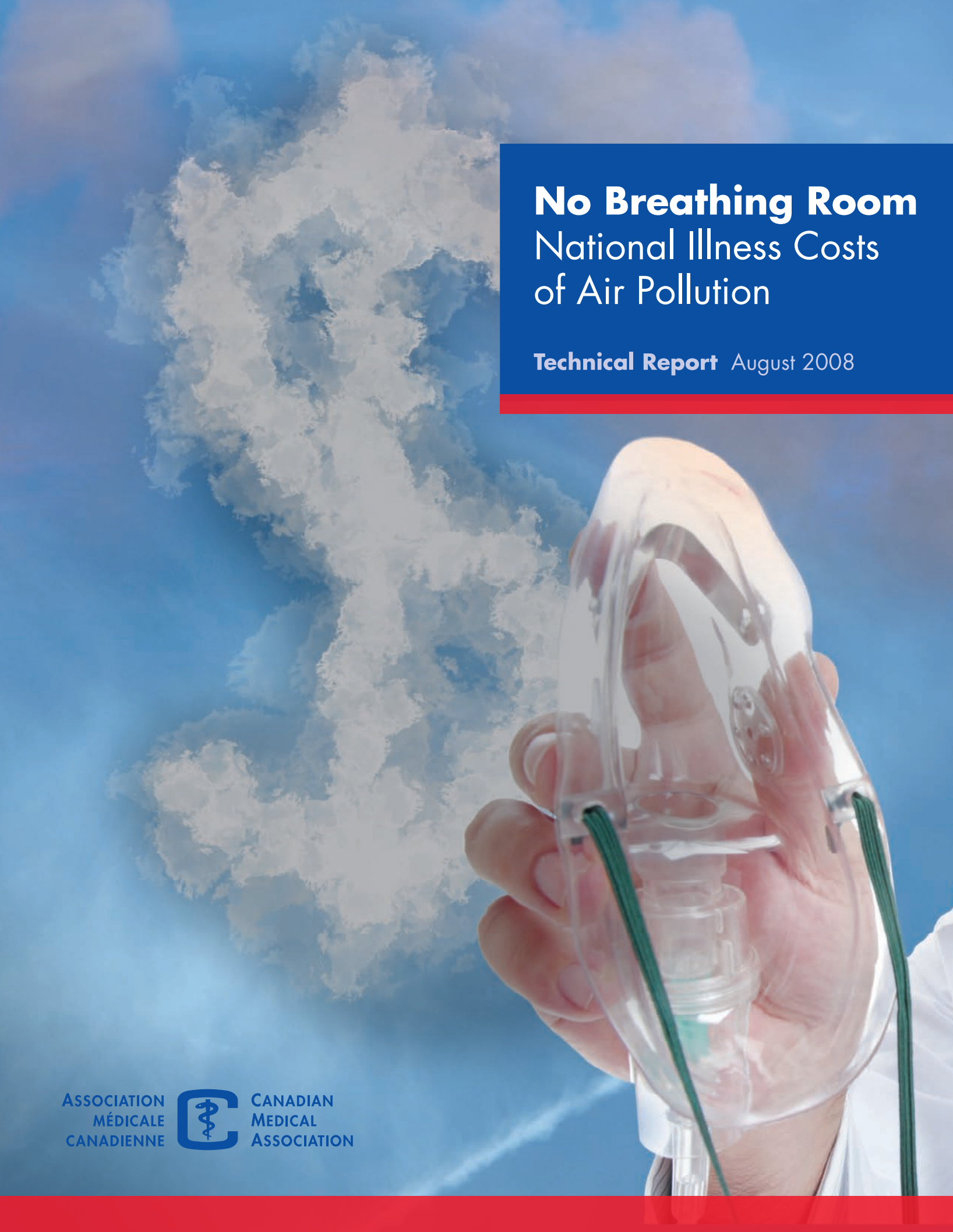

No Breathing Room
National Illness Costs of Air Pollution

Technical Report August 2008

ASSOCIATION MÉDICALE CANADIENNE
CANADIAN MEDICAL ASSOCIATION

TECHNICAL REPORT

ICAP Model

Version 3.0:

Provincial Models

And

National Damage Estimates

Submitted to

Canadian Medical Association

Prepared by

DSS Management Consultants Inc.

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List of Acronyms

$\mu g/m^3$	-	Microgram/cubic meter
BIR	-	Base incidence rate
CARB	-	California Air Resources Board
CD	-	Census division
CIHI	-	Canadian Institute of Health Information
CO	-	Carbon monoxide
COPD	-	Chronic obstructive pulmonary disease
CRF	-	Concentration-response function
DSS	-	DSS Management Consultants Inc.
DOV	-	Doctor's office visits
EDV	-	Emergency department visits
GIS	-	Geographic information system
HA	-	Hospital admissions
ICAP	-	Illness Costs of Air Pollution model
MI	-	Minor illnesses
NAPS	-	National Air Pollution Surveillance
NO_2	-	Nitrogen dioxide
O_3	-	Ozone
OHIP	-	Ontario Health Insurance Program
OMA	-	Ontario Medical Association
PM	-	Particulate matter
PMM	-	Premature mortality
PM_{10}	-	Particular matter less than 10 microns in aerodynamic diameter
$PM_{2.5}$	-	Particular matter less than 2.5 microns in aerodynamic diameter
ppb	-	Parts per billion
ppm	-	Parts per million
RMSE	-	Root means square error
SO_2	-	Sulphur dioxide
SO_4	-	Sulphate
US EPA	-	US Environmental Protection Agency

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Dr. **Douglas Dockery**, Chair, Department of Environmental Health, Professor of Environmental Epidemiology, Department of Epidemiology, Harvard School of Public Health, Harvard,
Dr. **Daniel Krewski**, Professor, Department of Epidemiology and Community Medicine, Faculty of Medicine, University of Ottawa,
Dr. **David Pengelly**, Associate Clinical Professor, Department of Medicine, McMaster University,
Dr. **David Stieb**, Medical Epidemiologist, Air Quality Health Effects Research Section, Health Canada,
Dr. **George Thurston**, Professor, Department of Environmental Medicine, New York University School of Medicine.

DPRA Canada undertook the interpolation of the air quality monitoring data to the provincial census divisions.
Ms. **Rachelle Laurin-Borg** was directly responsible for the GIS interpolation. She prepared the resulting maps included in Appendix E.

DSS Management Consultants Inc. was the prime consultant for this project. Various DSS associates participated in this project.
Mr. **Ed Hanna**, project manager, was responsible for the preparation of this report and participated in all aspects of the project.
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Mr. **Steve Spencer** was responsible for all programming changes to the ICAP software.

1. Introduction

1.1 Background

DSS Management Consultants Inc. first developed the Illness Costs of Air Pollution (ICAP) model for Ontario in 2000. This work was undertaken on behalf of the Ontario Medical Association (OMA). Since the release of the first version of ICAP, the software has been used for diverse applications by a broad group of users. These users include;

- local medical officers of health and doctors advocating improved local air quality
- private citizens and community groups striving to influence local policies and decisions having significant air quality consequences (e.g., transportation policies and routes)
- educators wishing to present to students the connections between air quality and health and economic damages
- policy analysts exploring alternative policies to improve air quality.

ICAP has been updated and revised since the first release. The last update of the Ontario ICAP software was released by the OMA in 2005.

The Canadian Medical Association (CMA) retained DSS to update and expand the Ontario ICAP model to all of the provinces of Canada. This report summarises the results of this CMA initiative.

1.2 Scope of Report

This report describes the methodology used to expand the Ontario ICAP system to each of the other provinces. As well, a number of significant refinements were made to the ICAP system as part of this project. These refinements are explained as are their impacts on forecast health damages.

This report is technical in nature and delves in detail into various aspects of health damages forecasting. The purpose of this report is to provide ICAP users with an understanding of the structure and contents of the provincial ICAP systems. This project builds on the advances made in previous updates. As result, this report refers to previous technical reports as appropriate where the technical details are described therein and are relevant to the current version of ICAP.

2. Provincial ICAP Model Development

The primary objective of this project was to produce provincial ICAP systems for all of the provinces. This section explains what was involved in transforming the Ontario ICAP system for each of the provinces.

2.1 Basic ICAP Structure

The basic structure of ICAP is described in detail elsewhere (DSS, 2000). The following discussion assumes that this basic structure is generally understood.

The spatial foundation for ICAP is census divisions[1] defined by Statistics Canada. ICAP allows users to forecast health damages down to the census division level of detail. The numbers, names and spatial boundaries of the census divisions are different for each province[2]. As a result, each provincial ICAP system has a unique set of spatial units. The spatial units to be included in an analysis are selected by ICAP users using the "Scope" pull-down menu in ICAP.

[1] Census divisions approximate the boundaries of counties in many provinces (see. http://geodepot.statcan.ca/Diss/Reference/COGG/ShortDescription_e.cfm?GEO_LEVEL=3&TUTORIAL=1&ABBRV=CD)
[2] See http://geodepot.statcan.ca/diss/maps/referencemaps/n_cd_e.cfm

For each census division, certain default parameter values are included in the ICAP system. Specifically, the following census division-specific default parameter values are included in each provincial ICAP system:

- Population broken down by age group and gender.
- Ambient air quality concentrations for seven pollutants

ICAP also includes a number of provincial-level parameter values. Specifically, the following province-specific default parameter values are included in each provincial ICAP system:

- Base incidence rates for different type of illnesses
- Average length of stay for different type of illnesses
- Healthcare unit costs for different type of illnesses
- Value of lost time

ICAP also includes a number of parameter values that are common across all provinces. Specifically, the following common default parameter values are included in each provincial ICAP system:

- Health risks of exposure to air pollution
- Value of a statistical life
- Value of quality of life

Each provincial ICAP system is based on a common set of algorithms that use these data to forecast the health effects and related economic damages associated with exposure to air pollution. The specific algorithms are discussed elsewhere (DSS, 2000). These algorithms are not discussed in this report except where a revision has occurred to an existing algorithm or a new algorithm has been added.

2.2 Provincial ICAP Systems

Each provincial ICAP system was developed from the Ontario ICAP framework. Revised parameter values specific to each province were added. Some "cosmetic" refinements were required to deal with labels and titles on some windows that are specific to each province. Otherwise, each provincial ICAP system shares a common foundation. That being said, forecast health damages do vary considerably from province to province given differences in air quality and the characteristics of the exposed population.

3. Parameter Estimation and Updating

This chapter summarises the sources and derivation methodologies for the ICAP parameter default values.

3.1 Population Data

Two revisions have been made to the population data within ICAP.

First, all population data have been updated and are based on the 2006 census. These data are maintained in ICAP for each census division at a highly disaggregated level (i.e., by five-year age groupings and gender).

The ICAP software has also been modified. In the past, population forecasts produced by Statistics Canada were used to define central, upper and lower values for population forecasts for each CD population group. The user could not alter these values. The new version of ICAP now allows users to select among one of four Statistics Canada population forecasts (i.e., low growth, medium growth – medium migration trends, medium growth – central-west migration trends and high growth). Further details on these forecasts are available from Statistics Canada (see http://www.statcan.ca/Daily/English/051215/d051215b.htm).

A notable feature of these projections is the increasing proportion of the Canadian population that will be made up of people over 65 years of age. This aging trend is an inherent feature of the Canadian population and has

significant implications for future health damages from air pollution given the relatively higher number of air-pollution-related illness cases among the elderly.

In the past, ICAP has been based on three age groups (i.e., 0-18, 19-64, 65+). The new version of ICAP has been modified to include early development effects of air pollution. The risks of these effects vary within children of different ages. For this reason, the 0-19 age group was subdivided into two age groups (i.e., 0-4, 5-19). The numbers of individuals in each age group were derived from the corresponding age groups in the census data.

3.2 Air Quality Data

ICAP contains default ambient concentrations for each census division for seven criteria pollutants, namely PM_{10}, $PM_{2.5}$, O_3, NO_2, SO_2, SO_4[3] and CO.

The latest air quality monitoring data were obtained as part of the updating of ICAP. The geographic interpolation of these data was undertaken using a mathematical procedure, referred to as kriging. The details of this procedure and the resulting air quality results are presented in Appendix E.

ICAP is based on the idea of forecasting future health damages as a means to inform public policy. Health damages are tied to specific air pollutants. ICAP includes as the default air quality forecast, continuation of current ambient concentrations of air pollution. In other words, the default air quality forecast in ICAP is no future change in air quality. ICAP does however provide a number of forecasting tools that allow users to construct air quality forecasts. A principal role of ICAP is to facilitate exploration of future changes in air quality and the consequences in terms of public health. Needless to say, the range of possible air quality forecasts is enormous. ICAP facilitates users specifying and analyzing these possibilities but does not include any specific default air quality forecasts other than everything staying the same in the future.

A common issue with the interpretation of the health damages of air pollution is the proportion of ambient pollutant concentrations that is associated with non-human sources; what is often referred to as background concentrations. These proportions are controversial and vary from region to region and pollutant to pollutant depending on local conditions and the nature and location of air pollution emission sources. ICAP contains a constant default background percentage for O_3 of 80%. In other words, 80% of the ambient O_3 is considered to be from non-human sources. Default background concentrations for all other pollutants are set to 0%.

ICAP allows users to specify the proportion or absolute concentration for each pollutant that should be assigned to background levels (i.e., associated with non-human sources). Altering the proportion of the ambient concentration assigned to background concentrations can affect significantly health damages forecasts.

3.3 Health Risk Functions

The health risks of air pollution are expressed as a relative risks. This means that air pollution causes the base incidence rates of certain illnesses to be elevated when air pollution increases relative to the normal base incidence rate. Health damages are therefore a function of both the relative risk posed by a given pollutant and the base incidence rates for specific types of illnesses. The sources for the ICAP default values for these relative risks and base incidence rates are presented following.

3.3.1 Base Incidence Rates

Base incidence rates vary by illness type, age group and location. ICAP includes default base incidence rates for each province, age group and illness type. These values may be changed by ICAP users. The default base incidence rates for each province are presented in Appendix C.

[3] SO_4 data are missing for some census divisions. However, SO_4 is a component of PM and its health effects are captured through this pollutant.

Base incidence rates for death from different causes were obtained from 2004 death statistics published by Statistics Canada (2008a). These statistics provide death rates by cause, age group and province. Each provincial ICAP system contains province-specific mortality base incidence rates for each cause of death included in the system.

Base incidence rates for hospital admissions and emergency department visits[4] were obtained from 2005-2006 Canadian health statistics provided by the Canadian Institute for Health Information (CIHI, 2007a). CIHI produced provincial base incidence rate statistics for each province based on ICD-10 codes assigned to each ICAP illness type.

The new Ontario version of ICAP includes health damages associated with doctor's office visits. The doctor's office visit routine for other provincial ICAP systems does not include default base incidence rates at this time. Base incidence rates for Ontario were derived by the Ontario Medical Association using the Ontario Health Insurance Program (OHIP) database. The base incidence rates are annual averages based on the 2004, 2005 and 2006 OHIP records.

Standardised statistics for minor illnesses are not routinely collected and reported through a central database. This matter was discussed during the expert opinion elicitation process (see Appendix D, Section D.8 for further elaboration). As a result, the potential to use the results of the Canadian Community Health Survey (http://www.statcan.ca/bsolc/english/bsolc?catno=82-621-X) to estimate base incidence rates for certain minor illnesses was investigated. The objective was to derive base incidence rates for three specific types of minor illnesses. Unfortunately, the survey does not contain sufficient detail to allow the required parameter values to be estimated. As a result, the base incidence rates for minor restricted activity days and restricted activity days were derived from work by Abt (2003). These values are much less than what had been used in the original version of ICAP. Considerable uncertainty remains as to these minor illness base incidence rates for different provinces.

The base incidence rates for asthma symptoms days were revised based on the results of the Canadian Community Health Survey (Statistics Canada, 2008b); more specifically, the reported prevalence rates of asthma among Canadians were used to derive population-wide asthma symptom day base incidence rates. The reported base incidence rate for asthma symptom days among asthmatics (Vedal, 1998) was used along with the prevalence of asthma in the Canadian population to derive a population average base incidence rates for asthma symptom days (Appendix B, Table 27).

3.3.2 Health Risk Factors

Five major health risk categories (i.e., premature death, hospital admissions, emergency department visits, doctor's office visits and minor illnesses) are included in ICAP. Each major category is further divided into more specific health outcomes. In total, 20 specific categories of health effects associated with air pollution are included. Default relative risk coefficients are included for various combinations of health outcome, pollutant type and age group[5]. These relative risks do not vary by province and are presented in Attachment B of Appendix D.

The epidemiological literature dealing with air pollution health risks is extensive, with the frequency of studies inversely related to the severity of the health endpoint. For example, many more studies are available for the most severe endpoint (i.e., premature death) than for the least severe outcome (i.e., minor illnesses). Considerable judgement is required to analyse this literature and to derive the default risk coefficients for ICAP. As a result, the

[4] The term "emergency department visits" is used in this version of ICAP. Previously versions referred to "emergency room visits". These terms are synonymous within ICAP. The former term more accurately reflects the modern organizational structure within hospitals.

[5] Note ICAP allows users to specific age-specific health risks. However, the results of the expert opinion elicitation process indicate that relative risks are not expected to vary by age group. While this version of ICAP still allows users to specify age – specific risks, the default risks are constant across all age groups for a given health outcome.

CMA undertook a formal expert opinion elicitation process, the objective of which was to derive the best possible estimates of these risk coefficients. This process is discussed further in Section 4 and Appendix D.

3.4 Economic Damage Functions

ICAP estimates health damages in physical terms (i.e., illnesses rates) and economic terms (i.e., monetary damages associated with air pollution-related illnesses). Specifically, ICAP estimates for each health outcome, the associated monetary damages according to the following categories:

- the value of avoiding premature death
- the value of reducing or avoiding pain and suffering
- the cost of health care treatment, and
- the value of lost productivity/time due to illness.

The ICAP default economic damages coefficients are presented in Appendix C. These coefficients have been updated where appropriate. All of the coefficients are expressed in Canadian 2006 dollars.

4. Expert Opinion Elicitation Process

The CMA conducted an expert opinion elicitation process (EOEP) to derive the estimates for the ICAP default relative risk coefficients. This section briefly describes the EOEP methodology and results. The detailed results of this process are provided in Appendix D.

4.1 Methodology

Appendix D describes the EOEP in detail including the methodology. The basic idea is to canvass a cross-section of experts in air pollution epidemiology on their interpretation of the scientific literature and their own research experience. The experts were asked a series of general and specific questions with this purpose in mind. As well, the experts were brought together in a workshop and encouraged to exchange opinions and to review critically the grounds for one opinion and another. Following the workshop, the experts were asked to reconsider their opinions in light of these discussions and revise their opinions as they saw fit.

4.2 Results

Two general types of results were obtained from the EOEP. First, the experts provided their insights and opinions on a range of broad overarching issues surrounding the question of the health risk of air pollution. Secondly, the experts provided relative risk coefficients for specific combinations of health outcomes and exposure to specific types of air pollutants. The results are highlighted following.

4.2.1 Causality

The experts shared a common view that adequate scientific evidence is available to reliably conclude that a positive causal relationship exists between exposure to air pollution and adverse health outcomes. There was general agreement that air pollution causes adverse health outcomes through certain physiological mechanisms that can result in different levels of severity of health outcome. The physiological mechanisms are common among health outcomes with a common diagnostic origin (e.g., respiratory-related mortality and respiratory-related hospital admissions) but not necessarily across classes of health outcome with different diagnostic origins (e.g., between respiratory-related hospital admissions and cardiovascular-related hospital admissions). For example, different severities of adverse outcomes (e.g., premature mortality and hospital admission) for a specific type of cardio-vascular outcome (e.g., arrhythmia) likely share a common physiological causal mechanism. The severity of the response to air pollution will depend on many environmental factors in addition to the health status and sensitivity of the individual.

Overall, the highest likelihood of causality exists for $PM_{2.5}$ and O_3. These are also the pollutants for which the greatest volume and weight of evidence are available.

4.2.2 Weight of Evidence

A common observation emerged from the discussion of causality; generally the greatest weight of evidence exists for the most severe adverse health outcomes (i.e., premature mortality). This greater volume of evidence provides both more confidence that a causal relationship exists and the ability to estimate the relative risks more precisely.

4.2.3 Multiple Pollutant Models

Previous versions of ICAP allowed users to combine relative risk coefficients for multiple pollutants to estimate health damages. The ICAP default relative risk coefficients were derived from epidemiological studies using multiple pollutant statistical models where available. However by necessity, the risks were derived from the results of single-pollutant statistical models in some cases.

Each of the six criteria pollutants may individually pose health risks; however, teasing out their individual contribution to overall health risks using multiple-pollutant models is statistically infeasible given the relatively modest changes in risk that are being detected and the large number of other factors potentially influencing health outcomes. For this reason among others, a dearth of results is available for multiple-pollutant statistical models. In the absence of relative risk coefficients derived from multiple-pollutant statistical models, using the relative risks derived from two-pollutant or single-pollutant statistical models cumulatively may overestimate health damages.

A reasonable level of precision and compatibility can be achieved when risk coefficients are estimated simultaneously using two-pollutant statistical models, in particular models which include $PM_{2.5}$ and O_3. Even in this case however, caution was advised in ascribing the proportions of the damages to individual pollutants.

4.2.4 Variations in Relative Risk

The presence of a common underlying causal physiological mechanism(s) associated with major illness types suggests that the relative risks for a broad illness type (e.g., respiratory illnesses) should be similar for different levels of severity. For example, the relative risk of respiratory-related hospital admissions should be comparable to the relative risk of respiratory-related emergency department visits provided the make-up of the number of different types of respiratory-related illnesses are comparable. Relative risks are expected to vary among major illnesses types (e.g., respiratory-related illnesses as compared to cardiovascular-related illnesses) since the underlying causal physiological mechanism is expected to be different among different classes of illnesses.

4.2.5 Excluded Health Outcomes

Earlier versions of ICAP included four major health risk categories (i.e., premature death, hospital admissions, emergency department visits and minor illnesses). There was general agreement among the experts that ICAP captured only a subset of the full range of adverse health effects associated with air pollutants, leading to the likelihood of actual damages being underestimated.

Some of the more significant excluded health effects include:

- Doctor's office visits
- Hypertension
- Lung function development
- Myocardial infarction
- New cases of chronic bronchitis
- Other cancers

Several of these omissions are addressed in the new version of ICAP as discussed in Section 5. In other cases, the supporting scientific literature is still emerging and has not matured to the point that quantitative risk estimates can be derived. These health outcomes should be added to ICAP once adequate scientific understanding is available.

4.2.6 Individual Relative Risk Coefficients

In addition to responding to these general questions, the experts provided specific risk coefficients for various illness and air pollutant combinations. As expected, some variation in opinion was present even following the workshop discussions. The individual responses were analysed to determine median, upper and lower ranges for each coefficient. The results are presented in Attachment B of Appendix D.

Considerable variation in the magnitude of the relative risks is evident from one severity level to another for similar health outcomes. For example, the median relative risk of respiratory-related acute[6] premature mortality with exposure to $PM_{2.5}$ is 1.1%[7]. The relative risks for respiratory-related hospital admissions and emergency department visits are 1.2% and 2.2%, respectively. In other words, the risk of $PM_{2.5}$ causing an increase in respiratory-related emergency department visits appears to be double the risk for an increase in the rate of respiratory-related premature mortality. Yet these health outcomes are associated at least to a degree with a common physiological mechanism.

On the other hand, the number of studies examining the risk of acute respiratory-related premature mortality is many times greater than the number of studies examining the risk of acute respiratory-related emergency department visits; the number of studies examining the relative risk of hospital admissions is intermediate. The question is whether the true risk of acute respiratory-related emergency department visits is in fact double that for premature mortality and hospital admissions. This variation in relative risks is feasible if the case mix differs significantly. On the other hand, this variation may be an indication of the more limited research results available and hence less precise risk estimates for less severe health outcomes.

A decision was made to use the relative risk estimates derived from the EOEP as the default values for the provincial ICAP models. A primary purpose of ICAP is to allow individuals to explore many of the facets of air pollution damages. The default parameter values are provided as a starting point for such inquiries. The best estimates of the relative risks for each health outcome are considered the best starting point for analysing the health risks of air pollution.

5. Revisions to ICAP

Several changes have been made to the ICAP software as a result of the outcome of these investigations. This section provides an overview of these changes. Greater detail on the specific modifications is provided in Appendix F.

5.1 Doctor's Office Visits

The first point of contact with our healthcare system for many people with illness is through doctor's office visits (DOV). The proportion of DOV cases relative to emergency department visits and hospital admissions is high as is expected based on the concept of the health effects pyramid; generally less severe illnesses require doctor's office visits compared to, say, hospital admissions.. In many cases, patients are treated only through DOV. DOV services importantly also account for a significant proportion of the total expenditures on healthcare resources.

The results of the EOEP indicate that air pollution-related health damages should be expected for differing levels of severity for illnesses having a common physiological causal mechanism. As well, the relative risks are expected

[6] The word "acute" in this context refers to an immediate response to exposure to air pollution (i.e., within days). This type of immediate response is detected commonly using a time-series epidemiological methodology. Acute premature mortality differs from chronic premature mortality. Chronic premature mortality is associated with chronic exposure to air pollution over an extended period of time (i.e., years). The risk of chronic premature mortality is commonly estimated using a cohort epidemiological methodology.

[7] All relative risks are expressed for 10 unit change in pollutant concentration. For example, $PM_{2.5}$ is measured in $\mu g/m^3$. Therefore, this relative risk means that for each 10 $\mu g/m^3$ increase in $PM_{2.5}$, respiratory-related deaths will increase 1.1% over the base incidence rate for a short time following the change.

generally to be similar across different levels of severity for the same type of illness. Many of the DOV cases involve respiratory-related and cardiovascular–related illnesses that have similar underlying causal physiological mechanisms as more severe cases treated through emergency department visits and hospital admissions.

The original version of ICAP included a "placeholder" for DOV. However, this routine was not activated due to an absence of supporting research results. Very few published studies have reported relative risks for DOVs[8]. As noted through the EOEP, the research available is directly proportional to the severity of the outcome. DOV cases are less severe generally than hospital admissions or emergency department visits. Furthermore, little change in the availability of useful research results is evident since the original version of ICAP was released. Nonetheless not including health damages of air pollution associated with DOV has been recognised as a major gap.

A further complication with estimating air pollution health damages associated with DOV is the absence of centralised national databases. Each province has its own record-keeping procedures and coding. For this version of ICAP, Ontario was selected to examine the feasibility of including DOV in ICAP. The Ontario Medical Association (OMA) has access to the OHIP database which is compiled by the province and used among other things to track payments to doctors. The database includes information on the nature of the service/diagnosis and fee for each visit plus demographic information on the patient. A list of diagnostic types corresponding to respiratory and cardiovascular-related illnesses was produced. The OMA then produced aggregate DOV statistics for 2004, 2005 and 2006. Specifically, the base incidence rates and fees for different types of illness and different age groups were derived. The averages for the three years were used to derive the ICAP default coefficients.

The default relative risk coefficients for DOV for $PM_{2.5}$ and O_3 were derived as follows. The relative risks for which the greatest weight of evidence was available (i.e., acute premature mortality) and which involved a similar underlying physiological mechanism (i.e., respiratory or cardiovascular) were used to derive the default DOV relative risk coefficients in ICAP. These values are presented in Attachment B of Appendix D.

Expanding the DOV routine for other provinces will require estimation of comparable base incidence rates and economic coefficients for each province. The ICAP software for each of the provinces is configured to accept these data should they become available in the future.

The ICAP results for Ontario for DOV damages are presented in Section 6.

5.2 Early Development Impacts

During the EOEP workshop, considerable discussion arose about the risk of early development health impacts being caused by exposure of children to air pollution. The evidence for some of these impacts is stronger than it is for others. The discussion of these effects is presented in Appendix D, Section 5. The conclusion of those discussions was that insufficient data are available to incorporate these risks in ICAP, with one exception.

Compelling evidence is mounting that exposure of young people during critical stages of lung development (i.e., up to around age 17) causes irreversible damage (Gaudermann 2000, 2002; Avo1 2001; Peters 2004). This damage is exhibited through reduced lung function. The reduction in lung function is proportional to air pollutant concentrations, in particular $PM_{2.5}$ (Gaudermann 2002; Lewis 2005; Islam 2007).

A new routine has been added to ICAP so that the potential magnitude of these early development effects on lung development can be initially explored. The details of the routine are presented in Appendix F. On the main ICAP screen, the "Illness" pull-down menu now includes two options; one of which is "Early Development Effects". Selection of this option begins the process of specifying risk values for early development effects. Three potential

[8] The only published air pollution risk analyses dealing with DOV are Choudbury 1987, Medina 1997 and Haj 2001. For various methodological reasons, the results of these studies have limited application in a Canadian healthcare system context.

effects are shown but only the "Impaired Lung Development" option is active in this version of ICAP. The next two windows in this routine are similar to those for specifying the risk of other illness types.

This routine operates quite differently than any other routine in ICAP. If air pollution concentrations do not change over time, no change in the amount of early development effects is assumed to occur. In other words, it is assumed that these developmental effects are already reflected in the population base incidence rates for various respiratory-related illnesses. When air pollution concentrations do change, this means that the level of lung impairment in the population will change gradually as the affected cohort matures and ages over time. The result is that population base incidence rates for certain illnesses will gradually change as well. These effects will persist for a long time since young people with impaired lung function will remain present in the population for their entire lives.

ICAP tracks the proportion of each age cohort with lung impairment from one year to next. These effects are cumulative since each new age group cohort will sequential move into the population and change the overall proportion of the population with impaired lung development. This cumulative sequence illustrates the potentially large and persistent consequences of early development impacts. These young people will exhibit the consequences of impaired development throughout their entire lives.

The scientific literature provides information on the relationship between the level of pollution and the amount of lung impairment (for example, Peters 2004). What is missing is the risk of future adverse health consequences with varying levels of lung impairment. Certainly, individuals with lung function impairment are more likely to require medical treatment over their lifetime, particularly for respiratory-related illnesses. The likelihood of increased future medical care demands is clearly related to the amount of lung function impairment. If a significant portion of a population has impaired lung development, this will be exhibited by elevated base incidence rates in that population for certain illnesses. What is not clear is the proportional relationship between the amount of lung function impairment and changes in base incidence rates for different illnesses.

The CMA attempted to address this gap by canvassing experienced practising respirologists on this question. Conclusive results were not obtained from this initiative. A hypothetical default proportion is included in each provincial ICAP for the purposes of illustration only. This routine has not been used to produce the primary damage forecasts presented in Section 6. Not including these health effects underestimates air pollution damages, particularly given the long-lasting nature of these impacts within an affected population. Section 6 does present some examples of the potential magnitude of these developmental effects on health damages forecasts.

5.3 Population Forecasts

ICAP is designed to be transparent and to ensure that users can track all of the calculations on which damage forecasts are based. Previous versions of ICAP included population data and population forecasts. Users however, were not able to change these forecasts. Previous versions of ICAP used Statistics Canada's "intermediate" population forecast as the central value and used low and high forecasts to define uncertainty ranges. The user could not change these population forecasts.

Statistics Canada has produced six population forecast for Canada that reflect different assumptions (see http://www.statcan.ca/Daily/English/051215/d051215b.htm). The new version of ICAP includes a new option on the main menu entitled "Population". This option allows users to select among four population forecasts (i.e., high and low growth scenarios plus two medium growth scenarios with differing assumptions about migration). This option allows ICAP users to explore how sensitive health damage forecasts are to changes in population growth. Further discussion of the impact of demographics on health damages is provided in Section 6.

6. Damage Estimates

This CMA initiative has resulted in provincial ICAP systems being produced for each of the ten provinces. It is now possible to forecast health damages for each Canadian province and for all of Canada in aggregate. This section presents the aggregate national estimates of health damages associated with exposure to air pollution based on the default coefficients included in each provincial ICAP system. Detailed results for each province are provided in Appendix A.

6.1 Health Damages

ICAP provides estimates of health effects according to four major health endpoints, namely:

- Premature Death
- Hospital Admissions
- Emergency Department Visits
- Minor Illnesses

Damages for each of these major health endpoints may be further broken down by more specific illness categories, age groups and geographic locations. The following summary includes the aggregate damage estimates for Canada.

Health effects forecasts for doctor's office visits for Ontario are also included. These results provide a sense of the magnitude of the damages that can be expected in other provinces when the DOV routine is calibrated for these other jurisdictions.

The potential impacts associated with early development effects, specifically impaired lung function, are presented for illustrative purposes. These results provide a sense of the persistent effects of exposure of children to air pollution on the overall long-term health of the Canadian population.

6.1.1 Premature Death

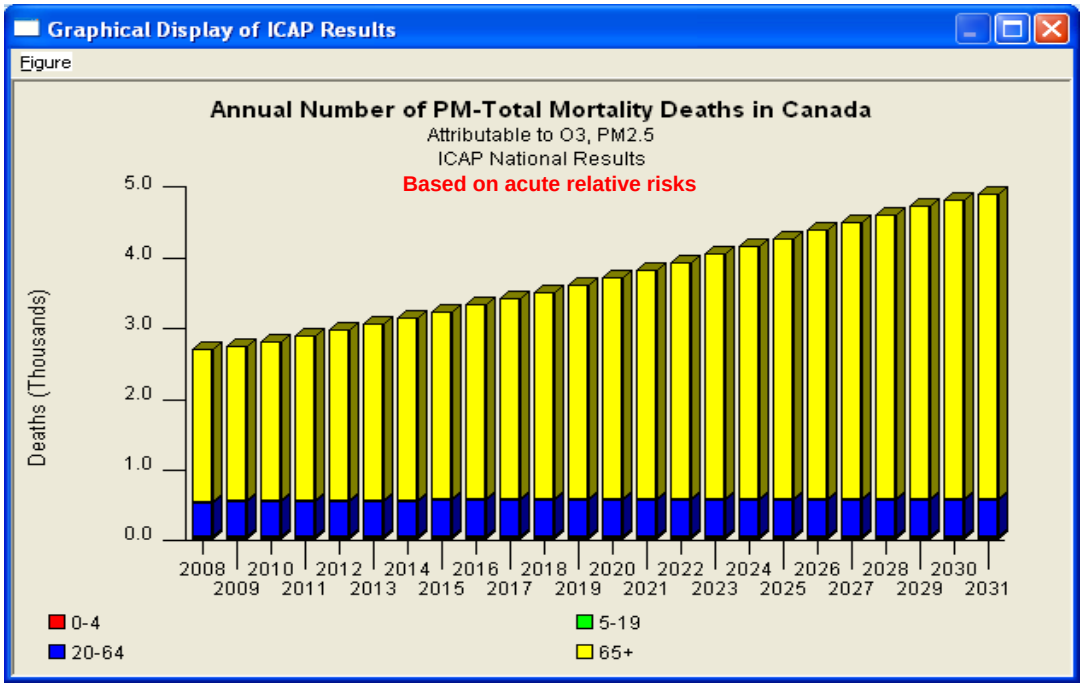
Two epidemiological methodologies are used to estimate the risk of premature mortality. The first is referred to as the time series methodology. Time series studies estimate the immediate (or what is referred to in this report as acute) risk of short-term exposure to air pollution. These effects are observed within days of exposure.

The second approach is referred to as the cohort methodology (or what is referred to in this report as chronic risk of premature mortality). With cohort studies, air pollution exposure and the health of a cohort of individuals is monitored for a number of years. Differences in death rates are correlated with cumulative differences in exposure to air pollution. ICAP includes the option of using either acute or chronic relative risks to estimate numbers of premature mortality cases.

These two methodologies measure different risks associated with air pollution exposure and the reported relative risks are significantly different as a result. The cohort-based relative risks are about nine times higher than the acute risks. Cohort-based relative risks are only available for premature mortality. The acute risk of premature death is more directly comparable to the relative risks for the other health outcomes included in ICAP. Forecast health damages are included in this section for both of these premature mortality risks.

Figure 1presents the expected number of acute premature deaths in Canada by age group from 2008 to 2031. The total annual number of premature deaths is expected to almost double from about 2,680 in 2008 to about 4,910 by 2031. The great majority of these premature deaths will be suffered by the elderly. Canada's aging population means that premature deaths from air pollution will increase significantly in the future.

Figure 1 - Acute Premature Deaths by Age Group



Children and infants with compromised health conditions are also at risk[9]. In 2008, approximately 24 deaths of people under the age of 19 will be attributable to short-term exposure to air pollution. In 2031, this number is expected to rise slightly.

Figure 2 presents the expected number of acute premature deaths according to two major illness types, namely respiratory and cardiovascular-related deaths[10]. The ratio of respiratory to cardiovascular-related deaths is in the range of 1 to 4.

Figure 3 presents the distribution of acute premature deaths by major region of Canada. The majority of the cases are associated with Ontario and Quebec (Central Canada). These provinces have the largest populations and some of the worst air quality in Canada.

Figure 4 presents the expected number of premature deaths associated with chronic exposure to air pollution. The total annual number of premature deaths in Canada from chronic exposure to air pollution is expected to rise from about 20,000 in 2008 to about 35,000 by 2031. The great majority of these premature deaths will be suffered by the elderly.

[9] The epidemiological evidence is growing stronger each year indicating air pollution exposure leads to premature death risks for children and infants (e.g., see US EPA, 2005, CARB, 2005 for discussions of this risk). However, the major research focus in the past has been on risks to adults and most often, the elderly age group. Assuming the youngest age group is not at risk of premature death tends to underestimate the number of premature deaths associated with air pollution. The ICAP default risk coefficients are the same for all age groups. On the other hand, the base death rates for younger people is considerably lower than for adults, therefore, the actual numbers of premature deaths with younger people will be considerably less than is the case with the elderly even when the relative risks are comparable.

[10] The total number of deaths in Figure 2 is considerably less than the total shown inFigure 1. Respiratory and cardiovascular-related deaths include only a portion of the premature deaths attributable to air pollution.

Figure 2 - Acute Premature Deaths by Illness Type

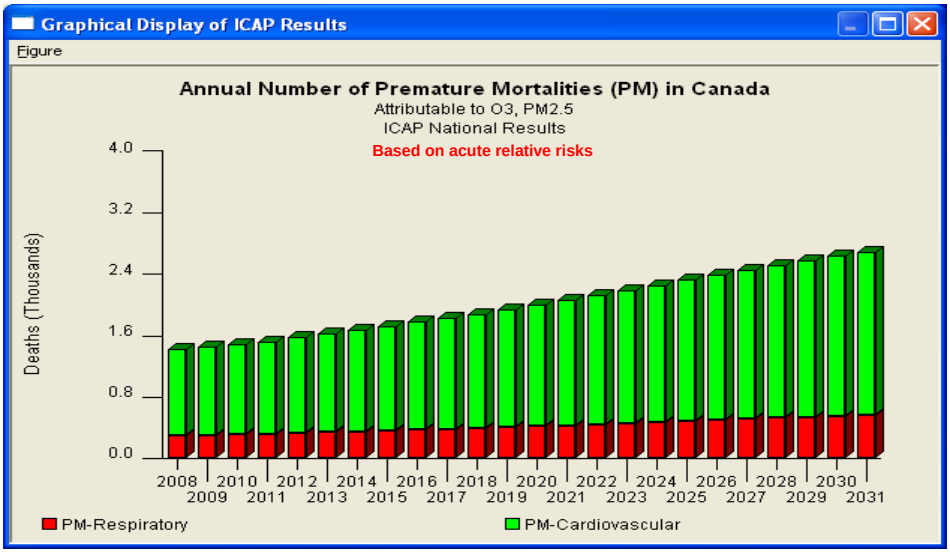
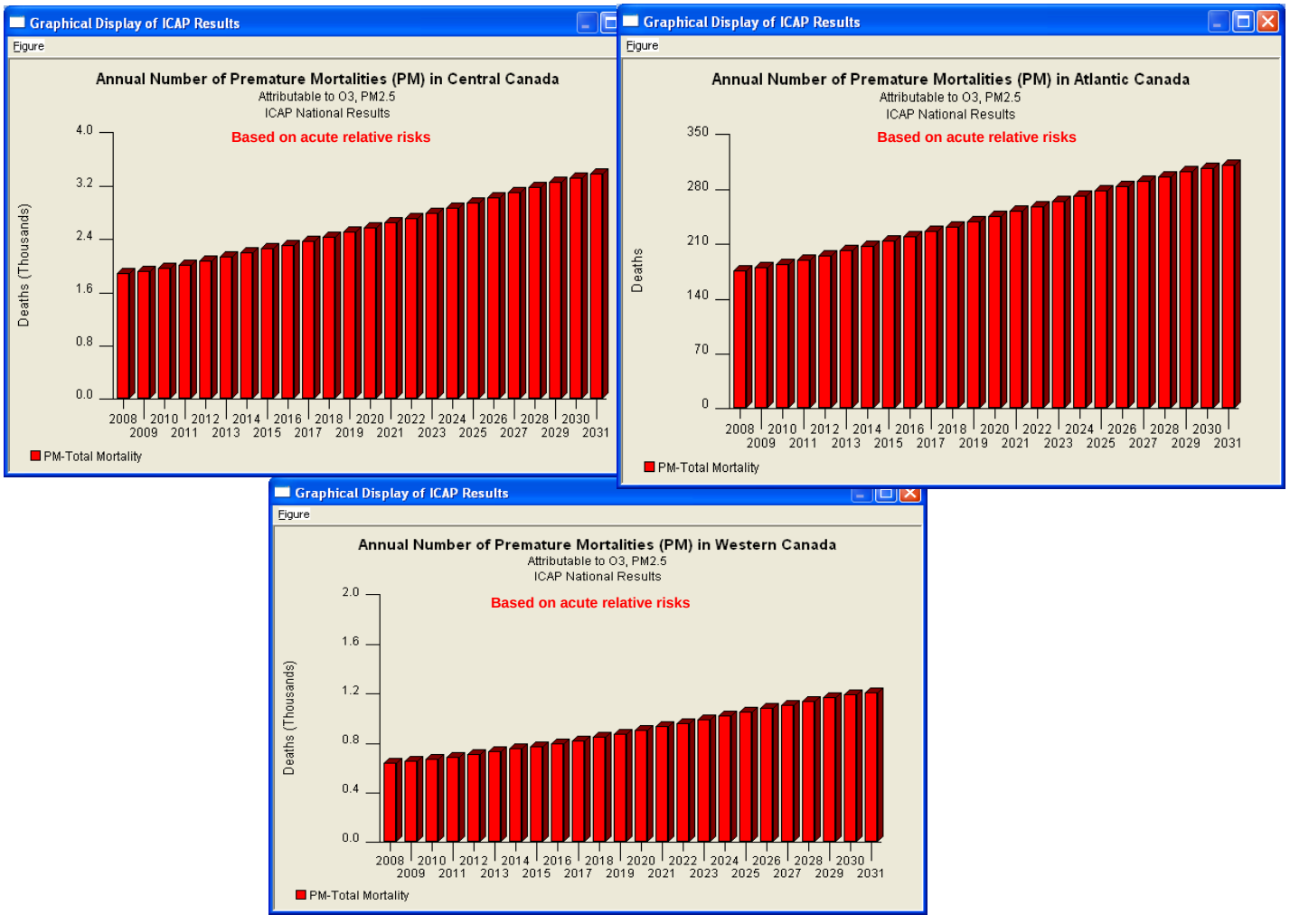
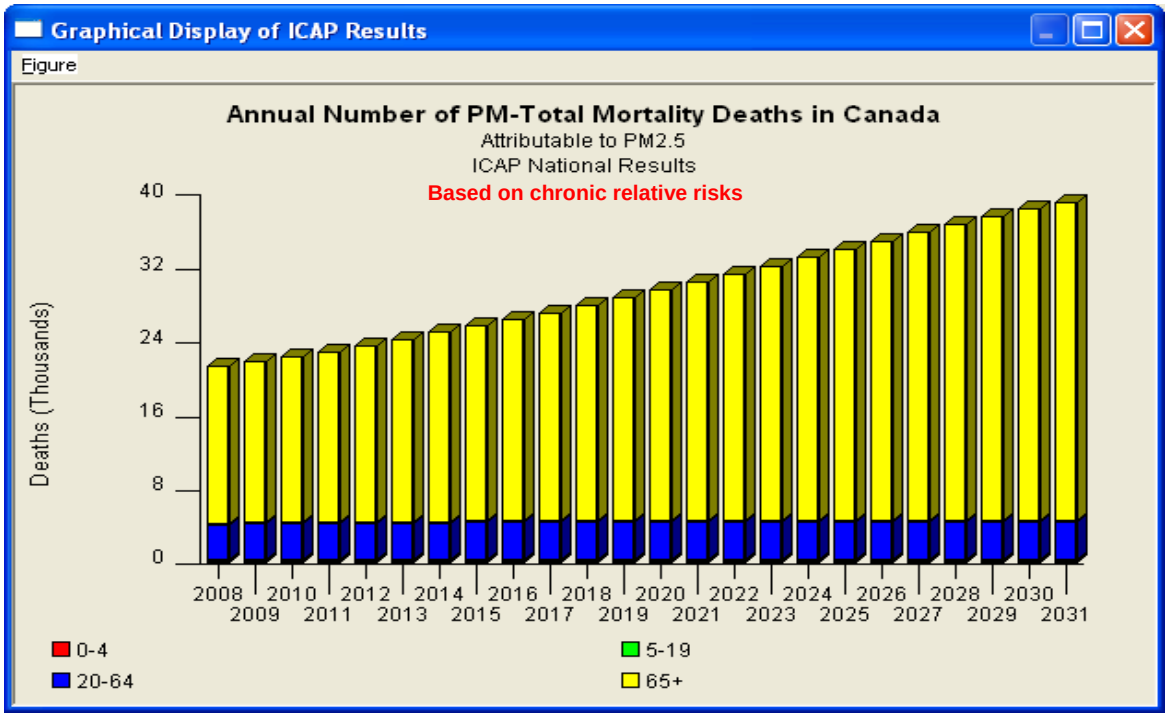


Figure 3 - Regional Distribution of Acute Premature Mortality[11]



[11] Note the units on the vertical axes in these graphs vary from one region to another.

Figure 4 - Chronic Premature Deaths by Age Group



The forecast number of premature deaths associated with chronic exposure to air pollution is more than nine times higher than the forecast acute premature mortality cases. This large difference is indicative of the morbidity health damages that may be overlooked using acute exposure relative risks for morbidity health outcomes[12]. The acute premature mortality cases are expected to be captured largely by the forecasts of chronic premature deaths and therefore, the two estimates should not be added together.

6.1.2 Hospital Admissions

The risks for all other health endpoints are based on time-series studies (i.e., acute effects of air pollution). For this reason, the following morbidity damages are likely an underestimate of the total damages when taking into account morbidity impacts associated with chronic exposure to air pollution.

Figure 5 presents the expected number of hospital admissions associated with respiratory and cardiovascular illnesses.

In 2008, the total hospital admissions associated with air pollution exposure are estimated at 11,000. Most of these cases (i.e., about 60%) are associated with cardiovascular illnesses.

Figure 6 presents total hospital admissions broken down by age group.

Most of the estimated hospital admissions are associated with the elderly (i.e., 65+ age group). However, young children up to age 4 also account for a significant portion of these cases (i.e., about 7.5%). As with other illness risk estimates, the proportion of cases associated with the elderly is forecast to increase substantially as the "baby boomers" age and move into the oldest age class.

[12] No comparable chronic relative risks have been estimated and reported for morbidity health outcomes at this time.

Figure 5 - Hospital Admissions by Illness Type

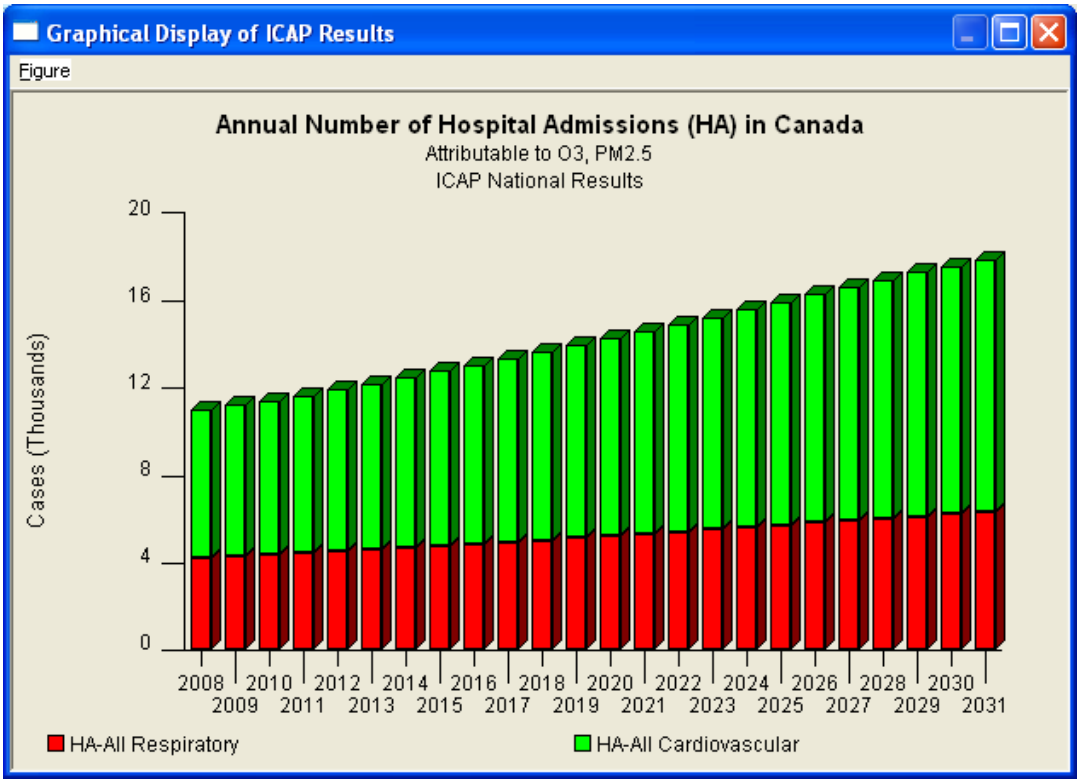
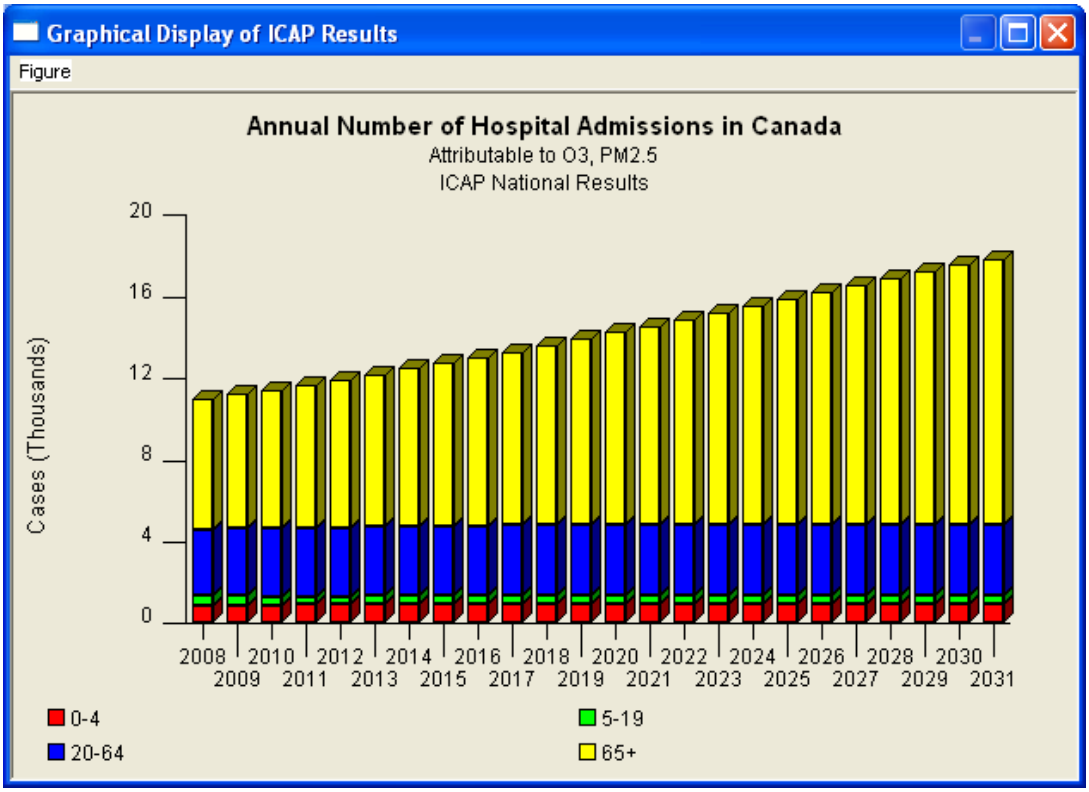


Figure 6 - Hospital Admissions by Age Group



The regional distribution of hospital admissions is similar to that for acute premature deaths. The same factors that determine the number of premature deaths affect the risk of less severe morbidity outcomes.

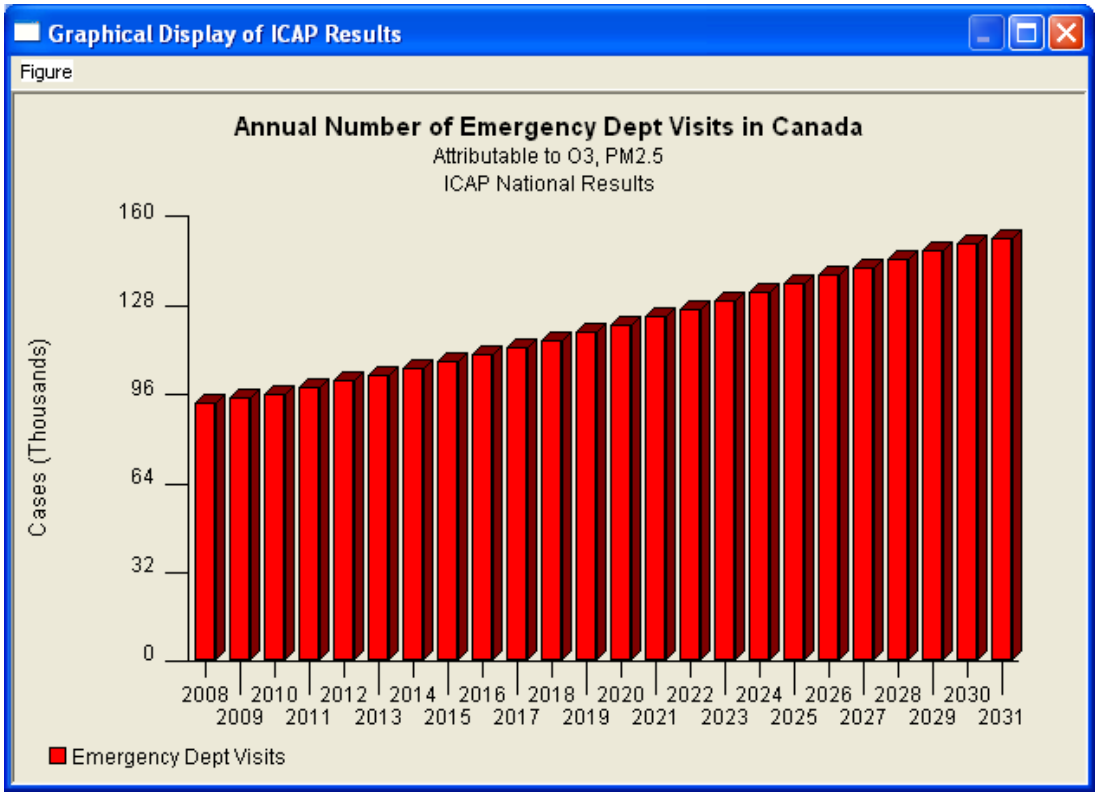
6.1.3 Emergency Department Visits

Less severe respiratory and cardiovascular illnesses are often treated by unscheduled emergency department visits. Figure 7 presents the expected number of emergency department visits in Canada associated with exposure to air pollution. The proportions of cardiovascular and respiratory-related illnesses are the same as those for hospital admissions. The reason is that same relative risks for cardiovascular and respiratory-related illnesses have been used for different severities of illnesses (see Section 4.2.6). The differences in the total numbers of cases is tied to variations in base incidence rates among different severities of a given illness type.

In 2008, the emergency department visits associated with air pollution exposure are estimated at over 92,000 cases. As with hospital admissions, most of these cases are associated with cardiovascular illnesses.

The distribution of these emergency department visits by age group is similar to that associated with hospital admissions. The distribution is strongly skewed toward the elderly age group.

Figure 7 - Total Emergency Department Visits



6.1.4 Minor Illnesses

Minor illnesses are the least severe adverse health outcome associated with air pollution exposure but are by far, the most common. Figure 8 presents the expected number of minor illnesses associated with exposure to air pollution broken down by three minor illness types.

In 2008, over 22 million minor illness days are expected to be attributable to air pollution. This total is expected to rise to over 26 million in 2031 if air quality does not change over that time. Most of these cases will be minor restricted activity days (i.e., slightly under 50%).

Figure 8 - Minor Illnesses by Illness Type

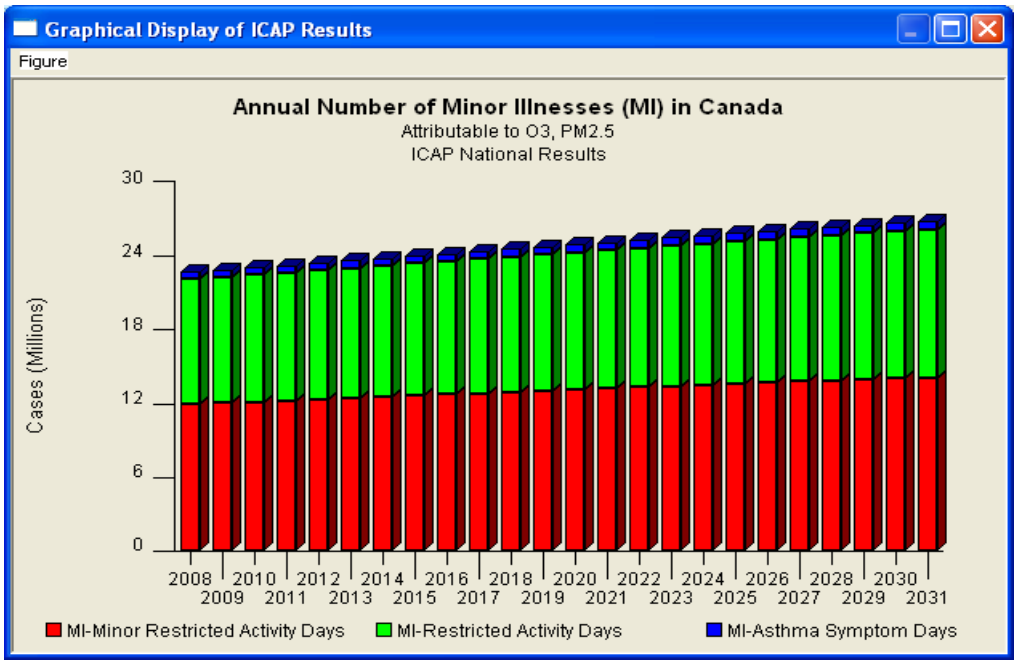
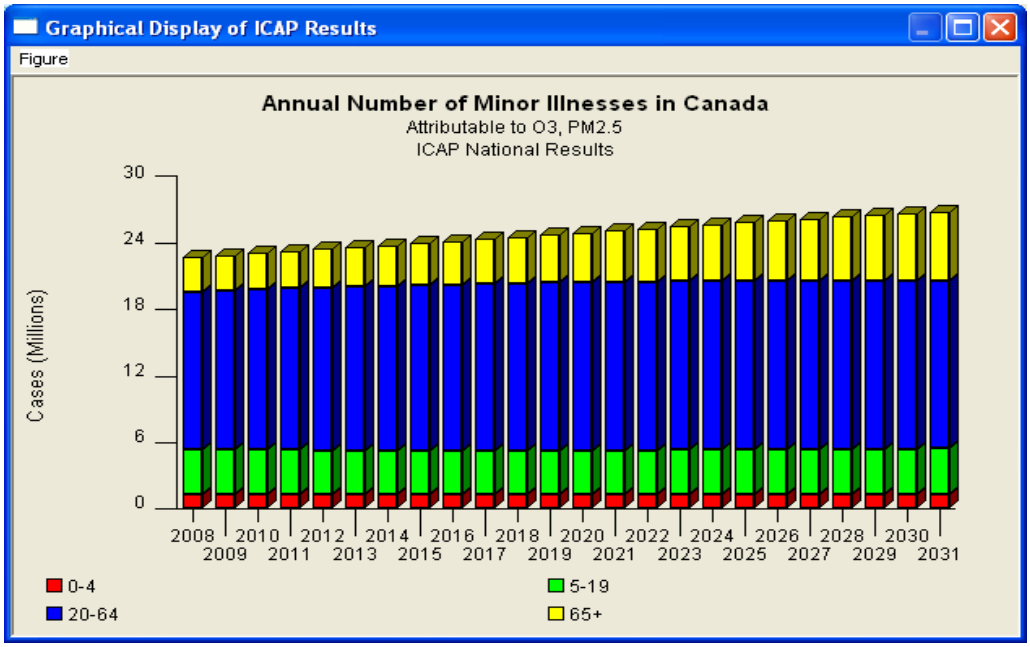


Figure 9 presents the expected number of minor illnesses cases broken down by age group. The distribution of these minor illness cases is concentrated in individuals aged 19-64[13]. This cohort comprises the majority of the Canadian population.

Figure 9 - Minor Illnesses by Age Group



[13] The age distribution of minor illnesses is uncertain since the derivation of minor illness base incidence rates was quite approximate (see Section 3.3.1). Base incidence rates for other illnesses suggest that minor illness base incidence rates will vary by age group and that the highest rates will be associated with the young and elderly age groups. Future refinements of the minor illness base incidence rates are expected to affect the distribution of cases among the age groups.

6.1.5 Summary

Table 1 summarises these national health damages associated with air pollution. These damages are distributed throughout Canada similar to the regional distribution of acute premature mortality cases shown previously in Figure 3. More detailed provincial results are presented in Appendix A.

Table 1 - National Health Damages Summary: 2008, 2015 and 2031

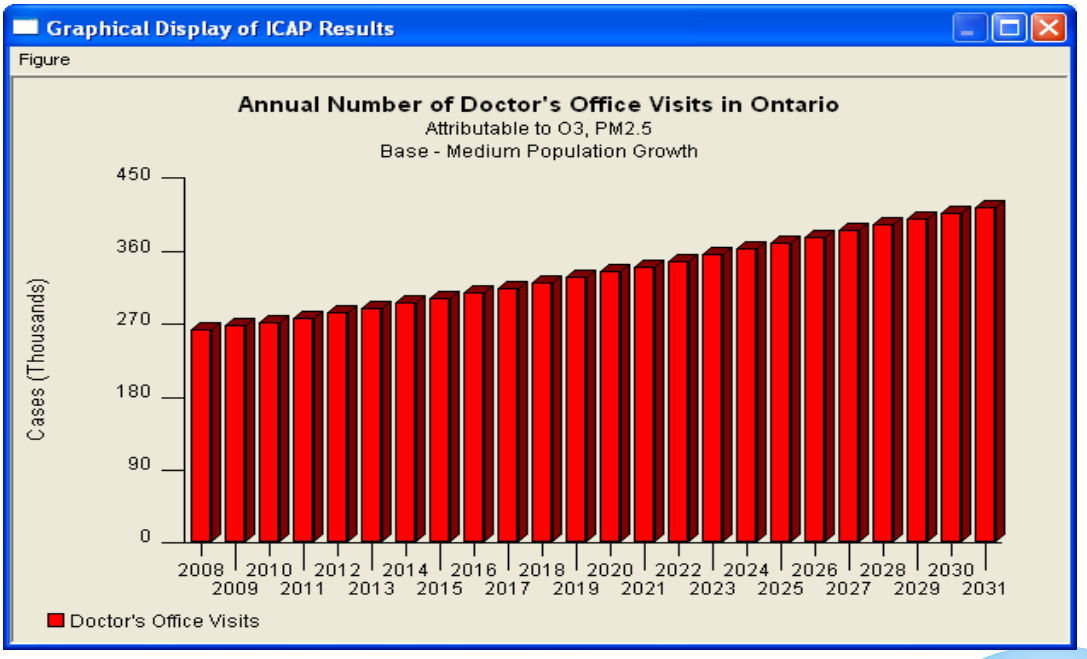
	Example Years		
	2008	**2015**	**2031**
Premature Deaths	**2,682**	**3,233**	**4,917**
Hospital Admissions	**10,966**	**12,685**	**17,748**
Emergency Dept. Visits	**92,690**	**107,896**	**152,266**
Minor Illnesses	**22,542,500**	**23,853,900**	**26,691,900**

Following are two examples of health damages that are not included in these national totals. These additional results provide some insight into the magnitude of health damages that are not included in Table 1.

6.1.6 Doctor's Office Visits

Default base incidence rate coefficients for the ICAP routine for forecasting doctor's office visits have been compiled only for Ontario at this time. Accordingly, this section includes only results for Ontario. Figure 10 presents the expected number of Ontario doctor's office visits associated with exposure to air pollution.

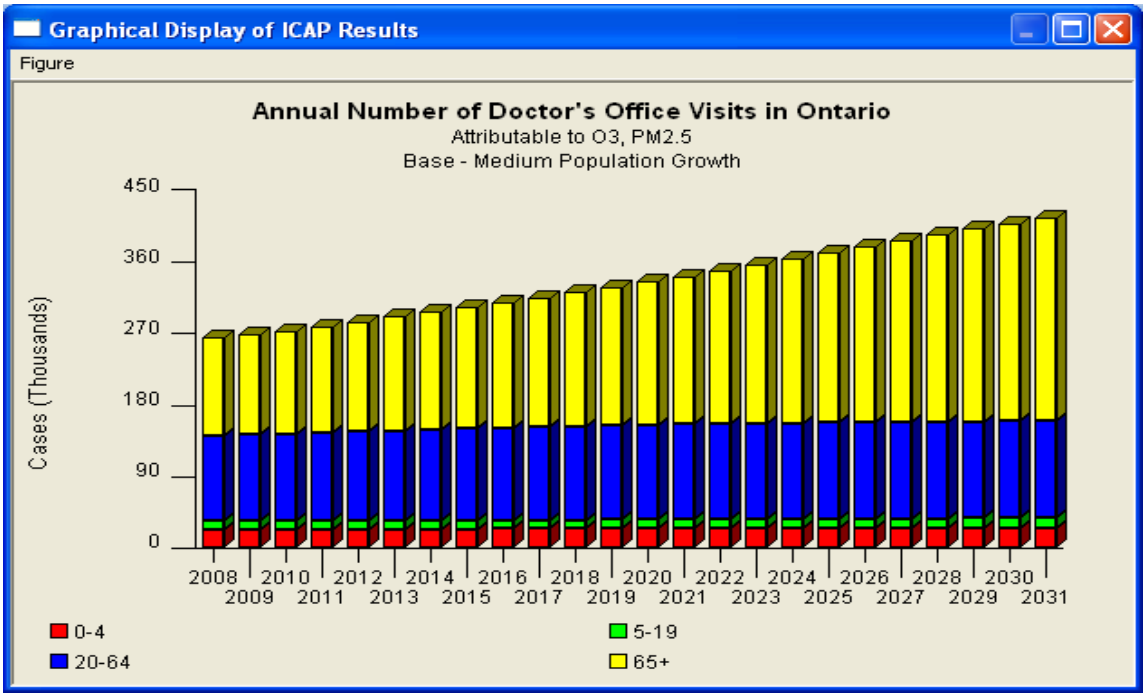
Figure 10 - Ontario Doctor's Office Visits



In 2008, Ontario doctor's office visits associated with air pollution exposure are estimated at over 260,000 cases. This total is expected to rise to over 410,000 in 2031 if air quality does not change over that time. As with more severe effects, most of these cases are associated with cardiovascular illnesses.

As shown in Figure 11, the distribution of these doctor's office visits by age group is similar to that associated with hospital admissions. The distribution is skewed toward the elderly age group and becomes increasingly so over time.

Figure 11 - Ontario Doctor's Office Visits by Age Group



The DOV cases for other provinces have been approximated using the Ontario results. More specifically, the ratio of DOV cases to hospital admissions and emergency department visits in Ontario have been calculated. These ratios were then used with the numbers of hospital admissions and emergency department visits in each province to estimate the expected number of DOVs. The average of these two estimates for each province was used to approximate the expected number of DOVs. Using this approach, it is estimated that the number of doctor's office visits associated with air pollution in Canada in total is about 2.5 times the Ontario total. In other words, a first approximation of the number of doctor's office visits in Canada in 2008 caused by air pollution is in the range of 620,000. In 2031, this total would increase to approximately 940,000 cases per year.

6.1.7 Early Development Effects

Early development effects are included in ICAP for illustrative purposes only. Only one early development effect is activated in the new version of ICAP and that effect (i.e., impaired lung development) is the basis for the following forecasts. These results are for Ontario only and are not included in the overall national or Ontario damage totals.

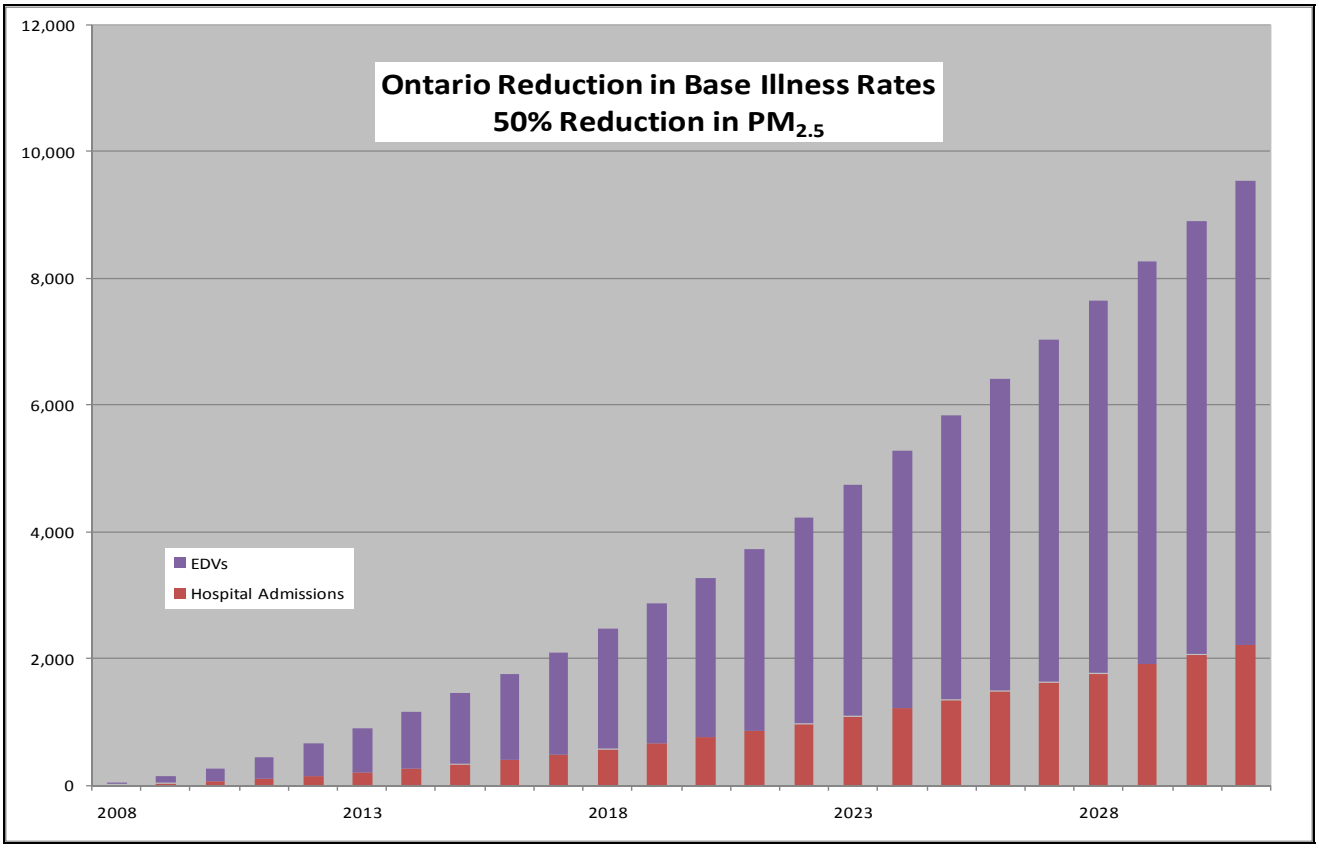
These early development effects are only exhibited if air quality changes over time[14]. For the purposes of this illustration, it is assumed that concentrations of $PM_{2.5}$ in Ontario are reduced by 50% in 2008relative to the 2007

[14] See technical explanation of this early development effects routine in Section 5.2 and Section D.5.2 of Appendix D for further details

ambient concentrations[15]. To show the effect of early development impacts, ICAP was run using this hypothetical air quality forecast with and without the early development effects routine activated. The difference in illness frequency between the two runs is attributed to early development effects.

These avoided damages are associated with two closely interrelated changes. First, reducing early development impacts over time will reduce base incidence rates for certain illnesses within a population. This effect on base incidence rates is independent of individual air pollution events. In other words, reducing air pollution will improve the baseline health of the population. The potential effect of reduced base incidence rates for hospital admissions and emergency department visits in Ontario is shown in Figure 12. Similar effects will also be evident for other major illness types as well (e.g., doctor's office visits, minor illnesses).

Figure 12 - Illustrative Example for Ontario of Reduced Base Incidence Rates



This improvement in overall health is measured by the difference in the base number of illnesses per year for different age groups and illness types. In other words, as the annual base incidence rate for a given illness declines with improved air quality, this improvement in the overall health of the population is attributable to improved air quality. This effect will persist for a long time and will cumulatively increase as the proportion of individuals in the population with impaired lung function declines. Each new cohort of children will enjoy this benefit for their entire lives.

In this hypothetical example, the numbers of avoided hospital admissions and emergency department visits cumulatively increase such that in 2031, the number of avoided cases is over 2,200 and 7,300 cases, respectively. These effects are associated strictly with individuals that were less than 19 in 2008. By 2031, the maximum age of these individuals is 44 and the average age is much less. As result the increasing trend in avoided illnesses evident

[15] Obviously, such a major reduction in $PM_{2.5}$ could not be practically achieved so suddenly. This sudden reduction simply makes interpretation of the impacts of early development effects easier for illustrative purposes.

in Figure 12 will persist well beyond 2031 and will not level out until those persons in the population that were exposed to the higher levels of air pollution in 2007 and previously have died.

Air pollution impacts are forecast based on relative risks; these risks are relative to base incidence rates of certain illnesses. The second beneficial outcome of reduced lung impairment in the population is that during poor air quality events, lower base incidence rates means that less acute cases will be occurring. Another way to consider this effect is that healthy people are more able to resist the negative effects of air pollution. This benefit of reduced susceptibility is also included as a benefit of reduced early development effects.

Notably, the impact of reduced early development effects on the overall base incidence rates in a population (i.e., the overall health of the population) is significantly greater than the reduction in the risk of acute air pollution-related illnesses. Air pollution-related cases of hospital admissions and emergency department visits will be reduced in 2031 by about 10 and 30 cases, respectively, in this hypothetical example.

This early development effects routine demonstrates how early development effects on young people persist in a population for an extended time and affect the overall health of a population. Indeed, the full effect of this hypothetical improvement in air quality would take an entire generation before a new equilibrium in the base level of public health would be reached and the effects would be fully evident in terms of reduced adverse health outcomes. These cumulative effects of exposure to air pollution have significant implications for the future costs of healthcare; costs which are largely irreversible once lung damage has occurred in young people.

6.2 Economic Damages[16]

In addition to estimates of physical health effects, ICAP provides estimates of the corresponding economic damages that these illnesses represent. These economic damages are estimated according to four major cost categories, namely,

- Lost productivity
- Healthcare costs
- Pain and suffering
- Loss of life

Table 2 presents a summary of the economic damages of air pollution[17] in Canada for 2008, 2015 and 2031 in constant 2006 dollars.

6.2.1 Lost Productivity

Lost productivity includes the time lost due to treatment and recovery from air pollution-related illnesses. Lost productivity also includes time lost by patients and caregivers. Lost time is valued at the going average wage rate for the corresponding age of the person affected.

In 2008, economic damages in Canada due to lost time from air pollution-associated illness are expected to be in the order of $690 million. This total is expected to increase to over $760 million by 2031.

6.2.2 Healthcare Costs

Healthcare costs include the costs of institutional care plus medication. In 2008, economic damages associated with healthcare costs in Canada for air pollution-related illness are expected to be in the order of $440 million. This total is expected to increase to over $610 million by 2031.

[16] None of the economic damages included in this section account for costs associated with doctor's office visits or early development effects related to air pollution. As a result, these economic damages forecasts are likely an underestimate of the full costs of air pollution in Canada.

[17] These economic damages are based on acute premature mortality cases. Given the high economic value assigned to avoiding premature mortality, the corresponding economic damages for chronic premature mortality would be much higher.

Table 2 - National Economic Damages Summary: 2008, 2015 and 2031[18]

	Example Year (Damages expressed in millions)		
	2008	**2015**	**2031**
Lost Productivity	**$688**	**$721**	**$765**
Healthcare Costs	**$438**	**$485**	**$614**
Quality of Life	**$379**	**$410**	**$487**
Loss of Life	**$6,552**	**$7,905**	**$11,836**
Total	**$8,058**	**$9,522**	**$13,702**

6.2.3 Quality of Life

Economic damages associated with reduced quality of life due to illness (i.e., pain and suffering) relate to the amount that people are willing to pay to avoid illnesses that cause pain and suffering. In 2008, economic losses in Canada associated with loss of quality of life from air pollution-related illness are expected to be in the order of $380 million. This total is expected to increase to nearly $490 million by 2031.

6.2.4 Loss of Life

The value of premature death is estimated based on the willingness of people to pay to reduce this risk (i.e., to reduce the risk of premature death due to air pollution exposure). In 2008, economic losses involving premature death are expected to be in the order of $8 billion. This total is expected to increase to nearly $14 billion by 2031.

6.2.5 Total Damages

Combining these four economic damage categories produces a Canada-wide estimate of economic damages associated with exposure to air pollution. In 2008, overall economic losses associated with air pollution exposure are expected to be over $10 billion. This total is expected to increase to over $17 billion by 2031.

6.2.6 Regional Distribution of Damages

These economic damages estimates are derived from the individual provincial ICAP systems using consistent scenario parameters. Appendix A provides a breakdown of these aggregate Canadian results by province. The regional distribution of damages is closely tied to the regional distribution of Canada's population and regional air quality. High population densities tend to be associated with poorer air quality so this further concentrates the damages in these regions.

[18] All economic values are shown in millions using constant 2006 dollars.

7. Conclusions and Recommendations

These conclusions and recommendations follow from the results and discussion presented in the preceding chapters.

7.1 Air Pollution Damages

Air pollution is expected to cause significant numbers of cases of illness and premature death in Canada in 2008. The numbers of cases will increase over time as the total population grows but even more importantly as the "baby boomers" age. These air pollution-related cases of illness and premature death are concentrated in major urban areas, particularly in Ontario and Quebec.

The economic cost of poor air quality is significant. Much of the cost is being borne by those people already economically compromised by poor health. All Canadians through their taxes are paying for the increased healthcare costs related to air pollution. These results show that significant benefits as measured by personal well being and in terms of economic value could be realized from improving air quality in Canada.

7.2 Expansion of Doctor's Office Visits

The Ontario results for air pollution damages associated with doctor's office visits indicate that a significant number of air pollution-related illness cases are being excluded in the damages forecasts for the other provinces and for Canada as a whole. ICAP has the capability to forecast these damages if suitable base incidence rates and corresponding economic damages coefficients can be estimated for each province. The Ontario results show that deriving these default coefficients should be a future priority.

7.3 Early Development Impacts

The CMA investigated the potential to derive the relationships between impaired lung development effects of air pollution and life-long consequences in terms of demand for healthcare services. The results of that initial investigation provide good reason to pursue this matter further.

The EOEP proved to be an efficient and reliable means to derive difficult-to-estimate risks. A similar methodology could be used to derive risks for early development effects on base incidence rates for specific illnesses. If this methodology proves fruitful, early development effects should be included in future ICAP health damages forecasts.

Several other potential early development effects of air pollution have been identified as being of concern (see Section 4.2.5). ICAP has the potential to incorporate damage estimation routines for these health effects. The major gap is the absence of adequate research to derive relative risks for these effects. The CMA should continue to monitor the relevant literature and update the provincial ICAP systems when adequate research is available for these other early development health effects.

7.4 Background Pollutant Concentrations

A constant percentage of the ambient concentration of O_3 is deducted to account for natural background levels. The background levels and percentage proportions vary from location to location. Changing the background concentration affects directly health damage forecasts. Ideally, the background proportions should be derived for each census division in each province. These proportions were not readily available but might be estimated by local air pollution agencies. The potential for refining these background concentrations, particularly for $PM_{2.5}$ and O_3, should be further investigated.

7.5 Base Incidence Rates for Minor Illnesses

Minor illnesses account for a large portion of the air pollution-related cases in Canada. As well, these illnesses in total account for a significant portion of the economic damages associated with air pollution, particularly associated with lost productivity. That being said, comprehensive minor illness base incidence rate statistics for Canada are generally not available. This gap introduces considerable uncertainty into the ICAP illness and economic damages forecasts. These minor illness statistics are valuable as well for other public health analyses. For these reasons, the CMA should work with the federal and provincial governments to secure reliable minor illness statistics on a regular basis that will allow base incidence rates for different types of minor illnesses and age groups to be estimated for each province or at least, for Canada as a whole.

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Appendix A – Provincial Estimates of Air Pollution Damages

This appendix provides ICAP results for each province. Each provincial ICAP system was configured to include:

- all of the census divisions in the province
- $PM_{2.5}$ and O_3 only
- constant ambient concentrations from 2008 to 2031
- medium population growth with medium migration trends forecast
- total mortality
- respiratory and cardiovascular-related hospital admissions
- respiratory and cardiovascular-related emergency department visits
- minor illnesses

This appendix presents select results for each province. More detailed results for each of the provinces can be produced using the ICAP output graphic display program that is part of the ICAP system which can be downloaded from the CMA website (http://www.cma.ca/index.cfm/ci_id/86830/la_id/1.htm)

For each province, the annual numbers of health cases associated with air pollution are shown. Two tables are also included; one summarizes the numbers of different types of air pollution-related health cases for three example years (i.e., 2008, 2015 and 2031); the other table provides the corresponding economic damages for these example years.

The trend over time in the number of minor illness cases differs significantly from the decrease over time for trends for other illnesses (e.g., hospital admissions, emergency department visits). For example in Figure 13 for Newfoundland, the number of air pollution-related cases increases significantly over time. On the other hand, the number of minor illness cases shown in Figure 14 decreases slightly over time. The reasons for these divergent trends over time are as follow.

First, the overall population of Newfoundland is forecast to decline in the future. As the population declines fewer people are exposed to air pollution leading to fewer air-pollution-related cases. On the other hand, the average age of the population is increasing as "baby boomers" age. The elderly account for a relatively high proportion of air pollution-related illnesses. The net result is that effects of the aging population overwhelm the offsetting effects of a declining population for those illnesses showing an increase over time.

However in the case of minor illnesses unlike with other types of illnesses (e.g., hospital admissions), the base incidence rates for minor illnesses do not vary among the age groups (see tables in Appendix B). As a result, the effect of an aging population is not as pronounced and the trend over time for minor illnesses is driven by the decline in the size of the population. Improving the estimates of base incidence rates for minor illnesses has been recommended partly for this reason (see Section 7.5).

A second seemingly unusual trend over time in the following results is also closely tied to the changing demographics of the provinces. A declining trend over time for economic damages associated with lost productivity is evident for some provinces despite an increase in illness cases. For example in Table 4 which shows the economic damages for Newfoundland, lost productivity damages are shown declining from slightly over $2 million in 2008 to less than $1.8 million in 2031.

Lost time due to illness is valued at the provincial average wage rate for each age and gender group (see tables in Appendix C). The average wage rate for people over 65 declines markedly. As the portion of cases associated with people over 65 increases, the result is that average value of a lost day of work declines. This leads to the result that the number of cases may be climbing but the lost productivity damages are declining. Note however, that the totals for other economic damage categories are increasing as would be expected.

A.1 Newfoundland and Labrador

The following summary results are for Newfoundland and Labrador.

Figure 13 - NL: Premature Deaths, Hospital Admissions and Emergency Department Visits

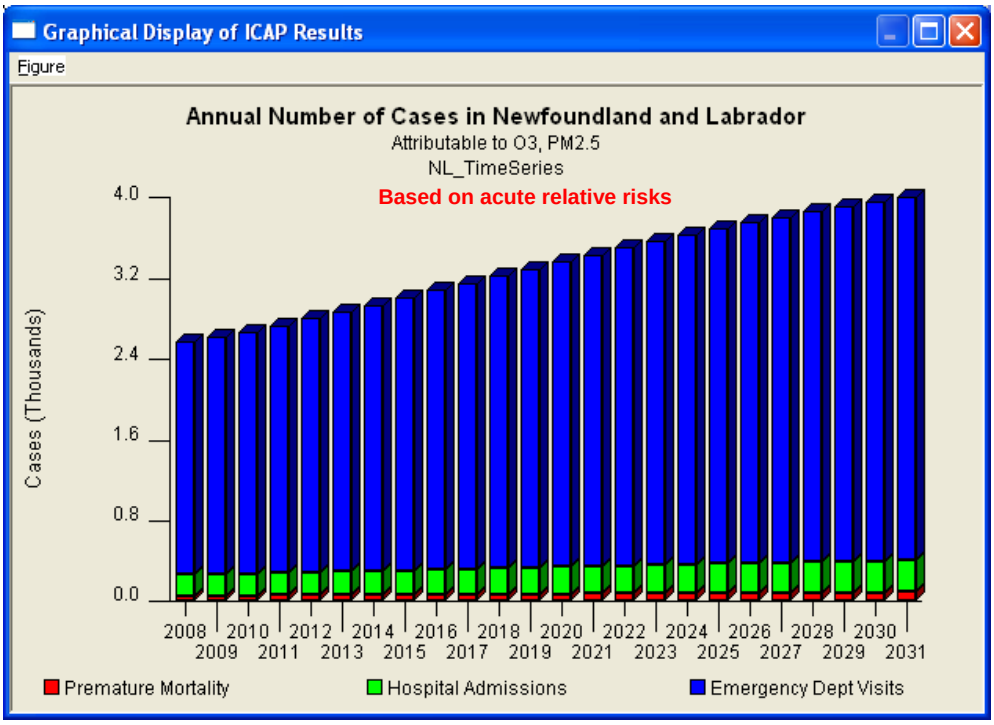


Figure 14 - NL: Minor Illnesses by Illness Type

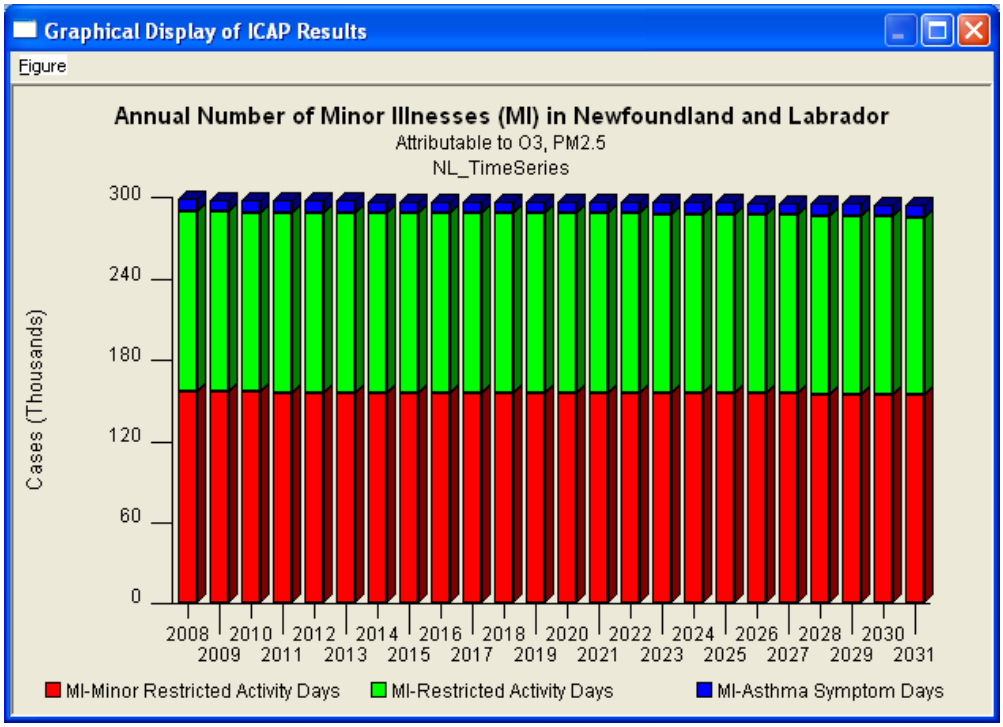


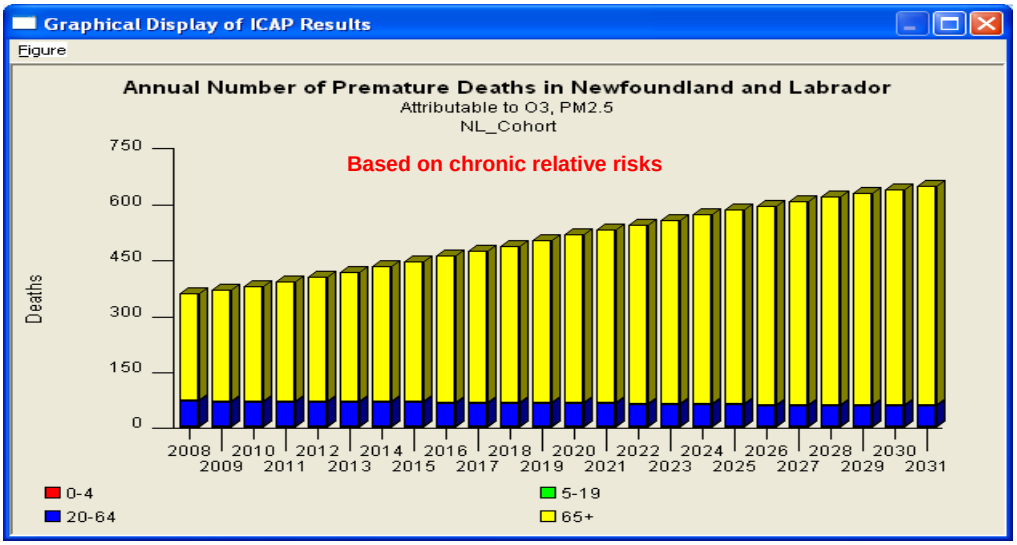
Table 3 - NL: Health Damages Summary: 2008, 2015 and 2031

	Example Years		
	2008	**2015**	**2031**
Premature Deaths	**43**	**54**	**78**
Hospital Admissions	**211**	**241**	**311**
Emergency Dept. Visits	**2,312**	**2,700**	**3,602**
Minor Illnesses	**297,764**	**296,315**	**293,426**

Table 4 - NL: Economic Damages Summary: 2008, 2015 and 2031

	Example Years (in $ thousands)		
	2008	**2015**	**2031**
Lost Productivity	**$6,345**	**$6,128**	**$5,533**
Healthcare Costs	**$7,071**	**$7,756**	**$9,372**
Pain and Suffering	**$5,863**	**$6,167**	**$6,884**
Loss of Life	**$106,372**	**$131,954**	**$186,612**
Total	**$125,652**	**$152,005**	**$208,402**

Figure 15 - NF: Chronic Premature Mortality



A.2 Nova Scotia

The following summary results are for Nova Scotia.

Figure 16 - NS: Premature Deaths, Hospital Admissions and Emergency Department Visits

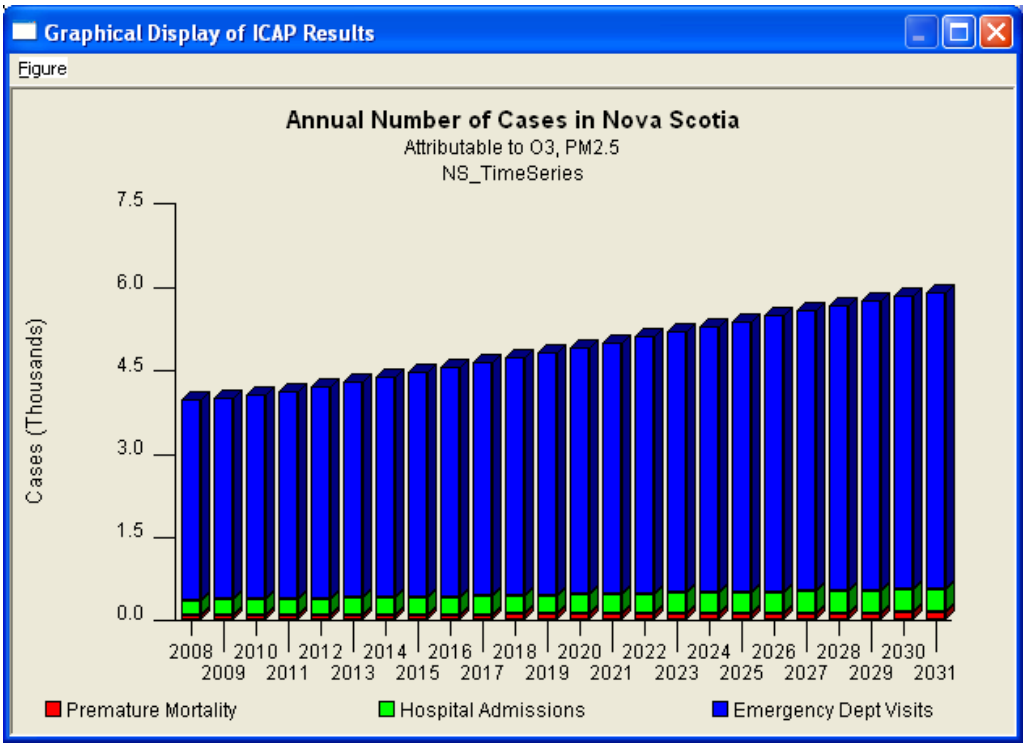


Figure 17 - NS: Minor Illnesses by Illness Type

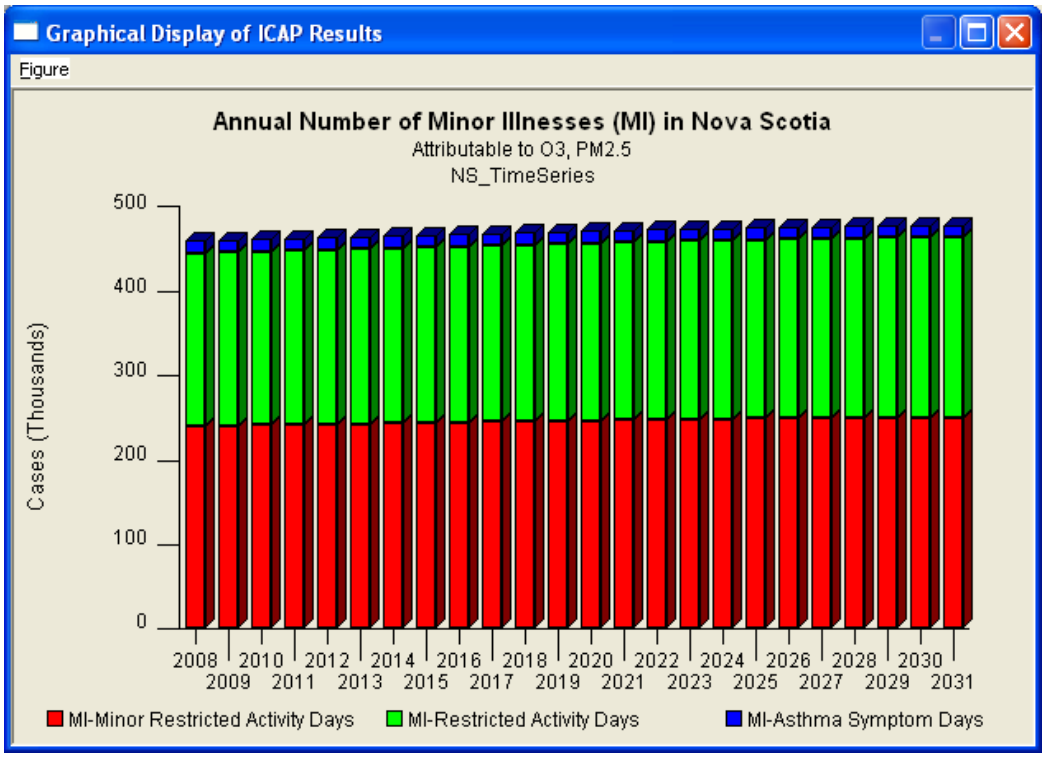


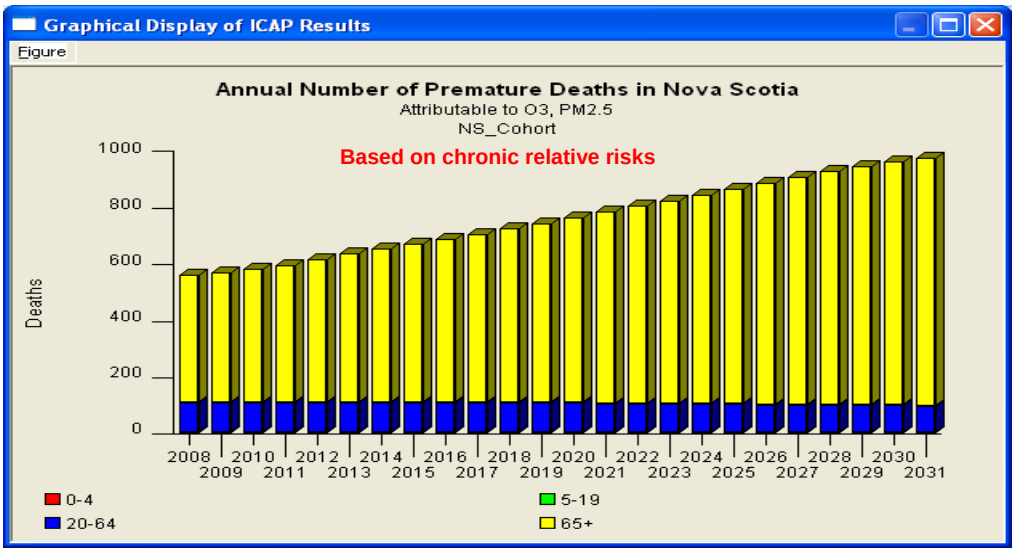
Table 5 - NS: Health Damages Summary: 2008, 2015 and 2031

	Example Years		
	2008	**2015**	**2031**
Premature Deaths	**69**	**82**	**120**
Hospital Admissions	**277**	**315**	**416**
Emergency Dept. Visits	**3,596**	**4,054**	**5,335**
Minor Illnesses	**457,795**	**464,090**	**475,907**

Table 6 - NS: Economic Damages Summary: 2008, 2015 and 2031

	Example Years (in $ thousands)		
	2008	**2015**	**2031**
Lost Productivity	**$11,098**	**11,005**	**$10,380**
Healthcare Costs	**$10,159**	**11,018**	**13,305**
Pain and Suffering	**$8,991**	**$9,460**	**$10,690**
Loss of Life	**$167,350**	**$201,201**	**$286,585**
Total	**$197,598**	**$232,684**	**$320,960**

Figure 18 - NS: Chronic Premature Mortality



A.3 New Brunswick

The following summary results are for New Brunswick.

Figure 19 - NB: Premature Deaths, Hospital Admissions and Emergency Department Visits

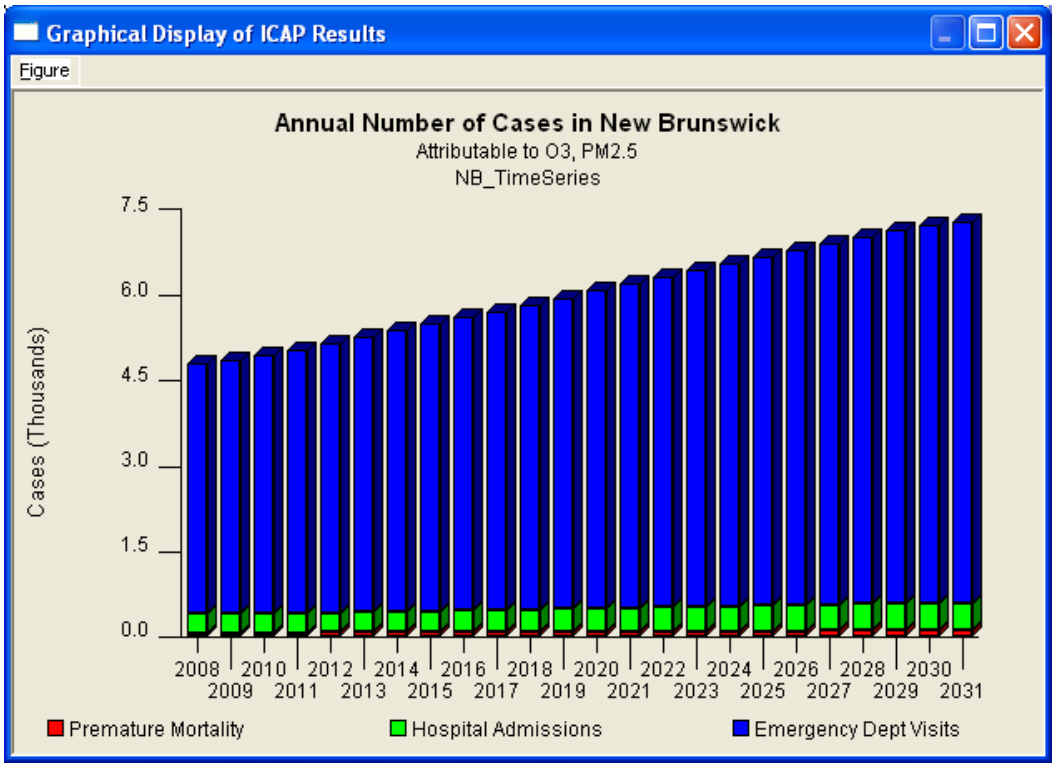


Figure 20 - NB: Minor Illnesses by Illness Type

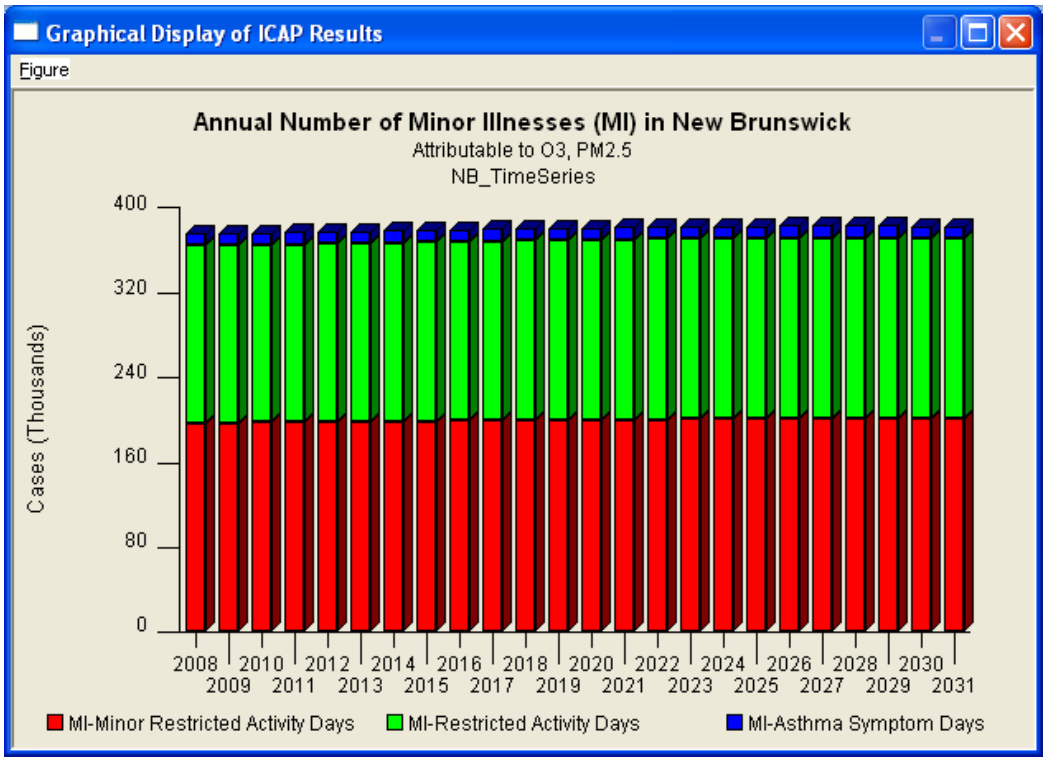


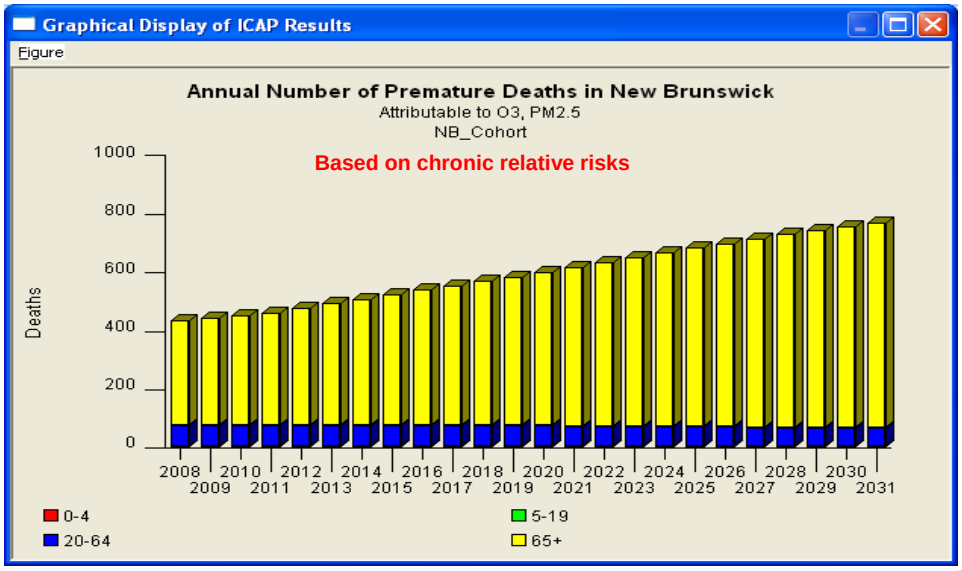
Table 7 - NB: Health Damages Summary: 2008, 2015 and 2031

	Example Years		
	2008	**2015**	**2031**
Premature Deaths	**54**	**65**	**96**
Hospital Admissions	**327**	**371**	**486**
Emergency Dept. Visits	**4,392**	**5,031**	**6,676**
Minor Illnesses	**374,250**	**377,420**	**380,830**

Table 8 - NB: Economic Damages Summary: 2008, 2015 and 2031

	Example Years (in $ thousands)		
	2008	**2015**	**2031**
Lost Productivity	**$7,770**	**$7,629**	**$6,992**
Healthcare Costs	**$8,954**	**$9,765**	**11,835**
Pain and Suffering	**$8,474**	**$9,034**	**$10,415**
Loss of Life	**$131,125**	**$159,450**	**$228,486**
Total	**$156,320**	**$185,880**	**$257,730**

Figure 21 - NB: Chronic Premature Mortality



A.4 Prince Edward Island

The following summary results are for Prince Edward Island.

Figure 22 - PE: Premature Deaths, Hospital Admissions and Emergency Department Visits

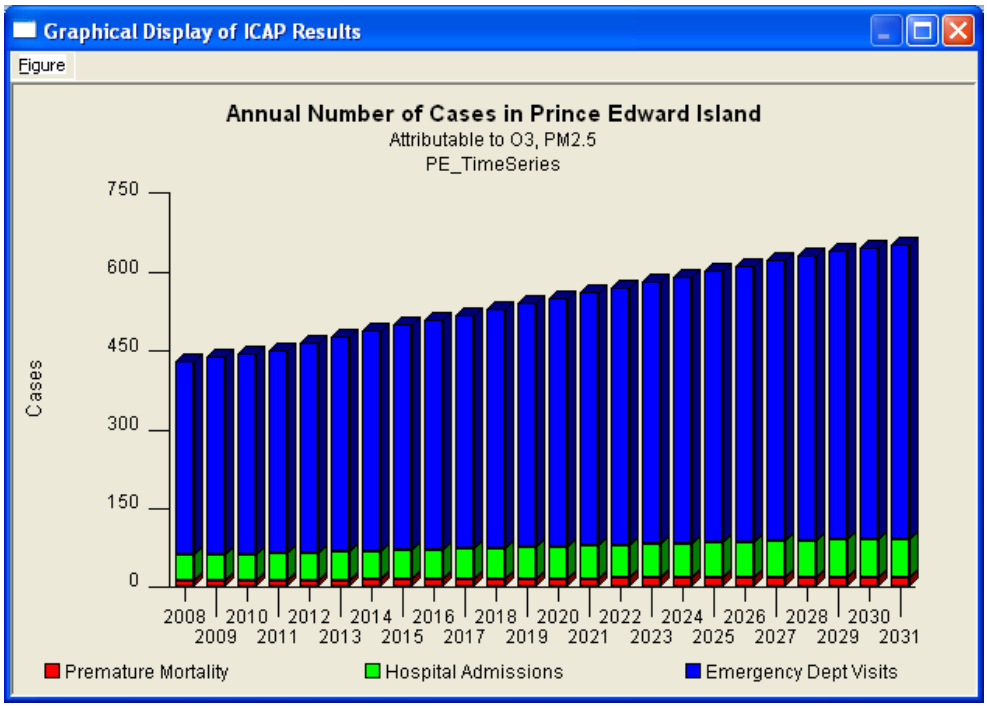


Figure 23 - PE: Minor Illnesses by Illness Type

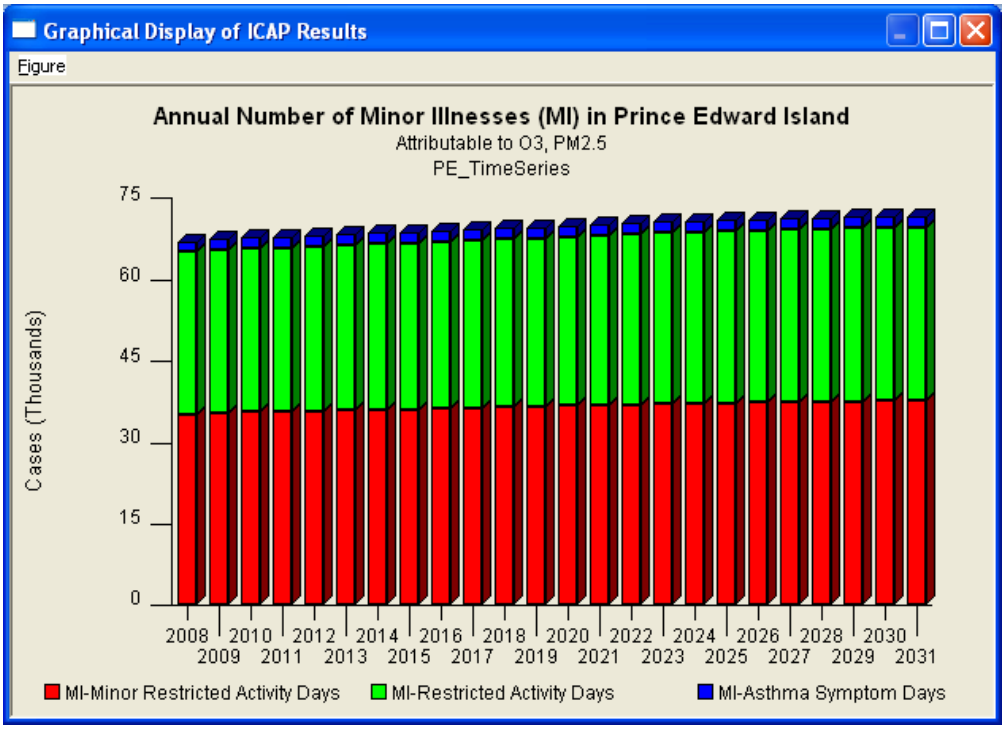


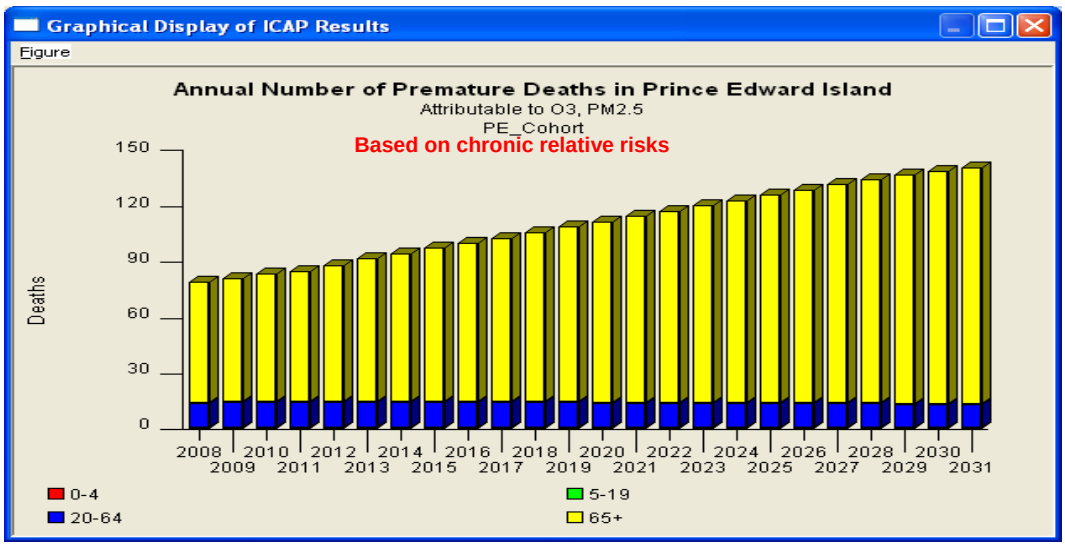
Table 9 - PE: Health Damages Summary: 2008, 2015 and 2031

	Example Years		
	2008	**2015**	**2031**
Premature Deaths	**10**	**12**	**18**
Hospital Admissions	**49**	**56**	**73**
Emergency Dept. Visits	**370**	**428**	**561**
Minor Illnesses	**66,826**	**68,480**	**71,490**

Table 10- PE: Economic Damages Summary: 2008, 2015 and 2031

	Example Years (in $ thousands)		
	2008	**2015**	**2031**
Lost Productivity	**$1,565**	**$1,578**	**$1,553**
Healthcare Costs	**$1,361**	**$1,490**	**$1,782**
Pain and Suffering	**$1,211**	**$1,286**	**$1,446**
Loss of Life	**$24,035**	**$29,706**	**$41,881**
Total	**$28,172**	**$34,060**	**$46,662**

Figure 24 - PE: Chronic Premature Mortality



A.5 Quebec

The following summary results are for Quebec.

Figure 25 - QC: Premature Deaths, Hospital Admissions and Emergency Department Visits

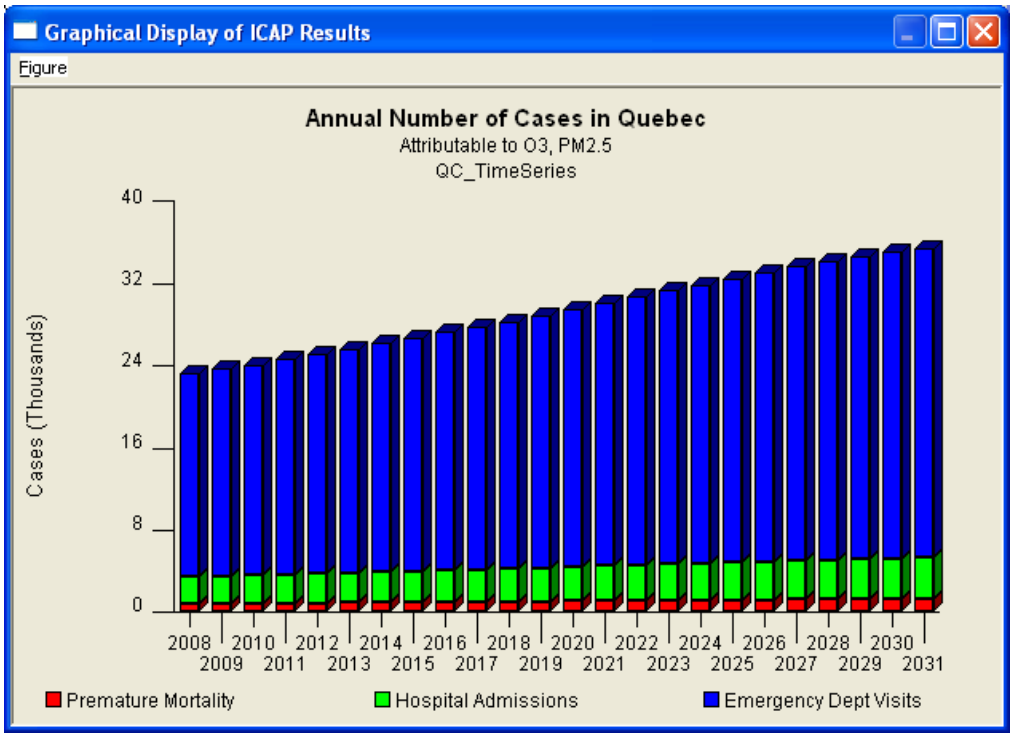


Figure 26 - QC: Minor Illnesses by Illness Type

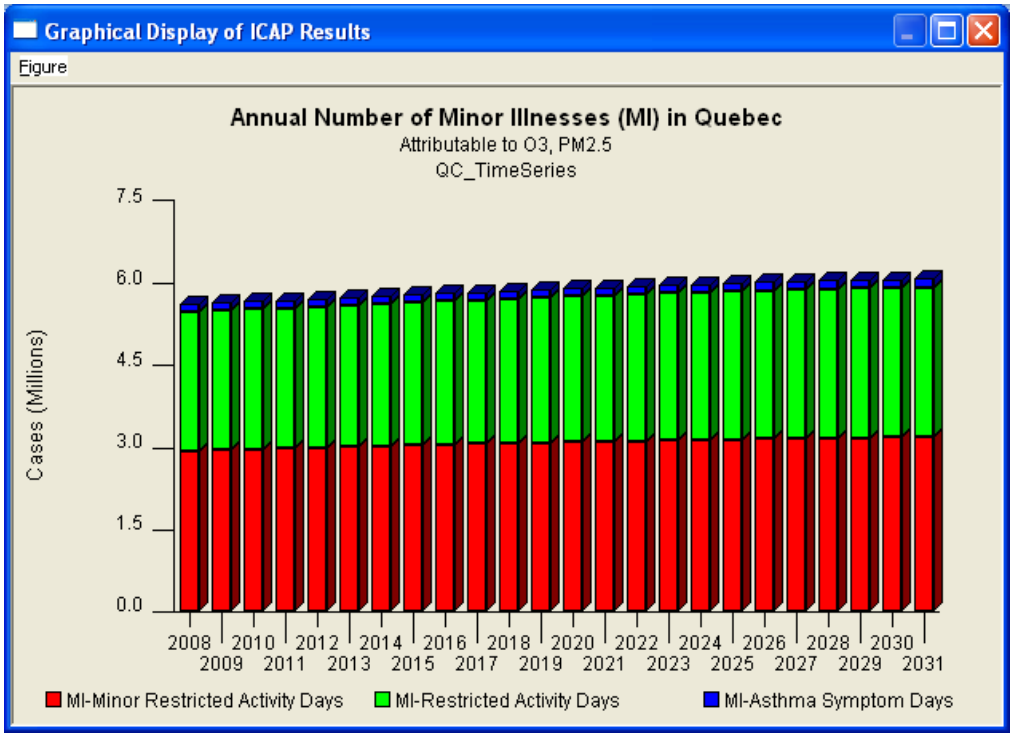


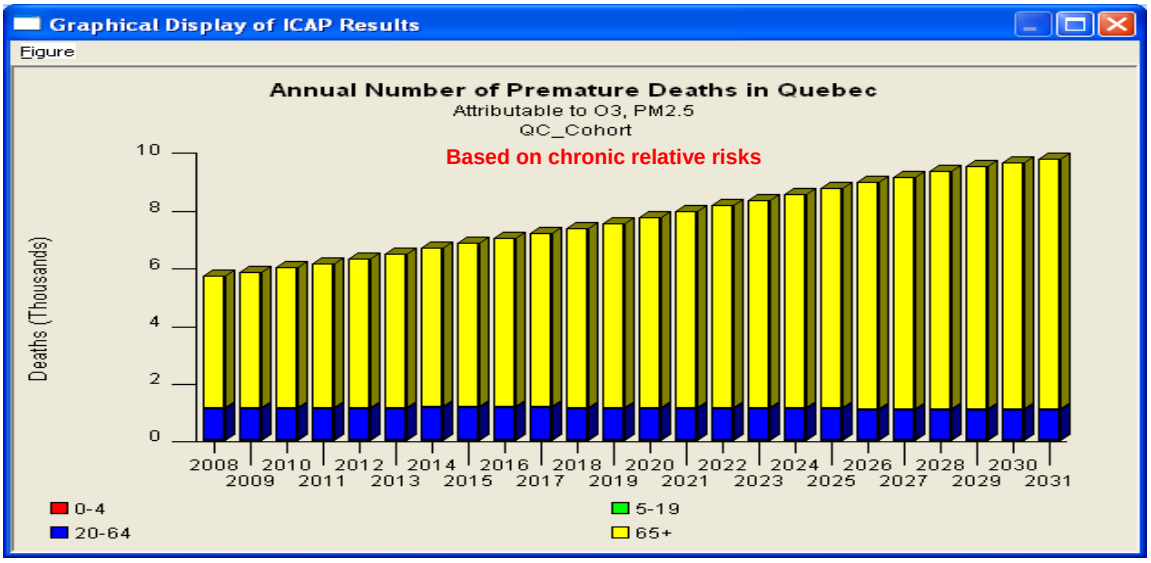
Table 11 - QC: Health Damages Summary: 2008, 2015 and 2031

	Example Years		
	2008	**2015**	**2031**
Premature Deaths	**691**	**825**	**1179**
Hospital Admissions	**2,667**	**3,043**	**3,988**
Emergency Dept. Visits	**19,730**	**22,692**	**30,139**
Minor Illnesses	**5,577,100**	**5,758,700**	**6,046,400**

Table 12 - QC: Economic Damages Summary: 2008, 2015 and 2031

	Example Years (in $ thousands)		
	2008	**2015**	**2031**
Lost Productivity	**$156,700**	**$158,200**	**$156,200**
Healthcare Costs	**$103,000**	**111,400**	**$130,700**
Pain and Suffering	**$91,800**	**$96,900**	**$107,600**
Loss of Life	**$1,693, 200**	**$2,020, 600**	**$2,830, 000**
Total	**$2,044,700**	**$2,387,100**	**$3,224,500**

Figure 27 - QC: Chronic Premature Mortality



A.6 Ontario

The following summary results are for Ontario.

Figure 28 - ON: Premature Deaths, Hospital Admissions and Emergency Department Visits

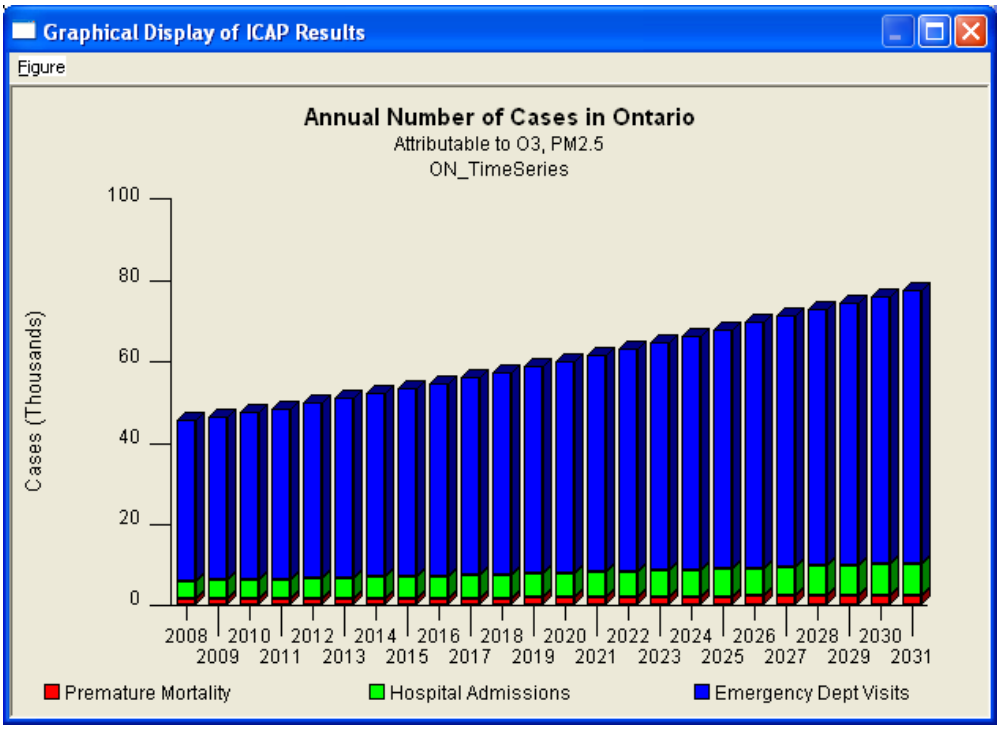


Figure 29 - ON: Minor Illnesses by Illness Type

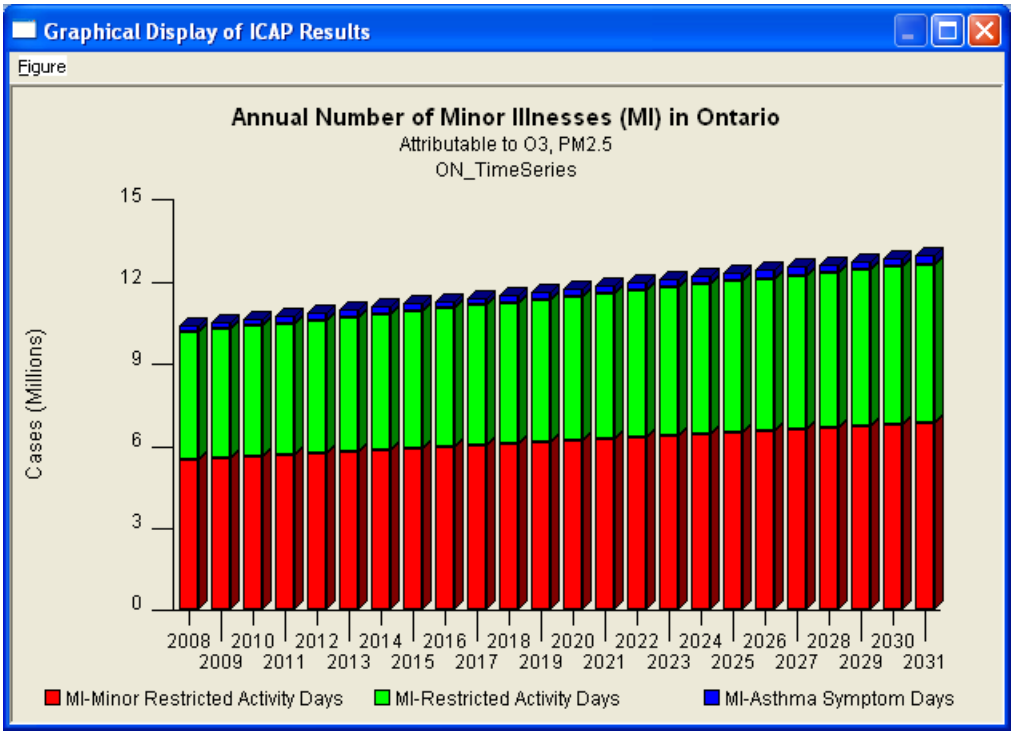


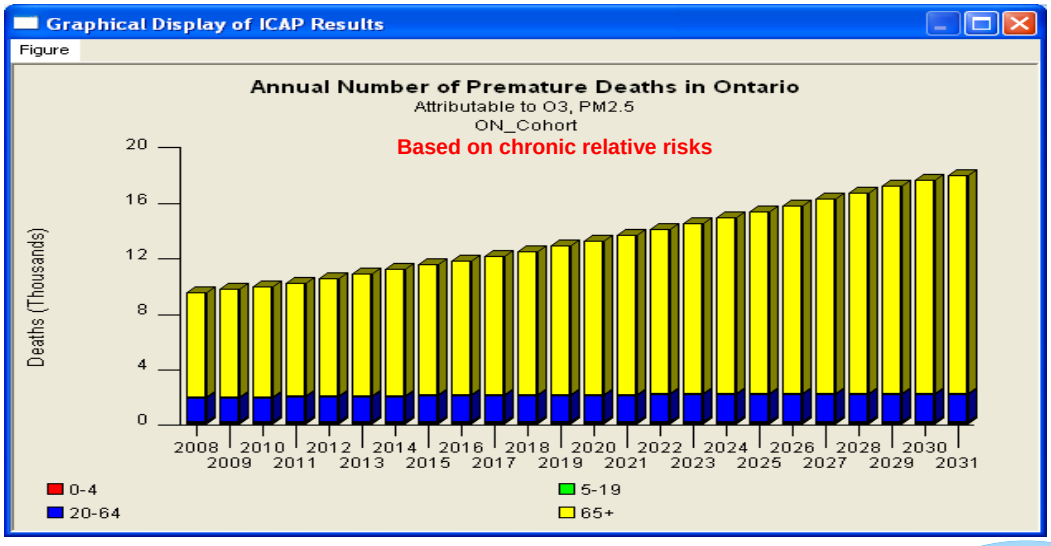
Table 13 - ON: Health Damages Summary: 2008, 2015 and 2031

	Example Years		
	2008	**2015**	**2031**
Premature Deaths	**1,178**	**1,423**	**2,221**
Hospital Admissions	**4,597**	**5,371**	**7,774**
Emergency Dept. Visits	**39,575**	**46,375**	**67,239**
Minor Illnesses	**10,383,000**	**11,154,400**	**12,920,100**

Table 14 - ON: Economic Damages Summary: 2008, 2015 and 2031

	Example Years (in $ thousands)		
	2008	**2015**	**2031**
Lost Productivity	**$349,400**	**$374,400**	**$412,700**
Healthcare Costs	**$221,800**	**$248,700**	**$325,200**
Pain and Suffering	**$194,100**	**$213,500**	**$265,000**
Loss of Life	**$2,878,800**	**$3,481,900**	**$5,364,300**
Total	**$3,644,100**	**$4,318,500**	**$6,367,200**

Figure 30 - ON: Chronic Premature Mortality



A.7 Manitoba

The following summary results are for Manitoba.

Figure 31 - MB: Premature Deaths, Hospital Admissions and Emergency Department Visits

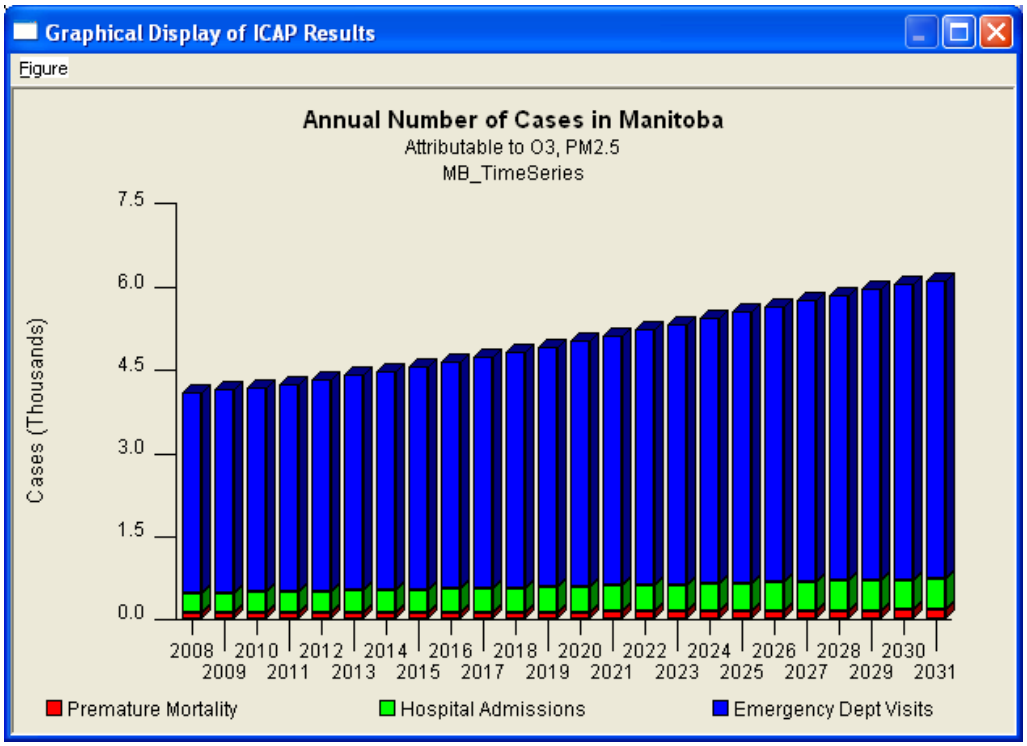


Figure 32 - MB: Minor Illnesses by Illness Type

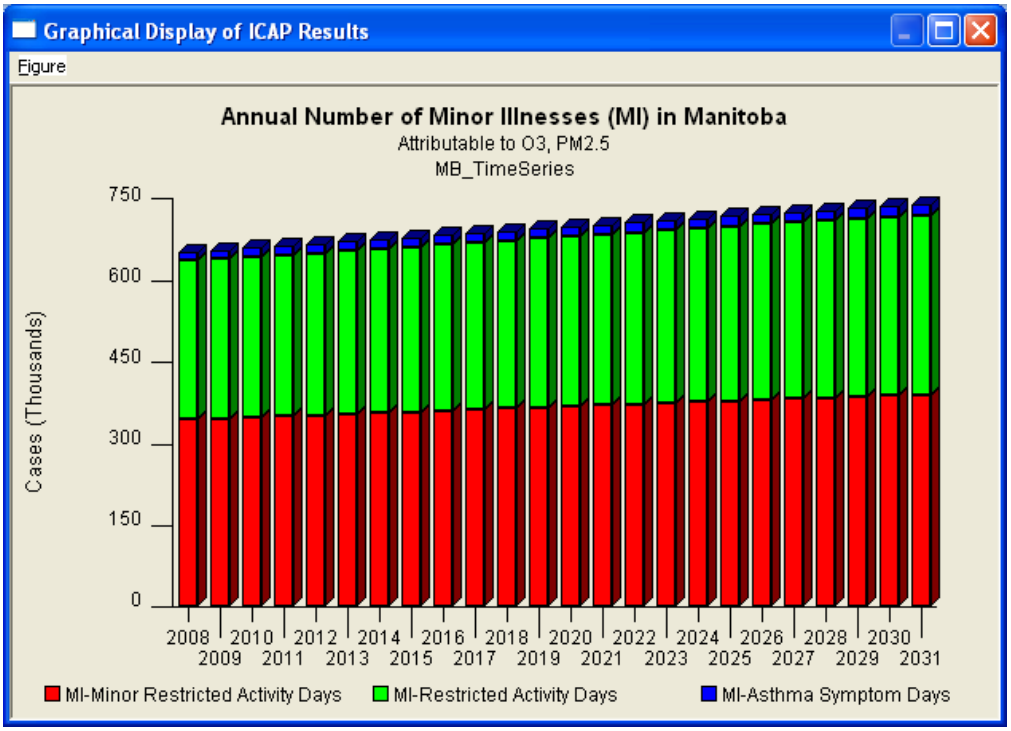


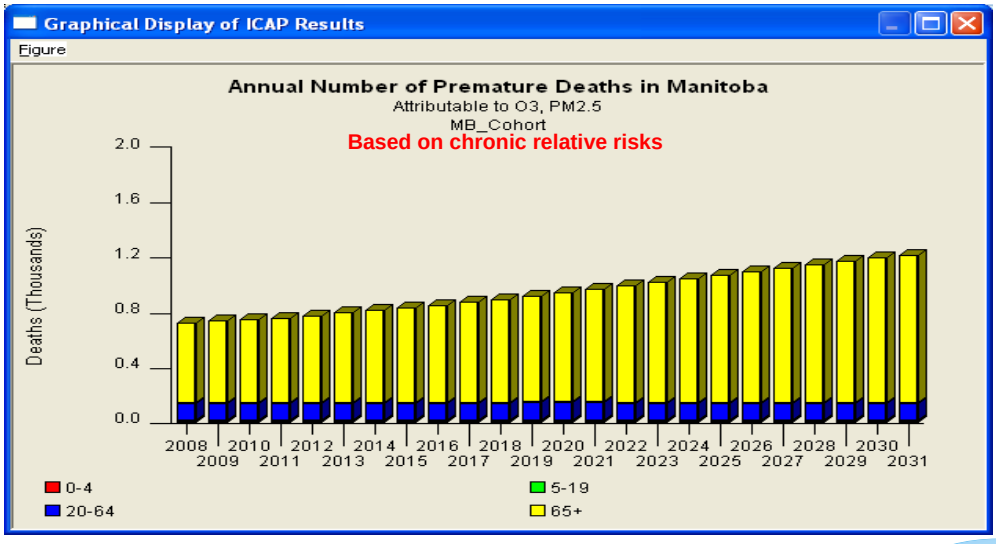
Table 15 - MB: Health Damages Summary: 2008, 2015 and 2031

	Example Years		
	2008	**2015**	**2031**
Premature Deaths	**89**	**102**	**148**
Hospital Admissions	**373**	**415**	**558**
Emergency Dept. Visits	**3,613**	**4,030**	**5,388**
Minor Illnesses	**650,279**	**676,183**	**736,596**

Table 16 - MB: Economic Damages Summary: 2008, 2015 and 2031

	Example Years (in $ thousands)		
	2008	**2015**	**2031**
Lost Productivity	**$18,152**	**$18,762**	**$19,420**
Healthcare Costs	**$12,444**	**$13,365**	**$16,186**
Pain and Suffering	**$11,647**	**$12,351**	**$14,337**
Loss of Life	**$214,869**	**$248,228**	**$356,338**
Total	**$257,112**	**$292,705**	**$406,281**

Figure 33 - MB: Chronic Premature Mortality



A.8 Saskatchewan

The following summary results are for Saskatchewan.

Figure 34 - SK: Premature Deaths, Hospital Admissions and Emergency Department Visits

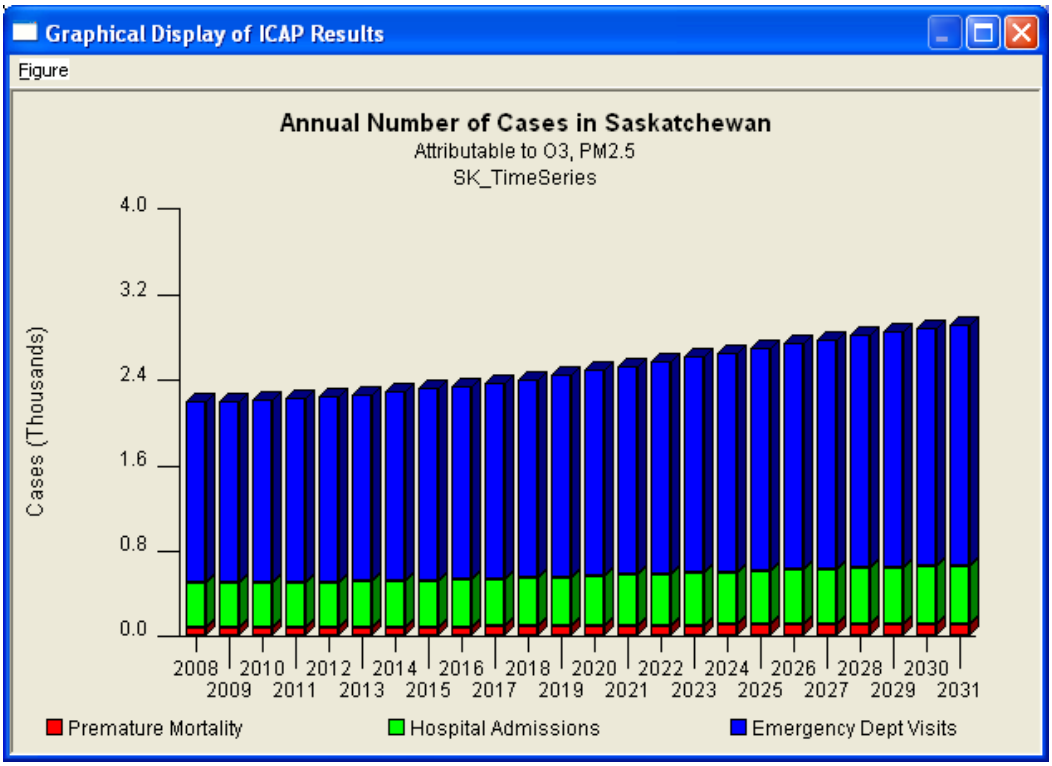


Figure 35 - SK: Minor Illnesses by Illness Type

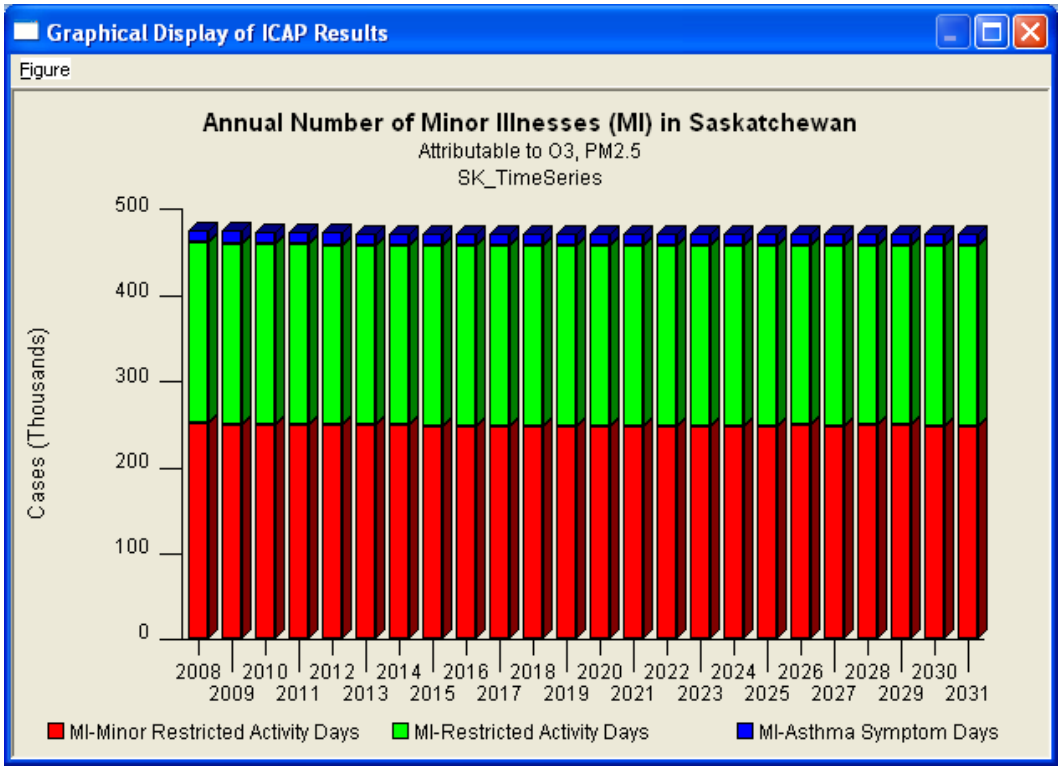


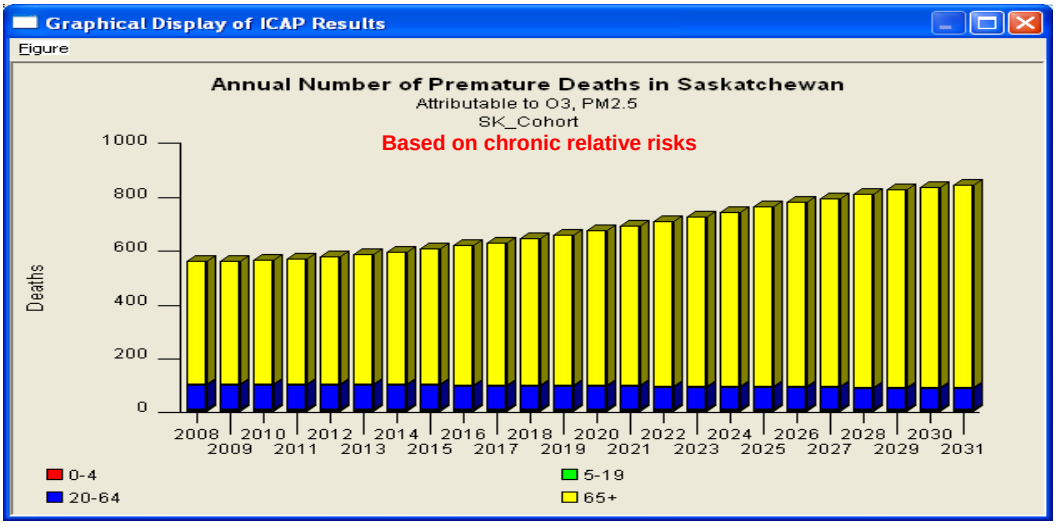
Table 17- SK: Health Damages Summary: 2008, 2015 and 2031

	Example Years		
	2008	**2015**	**2031**
Premature Deaths	**70**	**76**	**106**
Hospital Admissions	**415**	**436**	**543**
Emergency Dept. Visits	**1,702**	**1,795**	**2,248**
Minor Illnesses	**474,139**	**470,166**	**469,849**

Table 18 - SK: Economic Damages Summary: 2008, 2015 and 2031

	Example Years (in $ thousands)		
	2008	**2015**	**2031**
Lost Productivity	**$13,608**	**$13,439**	**$12,609**
Healthcare Costs	**$10,582**	**$10,882**	**$12,652**
Pain and Suffering	**$8,024**	**$8,071**	**$8,560**
Loss of Life	**$168,605**	**$183,890**	**$254,354**
Total	**$200,819**	**$216,281**	**$288,175**

Figure 36 - SK: Chronic Premature Mortality



A.9 Alberta

The following summary results are for Alberta.

Figure 37 - AB: Premature Deaths, Hospital Admissions and Emergency Department Visits

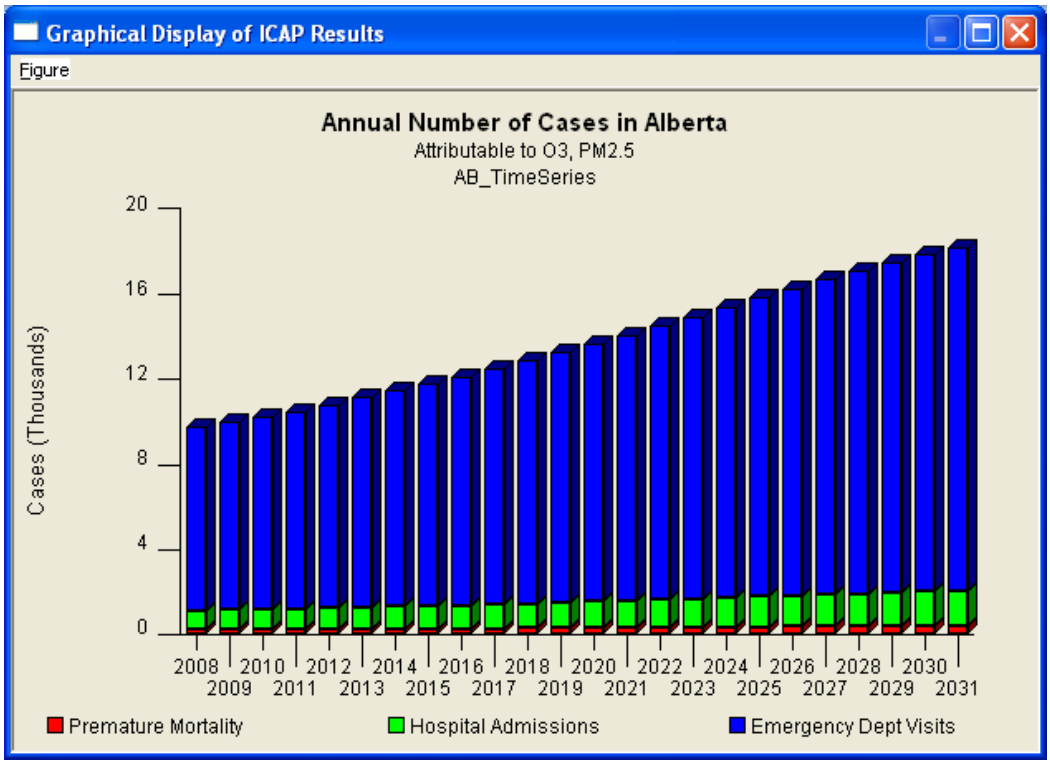


Figure 38 - AB: Minor Illnesses by Illness Type

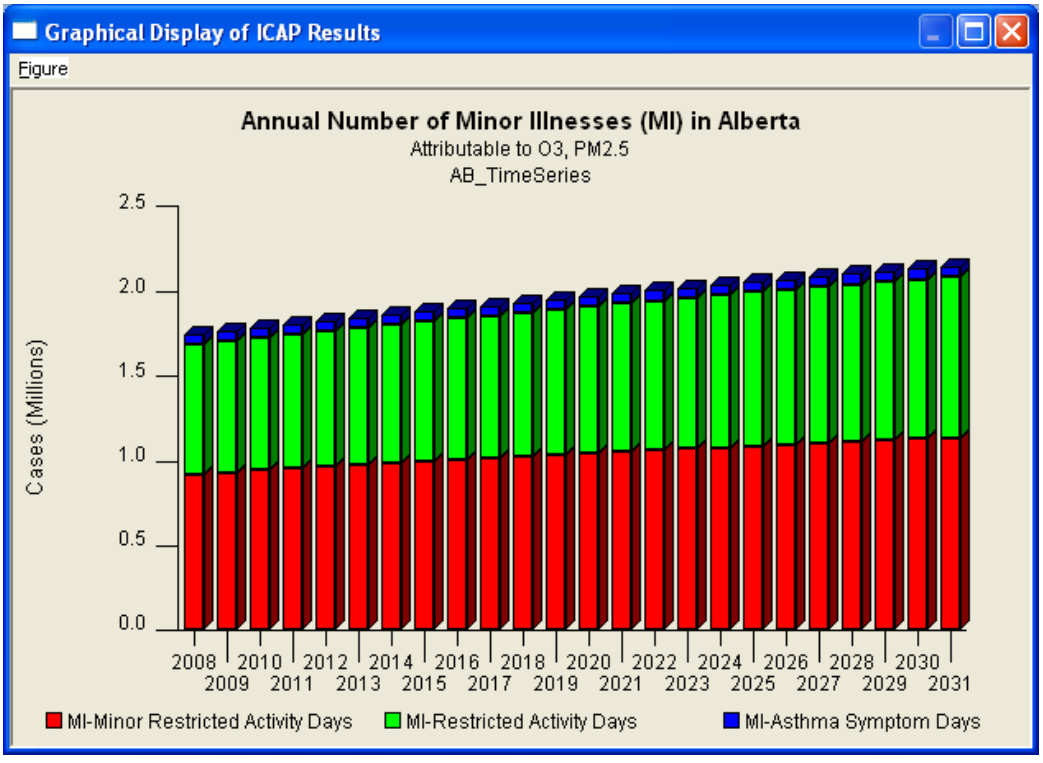


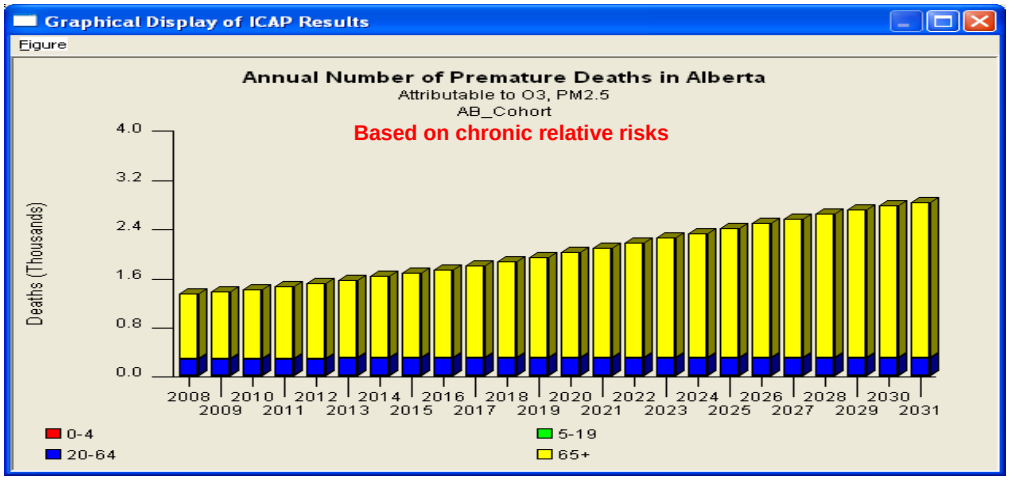
Table 19 - AB: Health Damages Summary: 2008, 2015 and 2031

	Example Years		
	2008	**2015**	**2031**
Premature Deaths	**173**	**217**	**366**
Hospital Admissions	**894**	**1,068**	**1,616**
Emergency Dept. Visits	**8,638**	**10,426**	**16,103**
Minor Illnesses	**1,734,300**	**1,868,300**	**2,173,000**

Table 20 - AB: Economic Damages Summary: 2008, 2015 and 2031

	Example Years (in $ thousands)		
	2008	**2015**	**2031**
Lost Productivity	**$61,824**	**$66,017**	**$71,025**
Healthcare Costs	**$34,922**	**$39,812**	**$53,822**
Pain and Suffering	**$30,043**	**$33,321**	**$41,691**
Loss of Life	**$422,712**	**$531,913**	**$882,696**
Total	**$594,500**	**$671,063**	**$1,049,234**

Figure 39 - AB: Chronic Premature Mortality



A.10 British Columbia

The following summary results are for British Columbia.

Figure 40 - BC: Premature Deaths, Hospital Admissions and Emergency Department Visits

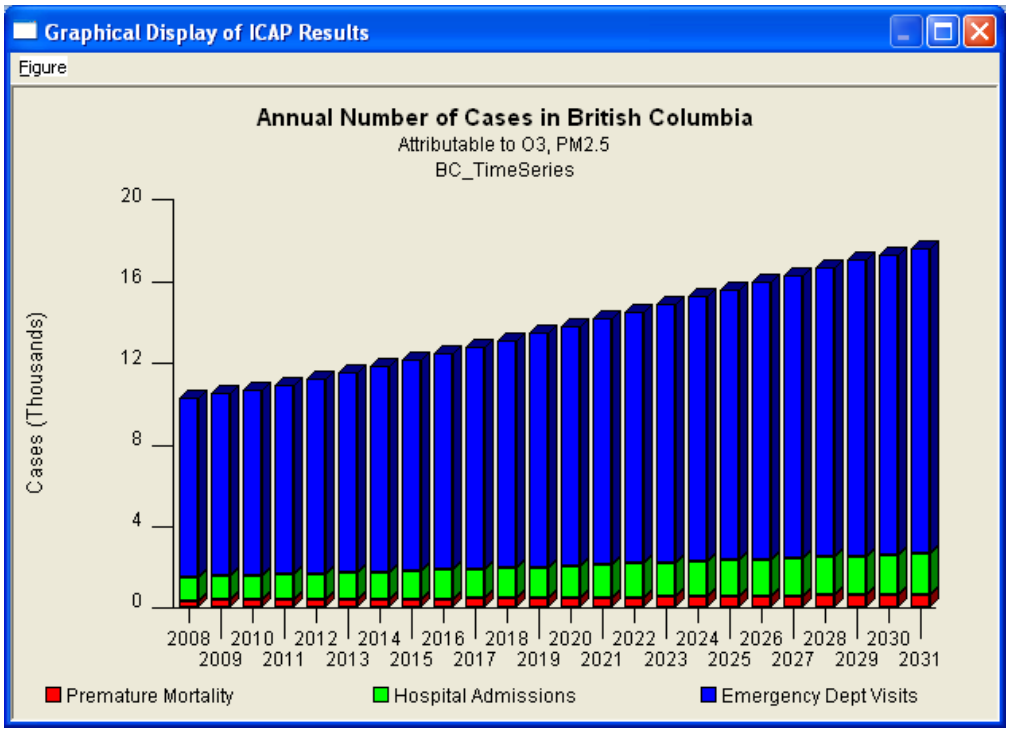


Figure 41 - BC: Minor Illnesses by Illness Type

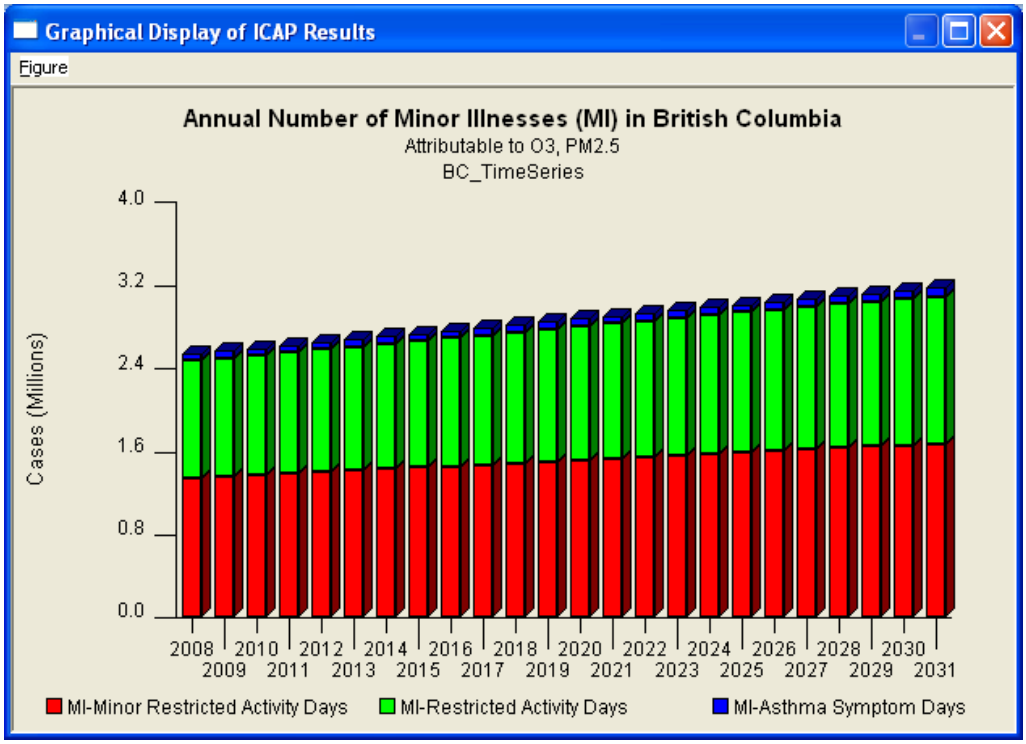


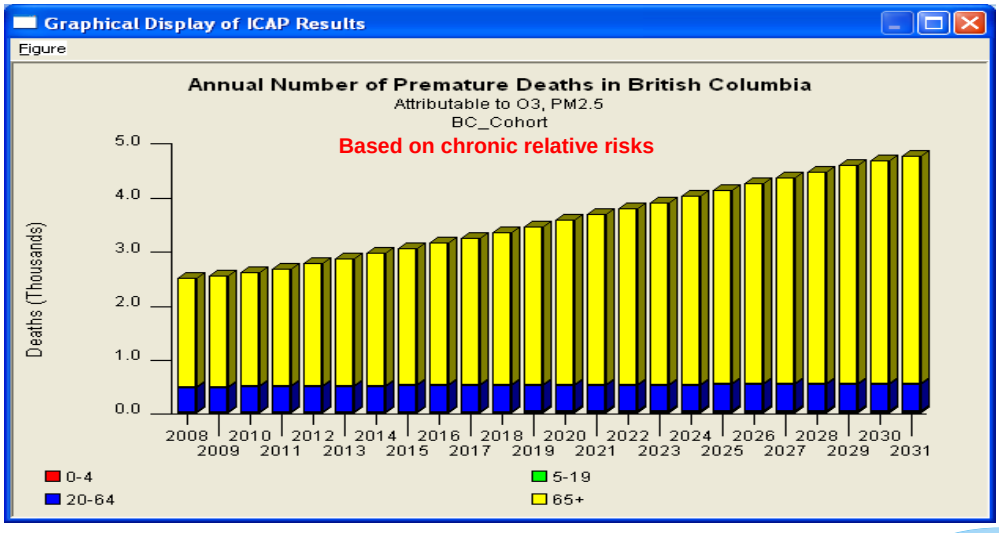
Table 21 - BC: Health Damages Summary: 2008, 2015 and 2031

	Example Years		
	2008	**2015**	**2031**
Premature Deaths	**306**	**375**	**585**
Hospital Admissions	**1,158**	**1,370**	**1,985**
Emergency Dept. Visits	**8,763**	**10,366**	**14,975**
Minor Illnesses	**2,526,900**	**2,721,800**	**3,160,000**

Table 22- BC: Economic Damages Summary: 2008, 2015 and 2031

	Example Years (in $ thousands)		
	2008	**2015**	**2031**
Lost Productivity	**$78,000**	**$82,900**	**$90,600**
Healthcare Costs	**$51,100**	**$57,800**	**$76,000**
Pain and Suffering	**$41,200**	**$45,200**	**$55,200**
Loss of Life	**$744,900**	**$916,100**	**$1,404,700**
Total	**$915,200**	**$1,102,000**	**$1,626,500**

Figure 42 - BC: Chronic Premature Mortality



Appendix B – Provincial Illness Base Incidence Rates

This appendix describes the methodology and sources for deriving the ICAP default base incidence rates (BIRs). These BIRs have a significant influence on expected health damages since the relative risks of air pollution exposure are expressed relative to the corresponding BIR for a given illness in the at-risk population. As the BIR increases or decreases in the population, so too in general will the air pollution-related health damages.

B.1 Deaths

Annual mortality rates for select causes, age groups, sex and province/territory are available from Statistics Canada's CANSIM database (http://cansim2.statcan.ca/cgi-win/cnsmcgi.exe?Lang=E&CANSIMFile=CII\CII_1_E.htm&RootDir=CII/, accessed March 6, 2008). The numbers of deaths are broken down by cause allowing accidental and self-inflicted deaths to be excluded. The most recent data available (2004) have been used to derive base mortality rates for each age group for each provincial ICAP system (see

Table 23).

B.2 Hospital Admissions

Provincial hospital admission rates were obtained from CIHI's Hospital Morbidity Database (CIHI, 2007a). The most recent period for which data were available is 2005-2006. The hospital admissions were reported by the acute inpatient most responsible diagnoses which were limited to respiratory and circulatory ICD-10-CA[19] codes (ICD-9 for Quebec only). CIHI included a breakout by age group so that base hospital admissions rates could be calculated for each specific illness category and age group (see Table 24).

B.3 Emergency Department Visits

Provincial emergency department visit rates were obtained from CIHI's Canadian Hospital Morbidity Database (CIHI, 2007a). The most recent period for which data were available is 2005-2006. Emergency department visits are not tracked by illnesses type or age group. The proportions of emergency department visits that are related to respiratory or cardiovascular causes were estimated based on the ratio of total hospital admissions that are associated with these causes. Similarly, the proportions of emergency department visits associated with each cause were divided by age group using the hospital admissions proportions. The result was that base incidence rates were estimated for respiratory and cardiovascular-related illnesses for each of the four age groups in ICAP (see

Table 25).

B.4 Doctor's Office Visits

Base incidence rates for doctor's office visits were derived only for Ontario. These rates were derived from the OHIP database. Data for 2004, 2005 and 2006 were aggregated according to diagnostic/service codes into respiratory and cardiovascular-related cases. These data were broken down by the four ICAP age groups. An annual average base incidence rate was calculated for each illness-age group combination (see

Table 26).

[19] These ICD-10 categories are similar to the old ICD-9 codes used in previous versions of ICAP. Some minor refinements to ICD-illness type mapping was required to accommodate the new coding system.

B.5 Minor Illnesses

The estimation of minor illness base incidence rates is highly uncertain. No centralized database is available that is suitable for estimating these rates. The base incidence rates for minor restricted activity days and restricted activity days are from base rates reported by Abt (2003 Exhibit E.6). According to Abt, these rates are based on work by Ostro and Rothschild (1989). On the face of it, these base incidence rates appear low but no better estimate is available at the present time.

The base incidence rates for asthma symptom days were updated based recent statistics on asthma incidence rates (Statistics Canada, 2008b: Table 105-0401 - *Asthma (percent) by age group and sex, household population aged 12 and over, provinces, territories, health regions, 2005*). These statistics were used to derive province-specific estimates of the number of asthma symptom days per year

Table 23 - Mortality Base Incidence Rates[20]

MORTALITY												
PROVINCE	Total Mortality				Respiratory				Cardiovascular			
	Age Group											
	1	2	3	4	1	2	3	4	1	2	3	4
NF	103	8	255	5000	4	1	11	446	4	2	81	2103
NB	73	10	224	4726	0	1	9	450	5	1	62	1823
NS	97	11	265	4798	5	0	13	547	2	3	119	2521
PEI	84	7	239	4939	0	0	13	652	0	0	47	2232
PQ	91	6	224	4160	1	1	10	458	2	1	51	1318
ON	116	8	202	4097	2	0	7	396	3	0	49	1559
MB	132	12	237	4862	4	0	10	457	7	2	67	1854
SK	132	9	240	4736	5	0	13	521	7	1	57	1880
AB	33	0	180	4088	1	0	7	426	1	0	48	1739
BC	86	10	206	4038	1	1	10	496	2	1	46	1566
Source: Statistics Canada, 2008												

[20] Base incidence rates are expressed per 100,000 persons.

MORTALITY								
PROVINCE	Cardio-Respiratory				Lung Cancer			
	Age Group							
	1	2	3	4	1	2	3	4
NF	8	3	92	2548	0	0	25	299
NB	5	3	72	2272	0	0	31	353
NS	7	3	131	3068	0	0	38	284
PEI	0	0	60	2884	0	0	24	300
PQ	3	1	61	1776	0	0	41	358
ON	4	1	57	1955	0	0	23	275
MB	11	2	77	2311	0	0	27	308
SK	11	1	70	2401	0	0	24	257
AB	2	0	55	2165	0	0	20	272
BC	3	1	56	2062	0	0	24	282
Source: Statistics Canada, 2008								

Table 24 - Hospital Admissions Base Incidence Rates[21]

HOSPITAL ADMISSIONS												
PROVINCE	All Respiratory				Asthma				COPD			
	Age Group											
	1	2	3	4	1	2	3	4	1	2	3	4
NF	5645	1444	536	3622	732	92	38	50	21	3	127	1854
NB	6868	885	618	4444	948	122	47	51	12	2	162	2419
NS	3991	498	371	2906	839	105	29	27	18	2	96	1503
PEI	7054	851	598	4249	1203	145	60	149	0	0	122	1907
PQ	2928	400	289	2532	675	92	33	110	29	4	62	974
ON	2529	350	249	2328	568	79	28	41	4	1	65	1115
MB	3469	482	420	3370	509	71	34	43	25	3	90	1552
SK	7132	983	683	4485	781	108	43	58	17	2	111	1896
AB	3150	471	397	3431	514	77	38	40	5	1	80	1635
BC	2829	374	309	2301	430	57	29	37	5	1	65	1060
Source: CIHI, 2007a												

[21] Base incidence rates are expressed per 100,000 persons.

HOSPITAL ADMISSIONS												
PROVINCE	Pneumonia				All Cardiovascular				Coronary Disease			
	Age Group											
	1	2	3	4	1	2	3	4	1	2	3	4
NF	647	81	98	818	65	33	864	7983	0	0	32	314
NB	829	107	112	1013	40	21	1006	8743	0	0	20	181
NS	407	51	84	810	37	19	859	6642	0	0	25	216
PEI	832	100	105	1035	24	12	674	6760	0	0	2	15
PQ	648	88	82	883	50	28	739	5779	0	0	13	98
ON	414	58	61	670	31	18	614	5943	0	0	9	90
MB	753	105	117	1006	28	16	657	6968	0	0	31	535
SK	1679	232	201	1281	42	24	795	8259	0	0	23	181
AB	550	82	116	873	34	21	516	6121	0	0	8	99
BC	432	57	85	710	19	10	536	5654	0	0	13	122
Source: CIHI, 2007a												

HOSPITAL ADMISSIONS								
PROVINCE	Dysrhythmia				Congestive Heart Failure			
	Age Group							
	1	2	3	4	1	2	3	4
NF	4	2	62	598	0	0	326	1564
NB	3	2	86	1034	0	0	413	2102
NS	3	2	50	487	0	0	350	1615
PEI	5	2	86	654	0	0	142	1011
PQ	3	8	79	740	2	1	247	1372
ON	2	1	43	502	0	0	213	1218
MB	4	2	38	509	0	0	199	1155
SK	7	4	82	959	0	0	211	1551
AB	2	1	38	560	1	0	146	1061
BC	0	0	44	589	0	0	178	1170
Source: CIHI, 2007a								

Table 25 - Emergency Department Visits Base Incidence Rates[22]

EMERGENCY DEPARTMENT VISITS								
PROVINCE	Respiratory				Cardiovascular			
	Age Group							
	1	2	3	4	1	2	3	4
NF	25894	3153	2180	17674	388	194	4000	35889
NB	40098	5000	3595	26901	557	284	6114	50627
NS	21270	10128	1873	13564	383	747	4126	33080
PE[23]	2843	332	276	1974	29	14	349	2760
PQ	9655	1276	909	7033	181	98	2091	17912
ON	8789	1183	938	7495	170	94	2219	19628
MB	14702	1979	1756	12969	216	119	3160	25832
SK	11458	1530	1407	9248	128	70	1921	13976
AB	14200	2054	1653	17066	170	101	2426	27715
BC	9649	1235	904	6809	168	88	1923	16039
Source: CIHI, 2007b								

[22] Base incidence rates are expressed per 100,000 persons.
[23] The annual number of EDV for PEI was not available from CIHI 2007b. A value was obtained from CIHI's NACRS 2003-2004 database

Table 26 - Doctor's Office Visits Base Incidence Rates

Doctor's Office Visits								
PROVINCE	Age Group							
	1	2	3	4	1	2	3	4
	Respiratory				Cardiovascular			
ON	205,855	27,705	65,930	285,057	942	1,932	17,585	168,924
Source: OMA, 2008								

Table 27 - Minor Illness Base Incidence Rates[24]

MINOR ILLNESSES												
PROVINCE	Minor Restricted Activity Days				Restricted Activity Days				Asthma Symptom Days			
	Age Group											
	1	2	3	4	1	2	3	4	1	2	3	4
NF	7.8	7.8	7.8	7.8	6.85	6.85	6.85	6.85	2.67	2.18	1.10	1.43
NB	7.8	7.8	7.8	7.8	6.85	6.85	6.85	6.85	2.3	1.88	1.09	1.08
NS	7.8	7.8	7.8	7.8	6.85	6.85	6.85	6.85	2.3	1.88	1.28	0.92
PEI	7.8	7.8	7.8	7.8	6.85	6.85	6.85	6.85	1.95	1.16	1.11	1.05
PQ	7.8	7.8	7.8	7.8	6.85	6.85	6.85	6.85	1.86	1.52	1.13	1.18
ON	7.8	7.8	7.8	7.8	6.85	6.85	6.85	6.85	1.15	1.4	1.07	0.94
MB	7.8	7.8	7.8	7.8	6.85	6.85	6.85	6.85	1.8	1.47	1.00	1.08
SK	7.8	7.8	7.8	7.8	6.85	6.85	6.85	6.85	2.16	1.77	1.09	0.96
AB	7.8	7.8	7.8	7.8	6.85	6.85	6.85	6.85	1.71	1.4	1.15	0.9
BC	7.8	7.8	7.8	7.8	6.85	6.85	6.85	6.85	1.55	1.27	1.10	1.05
Source: Abt, 2003; Ostro and Rothschild, 1989; Vedal, 1998; Statistics Canada, 2008b												

[24] Base incidence rates are expressed per person.

Appendix C –Economic Damages Coefficients

This appendix describes the methodology and sources for deriving the ICAP default economic damages coefficients. This appendix only deals with revisions to the methodology and the updating of these coefficients since the last version of ICAP was released.

C.1 Lost Productivity

Lost productivity results from individuals being sick and not being able to work. As well, non-paid caregivers (i.e., family members and friends) who provide care also may lose time from work. This lost time is valued based on provincial average wage rates. Wage rates vary by gender and age group; the rate tending to be higher for males and to increase with age up to age 65. The gender and age of the individuals afflicted with an illness is used to select the appropriate provincial average wage rate. With non-paid caregivers, the overall provincial average wage rate is used. Sick time for children is not assigned an economic value although extended absenteeism from school may have longer term economic consequences for children. These economic effects of air pollution are not included. The value of lost time coefficients in this version of ICAP are based on the latest provincial wage rate statistics (Statistics Canada, 2008c).

The amount of lost time is tied to the nature and severity of the illness. In the case of premature death and hospital admissions the lost time is tied to the expected length of stay. With less severe illnesses the lost time is tied to the amount of time spent receiving care and recovering from the illness. The lost time coefficients are the same as those used in previous versions of ICAP. Table 28 presents the ICAP provincial average wage rates that are used to calculate the value of lost time.

C.2 Healthcare Costs

Healthcare costs include institutional care through provincial healthcare systems. Healthcare costs vary from province to province. Healthcare costs also vary among illnesses. The latest available provincial daily health cost statistics were obtained (CIHI, 2007b).

Healthcare costs for individual illnesses were estimated using national resource intensity weights and expected lengths of stay factors, both of which vary by age group. The national resource intensity weights and expected lengths of stay factors are based on CIHI's Resource Intensity Weights, Expected Lengths of Stay and Case Mix, 2005 version. Table 29 and Table 30 present the provincial healthcare cost coefficients for each ICAP illness type.

C.3 Quality of Life

Increased pain and suffering experienced by those afflicted with illnesses attributable to air pollution exposure results in a loss of quality of life; not to mention the suffering experienced by family and others close to afflicted individuals. This loss of quality of life has an economic value. The economic value is measured by the amount that individuals would pay to reduce the risk of having to experience this pain and suffering. Complete details concerning the derivation of the quality of life coefficients used in previous versions of ICAP are provided elsewhere (DSS, 2005). The default quality of life economic coefficients in this version of ICAP are the same as those used in previous versions of ICAP except they have been adjusted to correspond to 2006 dollars.

C.4 Loss of Life

The most severe outcome of exposure to air pollution is premature death. Economists measure this loss by determining the value to people assign to reducing the risk. The methodology for deriving the economic value of premature loss of life is controversial, partly from an ethical perspective. Nonetheless, the methodology is widely accepted and used for purposes such as determining optimal pollution prevention investments and for civil suits involving damages claims. Complete details concerning the derivation of the loss of life coefficients used in previous versions of ICAP are provided elsewhere (DSS, 2005). The default value of a statistical economic coefficients in this version of ICAP are the same as those used in previous versions of ICAP except they have been adjusted to correspond to 2006 dollars.

Table 28 - Provincial Average Wage Rates by Age Group

Provincial Average Daily Wage Rates ($/day)																							
PROVINCE	Gender/Age Group																						Non-paid Caregiver
	16-20		21-25		26-30		31-35		36-40		41-45		46-50		51-55		56-60		61-65		>65		
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M/F
NF	25	22	29	25	59	43	67	48	74	54	82	59	89	64	96	70	60	38	55	35	5	1	64
NB	33	30	38	35	61	51	69	57	76	63	84	70	92	76	99	82	66	43	61	40	7	2	71
NS	34	31	40	36	65	50	73	57	81	63	89	69	98	75	106	82	68	46	63	42	8	3	73
PEI	31	33	36	38	58	54	66	61	73	68	80	74	88	81	95	88	71	49	66	45	11	4	72
PQ	39	34	46	39	76	58	86	66	95	73	105	80	114	88	124	95	81	51	75	47	10	4	85
ON	42	37	49	43	87	64	98	72	109	80	120	88	131	96	142	104	104	71	96	66	15	6	98
MB	41	37	48	43	75	59	84	66	93	74	103	81	112	88	121	96	89	67	82	62	15	5	86
SK	44	36	51	42	77	61	87	69	97	76	107	84	116	92	126	99	101	67	94	62	23	6	90
AB	54	41	63	48	98	65	110	73	123	81	135	89	147	97	159	105	131	76	120	70	23	7	106
BC	43	38	51	45	84	61	94	69	105	76	115	84	126	92	136	99	102	60	94	56	13	5	93
Source: Statistics Canada, 2008c																							

Table 29 - Provincial Daily Hospital Costs for Respiratory Illnesses

Provincial Daily Hospital Costs ($/day)																
PROVINCE	All Respiratory				Asthma				COPD				Pneumonia			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
NF	977	977	1536	1893	759	759	938	1356	953	953	1619	1905	1183	1183	1844	2021
NB	715	715	1141	1418	563	563	695	1005	706	706	1200	1412	876	876	1366	1498
NS	832	832	1339	1677	661	661	817	1181	830	830	1410	1659	1030	1030	1606	1760
PEI	656	656	1032	1297	522	522	645	932	0	0	1113	1309	813	813	1267	1389
PQ	667	667	1095	1341	535	535	661	955	671	671	1141	1342	833	833	1299	1424
ON	832	832	1339	1677	661	661	817	1181	830	830	1410	1659	1030	1030	1606	1760
MB	638	638	996	1228	487	487	602	870	612	612	1039	1223	759	759	1184	1297
SK	790	790	1241	1517	606	606	748	1082	760	760	1292	1520	944	943	1471	1613
AB	927	927	1464	1830	725	725	896	1295	910	911	1547	1820	1130	1129	1762	1931
BC	1000	1000	1591	1976	779	779	962	1391	978	978	1661	1954	1213	1213	1892	2074

Table 30 - Provincial Daily Hospital Costs for Cardiovascular Illnesses

Provincial Daily Hospital Costs ($/day)																
PROVINCE	All Cardiovascular				Coronary Artery Disease				Dysrhythmia				Congestive Heart Failure			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
NF	1525	1721	1682	1958	0	0	1293	1685	1363	1401	1634	1937	0	0	1776	2164
NB	1055	1070	1256	1450	0	0	958	1248	1010	1038	1211	1435	0	0	1316	1603
NS	1329	1347	1480	1729	0	0	1126	1467	1187	1220	1423	1687	0	0	1547	1884
PEI	951	964	1148	1345	0	0	889	1158	937	963	1123	1331	0	0	1220	1487
PQ	973	987	1188	1412	0	0	911	1187	960	987	1151	1364	0	0	1251	1524
ON	1329	1347	1480	1729	0	0	1126	1467	1157	1220	1423	1687	0	0	1547	1884
MB	893	906	1081	1246	0	0	830	1081	875	889	1049	1243	0	0	1140	1389
SK	1186	1214	1347	1567	0	0	1032	1344	1087	1118	1304	1545	0	0	1417	1726
AB	1505	1520	1619	1876	0	0	1235	1610	1032	1338	1561	1850	0	0	1696	2067
BC	1541	1551	1751	2009	0	0	1327	1728	1398	1437	1676	1987	0	0	1822	2220
Source: CIHI 2007a, 2007b, 2007c																

Table 31 - Provincial Emergency Department Costs per Visit

Provincial Emergency Department Costs ($/visit)								
PROVINCE	All Respiratory				All Cardiovascular			
	1	2	3	4	1	2	3	4
NF	1525	1721	1682	1958	0	0	1293	1685
NB	1055	1070	1256	1450	0	0	958	1248
NS	1329	1347	1480	1729	0	0	1126	1467
PEI	951	964	1148	1345	0	0	889	1158
PQ	973	987	1188	1412	0	0	911	1187
ON	1329	1347	1480	1729	0	0	1126	1467
MB	893	906	1081	1246	0	0	830	1081
SK	1186	1214	1347	1567	0	0	1032	1344
AB	1505	1520	1619	1876	0	0	1235	1610
BC	1541	1551	1751	2009	0	0	1327	1728
Source: CIHI 2007a, 2007b, 2007c								

Table 32 - Ontario Doctor's Office Costs per Visit

Ontario Doctor's Office Costs ($/visit)								
PROVINCE	All Respiratory				All Cardiovascular			
	1	2	3	4	1	2	3	4
ON	31	25	27	30	63	53	50	41
Source: OMA, 2008								

Appendix D – Expert Opinion Elicitation Process

ICAP EXPERT REVIEW WORKSHOP: Final Report[25]

D.1 Introduction

This report documents the results of an expert opinion elicitation process (EOEP) undertaken by the Canadian Medical Association (CMA) as part of its national ICAP model development research program. This report outlines the reasons for undertaking the EOEP, the methodology used and the results of the process. The results provided in this report have been used to derive the default risk coefficients for the individual provincial ICAP models that the CMA plans to release to the public.

D.1.1 Need for an EOEP

The purpose of ICAP is to inform health practitioners, policy makers and the general public about the health and economic damages associated with air pollution. ICAP includes default health and economic risk coefficients that are used by the system to forecast damages associated with air pollution. These coefficients are based on the latest and most reliable sources available. However, the air pollution health risk literature is large and constantly expanding. Reported results sometimes vary from one location to another, among different types of pollutants, among different groups of people, etc. Considerable judgement is required to determine the best results for a given application. The purpose of the ICAP expert workshop was to provide the CMA will the insights of leading experts in the air pollution health risk field on the best set of default risk coefficients given the current state of knowledge.

[25] This appendix contains the report that was produced as a result of the expert opinion elicitation process. A draft of this report was circulated to the experts following the expert workshop for review and comment..

D.1.2 EOEP Methodology

The challenge faced by the CMA in deriving a set of default risk coefficients for ICAP is not unique. In fact, it is common with environmental problems that involve large complex problems with high variability. Conventional scientific approaches are not able to deal with these problems in their totality due the statistical characteristics of what are referred to as "wicked" problems. Conventional scientific approaches, even modern epidemiological methodologies, are limited when dealing with these circumstances. As a result, expert judgement often is the only practical means to bridge the gap between what conventional scientific research approaches can tell us about these problems and what policy makers and the public really want to know (e.g., what would be the benefits in public health and economic terms of improvements in air quality in a given community or province?).

Every expert however has a different view on these matters. Similar reasons lie behind the idea of getting a second opinion when dealing with major medical decisions. The US EPA reached a similar conclusion recently on the matter of the most likely premature mortality health risk associated with exposure to $PM_{2.5}$. Several millions of dollars and over two years were spent eliciting the opinions of a diverse group of experts on this one concentration-response relationship. The problem faced by the CMA however is much greater. Instead of one pollutant and one health outcome, the CMA wished to obtain the best estimates for health risk coefficients for the wide range of pollutants and health outcomes included in ICAP. For these reasons the expert opinion elicitation process used by the CMA shares some common elements with the US EPA approach and follows the general principles essential for a rigourous outcome. The CMA process however is not as elaborate and structured from a statistical perspective as that used by the US EPA.

The basic CMA EOEP process was as follows:

1. Leading experts in the health risks of air pollution were identified.
2. The most suitable candidates were invited to participate. Where a candidate could not participate, an alternate candidate was invited. The target was to have a group of 4-6 experts participate.
3. An initial survey was circulated to the experts.
4. The responses to the survey were compiled and presented at an in-person workshop and discussed among the experts. The workshop was held in Ottawa at the CMA offices on September 14 and 15, 2007.
5. The experts were given a chance after the workshop to revise their opinions based on the discussions that had transpired.
6. As well, some additional research was undertaken after the workshop as suggested by the experts.

This report presents the results of this EOEP.

D.1.3 Report Organisation

The EOEP involved a number of general overarching questions plus a series of detailed questions concerning the relative risks of individual pollutant/illness combinations. This report starts out in Sections 2 to 11 with the results of the general questions and their interpretation with respect to the ICAP methodology. These responses led to a subsequent focused research on the issue of deriving the health risks of exposure to multiple pollutants. The results of that research are presented in Section 3. The results for the relative risks for specific pollutant/illness combinations are summarised in Section 12.

D.2 Causality

Four questions relating to the likelihood of there being and the nature of, a causal relationship between exposure to air pollution and adverse health effects were explored. The results of the discussion of these questions are presented following.

D.2.1 Overall Causal Connection

The first question was as follows:

Question 9.1.1: *Overall, how probable is that increases/decreases in illness/death rates associated with changes in air pollutant concentrations reported in various epidemiological studies reflect a causal connection? ___% (100% means that there is 100% certainty that a causal connection exists.)*

The responses to this question are shown in Table 33.

Table 33 - Responses to Question 9.1.1[26]

Expert 1	Expert 2	Expert 3	Expert 4	Expert 5
98%	95%	95%	90%	99%

The experts shared a common view that adequate scientific evidence is available to reliably conclude that a positive causal relationship exists between exposure to air pollution and adverse health outcomes. The nature of these causal connections was refined through later discussions; in particular during the discussion of exposure to multiple pollutants.

D.2.2 Connections Among Health Outcomes

The next question was as follows:

Question 9.1.2: *How likely is it that a causal connection exists for one health outcome (e.g., premature mortality) but does not exist for other health endpoints (e.g., emergency department visits, minor illnesses)? Highly Unlikely ___ Unlikely ___ Probable ___ Highly Probable ___*

The responses to this question are shown in Table 34.

Table 34 - Responses to Question 9.1.2

Expert 1	Expert 2	Expert 3	Expert 4	Expert 5
Highly Unlikely	N/R	Highly Unlikely	Unlikely	Highly Unlikely

There was general agreement that air pollution causes adverse health outcomes through certain physiological mechanisms that can result in different levels of severity of health outcome. The physiological mechanisms are common among specific health outcomes but not necessarily across classes of health outcome. For example, different severities of adverse outcomes (e.g., premature mortality and hospital admission) for a specific type of cardio-vascular outcome (e.g., arrhythmia) likely share a common physiological underlying causal mechanism. The severity of the response to air pollution will depend on many environmental factors in addition to the health status and sensitivity of the individual. Given the presence of a common causal physiological mechanism(s) with each major illness type, increases in adverse health outcomes for a given severity of an illness class (e.g., respiratory hospital admissions) are expected to be accompanied by increases in adverse health outcomes in less and more severe forms of the same illness class (e.g., respiratory emergency department visits and respiratory doctor's office visits).

D.2.3 Strength of Evidence

The following question examined the strength of evidence of causality as evinced was by different research methodologies.

Question 9.1.3: *Please indicate the importance of the following types of studies in providing compelling evidence of a causal connection based on the current state of research findings.*

[26] The names of the experts are not shown. The EOEP was a collaborative process designed to encourage free and candid exchange of ideas and opinions. The important result is not the opinion of one expert or another but the range and magnitude of the responses provided.

(Rate each source from 0 to 5 with 5 being the most compelling form of evidence.)

The responses to this question are shown in Table 35.

Table 35 - Responses to Question 9.1.3

Type of Evidence	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5
Time-series epidemiological studies	2	4	4	3	3
Cohort epidemiological studies	2	5	4	4	4
Human clinical studies	3	3	3	2	4
Animal experiment studies	3	4	2	2	2
Physiological mechanism studies	3	4	3	2	4
Intervention studies	N/R	N/R	4	4	N/R

The collective view was that all of the research methodologies that provide evidence of a causal connection between air pollution and adverse health outcomes are important and that no one type of evidence consistently dominated another. In other words, the differences among the scores for the different types of evidence are not significant. However, the combined effect of consistent evidence from these diverse research methodologies is compelling and strongly supports the conclusion that a causal connection is present.

D.2.4 Causal Connections for Individual Pollutants

The strength of causal connections between adverse health outcomes and individual pollutants was considered by means of the following question.

Question 9.1.4: *Please indicate the probability of a causal connection between specific pollutants and health endpoints.*

In the initial survey, the experts were asked to consider each major illness class (e.g., hospital admissions, emergency department visits) and pollutant type individually. During the workshop discussions and based on responses to other questions (e.g., Question 9.1.1 and 9.1.2), a common level of causality is expected among severity classes of an illness type (e.g., respiratory illnesses).

Some confusion with the initial question was expressed. The confusion arose from whether the question was asking about the weight of evidence to support a causal connection or the probability of a causal connection actually being present. It was clarified at the workshop that the intent of the question was the latter interpretation.

As a result, this follow-up question was sent after the workshop:

Modified Question 9.1.4: *Please indicate the probability of a causal connection between specific pollutants and adverse health outcomes based on your current understanding of the potential for a causal mechanism(s) to be present. Your response should not reflect strictly the volume of evidence but should also reflect your view that a causal effect is likely to be actually present.*

These responses are presented in Table 36.

Table 36 - Responses to Modified Question 9.1.4

POLLUTANT	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5
$PM_{2.5}$	94%	88%	95%	90%	99%
O_3	82%	70%	95%	90%	98%
NO_2	60%	N/R	90%	40%	80%
SO_2	63%	50%	90%	40%	42%
SO_4	86%	90%	95%	40%	95%
CO	94%	80%	70%	20%	20%

A general observation emerged from the discussion that generally the greatest weight of evidence exists for the most severe adverse health outcomes. Where more severe effects are uncommon within the normal range of ambient pollutant concentrations, the evidence may be stronger for less severe outcomes due to the larger number of adverse responses expected.

Overall, the highest likelihood of causality exists for $PM_{2.5}$ and O_3. These are also the pollutants for which the greatest volume and weight of evidence is available.

D.3 Multiple Pollutants

The survey explored the issue of estimating the health risks of exposure to multiple pollutants. The original version of ICAP, like many other health risk damages forecasting models, allowed users to combine relative risk coefficients for multiple pollutants to estimate health damages. The challenge is that the relative risk coefficients for individual pollutants were derived from epidemiological studies using single or two-pollutant statistical models. Methodologically this approach introduces some uncertainties. Two questions were asked pertaining to this issue in the survey.

D.3.1 Probability of Over-estimation

The first question was as follows:

Question 9.3.1: *Overall, how probable is that the combined estimated risks of illness/death are overestimated when risk factors for individual air pollutants that are estimated from single pollutant models are used together to forecast air pollution health damages? ___%.*
(100% means that there is 100% certainty that health risks are overestimated.)

The responses to this question are shown in Table 37.

Table 37 - Responses to Question 9.3.1

Expert 1	Expert 2	Expert 3	Expert 4	Expert 5
60%	60%	75%	60%	30%

Some confusion in the interpretation of this question was evident from the discussion at the workshop. There was strong opposition by some of the experts to using risk coefficients from multi-pollutant models; the concern was that doing so would overestimate health damages. The general view was that single pollutant models provide conservative damages estimates (i.e., unlikely to over-estimate health effects); albeit, these damages are unlikely exclusively attributable to one pollutant alone. The concentrations of many pollutants are strongly covariant and routinely they form an air pollution "soup". The combined effect of this soup may be largely captured by risk coefficients derived from a single pollutant statistical model due to the covariance among the constituents. The strong covariance among the concentrations of different types of pollutants presents a major statistical challenge for partitioning aggregate relative health risks to individual pollutants.

This challenge increases significantly as the number of potentially causal pollutants increases. The air pollution health effect signals being detected are relatively weak (i.e., sometimes less than 1% of the total health risk) in relation to the number and power of potentially confounding factors (see Section 4.1.2). As the number of pollutants included in statistical analyses of health risks increases, the health effect signal is "diluted" to the point that the coefficients in these statistical models become unstable (e.g., few statistically significant coefficients are evident and error ranges are large). As well, implausible results are common (e.g., some risk coefficients are less than one, in other words exposure to some air pollutants appear to have a positive health effect.). While all of the six criteria pollutants may individually pose health risks, teasing out their individual contribution to overall health risks using multiple-pollutant models is statistically infeasible; at least through the use of conventional statistical procedures.

A final complication relates to the underlying chemical and physiological interactions of air pollutants. The effects of individual pollutants may be additive, synergistic or partially counteractive and their net effect will depend on the specific contents of the local air pollution "soup". For this reason, the results of a multiple-pollutant model analysis for say Los Angeles may not be applicable to Toronto. Geographic variation in reported health risks may be partly a result of interactions among the pollutants making up the mix.

With these concerns in mind, the best path forward was explored. The experts agreed that using the results from multiple-pollutant statistical models would be acceptable if the aggregate impacts were being forecast and all of the risk coefficients were derived from a common statistical model and dataset. Further, a reasonable level of precision is provided with risk coefficients estimated using two-pollutant statistical models which include $PM_{2.5}$[27] and O_3. Caution was advised in ascribing the proportions of the damages to specific pollutants.

D.3.2 Multiple-pollutant Model Results

Opinion was divided on the potential to base health damage forecasts on a three-pollutant model. The concern revolved around the potential for the risk coefficients for the third pollutant, most often NO_2, to be unstable and to cause unnecessary confusion and controversy. The experts agreed that this issue would best be resolved through further research. Dr. Krewski agreed to undertake this research; the results of which are summarised in this section.

Specifically Dr. Krewski examined the statistical foundation available to derive health damage forecasts based on a three-pollutant model. He examined the difference between the risk coefficients derived for $PM_{2.5}$, O_3 and NO_2 using single, two and three-pollutant statistical models. He also examined to a lesser degree the potential of substituting SO_2, SO_4 and CO in place of NO_2. His research used extant databases compiled by several large studies (i.e., the American Cancer Society cohort health study, the APHENA meta-analysis). The general findings of this research are discussed following. The detailed findings cannot be reported until after the results are published in peer-reviewed journals; these results are expected within a year.

Health risks are most consistently associated with $PM_{2.5}$. Even when three pollutants are included in the statistical model, the $PM_{2.5}$ health risk is statistically significant. The O_3 results generally showed a positive health risk but

[27] $PM_{2.5}$ is used throughout this document to refer to particulate matter pollution generically.

not as strong and consistent as $PM_{2.5}$. The addition of O_3 to the statistical model did not affect greatly the $PM_{2.5}$ coefficient suggesting considerable independence between the effects. Adding a third pollutant tended to affect the O_3 coefficient more than the $PM_{2.5}$ coefficient. The health risk associated with NO_2, SO_2 and SO_4 is less strong and/or is not as consistent. Insufficient data were available to test the strength of health risks associated with exposure to CO.

Based on these results, modifications have been made to the ICAP software. Specifically, users will be given the option of producing health damages forecasts based on two-pollutant exposure scenarios comprising $PM_{2.5}$ and O_3. Damage forecasts using any of the other four pollutants included in ICAP will only be allowed using single air pollutants. Further details are provided elsewhere. The supporting documentation for the updated ICAP models includes a section discussing this issue. Specifically, users are cautioned about the interpretation of health damages forecasts involving multiple pollutants. Other issues relating to communications and messaging are not addressed in this document.

D.3.3 Other Factors

The second survey question relating to multiple-pollutant models was as follows:

Question 9.3.2: *Please list what you feel are the primary factors most likely to cause health risks from a mixture of air pollutants to be overestimated. List in descending order of significance.*

The responses to this question are shown in Table 38. Some of the responses to this question have been combined to reduce redundancy; even so, some of the causes listed do overlap to a certain extent. The responses are listed alphabetically and not listed in order of importance. Opinions differed as to the most and least important factors.

Table 38 - Responses to Question 9.3.2

Potential Cause for Over-estimation
Correlation among pollutant concentrations
Serial correlation over time
Spatial correlation across locations
Transference of causality

As mentioned during the discussion of Question 9.3.1, a major concern is the high degree of covariance among the pollutant concentrations. This covariance makes separating out the effects of individual pollutants difficult.

D.4 Confounding and Modifying Factors

The survey explored the nature of the major factors that might influence air pollution health risks. Originally, the term “confounding factors” was used. The experts suggested refining this terminology and distinguishing between confounding and modifying factors. A confounding factor is a factor that is strongly correlated with a causal factor but has no actual influence on the health risk associated with the pollutant. However, statistical models will tend to attribute a portion of the risk relationship incorrectly to this confounding factor(s). Modifying factors may also show a strong covariance but these factors do modify the actual risk (i.e., enhance or diminish it).

This difference is important from a health damages forecasting perspective. Where the effect of confounding factors can be estimated, this effect can be netted out of the risk coefficients and no further adjustment is required. In the case of modifying factors, risks should be based on forecasts of air pollution and the modifying factors, their interactions derived statistically and forecasts of health damages based on interactive risk functions rather than simple relative risk coefficients.

Given the nature of ICAP and its intended uses, all non-pollution factors affecting relative risk have been assumed to be confounding factors and netted out of the relative risks to the extent possible. Following are some specific factors that were examined in detail.

D.4.1 Effects of Weather

The experts were asked the following question relating to weather:

Question 9.2.1: *Overall, how probable is that estimated risks of illness/death are overestimated due to the confounding influence of weather factors? ___%.*
(100% means that there is 100% certainty that weather factors are causing health risks to be overestimated.)

The responses to this question are shown in Table 39.

Table 39 - Responses to Question 9.2.1

Expert 1	Expert 2	Expert 3	Expert 4	Expert 5
20%	10%	5%	10%	5%

The overall opinion was the statistical methodologies used to net out the confounding effects of weather are reliable. As a result, the potential for the effects of weather leading to an overestimate of the effects of air pollution is low. Indeed, several experts suggested that a parallel question should be included asking the likelihood that the adverse effects of air pollution are underestimated due to the confounding effects of weather. Where the effects of pollution are derived using a stepwise regression procedure and weather effects are first netted out, some of the effects of air pollution may be incorrectly attributed to weather such that the residual effect is less than is actually the case. The result is that the adverse effects of air pollution will be underestimated.

D.4.2 Other Factors

In addition to weather, other factors might be contributing to the reported health risks of air pollutants. The experts were asked the following question on other potentially confounding factors:

Question 9.2.2: *Overall, how probable is that estimated risks of illness/death are overestimated due to the confounding influence of factors other than weather? ___%.*
(100% means that there is 100% certainty that other confounding factors are causing health risks to be overestimated.)

The responses to this question are shown in Table 40.

Table 40 - Responses to Question 9.2.2

Expert 1	Expert 2	Expert 3	Expert 4	Expert 5
10%	25%	20%	60%	10%

Some variation in the interpretation of this question was evident. The high probability estimate reflected the view that where the effects of other pollutants that are closely covariant with a given pollutant are not adequately captured, this could result in overestimates of the risk coefficients for an individual pollutant. The conclusion is that results from multiple-pollutant models are less likely to overestimate the damages associated with an individual pollutant than are single-pollutant models.

The other experts interpreted the question as the probability that the effects of the six criteria air pollutants combined are overestimated. This interpretation led to the much lower probabilities of over-estimation. The opinion was expressed that similar to the situation with weather; namely, too much accommodation may be given to these other confounding factors leading to an overall underestimate of the risk.

Irrespective of the interpretation of this question, the overall opinion is that a relatively small likelihood of health effects being over-estimated due to confounding factors other than modifying factors associated with interactions among multiple pollutants.

D.4.3 Likely Confounding/Modifying Factors

The experts were asked to list the most significant potentially confounding/modifying factors:

Question 9.2.3: *Please list what you feel are the confounding factors most likely to cause health risks from air pollution to be overestimated.*
List in descending order of significance.

The responses to this question are shown in Table 41.

Table 41 - Responses to Question 9.2.3

Potential Confounding/Modifying Factors
Inadequate control of temperature
Inadequate and over-control of temperature
Other pollutants
Aero allergens (asthma)
Socio-economic status
Co-morbidities
Ecologic exposure indicators
Weather and other correlated environmental factors (e.g., noise and traffic)
Socioeconomic status

These responses are reported verbatim and some overlap is evident. As well, some variation in the importance ranking was evident. Nonetheless, this list covers that major factors discussed at the workshop and that are important to consider when interpreting health damage forecasts.

One complication relates to the differences between the time series and cohort methodologies. The potential confounding factors differ between the two. The overall conclusion is that a multitude of potential confounding factors are present but that their absolute effect is primarily one of degree; that is these factors may affect somewhat the magnitude of the risk but are not sufficient individually or combined to lead to the conclusion that no causal connection is present between health risks and exposure to the six criteria air pollutants included in ICAP.

D.4.4 Regional Variation

Some research has suggested that the health risks of air pollution may vary regionally. For example, should the ICAP default health risk coefficients for say Quebec be different than those for say British Columbia? The experts were asked the following question on this issue:

Question 9.2.4: *Overall, how probable is it that the estimated risks of illness/death vary significantly from one region of the continent to another? ___%.*
(100% means that there is 100% certainty that significant regional variation exists.)

The responses to this question are shown in Table 42.

Table 42 - Responses to Question 9.2.4

Expert 1	Expert 2	Expert 3	Expert 4	Expert 5
40%	80%	50%	60%	50%

Regional variation in risk coefficients has been regularly observed in many studies. Regional variations within North America and between Europe and North America have been found. The underlying causal factors contributing to this variation are unknown.

One of the strongest modifying factors in cohort risk analyses is socio-economic status as measured by level of education. Regional variations in socio-economic status among exposed populations are present but no compelling physiological mechanism explanation is available to conclude that education affects the health risk of air pollution. Instead, education may be simply a marker for the actual causal socio-economic factor that is strongly correlated with education.

The conclusion arising from this discussion is that no regional variation in the risk coefficients should be included in the individual provincial ICAP models until a compelling explanation of the underlying mechanism is available.

D.5 Excluded Health Effects

ICAP includes a fixed "menu" of illness types that are commonly influenced by air pollution. The need to add or remove certain illness types from the ICAP system was examined. Specifically, the survey included two questions relating to the need to expand the ICAP illness types menu. The results are summarised following.

D.5.1 Probability of Excluded Health Effects

The experts were asked the following question (Question 10.1.1):

Question 10.1.1: *Are there health outcomes associated with exposure to air pollution that pose significant public health risks that are not included in the current version of ICAP?*
Highly unlikely ___ Unlikely ___ Probable ___ Highly Probable ___

The responses to this question are shown in Table 43.

Table 43 - Responses to Question 10.1.1

Expert 1	Expert 2	Expert 3	Expert 4	Expert 5
Probable	Probable	Probable	Probable	Probable

There was general agreement that ICAP captured only a subset of the full range of adverse health effects associated with the six criteria air pollutants. The exclusion of significant adverse health effects will result in underestimates of the actual damages caused by air pollution.

D.5.2 Significant Excluded Health Effects

The experts were asked the following question (Question 10.1.2):

Question 10.1.2: *Please list those health risks associated with exposure to air pollution that are not included in ICAP and that pose the greatest public health risk.*
List in descending order of significance.

The responses to this question are shown in Table 44. The responses are listed alphabetically. Some of the responses to this question have been combined to reduce redundancy.

Table 44 - Responses to Question 10.1.2.

Significant Excluded Health Effects
Adverse birth effects
Doctor's office visits
Hypertension
Lung function development
Missing risks for certain age groups
Myocardial infarction
New cases of chronic bronchitis
Other cancers

The evidence supporting these various health effects was discussed in detail at the workshop. As well additional adverse health outcomes were mentioned. Further details of these discussions are presented by the individual illness types.

D.5.2.1 Adverse Birth Effects

Consistent results have been reported showing an association between exposure of mothers to air pollution and adverse effects on newborns (e.g., low birth weight). However the causal connections are unknown at this time. The current state of knowledge of these effects is similar to that which existed with PM in the mid 1990s. For this reason, it was recommended that these effects not be added to ICAP until a better understanding of the causal connections is available.

D.5.2.2 Doctor's Office Visits

The advantages and disadvantages of including doctor's office visits in ICAP were discussed. The conclusion was that doing so would increase the relevance of the results for many people. As well, if adverse effects are occurring in terms of hospital admissions, emergency department visits and minor illnesses, certainly, some individuals presenting at doctors' offices are also affected adversely by air pollution.

Little epidemiological research of these adverse impacts has been undertaken. Furthermore, the base incidence rates will vary from one jurisdiction to another based on the nature of the health care system. This being said, the basic proportions evident in the health effects pyramid have been used successfully in other instances to estimate the frequencies of missing levels within the pyramid. This approach would provide one means to estimate the scale of adverse effects of air pollution resulting in treatment through doctors' offices. Pursuing inclusion of this category of health outcome in ICAP was considered to be feasible and potential productive in advancing the overall goals of the ICAP system.

D.5.2.3 Hypertension

Considerable research is currently ongoing regarding the relationship between hypertension, diabetes and exposure to air pollution. Preliminary results show that an association may be present. Given the large health care demands associated with these health effects, increasing the prevalence of hypertension and diabetes could have major impacts on health damages forecasts. Adequate research results are not currently available to include this effect but this research should be carefully monitored and inclusion of these health outcomes in ICAP should be considered in the future.

D.5.2.4 Impaired Lung Development

The latest research results indicate that young persons exposed to air pollution have permanently impaired lung development. As expected the effect varies among individuals and the long-term consequences depend on the health status of the individual. As well, the effect is measured in terms of lung function. Making a connection

between reduced lung function and specific health outcomes on an incident-by-incident basis will be difficult. On the other hand, these types of effects have a large impact on the public and would increase public attention on the need for air pollution reduction.

Further investigation of this health effect may produce the information required to include this health outcome in ICAP. One approach that may be helpful is to convene a panel of clinicians to discuss how connections between lung development and adverse health outcomes might be established.

D.5.2.5 Missing Ages Groups

This gap related to the absence of risk coefficients for some age groups in ICAP. The reasons for these gaps were discussed. The conclusion set out in Section 4.4 eliminates this concern.

D.5.2.6 Myocardial Infarction

This adverse health outcome is included under some of the aggregate healthy outcome categories (e.g., cardio-vascular hospital admissions) but is not shown as a discrete health outcome. Considerable evidence is emerging that air pollution is a major risk factor for heart attacks. In particular, physiological evidence is emerging that air pollution causes an increase in plaque formation and increased rates of arteriosclerosis. Specific inclusion of this health outcome should be considered in the future.

D.5.2.7 Other Cancers

The potential for air pollution exposure to increase the severity of the effects of cancers other than lung cancer exists but extensive research on these effects is not available. The American Cancer Society cohort database could be analysed to see if these effects are statistically significant but this analysis has not been done at this time. For this reason, it was recommended that these effects not be added to ICAP until supporting research results are available.

D.6 Overlap Between Time Series and Cohort-based Risks

On the second day of the workshop, a series of new questions that arose from the preceding day's discussion were presented to the experts. Sections 6 to 11 contain the results of the discussion of these questions. This section deals with the first issue, namely whether time series and cohort-based risk coefficients are overlapping and measure the same or different health risks.

D.6.1 Independence of Risk Coefficients

The experts were asked the following question:

Currently ICAP includes relative risk coefficients based on time-series and cohort analyses. Are these risks independent of one another?

Some experts expressed the view that time series and cohort studies are measuring different health outcomes with little overlap between the two. However, the potential does exist for at least partially overlap and for this reason, the conservative approach is to use one or the other set of risk coefficients and not to combine the two.

D.6.2 Parallel Levels of Risk

The experts were asked the following question:

Is it reasonable to assume that the same difference in time series and cohort risk coefficients that is evident with premature mortality risk is applicable to other health outcomes?

The experts did not agree that this assumption should be applied to ICAP health damages forecasts. No research has been undertaken to validate this proposition and care should be exercised not to stray ahead of the science.

While there may be logical reasons for expecting some parallels to be present, reliance should ultimately be based on empirical scientific evidence.

D.7 Emergency Department Visits

These questions dealt with possible ways to improve the estimates of the number of emergency department visits (EDVs) attributable to air pollution. In general, the volume of research available declines as the severity of the adverse health outcome declines. The paucity of EDV risk analyses reduces the confidence in the estimates of these health outcomes.

D.7.1 Robustness of Estimates

The experts were asked the following question:

Currently ICAP includes for two categories of emergency department visits (EDV) and relies on a relatively weak research foundation. What can be done to improve the robustness of the estimates?

The experts agreed that the scientific foundation for estimating EDVs was not as strong as it was for more severe health effects. Many of the studies have relatively small sample sizes and report quite variable results.

D.7.2 Proportioning Methodology

The experts were asked the following question:

Is the proportioning methodology based on the health effects pyramid appropriate to use in this case?

The experts agreed that using a proportioning methodology was reasonable. While variation in the proportions of EDVs to hospital admissions can be expected among jurisdictions due to variations in the health care system and associated practices, the relative risks will not be affected. For this reason, the base incidence rates for EDVs should be specific to each province and the proportions may differ from one province to another.

D.7.3 Parallel Relative Risks

The experts were asked the following question:

Should the relative risk coefficients for respiratory and cardio hospital admissions be applied to the EDV base incidence rates to estimate the number of EDVs attributable to air pollution?

The experts agreed that the relative risks should in general be comparable. As a confirmation of this approach, it was recommended that a comparison of the relative risks among hospital admissions and EDVs within the same jurisdictions be undertaken to confirm the reasonableness of the approach.

D.8 Minor Illnesses

A similar challenge exists in predicting minor illness cases as was discussed with EDVs. These questions dealt with possible ways to improve the estimates of the number of minor illnesses attributable to air pollution.

D.8.1 Robustness of Estimates

The experts were asked the following question:

Currently ICAP includes for three categories of minor illness and relies on a relatively weak research foundation. What can be done to improve the robustness of the estimates?

A number of the experts indicated that they were not intimately familiar with this literature. They agreed that the literature is limited.

Given the responses discussed in Section 2, the risk coefficients for minor illnesses should be comparable to those estimated for more severe outcomes that are closely related. For example, the relative risk of asthma symptom days should be generally comparable to asthma related hospital admissions; albeit the base incident rates for the two health outcomes will be significantly different.

D.8.2 Improvement of Base Illness Rates

The experts were asked the following question:

How can estimates of base illness rates for minor illnesses be improved?

The experts indicated that this was not their area of expertise but offered several suggestions for further investigation. Specifically, they suggested relying on the national health survey results to estimate minor illness base incidence rates. Some conversion and interpretation of health outcomes will be required to equate the health outcome types used in the available minor illness risk studies with those used in the survey. However, these survey results are current and reliable.

D.9 Conversions

The following questions are of a technical nature and deal with converting air quality measures to a common metric. This type of conversion is necessary since not all research is based on the same air quality metric.

D.9.1 Application of PM_{10} Results

The experts were asked the following question (Question 8):

If ICAP is restricted to two pollutants (i.e., $PM_{2.5}$ and O_3), should relative risk estimates from studies using PM_{10} be used to derive $PM_{2.5}$ relative risk estimates?

The experts indicated that these types of conversions are common practice, that conversion factors are generally available and that they saw no reason not to continue this practice.

D.9.2 PM_{10} Conversion

The experts were asked the following question:

What conversion factors, or at least what conversion procedure, should be used to convert PM_{10} to $PM_{2.5}$ equivalents?

The experts indicated that these types of conversions are common practice, that conversion factors are generally available and that they saw no reason not to continue this practice.

D.9.3 O_3 Conversion

The experts were asked the following question (Question 10):

Three measures of O_3 are commonly reported, namely, 1 hr max, 8 hr average and 24 hr average. What conversion factors, or at least what conversion procedure, should be used to convert different measures of O_3 to a common metric?

The experts indicated that these types of conversions are common practice, that conversion factors are generally available and that they saw no reason not to continue this practice.

D.10 No-effect Thresholds

The responses were summarised for two questions relating to the probability of no-effect thresholds for certain pollutant/health outcome combinations. These responses were presented to the experts at the workshop. The initial responses and related workshop comments are summarised following.

D.10.1 Variation Among Illnesses

The experts were asked the following question (Question 9.4.1):

Question 9.4.1: *If a no-effect threshold exists for a given pollutant, how likely is it that an no-effect threshold exists for one health outcome (e.g., premature mortality) but does not exist for other health endpoints (e.g., emergency department visits, minor illnesses)?*
Highly unlikely ___ Unlikely ___ Probable ___ Highly Probable ___

The responses to this question are shown in Table 45.

Table 45 - Responses to Question 9.4.1

Expert 1	Expert 2	Expert 3	Expert 4	Expert 5
Highly Unlikely	Probable	Probable	Unlikely	Unlikely

The experts agreed that for the same reasons that the risks among health outcomes associated with comparable underlying causes (e.g., asthma hospital admissions and asthma symptom days), there is no basis to suspect that if an effect threshold existed for exposure to a given air pollutant that it would vary with the severity of the health outcome.

D.10.2 Probability of No-effect Threshold

The experts were asked the following question (Question 9.4.2):

Question 9.4.2: *Please indicate for each of the pollutants the probability of a no-effect threshold below which there is no risk of illness/death associated with exposure. Please also indicate the concentration at which this threshold is most likely. Reference to an authoritative study would be helpful irrespective of whether the probability of a non-zero no-effect threshold concentration is high or not. (100% means that there is 100% certainty that a no-effect threshold greater than zero concentration exists.)*

The responses to this question are shown in Table 46. The experts agreed that there was little evidence to suggest that an effect threshold exists for exposure to these air pollutants. If a threshold does exist, it well below current ambient concentrations.

D.11 Shape of Exposure-Response Functions

The responses were summarised for two questions relating to the likelihood of variations in the shape of the exposure response functions among different pollutants and health outcomes. These responses were presented to the experts at the workshop. The initial responses and related workshop comments are summarised following.

D.11.1 Variation in Function Shape

The experts were asked the following question (Question 9.5.1):

Question 9.5.1: *How likely is it that the basic shape (e.g., linear, log-linear) of the "real" exposure-response function for a given type of pollutant will vary from one health endpoint to another health endpoint? Highly unlikely ___ Unlikely ___ Probable ___ Highly Probable ___*

Table 46 - Responses to Question 9.4.2

POLLUTANT	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5
$PM_{2.5}$	**2%**	**0%**	**0%**	**N/R**[28]	**10%**
O_3	**10%**	**0%**	**0%**	**N/R**	**10%**
SO_2	**10%**	**0%**	**0%**	**N/R**	**N/R**
SO_4	**5%**	**0%**	**0%**	**N/R**	**10%**
CO	**10%**	**0%**	**0%**	**N/R**	**N/R**

The responses to this question are shown in Table 47.

Table 47 - Responses to Question 9.5.1

Expert 1	Expert 2	Expert 3	Expert 4	Expert 5
Highly Unlikely	Probable	Probable	Unlikely	Unlikely

There was some agreement that for the same reasons that the risks among health outcomes associated with comparable underlying causes (e.g., asthma hospital admissions and asthma symptom days), there is no physiological basis to suspect that the exposure-response function form will vary with the severity of the health outcome. However, the potential does exist that the functional form derived from statistical analyses of research results may be different than the "actual" form.

D.11.2 Variation Among Pollutants

The experts were asked the following question (Question 9.5.2):

Question 9.5.2: *How likely is it that the basic shape of the "real" exposure-response function for a given type of pollutant will differ from the basic shape for another type of pollutant?*
Highly unlikely ___ Unlikely ___ Probable ___ Highly Probable ___

The responses to this question are shown in Table 48.

Table 48 - Responses to Question 9.5.2

Expert 1	Expert 2	Expert 3	Expert 4	Expert 5
Highly Unlikely	Probable	Probable	Probable	Unlikely

The experts agreed that the form of and coefficients for the exposure-response functions may vary from pollutant to pollutant. However, the shape of the log-linear functions is quite close to linear and over relatively narrow ranges of pollutant concentrations that are commonly encountered, the difference between the linear and log-linear forecasts are minor. For this reason, the experts did not see the form of the functions to be a highly significant issue although there was some variance of opinion as to what the actual form of the relationships might be.

[28] Expert was reluctant to specify without performing a detailed review for each pollutant and outcome

D.12 Individual Risk Coefficients

The experts were asked to fill out a large number of tables relating to the individual risk coefficients included in ICAP. The survey asked each expert to provide their best estimate of the risk coefficient values for different combinations of pollutants, health outcomes and age group. The best means to arrive at the default set of values to include in ICAP was discussed extensively. This section summarises that discussion.

D.12.1 Risk Coefficient Values

The initial survey included a large number of tables which contained the original ICAP default risk coefficients. Each expert was asked to provide for each combination of pollutant, health outcome and age group, a central, high and low risk coefficient. As a result of the workshop discussions, the complexity of these tables has been reduced considerably. The revised tables are included in Attachment B. The reasons for the changes to the tables are discussed following.

D.12.2 Uncertainty Ranges

Much of the workshop discussion revolved around the matter of uncertainty ranges. A primary issue was the purpose of including uncertainty ranges in the estimates. Some experts offered suggestions for capturing the full range of uncertainty in damages estimates. Doing so would involve an elaborate statistical process similar to what was undertaken by the US EPA EOEP. One of the primary purposes of the US EPA EOEP for premature mortality risks of $PM_{2.5}$ was to generate rigourous uncertainty ranges. However, it was noted that the purpose of ICAP was quite different than the needs of the US EPA and that the uncertainty functions in ICAP had not been a major focus of public attention in the past. Furthermore, a primary purpose in making the ICAP framework readily available is to permit those wishing to explore various aspects of the health risks of air pollution in detail, the opportunity to do so easily and efficiently. In other words, if someone is inclined to explore the full range of the uncertainty of the estimates there is nothing in ICAP that would prevent this. The conclusion was that the purpose of the default uncertainty ranges is to provide ICAP users will an initial appreciation of the variation in the expert opinions regarding the best estimate of damages rather than a rigourous uncertainty analysis.

With this purpose in mind, the risk coefficient tables were simplified. Each expert was asked to provide only a central value for each cell in the table. No high or low ranges for the estimate were requested. Once the responses from the five experts were received, a median value was calculated and used as the central value in ICAP.

The upper and lower uncertainty ranges were defined by the maximum and minimum values among the recommended values by the experts; with some exceptions as explained following.

First, if all of the experts recommend the same central value, the central, maximum and minimum would be identical suggesting a low level of uncertainty. In cases where the uncertainty ranges resulting from the method described are narrower than the standard error reported in the authoritative research on which the coefficients are based, the reported standard errors were used to define the upper and lower ranges.

A second issue relates to the shape of the probability distribution defined by the central, maximum and minimum values. Three standard distributions are commonly used, namely, a normal, triangular[29] and square[30] distribution. It is not clear what shape of distribution should be assumed in this case. A triangular form has been used with 75% of the probability lying within the maximum and minimum values and 25% beyond. These values are somewhat arbitrary but do convey the message that there is a possibility that the true central value is outside the maximum or minimum range of the experts' best estimates.

[29] A normal distribution is the commonly assumed distribution in most statistical analysis methods. A triangular distribution is an approximation of a normal distribution except that the tails of the distribution intercept the x axis at the maximum and minimum values. Triangular distributions are commonly used where probability distributions are based on judgement since the distribution parameters are easier to specify.

[30] Square distributions are similar in purpose to triangular distributions except that they reflect greater uncertainty. With a square distribution, there is an equal probability that the upper, lower, mean and all values in between are the actual value.

D.12.3 Variation by Age

The original ICAP coefficients were specified by age group. This protocol was adopted to reflect the epidemiological literature in which health risks are commonly reported by age group. The experts recommended eliminating age-specific risk coefficients. There is not strong evidence to support the view that age is a risk modifier. Instead, the physiological mechanisms resulting in adverse health outcomes are independent of age.

This being said, the ICAP risk coefficients are relative risks, relative to the base incidence rate for each type of health outcome in the general population. Base incidence rates are highly dependent on age. As a result, using a constant risk coefficient and a variable base incidence rate produce quite different frequencies of health outcomes among different age groups.

The only exception to this general observation relates to the risks of intra-uterine, neonatal and early childhood development effects. These effects occur during specific stages of development and thus are associated with specific age groups.

D.12.4 Pollutant Types

Risk coefficients for six criteria pollutants were requested in the original survey. As a result of the discussion on multi-pollutant models (see Section 3), the basis for deriving these risk coefficients has been modified significantly. Following is a summary of the basis for the default ICAP risk coefficients.

The risk coefficients for $PM_{2.5}$ and O_3 are based on the results of two-pollutant statistical models wherever possible and appropriate. Risk coefficients for all other pollutants are consistent with single-pollutant statistical models.

D.12.5 Canadian-based Research

An issue that arose during the workshop discussions was the use of Canadian research in favour of research from other countries. Several reasons for generally preferring Canadian results were discussed. The conclusion was that priority should be given first to relying on the best available science that is applicable to Canada. This rule has been applied in deriving the ICAP default risk coefficients.

Attachment #A – Air Pollution Health Risks Experts

This attachment provides the names, affiliations and brief biographical information for each of the experts who participated in the EOEP process. The experts are listed in alphabetical order. In addition to the experts listed following, representatives from the CMA and OMA plus their consultant attended as well.

Douglas Dockery, M.S., Sc.D.

Dr. Dockery is Chair, Department of Environmental Health, Professor of Environmental Epidemiology, Department of Environmental Health, Department of Epidemiology Harvard School of Public Health, Harvard University. He is also Associate Professor of Medicine (Epidemiology), with the Harvard Medical School.

For over a decade, Professor Douglas Dockery has been conducting research with enormous implications for human health and for public policy. His work has focused on the potential for polluted air to cause a range of health problems, including cardiovascular disease, asthma and other respiratory ailments. Dockery's research has been at the center of the debate regarding what levels of particular pollutants are dangerous, and what limits the federal government should impose on sources of emissions to protect public health

Dockery is internationally known for his innovative work in environmental epidemiology, most recently in pursuing the biological mechanisms underlying the relationship between air pollution and acute cardiovascular mortality and morbidity. He was one of the principal investigators of the renowned Six Cities Study of Air Pollution and Health.

Daniel Krewski, B.Sc., M.Sc., Ph.D., M.H.A.

Dr. Krewski is Professor, Department of Epidemiology and Community Medicine, Faculty of Medicine, University of Ottawa and Director of the R. Samuel McLaughlin Centre where he holds the NSERC/SSHRC/McLaughlin Chair for Population Health Risk Assessment and cross appointment, Department of Mathematics and Statistics, Faculty of Medicine. He is also the Scientific Director of the PAHO/WHO Collaborating Centre in Population Health Risk Assessment at the University of Ottawa.

Dr. Krewski has also served as Adjunct Research Professor of Statistics in the Department of Mathematics and Statistics at Carleton University since 1984. Prior to joining the Faculty of Medicine at the University of Ottawa in 1998, Dr. Krewski was Director, Risk Management in the Health Protection Branch of Health Canada. While with Health Canada, he also served as Acting Director of the Bureau of Chemical Hazards and as Chief of the Biostatistics Division in the Environmental Health Directorate. His professional interests include epidemiology, biostatistics, risk assessment, and risk management.

David Pengelly, M.Sc., Ph.D., P.Eng.

Dr. Pengelly is currently an Associate Clinical Professor, Department of Medicine, a member of the McMaster Institute of Environment and Health, and Professor Emeritus, Department of Engineering Physics at McMaster University in Hamilton. In addition, he is an Associate Professor, Department of Medicine, University of Toronto.

He has worked in the field of air pollution research for over 40 years as an engineer, physiologist and most recently using the tools of epidemiology and has served as chair or member on committees of non-governmental organizations and government agencies relating to issues of environment and health, including the Advisory Committee on Environmental Standards in Ontario. Dr. Pengelly pioneered the use of literature-derived risk coefficients to determine the air pollution burden of illness for Hamilton in 1997, and again for the City of Toronto in 2000 and 2004.

David Stieb, MD, MSc, FRCPC

Dr. Dave Stieb is a public health physician and epidemiologist in the Biostatics and Epidemiology Division of the Healthy Environments and Consumer Safety Branch at Health Canada. Since joining Health Canada in 1993, Dr. Stieb's primary focus has been epidemiologic research on the health effects of outdoor air pollution and the application of these findings to quantifying the public health impacts of air pollution. From 1999 to 2002, he was head of the Air Quality Health Effects Research Section. He is an adjunct professor in the Department of Epidemiology and Community Medicine at the University of Ottawa, and affiliate scientist at the McLaughlin Centre for Population Health Risk Assessment.

George Thurston, Sc.D

Dr. Thurston is Professor, Department of Environmental Medicine, New York University School of Medicine, New York, NY. He is also Deputy Director of the NYU Particulate Matter Research Center, NYU School of Medicine.

He conducts epidemiological research into the human health effects of air pollution. Dr. Thurston has published widely in the scientific literature on the assessment of exposures to ambient air pollution and their human health consequences. He has served as the Director of the NYU-NIEHS Community Outreach and Education Program (1995-2004), and as Deputy Director of NYU's EPA Particulate Matter (PM) Health Effects Center (2002-2005). Dr. Thurston has also testified before both the U.S. Senate and the U.S. House of Representatives on multiple occasions regarding the potential human health effects of air pollution in the U.S. In addition, Dr Thurston has actively participated in multiple professional organizations, including serving as an Associate Editor of the International Society of Exposure Analysis' "Journal of Exposure Analysis and Environmental Epidemiology.

Attachment #B –Air Pollution Health Risk Coefficients

This attachment provides the health risk coefficients for the individual illness types included in the ICAP system. These results represent a synthesis of the opinions provided by the experts and the general principles of interpretation provided in response to the general questions in the survey.

B.1 Chronic Premature Mortality

Following are the default median, upper and lower premature mortality relative risk coefficients for long-term exposure to air pollution for different causes of premature mortality. The current epidemiological evidence indicates that this risk is largely attributable to exposure to $PM_{2.5}$. Potential for a lesser effect attributable to O_3 is present but the current epidemiological evidence is not adequate to derive suitable risk coefficients.

Table 49 to Table 51 present the ICAP default coefficients and ranges[31] for different forms of premature mortality as measured using cohort-based research methodology.

Table 49- Chronic All-cause Premature Mortality Risk Coefficients

Range	Relative Risk[32]	Comments
Median	1.110	Derived from Pope et al, 2002, Krewski et al., 2000, Laden, 2006 and Industrial Assoc, 2006
Upper	1.160	
Lower	1.070	

Table 50 - Chronic Cardio-respiratory Premature Mortality Risk Coefficients

Range	Relative Risk	Comments
Median	1.160	Derived from Pope et al, 2002, Krewski et al., 2000, Laden, 2006 and Industrial Assoc, 2006
Upper	1.184	
Lower	1.093	

Table 51 - Chronic Lung Cancer Premature Mortality Risk Coefficients

Range	Relative Risk	Comments
Median	1.135	Derived from Pope et al, 2002, Krewski et al., 2000, Laden, 2006 and Industrial Assoc, 2006
Upper	1.270	
Lower	1.090	

B.2 Acute Premature Mortality

Following are the default median, upper and lower relative risk coefficients for acute exposure to air pollution for different causes of premature mortality. The $PM_{2.5}$ and O_3 coefficients are considered to be additive and together represent the combined risk of premature mortality from acute exposure to air pollution. The relative risk

[31] ICAP includes the potential for risk coefficients to vary by age group. The experts however indicated that in general relative risks are not expected to vary by age group; albeit, base incidence rates vary greatly by age group. For this reason, the values shown in all of the relative risk coefficient tables in this appendix apply to all age groups.

[32] All relative risks are expressed as the risk associated with a 10 unit change in pollutant concentration.

coefficients for the other pollutants are discrete values that are not recommended to be used additively. As well, these acute risks are partially or fully captured by the chronic exposure premature mortality relative risks and should not be used additively.

Table 52 to Table 54 present the ICAP default coefficients and ranges for acute exposure to air pollution for different causes of premature mortality.

Table 52 - Acute All-cause Premature Mortality Risk Coefficients

Range	Relative Risk						Comments
	$PM_{2.5}$	O_3	NO_2	SO_2	SO_4	CO	
Median	1.010	1.005	1.008	1.004	1.012	1.000	Derived from Burnett & Goldberg, 2003, Dominici et al, 2003, Bell et al, 2005, Burnett et al, 2004, APHENA(Cdn cities), Schwartz, 1996, and Industrial Assoc, 2006
Upper	1.011	1.016	1.015	1.013	2.020	1.000	
Lower	1.008	1.003	1.004	1.002	1.000	1.000	

Table 53 - Acute Cardiovascular Premature Mortality Risk Coefficients

Range	Relative Risk[33]		Comments
	$PM_{2.5}$	O_3	
Median	1.014	1.002	Derived from Goldberg et al, 2000; Goldberg and Burnett, 2003, and APHENA (Cdn cities),
Upper	1.041	1.009	
Lower	1.000	1.000	

Table 54 - Acute Respiratory Premature Mortality Risk Coefficients

Range	Relative Risk		Comments
	$PM_{2.5}$	O_3	
Median	1.011	1.007	Derived from Lippmann et al., 2000; Ito, 2003 and APHENA (Cdn cities),
Upper	1.012	1.010	
Lower	1.010	1.000	

These relative risk coefficients are supported by the greatest volume of research. As well given the severity and clarity of the health endpoints (i.e., different causes of death), the relative risk estimates tend to be the most precise. For these reasons, we have used these relative risk coefficients for acute cardiovascular and respiratory mortality to derive the relative risk coefficients for less severe health endpoints associated with these causes. Further details follow.

B.3 Hospital Admissions

Table 55 presents the median, upper and lower relative risk coefficients for acute exposure to air pollution for all cardiovascular-related causes of hospital admissions. These values have been derived from the EOEP. The $PM_{2.5}$ and O_3 coefficients are considered to be additive and together represent the combined risk of hospital admissions from acute exposure to air pollution. The relative risk coefficients for the other pollutants are discrete values that are not recommended to be used additively.

[33] If a pollutant is not included in a table this means that adequate research findings were not available to derive a reliable relative risk coefficient.

Table 55 - EOEP Synthesis for All Cardiovascular Hospital Admissions Risk Coefficients

Range	Relative Risk				Comments
	$PM_{2.5}$	O_3	NO_2	SO_2	
Median	1.009	1.019	1.076	1.019	Derived from Burnett et al, 1999,97 and 1995, APBIT, 2000, Sunyer et al, 2003, Schwartz and Morris, 1995and APHENA (Cdn cities)
Upper	1.012	1.087	1.115	1.025	
Lower	1.007	1.003	1.060	1.006	

Table 56 to Table 58 presents the ICAP default coefficients and ranges for acute exposure to air pollution for specific types of cardiovascular-related hospital admissions. These values have all been derived from the EOEP.

Table 56 - Dysrhythmia Hospital Admissions Risk Coefficients

Range	Relative Risk					Comments
	$PM_{2.5}$	O_3	NO_2	SO_2	CO	
Median	1.020	1.011	1.011	1.005	1.000	Derived from Burnett et al, 1999
Upper	1.024	1.013	1.063	1.045	1.000	
Lower	1.016	1.009	1.000	1.000	1.000	

Table 57 - Congestive Heart Failure Hospital Admissions Risk Coefficients

Range	Relative Risk					Comments
	$PM_{2.5}$	O_3	NO_2	SO_2	CO	
Median	1.022	1.004	1.019	1.014	1.000	Derived from Derived from Lippmann et al., 2000; Ito, 2003; Burnett et al, 1999
Upper	1.026	1.011	1.058	1.041	1.002	
Lower	1.018	1.000	1.000	1.000	1.000	

Table 58 - Coronary Artery Disease Hospital Admissions Risk Coefficients

Range	Relative Risk					Comments
	$PM_{2.5}$	O_3	NO_2	SO_2	CO	
Median	1.025	1.002	1.020	1.017	1.000	Derived from Burnett et al, 1999
Upper	1.031	1.009	1.115	1.135	1.000	
Lower	1.018	1.000	1.000	1.000	1.000	

Table 59 presents the median, upper and lower relative risk coefficients for acute exposure to air pollution for all respiratory-related causes of hospital admissions. These values have been derived from the EOEP. The $PM_{2.5}$ and O_3 coefficients are considered to be additive and together represent the combined risk of hospital admissions from acute exposure to air pollution. The relative risk coefficients for the other pollutants are discrete values that are not recommended to be used additively.

Table 59 - EOEP Synthesis for All Respiratory Hospital Admissions Risk Coefficients

Range	Relative Risk					Comments
	$PM_{2.5}$	O_3	NO_2	SO_2	CO	
Median	1.012	1.012	1.074	1.075	1.000	Derived from Burnett et al, 1999,1997 and 1995, APBIT 2000, Fusco, 2001 and APHENA
Upper	1.017	1.033	1.084	1.085	1.000	
Lower	1.008	1.004	1.064	1.065	1.000	

Table 60 to Table 62 presents the ICAP default coefficients and ranges for acute exposure to air pollution for specific types of respiratory-related hospital admissions. These values have all been derived from the EOEP.

Table 60 - Asthma-related Hospital Admissions Risk Coefficients

Range	Relative Risk					Comments
	$PM_{2.5}$	O_3	NO_2	SO_2	CO	
Median	1.021	1.013	1.007	1.007	1.000	Derived from Burnett et al, 1999
Upper	1.025	1.016	1.039	1.057	1.001	
Lower	1.017	1.010	1.000	1.000	1.000	

Table 61 - COPD-related Hospital Admissions Risk Coefficients

Range	Relative Risk					Comments
	$PM_{2.5}$	O_3	NO_2	SO_2	CO	
Median	1.018	1.018	1.005	1.000	1.000	Derived from Burnett et al, 1999
Upper	1.019	1.019	1.026	1.001	1.001	
Lower	1.017	1.016	1.000	1.000	1.000	

Table 62 - Pneumonia-related Hospital Admissions Risk Coefficients

Range	Relative Risk					Comments
	$PM_{2.5}$	O_3	NO_2	SO_2	CO	
Median	1.030	1.014	1.014	1.017	1.000	Derived from Burnett et al, 1999
Upper	1.041	1.016	1.081	1.051	1.000	
Lower	1.017	1.011	1.000	1.000	1.000	

B.4 Emergency Department Visits

Table 63 and Table 64 present the median, upper and lower relative risk coefficients for acute exposure to air pollution for all cardiovascular-related and respiratory-related causes of emergency department visits, respectively. These values have been derived from the EOEP. The $PM_{2.5}$ and O_3 coefficients are considered to be additive and together represent the combined risk of emergency department visits from acute exposure to air pollution. The relative risk coefficients for the other pollutants are discrete values that are not recommended to be used additively.

Table 63 - EOEP Synthesis for Cardiovascular Emergency Department Visits Risk Coefficients

Range	Relative Risk			Comments
	$PM_{2.5}$	O_3	NO_2	
Median	1.058	1.000	1.000	Derived from Stieb et al, 2000, Burnett et al 1995 and Ito, 2003
Upper	1.064	1.000	1.023	
Lower	1.007	1.000	1.000	

B.5 Doctor's Office Visits

Following are the default median, upper and lower relative risk coefficients for acute exposure to air pollution for different causes of doctor's office visits. The $PM_{2.5}$ and O_3 coefficients are considered to be additive and together represent the combined risk of doctor's office visits from acute exposure to air pollution. The relative risk coefficients for the other pollutants are discrete values that are not recommended to be used additively. There are

Table 64 - EOEP Synthesis for Respiratory Emergency Department Visits Risk Coefficients

Range	Relative Risk			Comments
	$PM_{2.5}$	O_3	CO	
Median	1.022	1.009	1.000	Derived from Stieb et al, 2000, Burnett et al 1995 and 1997, Ito, 2003 and Jaffe et al, 2003
Upper	1.023	1.030	1.001	
Lower	1.008	1.004	1.000	

insufficient studies of the risk of doctor's office visits to derive risk estimates independently. Instead, these values are based on the opinions expressed by the experts that the relative risks of exposure to a given pollutant will be similar across different severities of the same illness.

Table 65 to Table 66 present the ICAP default coefficients and ranges for acute exposure to air pollution for cardiovascular and respiratory-related causes for doctor's office visits.

Table 65 - Cardiovascular Doctor's Office Visits Risk Coefficients

Range	Relative Risk		Comments
	$PM_{2.5}$	O_3	
Median	1.014	1.002	Derived from Table 53 - Acute Cardiovascular Premature Mortality Risk Coefficients
Upper	1.041	1.009	
Lower	1.000	1.000	

Table 66 - Respiratory Doctor's Office Visits Risk Coefficients

Range	Relative Risk		Comments
	$PM_{2.5}$	O_3	
Median	1.011	1.007	Derived from Table 54 - Acute Respiratory Premature Mortality Risk Coefficients
Upper	1.012	1.010	
Lower	1.010	1.000	

B.6 Minor Illnesses

Unlike the base illness rates for other health endpoints, no centralised database for minor illnesses is available. Suggestions were provided through the EOEP how these base illness rates might be estimated. Table 67 provides the base illness rates for different types of minor illness and the sources relied on to derive these rates.

Table 67 - Minor Illness Base Rates Risk Coefficients

Range	Relative Risk			Comments
	Restricted Activity Day	Minor Restricted Activity Day	Asthma Symptom Day	
Median	6.85	7.8	1.29	Derived from Vedal et al, 1998, Ostro and Rothschild, 1989 and Canadian Health Survey
Upper	6.85	7.8	1.42	
Lower	6.85	7.8	1.15	

Table 68 to Table 70 present the median, upper and lower relative risk coefficients for acute exposure to air pollution for restricted activity days, minor restricted activity days and asthma symptom days, respectively. These values have been derived from the EOEP. The $PM_{2.5}$ and O_3 coefficients are considered to be additive and together represent the combined risk of minor illnesses from acute exposure to air pollution.

Two of the categories of minor illness (i.e., restricted activity days and minor restricted activity days) are primarily associated with respiratory causes.

Table 68 - EOEP Synthesis for Minor Illness Restricted Activity Days Risk Coefficients

Range	Relative Risk $PM_{2.5}$	Comments
Median	1.050	Derived from Ostro, 1987
Upper	1.070	
Lower	1.029	

Table 69 - EOEP Synthesis for Minor Illness Minor Restricted Activity Days Risk Coefficients

Range	Relative Risk		Comments
	$PM_{2.5}$	O_3	
Median	1.049	1.005	Derived from Ostro, 1989
Upper	1.052	1.064	
Lower	1.032	1.000	

The relative risks for asthma symptoms days are presented in Table 70. This third minor illness type is a specific respiratory illness type. These ICAP default values were derived through the EOEP.

Table 70 - EOEP Synthesis for Minor Illness Asthma-Symptom Days Risk Coefficients

Range	Relative Risk		Comments
	$PM_{2.5}$	O_3	
Median	1.008	1.018	Derived from Ostro, 1991, Whittemore & Korn, 1980
Upper	1.011	1.031	
Lower	1.000	1.005	

B.7 Early Childhood Lung Development

Table 71 presents the ICAP default coefficients and ranges for early childhood lung development. $PM_{2.5}$ is most commonly cited as the primary causal air pollutant and positive relative risks are only included for this pollutant. Lung impairment is measured by FEV_1 for the purposes of these tables.

Table 71 - Early Childhood Lung Development Risk Coefficients

Range	Relative Risk		Comments
	$PM_{2.5}$	O_3	
Median	1.004	1.000	Derived from Gaudermann 2000.
Upper	1.011	1.000	
Lower	1.000	1.000	

Appendix E – Air Pollution Methodology and Results

This appendix provides technical details relating to the methodology used to interpolate ambient air pollution levels for each CD in each province[34]. The new version of ICAP includes the potential for concentration-response functions[35] (CRF) for five pollutants, namely, $PM_{2.5}$, O_3, NO_2, SO_2, and CO. Default ambient concentrations are included for these pollutants in ICAP. The results of this interpolation process are presented in tabular form (Table 74) and in graphical form (Figure 43 to Figure 47).

E.1 Primary Data

The ICAP default air quality concentrations have been updated using the most recent, available air quality monitoring data from 2003-2006.

E.1.1 Sources

Air quality monitoring data for each of the pollutants for a network of National Air Pollution Surveillance (NAPS) stations distributed throughout Canada were provided by Environment Canada. The data set extended from 1985 to 2006, although the datasets had gaps for some years, for some stations and for some pollutants. Latitude and longitude coordinates were also provided for each monitoring station.

Not all CDs have a NAPS station within their boundaries. Others have multiple stations. Furthermore, the stations are often quite distant from one another making interpolation to intervening CDs difficult. Initial interpolations based solely on NAPS data resulted in dubious spatial patterns, even in some of the more densely populated areas where the stations tend to be concentrated. The U.S. air monitoring network includes many stations close to the Canadian border. By including these data, the Ontario interpolations were significantly improved.

U.S. air quality monitoring data for 2003 to 2006 for all target pollutants, except for SO_4, were obtained for all monitoring sites within 500 km of the Canadian border. These data were downloaded from the U.S. Environmental Protection Agency website (http://www.epa.gov/air/data), Latitude and longitude coordinates for all of the U.S. stations were also obtained.

E.1.2 Data Adjustments

As noted, the air pollution datasets were not complete in all cases. Additionally, some variations among pollutants and among datasets were present in terms of metrics and monitoring techniques. Adjustments to some of the data were necessary before initiating the kriging procedure. Following is a description of the adjustments made for each pollutant dataset.

$PM_{2.5}$

The mean concentration of $PM_{2.5}$ was calculated for the years 2003 to 2006. Annual average concentrations for $PM_{2.5}$ were derived for a total of 41 Canadian stations and 46 U.S. stations.

One anomaly in the Canadian data was noted. The Elk Island station in Alberta was not included. The annual average ambient concentration for Elk Island was 0.68 ug/m^3 compared to nearby Edmonton with a value of 9.38 ug/m^3. While the value for Elk Island might reasonably be less than that in Edmonton, this concentration is much lower than that expected even in a relatively pristine environment, which Elk Island is not.

[34] Interpolation of ambient air quality conditions was done for all of Canada. The following description of the methodology includes the data and procedures used for the entire data set. The average provincial ambient concentrations were obtained by overlaying the provincial CDs on the Canada-wide air quality interpolations.

[35] Complete default CRF datasets are included only for $PM_{2.5}$ and O_3. ICAP includes ambient air quality data for other pollutants but users need to provide the risk coefficients for these other pollutants for most illnesses.

A second complication arose with the $PM_{2.5}$ dataset provided by Environment Canada. Some measurements were from dichotomous samplers while others were from Partisol samplers. While measurements from both samplers are considered to be reasonably similar (T. Dann, personal communication), some variation was evident among comparable measurements from the same station and time period. Accordingly, an adjustment factor was applied to convert all readings to the same sampler type.

Values obtained from Partisol samplers were converted to comparable dichotomous sampler values based on the results of a regression analysis. Fifteen stations reported measurements for both dichotomous and Partisol samplers for the same time period and these records were used in the analysis. The resulting regression model ($r^2 = 0.94$ and SE = 0.98) follows:

$$d = 1.027249\ (p) - 0.81869$$

where: d is a dichotomous sampler value and
p is the Partisol sampler value

As indicated by the relatively large standard error, considerable variation among measurements obtained from the two samplers was present. Overall this adjustment had minor effects on the original values. Partisol $PM_{2.5}$ measurements for a total of 10 stations were adjusted in this way.

PM_{10}
The average annual ambient concentration for PM_{10} was calculated for all stations for the years 2003 to 2006. All PM_{10} readings were recorded with dichotomous samplers. The final combined dataset used in the kriging procedure included 25 Canadian stations and 180 U.S. stations.

Ozone
The average daily 8-hour maximum ozone (April to September) at the Canadian stations was calculated for the years 2000 to 2002. The U.S. data were reported as 8-hour maximum values. The 4th maximum quartile was used and converted from ppm to ppb. The final combined dataset used in the kriging procedure included 203 Canadian stations and 54 U.S. stations.

Nitrogen Dioxide
The average annual ambient concentration of NO_2 was calculated for the years 2003 to 2006. U.S. data were converted from ppm to ppb. The final combined dataset used in the kriging procedure included 140 Canadian stations and 13 U.S. stations.

Sulphur Dioxide
The average annual ambient concentration of SO_2 was calculated for the years 2003 to 2006. U.S. data were converted from ppm to ppb. The final combined dataset used in the kriging procedure included 139 Canadian stations and 35 U.S. stations.

Carbon Monoxide
The average annual ambient concentration of CO was calculated for all stations for the years 2000 to 2002. The final combined dataset used in the kriging procedure included 83 Canadian stations and 19 U.S. stations.

Measurements derived from Partisol samplers were adjusted to make them comparable to dichotomous readings using a similar approach described for $PM_{2.5}$. Fifteen stations reported readings for both dichotomous and Partisol samplers. The regression model ($r^2 = 0.92$ and SE = 0.29) follows:

$$d = 0.879463\ (p) - 0.15268$$

where: d is a dichotomous sampler value and
p is the Partisol sampler value

Sulphate
No sulphate data were available for U.S. stations. Results for 26 Canadian monitoring stations were used in the kriging procedure.

E.2 Population-weighted Centroids

The 2001 population census data were obtained for 5,600 census subdivision. The coordinates for the population-weighted centroid for each of the 288 census divisions (CD) were estimated using these data and the following formulae:

$$\bar{X}_w = \frac{\sum xw}{\sum w} \qquad \bar{Y}_w = \frac{\sum yw}{\sum w}$$

where; x and y are the coordinates provided for the centroid of each census subdivision
w denotes the numerical population weight assigned to each centroid.

All census subdivisions within a given census division were combined to estimate the CD population-weighted centroid.

E.3 Kriging

Kriging is a geostatistical interpolation technique which takes into account the spatial continuity of observed data, resulting in a map or estimates that reflect the spatial behaviour of a specific pollutant (Bobbia et al., 2004).

The data for each air pollutant were interpolated between monitoring sites using a regular grid that covers all of Canada. The "KRIGING" algorithm included in the ArcInfo software was used to interpolate a surface (i.e., a smoothed map of changes in pollutant concentration from one monitoring station to another) using the most proximal air quality monitoring station data for each pollutant.

E.3.1 Kriging Procedure

The same basic kriging procedure was used for each pollutant dataset. Kriging involves statistically fitting observed values for spatially disaggregate points to alternate statistical distribution forms (i.e., spherical, circular, exponential, Gaussian and linear mathematical functions). The application of each different kriging statistical form results in a different goodness of fit with the observed dataset. More specifically, with the application of each mathematical function, various statistics are reported. Two critical statistics are the semi-variance and the root means square error (RMSE). Inserted on each spatial interpolation map for each pollutant is the semi-variogram for the selected statistical model used for the interpolation. The semi-variogram provides a graphic indication of the goodness of fit between the data and the interpolation function used to produce the map.

The best statistical form was determined by systematically comparing the goodness of fit with each mathematical model. Three tests were used to make these selections. First, the semi-variograms for each functional form for each pollutant were visually examined. Preference was given to options where the forecast and observed values diverged the least. Secondly, the RMSEs for each option were considered. In general, forms with the lowest RMSEs were preferred. Finally, a visual inspection of the resulting map of the interpolated pollutant concentrations was performed. Maps with the least number of apparently anomalous patterns were preferred. In other words, the selection of the best functional form was a combination of quantitative criteria and qualitative considerations.

E.3.2 Spatial Variation in Uncertainty

The locations of the air quality monitoring stations fall between the 40.37 degree and 68.36 degree latitudes and –135.05 degree and 52.71 degree longitudes. Air pollution estimates for CDs in areas with many stations in near

proximity are the most reliable. The majority of Canada's population is concentrated in areas with relatively high densities of monitoring stations. The more northern CDs are less confined by surrounding stations. As a result, the interpolated values for these CDs have a higher degree of uncertainty. On the other hand, the population in these more northern CDs is much smaller. Therefore, these interpolation errors will have relatively minor effects on the ICAP health damage forecasts, at least at a provincial or national level.

E.3.3 Statistical Summary

This section provides a statistical summary of the interpolations derived using the kriging procedure. Table 72 presents some key statistics for each pollutant. These statistics are based on the Canada-wide interpolations. The level of statistical precision varies from location to location depending on the density of monitoring stations and the presence of confounding and variable environmental factors.

Table 72 - Statistics for Selected Kriging Models for Each Pollutant

Variable	Model	c0	C	a	sill
$PM_{2.5}$	spherical	1.85	10.74	1414 km	12.591
PM_{10}	linear	35.02	3.82	2948 km	38.83
SO_2	exponential	0.00	4.30	80 km	4.047
NO_2	exponential	22.45	15.98	523 km	37.63
O_3	spherical	2.27	80.25	1528km	82.52
CO	exponential	0.02	0.02	5200 km	0.03

The first two columns indicate the pollutant type and the mathematical function used for the interpolation. The nugget (c0), range (a) and sill are the controlling parameters of the variogram curve shape. The "**c0**" column presents the nugget effect statistic. A low nugget value indicates a smooth (i.e., consistent) spatial continuity among neighbouring points. A high value indicates a more ragged (i.e., less consistent) pattern. The "**C**" column represents the degree of structural variance. The "**a**" column indicates the range of spatial dependency among monitoring stations. A large value in this column indicates that measurements among distant monitoring stations are interdependent. The "z" value is the point beyond which monitoring stations have no influence. The kriging procedure captures both local and regional pollution patterns depending on the degree to which such patterns are evident from the data. Finally, the "**sill"** represents the variance at a distance equal to the range (a). The higher the sill value, the higher is the variance associated with the predicted value.

These statistics show the significant variations in spatial dependence among pollutants. The highest spatial dependences are seen in CO and PM_{10}. Overall, the spatial interpolations of these values tend to be more reliable at this regional scale. The interpolations for SO_2 and NO_2 have lower spatial dependences.

The zero and near zero nugget value for SO_2 and CO indicates a very smooth spatial continuity between neighbouring points. Overall, the interpolations for O_3, CO and $PM_{2.5}$ are the most consistent of all of the pollutants.

The interpolated pollutant concentrations were then evaluated against the known concentration. Table 73 presents the RMSEs for each pollutant. These statistics provide further support for the observations based on Table 74. CO and SO_2 have the lowest RMSE. The highest values are associated with PM_{10}, and NO_2.

Table 73 - Root Mean Square Error Statistics For Each Pollutant

Variable	RMSE	n
$PM_{2.5}$	1.9244	87
PM_{10}	6.1798	62
SO_2	0.9183	174
NO_2	4.7301	153
O_3	2.3718	257
CO	0.1305	102

E.3.4 CD Overlay

Ambient air pollution maps were prepared for each pollutant. The coordinates for the population-weighted centroids for each CD were then overlaid on the pollution maps. Pollutant concentration for the centroid location was recorded and exported to a spreadsheet file. These data were then read into the ICAP software. The result is that average ambient concentrations for each of the five air pollutants are available as default values in the new version of ICAP.

Table 74 - Census Division Concentrations

CD	XCOORD	YCOORD	PRCD2	CO	CO VAR	NO2	NO2 VAR	O3	O3 VAR	PM10	PM10 VAR	PM2.5	PM2.5 VAR	SO2	SO2 VAR
1	-1613740	1529390	5939	0.361	0.017	8.982	28.273	37.926	10.215	19.037	38.426	8.894	4.399	0.604	3.505
2	-1929210	1516260	5931	0.394	0.017	12.016	27.859	38.271	4.972	18.307	38.412	7.513	3.567	0.409	2.953
3	-1729870	1534570	5933	0.361	0.017	8.982	28.273	43.372	8.117	18.356	38.379	8.894	4.399	0.445	0.917
4	-1688300	1428680	5935	0.450	0.017	8.982	28.273	42.061	4.735	18.511	38.239	8.894	4.399	0.134	0.636
5	-1661150	1472130	5937	0.361	0.017	8.982	28.273	42.061	4.735	19.037	38.426	8.894	4.399	0.331	1.566
6	1264170	850279	3549	0.448	0.017	14.528	27.930	47.846	7.630	15.681	38.438	9.675	5.357	5.766	4.141
7	-623754	1913280	4718	0.359	0.019	7.227	35.323	26.894	35.914	16.027	39.125	5.451	10.963	3.020	5.222
8	1854080	995731	2440	0.366	0.016	12.513	29.092	42.326	4.339	18.455	38.077	10.291	3.148	2.105	3.767
9	-923426	1531110	4713	0.382	0.017	10.244	31.278	40.794	12.848	17.492	38.652	6.676	4.657	1.049	4.957
10	-825537	1515160	4712	0.382	0.017	10.244	31.278	36.727	11.796	17.492	38.652	6.676	4.657	0.832	3.819
11	-1613740	1529390	4711	0.382	0.017	8.550	30.676	33.162	5.160	17.405	38.702	6.676	4.657	0.831	1.394
12	-1929210	1516260	3540	0.433	0.016	13.381	26.618	53.827	3.964	18.329	38.181	11.518	2.777	3.311	3.245
13	-1729870	1534570	4717	0.364	0.017	10.912	32.883	36.580	19.206	17.483	38.816	6.275	6.358	1.198	5.198
14	-1688300	1428680	4716	0.382	0.017	10.244	31.278	34.038	14.308	17.416	38.881	6.275	6.358	1.903	4.242
15	-1661150	1472130	4715	0.372	0.018	8.550	30.676	25.836	7.377	17.405	38.702	6.455	5.914	0.813	1.592
16	1264170	850279	4714	0.372	0.018	8.550	30.676	27.178	22.833	17.336	38.914	6.455	5.914	2.032	4.321
17	-623754	1913280	3553	0.446	0.017	9.661	31.168	43.668	8.197	14.857	38.677	9.675	5.357	2.644	0.729
18	1854080	995731	3552	0.446	0.017	9.661	31.168	43.745	12.350	16.425	38.789	11.948	5.350	3.003	3.488
19	-923426	1531110	2492	0.347	0.018	13.083	34.933	33.899	10.077	18.884	38.885	8.896	9.136	6.372	4.257
20	-1995230	1477990	5929	0.441	0.017	12.016	27.859	33.782	7.877	18.240	38.571	7.513	3.567	0.466	1.658
21	2433530	994187	1204	0.400	0.017	6.442	30.489	37.491	8.100	17.081	38.434	6.412	5.652	3.887	4.136
22	-2099250	1475480	5923	0.441	0.017	10.942	30.442	32.812	11.223	18.240	38.571	7.513	3.567	0.499	3.924
23	-2036580	1453880	5921	0.454	0.016	10.942	30.442	33.666	5.370	18.256	38.392	7.513	3.567	0.507	1.737
24	-2040150	1532180	5927	0.441	0.017	10.942	30.442	33.782	7.877	18.240	38.571	7.513	3.567	0.252	1.056
20	-1995230	1477990	5929	0.441	0.017	12.016	27.859	33.782	7.877	18.240	38.571	7.513	3.567	0.466	1.658
21	2433530	994187	1204	0.400	0.017	6.442	30.489	37.491	8.100	17.081	38.434	6.412	5.652	3.887	4.136
22	-2099250	1475480	5923	0.441	0.017	10.942	30.442	32.812	11.223	18.240	38.571	7.513	3.567	0.499	3.924
23	-2036580	1453880	5921	0.454	0.016	10.942	30.442	33.666	5.370	18.256	38.392	7.513	3.567	0.507	1.737
24	-2040150	1532180	5927	0.441	0.017	10.942	30.442	33.782	7.877	18.240	38.571	7.513	3.567	0.252	1.056
25	-2088230	1541890	5925	0.441	0.017	10.942	30.442	31.111	8.484	18.240	38.571	7.513	3.567	0.369	2.692
26	2661160	1339950	1218	0.361	0.018	4.799	33.168	32.882	11.251	17.776	39.426	7.090	11.994	2.470	2.339
27	-1090090	2741430	6106	0.289	0.019	4.064	33.755	29.971	7.670	14.550	39.683	4.202	5.828	0.624	3.510
28	-1661120	3674370	6107	0.290	0.023	3.746	40.671	27.749	22.415	13.609	41.819	5.733	16.082	0.726	4.398

29	1547010	838735	3509	0.395	0.016	11.435	29.712	48.386	8.036	16.124	38.175	9.186	3.291	2.160	2.985
30	1749700	958016	2459	0.366	0.016	12.513	29.092	41.967	4.448	18.455	38.077	10.291	3.148	2.147	1.449
31	-370815	1342930	4616	0.361	0.018	7.330	30.597	34.408	19.936	18.486	38.767	6.976	7.165	2.156	4.568
32	-279853	1360670	4617	0.359	0.018	7.330	30.597	33.642	19.962	18.526	38.914	6.976	7.165	2.033	4.464
33	-100655	1251160	4614	0.351	0.017	8.715	29.909	34.630	12.174	18.026	38.819	6.735	4.859	2.254	4.470
34	-298283	1268450	4615	0.359	0.018	7.330	30.597	35.350	12.620	18.537	38.821	6.735	4.859	2.033	4.464
35	-48048	1219550	4612	0.351	0.017	8.715	29.909	36.434	9.278	19.205	38.809	7.683	5.356	2.254	4.470
36	-66996	1244580	4613	0.351	0.017	8.715	29.909	35.452	13.138	18.026	38.819	7.683	5.356	2.254	4.470
37	-113674	1199310	4610	0.351	0.017	8.715	29.909	35.669	7.402	18.026	38.819	6.735	4.859	2.254	4.470
38	-84054	1209490	4611	0.351	0.017	8.715	29.909	35.669	7.402	18.026	38.819	7.683	5.356	2.254	4.470
39	1134650	461799	3536	0.433	0.016	13.381	26.618	57.725	5.959	17.223	38.086	11.518	2.777	3.521	1.562
40	1072240	433651	3537	0.411	0.016	13.381	26.618	55.826	4.852	17.480	38.265	11.494	3.016	4.707	0.663
41	1206750	512120	3534	0.433	0.016	13.381	26.618	58.482	5.809	17.223	38.086	11.518	2.777	2.952	1.770
42	1231280	554595	3532	0.433	0.016	13.381	26.618	53.983	5.469	17.223	38.086	11.518	2.777	2.533	1.834
43	2354920	983753	1203	0.400	0.017	6.442	30.489	37.490	7.472	17.081	38.434	6.412	5.652	3.067	4.016
44	-112579	1325040	4618	0.348	0.018	8.715	29.909	34.026	20.139	17.998	38.948	6.976	7.165	2.254	4.470
45	-100776	1414140	4619	0.348	0.018	8.613	34.921	33.407	27.323	17.998	38.948	6.976	7.165	2.048	4.467
46	1830010	1109910	2434	0.363	0.017	12.513	29.092	39.011	4.106	19.313	38.269	9.769	3.692	3.002	2.648
47	1778490	1094920	2435	0.363	0.017	12.513	29.092	37.532	7.378	19.313	38.269	9.769	3.692	3.603	2.689
48	2417390	929115	1201	0.400	0.017	6.442	30.489	37.491	8.100	17.081	38.434	6.412	5.652	3.308	4.409
49	1932210	1004710	2430	0.367	0.017	12.513	29.092	40.854	5.922	18.844	38.143	9.769	3.692	2.632	4.756
50	1892390	1040200	2431	0.367	0.017	12.513	29.092	41.021	5.395	19.747	38.261	9.769	3.692	2.311	3.551
51	1853140	1049800	2432	0.366	0.016	12.513	29.092	41.021	5.395	19.313	38.269	9.769	3.692	2.160	2.950
52	1861290	1086720	2433	0.363	0.017	12.513	29.092	39.011	4.106	19.747	38.261	9.769	3.692	2.410	2.644
53	2478530	1114050	1208	0.374	0.017	6.442	30.489	30.795	7.404	17.003	38.731	6.460	4.144	5.456	3.218
54	-2145640	1847950	5945	0.454	0.018	8.073	32.805	31.694	27.756	18.172	39.334	8.480	6.559	1.524	5.054
55	1812100	1055090	2438	0.366	0.016	12.513	29.092	40.046	4.178	19.313	38.269	9.769	3.692	2.022	1.785
56	1841920	1025070	2439	0.366	0.016	12.513	29.092	41.021	5.395	19.313	38.269	9.769	3.692	2.067	3.354
57	1935500	1049520	2429	0.367	0.017	12.513	29.092	40.854	5.922	19.747	38.261	9.769	3.692	2.625	4.498
58	1266230	566559	3529	0.453	0.016	15.925	28.125	53.983	5.469	17.223	38.086	11.518	2.777	2.291	0.771
59	2073570	1245390	1313	0.379	0.017	8.294	32.666	35.025	8.017	18.671	38.474	6.576	3.354	2.890	1.490
60	2530360	1274200	1101	0.361	0.018	4.799	33.168	33.220	11.301	17.769	38.915	6.460	4.144	3.212	4.158

61	2420790	1267480	1103	0.374	0.018	5.780	30.553	35.682	11.911	17.859	38.669	6.460	4.144	3.891	4.468
62	2484030	1259230	1102	0.374	0.017	5.780	30.553	34.726	12.195	17.769	38.915	6.460	4.144	3.810	4.273
63	2547480	1200130	1212	0.374	0.017	4.799	33.168	32.372	7.553	17.769	38.915	6.460	4.144	4.001	3.810
64	2639740	1207590	1213	0.374	0.017	4.799	33.168	31.576	12.040	17.026	39.224	6.912	8.699	2.937	2.977
65	-2216700	3003150	6001	0.308	0.020	3.148	34.779	32.094	13.337	14.361	41.029	6.225	16.790	1.457	4.656
66	-2092920	2705680	5957	0.309	0.019	3.442	35.708	31.214	34.661	14.418	40.299	6.383	15.263	1.657	4.764
67	-1611830	2136650	5955	0.364	0.018	5.770	33.705	34.655	22.327	14.125	38.984	8.846	9.101	1.462	1.900
68	-1780870	1937840	5953	0.410	0.018	7.428	30.636	37.177	7.282	17.008	39.087	8.846	9.101	3.042	0.304
69	-1965270	2047860	5951	0.436	0.018	7.428	30.636	33.171	15.355	16.919	39.175	8.430	10.777	1.636	4.854
70	-4100	1221930	4601	0.351	0.017	9.419	33.831	36.434	9.278	19.205	38.809	7.683	5.356	2.254	4.470
71	1285140	536549	3528	0.453	0.016	15.925	28.125	54.275	4.558	14.122	38.080	11.518	2.777	4.642	1.835
72	-136919	1138650	4603	0.367	0.018	8.715	29.909	37.729	14.248	18.067	38.786	6.735	4.859	2.254	4.470
73	-56645	1172160	4602	0.351	0.017	8.715	29.909	36.434	9.278	19.205	38.809	7.683	5.356	2.254	4.470
74	-310704	1147100	4605	0.367	0.018	7.330	30.597	40.619	12.936	17.629	38.800	6.735	4.859	1.778	4.355
75	-209001	1144600	4604	0.367	0.018	8.715	29.909	38.101	14.894	17.629	38.800	6.735	4.859	2.114	4.431
76	-283670	1209220	4607	0.367	0.018	7.330	30.597	36.916	6.582	18.537	38.821	6.735	4.859	1.935	4.428
77	-358069	1214600	4606	0.399	0.018	7.330	30.597	38.283	10.749	18.487	38.686	6.735	4.859	1.854	4.390
78	1305010	630774	3521	0.453	0.016	14.528	27.930	52.856	4.042	14.608	38.066	11.518	2.777	1.806	0.401
79	1327000	645339	3520	0.453	0.016	14.528	27.930	52.856	4.042	14.608	38.066	11.518	2.777	2.523	0.392
80	1256270	620409	3523	0.433	0.016	15.925	28.125	50.355	7.138	18.329	38.181	11.518	2.777	2.255	1.302
81	1262980	661526	3522	0.450	0.017	14.528	27.930	50.355	7.138	18.329	38.181	11.518	2.777	1.649	2.282
82	1295660	578489	3525	0.453	0.016	15.925	28.125	54.275	4.558	14.122	38.080	11.518	2.777	4.487	0.716
83	1299390	609342	3524	0.453	0.016	15.925	28.125	54.275	4.558	14.608	38.066	11.518	2.777	2.427	0.925
84	1353230	576958	3526	0.453	0.016	15.925	28.125	52.761	3.875	14.122	38.080	11.518	2.777	3.320	1.350
85	1920690	1072120	2427	0.334	0.017	12.513	29.092	40.854	5.922	19.747	38.261	9.769	3.692	2.483	3.507
86	1901470	1090400	2426	0.334	0.017	12.513	29.092	38.798	6.068	19.747	38.261	9.769	3.692	2.483	3.507
87	-567902	1437980	4710	0.356	0.017	8.550	30.676	33.598	16.303	17.313	38.818	6.455	5.914	1.909	4.336
88	1874360	1123040	2423	0.334	0.017	12.513	29.092	39.011	4.106	19.747	38.261	9.769	3.692	2.771	1.064
89	1855450	1137530	2422	0.363	0.017	13.083	34.933	39.011	4.106	19.313	38.269	9.769	3.692	3.325	2.015
90	1884510	1151670	2421	0.334	0.017	13.083	34.933	39.011	4.106	19.747	38.261	9.769	3.692	3.874	2.697
91	1889150	1138240	2420	0.334	0.017	13.083	34.933	39.011	4.106	19.747	38.261	9.769	3.692	2.771	1.064

92	2634560	1298570	1215	0.361	0.018	4.799	33.168	32.596	10.670	17.026	39.224	6.912	8.699	2.555	2.986
93	2599020	1235030	1214	0.374	0.017	4.799	33.168	32.372	7.553	17.026	39.224	6.460	4.144	2.849	2.388
94	2707870	1316180	1217	0.359	0.018	4.799	33.168	32.151	10.175	17.026	39.224	7.090	11.994	2.275	1.649
95	2671560	1255490	1216	0.368	0.018	4.799	33.168	32.596	10.670	17.026	39.224	6.912	8.699	2.352	2.257
96	2438630	1180010	1211	0.385	0.017	5.780	30.553	36.817	7.620	17.859	38.669	6.460	4.144	4.362	4.216
97	1164090	692013	3541	0.450	0.017	12.377	30.689	48.441	9.298	18.329	38.181	11.518	2.777	1.897	4.433
98	1203580	704904	3542	0.450	0.017	12.377	30.689	48.905	8.113	18.329	38.181	9.675	5.357	1.837	4.047
99	1952680	1086100	2428	0.334	0.017	12.513	29.092	38.798	6.068	19.747	38.261	9.769	3.692	2.484	3.990
100	2281790	1501830	2403	0.348	0.018	5.440	35.193	34.776	15.353	17.975	39.124	7.514	8.382	3.755	4.492
101	-292246	3503950	6208	0.275	0.024	4.580	44.495	29.253	99.223	15.346	41.325	6.451	15.195	0.668	4.700
102	1248540	598688	3530	0.433	0.016	15.925	28.125	53.983	5.469	18.329	38.181	11.518	2.777	2.035	1.221
103	1306430	799772	3544	0.448	0.017	14.528	27.930	48.926	6.067	14.554	38.301	9.675	5.357	4.783	4.014
104	1366940	807842	3546	0.448	0.017	14.528	27.930	50.479	8.479	14.554	38.301	9.675	5.357	4.194	3.906
105	1468220	891950	3547	0.368	0.017	9.948	30.888	45.521	10.563	16.094	38.331	9.186	3.291	4.188	4.164
106	214849	2776770	6205	0.329	0.022	7.590	44.308	35.216	105.13	15.577	40.408	7.340	15.446	2.472	4.981
107	1176910	3332660	6204	0.294	0.024	7.610	42.448	38.786	107.95	17.389	41.498	6.656	17.046	5.077	4.471
108	-2131990	2136130	5949	0.419	0.018	4.763	33.330	31.184	23.316	16.891	39.801	8.430	10.777	1.010	3.432
109	1400920	728896	3515	0.448	0.017	14.528	27.930	50.173	5.303	14.608	38.066	9.675	5.357	1.348	0.932
110	1355050	745584	3516	0.448	0.017	14.528	27.930	50.173	5.303	14.554	38.301	9.675	5.357	1.514	2.953
111	1538160	753422	3510	0.395	0.016	11.435	29.712	50.720	5.238	16.124	38.175	9.186	3.291	1.849	3.240
112	1423720	703022	3514	0.448	0.017	14.528	27.930	50.173	5.303	14.729	38.149	10.484	3.159	1.690	2.059
113	1463430	741845	3512	0.395	0.016	14.528	27.930	53.923	5.222	16.124	38.175	9.186	3.291	1.314	2.296
114	1505880	711093	3513	0.395	0.016	11.435	29.712	50.720	5.238	14.729	38.149	9.186	3.291	1.539	1.826
115	-1793020	1750790	5941	0.401	0.017	9.885	29.592	41.656	8.118	17.556	38.579	9.642	4.330	0.814	4.659
116	-2199190	1680700	5943	0.454	0.018	8.073	32.805	31.128	24.833	18.247	39.090	8.696	11.153	0.660	5.915
117	-1611950	2485650	5959	0.314	0.018	3.805	33.664	31.958	44.556	13.962	39.428	6.918	11.591	1.354	4.731
118	1320920	666619	3519	0.448	0.017	14.528	27.930	52.856	4.042	14.608	38.066	11.518	2.777	1.869	1.022
119	-2284400	2135620	5947	0.433	0.019	4.266	36.879	30.690	44.144	16.889	40.020	8.598	13.926	1.721	4.570
120	2231660	1135160	1310	0.379	0.017	8.294	32.666	36.375	4.728	17.976	38.302	6.576	3.354	4.264	3.999
121	2006030	1803420	2497	0.347	0.019	8.109	40.236	33.363	34.918	18.677	39.777	8.578	14.270	4.327	4.714
122	2363490	932756	1202	0.400	0.017	6.442	30.489	37.490	7.472	17.081	38.434	6.412	5.652	3.051	4.391

123	2546500	1115170	1209	0.374	0.017	5.275	33.928	29.465	9.737	17.003	38.731	6.460	4.144	5.493	2.920
124	1742410	1013480	2452	0.366	0.016	12.513	29.092	40.046	4.178	18.455	38.077	9.769	3.692	6.207	1.931
125	1758240	998442	2453	0.366	0.016	12.513	29.092	41.967	4.448	18.455	38.077	10.291	3.148	4.024	1.182
126	1794700	1025920	2450	0.366	0.016	12.513	29.092	40.046	4.178	19.313	38.269	9.769	3.692	2.414	1.737
127	1756810	1038330	2451	0.366	0.016	12.513	29.092	40.046	4.178	19.313	38.269	9.769	3.692	4.515	1.309
128	1773590	909354	2456	0.366	0.016	12.513	29.092	46.456	5.639	18.455	38.077	10.291	3.148	1.453	2.303
129	1761560	945082	2457	0.366	0.016	12.513	29.092	41.967	4.448	18.455	38.077	10.291	3.148	2.147	1.449
130	1782110	966762	2454	0.366	0.016	12.513	29.092	41.967	4.448	18.455	38.077	10.291	3.148	1.911	2.666
131	1775330	936784	2455	0.366	0.016	12.513	29.092	41.967	4.448	18.455	38.077	10.291	3.148	1.484	1.373
132	520384	1088590	3558	0.381	0.018	10.555	33.088	45.644	21.955	20.808	39.149	10.506	8.079	1.945	2.489
133	1092610	832894	3551	0.450	0.017	12.377	30.689	46.755	13.077	16.594	38.572	11.948	5.350	3.515	4.198
134	205346	1080910	3559	0.358	0.018	9.197	34.735	43.734	14.566	18.768	38.830	7.683	5.356	2.615	4.505
135	3140150	1700280	1001	0.338	0.018	4.897	31.371	33.632	9.570	17.410	40.782	7.726	17.732	1.386	1.592
136	3000110	1593260	1002	0.346	0.018	4.689	34.433	32.849	18.758	17.760	40.256	7.433	15.673	3.308	4.425
137	2833010	1572070	1003	0.349	0.018	4.534	33.982	32.568	15.211	17.424	39.950	7.090	11.994	3.183	4.297
138	2707000	1614470	1004	0.349	0.018	4.810	34.203	32.572	14.010	17.793	39.948	8.179	15.767	2.845	3.901
139	2742270	1699170	1005	0.343	0.018	4.687	33.678	32.885	6.256	17.793	39.948	8.179	15.767	1.569	0.642
140	2908640	1770760	1006	0.340	0.018	4.687	33.678	34.722	4.894	17.450	40.734	8.179	15.767	3.373	4.434
141	3034210	1774780	1007	0.340	0.018	4.897	31.371	34.282	13.628	17.450	40.734	7.726	17.732	3.231	4.314
142	2891880	1833200	1008	0.340	0.018	4.687	33.678	36.836	12.878	17.450	40.734	8.179	15.767	3.439	4.467
143	2728920	1906680	1009	0.337	0.019	5.069	38.671	42.432	8.594	17.821	40.249	8.942	18.419	3.405	4.451
144	1585620	805772	3507	0.395	0.016	11.435	29.712	48.201	6.525	16.454	38.122	9.186	3.291	2.296	3.344
145	1566450	876268	3506	0.368	0.017	11.435	29.712	43.211	5.562	16.454	38.122	9.186	3.291	2.022	1.981
146	-1469420	1915540	4818	0.352	0.017	7.853	31.012	40.304	10.841	17.266	39.055	7.538	7.975	0.930	3.146
147	-1478490	2028170	4819	0.352	0.017	7.853	31.012	36.413	9.298	17.266	39.055	7.538	7.975	0.540	0.998
148	1649420	867644	3501	0.368	0.017	11.435	29.712	45.477	5.942	16.454	38.122	9.186	3.291	1.949	1.691
149	-1419350	1786720	4814	0.369	0.017	6.302	28.353	46.387	5.880	17.315	38.761	9.215	5.201	0.627	3.175
150	-1383530	1498150	4815	0.373	0.017	10.921	28.367	44.843	9.054	19.622	38.367	9.749	3.826	1.012	3.714
151	-1000370	2210250	4816	0.307	0.018	5.669	30.272	34.236	10.874	16.564	39.254	5.106	8.421	1.337	3.650
152	-1286100	2153920	4817	0.317	0.018	5.421	33.634	34.832	24.913	16.389	38.920	5.822	7.317	1.354	5.158
153	-1071590	1690720	4810	0.357	0.017	10.552	25.717	44.003	14.453	18.671	38.771	6.246	3.054	1.681	4.631

154	-1190600	1741200	4811	0.364	0.016	10.552	25.717	44.022	5.874	19.440	38.606	6.246	3.054	1.398	1.468
155	-1004660	1800150	4812	0.357	0.017	10.912	32.883	38.649	21.668	19.368	39.022	6.246	3.054	1.664	5.229
156	-1229090	1826790	4813	0.364	0.016	10.552	25.717	42.942	12.560	19.389	38.860	6.246	3.054	1.778	4.243
157	-117044	2021410	4623	0.361	0.020	8.450	40.287	32.823	66.260	15.872	39.489	6.365	12.929	1.969	4.713
158	-54338	1799490	4622	0.361	0.019	8.377	38.447	33.078	58.252	16.028	39.539	7.875	12.009	2.098	4.569
159	-342059	1705290	4621	0.346	0.018	9.193	36.204	27.767	37.982	18.038	39.226	7.082	10.692	3.886	4.095
160	-363849	1474060	4620	0.339	0.018	8.198	33.636	32.497	24.975	18.180	38.975	6.976	7.165	2.373	4.642
161	2015650	1442950	2496	0.351	0.018	8.125	36.824	34.177	18.775	18.083	38.739	7.514	8.382	4.334	4.767
162	1809210	995661	2449	0.366	0.016	12.513	29.092	41.967	4.448	18.455	38.077	10.291	3.148	2.018	3.126
163	1809280	969926	2448	0.366	0.016	12.513	29.092	41.967	4.448	18.455	38.077	10.291	3.148	1.889	3.539
164	1852800	931444	2445	0.366	0.016	12.513	29.092	42.326	4.339	18.455	38.077	10.291	3.148	2.095	4.251
165	1879850	931086	2444	0.367	0.017	12.513	29.092	42.326	4.339	18.844	38.143	10.291	3.148	2.304	4.682
166	1806070	940382	2447	0.366	0.016	12.513	29.092	41.967	4.448	18.455	38.077	10.291	3.148	1.542	2.812
167	1802290	918170	2446	0.366	0.016	12.513	29.092	46.456	5.639	18.455	38.077	10.291	3.148	1.542	2.812
168	1889410	977491	2441	0.367	0.017	12.513	29.092	42.326	4.339	18.844	38.143	10.291	3.148	2.300	4.268
169	-616268	1307730	4706	0.356	0.017	9.098	30.206	41.348	5.683	17.687	38.649	6.455	5.914	0.858	0.961
170	1847420	970218	2442	0.366	0.016	12.513	29.092	42.326	4.339	18.455	38.077	10.291	3.148	2.016	4.195
171	2243180	1392060	2405	0.381	0.018	5.440	35.193	34.546	7.599	17.965	38.795	7.514	8.382	4.298	4.587
172	2263870	1996830	1010	0.340	0.019	6.073	40.174	34.539	21.651	18.612	40.180	8.718	17.508	3.456	4.475
173	1738020	973517	2460	0.366	0.016	13.783	29.593	42.733	5.581	18.455	38.077	10.291	3.148	5.803	1.599
174	2093890	1383230	2407	0.381	0.018	8.125	36.824	34.317	13.783	18.083	38.739	7.514	8.382	4.808	4.398
175	2168350	1339390	1314	0.381	0.018	8.294	32.666	34.656	11.707	17.965	38.795	7.514	8.382	4.085	4.397
176	2135560	1220590	1312	0.379	0.017	8.294	32.666	35.988	8.571	18.671	38.474	6.576	3.354	4.301	3.810
177	2163000	1150150	1311	0.379	0.017	8.294	32.666	35.210	5.034	17.976	38.302	6.576	3.354	4.697	4.293
178	-1343900	1635850	4809	0.373	0.017	6.302	28.353	47.106	8.735	19.526	38.563	9.215	5.201	0.682	3.245
179	-1232890	1606640	4808	0.375	0.016	12.160	29.444	44.545	6.587	19.546	38.473	6.246	3.054	0.476	0.576
180	-1083130	1604730	4807	0.370	0.017	12.160	29.444	44.712	13.730	18.736	38.634	6.246	3.054	1.297	5.090
181	-1280680	1470560	4806	0.375	0.016	10.921	28.367	41.962	7.165	19.622	38.367	7.522	4.726	1.563	1.035
182	-1205640	1471750	4805	0.375	0.016	12.160	29.444	43.306	9.916	19.546	38.473	7.522	4.726	1.096	3.804
183	-1070630	1489020	4804	0.370	0.017	12.160	29.444	45.463	10.799	18.736	38.634	7.522	4.726	0.927	4.844
184	-1275210	1300570	4803	0.443	0.017	8.978	29.990	43.564	9.897	19.901	38.229	8.885	5.806	1.171	3.502

185	-1201680	1315760	4802	0.443	0.017	9.490	30.821	45.242	6.900	20.310	38.409	7.522	4.726	0.799	1.943
186	-1066750	1312360	4801	0.432	0.017	9.490	30.821	45.863	9.047	17.510	38.436	7.522	4.726	0.849	4.591
187	1272040	930894	3548	0.376	0.017	9.948	30.888	42.474	5.890	16.954	38.484	9.675	5.357	10.60	3.073
188	1926440	1243700	2415	0.334	0.017	13.083	34.933	35.266	10.184	19.910	38.488	9.769	3.692	5.255	4.046
189	2452270	1037520	1206	0.400	0.017	6.442	30.489	31.089	7.920	17.003	38.731	6.460	4.144	5.405	3.310
190	2385120	1053980	1205	0.400	0.017	6.442	30.489	38.734	5.971	17.073	38.470	6.460	4.144	4.134	3.598
191	2425310	1095650	1207	0.385	0.017	6.442	30.489	38.070	5.580	17.073	38.470	6.460	4.144	5.102	3.679
192	-203865	1236210	4608	0.367	0.018	8.715	29.909	36.240	11.122	18.026	38.819	6.735	4.859	2.033	4.464
193	-164447	1217110	4609	0.367	0.018	8.715	29.909	36.240	11.122	18.026	38.819	6.735	4.859	2.050	4.428
194	1649200	985956	2478	0.368	0.017	13.783	29.593	40.299	6.689	16.499	38.161	9.186	3.291	3.351	3.908
195	1576520	1014610	2479	0.368	0.017	13.783	29.593	33.078	6.750	16.499	38.161	10.631	6.699	2.666	4.705
196	1287490	716090	3543	0.448	0.017	14.528	27.930	48.513	5.750	14.608	38.066	9.675	5.357	1.382	1.088
197	1720650	900216	2470	0.366	0.016	13.783	29.593	47.178	4.492	18.455	38.077	10.291	3.148	1.645	1.855
198	1699950	912270	2471	0.366	0.016	13.783	29.593	47.178	4.492	16.499	38.161	9.186	3.291	1.856	1.529
199	1707670	933710	2472	0.366	0.016	13.783	29.593	42.733	5.581	16.499	38.161	9.186	3.291	3.151	1.969
200	1712630	948207	2473	0.366	0.016	13.783	29.593	42.733	5.581	18.455	38.077	9.186	3.291	4.643	2.255
201	1698990	944813	2474	0.366	0.016	13.783	29.593	42.733	5.581	16.499	38.161	9.186	3.291	4.643	2.255
202	1693070	962411	2475	0.366	0.016	13.783	29.593	42.733	5.581	16.499	38.161	9.186	3.291	4.643	2.255
203	1672610	940143	2476	0.366	0.016	13.783	29.593	42.733	5.581	16.499	38.161	9.186	3.291	2.816	2.658
204	1678800	970519	2477	0.366	0.016	13.783	29.593	42.733	5.581	16.499	38.161	9.186	3.291	3.618	3.094
205	-707902	1312930	4707	0.356	0.017	9.098	30.206	42.912	17.460	17.102	38.619	6.676	4.657	1.496	3.764
206	1927200	1149410	2418	0.334	0.017	13.083	34.933	38.798	6.068	19.747	38.261	9.769	3.692	3.961	3.702
207	-2013410	1359720	5917	0.454	0.016	13.000	32.304	34.310	3.787	18.256	38.392	7.513	3.567	0.872	1.477
208	1909780	1119130	2419	0.334	0.017	12.513	29.092	38.798	6.068	19.747	38.261	9.769	3.692	2.974	2.727
209	-1954970	1427670	5915	0.454	0.016	12.016	27.859	38.531	4.662	18.322	38.205	7.513	3.567	1.356	0.242
210	1901980	1205640	2416	0.334	0.017	13.083	34.933	36.809	8.418	19.910	38.488	9.769	3.692	4.569	3.651
211	1947410	1178620	2417	0.334	0.017	13.083	34.933	36.809	8.418	19.910	38.488	9.769	3.692	4.397	3.893
212	1953120	1221970	2414	0.334	0.017	13.083	34.933	36.809	8.418	19.910	38.488	9.769	3.692	4.854	4.002
213	-2026110	1402120	5919	0.454	0.016	10.942	30.442	33.666	5.370	18.256	38.392	7.513	3.567	0.734	2.156
214	1971210	1272790	2412	0.351	0.018	13.083	34.933	35.266	10.184	19.910	38.488	9.769	3.692	4.695	4.045
215	2021390	1261010	2413	0.334	0.017	8.294	32.666	34.397	5.846	18.671	38.474	6.576	3.354	3.467	2.896

216	2014770	1345100	2410	0.351	0.018	8.294	32.666	34.300	13.699	18.083	38.739	7.514	8.382	4.156	4.226
217	1989580	1306210	2411	0.351	0.018	8.294	32.666	34.397	5.846	19.910	38.488	8.896	9.136	4.363	4.077
218	1113760	526266	3538	0.433	0.016	13.381	26.618	57.725	5.959	17.357	38.155	11.518	2.777	6.266	1.298
219	1204560	590267	3531	0.433	0.016	13.381	26.618	53.983	5.469	18.329	38.181	11.518	2.777	2.469	2.041
220	1192400	535392	3539	0.433	0.016	13.381	26.618	53.983	5.469	17.223	38.086	11.518	2.777	2.161	0.951
221	1962070	1345260	2495	0.351	0.018	13.083	34.933	34.461	14.302	19.909	38.816	8.896	9.136	4.902	4.332
222	1629290	905112	3502	0.368	0.017	13.783	29.593	45.477	5.942	16.499	38.161	9.186	3.291	2.008	2.314
223	1787490	1298440	2493	0.347	0.018	13.083	34.933	34.948	8.019	18.862	38.549	9.769	3.692	8.321	2.753
224	1590850	1231430	2490	0.368	0.018	14.102	36.858	33.420	13.047	17.965	38.681	10.631	6.699	5.366	5.188
225	1743490	1290690	2491	0.347	0.018	13.083	34.933	34.948	8.019	18.862	38.549	9.769	3.692	6.361	4.238
226	-455449	1405970	4709	0.361	0.018	8.198	33.636	32.455	22.905	18.486	38.767	6.455	5.914	2.069	4.494
227	268433	1338020	3560	0.372	0.018	9.400	35.439	41.918	16.672	18.732	39.230	8.776	10.461	2.384	4.459
228	2438160	1756000	2498	0.343	0.019	5.318	37.769	35.902	19.850	17.908	39.575	7.851	14.156	3.456	4.475
229	1394220	1761100	2499	0.366	0.021	10.398	44.078	34.581	54.468	17.470	39.903	10.801	15.299	6.204	4.652
230	2511270	1166790	1210	0.374	0.017	4.799	33.168	33.842	8.460	17.003	38.731	6.460	4.144	4.720	3.743
231	1710450	882851	2469	0.366	0.016	13.783	29.593	47.178	4.492	16.499	38.161	9.186	3.291	1.339	1.188
232	1747760	902555	2468	0.366	0.016	12.513	29.092	46.456	5.639	18.455	38.077	10.291	3.148	1.645	1.855
233	1714870	976495	2463	0.366	0.016	13.783	29.593	42.733	5.581	18.455	38.077	10.291	3.148	5.288	2.716
234	1701560	1014460	2462	0.366	0.016	13.783	29.593	39.696	9.082	16.499	38.161	10.631	6.699	5.427	3.064
235	1732140	994789	2461	0.366	0.016	13.783	29.593	42.733	5.581	18.455	38.077	10.291	3.148	5.803	1.599
236	-478673	1169220	4701	0.399	0.018	7.330	30.597	41.833	12.060	17.527	38.662	6.160	4.216	1.872	3.691
237	1737770	919923	2467	0.366	0.016	13.783	29.593	47.178	4.492	18.455	38.077	10.291	3.148	2.733	0.601
238	2279650	1350290	1315	0.374	0.018	5.780	30.553	34.546	7.599	17.965	38.795	7.514	8.382	3.754	4.491
239	1723160	945928	2465	0.366	0.016	13.783	29.593	42.733	5.581	18.455	38.077	10.291	3.148	4.866	0.688
240	1727610	964393	2464	0.366	0.016	13.783	29.593	42.733	5.581	18.455	38.077	10.291	3.148	4.866	0.688
241	2044330	1374340	2409	0.351	0.018	8.294	32.666	34.300	13.699	18.083	38.739	7.514	8.382	4.076	4.446
242	2081580	1425260	2408	0.381	0.018	8.125	36.824	34.474	17.443	18.083	38.739	7.514	8.382	5.120	4.636
243	-935137	1252590	4704	0.440	0.018	9.423	32.061	45.163	18.583	17.367	38.581	6.973	6.021	1.196	4.527
244	-1899280	1400680	5909	0.398	0.016	12.016	27.859	38.531	4.662	18.322	38.205	7.513	3.567	0.507	0.779
245	-1610120	1324660	5905	0.450	0.017	7.893	29.294	40.222	8.762	19.241	38.267	8.894	4.399	6.838	1.811
246	-1717560	1382370	5907	0.450	0.017	8.982	28.273	42.962	6.968	18.511	38.239	8.894	4.399	0.273	2.318

247	2308370	1458800	2402	0.374	0.018	5.440	35.193	34.874	15.982	17.852	38.937	7.514	8.382	3.755	4.492
248	-1417800	1348140	5901	0.491	0.017	8.978	29.990	39.127	10.912	19.548	38.229	9.749	3.826	1.528	4.389
249	2151140	1479080	2404	0.367	0.018	8.125	36.824	34.783	16.902	18.696	39.066	7.514	8.382	4.323	4.603
250	-1542090	1347200	5903	0.450	0.017	7.893	29.294	38.120	6.133	19.241	38.267	9.749	3.826	3.179	2.136
251	2177510	1368760	2406	0.381	0.018	8.294	32.666	34.656	11.707	17.965	38.795	7.514	8.382	4.163	4.477
252	-879309	1336990	4708	0.385	0.018	9.423	32.061	43.728	16.033	17.500	38.577	6.676	4.657	1.189	4.493
253	1612430	934686	2480	0.368	0.017	13.783	29.593	40.299	6.689	16.499	38.161	9.186	3.291	2.049	2.992
254	1535210	978025	2483	0.368	0.017	13.783	29.593	38.032	8.444	16.094	38.331	9.186	3.291	2.177	4.747
255	1561590	909380	2482	0.368	0.017	13.783	29.593	43.211	5.562	16.094	38.331	9.186	3.291	0.805	1.735
256	1267400	1036320	2485	0.376	0.017	9.948	30.888	39.570	10.500	17.449	38.921	10.765	9.802	8.457	3.367
257	1494030	912550	2484	0.368	0.017	13.783	29.593	45.521	10.563	16.094	38.331	9.186	3.291	3.805	3.840
258	1239290	1200900	2487	0.407	0.018	9.558	36.546	35.816	11.310	17.757	39.156	10.765	9.802	3.394	3.402
259	1382550	1165380	2489	0.348	0.018	9.558	36.546	32.579	5.706	16.990	38.719	10.765	9.802	5.382	4.367
260	1331690	1196090	2488	0.348	0.018	9.558	36.546	34.394	9.759	16.765	38.969	10.765	9.802	4.089	3.763
261	-587623	1206550	4702	0.409	0.018	9.098	30.206	43.505	11.274	17.687	38.649	6.160	4.216	1.908	4.014
262	-754364	1222050	4703	0.440	0.018	9.098	30.206	45.028	19.483	17.102	38.619	6.973	6.021	1.154	4.398
263	1200810	1094980	3554	0.407	0.018	9.661	31.168	37.467	9.049	17.449	38.921	10.765	9.802	4.689	3.613
264	-456476	1306720	4705	0.361	0.018	7.330	30.597	37.721	15.527	18.487	38.686	6.455	5.914	1.753	4.375
265	1061230	1183160	3556	0.457	0.018	9.386	37.157	37.243	13.361	16.828	39.383	11.987	8.985	3.352	4.507
266	912099	910434	3557	0.450	0.017	9.704	31.709	45.130	5.566	19.155	39.027	11.948	5.350	1.850	1.441
267	1358080	676726	3518	0.448	0.017	14.528	27.930	50.017	5.724	14.608	38.066	11.518	2.777	1.991	1.986
268	1510680	747901	3511	0.395	0.016	11.435	29.712	50.720	5.238	16.124	38.175	9.186	3.291	1.555	2.632
269	2281590	1273010	1309	0.374	0.018	5.780	30.553	36.028	6.973	17.637	38.507	6.576	3.354	4.009	4.493
270	2352010	1241300	1308	0.385	0.017	5.780	30.553	36.301	8.093	17.859	38.669	6.460	4.144	3.940	4.413
271	2258210	1128830	1303	0.379	0.017	6.442	30.489	36.375	4.728	17.976	38.302	6.576	3.354	4.239	3.651
272	2242220	1039520	1302	0.391	0.017	6.442	30.489	35.864	4.778	17.976	38.302	6.576	3.354	3.712	3.888
273	2310060	1078710	1301	0.385	0.017	6.442	30.489	37.395	6.381	17.073	38.470	6.576	3.354	3.597	0.944
274	2375260	1200160	1307	0.385	0.017	5.780	30.553	36.817	7.620	17.859	38.669	6.460	4.144	4.396	4.239
275	2373970	1187400	1306	0.385	0.017	5.780	30.553	36.817	7.620	17.859	38.669	6.460	4.144	4.396	4.239
276	2314840	1108300	1305	0.385	0.017	6.442	30.489	39.433	4.624	17.073	38.470	6.460	4.144	5.003	1.908
277	2287480	1152200	1304	0.385	0.017	5.780	30.553	36.375	4.728	17.976	38.302	6.576	3.354	4.253	3.854

278	8399320	1778907	2401	0.361	0.018	4.810	34.203	33.598	18.283	17.465	39.154	7.115	9.187	3.358	4.403
279	7770508	1442671	2424	0.334	0.017	12.513	29.092	39.011	4.106	19.747	38.261	9.769	3.692	2.771	1.064
280	7763563	1426267	2425	0.334	0.017	12.513	29.092	39.011	4.106	19.747	38.261	9.769	3.692	2.644	1.628
281	7658642	1378590	2436	0.363	0.017	12.513	29.092	40.046	4.178	19.313	38.269	9.769	3.692	4.536	1.227
282	7677703	1361907	2437	0.366	0.016	12.513	29.092	40.046	4.178	19.313	38.269	9.769	3.692	3.089	0.068
283	7759521	1272203	2443	0.367	0.017	12.513	29.092	42.326	4.339	18.844	38.143	10.291	3.148	2.016	4.195
284	7640444	1247720	2458	0.366	0.016	12.513	29.092	41.967	4.448	18.455	38.077	10.291	3.148	2.733	0.601
285	7625548	1245692	2466	0.366	0.016	13.783	29.593	42.733	5.581	18.455	38.077	10.291	3.148	2.733	0.601
286	7471064	1198987	2481	0.368	0.017	13.783	29.593	43.211	5.562	16.499	38.161	9.186	3.291	1.262	1.171
287	7148756	1438592	2486	0.407	0.018	9.558	36.546	37.467	9.049	17.449	38.921	10.765	9.802	3.801	0.913
288	7711817	1611521	2494	0.347	0.018	13.083	34.933	35.570	7.022	18.862	38.549	9.769	3.692	9.710	1.285

Figure 43 - Interpolated Average Daily 8-hour Maximum Ozone Concentration

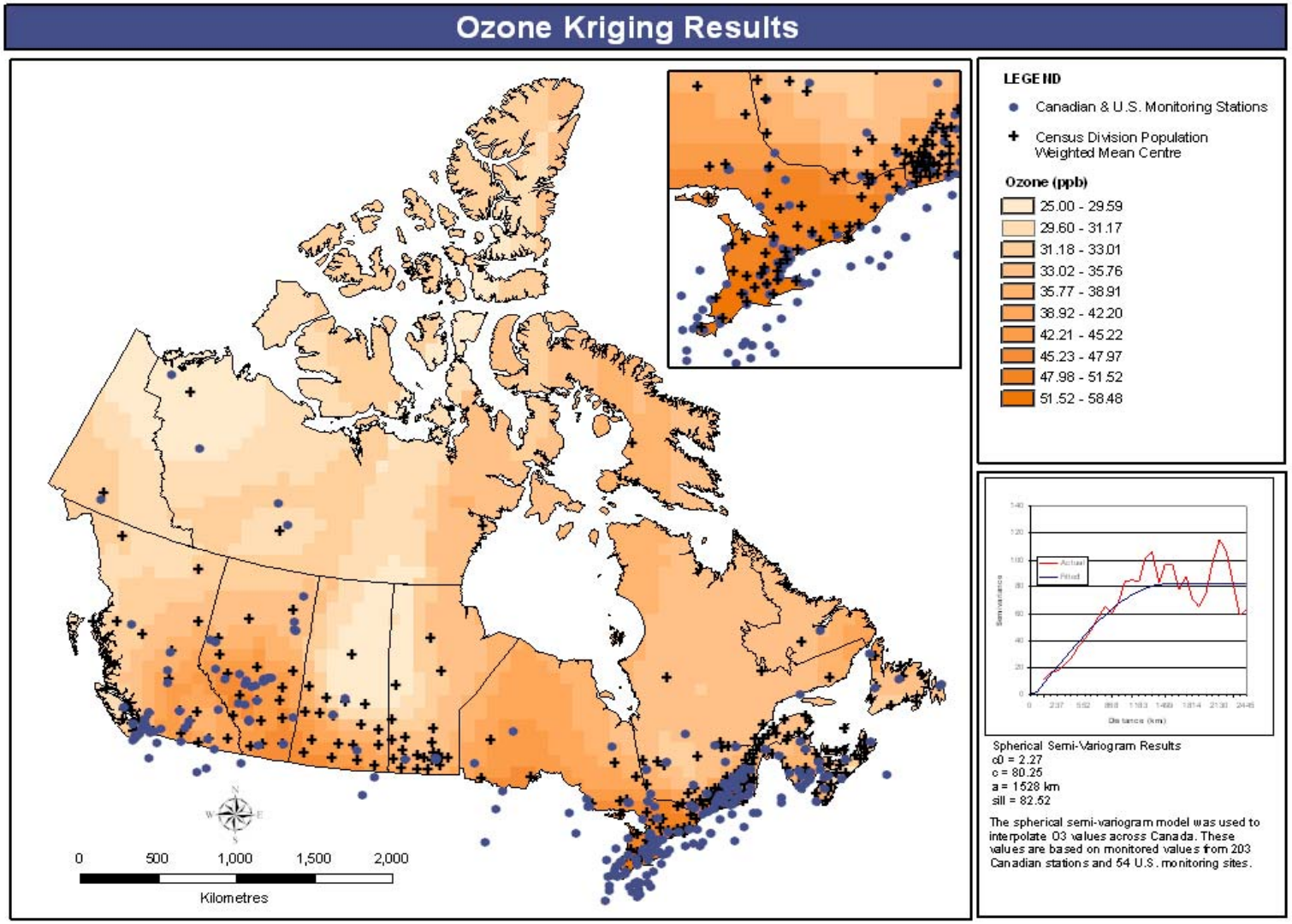


Figure 44 - Interpolated Average Annual $PM_{2.5}$ Concentration

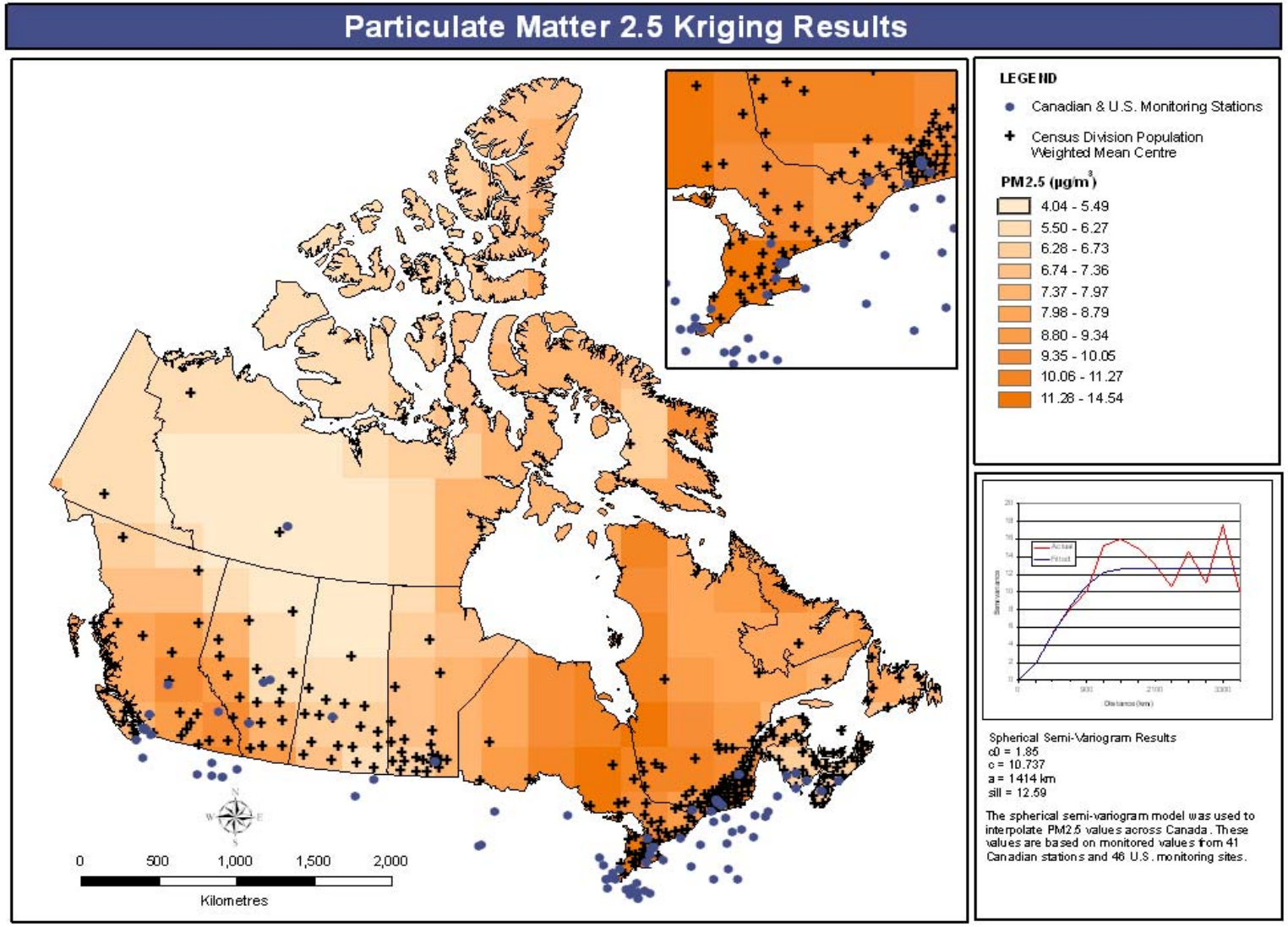


Figure 45 - Interpolated Average Annual SO_2 Concentration

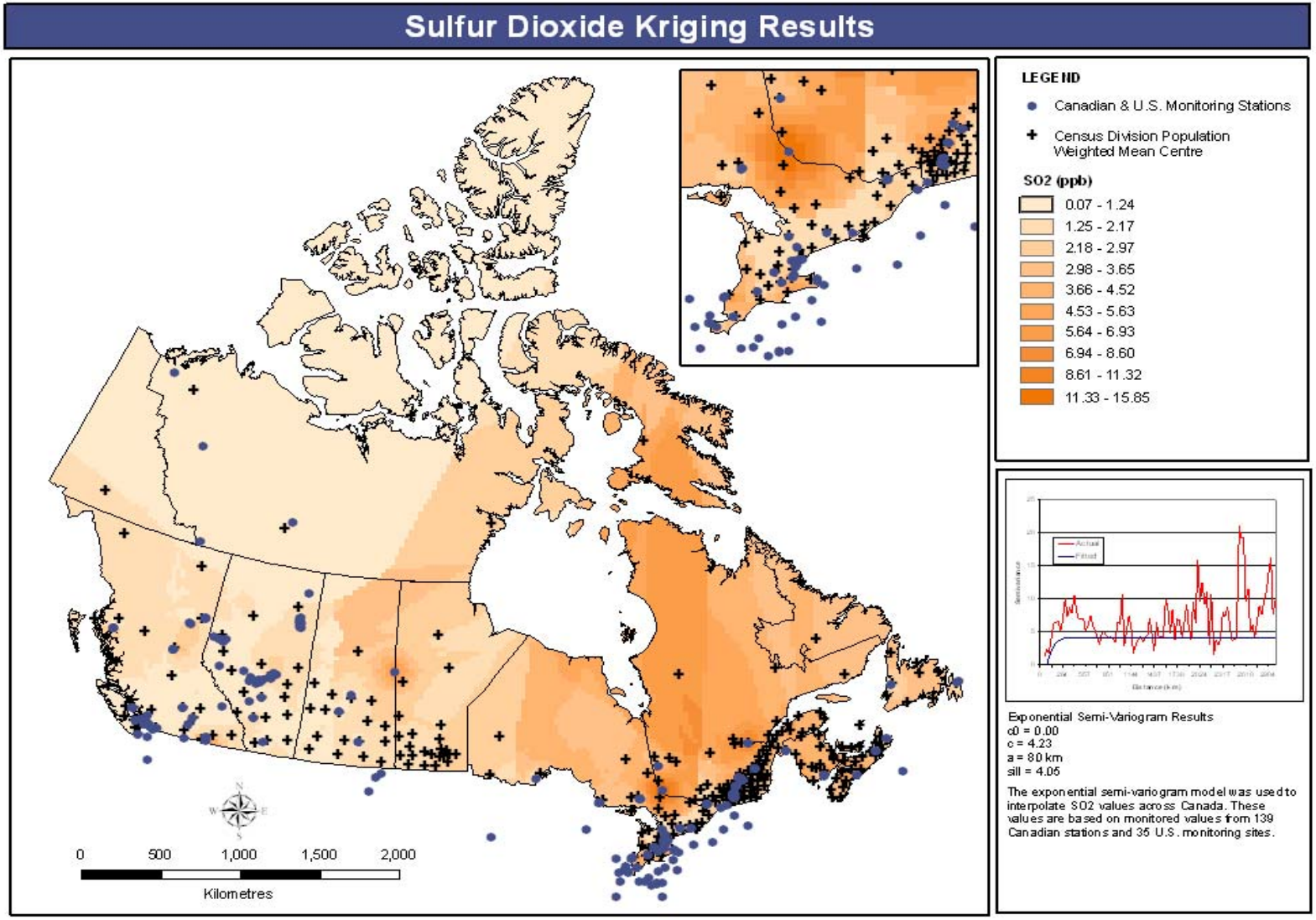


Figure 46 - Interpolated Average Annual NO_2 Concentration

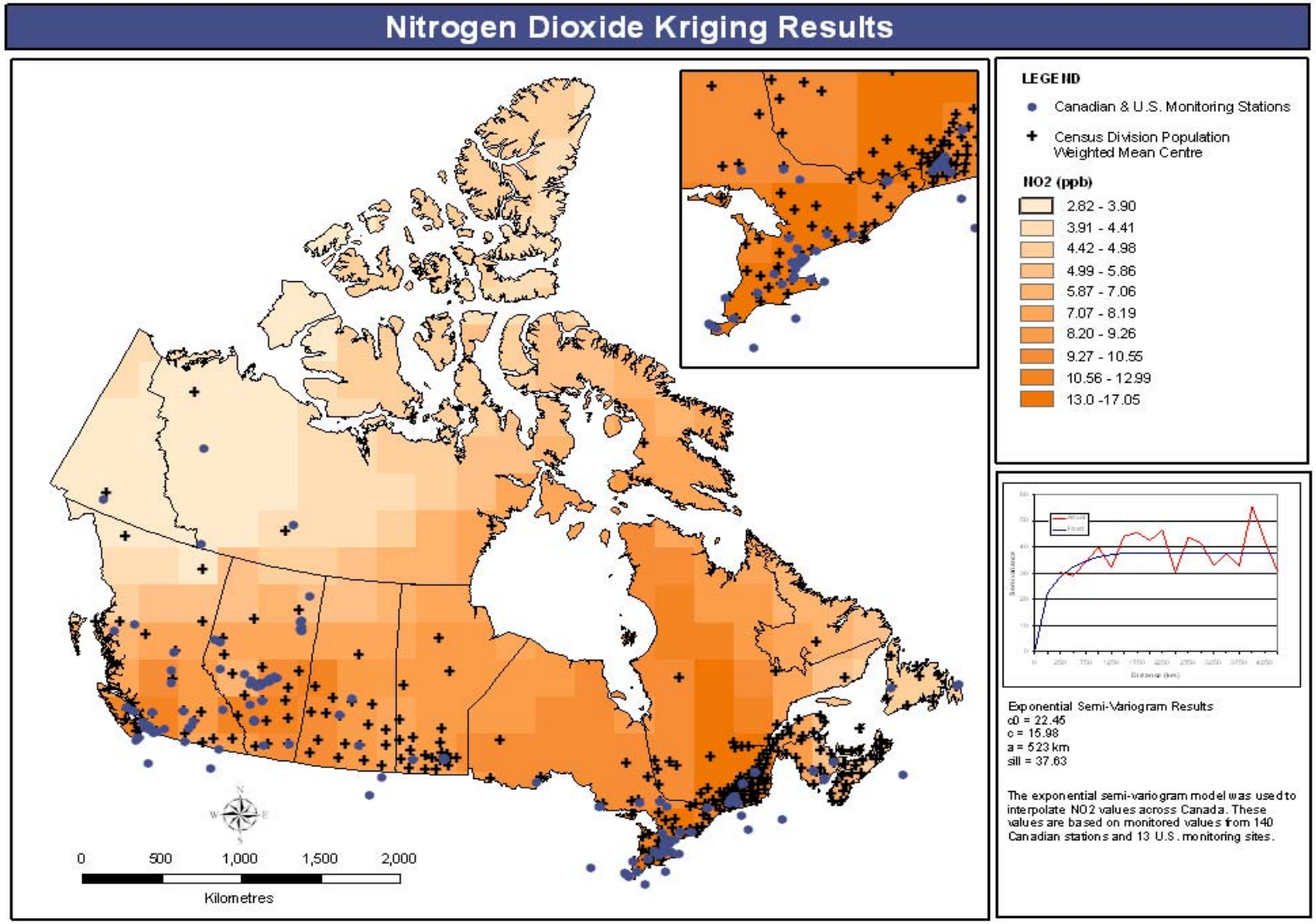
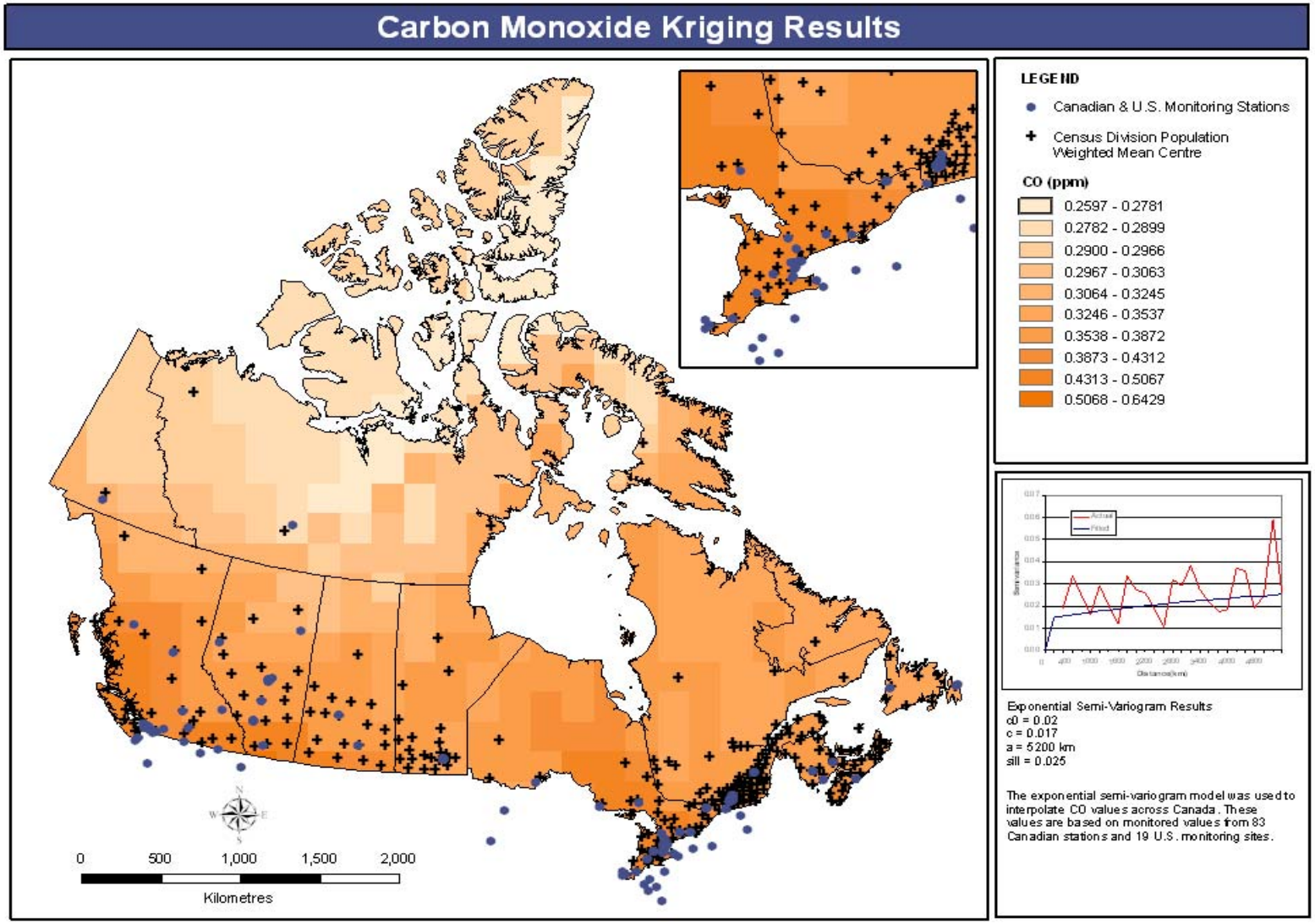


Figure 47 - Interpolated Average Annual CO Concentration



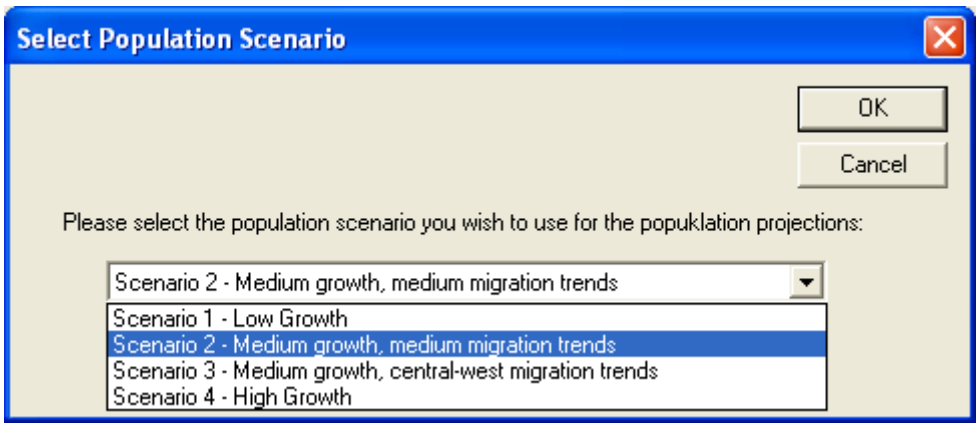
Appendix F – ICAP Software Revisions

This appendix reviews the refinements that have been made to the ICAP Version 3.0 screens. The changes that have been made to each of the major components of the program are presented.

F.1 Population Forecasts

Version 3.0 includes a new main menu option entitled "Population". This option allows users to select the population growth forecast to be used in a damages forecast (Figure 48). Previous versions of ICAP used a constant population forecast that could not be modified by the user.

Figure 48 - ICAP Population Forecast Selection Window

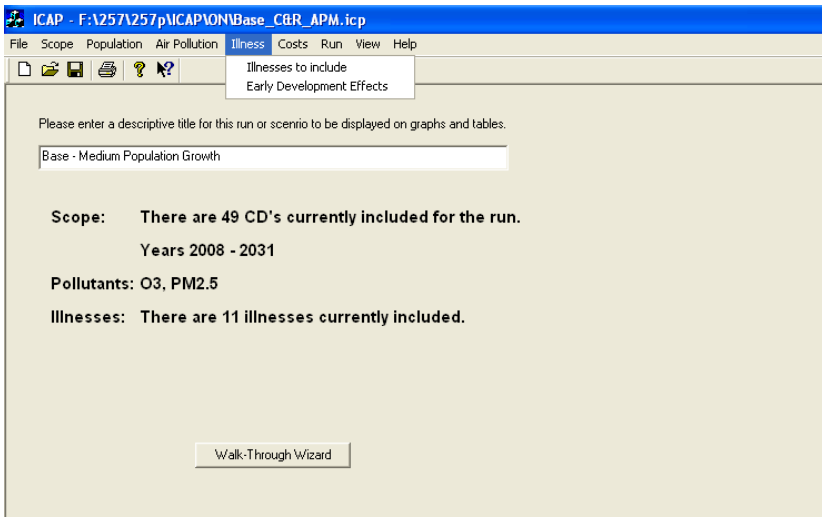


These population growth forecasts have been developed by Statistics Canada (see http://www.statcan.ca/Daily/English/051215/d051215b.htm).). The user cannot alter the forecasts themselves. The user must choose one of the four forecasts to use for the ICAP analysis.

F.2 Early Development Impacts

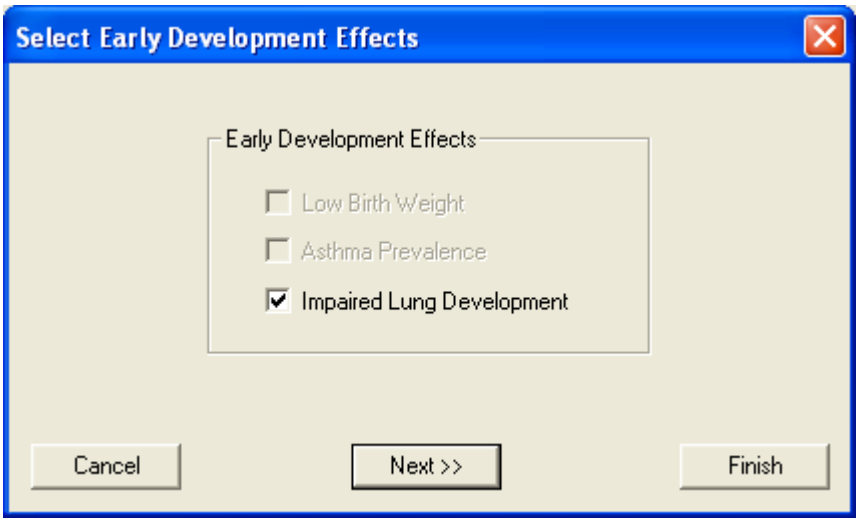
The addition of an early development effects routine is included within the Illnesses main menu option (Figure 49). Selection of this option opens a new series of screens as follow.

Figure 49 - ICAP Population Forecast Selection Window



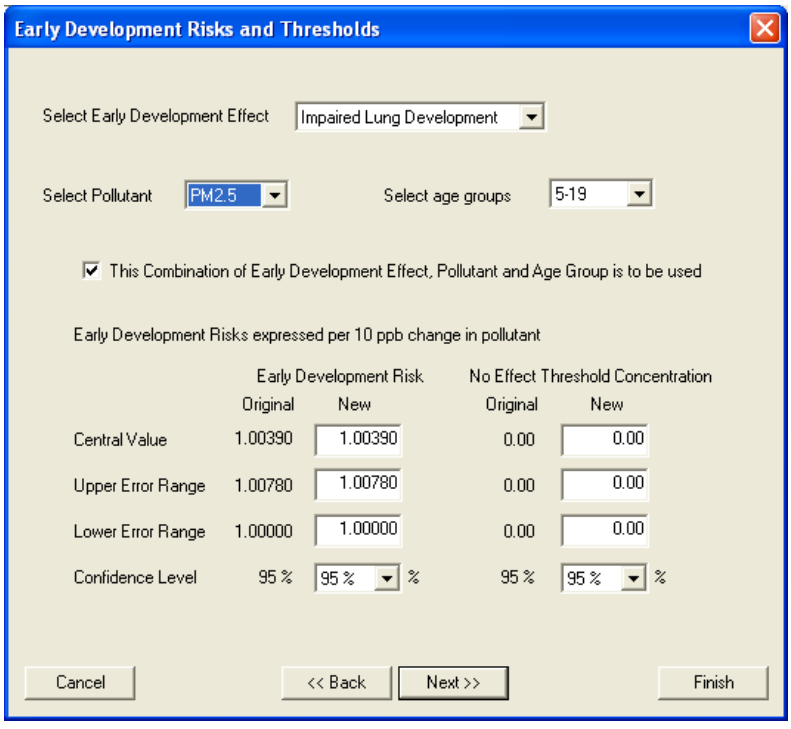
The user is given the option to choose among three types of potential early development effects to include in the forecast (Figure 50). At this time, only the impaired lung function option is activated.

Figure 50 - ICAP Early Development Effects Selection Window



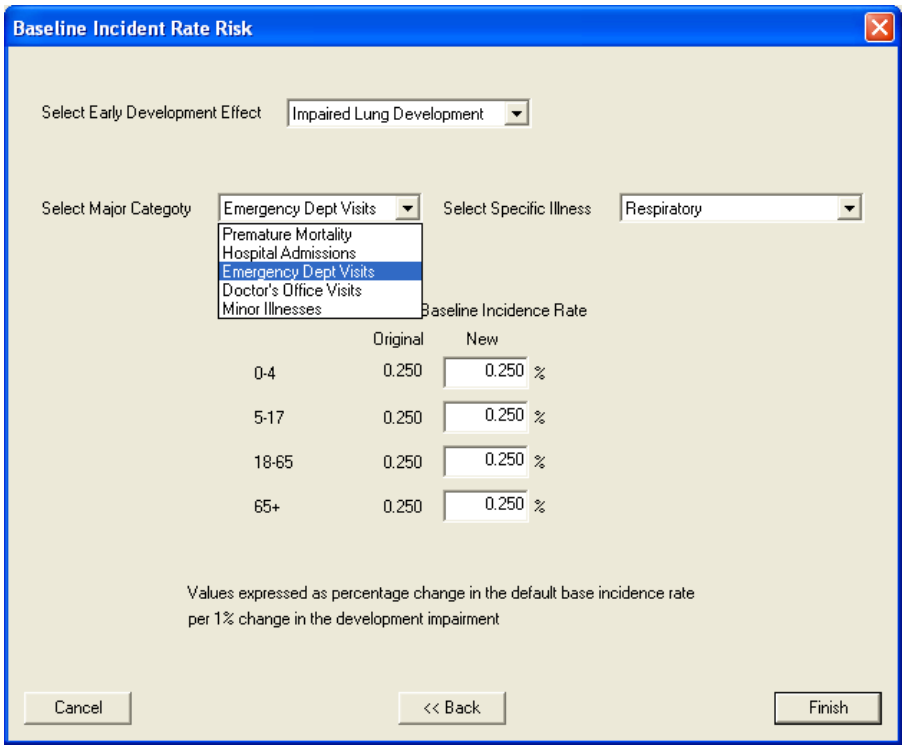
Next the user is given the opportunity to specify the relative risks of the early development effect for different pollutants and age groups (Figure 51). The user may also specify a no-effect threshold below which no effects are expected to occur. These relative risks are derived from the epidemiological literature as discussed in Section 4.2.6.

Figure 51 - ICAP Early Development Risks Selection Window



Next the user is given the opportunity to specify the relationship between the amount of lung function impairment and the change in the expected base incidence rate for specific illnesses (Figure 52). These relationships are expressed on a proportional basis. For example, a 1% reduction in lung function in the population might result in a 0.25% increase in the base incidence rate for emergency department visits. These proportions are hypothetical at this time and this routine should be used only for illustrative purposes until reliable proportions have been derived.

Figure 52 - ICAP Base Incidence Rate Risk Selection Window



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