather than using a number of vehicles with smaller loads.
- Designate access routes to the site through consultation with potentially noise-affected residences and other sensitive receptors, and inform drivers of nominated vehicle routes.
- Provide on-site parking for staff and on-site truck waiting areas away from residences and other sensitive receptors. Truck waiting areas may require walls or other barriers to minimize noise.

NOISE TRANSMISSION PATH

- Physical methods to reduce the transmission of noise between construction locations and residences or other sensitive receptors are generally suited to construction projects in which there is long-term noise exposure.
- Reduce the line-of-sight noise transmission to residences and other sensitive receptors using temporary noise barriers.
- Temporary noise barriers can be constructed from boarding (plywood boards, panels of steel sheeting or compressed fibre cement board) with no gaps between the panels at the site boundary. Stockpiles and shipping containers can be effective noise barriers.
- Erect temporary noise barriers before work commences to reduce noise from construction as soon as possible.
- Where high-rise dwellings adjoin the construction site, the height of a barrier may not be sufficient to effectively shield the upper levels of the residential building from construction noise. Find out if this is a consideration for the project and examine alternative mitigation measures, where needed.