AECOM

Chapter 15

Human Health Risk Assessment

Table of Contents

Figures

List of Tables

15. Human Health

15.1 Introduction and Scope of Assessment

This chapter forms part of a Comprehensive Study (CS) for the Proposed Parallel Runway Project (PRP) at the Calgary International Airport (YYC). The process shadows the environmental assessment (EA) process under the *Canadian Environmental Assessment Act (CEAA)*. This chapter examines the potential residual and cumulative effects that the construction, operation and reclamation of the PRP may have on the health of humans within the Local Study Area (LSA) of the PRP. The PRP consists of a 14,000 ft (4,267 m) runway and associated infrastructure. The project components are described in further detail in Volume II, Chapter 7 of the CS.

The potential for health effects are evaluated herein for three sets of issues arising from changes to environmental quality as a direct result of the development of the PRP:

- aircraft noise and vibration;
- air quality changes resulting from aircraft and other emissions; and
- changes in the amounts and particulars of chemical use in association with the proposed completion of a parallel runway.

Methods used to complete the Human Health Risk Assessment (HHRA), along with important decision criteria regarding thresholds of effects, are described in detail in Volume V, Item 13 (Human Health Baseline Report) and are summarized below.

For assessing the implications for human health especially as a result of increases in aircraft noise and emissions, two types of assessment methods were used. Firstly, predicted human exposure levels after completion of the proposed PRP were compared with numerical thresholds below which no health risks are expected, and above which health risks begin to occur. Secondly, direct comparisons were made between estimated exposure conditions with and without the PRP. This second major assessment method is the most relevant to understanding project-related effects, both positive and negative. To facilitate the health assessment, quantitative evaluations have been developed of spatially explicit human exposure under existing conditions, through two future periods (the years 2015 and 2025) if the parallel runway is not constructed (i.e., “Do Nothing, DN”). The same two years were also evaluated to determine what the differences in human health impacts would be if the PRP is constructed (i.e. “Do Something, DS”). By evaluating the development and non-development scenarios, the net difference to human health that could reasonably be attributed to the project can then be determined.

The aircraft noise HHRA is based on detailed analysis and modelling of noise as described in Chapter 10 of this Volume. The assessment of effects on health of air quality changes from aircraft and other emissions is based on detailed analysis and modelling described in Chapter 12 of this Volume. Issues associated with chemical use at YYC are covered herein in Section 15.8. The implications of possible changes in chemicals use are discussed for not just humans, but also non-human environmental components such as aquatic life in waters that receive runoff from YYC lands.

The effects assessment for human health was completed following the general methods outlined in Chapter 1 of this Volume. The environmental effects assessment not only examines potential direct and indirect environmental effects that might result from the PRP, but also examines ways in which effect levels can be reduced through mitigation. Estimates of the level and magnitude of residual effects that were predicted to remain following the implementation of mitigation measures were also completed.

15.2 Defined Study Area

The defined study area that was selected for use in the HHRA was the same as the one used to evaluate noise issues (Volume V, Item 8, Noise Baseline Report) and air quality (Volume V, Item 10, Air Quality Baseline Report). Unlike some project issues or valued components (VCs) such as soil disturbance or loss, the study area used for the HHRA study extends outward from the proposed project footprint to encompass all areas where there is a potential for human exposures to noise or airborne contaminants at levels greater than the existing or expected future background (ambient) levels. For the air quality assessment (emissions), the Local Study Area (LSA) was defined as a 16 km x 17 km domain centred on the PRP (Volume V, Item 10). A similar but slightly larger area of interest was used to focus the noise assessment conducted for the PRP. The noise predictions and evaluation of associated effects covers an LSA (centred on the airport) of approximately 25 km x 25 km.

Noise (essentially undesired sound) propagates outward in the air from its sources as energy waves. While noise and vibrations can also propagate through other media such as soil, built structures or water, the human exposure associated with sound propagation in these media compared with air is trivial, for all but the lowest frequency events (low frequency noise (LFN); see Chapter 8 of ACRP 2008a). Sound propagation though media other than air is generally overlooked or assigned a very low priority in the evaluation of airport noise health effects.

Airborne contaminants potentially arising from jet engine exhaust, other combustion sources, or dust suspension also propagate within the air. Since airborne transport of contaminants is the human exposure pathway of interest, the study area includes areas on the landscape where as a result of the development of the PRP there is a potential for increases in levels of airborne substances of interest beyond ambient levels to occur.

The overall area of interest for the HHRA potentially covers those areas in which noise and/or airborne contaminants generated as a result of the project could be higher than ambient levels. The health risk assessment focuses especially on areas surrounding YYC lands where more sensitive human receptors are present over extended periods of time.

15.3 Overview of Human Health Assessment Methods

HHRA is a decision-making tool that is intended to address the health related concerns of potentially affected individuals or parties, managers, planners, and regulators, through formal (ideally objective) analysis of three major elements:

- the potential sources of various stressors, toxicants, or other possible hazards;
- individuals or groups of people that might be exposed; and
- potential routes or mechanisms of exposure.

HHRA is intended to address the following five major components, each of which is a major constituent of the analysis:

- **Problem Definition**: What are the issues of concern, and which are higher versus lower priority issues for further scrutiny?
- **Health Effects Assessment**: For each risk driver, what are the lower limits of exposure that could lead to undesired health consequences? (Alternatively, at a given level of predicted or measured exposure, what is the level of health effect likely to be encountered?)

- **Exposure Assessment**: For each type of potential stressor, toxicant, or other type of hazard (i.e., risk drivers) that might potentially arise from a situation or undertaking, who are the people (i.e., receptors) who might possibly be exposed, and at what magnitude or level?
- **Risk Characterization**: Are potential health effects (or risks) possible in light of the predicted (or measured) magnitude of exposure in comparison with expected thresholds for health effects?
- **Uncertainty Analysis**: How certain are we about the information assembled to arrive at conclusions about health risk potential?

The various components of the HHRA are illustrated in Figure 15-1 and are those that are commonly endorsed by Health Canada (HC), the World Health Organization (WHO), United States Environmental Protection Agency (EPA), and various other agencies. The particulars of the each component are described in more detail in subsequent sections in the context of the PRP.

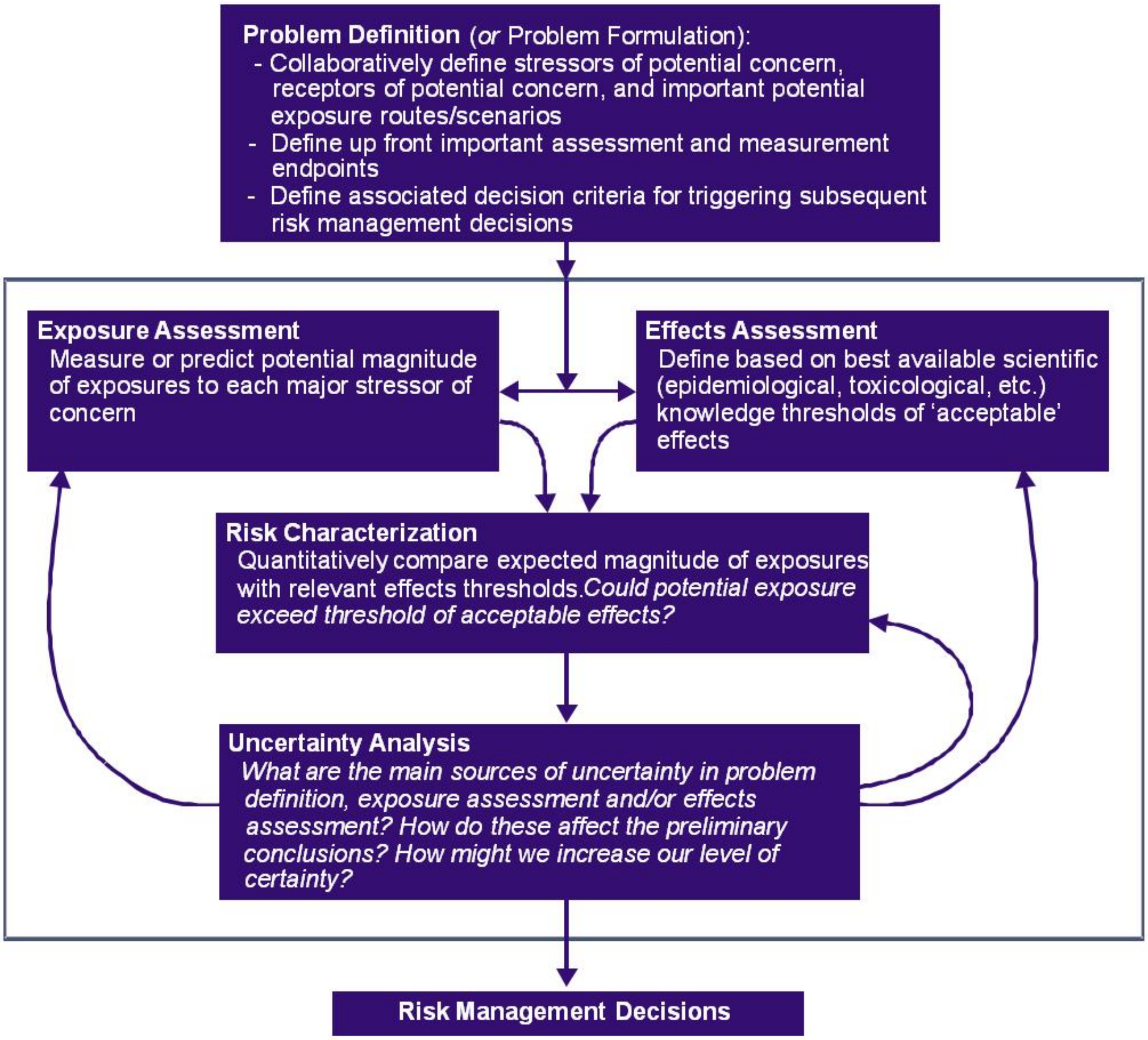
HHRA can provide useful information at a variety of levels. For example, a qualitative assessment is often useful for ruling out some concerns and focusing the HHRA on other issues. Adverse health outcomes are plausible only to the extent that the source of a stressor, its propagation or transport along an exposure route, and the subsequent exposure of potentially affected people or VCs co-occur. If any of the three elements are absent, then the underlying risk hypothesis is not plausible. By extension, predicted health risks can be mitigated by effectively managing either of these three components or combinations thereof: health risk management can be achieved by reductions of levels of a putative stressor, pathogen or toxicant at its source, reducing the amount of exposure experienced by altering the nature of the exposure route(s), and/or removing humans from areas of high exposure potential.

Where the possibility of risks has been qualitatively confirmed through a screening analysis, it does not necessarily mean that there are unacceptable health risks. Health risk potential increases with an increase in the magnitude of exposure to one or more stressors or perturbations, and decisions about whether such increases are acceptable from a human health perspective are routinely made through comparison with thresholds of effects, beyond which adverse effects would be expected. These comparative threshold levels are generally obtained from the best available scientific/technical information.

Further information regarding the HHRA process, as used in this study, is provided in Volume V, Item 13. Through the Problem Definition stage of the health risk assessment, aircraft noise and air quality changes associated with aircraft issues were identified as the major issues of potential concern. A third, lower priority issue is also discussed herein: the expanded use of chemicals on YYC lands as a result of the PRP development.

The assessment of future changes in air quality or community noise associated with the PRP considers not just a human resident of average physical health, but focuses on potentially sensitive individuals within the larger population and portions of the overall study area where such individuals might experience a higher level of project-related exposure than elsewhere. For assessment of health effects associated with potential changes in air quality associated with the PRP, formally adopted health-based effects thresholds as promulgated by HC, the WHO, United States EPA, California EPA, or other agencies were used. The effects thresholds used by these agencies generally also take into account and adjust for potentially higher sensitivity population cohorts such as developing children, the elderly, and other potentially sensitive individuals.

Figure 15-1 The PRP Health Risk Assessment Model



15.4 Aircraft Noise

Airport noise arises primarily from airside operations - which include engine run-up, takeoff, landing, and overflights of various wide-bodied or narrow-bodied jets, propeller driven airplanes, and helicopters. Secondarily, airport noise is generated from groundside operations, primarily from maintenance vehicles (Volume V, Chapter 8).

Community noise at airports comes primarily from aircraft approaching or taking off, from taxiing aircraft, and from engines that are running on the airfield (Edinburgh Noise Action Plan 2008-2013; May 2008). The WHO (1999) defines community noise as follows:

> *"Community noise (also called environmental noise, residential noise or domestic noise) is defined as noise emitted from all sources except noise at the industrial workplace. Main sources of community noise include road, rail and air traffic; industries; construction and public work; and the neighbourhood."*

Noise is measured as a sound pressure level along a logarithmic (log10) scale, for which the basic unit for measurement is the decibel (dB). The measured sound pressure levels are correlated with the loudness perceived by the human ear using an A-weighted logarithmic scale. Weightings of noise pressure can be described in terms of a weighting function that is used to modify the amplitude of unweighted noise levels. A-weighting originated in the 1930s, and is currently used almost exclusively in the measurement of environmental noise (for example from, roadways, rail and aircraft) primarily because humans are considerably more sensitive to noise in the region of 6 kHz, and A-weighting emphasizes noise especially in the 1 - 6 kHz range. The noise assessment for the YYC and PRP was, therefore, carried out using the A-weighted sound level, denoted as 'dBA'. Sound levels that are less than 5 dBA above the background level are generally noticeable but not obtrusive. Higher noise levels may generate complaints.

Vibrations also can result from aircraft operations and these might occur during construction. However, it was concluded that there is a low potential to experience ground vibration beyond YYC lands (Chapter 10 of this volume). It was further determined that it is unlikely that vibration from YYC, at a magnitude that would result in physiological effects in humans, will be felt beyond the airport perimeter during either the construction or operational phases of the PRP project. This is due to the large separation distance from construction sources of ground vibration at the airport to vibration sensitive premises beyond the airport perimeter (i.e., over 1,000 m, for both DN and DS scenarios), and the rapid dissipation of vibration in the ground. Vibration can cause changes in tendons, muscles, bones and joints, and the nervous system. Whole body vibration can cause fatigue, insomnia, stomach problems, headache and shakiness during or following exposure (*Canadian Centre for Occupational Health and Safety: http://www.ccohs.ca/oshanswers/phys_agents/vibration/vibration_effects.html*). Vibration-related health effects to date, however, have been predominantly associated with long-term exposure to vibrations in an occupational setting; for example, through use of power tools or heavy equipment. The energy and duration of such exposures in far greater – both during construction and operations - than is expected for residential areas surrounding the PRP project.

15.4.1 Noise Effects Assessment

Volume V, Item 13 (HHRA Interim Report) provides an extensive review of the available knowledge about how humans might be affected by aircraft noise. The Airport Cooperative Research Program (ACRP 2008a) and others (e.g., Harris 1997) provide a recent review of research and conclusions on the effects of aircraft noise developed since 1985. The various studies regarding human health fall within the following noise effects categories:

- annoyance;
- hypertension and cardiovascular effects;
- effects in developing children;
- sleep disturbance;
- speech interference; and
- effects of aviation noise on schools and learners.

As discussed in Volume V, Item 13, the recent and overall epidemiological research is useful for providing reasonable data on quantitative noise exposure – response relationships for the following effects endpoints:

- percent of moderately or highly annoyed individuals within the population exposed; and
- sleep disturbance.

In addition, the available epidemiological evidence suggests a need to evaluate effects on learning performance of pre-school aged children and those attending elementary schools in spite of the fact that robust quantitative exposure – response relationships have yet to be developed.

The emerging information also suggests an influence of noise (and degree of disturbance) on hypertension and possibly cardiovascular disease; however, the particulars of the exposure magnitude – response relationship have yet to be adequately resolved.

The various noise metrics that have been used by researchers to assess these health effects are also described in Volume V, Item 13 (Table 1). Based on our review and understanding of the current state of knowledge, three general types of health effects were chosen for evaluation, as listed in Table 15-1.

The 'Continuous Equivalent Noise Level' for a 24-h period ($L_{Aeq,\ 24\ h}$) or a 15-h daylight only period ($L_{Aeq,15h}$) was also used in this health assessment. L_{Aeq} can be defined as the hypothetical steady sound, which contains the same sound energy as the actual variable sound, over a defined measurement period. L_{Aeq} is the most commonly used noise descriptor for all types of noise source, and for aircraft noise, its use is widespread across the world. It is particularly useful for comparative assessments of overall changes in noise levels.

Volume V, Item 8, Section 2.4 (Noise Baseline Report) further describes noise metrics that have been used in research on noise effects and in effects assessments.

The Day-Night Noise Level (or DNL) metric is calculated differently by different agencies. In particular, the cumulative noise measure assigns a 10 dBA weighting for noise occurring at night, when background noise levels are typically lower and possibility of sleep disturbance is higher relative to the absolute sound value. Different agencies and assessments have included various cut-offs for differentiating between night-time and day-time effects, with night-time durations of either 8 or 9 hours. For this study, it is assumed that the night-time period of interest occurs from 22:00 h (10:00 p.m.) to 07:00 h (7:00 a.m.). This is a 9 hour period and it represents a conservative assumption in that it will lead to higher estimated DNL levels than alternative, shorter duration night time period designations.

Table 15-1 Summary of Noise Descriptors and Decision Criteria Used in the Health Risk Assessment

Effect	Metric and Risk Threshold or Indicator
Annoyance: Increase in Percent Highly Annoyed (%HA) Individuals within Exposed Population	**Day-Night Noise Levels: DNL**[1,2] (A-weighted). Threshold of possible substantial effects at DNL 65 dBA (U.S. Department of Transportation, Federal Aviation Administration (FAA 20 March, 2006)[3].
Sleep Disturbance	**Sound Exposure Level: SEL**[4] Threshold of possible substantial effects at 90 dBA SEL[5]
Cognitive Development in Children[6]	Predicted change (increase or decrease) in noise exposure levels at facilities where children are routinely engaged in learning and development activities (day care centres, kindergartens, home-schooling, etc). The major metric used in evaluating effects on cognitive development is – (i) **$L_{Aeq,15\ h}$** Like DNL, this is an integrated measure of cumulative noise exposures over daytime periods when learning institutions might be active. Although not formally assessed in this chapter, some researchers have used the intensity and number of individual loud events as a potential correlation of learning disruption and effects on cognitive development. The potential for cognitive disturbance increases with the level of an individual noise event, such as an aircraft overflight, as well as the number of potentially disturbing events within a set period. L_{Amax}. (ii) **Maximum A-weighted Sound Level: L_{Amax}** Among the most simple measure of a noise event, such as the overflight of an aircraft, is the maximum sound level recorded: L_{Amax}. (iii) **Number of Events Above: NA L_{Amax}** NA L_{Amax} is the number of noise events exceeding a given threshold over a pre-determined period. For this study, the number of individual events over a period of interest, with an L_{Amax} greater than 65, 75 and 85 dBA was estimated. Predictions of L_{Amax} and NA L_{Amax} are presented in Chapter 10.

Notes:

(1) DNL (Day-Night Noise Level) is a 24-hour cumulative noise level measure calculated from two separate time periods (day and night), with a 10 dBA weighting for any noise events occurring during the night which is defined as the period 22:00-07:00 hours, when it is considered that peoples' sensitivity to noise is heightened.

(2) According to Michaud et a. (2008), the viewing of a high degree of annoyance is consistent with HC's definition of "health", and percent highly annoyed is the preferred alternative as a long term health endpoint. A goal of the HC deliberations is to "establish quantitative criteria for adverse health effects as a function of project-related long-term changes in noise". Michaud et a. (2008) provide an extensive review of the noise metrics and thresholds developed over the last two decades to predict percent highly annoyed (%HA), including a critical evaluation of dose-response relationships; however, no specific set of effects thresholds have yet been recommended by HC. Nonetheless, the detailed analysis tends to indicate that using a change in %HA_n is an acceptable noise effect mitigation criterion, coupled with DNL as an appropriate exposure metric.

(3) According to the FAA (2006), "A significant noise impact would occur if analysis shows that the proposed action will cause noise sensitive areas to experience an increase in noise of DNL 1.5 dB or more at or above DNL 65 dB noise exposure when compared to the no action alternative for the same timeframe. For example, an increase from 63.5 dB to 65 dB is considered a significant impact."

(4) The SEL of an aircraft noise event is the sound level, in dBA, of a one second burst of steady noise that contains the same total A-weighted sound energy as the whole event. In other words, it is the dBA value that would be measured if the entire event energy were uniformly compressed into a reference time of one second. SEL, therefore, can be higher than L_{Amax} for a noise event.

(5) See Michaud et a. 2007.

(6) The metrics L_{Amax}, and NA 24-h L_{Amax} are also appropriate for assessing human responses based on other disturbance-type responses, such as speech interference and attentiveness.

15.4.2 Aircraft Noise Exposure Assessment

15.4.2.1 Baseline Noise Exposure Levels

Volume V, Item 8 provides the baseline assessment of noise levels and exposure potential within the LSA around YYC. Available noise monitoring data for Noise Monitoring Terminals (NMTs) installed around YYC provide good information on baseline noise levels. These data were augmented by acquisition of noise data at 15 additional supplementary Noise Monitoring Stations (NMSs) operated for 28 days or longer. The noise events recorded at the 14 NMTs and 15 NMSs can be separated into those attributable to aircraft overflights and noise from other sources by matching a noise event against real-time and archived records of flight tracks for arrivals and departures at YYC. Noise, measured as DNL, attributable to sources other than aircraft is designated as general community noise (DNL_C).

Over the recent four month monitoring period (27 July, 2009 to 2 December, 2009), overall (aircraft plus community) DNL noise values exhibited an average that varied from as low as 55 dBA to as high as 72 dBA at the 14 NMTs. The range of average DNL levels over the four month period was similar across the NMSs (i.e., 53 to 69 dBA DNL). The 90^{th} percentile DNL at each NMT or NMS was 1 to 3 dBA higher than the average DNL over the four month monitoring period. The average $L_{Aeq\ 1\text{-}hr}$ noise levels ranged from 47 to 64 dBA, as can be expected for urban neighbourhoods.

Overall, the ambient noise values measured at different community receptors around the LSA are considered to be within a typical range of an urban neighbourhood. Analysis of the trends in noise measured by the YYC monitoring network over the last five years (Appendix B of Volume V, Item 8) show that:

- the measured noise levels have been relatively stable over this period;
- where there has been an overall trend either for increase or reduction in noise levels, the change has been relatively slow;
- where there has been a trend either for increase or reduction in noise levels, the difference between current conditions and five years ago is relatively small;
- typically, the aircraft noise DNL values are lower than or do not exceed the equivalent community noise levels; and
- aircraft noise is more variable than community noise.

While aircraft noise might be intermittently intrusive at each monitoring location, it was not the major contributor to overall noise levels. In addition to typical sources of community noise, road traffic noise was persistently audible at all monitoring stations and other less constant sources of noise included children playing, birdsong, domestic pets, and construction noise (at the Martindale monitoring station).

The baseline data collected at the NMTs and NMSs were used to validate the predictive model of noise from aircraft overflights in the LSA.

15.4.2.2 Predicted Noise Exposure Levels

Chapter 10 of this Volume provides an extensive assessment of predicted noise levels in future years. The operational phase of the PRP was quantitatively assessed using noise predictions for the following four scenarios:

- **2015 Do-Nothing scenario (DN)**, which describes YYC and the local road network without the parallel runway in place in the year 2015, the proposed first operational year for the PRP;

- **2015 Do-Something scenario (DS)**, describes YYC and the local road network with the parallel runway in place in 2015;
- **2025 Do-Nothing scenario (DN)**, which describes YYC and the local road network without the parallel runway in place in 2025; and
- **2025 Do-Something scenario (DS)**, describes YYC and the local road network with the parallel runway in place in 2025

The operational assessment is in addition to the assessment of baseline (pre-construction) noise conditions, as well as an assessment of noise issues associated with the construction phase of the PRP.

As discussed above and in Chapter 10, the core metric used to predict changes in degree of annoyance is DNL. This is a 24-hour L_{Aeq} measure with a 10 dBA weighting for any noise events occurring during night-time (22:00-07:00), when it is considered that people's sensitivity to noise is heightened. There is a split of 15 hours for the daytime and 9 hours for night-time. No weightings are applied to the day and evening periods. This metric is currently used for this type of assessment in the United States, Belgium and New Zealand. Evaluation of annoyance as a major health effect tends to capture other health effects as well, including sleep disturbance and speech interference, since these also increase an individual's perception of being highly annoyed. The extent to which annoyance is correlated with hypertensive responses and possibly cardiovascular disease remains speculative based on the current state of scientific knowledge, but such a linkage is plausible from a mechanistic/physiological perspective.

Other metrics used to assess various health affected endpoints include especially SEL, $L_{Aeq, 15 h}$, L_{Amax} and, NA L_{Amax} (Table 15-1).

Spatially explicit noise predictions were developed based on the following types of information, with values that differ for each of the four modelled scenarios:

- **Number and types of aircraft using YYC** on a hypothetical high use day [the 90th percentile of overall air traffic volume (peak planning day), based on data summaries for 2009 and predictions in increased air traffic as provided by Transport Canada (TC) (Vol. 4)].
- **Acoustic and performance data for each aircraft type** (including speed and engine power changes with height during takeoff and landing).
- **Assumed flight paths** in the airspace. This, in turn, is based on:
- Ground tracks: Ground track information is needed to define two of the three coordinates of the flight path of an aircraft.
- **Vertical profile of height at takeoff and landing**.
- **Noise emission profile** for each aircraft type.
- **Movements and acceleration patterns** while on the ground (ground roll).
- **Reverse thrust effects** during landing.
- **Free-air attenuation:** This is the rate at which the sound level decays with distance from the source in still, free air.
- **Lateral directivity** (engine installation effects): This refers to directionality in sound propagation about the aircraft roll axis. It results primarily from acoustic interactions between the engine noise sources and/or the aircraft structure.
- **Longitudinal directivity:** Noise radiated varies markedly in the longitudinal (fore/aft) direction usually with higher emissions to the rear of aircraft.
- **Lateral attenuation:** This affects sound propagating at acute angles to the ground surface. It is largely caused by interference between directly radiated sound and reflection from the ground surface - which depends on the angle of sound incidence, ground properties and receiver height.

- **Receiver factors:** Local ground surface features including topography and ground cover may have significant effects upon noise transmission through reflectance, refraction and damping.
- **Integration along the flight path:** Computing duration dependent event levels means summing the contributions from different parts of the flight path.
- **Runway Utilization:** Assignment of aircraft to runways by Air Traffic Control (ATC).

The Integrated Noise Model (INM), developed and updated by the USA FAA, was used for the prediction of spatially explicit DNL and other noise metrics. INM is a very comprehensive aircraft noise model, but the accuracy of its outputs is dependent on the quality of input data and the way in which the model is used. The model uses Noise-Power-Distance (aircraft noise level at ground height as a function of distance) data to estimate noise levels, accounting for specific operation modes, engine thrust setting, source-to-receiver geometry, acoustic directivity and other environmental factors. The INM can calculate exposure, maximum-level and time-based noise contours, as well as levels at pre-selected locations.

Aircraft approach and departure flight paths were considered to be straight and were derived using typical aircraft modelling procedures and following the Standard Instrument Departure (SID) program adhered to by the Authority. Using straight departure paths enabled simple derivation of the flight paths for the future parallel runway and ease of comparison. Continuous descent approaches using a fixed glide slope as opposed to an initial more rapid descent followed by a shallower approach to the runway can reduce aircraft generated noise. Use of a fixed glide slope, therefore, is a conservative assumption. The noise modelling in chapter 10 assumes a 3 degree glide slope.

Model validation was completed by comparing modelled noise exposure levels for the 90th percentile day in 2009 (peak planning day: pre-construction) with measured noise levels recorded at permanent monitoring stations around YYC. As shown in Table 15-2, the INM modelled predictions for the DNL noise metric over-predicted noise exposure levels at all but two of thirteen YYC NMTs) (i.e., actual noise measurements were lower than predicted by the modelling). Note that this analysis excludes data from NMT 9, which was considered to be unreliable.

The predicted noise levels were within 3 dBA of the measured DNL noise levels at five locations, and within approximately 5 dBA at two locations. This indicates that there is a reasonable correlation between noise predictions and the equivalent measured baseline noise levels. At six locations, predictions vary from the equivalent measured value by a value greater than 5 dBA. This lack of accuracy may have been caused by a variety of factors such as aircraft straying from the flight paths within INM and adverse weather conditions. While the fit between predicted and modelled was not perfect, the INM predictions were generally higher than actually measured (i.e., were adequately conservative).

Table 15-2 Comparison of Predicted and Measured Noise Levels, Pre-construction/Baseline Scenario

Monitoring Location	INM DNL Predictions (dBA)	DNL from Noise Monitors (dBA)	Difference
NMT01	62.8	53.5	8.7
NMT02	54	45.1	8.9
NMT03	62.6	58.2	4.4
NMT05	50.8	43	7.8
NMT06	65.6	67.5	-1.9
NMT08	58.7	49.3	9.4
NMT10	66.8	54.9	13.9
NMT11	65.5	60.3	5.2
NMT12	59.8	67.8	-8.0
NMT13	64	66.9	2.9
NMT14	61.2	60	1.2
NMT15	59.4	58.9	0.5
NMT16	56	55.5	0.5

An extensive presentation and discussion of modelled noise predictions is provided in Chapter 10 of this Volume, with the results of immediate relevance to interpretations of human health effects summarized further below. The model assumed that aircraft movements would be distributed between runways in certain proportions. Changing runway utilization would change the distribution of noise communities surrounding YYC and could possibly change the results of the assessment. Runway utilization will not be finalized until NAV CANADA designs airspace management for the airport when the parallel runway is operational. The implications of different runway splits are discussed in more detail in Volume III, Chapter 10. The expected change in aircraft noise exposure levels within the LSA is illustrated in a series of maps in Chapter 10 of this Volume (Appendix B). The potential influence of the PRP on percent of residents or visitors within surrounding neighbourhoods that might be annoyed by aircraft noise is indicated by DNL experienced within the LSA. Predicted DNL exposure levels are mapped for the baseline case (current, pre-construction) in Figure 10-15 (Chapter 10, Appendix B). Predictions about DNL levels as a result of future scenarios are provided in Figure 10-21 (2015 DN), 10-27 (2025 DN), 10-33 (2015 DS), and 10-39 (2025 DS) in Chapter 10, Appendix B.

Changes in noise exposure associated with the four scenarios are interpreted based firstly on absolute predicted DNL levels, and secondly (and more importantly) on predicted differences in noise exposures with or without completion of the PRP (DS vs. DN). Figure 10-45 (Chapter 10, Appendix B) shows the predicted difference in DNL levels (and expected degree of annoyance) for the DN and DS scenarios for the year 2015. The noise modelling predicts a net improvement (net decrease) in aircraft-related noise levels to the immediate north and south of the existing north-south runway and to the west, along with a net increase in DNL along the flight path of the proposed parallel runway. This is intuitively reasonable, since some percentage of takeoffs and landings would be directed eastward to the parallel runway if completed.

Similarly, Figure 10-46 (Chapter 10, Appendix B) shows the predicted difference in DNL levels for the DN and DS scenarios for the year 2025. The same pattern is evident in the predictions for 2025; however, the magnitude of the effect is expected to be greater in both directions (areas of net reductions in DNL in the western half of the LSA and areas of net increases in DNL in the eastern half).

The predicted trends are mapped in Chapter 10 for L_{Amax}, as an indicator of potential changes in especially sleep disturbance, speech impairment, and other health effects associated with a distraction-type or startle-type response to exceptionally high, short duration noise events.

Volume III, Chapter 10 also provides information on other health indicators, including:

- SEL as an indicator of predicted trends in occurrence of sleep disturbance;
- $L_{Aeq, 15\text{-}h}$;
- $L_{Aeq, 24\text{-}h}$; and
- $L_{Amax\ 15\text{-}h}$.

15.4.3 Noise Risk Characterization

15.4.3.1 Annoyance

Since 1979, US federal agencies have considered a DNL of 75 dBA or greater as incompatible with all residential use, except transient lodging (FAA 1985, 2000; FICUN 1980; FICON 1992a). Under the *Aviation Safety and Noise Abatement Act* of 1979, the FAA adopted the DNL metric and 65 dBA compatibility standard. Lands exposed to DNL 65-74 dBA are regarded as “normally” incompatible with residential use, while lands exposed to a DNL of less than 65 dBA are regarded as “normally” compatible with such use. Further, at 65 dBA and above, increases in exposure of 1.5 dBA or more are regarded as a significant addition of noise, and require an environmental impact statement.

Model predictions in Chapter 10 of this Volume suggest area-specific changes in DNL levels for 2015 and 2025 scenarios. The number of individuals predicted to experience various ranges of outdoor noise exposure, measured as DNL, with completion of the PRP in comparison with the DN scenario for each of 2015 and 2025 is shown in Tables A-1 to A-5 in Chapter 10.

When interpreting the noise exposure predictions, it is important to remember that:

(i) the aircraft movements reflect a 90th percentile air traffic volume planning day (i.e., lower air traffic volumes are expected than modelled for 90% of all days in a year); and
(ii) the calibration results for the model indicate a bias towards over-prediction of noise levels relative to the actual case. See Table 15-2 and the associated discussion.

HC (Michaud et al 2008) has recommended the use of %HA (percent highly annoyed) and DNL as a major indicator of health effects, based on the following understanding:

- a 6.5% increase in %HA individuals within an exposed cohort is a reasonable threshold for identification of severe noise effect; and
- a step from 60 dBA DNL to 65 dBA corresponds to a change of about 6.5 in %HA.

The decision criteria for significance of noise effects are summarized in Table 10-10 of Chapter 10, which is reproduced below:

Table 15-3 Annoyance/DNL Decision Criteria

Onset of Detectable Effects	Effects Regarded as Significant	Unacceptable Effects	Changes Required to Have Significant Effects	Change in Population Representing a Significant Community Reaction
55 dBA	65 dBA	75 dBA	5 dBA	6.5%

As shown in Figure 15-2, it is predicted that fewer individuals would experience DNL levels greater than 65 dBA in either 2015 or 2025 for the scenario involving completion of the PRP (DS) in comparison with the DN scenario.

As shown in Table 15-4, it is predicted that a total of 31,938 fewer people would experience DNL levels greater than 65 dBA in 2015 with the PRP in place in comparison with the DN Scenario. Similarly, it is predicted that a total of 47,012 fewer people would experience DNL levels greater than 65 dBA in 2025 with the PRP in place in comparison with the DN Scenario.

Figure 15-2 Predicted Number of Residents in Each DNL Noise Band

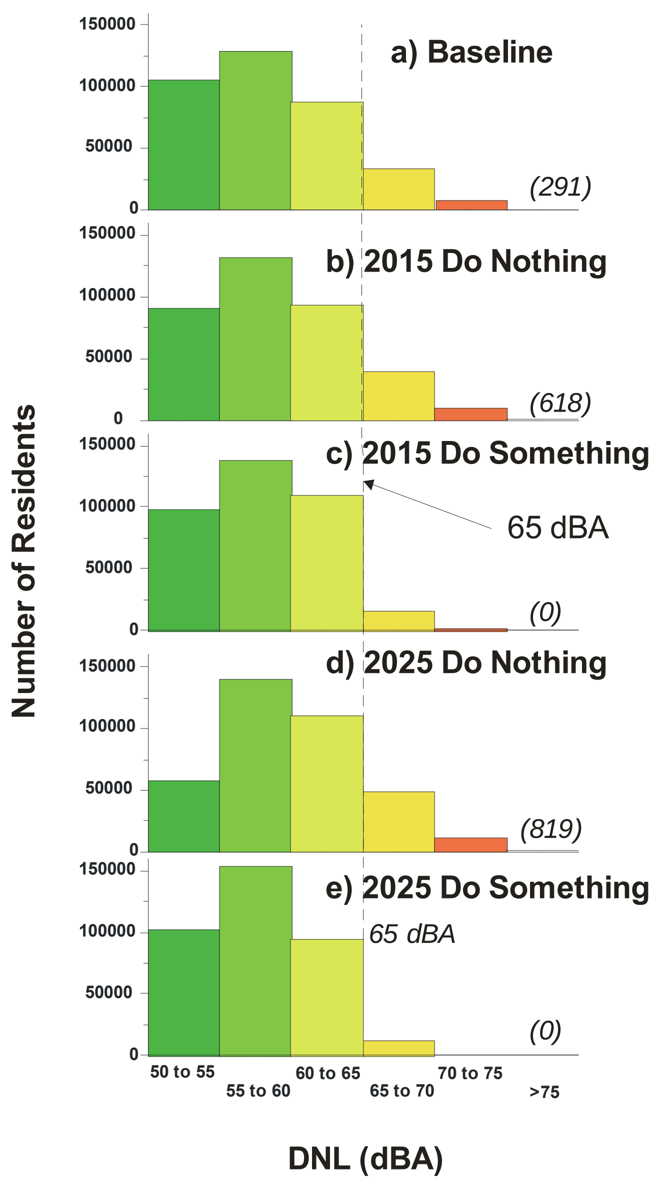


Table 15-4 Difference in Predicted Number of People in Each DNL Band

Scenario	DNL Range (dBA)					
	50 ≤ x < 55	55 ≤ x < 60	60 ≤ x < 65	65 ≤ x < 70	70 ≤ x < 75	x ≥ 75
DS vs. DN 2015	7133	5785	15830	-23373	-7947	-618
DS vs. DN 2025	44163	13324	-15977	-35919	-10274	-819

Predictions of the change in number of highly annoyed individuals as a result of the PRP depend on both the final predicted magnitude of exposure (in DNL) and the magnitude of change experienced. A DNL of 55 dBA is a generally accepted threshold for onset of annoyance, based on the large number of epidemiological studies that have been conducted to date. DNL 65 dBA is considered to be a noise exposure threshold for significant effects that are manifested in persons as a high degree of annoyance. In other words, a significant increase in the people highly annoyed would be those initially exposed to 60 dBA DNL or more who would experience an increase of at least 5 dBA. It is important to appreciate, however, that small incremental changes for individuals who are already experiencing high noise levels are predicted to increase the percentage of the exposed population feeling highly annoyed far more than the same incremental numerical change in DNL levels for subpopulations experiencing lower noise levels (Figure 15-3) (refer to Figure 10-3 of Chapter 10).

A 6.5% change in %HA, as discussed by Michaud et al (2008), is adopted herein as a criterion for defining noise effects to human health, based on the following equation:

$$\%HA = 100 / [1+\exp(10.4-0.132*(DNL+5dBA))] \quad \text{[Equation 1]}$$

In line with the advice of Michaud et al (2008) and CSA 1996:2003, the DNL has been adjusted by the addition of 5 dBA, in order to account for the increased annoyance effect of aircraft noise (compared to road and rail sources).

Tables 15-5 and 15-6 provide a summary of the noise modelling using the decision criteria discussed above.

Figure 15-3 Smaller Incremental Changes in DNL at Higher Exposure Levels Lead to Significant Changes in Percent Highly Annoyed

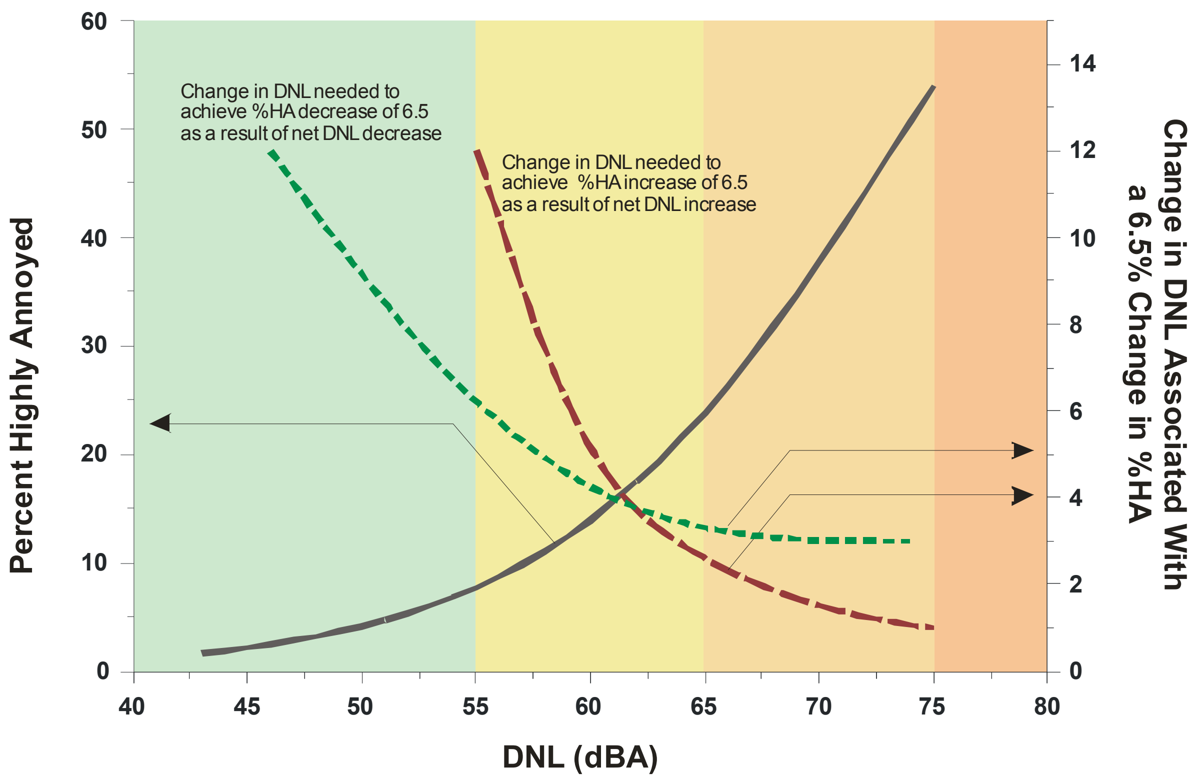


Table 15-5 Summary of Community Population Exposure Changes in DNL Between 2015 DS and DN Scenarios

DNL Noise Band dBA	Change in Noise Level from DN 2015 to DS 2015 (dBA)								
	-10 ≤ x < -5	-5 ≤ x ≤ -3	-3 ≤ x ≤ -1	-1 ≤ x < 0	x = 0	0 < x < 1	1 ≤ x < 3	3 ≤ x < 5	5 ≤ x < 10
50 ≤ x < 55	0	3,612	20,047	8,403	21,204	5,854	21,511	10,394	550
55 ≤ x < 60	1,223	25,000	28,986	5,038	29,107	9,365	10039	19,075	4,342
60 ≤ x < 65	9,004	24,506	22,383	3,064	20,106	9,689	3,053	1,533	102
65 ≤ x < 70	14,447	18,757	3,502	63	351	2,346	0	0	0
70 ≤ x < 75	1,245	8,695	0	0	0	0	0	0	0
x ≥ 75	0	618	0	0	0	0	0	0	0
Beneficial Effect	Major	24,696		Not significant			Adverse Effect	Major	102
	Moderate	28,070		Total				Moderate	2
	Minor	3,502						Minor	0
	Total	56,268		310,844				Total	102

Table 15-6 Summary of Community Population Exposure Changes in DNL Between 2025 DS and DN Scenarios

DNL Noise Band dBA	Change in Noise Level from DN 2025 to DS 2025 (dBA)								
	-10 ≤ x < -5	-5 ≤ x < -3	-3 ≤ x < -1	-1 ≤ x < 0	x = 0	0 < x < 1	1 ≤ x < 3	3 ≤ x < 5	5 ≤ x < 10
50 ≤ x < 55	2,220	4,587	16,368	7,669	18,901	4,685	3,193	0	0
55 ≤ x < 60	16,307	23,085	28,725	14,880	28,746	6,756	20,529	863	0
60 ≤ x < 65	26,095	35,896	22,173	5,160	13,722	2,747	4,915	132	0
65 ≤ x < 70	28,447	12,974	6,546	214	347	4	0	0	0
70 ≤ x < 75	8,709	2,437	0	0	0	0	0	0	0
x ≥ 75	2,47	572	0	0	0	0	0	0	0
Beneficial Effect	**Major**	**63498**		**Not significant**			**Adverse Effect**	**Major**	**0**
	Moderate	**15983**		**Total**				**Moderate**	**0**
	Minor	**6546**						**Minor**	**0**
	Total	86027		**282,824**				**Total**	**0**

Using the 90th percentile busy day, and using a model that slightly over-predicts noise exposures relative to the true case, it was predicted in the absence of any mitigation other than that provided by the new runway, that:

- in the year 2015, 15% of community residents would experience a net beneficial health effect based on annoyance for the DS scenario in comparison with the DN scenario;
- in the year 2015, 0.03% community residents would experience a net adverse health effect based on annoyance for the DS scenario in comparison with the DN scenario;
- in the year 2025, 23% of community residents would experience a net beneficial health effect based on annoyance for the DS scenario in comparison with the DN scenario;
- in the year 2025, no community residents would experience a net adverse health effect based on annoyance for the DS scenario in comparison with the DN scenario.

Overall, it is concluded that the development of the PRP would have a strong beneficial effect on the existing levels of noise-caused annoyance as an indicator of human health. This positive result can be attributed to two major factors:

(i) Re-direction of air traffic onto the parallel runway would alleviate some portion of the aircraft overflights experienced by people situated under the flight paths of the existing runways.

(ii) Continued growth in air traffic, per TC's projections, through 2015 and 2025 will place significant demands on the existing airspace and runway configuration especially during peak usage periods daily. Such growth, therefore, can only be accommodated by increasing taxiing, take-offs and landing activities during the night-time period (23:00 h to 07:00 h), for which there is greater average sensitivity to noise. Completion of the PRP, therefore, would facilitate greater numbers of flights during daytime, as opposed to night-time periods.

15.4.3.2 Sleep Disturbance

The potential for sleep disturbance from aircraft noise was assessed through quantification of noise exposures as SEL. In 1991-92, research that was conducted for the Department for Transport (DfT) in the United Kingdom (UK) into aviation noise effects at night found that outdoor noise events below 90 dBA

SEL (equivalent to approximately 80 dBA maximum sound level, L_{max}) are very unlikely to cause any increase in the normal rate of sleep disturbance. The same studies found that for aircraft noise events in the range of 90-100 dBA SEL, the likelihood of the average person being awakened was about 1 in 75. The use of the 90 dBA SEL criterion for assessment purposes is also in line with more recent findings, as presented in the Michaud *et al.* paper published in 2007 on aircraft noise-induced sleep disturbance.

The calculation of percentage noise-induced wakenings was based on Passchier-Vermeer (2003):

$$\textbf{\% noise-induced awakening - -0.564 + 1.909ee-04} \bullet \textbf{(SELi)}^2 \qquad \text{[Equation 2]}$$

- where SELi is the indoor sound exposure level. It was necessary, therefore, to convert modelled outdoor noise (SEL) to expected indoor exposure levels (SELi) with household windows closed or open.

Table 15-7, which is reproduced from Chapter 10, Table 10-12, provides evaluation criteria for defining the significance of effects for predictions of project-related changes in SEL. The important decision criteria are reproduced below.

Table 15-7 Criteria for Interpretation of Significance of Changes in Noise Exposures, as SEL (dBA), for Sleep Disturbance

Onset of Detectable Effects	Effects Regarded as Significant	Unacceptable Effects	Changes Required to Have Significant Effects	Change in Population Representing a Significant Community Reaction
60 dBA	90 dBA	100 dBA	5 dBA	6.5%

The predicted number of community members' exposures to noise, as SEL, in various noise bands is summarized in Tables 15-8 and 15-9.

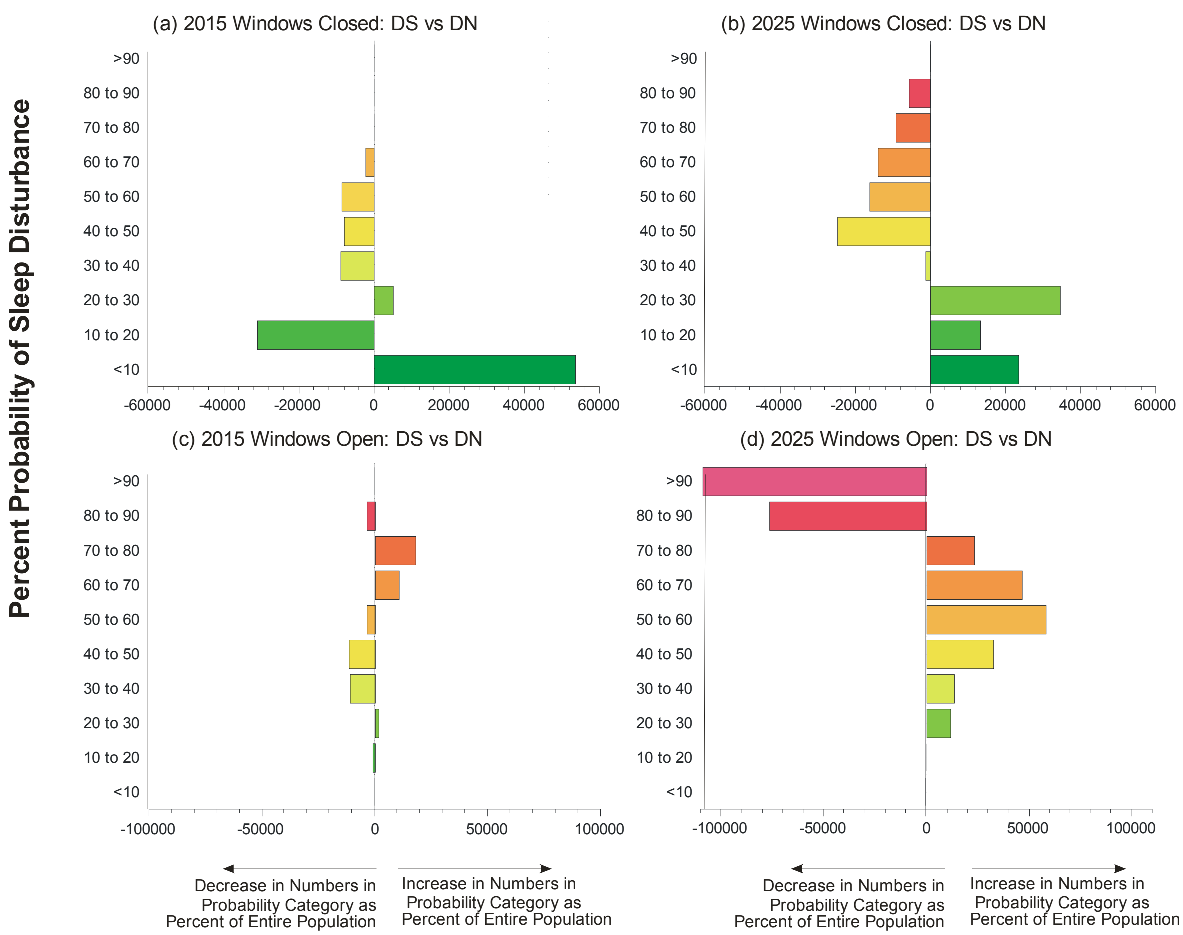
Table 15-8 Predicted Change in Percent Probability of Sleep Disturbance - Windows Closed

Scenario	Percent Probability of Awakening									
	<10	10 to <20	20 to <30	30 to <40	40 to <50	50 to <60	60 to <70	70 to <80	80 to <90	90 to 100
DN 2015	112,662	121,956	66,629	41,708	15,763	8,620	2,149	0	0	0
DS 2015	166,155	91,047	71,464	32,765	7,911	144	0	0	0	0
2015 DS vs. DN	53,493	-30,909	4,835	-8,943	-7,852	-8,476	-2,149	0	0	0
% of Community Members	**14%**	**-8%**	**1%**	**-2%**	**-2%**	**-2%**	**-1%**	**0%**	**0%**	**0%**
DN 2025	168,002	57,099	28,586	34,992	34,747	17,238	14,080	9,089	5,653	0
DS 2025	191,477	70,258	62,922	33,703	9,944	1,182	0	0	0	0
2025 DS vs. DN	23,475	13,159	34,336	-1,289	-24,803	-16,056	-14,080	-9,089	-5,653	0
% of Community Members	**6%**	**4%**	**9%**	**0%**	**-7%**	**-4%**	**-4%**	**-2%**	**-2%**	**0%**

Table 15-9 Predicted Change in Percent Probability of Sleep Disturbance - Windows Open

Scenario	Percent Probability of Awakening									
	<10	10 to <20	20 to <30	30 to <40	40 to <50	50 to <60	60 to <70	70 to <80	80 to <90	90 to 100
DN 2015	546	2,739	15,286	39,189	75,306	92,529	94,950	38,109	10,832	0
DS 2015	320	1,769	16,955	28,216	63,824	89,246	105,680	55,971	7,505	0
2015 DS vs. DN	-226	-970	1669	-10973	-11482	-3283	10730	17862	-3327	0
% of Community Members	**-0.2%**	**-4.3%**	**-3.1%**	**-10.87%**	**-13.12%**	**-3.8%**	**16%**	**14%**	**5.2%**	**0.0%**
DN 2025	320	839	220	5,241	5,320	12,395	41,744	77,033	117,206	109,172
DS 2025	318	1,076	11,890	18,769	37,830	70,227	88,191	100,575	40,608	0
2025 DS vs. DN	-2	237	11,670	13,528	32,510	57,832	46,447	23,542	-76,598	-109,172
% of Community Members	**-0.001%**	**0.064%**	**3.2%**	**3.7%**	**8.8%**	**16%**	**13%**	**6.4%**	**-21%**	**-30%**

Figure 15-4 Predicted Shifts in Probability of Sleep Disturbance Within LSA



The predicted change in percent probability of sleep disturbance within the LSA is presented in Figure 15-4.

As summarized in Chapter 10, the following effects of the PRP on sleep disturbance were predicted through comparison of the DS and DN scenarios:

- When windows are closed, it is predicted that there will be a decrease in the probability of sleep disturbance throughout the LSA; the decrease is illustrated in Figure 15-4 as a shift in number of individuals from categories indicative of a higher probability of sleep disturbance to those in lower probability categories.
- For the 2015 Windows Open scenario, minimal changes in percent probability of sleep disturbance are predicted for the DS versus DN scenario.
- For the 2025 Windows Open scenario, there predicted to be a shift in number of individuals from categories indicative of a higher probability of sleep disturbance (80% or higher) to those in lower probability categories (lower than 80%).

15.4.3.3 Early Childhood Cognitive Development

Cognitive development effects of the PRP are assessed through modelled exposures to noise based on quantification as $L_{Aeq,15\ hr}$ values (Chapter 10 of this volume). Changes in exposure associated with the project were examined for locations where children are engaged in learning and development as the prime focus of their activities; for example, nurseries, play schools, kindergartens, and schools. $L_{Aeq,15\ hr}$ is an integrated measure of noise for daylight hours only (07:00 h to 21:00 h), and is an appropriate measurement for this type of assessment since learning institutions are not generally used in the night-time hours.

As discussed in Item 13 of Volume V, the available epidemiological evidence strongly indicates a link between some community noise events and the impairment of cognitive development, or learning. Nonetheless, the relationship between aircraft noise and children's cognitive development cannot currently be defined with any confidence based on any available and suitable numeric model. This is due in part to the fact that reading age cannot be quantified in units of less than one month duration using the Suffolk Reading Scale, which was used in the most recent major recent epidemiological study available for review (RANCH Study 2005). As well, there are uncertainties when measuring reading performance in the classroom, when translating actual test scores into 'reading age' and in estimating noise exposure. The noise-cognitive development relationship should be expressed in relatively coarse units if used to quantify effects on reading age, with an acknowledgement of the degree of uncertainty around individual numbers.

This assessment evaluates effects on the cognitive development of children associated with the PRP by scrutinizing levels above 55 dBA $_{LAeq,15\ hr}$ at schools in 5 dB bands. Significance of effects evaluation criteria are tabulated in Table 15-10.

Table 15-10 Significant of Effects Criteria for Cognitive Development Based on $L_{Aeq,\ 15\ h}$

Onset of Detectable Effects	Effects Regarded as Significant	Unacceptable Effects	Changes Required to Have Significant Effects	Change in Population Representing a Significant Community Reaction
40 dBA	55 dBA	75 dBA	5 dBA	Not Applicable

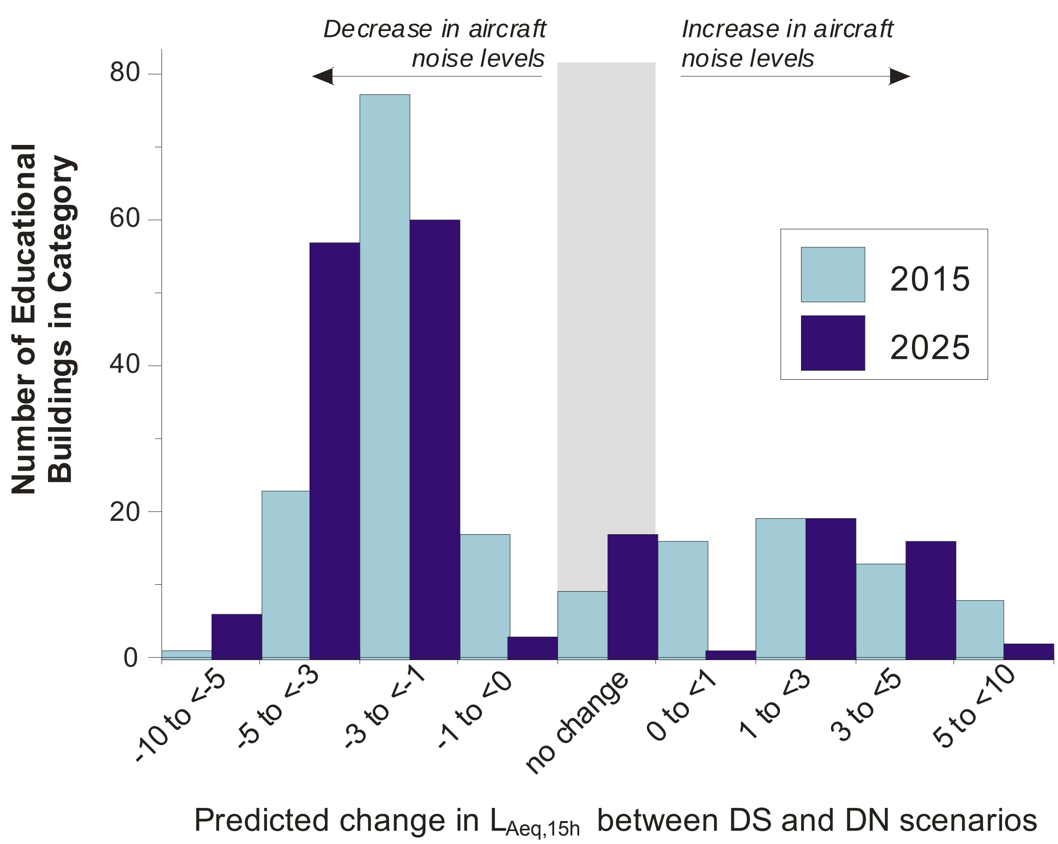
As shown in Table 15-11, no schools in the LSA are predicted to experience an $L_{Aeq,\ 15\ h}$ noise level of greater than 70 dBA. Within the 65 to 70 dBA $L_{Aeq,\ 15\ h}$ band, the project is expected to result in a decrease in schools subjected to this noise level (five fewer schools in 2015 and two fewer schools in 2025) which would fall into lower noise bands (<65 dBA $L_{Aeq,\ 15\ h}$).

Table 15-11 Summary of Predicted Daytime Noise Exposures for Schools Within the LSA

$L_{Aeq,\ 15\ h}$ Noise Band	Baseline	DN 2015	DS 2015	DS vs. DN 2015	DN 2025	DS 2025	DS vs. DN 2025
50 ≤ x < 55	74	89	75	**-13**	88	77	**-11**
55 ≤ x < 60	54	57	48	**-9**	58	54	**-4**
60 ≤ x < 65	18	20	19	**-1**	20	22	**2**
65 ≤ x < 70	5	7	2	**-5**	6	4	**-2**
70 ≤ x < 75	0	0	0	**0**	0	0	**0**

In light of the noise predictions, no negative effect of the project on cognitive development within formal learning institutions is predicted. While there are no schools in the LSA that are predicted to be experiencing unacceptable effects (>70 dBA $L_{Aeq,15h}$) either currently (baseline conditions) or in the future under the Do Nothing scenarios, the completion of the PRP is nonetheless expected to have a strong positive influence through further reductions in $L_{Aeq,15h}$ within the 55 to 70 dBA range (Figure 15-5).

Figure 15-5 Predicted Aircraft Noise Levels Outside Educational Buildings



15.4.3.4 Possible Effects on Other Sensitive Populations

Table A-28 of Chapter 10 shows predicted noise, as DNL, for community centres. Compared to the DN scenario, the DS scenario in 2025 is predicted to:

- decrease the number of community centres in the DNL 70 to <75 dBA band to zero from one;
- decrease the number of community centres in the DNL 65 to <70 dBA band to two from three; and
- decrease the number of community centres in the DNL 60 to <65 dBA band to 6 from 16.

Similar benefits are predicted for 2015.

The predicted net benefit to community centres is show in Table 15-12. In 2015, 49 community centres were predicted to experience a decrease in day-night noise levels with the PRP in place, while 8 were predicted to experience an increase. In 2025, 57 community centres were predicted to experience a decrease in day-night noise levels with the PRP in place, while only 6 were predicted to experience an increase.

Table 15-12 Predicted Number of Community Centres that Will Experience a Net Decrease or Increase in Noise Levels, as DNL

X = Noise Level Difference (dB)	DN vs. DS 2015	DN vs. DS 2025
-10 ≤ x < -5	2	26
-5 ≤ x < -3	26	24
-3 ≤ x < -1	20	5
-1 ≤ x < 0	1	2
x = 0	3	2
0 < x < 1	0	1
1 ≤ x < 3	3	5
3 ≤ x < 5	5	0

As shown in Table 15-13, five health centres are expected to benefit from reduced noise levels (as DNL), while one or two others may experience an increased probability of sleep disturbance being felt by overnight patients. The incremental changes between the DS and DN scenarios are, in most cases, within or beyond the range of spatially explicit predictive accuracy of the model.

Table 15-13 Predicted Number of Health Centres that Will Experience a Net Decrease or Increase in Noise Levels, as DNL

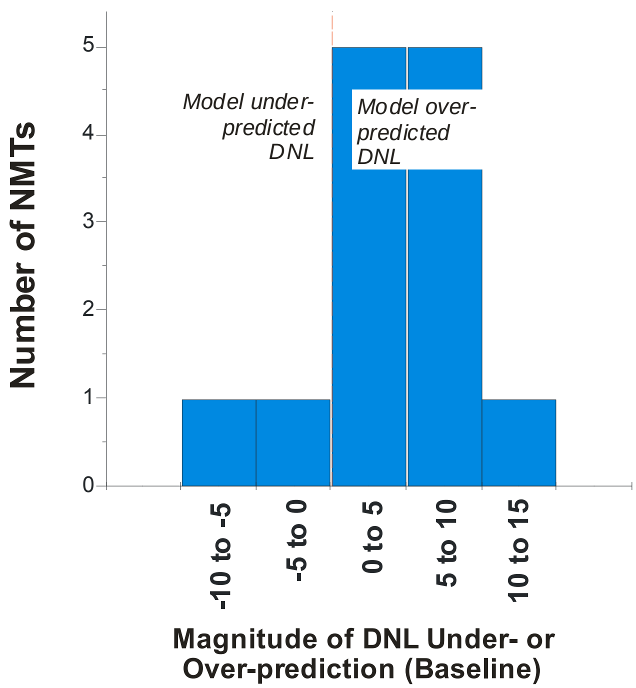
X = Noise Level Difference (dB)	DN vs. DS 2015	DN vs. DS 2025
-10 ≤ x < -5	0	3
-5 ≤ x < -3	3	1
-3 ≤ x < -1	2	1
-1 ≤ x < 0	0	0
x = 0	0	0
0 < x < 1	0	0
1 ≤ x < 3	0	1
3 ≤ x < 5	1	1

15.4.4 Uncertainty Analysis

Noise-related effects are complicated by individual variability in responses such as annoyance which can be significant. Furthermore, habituation of persons to recurring noise can result in disparate responses from a sensitivity and effects perspective. In some instances, chronic noise exposure will de-sensitize an individual to future exposures, while in other instances, the history of exposure can lead to a hyper-sensitization response. Noise-exposure and effects relationships tend to describe only the average response within a sub-population of interest.

Comparison of predicted noise levels from the INM modelling under baseline conditions with actual noise measurements collected from YYC's permanent NMTs suggests a strong bias toward over-prediction of noise exposure levels (Table 15-2).

Figure 15-6 INM Modelling for YYC Generally Over-Predicted 2015 and 2025 Noise Exposure Levels



A decrease in the actual noise exposures, such as measured by DNL, would result in a significant reduction in the number of individuals that would be concluded to be negatively affected by aircraft noise for both the DS and DN scenarios.

A second major factor that might have resulted in a general over-prediction of noise exposure levels is the fact that the aircraft movements and associated activity modelled was based on a day comprising the 90th percentile day for flight volume, in 2009, with air traffic through 2015 and 2025 further increased based on Transport Canada's growth projections for the YYC. By extension, air traffic volumes and hence noise exposure levels would be expected to be lower than presented herein for 9 out of every 10 days.

15.5 Traffic Noise

Chapter 10 of this Volume (Section 10.4.1.2) provides an assessment of noise and vibration health effects associated with predicted changes to traffic if the PRP proceeds. The planned expansion of YYC includes the closure of parts of Barlow Trail which runs to the north and east of the airport. The closure will cause traffic to be diverted onto 36 Street NE, Métis Trail and Deerfoot Trail. The approximate average daily (24-hour) weekday traffic flows along the relevant sections of Barlow Trail are 18,000 vehicles compared with 77,000 vehicles along Deerfoot Trail, and 25,000 and 32,000 along 36 Street NE and Métis Trail, respectively.

Health effects were assessed as the percent of increase or decrease in number of highly annoyed individuals estimated from the predicted $L_{Aeq,T}$ noise levels. The results show that the estimated change in traffic noise along Deerfoot Trail, Métis Trail and 36 Street NE is unlikely to exceed an increase of 1 dBA even if it is assumed that the increase in traffic has no effect on mean traffic speeds. It is therefore concluded that the closure of Barlow Trail, with the subsequent diversion of the majority of traffic it carries onto 36 Street NE, Métis Trail and Deerfoot Trail, will have a negligible noise effect on residents living alongside these highways.

15.6 Airport Ground Noise and Vibration

Chapter 10 of this Volume (Section 10.4.1.2) provides an assessment of noise and vibration effects expected to be associated with the PRP. Engine test run-up, mobile and fixed plant operations at YYC have the potential to generate low frequency noise and vibration. However, the separation distance between these sources and the nearest noise sensitive receptors beyond the YYC perimeter is typically over 1,000 m. As discussed in Chapter 10, the modelling of noise for the future scenarios with the parallel runway shows that the areas where low frequency noise induced vibration might arise for the future scenarios considered in this study are mainly non-residential districts. The exception is engine test run-up which is currently intermittently audible beyond the airport perimeter. The airport has identified a location where the engine run-up noise effects beyond the perimeter are minimized as far as is practicable and the development of the PRP will not alter that arrangement. Consequently, the PRP has a neutral effect in regard to the effect of engine run-up noise. As a separate project, the airport advised that they are investigating the provision of a purpose built noise attenuating pen within which to carry out engine test run ups. AECOM’s experience of such facilities at other airports is that they are capable of substantially reducing the noise effects caused by aircraft engine run-up

There are large separation distances between the ground sources of the vibration at YYC and vibration sensitive premises beyond the airport perimeter, i.e., over 1,000 m, for both DN and DS scenarios. Separation distance in combination with the rapid dissipation of vibration in the ground, makes it is very unlikely that perceptible vibration from YYC will be felt beyond the airport perimeter during either the construction or operational phases of the PRP.

15.7 Aircraft Emissions and Airport Air Quality Issues

The operation of aircraft and airports can result in the generation of the same kinds of airborne contaminants as are produced by many other forms of road transportation and urban combustion emissions. Less is known about existing emission levels associated with aircraft operations and ground vehicle support at YYC than is known about aircraft noise. Airport Cooperative Research Projects (ACRP) provides three recent reviews of aircraft and airborne air pollutants (ACRP 2008b, c, d). These reviews provide good background information and a current understanding of aircraft operations and their effects on air quality issues.

15.7.1 Scope of Emissions Effects Assessment

Air pollutants that can be generated at airports and by aircraft operations include particulate matter (PM), volatile organic compounds (VOCs), and other noxious compounds such as oxides of nitrogen (NO_x). As identified in Volume V, Item 10, Air Quality Baseline Report, the primary airborne pollutants of interest at YYC include the following:

- Total Suspended Particulates and particulate matter with a diameter of less than 10 microns (µm) (PM_{10}), particulate matter with a diameter of less than 2.5 µm ($PM_{2.5}$);
- VOCs, with a focus on benzene;
- Carbon Monoxide (CO);
- Nitrogen Dioxide (NO_2);

In addition, ozone (O_3) was measured as part of the baseline monitoring. O_3 was not actually assessed for the operational phase; rather, the ozone concentration was used to convert NO_x to NO_2 for predictive modelling of air quality (Ozone Limiting Method).

Potentially important sources of airport-related PM emissions include aircraft engines, auxiliary power units (APUs), ground support equipment, construction vehicles and their activity, ground access vehicles (e.g., passenger cars, delivery and freight trucks), and stationary equipment. Within the immediate vicinity of the runway, the largest emission sources for VOCs are aircraft engine operation during idling and taxiing. For areas peripheral to the airport, however, there is no single dominant source type for air pollutants, nor generalizable pattern of emissions-producing activity.

A large variety of combustion-related VOCs have been documented in aircraft emissions, in addition to benzene. For example, ACRP (2008c) assesses potentially important “hazardous air pollutants” (HAPs) that can be produced as a result of from aircraft operations. The HAP list includes acrolein (propenal), formaldehyde, 1,3-butadiene, naphthalene, acetaldehyde, ethylbenzene, and propanal (propionaldehyde). It should be noted that these types of HAPs are also produced from other internal combustion sources, including vehicular traffic.

When considering the above-listed HAPs and the larger suite of emitted HAPs, based on both relative emission rates and expected degree of human (mammalian) toxicity, benzene is among those assigned the highest priority. Therefore, benzene air quality data are considered to be a good surrogate for the determination of the health impact potential for the larger suite of HAPs. The concentration of naphthalene, another VOC and listed HAP, in air was also assessed.

The scope of this quantitative emissions health assessment was limited to an assessment of emissions resulting from identified sources at YYC during airport operation. The assessment specifically excludes PRP construction related emissions, which are discussed in detail in Chapter 12 of this Volume (Section 12.6.3.1).

Construction activities related to the PRP that have the potential to affect the local air quality which were assessed in Chapter 12 include the following:

- construction of and use of temporary facilities and construction staging areas;
- general earthworks for site preparation, construction, and landscaping;
- installation of site services; and
- paving of runway, taxiways, and aprons.

Possible effects on air quality and human health that could result from these construction related activities were assumed occur in the absence of further mitigative actions designed to reduce the negative impacts that were identified. The mitigative actions, Best Management Practices and remedies suggested to offset identified impacts to air quality related to construction activities resulting from project development are described in Chapter 12 of this Volume (Section 12.8).

The remainder of this section is focused on the health effects assessment for emissions associated with operational sources of airborne contaminants.

15.7.2 Emissions Effects Assessment

The Criteria Air Contaminants (CAC) included in the health effects assessment are listed in Table 1 of Volume V, Item 9, and are listed in Section 15.7.1 above. Various Canadian jurisdictions have provided ambient air quality objectives for these and other CACs. Ambient air quality objectives are set at airborne concentrations below the threshold concentrations that have been found to cause adverse effects on human health. This health assessment does not establish new thresholds of effects for airborne CAC concentrations. Rather, the assessment was based on the thresholds established by a large body of available epidemiological and toxicological information for each assessed substance. The ambient air quality objectives listed in Table 15-14 were used to predict whether humans might be adversely affected by changes in air quality associated with the PRP.

As stated in Section 2.6 of Volume V, Item 10, Air Quality Baseline Report, the threshold for the determination of significant adverse effects on air quality (and, in turn, on human health) is defined as follows:

- there are frequent or sustained exceedences of air quality criteria;
- the duration of the adverse effect is long term and high in magnitude;
- the effect on air quality will persist after the project is complete; or
- the social context is substantially affected by air emissions from project activities.

Table 15-14 Federal and Provincial Ambient Air Quality Criteria

Criterion Air Contaminant (CAC)	Averaging Time Period	Alberta[1]	Canada			
			Canada-Wide Standards (CWS)[2]	Ambient Air Quality Objectives[3]		
				Maximum Desirable	Maximum Acceptable	Maximum Tolerable
CO (μg/m^3)	1-hour	15,000	-	14,900	35,500	-
	8-hour	6,000	-	5,700	14,888	19,468
NO_2 (μg/m^3)	1-hour	400	-	-	400	1000
	24-hour	200	-	-	200	300
	Annual	60	-	60	100	-
PM_{10} (μg/m^3)	24-hour	50[4]	-	-	-	-
$PM_{2.5}$ (μg/m^3)	24-hour	30	30	-	-	-
Benzene (μg/m^3)	1-hour	30	-	-	-	-
Naphthalene (μg/m^3)	24-hour	22.5[4]	-	-	-	-

Notes:

(1) Alberta Environment (June 2009), Air Quality Objectives and Standards.
(2) CCME (2000), Canadian Wide Standards.
(3) Government of Canada (2004), National Ambient Air Quality Objectives.
(4) There is no PM_{10} guideline for Alberta, the guideline from British Columbia is used for reference. (Air Quality Objectives and Standards, British Columbia, Ministry of Environment 1995.)
(5) Ambient Air Quality Criteria developed by the Ontario Ministry of the Environment.

15.7.3 Emissions Exposure Assessment

15.7.3.1 Baseline Air Emissions Exposure Levels

The baseline air quality conditions in Calgary, and around YYC, are discussed in Volume V, Item 10 Air Quality Baseline Report*.* Air quality has been selected as a VC because of its intrinsic importance to the health and well-being of humans and other important receptors. Baseline data provide important contextual information for possible changes to air quality that might occur either during construction of the PRP, or in the post-construction operational phase, in association with altered emission patterns and magnitudes derived from aircraft, mobile ground sources (e.g., service vehicles), or stationary ground sources.

The baseline air quality data were used to develop, validate and improve the accuracy of the predictive air emissions models used.

Existing air quality monitoring data exist for three general locations within the larger Calgary area [Calgary Regional Area Zone (CRAZ) data]: Calgary Northwest, Calgary Central, and Calgary Southeast. In addition, data were collected from two air quality monitoring stations supported by the Authority: one on-site and one off-site. Recent baseline data are available for CO, O_3, NO_2, $PM_{2.5}$, PM_{10}, and various VOCs from these five monitoring locations and these data were used to complete the baseline assessments for the YYC.

Based on an assessment of the available data, the ambient air quality data measured around the LSA was considered to be within a typical range of for an urban neighbourhood. Monitoring data for CO, NO_2, sulphur dioxide (SO_2), and VOCs were below the Alberta air quality criteria. However, CO, NO_2, O_3, $PM_{2.5}$, and PM_{10} occasionally exceeded the air criteria. Despite these exceedences, the 90th percentile for all data were below the Alberta air criteria target concentrations. The average and 90th percentile concentration was markedly lower at the YYC on-site and off-site monitoring stations than the CRAZ Calgary Central or Calgary Southeast stations for CO; however, naphthalene concentrations (1-h average) at the on-site and off-site stations were generally higher than at the Calgary Central CRAZ station.

In addition to the ambient air monitoring, the National Pollutant Release Inventory (NPRI) provides supplementary information that was incorporated into the baseline PRP assessment. The NPRI emissions inventory for CAC emissions for all sources in Alberta indicates that PM emissions are largely contributed by what are termed open sources. Open sources for PM emissions include agriculture, construction activities, landfill sites, mine tailings, paved and unpaved roads, forest fires, and prescribed burning. According to the NRPI, NO_2, and VOC emissions in Alberta are mainly contributed from industrial sources, while CO emissions are largely due to transportation sources.

15.7.3.2 Predicted Air Emissions Exposure Levels

Construction phase effects predicted for the PRP on air quality were qualitatively assessed and typical mitigation measures designed to negate or minimize those effects for the construction phase were discussed in Volume III, Chapter 12.. Therefore, no formal quantitative health assessment was completed.

The operational phase of the PRP was quantitatively assessed using emission inventory calculations along with appropriate air dispersion models. The dispersion model for the operational phase considered all significant sources of emissions to air. The modelling and the emissions inventory was completed for the same four scenarios detailed in Section 15.4.2.1 of this Chapter.

Predicted air quality levels are, therefore, provided in Chapter 12 of this volume for each CAC and for each of the four scenarios. Outputs from the dispersion models are provided in Chapter 12, in the form of airborne contaminant concentrations plots.

The modelled air quality for each of the four scenarios was based on the following:

- **Expected CAC emissions rate for each of 19 different groups of aircraft**, based in part on engine type and aircraft size (Volume V, Item 9, Table 6).
- **Expected number of aircraft movements** for each of the 19 different groups associated with the various aprons and concourses, while on ground and movements in the air, including takeoffs and landings (Volume V, Item 9, Tables 7 and 8). Emissions are estimated from the entire Landing-Takeoff (LTO cycle), which includes the approach, taxi in, start-up after unloading/loading, taxi out, takeoff, and climb out. Fuel consumption varies over the LTO cycle. Air emissions can be predicted from relative and total fuel consumption.
- **Modelling of aircraft movement sequencing** (Volume IV): Delays in taxiing and departure delays associated with airport capacity will affect various parts of the LTO cycle, and hence, the expected air emissions (and fuel consumption) for each aircraft type through a projected LTO cycle. Modelling of airspace and airside sequencing under each of the four future scenarios (2015 vs. 2025; DN vs. DS).
- **Estimated emissions from ground support equipment**.
- **Estimated emissions from Auxiliary Power Units (APUs):** APUs are mostly on-board small jet engine generators that provide electrical poser to the aircraft while is engines are shut down. Normally, pilots start the on-board APU while taxiing to the gate but, mostly, it is started when the aircraft reaches the gate. As APUs are onboard aircraft, they are modelled based on an aircraft's activity.
- **Estimated emissions from stationary sources** including power generation plants, and aircraft de-icing and anti-icing areas.
- **Estimated emissions from road traffic vehicles and parking**: annual travelled distance and traffic volume were determined for traffic within the airport area and included the following roads: Aero Drive, Aero Gate, 64 Avenue NE, 11 Street NE, Airport Trail, Barlow Trail, Aviation Boulevard, and McCall Drive. Road traffic allocations from road closures and vehicle routing changes were considered to estimate potential air quality effects for the proposed scenarios. The road traffic emission calculations considered the length of the road, the vehicle speed and the number of vehicles on the roads.
- **Meteorological Data**: Data for the quantitative assessment was obtained from meteorological stations, which would best represent the conditions for the region of the project. Raw meteorological (MET) data was obtained from the on-site meteorological station from Environment Canada (EC). One-year of site specific meteorological data was used for estimation of surface wind parameters.
- **Terrain Data**: Terrain information is required for airborne contaminant dispersion modelling. Terrain data was based on the Canadian digital elevation data (CDED). These data were obtained from the Geobase Canada website (http://www.geobase.ca). Geobase Canada provides the terrain data in USGS DEM files for a 1:50,000 and a 1:250,000 map scale (NAD83). The appropriate region was selected based on the UTM coordinates of the PRP site.

Hourly emission rate files were developed for each source. The hourly emission files were then used as a key input for dispersion modelling. AERMOD was selected as the preferred model for this assessment. AERMOD is a steady-state Gaussian plume dispersion model which incorporates terrain algorithms, meteorology and building downwash effects on air concentrations. Air dispersion modelling requirements in Alberta are outlined in the Air Quality Model Guideline (May 2009) by the Government of Alberta. One of the regulatory approved dispersion models in Alberta is AERMOD. Furthermore, the FAA recognizes AERMOD as the preferred model to use with the Emissions and Dispersion Modelling System (EDMS).

Dispersion models were used to simulate how emission sources influence concentrations of substances during specified meteorological conditions for the associated terrain in the LSA. The predicted emission rates and dispersion modelling files were calculated based on the 90th percentile busiest operating day. In reality, the actual operations will vary from hour to hour and day to day, and actual annual operations will be less than those used in this study, thus providing a conservative estimate of air quality receptor grids. These receptor grids are required to define the locations within the LSA where the maximum emission effects of the PRP are expected. As such, the modelled concentrations of CACs were predicted by AERMOD using an array of receptors. The cartesian receptor grids were developed to capture the change of regional topography in the study area. The modeled receptor grid was based on the following spacing and distances:

- 250 m spaced receptors within 2 km from the YYC boundary; and
- 500 m spaced receptors within 5 km from the YYC boundary.

In addition, 20 m spaced receptors were placed along the YYC property line as a distinction of the boundary with ambient air and restricted public access.

Predicted airborne contaminant levels at breathing height were based on the sum of the maximum predicted ground level concentrations and the background ambient concentrations for comparison with the ambient air quality criteria in Table 15-11. The off-site air monitoring site was selected to represent typical urban community background concentrations near the project area. It should be noted that the background concentrations for each parameter presented in the tables below reflect the average values from the six month monitoring program (from July 2009 to February 2010) carried out at the off-site air monitoring station.

Table 15-15 presents predicted maximum ground-level (breathing zone) exposure concentrations beyond the YYC property for 2015 DS or DN scenarios.

Table 15-15 Maximum Predicted Airborne Contaminant Concentrations for 2015 DN and 2015 DS Scenarios

			2015 DN Scenario			2015 DS Scenario		
Contaminant	**Averaging Period**	**AENV AAAQO[1]**	**Maximum Predicted Conc.[2]**	**Estimated Background Conc.[3]**	**Total Maximum Conc.**	**Maximum Predicted Conc.[2]**	**Estimated Background Conc.[3]**	**Total Maximum Conc.**
		($\mu g/m^3$)						
Benzene	1-Hour	**30**	7.5	2.6	**10.1**	5.7	2.6	**8.3**
CO	1-Hour	**15,000**	4,545	225.5	**4,771**	3,084	226	**3,310**
	8-Hour	**6,000**	2,479	223.1	**2,703**	1,829.0	223	**2,052**
Naphthalene	24-Hour	**22.5[4]**	0.3	0.3	**0.6**	0.4	0.3	**0.7**
NO_2	1-Hour	**400**	450	34.4	**484**	352	34.4	**386**
	24-Hour	**200**	125	36.4	**161**	85.3	36.4	**122**
	Annual	**60**	47.7	36.4	**84.1**	26.6	36.4	**63.0**
$PM_{2.5}$	24-Hour	**30**	3.7	6.7	**10.4**	3.8	6.7	**10.5**
PM_{10}	24-Hour	**50[5]**	4.6	24.0	**28.6**	4.5	24.0	**28.5**

Notes:

(1) Alberta Ambient Air Quality Objectives and Guidelines (Alberta Environment June 2009). The 1-hour maximum concentrations exclude the eight highest 1-hour predictions, as per Alberta air quality model guideline (AENV 2009) for comparison with AAAQO.

(2) These predicted concentrations exclude the area inside the project boundary.

(3) There is no PM_{10} guideline for Alberta, the guideline from British Columbia is used for reference. (Air Quality Objectives and Standards, British Columbia, Ministry of Environment 1995.)

(4) There is no naphthalene guideline for Alberta; the guideline from the Ministry of Ontario is used as a reference (MOE 2008).

(5) The background concentrations are obtained from the six month monitoring program carried out at the off-site air monitoring station.

An important conclusion from the 2015 predictions is that airborne contaminant concentrations are expected to be higher under the DN scenario compared to the DS scenario. This is attributed to the fact that construction of the PRP would limit operational bottlenecks that are predicted to result in increased aircraft cueing and wait times during taxiing, takeoff and landing. Such factors would all lead to an increase in emissions. During peak periods, aircraft spend a longer period on taxiways prior to takeoff, and this will result in greater operating times of aircraft engines and greater fuel consumption. Construction of the PRP will directly reduce the length of periods when aircraft and associated ground service operations are constrained by limitations in the ability of the airport to handle air traffic.

As can be seen from Table 15-15, maximum predicted breathing height exposure levels are not predicted to exceed relevant ambient air quality objectives in 2015 either with or without completion of the PRP for any CAC except NO_2 (1-hour averaging period). This is discussed in more detail below.

Table 15-16 provides summary predictions for the 2025 period. As for 2015, it is predicted that maximum airborne exposure levels would be improved for the completion of the PRP in comparison with the DN scenario. A slight increase in airborne concentrations of CAC is predicted between 2015 and 2025 under both scenarios; however, no maximum predicted CAC exposure level off-site exceeds its respective Alberta Environment ambient air quality objective, with the exception of NO_2.

Table 15-16 Maximum Predicted Airborne Contaminant Concentrations for 2025 DN and 2025 DS

			2025 DN Scenario			2025 DS Scenario		
Contaminant	**Averaging Period**	**AENV AAAQO[1]**	**Maximum Predicted Conc.[2]**	**Estimated Background Conc.[3]**	**Total Maximum Conc.**	**Maximum Predicted Conc.[2]**	**Estimated Background Conc.[3]**	**Total Maximum Conc.**
		($\mu g/m^3$)						
Benzene	1-Hour	**30**	8.0	2.6	10.6	6.3	2.6	8.9
CO	1-Hour	**15,000**	4,650	226	4,876	3,631	226	3,857
	8-Hour	**6,000**	2,530	223	2,753	1,904	223	2,127
Naphthalene	24-Hour	**22.5[4]**	0.4	0.3	0.7	0.3	0.3	0.6
NO_2	1-Hour	**400**	687	34.4	721	519	34.4	553
	24-Hour	**200**	137	36.4	173	118	36.4	154
	Annual	**60**	50.1	36.4	86.5	28.1	36.4	64.5
$PM_{2.5}$	24-Hour	**30**	3.9	6.7	10.6	4.8	6.7	11.5
PM_{10}	24-Hour	**50[5]**	4.7	24.0	28.7	5.0	24.0	29.0

Notes:

(1) Alberta Ambient Air Quality Objectives and Guidelines (Alberta Environment June 2009). The 1-hour maximum concentrations exclude the eight highest 1-hour predictions, as per Alberta air quality model guideline (AENV 2009) for comparison with AAAQO.

(2) These predicted concentrations exclude the area inside the project boundary.

(3) There is no PM_{10} guideline for Alberta, the guideline from British Columbia is used for reference. (Air Quality Objectives and Standards, British Columbia, Ministry of Environment 1995.)

(4) There is no naphthalene guideline for Alberta; the guideline from the Ministry of Ontario is used as a reference (MOE 2008).

(5) The background concentrations are obtained from the six month monitoring program carried out at the off-site air monitoring station.

For NO_2, the predicted maximum 24-h off-site concentration at breathing zone height was lower than the Alberta Environment ambient air quality objectives for all modelled scenarios and years. The 1-hour maximum predicted concentrations, however, exceed the 1-hour air criterion of 400 $\mu g/m^3$ for both DN and DS scenarios. The frequency of predicted exceedences (1-h) for the 90^{th} percentile busy day under a range of meteorological conditions was very low; i.e.:

- 2015 DN scenario: 3.8%;
- 2015 DS scenario: 0% (no exceedences);
- 2025 DN scenario: 10.2%; and
- 2025 DS scenario: 7.5%.

The maximum annual predicted NO_2 concentrations exceed the annual air criterion of 60 µg/m³ for both DN and DS scenarios. The frequency of predicted exceedences for the 90th percentile busy day over the one year assessed under a range of meteorological conditions was, however, very low; as shown below:

- 2015 DN scenario: 0.5%;
- 2015 DS scenario: 0.1%;
- 2025 DN scenario: 0.7%; and
- 2025 DS scenario: 0.1%.

These frequency estimates for concentration exceedences predicted for NO_2 do not take into account inter-annual variability. Therefore, predicted exceedences of the NO_2 annual air criterion, while of very short duration and highly limited spatially, might occur with a slightly higher or lower frequency across different years.

Also, the exceedences were localized at the project boundary and dissipated quickly within less than 400 m (Volume III, Chapter 12, Figures 5 to 16). In light of this, it is expected that (i) NO_2 levels in surface air beyond the airport property will be slightly lower if the PRP is completed than if not completed; and (ii) the maximum predicted concentrations for all of the parameters are localized to the project boundary and are expected to have a very low impact on the neighbouring communities such as Martindale.

NO_2 can directly affect humans by acting as an irritant of the mucosa of the eyes, nose, throat, and respiratory tract. More profound effects such as the development of pulmonary edema and diffuse lung injury is thought to occur only at very high doses; for example, inhaled levels associated with a building fire. Lower level NO_2 exposure has been associated with increased bronchial irritation in some asthmatics, an increased incidence of respiratory infections in young children, and decreased lung function in people with chronic obstructive pulmonary disease.

15.7.4 Emissions Risk Characterization

The detailed evaluation of emissions predictions for the years 2015 and 2025, for both DN and DS scenarios, is provided in Chapter 12 of this volume. Health effects are plausible for NO_2 to the extent that predicted airborne exposure levels (Section 15.7.3.2) exceed risk-based thresholds of health effects. For the purpose of this assessment, it is assumed that the Alberta Environment and other ambient air quality objectives tabulated above would be adequately protective of human health.

The air emission modelling demonstrates that for all CACs other than NO_2, the maximum predicted exposure concentration beyond YYC lands would not exceed Alberta's ambient air quality objectives. Therefore, health risks from all assessed CACs except NO_2 are concluded to be acceptably low. In addition, maximum exposure concentrations for all CACs are predicted to be higher in both 2015 and 2025 without construction of the PRP than with its completion.

Similarly, it was concluded that completion of the PRP will not increase human exposure levels to NO_2 in the areas surrounding YYC lands relative to the DN scenario. In fact, completion of the PRP is predicted to decrease the overall amount of airborne and ground-source CAC emissions as a result of reductions to aircraft wait times for taxiing, landing and takeoff when the PRP becomes operational.

In spite of the fact that the PRP is not predicted to adversely affect air quality and associated human health outcomes from a comparative perspective, the predictions regarding maximum NO_2 levels merit further discussion. This is especially important since the predicted maximum NO_2 levels associated with aircraft emissions and related sources far exceed estimated background concentrations by 13- to 20-fold. An important question, therefore, is whether the predicted maximum exposure estimates or effects thresholds as promulgated in the Alberta Environment ambient air quality objectives are adequately accurate.

Brauer et al (2002) prepared a Review of the Health Risks Associated with Nitrogen Dioxide and Sulphur Dioxide in Indoor Air, on behalf of HC. These authors discuss the available epidemiological evidence for establishment of a Lowest Observed Adverse Effects Level (LOAEL). In particular, Brauer et al note:

> *"Neas et al (1991) report that a 15 ppb increase in long-term NO_2 exposure associated with a 40% increase in the increased cumulative incidence of lower respiratory symptoms (shortness of breath, wheeze, chronic cough, chronic phlegm, bronchitis). Based on this relationship, the results of other studies reporting associations between long term exposure to NO_2 and similar lower respiratory symptoms in children, and supported by acute impacts observed in controlled exposure studies, a LOAEL for chronic exposures of 25 ppb (47 µg/m^3) is recommended. This value is based upon the increased indoor NO_2 concentrations associated with major indoor sources for which health effects have been observed in epidemiological studies...*
>
> *... This LOAEL is somewhat lower than... ...the North American outdoor air standard (the U.S. National Ambient Air Quality Standard and the Canadian Maximum Acceptable Air Quality Guideline), an annual mean of 53 ppb (100 µg/m^3)."*

A chronic exposure threshold of 47 µg/m^3 is similar to but slight lower than the Alberta Environment ambient air quality objective referenced in this health assessment. The proposed LOAEL value is based on actual epidemiological data without the further addition of safety (or uncertainty) factors. The Alberta Environment ambient air quality objective for NO_2 (annual) is, therefore, concluded to provide a reasonably accurate threshold of chronic effects. Similarly, Brauer et al (2002) propose an acute LOAEL for NO_2 based on the epidemiological evidence in the range of 200 µg/m^3, which is approximately one half the Alberta Environment and Canadian 1-h acceptable concentration.

The maximum predicted airborne concentrations of NO_2 at breathing zone height were in the following range for all four modelled scenarios:

- 1-hour: 386 – 721 µg/m^3;
- 24-hour: 122 – 173 µg/m^3; and
- Annual: 63 – 87 µg/m^3.

There was only a small incremental change in predicted maximum NO_2 levels between 2015 and 2025 for the DN scenario. The rate of change, if adequately predicted, should be similar to or greater than the change from recent (2009) baseline conditions, as captured in the baseline monitoring data (Volume V, Item 10) to 2015. In particular, the on-site and off-site YYC air quality monitoring stations should reflect NO_2 levels similar to the maximum predicted off-site concentrations, allowing for some minor increase in air traffic and associated activities on the 90th percentile busy day. The average and maximum 1-hour and 24-hour NO_2 concentrations measured at these two sites is summarized below:

	1-hour average	1-hour maximum	24-hour average	24-hour maximum
On-Site Station	36 μg/m^3	167 μg/m^3	37 μg/m^3	118 μg/m^3
Off-Site Station	34 μg/m^3	165 μg/m^3	36 μg/m^3	105 μg/m^3

These results reflect the combined effects of background and YYC emissions sources, as do the predicted maximum NO_2 concentrations. In comparing the baseline monitoring data for NO_2 with the predicted maximum off-site NO_2 exposure concentrations, it is clear that especially the 1-hour averaged levels of 2015 and 2025 are over-predicted by the modelling efforts. The 24-h predicted results are more in line with the baseline data.

While risks to residents immediately beyond YYC lands associated with NO_2 are likely to be acceptably low, the measured and predicted concentrations may nonetheless support the need for follow-up to verify that airport-related emissions, including aircraft emissions do not result in concentrations of airborne NO_2 that exceed thresholds of effects for chronic or acute exposure. If required, verification could be by further modeling based on actual operations or by monitoring.

15.7.5 Emissions Effects Assessment – Uncertainty Analysis

The conclusions regarding health risks associated with PRP air quality issues depend on the accuracy of specific inputs and the assumptions used. Assumptions regarding air traffic volume and the associated ground traffic volume emissions were modelled assuming the 90th percentile day for air traffic volume, further projected to 2015 and 2025 using growth projections provided by TC (Volume III, Chapter 12). As stated in Section 15.4.2.2, changing the runway utilization would change the distribution of noise in communities surrounding YYC and could possibly change the results of the assessment. This would tend to over-estimate airborne contaminant concentrations relative to the true case. The over-conservatism associated with modelling the 90th percentile day for air traffic volume might account for the probable over-prediction of NO_2 maximum concentrations as discussed above. There was less apparent discrepancy between baseline data for the off-site monitoring location and predicted maximum concentrations for CO and benzene as a representative VOC. $PM_{2.5}$ maximum exposure concentrations, however, appear to be slightly under-predicted relative to the 24-h off-site baseline monitoring data, perhaps by a factor of 3, as were PM_{10} 24-h off-site levels. As for NO_2, therefore, fine particulate matter merits additional follow-up study is spite of the absence of any evidence for project-related effects.

15.8 Chemicals Use and Associated Issues

Three major types of chemical use at YYC merit further analysis as follows:

- **Aircraft and runway de-icing agents**, including glycols and other chemicals that may occur in "add-paks" and then be released to the environment during aircraft de-icing;
- **Use of herbicides to control noxious weeds**, the nature of vegetation growing around runways and taxi-ways, and hence, important safety issues related to reductions in incidence such as bird strikes; and,
- **Solvent use for aircraft tire rubber removal** in touch down areas.

Each of these chemical use related issues is discussed in more detail below, especially with regard to possible human health or ecological effects. For all three categories of chemicals, it is important to note that direct human exposure to potential individuals other than those occupationally engaged in their application would not occur, since the areas of application are closed to the public. The problem formulation for chemical exposures, therefore, includes a simplification of the types of exposure pathways and effects that are plausible. The issues that merit further consideration revolve almost entirely around the entry of chemicals used on YYC lands into surface and groundwater, followed by off-site transport. In the case of stormwater runoff, there is a small possibility that chemicals could be transported along stormwater collection and discharge pathways enroute to areas where freshwater life or wildlife such as ducks could be exposed. Both groundwater and stormwater flow from the YYC and the PRP is towards Nose Creek.

The risks to aquatic life or other biota in or enroute to Nose Creek are expected to depend on the following:

- amount of chemical used;
- spatial extent of application area;
- timing of application relative to larger precipitation events (rainfall, snowmelt);
- extent of infiltration versus runoff;
- degree of retention of residues on soils or sediments versus amount mobilized in groundwater or stormwater;
- rate of breakdown via microbial biodegradation, photolysis, volatilization or other processes;
- water (and contaminant) transport velocities toward surface water bodies that provide important habitat and foraging opportunities;
- quality and characteristics of the receiving environment into which the runoff discharges; and
- toxicological sensitivity of valued aquatic ecosystem components within the receiving environment.

The Authority has an operational goal of minimizing the use of chemicals at the airport, which is balanced with safety considerations (personal communication Gary Kindrat March 2010).

Groundwater quantity and quality effects of the PRP are assessed in Chapter 7 of this Volume. Section 7.4.3.2 states that groundwater recharged in the LSA is expected to move slowly downward and laterally to the southwest and eventually discharge into Nose Creek. Any contamination from runway operation that infiltrates the ground in the LSA will not move rapidly due to the low permeability of the clay till and underlying claystone bedrock. The average linear lateral groundwater flow velocity in the fractured claystone was calculated to be about 0.5 m/yr. The distance from the LSA to Nose Creek is 3 km; therefore, the groundwater travel time to Nose Creek is estimated to be about 600 years. During this long travel path, natural renovation processes in the subsurface will reduce and attenuate any potential contaminant concentrations.

Surface water quantity and quality issues are discussed in Chapter 5 of this Volume. A stormwater drainage management plan for the existing YYC and proposed PRP areas was developed in 2000 and updated in 2003. The plan is currently being updated to incorporate all development on YYC lands. There exists stormwater retention ponds associated with most of the stormwater outlets exiting YYC property. Associated with each pond is a control gate at the outlet that can be used to regulate the discharge rate of treated stormwater from the pond to YYC property if necessary or if required to satisfy water quality objectives. Monthly monitoring is conducted by YYC at all stormwater exit points from YYC property. All water quality data are compared to established water quality objectives outlined by EC (1976), CEPA (1994), and CCME (1994). The treated stormwater discharges into Nose Creek after release from the retention ponds.

15.8.1 Aircraft and Runway De-icers

Construction of centralized de-icing facilities and rationalization of de-icing technologies and practices into the future are being formally addressed as a separate project from the PRP. Nonetheless, minor amounts of de-icing fluids used on aircraft may remain after the aircraft has departed the formally defined de-icing area, with some potential for minor releases on the newly constructed PRP and its taxiways.

In addition, the Authority applies limited quantities of de-icing agents on runways and taxiways during cold weather periods for safety reasons. Runway de-icing agents that have been used at YYC include potassium acetate and sodium formate. Road salts (sodium chloride) are not used on runways as a result of their very high potential to accelerate aircraft corrosion.

The Canadian Council of Ministers of the Environment (CCME 2007) recently published a review of the environmental fate and effects of propylene glycol, which is the major constituent of air-craft de-icing fluids, along with ethylene glycol (EG), which is used mainly at Canadian airports. Propylene glycol (PG) is readily biodegraded in the environment by microbiological and other biological processes. In fact, the ease with which PG is degraded to simple carbon dioxide and water accounts for its primary environmental effects: Rapid biodegradation results in a very high biochemical oxygen demand (BOD) in groundwater or surface water contaminated with PG, and an associated reduction in the dissolved oxygen levels in these receiving waters. While this can be a serious problem if PG is discharged directly into surface water bodies that contain aquatic life, introduction to stormwater or groundwater that has ample opportunity to become re-oxygenated prior to entry into aquatic receiving environments, either through re-oxygenation or mixing with higher redox water masses along the flow path, would result in minimal to negligible effects. The expected fate and effects of EG are similar to PG. A key difference between EG and PG is that EG, if consumed by mammals such as domestic animals can result in acute toxicity, while PG is virtually non-toxic to humans and other mammals.

YYC has adopted a Glycol Mitigation Plan, developed through AAC/ATAC, with the majority of airline companies that use YYC as active participants. The Plan for 2007 indicates that the anticipated period in which de-icing could occur between 1 September and 31 May, a duration of 227 days. Anticipated use rates in 2007 were as follows:

- Type 1 – ethylene based: 1,200,000 L
- Type 4 – ethylene based: 300,000 L

- Estimated volumes used on Apron VII:
  - Type 1 – Propylene based: 30,000 L
  - Type 4 – Propylene based: 8,000 L.

The Plan specifies areas where de-icing can take place and especially the procedures used to minimize excess use, and recover spilled and other de-icing fluids that ends up on the ramp. All de-icing crews are instructed to use only the amount of glycol required to comply with CARS 602.11 to clean critical flight control surfaces (i.e., no unnecessary spraying of fluid). YYC enlists a fleet of Glycol Recovery Vehicles and vacuum recovery equipment to recover to the extent possible any over-spray and runoff of de-icing fluids before they reach the pad drainage system. When remote de-icing operations are conducted, the Plan requires that operators close the storm drain valve prior to commencement, and communicate with the De-icing Coordinator. Accurate records are maintained of storm valve closures, amount of de-icing fluid applied, and volume recovered.

The apron drainage system directs all water runoff from the apron to the Northern Retention Pond System, which is engineered to allow for control of outflows (thus preventing discharge until such time as water quality objectives are met), to allow for aeration to aid treatment and reduce BOD, and finally to allow for a sanitary sewer diversion system. Waters with residual glycol are released to receiving waters only after total glycol levels are less than 100 mg/L (per CEPA) and BOD is less than 20 mg/L per federal and provincial stormwater discharge guidelines.

Potassium acetate and sodium formate are used sparingly on the runways themselves. Recently, there was a shift at YYC from a urea based de-icer to potassium acetate and sodium formate. This was an aviation wide initiative intended to address the effects urea de-icers were having on surface water quality.

As for PG, the acetate ion and formate ion in runway de-icers are readily biodegraded in surface soils and in shallow subsurface environments, especially under aerobic conditions. Both acetate and formate are readily metabolized by various bacteria as their sole source of carbon. The quantities of sodium and potassium associated with the runway de-icer application could result in alteration of the ratios of major cations sorbed to soils within the area of runoff and infiltration. Through cation exchange processes, runoff of sodium and potassium cations could displace other naturally occurring cations from the surfaces of soil particles, including calcium and magnesium. In the case of potassium, no known adverse effects on soil properties or ability to support vegetation would be expected except at very high concentrations. In the case of sodium, displacement of ions such as calcium and magnesium by sodium can result in the development of sodic soils if the soils contain appreciable amounts of some types of clay. Sodic clay soils exhibit increased hydration within the microenvironment around individual clay particles, accompanied by swelling and occlusion of pore spaces between the particles. This, in turn, results in a highly reduced ability of sodic soils to infiltrate snow melt or rainwater, and to support vegetation growth. Loading of sodium ions to soils can, therefore, lead to sodic soils depending on the loading rates relative to flushing rates as re-supply of other cations that are contributed from the soil matrix by means of natural weathering processes. Sodic soils can result in decreased vigour of vegetation growth.

The runoff of sodium formate from the parallel runway could result in an incremental increase in sodium loading to soils that are situated adjacent to the runway. This is not predicted to result in a significant impact, however, for several important reasons:

- Many areas around Calgary are naturally salinized and it is common to observed salinization of surface soils, as well as soil sodicity, especially in areas where subsurface salt ions are re-supplied to the surface through groundwater discharge alongside slopes and into impoundments, or via capillary rise of salinized groundwater. The amount of sodium or potassium introduced in runway de-icers is very small in relation to the mass of sodium (or potassium) that may be present in naturally salinized soils.
- Even if soil sodicity were to develop in association with increased runway de-icer use as a result of completion of the PRP, the resulting effects on vegetation would not comprise an appreciable loss in productivity from an ecosystem functioning perspective or agronomic perspective. Vegetation in the vicinity of the runways and taxiways is managed (e.g., through use of broadleaf herbicides) to limit the viability of larger plant species with higher biomass or rates of primary productivity. If a decrease in plant productivity were occurring as a result of localized soil salinization, this would not materially impair any valued function on these lands.
- If the lands and soils were converted to other more agriculturally productive uses in the future, localized sodicity and salinization can be remedied through proven techniques, developed to address soil salinization issues over large areas of otherwise agronomically productive lands worldwide.

The available data (Volume V, Item 3, Surface Water and Aquatic Resources) suggest that use of these chemicals has not caused an impact to water resources or failure to comply with surface water quality objectives at YYC based on existing stormwater monitoring program chemical measurements. No deterioration to existing stormwater quality is anticipated to occur i as a result of the new PRP. This impact prediction is based on the very rapid rates of biodegradation of the organic constituents (PG, formate, acetate) and tendency of associated cations to remain sorbed to soils close to the point of release into the environment.

15.8.2 Herbicide Use

Herbicide use at YYC and at many international airports is important for at least two reasons. First, the control of vegetation to preclude taller-growing vegetation varieties limits the habitat value of the areas surrounding the runways and taxiways for nesting, burrowing, foraging, and other focused wildlife activities. It is important that wildlife in the region, and especially various bird species, are encouraged to use habitat in areas farther away from areas of intense aircraft operations, for the protection of both humans and the wildlife themselves. Vegetation cannot be allowed to exceed a certain height around runways and taxiways, since this would impair safe operations by obstructing the views of airside traffic signage. Second, herbicide use is one means for limiting the presence of invasive weed species (Canada thistle, knapweed, others), and presence of a seed supply that could otherwise encourage their spread to adjacent lands.

The Authority currently uses mechanical control techniques primarily to control unwanted vegetation. A limited number of herbicides such as Tordon 101 are used to control the growth of noxious weeds and other vegetation on lands surrounding the airfields and taxiways. No records are available regarding pesticide use at YYC prior to 2003. In 2003, the Authority contracted an agricultural spray applicator to treat 434 ha with Tordon 101. This helped resolve an issue with noxious weeds including thistles and dandelions. The application was effective in substantially reducing dandelion growth for about five years. A follow-up application of Tordon 101 was completed in 2004 using the same contractor which treated approximately 250 ha with the herbicide. In each of 2005 and 2006, approximately 80 ha were treated with herbicide. These were areas that have limited access for routine mowing as a result of air traffic (e.g., under glide slopes). In 2007, approximately 40 ha were treated with herbicide by the Authority. In 2008, approximately 12 ha were sprayed with herbicide to control Hoary Cress at the threshold.

Since 2003, the area treated annually with herbicide has declined along with the volume of herbicide used. The major driver for this has been utilization of alternative techniques for noxious weed management, such as spot spraying with hand held applicators, use of a truck mounted boom sprayer, hand pulling, and mechanical mowing.

Over the last eight years or so, the Authority has used an average of 450 L/y of herbicides, including planned use for the summer of 2010. An approximate breakdown through this period of different herbicides is as follows (personal communication Gary Kindrat, YYC):

- Tordon 101: 2,980 L;
- Lontrel 300: 400 L;
- Round Up Weather Max: 20 L (used only to control vegetation around signs and lights for ease of mowing and light repair); and
- Transline/Killex: 200 L.

The Authority uses herbicides in a manner that is entirely consistent with requirements from the Canadian and provincial regulating bodies. It is expected that regulatory controls and application guidelines are adequate to prevent environmental and health risks.

HC's Pest Management Regulatory Agency (PMRA) completed a major review of Picloram, an active ingredient in Tordon 101, in 2009 (http://www.hc-sc.gc.ca/cps-spc/alt_formats/pacrb-dgapcr/pdf/pubs/pest/decisions/rvd-drv/rvd2009-02-eng.pdf). Tordon 101 is manufactured and sold by Dow AgroSciences specifically for "control of broadleaf weeds and woody plants in rangeland, permanent pasture, industrial and other non-crop areas of Canada". In Canada, Tordon 101 is registered under the *Pest Control Products Act.* The active ingredient in Tordon 101 goes by the trade name "Aminopyralid" (Picloram and 2,4-D), which promotes uncontrolled growth in broadleaf plants and subsequent death. Because the active ingredient affects both terrestrial and aquatic broadleaf plants, it is important to leave riparian buffer strips when applying. Recommended non-application strips for Tordon-101 are relatively narrow. According to the manufacture's instructions, no more that 0.5 L/ha should be applied annually, which is close to the recommended application rate for various weed species.

The major ingredient in Killex is 2,4-D. The active ingredient in Lontrel 300 is Clopyralid, present as a triisopropylamine salt. The major active ingredient in Round Up Weather Max is Glyphosate.

It should be noted that very few agencies that apply Tordon 101 or other herbicides evaluate concentrations of various residuals in soil, surface runoff or groundwater. Rather, it is routinely assumed that adherence to application guidelines will protect the environment and human health (including that of the applicators).

Estimated degradation rates of the herbicides used, once released to the environment are as follows:

- Picloram (aminopyralid: 4-amino-3,6-dichlorpyridine-2-carboxylic acid) (http://www.epa.gov/opprd001/factsheets/aminopyralid.pdf ; accessed 05 May, 2010): breakdown in soil can be relatively slow, with a persistent half-life in the range of 31 to 530 days. Estimated persistence in surface water, however, is much shorter (e.g., half-life of persistence of 0.6 days in the presence of sunlight). In aerobic sediment-water systems, degradation can also be relatively slow (half-life of 462 to 990 days);
- 2,4-D: (2,4-dichlorophenoxyacetic acid) (http://en.wikipedia.org/wiki/2,4-Dichlorophenoxyacetic_acid; accessed 05 May, 2010): estimated half lives in soils from 1.6 to 16 days. 2,4-D is readily degraded by microorganisms and photolysis; however, persistent half-lives under oxygenated conditions can be in the order of one to several weeks;
- Clopyralid (3,6-dichloro-2-pyridinecarboxylic acid): According to the USEPA, persistent half-lives in agricultural soil vary from approximately 2 to 14 months depending on soil type and climate; and
- Glyphosate (N-(phosphonomethyl) glycine) (http://en.wikipedia.org/wiki/Glyphosate#Environmental_degradation; accessed 05 May, 2010): In soils, half-lives vary from as little as three days at a site in Texas to 141 days at a site in Iowa.

The published estimates of persistence in soils, water and sediment suggest a need for judicious use of herbicides.

15.8.3 Airfield Rubber Removal

Aircraft tire rubber builds up over time as a result of aircraft landings, especially at or near the point of touch down, since the tire is not spinning prior to landing, and has a small "spin-up time" during which there is appreciable friction between the tire surface and runway. The build-up of rubber over time is a safety hazard since it affects the level of friction and hence, reduces aircraft braking and ground handling performance. “Viscous hydroplaning” can be minimized by carefully controlling the surface microtexture of the runway which, in turn, is affected by rubber build-up.

Various techniques have been developed for removal of rubber build-up from runway surfaces, including:

- high and ultra-high pressure water removal (hydrocleaning);
- solvent cleaning/removal;
- high velocity impact removal (sand-blasting); and
- mechanical removal, involving physical abrasion of the top few millimetres of the runway surface.

The Authority has used Avisol in recent years (solvent technique), in conjunction with an abrasion technique involving shot sand with vacuum clean-up. Avisol was selected for use by the Authority after the completion of studies between 2005 to 2007 on the comparative effectiveness and environmental issues associated with various rubber removal alternatives. Avion 50 was used at the airport prior to 2006; however, common complaints with its use revolved around runway down time, respiratory sensitivity, product crystallization in product shipping drums and associated clean up of equipment. The Authority conducted testing in the spring of 2006 of Cryotech E-36, Hurrisafe and Biosol Runway Cleaners. Further testing in the fall included Hurrisafe with mechanical scrubbing and Hurrisafe with water blasting. Additional testing was completed in 2007. Biosol Runway cleaner was used on four runways as the preferred product. Runway down time, product cost, rubber removal success, equipment clean up, and environmental and operator friendliness were the primary reasons for the choice. Additional testing of the effluent was done to confirm the potential toxicity of the surface discharge, as well as the total water requirement for neutralizing the product.

The currently available products have been evaluated by the Authority, with key decision criteria being occupational hazard level and possibly influence on stormwater quality. The current products and practices, therefore, reflect best practices and balance environmental considerations with aircraft safety.

It is highly unlikely that solvent use in rubber removal on the new parallel runway would result in an environmental release, depending on the extent to which all solvent use is recovered during the rubber removal operation. The majority of solvent is recovered.

15.8.4 Future Conditions if PRP is Approved

There is a possibility of an increased areal extent of managed lands that will be subject to herbicide application if the PRP is approved. In addition, the parallel runway would be subject to the infrequent application of de-icers, especially potassium acetate and sodium formate. Finally, some glycol-based de-icer release could occur while taxiing to or on the parallel runway.

15.8.5 Potential for Effects

No known or suspected effects have been attributed to current chemical uses, although there is little available data that would allow for a more rigorous examination of the key questions (e.g., on stormwater concentrations of herbicides or their breakdown products). From an ecological or human health risk perspective, the major concern about herbicide residues would be in association with entry into surface waters, followed by transportation to areas of potential exposure – especially Nose Creek or areas where there is a substantial human contact or water ingestion potential. The possibility of human exposures is highly unlikely since (i) surface water or groundwater leaving YYC property does not currently influence any known human drinking water source; and (ii) any groundwater outflows or surface water movements are not likely to transport herbicide residues to areas that are focal points for human visitation and exposure. Human exposure potential associated with herbicide residues in terrestrial areas of airport lands is minimal, since these are not publicly accessible areas.

Ecological risks from herbicide residues are more plausible to the extent that (i) waterfowl, amphibians, and other aquatic biota might be exposed in wetlands that receive stormwater; and/or (ii) herbicide residues are making their way through the existing stormwater management system and into Nose Creek prior to complete breakdown (e.g., through biodegradation or UV photolysis). The residue concentrations are furthermore expected to vary as a function of the effectiveness of stormwater management features currently in place to increase hydraulic residence times and promote the degradation of herbicide residues and other organic substances. In terrestrial soils, the use of herbicides is intended, in part, to limit the value of vegetation communities and hence attractiveness of YYC lands to wildlife. This, in turn, is intended to minimize potential conflicts between avian and mammalian wildlife and airplanes or ground vehicles. The limited habitat value provided by the managed vegetation growth will also minimize wildlife exposure potential associated with grazing on, traversing, or otherwise habituating managed lands to which herbicides have been applied.

Application areas for de-icing, airfield rubber removal or herbicides could result in either (i) entry of various chemicals into the apron drainage system, and then to the Northern Retention Pond System; or (ii) infiltration into soils. Chemical residues in the stormwater collection system can be actively monitored and managed prior to discharge to viable aquatic habitats through engineered retention structures that also provide aeration to accelerate the biodegradation and photolysis of residual chemical products. As a result, it is expected that no appreciable loading of chemical residues to Nose Creek are likely to occur. The soils surrounding impervious surfaces, such as runways, will tend to exhibit very limited vertical relief, thus encouraging direct infiltration and minimizing runoff. As discussed above, any contamination that infiltrates the ground in the LSA will move very slowly in the low permeability of the clay till and underlying claystone bedrock. The estimated travel times between the point of residue introduction to soils and entry of groundwater into Nose Creek or other important systems would, therefore, far exceed time intervals for the degradation and attenuation of the various chemical residues discussed above.

The current limited data regarding the existing concentrations of chemical residues in surface flows emanating from the YYC and its lands does not allow a more quantitative evaluation of risk potential. As a result, possible effects to surface water and aquatic environments associated with chemical usage at YYC cannot be unequivocally ruled out. The assessment concludes that significant effects to surface water systems would not be likely to occur, but nonetheless proposes the following approach for future herbicide and pesticide use, so that there is not an incremental increase in annual mass used in spite of the increase in size of managed lands.

15.8.6 Proposed Management Strategies/Sustainability Measures

The Authority is committed to reducing to the extent possible the use of herbicides, de-icers and other chemicals on airport lands, balancing this against the continuing importance of public protection. A viable strategy for maintaining the effectiveness of herbicide application while minimizing the amounts applied on a one-time basis or annually during the active growing season is through the use of a more formalized integrated pest management (or sustainable pest management) strategy. Such strategies aim to maximize efficacy while minimizing amount used and any unintended effects through:

- reducing or eliminating over-application so that there is minimal potential for movement from the area of application to other environmental compartments such as surface water;

- optimizing the timing of application and application rates at different points on the landscape based on observations of pest species densities and development cycles;
- reducing the frequency of applications by maximizing effectiveness of each application (e.g., in relationship to precipitation events, meteorological and other conditions); and
- critically examining and adopting as appropriate alternative control technologies.

The Authority has already made significant progress in addressing over-application, reducing application frequency, and routinely evaluating alternatives towards the implementation of best practices.

In order to anticipate and avoid any possible incremental impact of herbicide use over an expanded area of managed lands, the Authority will

- develop and implement a formalized integrated/sustainable pest management (SPM) plan (with provisions for continual improvement);
- maintain a formal inventory of herbicide/pesticide and other chemical uses on YYC lands;
- routinely evaluate trends in herbicide/pesticide and other chemical use with an aim to the facilitation of ongoing reductions in use;
- develop a monitoring program to detect relevant pesticide/herbicide or other chemical residues in surface runoff from treated areas, and provide feedback to application practices and rates; and
- establish performance objectives adequate to prevent future effects to aquatic ecological receptors.

As noted above, these measures are substantially in place at YYC.

15.9 Mitigation Measures

The CS for the parallel runway at YYC used a mitigation-by-design approach. This approach systematically considers measures that could be used to reduce the potential effects of the PRP at the earliest possible stage in the assessment. The process of refining the project description and identifying new mitigation measures continued throughout the process of assembling the CS.

15.9.1 Noise

The requirement for mitigation of construction phase noise and vibration effects has not been identified as a result of this assessment.

The HHRA does not indicate potential health risks in the absence of mitigative measures for post-construction operations of the PRP. Furthermore, there is predicted to be a strong, positive net benefit in terms of overall reductions in predicted levels of aircraft-related annoyance; and a decrease in the percentage of residents with the RSA that might experience higher probabilities of aircraft-related sleep disturbance.

The aircraft noise predictions discussed above were developed after completion of multiple model runs especially for the DS Scenario that considered operation of the air field and air space in various scenarios. Scenarios were modelled if (i) they could be credibly applied without jeopardizing aircraft safety or other important facets of airport operations; and (ii) the operational scenario could reasonably be put into practice. The major outcome of this optimization exercise based on predictive noise modelling is nomination of a defined set of airport operational conditions, which should lead to strong positive health benefits associated with the completion of the PRP without appreciable negative impacts on individuals or communities.

The completion of the PRP within the constraints described by the modelling assumptions can itself be considered as a suite of clearly defined mitigative actions. Such actions are described in detail in Chapter 10 of this volume. The collective actions and adaptive management are herein referred to as "Noise Abatement Procedures (NAP) for YYC".

Under the *Aeronautics Act*, enforceable NAP are a set of published rules outlining how jet aircraft are to be operated on arrival and departure. NAP are published in the Canada Air Pilot, and violations of published NAP procedures are subject to investigation by Transport Canada Civil Aviation Enforcement and may result in pecuniary fines.

In comparison with the modelled operating modes for the 2015 and 2025 DS scenarios, NAP for YYC will consider:

(i) preferential runway use and especially diversion of departures as operating volumes permit from flight paths over residential neighbourhoods: especially neighbourhoods in closer proximity to the new parallel runway;
(ii) departure procedures: ICAO Annex 16, Chapter 2 and non noise certified military aircraft will be assigned to runway 34 for departure when runways 28 and 34 are in use; and
(iii) arrival procedures (as discussed in Chapter 10 of this volume).

Overall, the proposed YYC NAP provide sufficient justification for weighting use of the 34 runways over the 16 runways; and for departing south and westbound, short haul traffic on runway 28, as well as arrivals from the northwest and southwest on runway 10 to be considered as mitigation options when winds permit. Implementation of the NAP is expected to substantially reduce the number of persons exposed to the onset of effects thresholds in this assessment.

NAV CANADA will be performing its detailed airspace design in the near future with input from the Authority with respect to operational procedures including runway utilization and noise mitigation. The predictive models used in this assessment can be used to gain further insight into how variations in runway utilization can mitigate noise exposures. The Authority will make use of this capability in formulating its preferences for runway utilization.

15.9.2 Emissions and Air Quality

Air quality issues associated with the PRP are discussed in this chapter as well as Chapter 12 of this volume. The reader is directed to Chapter 12 for information on air quality issues and proposed mitigative measures for construction-phase activities within the RSA.

Predicted air emissions from the operational phase of the project were generally lower than relevant ambient air quality criteria, indicating no significant negative impact of the PRP prior to any mitigation. A minor exception related to the predictions of NO_2 which may occur at concentrations that might occasionally exceed Alberta air quality criteria at the edge of airport lands (LSA inner boundary). The same models did not, however, predict these exceedences to occur at a substantial distance beyond the YYC perimeter. Further, the model predictions for naphthalene, benzene, CO, and NO_2 are that airborne concentrations would be lower for each of the 2015 and 2025 DS scenarios in comparison with the DN scenario.

In light of the above, no significant affects on air quality directly attributable to the PRP have been identified. No mitigative measures are required based on the air quality modelling exercise. While risks to residents immediately beyond YYC lands associated with NO_2 are likely to be acceptably low, the measured and predicted concentrations nonetheless suggest that there is merit to follow-up actions intended to ensure that airport-related emissions, including aircraft emissions do not result in concentrations of airborne NO_2 that exceed thresholds of effects for chronic or acute exposure.

15.9.3 Chemicals Use

The major mitigation measure for chemical effects, instances where greater chemical use might otherwise be catalyzed by the PRP, is implementation of sustainable chemicals management, as described in Section 15.9.3, above. The most important overall objective of management actions is to prevent entry of chemical residues into Nose Creek and other viable aquatic habitats at levels that could cause harm. Such an approach includes the controlled release and treatment through aeration of stormwater, embracing a continuous improvement philosophy for chemical applications relative to required efficacy, enhanced monitoring, and adaptive management.

15.10 Residual Effects after Mitigation

No residual effects after mitigation are predicted for air quality issues within the LSA. Similarly, any residual effects of chemicals use can be minimized or eliminated through judicious chemicals use within a sustainable chemicals management framework and based on adaptive management approaches with adequate ongoing monitoring.

The possibility of residual effects from noise exposures in association with the PRP can be substantially reduced or eliminated through implementation of an updated and effective NAP for YYC. Ongoing efforts to use the existing noise model, developed for this EA, for evaluating operational alternatives would provide an effective tool for the prevention of residual effects. If such scenario analyses are completed, they can be accompanied by further comparisons of newly acquired NMT data and noise predictions, towards further refinement of the predictive accuracy. A combined monitoring and iterative modelling approach may be particularly useful for those geographic locales predicted in Chapter 10 to experience a significant net negative impact from noise (DS scenario) in the absence of any mitigative measures.

15.11 Issues Raised by Stakeholders

Issue: Potential vibration related human health effects.

Response: It is very unlikely that perceptible vibration from the project will be felt beyond the airport perimeter during either the construction or operational phases of the PRP. This is because of the large separation distance between construction sources or ground vibration at the airport and vibration sensitive premises and potential receptors beyond the airport perimeter (i.e., over 1,000 m, for both DN and DS scenarios), coupled with the rapid dissipation of vibration in the ground.

Issue: Noise related human health effects.

Response: Primarily positive changes in noise exposure are anticipated when comparing the DS and DN scenarios. In particular, it was predicted that many residents of neighbourhoods surrounding the airport will experience a significant reduction in annoyance from aircraft noise (~56,000 in 2015 and ~86,000 in 2025) while a much smaller number of individuals could experience an increase in aircraft noise beyond thresholds associated with significant annoyance (102 in 2015 and no individuals in 2025). Residential areas of concern can be protected against significant noise increases at levels sufficient to cause annoyance and various other health effects through the implementation of airport operating modes that reduce the number of landings and especially take-offs in the direction of the potentially affected sub-population, especially during critical periods (night-time). Such operating modes will serve to redirect some portion of the total aircraft volume, limit the magnitude of cumulative noise exposure (predicted as Day-Night Levels, DNL), and reduce the number of negatively affected individuals to virtually negligible.

Issue: Air quality related human health effects.

Response: Airborne pollutant emissions modelling demonstrates and suggests that for all contaminants of interest other than nitrogen dioxide (NO_2), the maximum predicted exposure concentration beyond YYC lands would not exceed ambient Alberta air quality objectives. Therefore, health risks from all airborne contaminants except NO_2 are concluded to be acceptably low. In addition, maximum exposure concentrations for all contaminants of interest are predicted to be higher in both 2015 and 2025 without construction of the PRP than with its completion.

It was concluded that the model predictions over-estimate NO_2 concentrations in comparison with actual measured concentrations at air monitoring sites. Predicted NO_2 concentrations in excess of ambient air criteria were confined to a narrow zone immediately adjacent to the airport, and the concentration dropped rapidly at increasingly farther distances from the airport. In addition, the frequency of predicted exceedences for the 90th percentile busy day under a range of meteorological conditions was very low for the period modelled (less than one year). Overall, it was concluded that no health effects from the project are expected in association with airborne NO_2 levels.