UNIVERSITY OF ALBERTA

CLIMATE CHANGE AND HUMAN HEALTH: A CANADIAN PRAIRIE PERSPECTIVE

by

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Abstract

Climate change and human health research is a relatively new field of inquiry, grounded in traditional epidemiological methods and study designs. However, there are no standard methods to investigate the complex and interdisciplinary nature of health outcomes resulting from climate change. Because each geographical region and its population within will respond to climate change differently, there remains a need to study the human health effects on a regional level. Necessary first steps include knowledge and integrated assessments of the issue. This thesis aims to initiate knowledge assessment by networking, identifying resources and expertise, and an in-depth literature review. Integrated assessment will be furthered through modeling of the direct and indirect health consequences of climate change scenarios on the Canadian Prairies. This paper ends with an 'ideal' research proposal in anticipation of future climate change and human health research, as well as recognizing 'real world' pitfalls.

To my Mom, Dad, Jay, and Grandma and Grandpa W.

"The over-exploitation of forests and fisheries, the depletion of soil and other renewable resources, the pollution of the air, water and the food chain, the pervasive undermining of human health—all these reduce the stock of natural capital that our economic survival and well-being depend on and impose huge costs on future generations. It doesn't take a genius to see that living off our capital in this way is simply not sustainable."

-Maurice Strong, Where on Earth are We Going?

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ABBREVIATIONS

°C	Degree Celsius
AAFC	Agriculture and Agri-Food Canada
AAFRD	Alberta Agriculture, Food and Rural Development
AHW	Alberta Health and Wellness
ACCS	Ambulatory Care Classification System
ALA	Alberta Lung Association
BP	Before Present
CASA	Clean Air Strategic Alliance
CCAF	Climate Change Action Fund
C-CIARN	Canadian Climate Impacts and Adaptation Research Network
CCIS	Canadian Climate Impacts Scenarios
CGCM1	Canadian Global Climate Model 1
CHRP	Climate and Health Research Program
CICS	Canadian Institute for Climate Studies
CIHI	Canadian Institute for Health Information
CO	Carbon monoxide
CO_2	Carbon dioxide
COPD	Chronic Obstructive Pulmonary Disease
DD	Degree Days
EC	Environment Canada
EHI	Environmental Health Indicator
ENGO	Environmental Non-Governmental Organization
ENSO	El Niño Southern Oscillation
FWC	Food/Water-borne Contaminants Network
FYI	For Your Information
GCM	General Circulation Model
GHG	Greenhouse Gases
GIS	Geographical Information System
GPI	Genuine Progress Indicator
HA	Health Authorities
HVP	Hantavirus Pulmonary syndrome
IA	Integrated Assessment
IAF(M)	Integrated Assessment Framework (Model)
ICD-9-CM	International Classification of Diseases, 9th Revision, Clinical Modification
IHE	Institute for Health Economics
IJC	International Joint Commission
ILO	Intensive Livestock Operations
IPCC	Intergovernmental Panel on Climate Change
K-12	Kindergarten to Grade 12

Abbreviations Continued

NAST	National Assessment Synthesis Team [United States]
NGO	Non-Governmental Organization
NO_x	Oxides of nitrogen
NRC	National Resource Council
NRCan	Natural Resources Canada
PARC	Prairie Adaptation Research Collaborative
PC	Personal Communication
PCA	Principal Component Analysis
PDSI	Palmer Drought Severity Index
$PM_{1.0}$	Particulate Matter (particle size < 1.0 μm)
$PM_{1.0-2.5}$	Particulate Matter (particle size between 1.0 and 2.5 μm)
$PM_{2.5}$	Particulate Matter (particle size < 2.5 μm)
PM_{10}	Particulate Matter (particle size < 10 μm)
PTSD	Post-Traumatic Stress Disorder
REB	Research Ethics Board
REHEX	Regional Human Exposure model
RHA	Regional Health Authority
RMSF	Rocky Mountain Spotted Fever
RTD	Round Table Discussions
SEA/SEV	Socio-economic Adaptability/Vulnerability
SES	Socio-economic Status
SESCI	Solar Energy Society of Canada Inc.
SO_2	Sulfur dioxide
SRC	Saskatchewan Research Council
SSR	Seasonal Severity Rating
TC	Transport Canada
TSP	Total Suspended Particulates
UNEP	United Nations Environment Program
VOC	Volatile Organic Compound
WEE	Western Equine Encephalitis
WHO	World Health Organization
WMO	World Meteorological Organization

Chapter 1

Climate Change and Human Health: Introduction and Epidemiology

Climate change and human health research is both complex and multidisciplinary, occurring over extended periods of time and on a global scale. In order to fully understand the scope of climate change and human health research, it is important first to be acquainted with the climate change phenomenon from a climatic perspective. This chapter introduces climate change from a Canadian Prairie perspective over geologic time. It then explains the connection between weather, climate and climate variability and human health on the global and regional levels. This chapter concludes with how epidemiology 'fits' into the climate change and human health research agenda, paying particular attention to the methods associated with linking climate and health, as well as the limitations to the study of climate change and health on a macro-level.

1.1. Global Climate Change: Historical Overview

Climate change is a phenomenon gaining global attention. It can result from two processes, either warming (i.e., global warming) or cooling. The Intergovernmental Panel on Climate Change (IPCC) predicts a 1.4-5.8°C global mean surface air temperature rise over this century. Although the average global temperature is expected to increase and most world regions will likely become warmer, some regions are also expected to cool (IPCC, 2001). Unless otherwise stated, in this thesis climate change is a result of global warming.

Climate change can be driven by forces whose origins are natural (e.g., ocean circulation, orbital changes of the Earth, volcanic activity) or anthropogenic (e.g., fossil fuel combustion, aerosols, biomass burning), and these forcings can have positive (yield warming) or negative (yield cooling) potential (IPCC, 2001). However, the largest forcing of current climate change is from greenhouse gases (GHGs), which is a positive forcing and is largely a result of people burning fossil fuels. Thus, climate change is associated with elevated levels of GHGs in the atmosphere, and is referred to by the IPCC as any change in climate over time, from either natural variability or human activity (IPCC, 2001).

The presence of GHGs and the consequential warming of the earth are normal and essential, for without GHGs, the average global temperature would be about -18°C (Bruce et al., 1999). However, concentrations of GHG in our atmosphere are greater than ever before, partly from the burning of fossil fuels and other human activities (IPCC, 2001). Whenever carbon dioxide levels reached these extremes in the past, major changes in the global climate have occurred (Canadian Institute for Climate Studies (CICS), 2001).

With climate, there will be changes in the long-term climate trends, in addition to the short-term weather patterns, that will, in turn, change the physical environment in which humans live. But, what is the difference between climate, climate variability and weather? **Climate** is 'what we expect'; it is the average long-term pattern associated with a region (Briggs et al., 1993). **Climate change**, which is commonly based on the departure from 30-year average normal periods, refers to a point in the future (e.g., 2031-2060), or in the past (1901 – 1930), as compared to now, (1971-2000). **Climate variability** is expressed as the difference from the climate ('what we expect') trend. For example, the 1970s are remembered as a cool decade and the 1980s as hotter. **Weather,** on the other hand, is 'what we get'; it is the short-term transient condition of the atmosphere (Briggs et al., 1993) as experienced in daily weather conditions.

1.1.1 Prairie Climate

The climate on the Canadian Prairies and around the world is changing. However, how much of this change can be attributed to natural processes and how much is anthropogenic (i.e., human-induced) is still being debated. Thus, it is important to explore the climate, climate variability, and change in the past in order to understand the influences of human-induced climate change today. Past climate variability and change (since the last major ice age) are useful as a reference point for the comparison of present climate variation under human influence with respect to the speed and magnitude of change. In addition, past climate can be insightful for understanding the impacts from future climate change (Lemmen and Vance, 1999a).

Climatic shifts can vary in scale and intensity, and have occurred frequently over Earth's history. Currently, Earth is in its fourth interglacial period (Nkemdirim, 1991). Each glacial period can last for tens or hundreds of thousands of years, and the corresponding interglacial periods often last several thousands of years (Beaudoin, 1999). During these interglacial periods, there are warming and cooling trends, or intervals, lasting hundreds of years or more (Nkemdirim, 1991). To an even smaller degree, each warming or cooling interval is interspersed with warmer than average or cooler than average temperature years.

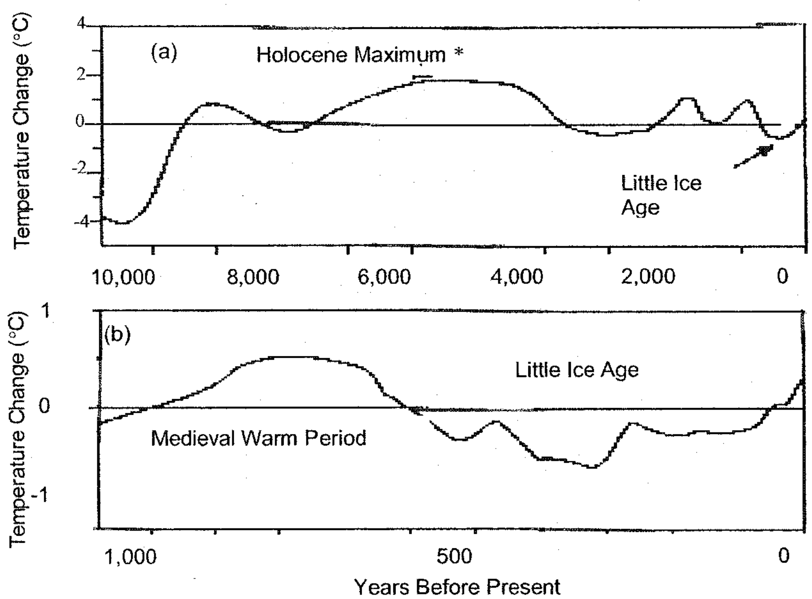
Scientists have concluded that the principal human influence with respect to climate change is the burning of fossil fuels and the subsequent release of greenhouse gas by-products (IPCC, 2001). The use of fossil fuels began in the latter portion of the eighteenth century and consumption of these grew exponentially with population growth, in the late 19^{th} and early 20^{th} centuries (Pollack and Huang, 2000). Thus, the speed and magnitude of climate changes since the beginning of fossil fuel consumption are of interest to climate scientists in order to gain an understanding of the possible anthropogenic influence on climate change. However, both anthropogenic and natural climate change model simulations are employed to aid in the prediction of future climate change scenarios.

To reconstruct past climate, before the availability of instrumental data collection, proxy (e.g., tree rings, pollen, ice cores, paleosoils, boreholes, plant and animal fossils, lake and river sediments) climate data are used (Beaudoin, 1999; Nkemdirim, 1991; Pollack and Huang, 2000). The last major ice sheet (Laurentide Ice Sheet) maximized its extension south around 18,000 years BP* (before present) and by approximately 11,000 years BP, most of Alberta and parts of the Prairies were ice-free (Beaudoin, 1999; Nkemdirim, 1991). In general, Prairie climatic shifts occurred gradually over time from west to east, with Alberta feeling the climatic shifts first and Manitoba being last (Beaudoin, 1999). From the period between 12,000 and 10,000 BP, the Prairies were characterized by a cool climate (Nkemdirim, 1991; Beaudoin, 1999), with more permanent water sources

* The dates that correspond to major events or periods in geological time are approximate, and vary according to region, source of data, and proxy instrument used to date the time period.

(Beaudoin, 1999). Figure 1.1.1 presents a general overview of global temperature variations in the last 10,000 and 1,000 years.

Figure 1.1.1 Global temperature variations in the past 10,000 and 1,000 years.



Source: Adapted from IPCC, 1990 (Folland et al., 1990). Graphs show the departures of average global temperatures from current values (1990) (a) over the past 10,000 years, and (b) over the past 1,000 years.

* Holocene Maximum is the approximate time period of the Hypsithermal interval

Drought-like conditions prevailed in Alberta and the Prairie region for the next 3,000 years (9,000-6,000 BP) and this period was termed the 'Hypsithermal' interval (Beaudoin, 1999). Permanent water sources evaporated and deep lakes became more saline (Beaudoin, 1999). Quantification of temperature in the Canadian Prairies 6,000 years BP have suggested that the mean annual temperature was 0.5 to 1.5°C higher than today, and average summer temperatures may have been up to 3°C higher (Vance et al., 1995). The mean annual precipitation may have been reduced by 65 mm, of which a 50 mm reduction occurred in the summer months as compared to the present (Vance et al., 1995). This time period was also characterized by higher tree lines in the Rocky Mountains, movement of the Prairie grasslands northward and fires were frequent in forested regions (Vance et al, 1995). This interval serves as an analogue for the conditions of $2 \times CO_2$* concentrations by General Circulation Models (GCMs) (Herrington et al., 1997).

After a long period of drought characterized by increased warmth and dryness, Alberta climate progressively grew colder and wetter. This began around 6,000-5,000 years BP in the Rocky Mountains and reached the eastern Prairie margin approximately 4,000-3,000 years BP (Beaudoin, 1999; Herrington et al., 1997). Renewed glaciation in the Alberta Rocky Mountains began approximately 4,000 years ago and was termed the 'Neoglacial' interval (Beaudoin, 1999; Herrington et al., 1997).

However, within the Neoglacial interval there were periods of drought and intervals of warmer climate. The most noted warming period was the 'Medieval Warm Period', which lasted roughly 400 years between 800 and 1200 AD (Beaudoin, 1999). During the Medieval Warm period, the global controls on climate were quite similar to those today and thus could be analogous to future climate events in the Prairie region (Lemmen and Vance, 1999b).

In addition to the warm periods, the largest advance of ice also occurred within the Neoglacial, a period called 'the Little Ice Age' which began around 1150 AD, and glaciers reached a maximum between 1750 and 1850 AD (Beaudoin, 1999; Nkemdirim, 1991). Proxy data, compared with present instrumental data suggest the mean annual temperature in the Little Ice Age was approximately 1°C cooler than today's temperatures, with the mid-19^{th} century being the coolest point (Beaudoin, 1999). Since the beginning of the 20^{th} Century, the glaciers in the Canadian Rockies have been receding in response to climatic warming (Beaudoin, 1999).

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* Canadian Global Climate Model (CGCM1) increases GHG at a rate of 1% compounded per year. This is the same as a doubling of 1980 carbon dioxide concentrations (or tripling of pre-industrial concentrations) by 2050. GHG concentrations will increase to the equivalent of three times 1980, and four times pre-industrial, carbon dioxide levels by 2100 (Hengeveld, 2000).

1.1.2 Prairie Climate-The Last 100 years

The use of proxy climate data is exceedingly general in geological time scales. Not until the 19th century was there use of standardized instrumental climate data (Nkemdirim, 1991), and temperature and precipitation measurements became increasingly specific. In addition, it was not until the end of the 1800s that meteorological observations became widespread in the southern and northern hemispheres (Pollack and Huang, 2000; Herrington et al., 1997), thus highlighting the variability of climate in the Prairie region Sauchyn and Beaudoin, 1998; Wheaton, 1998).

Recent advances in paleoclimatologic research have established more reliable climate data (mainly temperature and precipitation) from comparing tree ring width records with instrumental data for the same region and time interval (Beaudoin, 1999). In addition, these recent advances in paleoclimatology have pointed to significant and rapid changes in climate over short periods of time (abrupt climate change), even in the absence of human-induced greenhouse gas emissions (Overpeck and Webb, 2000; IPCC, 2001). Therefore, the possibility of naturally occurring abrupt climate changes may become more frequent in the presence of human-induced gradual climate change (e.g., greenhouse gas-related), and may bring forth unanticipated climatic surprises (Overpeck and Webb, 2000).

Although, climate predictions are uncertain, we do know average global temperatures are increasing. The Intergovernmental Panel on Climate Change (2001), IPCC, has recorded an approximate 1°C increase in global surface temperature over the last 100 years (IPCC, 2001). In addition, as geological and paleological climatic records show, climate can abruptly change the environment on which humans depend. This is apparent in the archeaological study of past Old World and New World societies where whole empires collapsed in conjunction with persistent, multi-century shifts in climate (mainly drought) (DeMenocal, 2001).

The IPCC (2001) predicts a 1.4-5.8°C mean increase in global surface air temperature by 2100. This rate of warming is greater than that occurring over the past 10,000 years. The levels of CO_2 have risen 30% since the late 1800s, and the concentration of CO_2 is higher than it has been in the last 400,000 years (National Assessment Synthesis Team (NAST), 2001; IPCC, 2001). In keeping with this, the IPCC, in its 2001 report, commented that the warming observed over the last 100 years is very unlikely to be caused by natural variation (IPCC, 2001).

Consequences of global warming, predicted by the IPCC (2001) to occur in the 21st century, include: sea level rise; higher maximum temperatures and more hot days; fewer cold days; higher heat indices; more intense precipitation events; increased summer continental drying and the associated risk of drought; increased tropical cyclone peak wind intensity and precipitation intensities; and, the continuing retreat of arctic icecap and continental glaciers (Vellinga and van Verseveld, 2000).

It is likely that global temperatures and the underlying environmental conditions will continue to be influenced by anthropogenic GHGs, even after human-produced GHG emission levels have been stabilized. This is because of the extended half-life of GHGs in the atmosphere, and the lag time between GHG emissions, subsequent global warming, and environmental change.

Atmospheric GHG levels are dependent on the sources and sinks of GHGs, mainly CO_2. Some of the main sources of GHGs are biomass burning, decomposition, and fossil fuel burning. Whereas the important sinks for CO_2 are the land and ocean ecosystems (WHO, 1996), the capabilities of these sinks to absorb CO_2 can vary. For example, as humans decrease the amount of vegetative cover in the biosphere, the Earth's ability to absorb CO_2 decreases. Further, the phytoplankton in the oceans is a major sink for CO_2, in addition to being the primary producer of the ocean food chain. However, its survival is highly dependent on ocean temperatures. Thus, as ocean temperatures rise, the ability of oceans to absorb CO_2 may decrease.

Because of the complex relationships between sources and sinks of GHGs, true equilibrium of GHGs in the atmosphere will most likely not occur. Rather, a succession of new equilibriums with respect to environmental conditions will ensue. Environmental equilibrium will not likely occur on a human time scale.

1.1.3 Climate Change in Canada and the Prairies

Climate change is a serious issue for Canadians. Although there is a predicted 1.4-5.8°C increase in average global temperatures over the next 100 years, land areas will warm more rapidly than the global average, especially in the high northern latitudes (IPCC, 2001). The Canadian Centre for Climate Modeling and Analysis' Canadian Global Climate Model (CGCM1) predicts, under a $2 \times CO_2$ scenario, that southern Canada (below the Arctic Circle) will have a 4-10°C increase in temperature by 2100. Northern Canada (above the arctic circle) will experience 5-15°C increase in the winter and a 2-5+°C increase in summer temperatures during the same time period. In the high arctic winter temperatures could warm in excess of 20°C by 2100 (Hengeveld, 2000).

What do these past scenarios tell us about the climate change impacts on the Canadian Prairies today? On the Canadian Prairies there is a tendency towards drought with increased temperatures (Beaudoin, 1999). The 'Hypsithermal' interval, or the climatic conditions associated with the period around 6,000 years BP, has been chosen as one point for testing the outcome of the GCMs (Vance et al., 1995). The predictions made for the mid-Holocene period with respect to temperature and precipitation are comparable to the GCM predictions under an enhanced greenhouse gas ($2{\times}CO_2$) emissions scenario (Wheaton et al., 1992). Thus, it is reasonable to conclude that future climate changes may, in fact, have similar consequences on ecological systems to the past climate changes during the mid-Holocene or Hypsithermal interval.

1.2 Climate Change and Health

Human health is intimately linked to our environment, to climate, and to weather patterns. As the climate and environment change, so will human health. Coping with the health effects of climate change will depend on the specific regional influences of climate change, the underlying social structure of the country and the region, and the degree to which the country and region will need to extend its current capacity to cope.

1.2.1 A Global Perspective

We know that climate change and the subsequent temperature and precipitation variations will affect the regions around the world differently. We also know that various adverse health outcomes will be directly or indirectly associated with this change. These include: increased morbidity and mortality from heatwaves and weather disasters; increased incidence of local water- and food-borne infectious diseases; increased incidence of human diseases transmitted by vectors associated with the change of their geographical distribution; malnutrition from decreased food productivity; health problems resulting from air pollution; increased numbers of ecological refugees; and, various problems stemming from the inability of existing social, political and economic systems to cope with the changes occurring under climate change (Kovats et al., 1999; Martens, 1999; World Meteorological Organization (WMO), 1999; World Health Organization (WHO), 1999; Haines et al., 2000).

Heatwaves may be the most obvious and immediate global warming concern for human health. Populations most at risk of heat related illnesses and mortality are the elderly, the poor, children, and people with underlying co-morbidities such as heart disease or lung infections (Martens, 1999; WHO, 2000a). However, deaths from increased temperatures may be offset somewhat by fewer cold-related deaths during milder winters (WHO, 1999). In addition, stratospheric ozone depletion may increase the number of melanomatus skin cancers all around the world (WHO, 2000b).

Another significant consequence of global warming associated with heat is decreased air quality owing to the combustion of fossil fuels in urban centres. Some air pollutants, such as ground-level ozone (the major component of smog), are temperature-dependent, and form more readily in higher atmospheric temperatures (WHO, 1999; WHO, 2000a). The elderly, children, and individuals with underlying medical problems (especially respiratory or cardiovascular diseases) are at greater risk of adverse health effects from air pollution than are healthy adults (Last et al., 1998).

Drought in existing agricultural areas will decrease agricultural yields (Last et al., 1998; Martens, 1999). Populations at greatest risk for significant regional impacts on agricultural yields are in sub-Saharan Africa, south-east Asia, and some Pacific island nations (WMO, 1999). Malnutrition and famine may become more prevalent in developing nations (Martens 1999), because of decreased agricultural yields. These nations may be affected on two different fronts. First, they may be less able to feed themselves. Second, many developing nations produce cash crops and decreased yields result in less money available for the purchase of foodstuffs on the world market.

Drought is not the only extreme event that can decrease crop yields. Hailstorms, tornadoes, tropical cyclones and floods, which are all expected to increase with climate change, can also destroy crops and lessen agricultural output (Martens, 1999). In addition, in some agricultural areas, too much moisture will foster the growth of moulds and other crop pests (Last et al., 1998). However, in other parts of the world, agricultural yields will increase as warmer surface temperatures generate more favourable conditions for crop growth. Such positive changes are likely to occur mainly in northern areas, which may be able to convert to and sustain agriculture.

Extreme weather events build upon evaporation and an accelerated energy transfer between the hydrosphere and atmosphere. A warmer atmosphere can hold more water vapour and thus condensed water is released as larger downpours. In addition, warmer atmospheric temperatures warm up land masses, creating expanded pressure gradients leading to extreme windstorms and tornadoes. In cities, torrential downpours can overwhelm existing sewer systems, thus increasing the chance of contamination of drinking water (Patz et al., 1996; Kovats et al., 1999; WMO, 1999; WHO, 2000a). In rural areas, heavy rains and flooding can wash faecal matter and fertilizers from agricultural and ranching operations into surface and ground water supplies used for drinking water. In addition to water quality, extreme weather events can have profound psychosocial effects. The death of loved ones, homelessness, and possibly the loss of livelihood from, for example, crop failure, all add to the dynamic health effects of climate change.

Transmission of food-, and vector-borne disease may increase in warmer temperatures, because bacteria and other vectors may have better survival capabilities (Kovats et al., 1999; WHO, 1999). With respect to food-borne diseases, warmer temperatures also promote the growth of the bacterium responsible for botulism (Martens, 1999). Contamination of shellfish with biotoxin-producing plankton and the spread of the cholera bacterium from algal blooms, are likely to increase as the ocean temperature warms in correspondence to surface temperatures (Patz et al., 1996; Martens, 1999; WHO, 1999).

Vectors such as insects also can take advantage of and adapt easily to climatic disturbances. Mosquitoes are the vectors for diseases such as malaria, yellow fever, dengue, and several forms of encephalitis (Martens, 1999; Epstein, 2000). Their life cycle is intimately linked to atmospheric temperatures and water cycles (WHO, 1999). Warmer temperatures will increase the mosquito's geographical distribution and season length (Last et al., 1998). Creating more optimal temperatures for mosquitoes also provides more favourable conditions for their parasites, enabling them to proliferate faster (Martens, 1999).

Some malaria models have projected that with increased warming, the percentage of the world's populations living in areas at risk for malaria transmission could enlarge from the current 45% to 60% (Epstein, 2000), including portions of Canada. Furthermore, new drug-resistant strains of malaria parasite and the increased resistance of mosquitoes to conventional pesticide control may aid in the resurgence of malaria in previously eradicated areas (Epstein, 2000).

Importation of mosquito-borne diseases, and the possibility of establishing the disease from abroad, may become a larger concern as the temperatures rise. The recent appearance of the West Nile virus in New York State (Githeko et al., 2000; Gubler et al., 2001) and nearly all cases of malaria diagnosed in the United States have been imported (Gubler et al., 2001). Both the United States and Canada have natural populations of mosquitoes that harbour the West Nile virus and that transfer the malaria parasite (Darsie and Ward, 1981).

Rodent-borne diseases may also become a threat to human health. At higher latitudes, the hantavirus pulmonary syndrome is the newest zoonotic disease in North America. Hantavirus pulmonary syndrome has been documented to thrive under disturbed conditions, such as drought interrupted by intense rains (Epstein, 2000).

"Ecological refugees" are defined by the United Nations Environment Program (UNEP) as "people who have been forced to leave their traditional habitat, temporarily or permanently, because of a marked environmental disruption- either natural or human induced- that jeopardizes their existence and/or seriously affects their quality of life" (El-Hinnawi, 1985;34). Environmental refugees are expected to increase under conditions of climate change (WHO, 2000a; Last and Guidotti, 1991).

Canada's future concerns with respect to climate change will be much different than a tropical country or even the United States of America. Each geographical region within Canada will also have its own specific human health challenges to overcome in order to adapt to a changing climate.

1.2.2 A Prairie Perspective

As Canadians, we enjoy a universal health care system and a social support network that will aid us in times of crisis. Our present social support system can cope with the demands of nature and the disasters that sometimes ensue. However, as the climate continues to change, there will be increased pressure placed on our social support structures and health care systems, and questions will begin to arise concerning how much of our social support system can, and will, be funded publicly. For these reasons, every effort is needed to understand: 1) what environmental and climatologic changes are likely to occur under climate change within the Prairie Provinces; 2) what the potential direct and indirect human health consequences from these changes will be in the Prairie Provinces, including those associated with social, political, and economic determinants of health; and 3) how our current health care and social support systems can adapt to these new demands imposed by climate change, and incorporate new health and social strategies, reflecting the needs and values of Prairie populations, without compromising health and well-being under a publicly-funded system.

According to the *Canada Country Study: Climate Impacts and Adaptation-Health Sector* (1999), directly related health impacts of climate change would be those related to thermal stress and extreme weather events. Climate change could indirectly affect the health of Canadians in several ways: introduce new vector-borne diseases or revitalize old ones; decrease water quantity and quality; increase the risk of food-borne diseases associated with food imports; affect the seasonality of certain respiratory disorders; increase the number of environmental refugees (within Canada and internationally); and place more pressure on public health infrastructure not organized to cope with the effects of climate change on health (Duncan et al., 1999). However, the regional health priorities that will result from climate change will not necessarily reflect priorities at the national level. Therefore, by identifying the regional health priorities, regional health decision-makers could be aided in the allocation of limited resources.

The four environmental and climatic challenges most expected in Canada and the Prairies to affect the health of residing populations from climate change are drought (Herrington et al., 1997; Beaudoin, 1999), increased heat (Etkin, 1999; Hengeveld, 2000), extreme hydrological events (Etkin, 1999; Francis and Hengeveld, 1998), and changing ecological systems (Duncan et al., 1999; Herrington et al., 1997).

1.3 Climate Change and Epidemiology

Epidemiology is the "study of the distribution and determinants of health-related states or events in specified populations, and the application of this study to control of health problems" (Last, 2001:62). Thus, it is an intuitive science to use to study the health effects from climate change. However, for the study of climate change, a more fitting definition might be associated with environmental epidemiology. Environmental epidemiology is "the study of health effects on populations of exposure to physical, chemical, and biological agents external to the human body, and of immediate and remote social, economic, and cultural factors related to these physical, chemical and biological agents"

(Last, 2001:59). In this sense, environmental epidemiology could view climate change as a physical agent whose influence on the distribution and determinants of health-related states in populations is a function of its influence on day-to-day weather, climate variability, and long-term climate changes, in addition to how these influences directly and indirectly change the underlying social, economic, and cultural realities related to health-related states.

Steenland and Savitz (1997a), however, explain environmental epidemiology more specifically as the study of health consequences from exposures that are involuntary in nature and occur in the general environment (e.g., air, water, soil, or diet); for example, microbes in drinking water or air pollution. In addition, this definition emphasizes the etiology (which is the science of causes (Last, 2001)) of diseases in the general public from exposure to low-levels of toxins (Steenland and Savitz, 1997a). These proximate causes are more able to be directly connected to health outcomes. However, it is important to recognize that, at best, the connections between climate change and health would be indirectly related as measurable by environmental epidemiological inquiry.

The complexities associated with conducting climate change human health research do not lend themselves easily to the current paradigms of epidemiology and even environmental epidemiology, which is dominated by reductionist practice centred on individual risk factors (Susser, 1998), or on cause-and-effect analysis. However, the problems associated with climate change and human health have been recently acknowledged as adding another dimension to, and is a future field of inquiry for, environmental epidemiology (Last, 2001; Steenland and Savitz, 1997b).

In general, environmental health problems can be approached on four different spatial scales: molecular, individual, population, and ecosystem (Pearce, 1996). Traditionally, there has been a tendency towards reductionist epidemiology, or molecular and individual epidemiology. For example, molecular epidemiology attempts to determine the etiologic mechanism between exposure and disease (Pekkanen and Pearce, 2001). Individual level epidemiology has been characterized as individual 'risk factors' for disease, taking into account individual susceptibility, habits, and interventions (Pekkanen and Pearce, 2001). Often, climate change epidemiology will need to integrate several levels at once.

With the disruption of those environmental systems that maintain population health (McMichael et al., 2000), such as food production, it may be that current study designs and methods of analysis may not be adequate to measure the health consequences associated with changing environmental systems. With respect to climate change, this is mainly because, in order to asses the health impacts of climate change, there are three distinctive features of the system being studied that must be accommodated: 1) the large spatial scale of the impacts (i.e., regional or national versus local); 2) the timing and potentially long temporal scale as climate change research extends backwards in time (e.g., analog studies), in order to predict future outcomes that may be one hundred years into the future; and 3) the level of complexity of the system being studied (e.g., climate change and vector-borne disease studies require molecular, individual, and population variables, in addition to the involvement of multiple disciplines) (McMichael et al., 2000).

In light of the new global challenges facing human health, there is a need for epidemiologists to reintegrate the population and ecosystem perspectives (Pearce, 1996; Pekkanen and Pearce, 2001). At least three different types of variables (or indicators) needed at the population- or ecological-level of analysis:

- aggregate (summaries of individually measured variables);
- environmental (physical characteristics of the places in which people reside); and
- global characteristics of groups that have no analogue at the individual level (Morgenstern, 1998; Pekkanen and Pearce, 2001).

Often, this means deriving population-attributable risks based on prevalent exposures and expected health outcomes from individual studies, in addition to the need for a systematic research approach that integrates biophysical, social, economic, and human health dimensions (Pekkanen and Pearce, 2001).

Stemming from the ecosystem level of analysis, eco-epidemiology is a relatively new sub-specialty, which might be the 'best fit' for climate change epidemiology. Eco-epidemiology attempts to integrate the multiple levels of a problem such as combining molecular, social, and population-based epidemiology for use in public health problems (Susser, 1998). For example, we need to integrate the malaria parasite's reproductive capacities within an *Anopholes* mosquito with the social context of the malaria threat to human populations, and the geographical mosquito range. Thus, the ecosystem level of analysis involves epidemiological research on many spatial scales. In addition, it must be integrated with other disciplines.

In order to assess the health impacts of climate change and to address its complexities, the WHO (1999) suggests that climate change and human health research can be conducted within three different logical frameworks. These are: 1) referring to analogue situations in the past to indicate future aspects of climate change; 2) investigating evidence of early changes in health risk indicators or health status in known climate sensitive, early responding, phenomena; and 3) using existing empirical knowledge and theory for the initiation of integrated mathematical modeling of likely future health outcomes.

The next section will describe some of the current methods used to investigate the health consequences from climate change within the three frameworks as categorized by the WHO. In addition, some challenges and limitations of climate change epidemiology are presented.

1.3.1 Logical Frameworks for Investigating Climate Change and Human Health

The goal of climate change and human health research is to determine how climate or weather, directly or indirectly, are associated with the determinants of health. Researchers must delineate these relationships and relate them to the public and policy makers in a meaningful and useful way, such that public health is advanced.

1.3.1.1 Analogues of the Past, as Indications of the Future

Because of the complex nature of climate change and human health research, it is not possible to estimate the health effects from climate change without understanding the processes at smaller scales (Buck and Aron, 2001). Thus, the initial epidemiological study designs most appropriate for climate change and health are often observational and exploratory (Buck and Aaron, 2001). As mentioned previously, the Hypsithermal interval serves as the best analogue for environmental conditions under double the atmospheric CO_2 concentrations, predicted to occur with global climate change. However, because there are no health records of this time, researchers must use the short time periods within the last century that have temperature and precipitation levels that approximate the Hypsithermal period.

There are three basic types of analogues that can be applied to obtain an estimate of the possible health impacts associated with climate change: 1) historical trend (e.g., local warming trend and malaria incidence); 2) extreme event (e.g., consequences of floods or droughts, major and minor in intensity); and 3) geographical (e.g., comparing one location with another location analogous to what the first may be like under conditions of climate change) (McMichael et al., 2000).

In analogous investigations, conventional environmental epidemiological methods (e.g., cross-sectional, cohort, case-control, and ecological study designs) can be employed for these investigations, as well as their common exploratory statistical techniques. Analogue studies are used to gain insight into the relationships between climate and health outcomes, are often the basis of predictive models (McMichael et al., 2000; Patz and Balbus, 1996) and theory development (National Research Council (NRC), 2001), and can be employed to identify human health indicators that may vary in the long- or short-term with weather-related changes.

A major limitation of the analogue study design is that it is only an estimation of the real environmental conditions. For example, although current temperature and precipitation levels are similar to historical analogue conditions, these variables are part of the total environmental picture, which includes vegetation, biodiversity, and surface water coverage. Another limitation is that the events have already occurred and the measured outcomes are extrapolated into frameworks and models, which have a high degree of uncertainty to predict future health outcomes (Buck and Aron, 2001). Thus, the challenge remains to develop stronger linkages between observational studies and integrated assessments (discussed in Section 1.3.1.3) for improvement of the overall process (Buck and Aron, 2001).

One regularly used analogue that has been employed to represent future changes in climate variability is the El Niño Southern Oscillation (ENSO). However, this is not indicative of future climate change because patterns of climate variability are difficult to discern and future estimates are made with a large amount of uncertainty (McMichael et al., 2000). ENSO produces global fluctuations in precipitation (McMichael et al., 2000) and is linked to global weather changes and changes the risk for droughts, floods and tropical cyclones (Kovats, 2000). These events have been correlated with variations in the number of people affected by natural disasters (Bouma et al., 1997), as well as outbreaks of mosquito-borne infectious disease (McMichael et al, 2000).

An extreme event analogue that is important and relevant to the Canadian Prairie region under conditions of climate change is the drought of the 1930s or 'dirty thirties'. In the 1930s, there was a lack of water for crops and cattle, dry soil conditions leading to soil erosion and dust storms, and infestations of insects that thrive in dry conditions (e.g., grasshoppers) (National Drought Mitigation Center (NDMC), 2002). However, in the 1930s there was more moisture from the winter snowfalls, which is not occurring today (*Edmonton Journal*, 2002). In addition, in the 1930s, millions of people in the USA migrated from drought-stricken areas, and financial pressures associated with the drought (and the Great Depression) forced many families into bankruptcy. Many relied on financial aid from the government for relief, but still had to concern themselves with emotional and financial stress that accompanied the times (NDCM, 2002).

Canadian farmers today are also experiencing similar environmental and social realities as in the 1930s, because a multi-year drought is currently underway. Although, differences in the social conditions between the 1930s and the present are apparent, the effects of the 1930s drought provide an indication of how drought can impact the health of Prairie populations. For example, because of advances in technology, fewer farmers are responsible for larger areas, decreasing the numbers of farmers at risk for drought, but increasing their individual risk and stress. Technology (e.g., green revolution) and better farm practices may allow farmers to increase yields and livestock numbers on the land, but these technologies are more expensive and make farming more of a vulnerable enterprise in the event of drought. In addition, dry soils and dust storms can directly impact the respiratory health of rural communities.

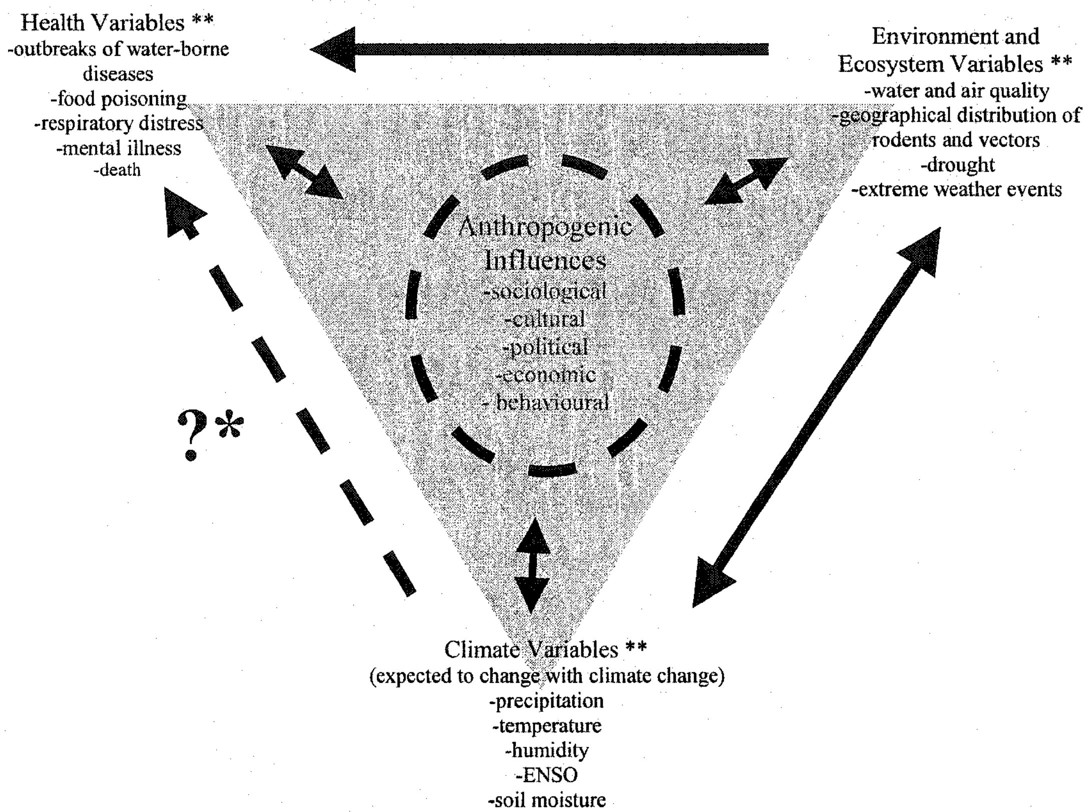
1.3.1.2 Health Risk Indicators of Climate Change

Climate change and human health research have two general components: weather and health. Thus, it is important to link changes in environmental quality and ecosystem health (as they relate to climate change) to human health. Figure 1.3.1.2 depicts this relationship. Once the relationship between climate variables and human health outcomes is better understood, monitoring and surveillance could be implemented as the climate changes.

Environmental Health Indicators

Environmental health indicators (EHIs) are those that summarize and provide information about the scientific relationship between environment and health (Kjellstrom and Corvalan, 1995; Corvalan et al., 1996). Thus, an indicator that purely describes the environment or only health status, without reference to the other is not an EHI (Kjellstrom and Corvalan, 1995). Two important community EHIs are percentage of the population with access to safe drinking water and sanitation (Corvalan et al., 1996). Global influences have not been thought of as EHIs. The main limiting factor for using EHIs for climate change research is that the collection of the relevant climate-social indicators (e.g., agricultural loss and weather) is not performed for health-related purposes (Kjellstrom and Corvalan, 1995). However, EHIs can be helpful on a more regional level.

Figure 1.3.1.2. Pathways and linkages between climate/weather, environmental variables, and human health from an anthropogenic perspective



The primary challenge faced by human health and climate change researchers is represented by the question mark. How will climate change affect human health? Once an understanding is reached of how health outcomes may directly and indirectly vary with changing climate variables, human health and climate change researchers could incorporate these variables into "what if" scenarios to predict likely human health outcomes under climate change scenarios.

* It is noted that some climate variables, namely heat and cold, have direct, demonstrated effects on human health.

** Not all variables possible for investigation have been listed.

Indicators are important as they provide information for their direct use by decision-makers (Corvalan et al., 1996). For example, data are collected and aggregated to provide statistics. These statistics are then analyzed and re-expressed as an indicator, which is entered into the decision-making process (Corvalan et al., 1996).

An EHI can be static or dynamic, such that it can be a point estimate in time, or it can change during a specific period of time. We can use epidemiological tools, such as prevalence and incidence rates or point estimates, to measure these changes (Kjellstrom and Corvalan, 1995). EHIs can be exposure-based, such that the indicator predicts, given some knowledge about the environmental hazard, an estimated measure of risk (Corvalan et al., 1996); for example, the risk of skin cancer from present and continued ozone depletion (Kovats et al., 2000). An EHI can also be an effect-based indicator, which projects backwards from the health outcome to give an indication of the cause (Corvalan et al., 1996). This type of indicator can be employed in epidemiological study designs associated with extreme weather, for example intense rainfall events and outbreaks of water-borne disease.

The WHO (1999) indicates that the health effects from climate change in the 'foreseeable future' are those associated with thermal stress, vector-borne diseases, water-borne and food-borne diseases, extreme floods, and a rise in sea level. More specifically, potential indicators could be mortality associated with heat and cold waves; infectious diseases (i.e., malaria, campylobacter infection, cryptosporidosis, tick-borne encephalitis, Lyme disease, and legionellosois); vector density and distribution; and water- and food-borne diseases associated with floods (WHO, 1999).

These 'foreseeable' health effects from changing climates can be used as possible EHIs, but they can also provide an important link for surveillance of the health effects associated with climate change. Surveillance requires the systematic ongoing collection, assemblage and analysis of data, and timely dissemination of information to organizations, institutions, or sectors that need to know for action to be taken (Last, 2001). EHIs provide a link between changes in the environment and health outcomes. Thus, if a change in environmental conditions can trigger an adverse outcome to health and well-being, a more timely delivery of information, public health resources, and the implementation of adaptation processes could be achieved if a surveillance program were in place. For example, if the environmental conditions that facilitate outbreaks of hantavirus pulmonary syndrome (HVP) occur, surveillance systems can alert public health officials in vulnerable areas to be prepared for cases of HVP (e.g., notify physicians and hospitals), in addition to warning vulnerable populations (e.g., rural communities with high densities of deer mice) to avoid the risks associated with HVP infection.

Ecosystem Health

Another unique way to investigate the possible health consequences of changes in climate on human health is to bridge ecosystem health with epidemiology (Rapport, 1999). The underlying idea is that humans are the infective agent and degrade the ecosystem in their wake. Thus, epidemiological methods serve as a metaphor to describe the temporal and spatial spread of ecosystem degradation, and indicate that epidemiologic occurrences (e.g., disease prevalence in plants, animals or humans) are connected and influenced by ecological conditions. Thus, elevated disease prevalence is an indicator of ecosystem pathology, and this will place increased risk on the health of all the components within, including humans (Rapport, 1999).

In summary, ecosystem health is an indicator (e.g., prevalence of animal and plant diseases) of the health of the environment that humans depend on for resources for survival (e.g., air, water and food) and also for social well-being (e.g., employment and material goods) all of which, directly or indirectly, affect our health. Thus, as we degrade our environmental systems (e.g., climate change) and diminish ecosystem health, we can extrapolate future changes in social and physical health (e.g., unemployment and respiratory health).

An example of an ecosystem health indicator could be nutritional status and stress levels of populations (e.g., Atlantic seaboard fishing communities or indigenous peoples) dependent on fish as a way of life, or as a dietary staple. Thus, as we over-fish and deplete our fish stocks on a global scale, we may begin to extrapolate the physical, mental and social discontent within populations that are closely tied to the survival of ocean fish stocks. However, Rapport (1999) states clearly that these indicators are not meant to be employed as sole indicators of health consequences, but should be used in conjunction with others.

One ecosystem health study by Sieswerda et al. (2001) measured the impact of global scale ecological disintegrity on life expectancy. The study found that several variables measuring ecological disintegrity were inversely related to life expectancy, whereas others were very close to no association, after controlling for Gross Domestic Product (GDP).

This means that countries with lower ecological integrity actually had higher life expectancies. One explanation for the finding was that high-income countries attained wealth and good health from the initial exploitation of their own natural landscapes. These countries could then use their wealth to take advantage of resources in distant lands and use those lands for their wastes.

EHI investigations are mainly limited to those aspects of the ecosystem that have a short-term (i.e., 2 or fewer years) response to climate variability. This is most evident for microbial or pathogenic organisms that are climate sensitive. For example, vector-, rodent-, water-, or food-borne pathogens are climate sensitive and responsible for a host of human illnesses. The short-term applicability of EHIs is mainly because they are important in the policy decision-making process and their utility in this arena relies on their ability to relate aspects of environment to health (Corvalan et al., 1996). Both of these must have relevance to the decision-maker, and be amendable and controllable (Corvalan et al., 1996).

Ecological Risk Assessment

In addition to identifying health risk indicators, Patz and Balbus (1996) outline the use of ecologically based health risk assessment. Ecological risk assessment frameworks, unlike conventional risk assessment, can evaluate several ecological stress factors and their impacts on a variety of species in a system. Three phases define the framework. The first phase, problem formulation, entails early consideration of human health end points (based on empirical evidence), and the use of conceptual models to guide the analysis. This could include investigating temperature and humidity thresholds associated with significant death or morbidity for various climatic regions across Canada or the Prairies.

The second phase, one of analysis, uses the conceptual model identified in the problem formulation phase, and evaluates potential responses to the defined stressor (which is not necessarily climate change, but rather climate variability, extreme events, or timing of events). In this phase, it is essential to define the ecosystem type or region (Patz and Balbus, 1996). At this point, researchers could analyze various stressor-response (e.g., heat-death) relationships over various geographical regions, and time. Here, the threshold is identified as the "sudden change in the slope of the dose-response curve" (Patz and Balbus, 1996). The last phase, risk characterization, integrates stressor characterization and response analysis, in addition to human adaptive responses (Patz and Balbus, 1996).

1.3.1.3 Predictive Modeling

Modeling is an important tool for estimating future health impacts from climate change on human health. There are three types of models appropriate for climate change and human health research: empirical-statistical, process-based, and integrated assessment (McMichael et al., 2000). Only empirical and integrated assessment will be addressed here.

Empirical-statistical

Empirical-statistical modeling is based on previously observed and documented statistical relationships between climate or weather and health (McMichael et al., 2000). These can be simple relationships such as temperature thresholds for disease-carrying vectors, or more complicated relationships that require multi-level modeling or structural equation modeling. For example, mathematical models have been utilized in the early prediction of human vector-borne diseases that are sensitive to climate. The mathematical formula includes terms such as 'vectorial capacity', 'blood feeding per vector', 'vector's daily survival probability' and the 'extrinsic incubation period' (Reiter, 1988). These models can be entered into more complex models such as process-based models or integrated assessments (McMichael et al., 2000; Patz and Balbus, 1996).

Integrated Assessment

Integrated assessments (IAs) are the most comprehensive of predictive models. However, they are often loosely defined, and can best be described as a process or approach (Rotmans and van Asselt, 1996). Integrated assessments use both qualitative (value added and expertise) and quantitative (mathematical modeling and empirical science) methods or approaches (Dowlatabadi and Morgan, 1993), which provide both scientific and policy dimensions (Rotmans and van Asselt, 1996). For example, integrated assessment models (IAMs) are quantitative in nature and attempt to link human actions to consequences by developing complex computer models (Dowlatabadi and Morgan, 1993; Aron et al., 2001). With respect to a more qualitative approach, Rotmans and van Asselt (1996) defined IA as "an interdisciplinary and participatory process of combining, interpreting and communicating knowledge from diverse scientific disciplines to allow a better understanding of complex phenomena". This approach also employs participatory methods to engage non-scientists such as civil society, government officials, or industry stakeholders in IA (Aron et al., 2001).

In general, an IA has two main characteristics: 1) provide a value-added component when compared to the limited insights derived from disciplinary research; and 2) provides decision-makers and society with useful information (Rotmans and van Asselt, 1996). Thus, the task of IA is to usefully integrate and synthesize information from the contributing disciplines (Parsons, 1996). IAs attempt to quantify, as much as possible, the cause-effect relationships (vertical integration), and the cross-linkages and interactions between different contextual circumstances (e.g., political and economic), including feedback loops and societal adaptations (McMichael et al., 2000).

IAs are also distinct in that they attempt to link together social, economic, and environmental factors for the purpose of examining policy and decisions that could affect a variety of sectors. Thus, IA extends beyond risk assessment such that it provides support for decisions to manage risk, and a context for decisions that is more complex than that of a single agency (Aron et al., 2001).

1.4 Challenges to and Limitations of Climate Change Epidemiology

The above review outlines the diverse methods available to climate change and human health researchers, as well as the progressive complexity of these methods. However, because of its complexity and interdisciplinary nature, climate change and human health research also presents several limitations.

1.4.1 Interdisciplinary Research Endeavours

Interdisciplinary research relies on access to data and expertise in a variety of disciplines. In addition to these academic needs, in order for the results to produce positive change, outcome information must be useable by decision-makers, relevant to public sectors, and understandable to sectors that might be adversely affected by policy change. Thus, it is important for research groups to build networks that involve individuals and organizations from societal sectors (i.e., academia, public, government, and industry) for access to resources, information, values, viable solutions, dissemination, and aid evidence-based decision-making. However, networks should also be maintained and fortified, for an eventual re-examination of the policy and for adaptation purposes.

1.4.2 Human Adaptation and Feedback Loops

The global environment is constantly changing and humans are constantly adapting, both of which, in turn, will change the way research is conducted, what outcomes are being measured, and how decisions and policies will be kept relevant. IA and IAF provide such a channel for re-examination. In addition, it is important for researchers to involve all stakeholders from the beginning, and strengthen networks in order for revaluation and to continually readdress concerns.

1.4.3 Indicators

In addition to the obvious indicators, such as heat and mortality, how will climate change affect the more subtle aspects of health, such as the determinants of health? In particular, how will climate change affect poverty, economics, and social structures? At present, it is difficult to quantify the socio-economic factors and the health determinants that play a large role in determining the health status of populations (Patz and Balbus, 1996), especially in the developed world because public health has a large capacity to adapt.

It may be necessary to develop or employ a measurement or indicator of the societal aspects of health. For example, the Pembina Institute has developed Genuine Progress Indicator (GPI) Accounting to measure the genuine well-being of nation states (Aneilski et al., 2001). This accounting method considers 51 different population variables in the categories of economic (e.g., savings, debt, weekly wages), environmental (e.g., air quality, forest fragmentation), social (e.g., income distribution, unemployment), and human health (e.g., obesity, suicide). These variables are combined as an alternative measure of a nation's prosperity or genuine well-being that incorporates social-personal, environmental, *and* economic objectives. This is compared to the conventional method of measuring economic growth and prosperity, the Gross Domestic Product (GDP), which only measures the flow of cash in an economy (Aneilski et al., 2001).

1.4.4 Ecological Fallacy

Ecological studies employ population data as the unit of analysis, which provides a useful way to compare population level data across geographic regions or in the same area over time (Buck and Aron, 2001). However, group level associations are not necessarily the same at the individual level (Soskolne et al., 2000). For example, because we may observe that during a drought period there were higher rates of physician visits for mental health related problems in rural areas, it does not mean that individual Prairie farmers are having a harder time coping with the drought. It could possibly be attributed to the economic and political conditions at that time, or a change in physician reporting. However, Pekkanen and Pearce (2001) also caution that fallacious conclusions are possible at the individual level if relevant population variables are excluded.

Although there are many cautionary notes associated with ecological studies, they are useful and necessary in some situations. Ecologic studies are useful for broad hypotheses related to strong associations, as well as for some exposure variables that are inherently ecologic (Susser, 1994). They are also valuable for generating hypotheses for more specific and disciplinary research, and are useful for investigating the baseline health status of populations in different geographical regions where the exposure is universal. In addition, the contextual effects associated with populations and societies under study often cannot be broken down into parts or measured at the individual level. Thus, ecologic studies also provide a holistic approach to climate change and human health research.

1.4.5 Large Spatial and Temporal Scales

Various feasibility issues, methodological concerns, and statistical complexities will present themselves as researchers attempt to investigate data that may extend over several decades, across geopolitical boundaries, and that stem from different disciplines. Feasibility issues include time, money and the large amount of data that may not be available and would be required to conduct climate change and human health research. These are compounded by the need to cross disciplinary boundaries and have large collaborative research groups. In addition, especially in large geographical regions, efforts to coordinate networks and disseminate findings become much more demanding.

Methodological concerns are similar to other epidemiological studies that are conducted over time and space. Physician diagnostic bias, changing classification systems (e.g., ICD-8 to ICD-9 to ICD-10), public awareness of health issues, the population's underlying health or socio-economic status, changes in health or environmental policy, shifts in the nature or intensity of economic activity (e.g., intensive livestock operations), or human adaptation could all confound or bias health-climate relationships found across time and space.

Statistical analysis becomes more complex as climate change and human health research extends into different levels of variables and encompasses direct and indirect effects. This calls for more complex strategies for analysis like multi-level data analysis, path analysis, and structural equation modeling. These strategies could provide a basis for the mathematical modelling of health effects from climate change.

1.4.6 Predictive Model Uncertainties

As mentioned earlier, GCMs are the current tools used by climate change researchers to estimate future climate scenarios. These models are based on certain assumptions of the ocean-atmospheric conditions and are used to make future approximations of temperature on a global scale. However, not all variables associated with the driving of global climate are known, nor do we know what the future atmospheric conditions will be for incorporating CO_2 levels into the model. Thus, a range of possible outcomes is computed by entering different estimates of variables that are unknown, for example future yearly anthropogenic GHG emissions (CICS, 2000).

The scale on which GCMs can predict climate outcomes is global and they have a relatively course resolution (i.e., 3.7° longitude by 3.7° latitude) (Hengeveld, 2000). This presents a problem for regional-level research because much uncertainty is associated with a GCMs' ability to predict future climates on smaller scales (Herrington et al., 1997). However, downscaling of models to smaller areas, using regional climate models is occurring (Hengeveld, 2000). In addition to the problems associated with resolution, the ability of GCMs to predict all aspects of climate is not possible (IPCC, 2001), adding further uncertainty to estimating climate change scenarios.

In summary, the climate scenarios on which we are basing climate change and human health research are very uncertain (Last and Logan, 1999). Thus, in a sense, climate change and human health research could be biased from the beginning. Bias is the introduction of systematic error (e.g., basing climate scenario research on a flawed scenario) at the beginning of the research process, and once bias has been introduced, there are limited statistical techniques to correct for it (Soskolne et al., 2000). In addition, political decision-making projecting 50-100 years into the future is difficult under conditions of uncertainty (Last and Logan, 1999).

Although there is much uncertainty surrounding the predictions made from GCMs at a regional level and for various weather variables, there is comfort in the fact that all GCMs point in the same general direction. This includes warming over much of the western and northern portions of Canada (Herrington et al., 1997). However, by using proxy data, we can have an idea of what future environmental scenarios might emerge under climate change in the Prairie region.

1.5. Conclusion

Climate change and human health research is a relatively new field. One of the main conclusions from this chapter is that health outcomes, stemming from climate change, often result from complex pathways that vary over time and are embedded within our social structure. Because of the complexity and interconnectedness of the human health consequences of climate change, there is a need to incorporate research data into more comprehensive models such as IA. However, IA, which needs to quantify the linkages and interactions, as well as be participatory in nature, may provide too narrow a scope to view the broad effects that climate change can have on human health.

As mentioned, there is a certain degree of interrelatedness of all aspects of climate change and how each can impact human health. Therefore, there is also a need to integrate information and participation across sectors (e.g., political, economic, health), resources (e.g., primary, secondary, monetary), and systems (e.g., biological, physical, social) in order to understand climate change and human health as it pertains to the community or region affected on a broader level. Integrated assessment frameworks (IAFs), therefore, can provide a broader context, and they add structure to the climate change and human health problem.

IAFs represent a cyclical and participatory process of IAs involving government, scientific, economic, and societal stakeholders (Rotmans and van Asselt, 1996). Thus, IAFs are an important part of: understanding climate change and human health on a broader level (Aron et al., 2001); initiating a review and re-evaluation process of policy decisions as they evolve with adaptations and societal values (Rotmans and van Asselt, 1996); and, identifying what is known, knowledge gaps (Aron et al., 2001), and future research questions or IA exercises (Rotmans and van Asselt, 1996).

The IAF, grounded in an in-depth review of the peer-reviewed literature, is the foundation of Chapter Three. Although the chapter adopts an IAF format similar to the climate change and infectious disease IAF proposed by Chan et al. (1999), it is structured around the climate scenarios most likely to occur in the Prairie region under conditions of climate change, rather than a specific disease process, such as infectious diseases.

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Chapter 2

Building a Prairie-wide Climate Change and Human Health Network-the Involvement of Stakeholders

2.1 Introduction

The Prairie Adaptation Research Collaborative (PARC) was formally established on March 24, 2000. It was the first node of approximately 12 initially established by the Canadian Climate Impacts and Adaptation Research Network (C-CIARN). The 12 identified nodes represent the geographical regions within Canada and the various sectors that would be affected by climate change. PARC is a facilitative, interdisciplinary research collaborative that addresses the impacts of, and necessary adaptations to climate change on the Prairie Provinces.

The initial call for proposals was in April 2000, and of 32 successful grant applications awarded funding by PARC, this project entitled "A Feasibility Assessment to Study Societal Adaptation and Human Health Impacts under Various Future Climate Scenarios Anticipated in the Canadian Prairies: Report on Prairie Round Table Discussions"* was the sole one to investigate the relationship between human health and climate change on the Canadian Prairies. Because no known prior research was identified that studied human health adaptation measures needed in the wake of climatic change in the Prairie region, it was our intent to:

a) Examine the linkages and commonalities among the various sectors potentially affected by climate change (i.e. industry, government, academia, and public sectors);
b) Establish a network of research collaborators and potential stakeholders concerned with the health effects of climate change on people residing on the Canadian

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* Principal Investigator: Dr. Colin L. Soskolne, Co-Investigators: Dr. Donald W. Spady, and Dr. Karen E. Smoyer-Tomic. Grant # 8 Report Dated: April 18, 2001, with final minor updates on July 10, 2001.

Prairies for the purpose of providing information and opinions on the relevant components of the research process;

c) Identify priority research areas and questions, potential outreach opportunities, and target audiences for increasing public awareness of individual adaptation strategies in the face of climate change and human health from the perspectives of the stakeholders and collaborators*; and

d) Present an in-depth literature review, based on current knowledge, investigating the potential human health impacts from the various climate scenarios predicted by GCM models in the Prairie Region.

The focus of this chapter is the first three objectives; Chapter Three will specifically respond to the fourth objective in the context of an integrated assessment framework (IAF). In this chapter, the methods section provides an explanation of how the first two objectives were achieved. The results section then elaborates on the third objective with a view to the involvement of stakeholders in climate change and human health research. This third objective focuses on three prearranged questions that aimed to identify priority research issues, resource availability, and dissemination opportunities.

A discussion section follows the results to reflect on the general discussion and emerging ideas brought forth in the Round Table Discussions (RTDs) that went beyond the three prearranged questions. This includes innovations, and adaptive and mitigative solutions to the research topics introduced in the results. In addition, this section identifies the barriers or considerations that must be addressed or anticipated when conducting climate change and human health research. The final section of this chapter contains recommendations and conclusions. In addition, appendices provide a visual representation of question one, a participant e-mail address list, and a detailed description of the second and third research questions for information purposes, resource sharing, idea generation, and potential collaboration.

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* This objective is slightly revised from that in the original proposal through the additional focus on "priority research areas and questions"

2.2 Methods

Using an established PARC network, the networks of the co-investigators on this grant, and internet searches, individuals and organizations were identified to be potentially affected by climate change in the Canadian Prairie region. Four main sectors were identified, Government, Industry, Academia, and Public (NGO/ENGO). E-mail correspondence was employed as the medium for establishing contact. The initial inquiry regarded whether the particular organization would be interested in participating in discussion groups, and becoming a part of a Canadian Prairie resource network regarding climate change and human health. In addition, we encouraged the recipients to forward the initial contact letter and attachment to any other person or organization known to have an interest in climate change and human health issues (snowball sampling). In total 245 individuals were contacted, all of whom have health or climate change expertise or experience, or have had prior research experience with health, climate change or a related area.

Through this initial endeavour, it came to our attention that some individuals and organizations were interested in the research project, but could not participate because of time constraints. At this point, a "For Your Information (FYI)" copy list was started. This allowed individuals to remain informed through periodic updates. Although, participants made a commitment to participate, we kept the invitation to participate in the RTDs open to the FYI. Thus, at this point there was a pool of 47 individuals on the participant and FYI copy lists that were informed of, and invited to attend the RTDs. This was a 19.2% response rate from the original 245.

Judging from the locations and availability of the agreed participants, three RTDs were scheduled in three Prairie cities: Regina (February 20, 2001), Winnipeg (February 21, 2001), and Edmonton (February 22, 2001). The total number of attendees at all three RTDs was 20*. The discussions were designed to answer three questions: a) What is (are) the most pressing issue(s) regarding climate change and human health that your sector faces

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*The final 20 was not a fraction of the original 47 on the FYI and Participant lists. The RTDs were not closed, thus 5 additional participants who were not originally on the participant or FYI list also attended.

today that needs further research consideration?; b) What resources would your sector have available, or could be made available, for the conduct of relevant research and/or the dissemination of research findings?; and c) What is your sector doing to reach, educate, and extend public consciousness, mitigation or adaptation to climate change, and could these efforts be expanded? If so how? Each RTD lasted three hours and, in addition to discussion, each participant wrote their responses to each question on separate pieces of paper. Additional participation was via e-mail by individuals that could not attend. The number of e-mailed submissions was 7.

2.3 Results

The Round Table Discussions had three specific goals:

- To identify meaningful and feasible climate change and human health research questions specific to the Prairie Provinces;
- Identify the resources each sector would have available for the conduct of research or for the dissemination of findings regarding climate change and human health; and
- Identify current public outreach and educational opportunities regarding adaptation and mitigation to climate change.

Although it was not our original intent, this report could provide a general framework for judging the relevance of research projects that pertain to climate change and human health in the Prairie region. The framework thus could be of assistance with respect to resource allocation for future climate change and human health research.

2.3.1 Question 1. What is (are) the most pressing issue(s) regarding climate change and human health that your sector faces today that needs further research consideration?

Three primary themes were raised by all sectors for priority attention. As such, these could be seen as priority areas for future climate change and human health research on the Prairies. Appendix A contains a diagrammatic representation of how these three core areas could provide answers to climate change and human health research questions.

2.3.1.1 Climate Scenarios

It is necessary to understand what future climate might result from climate change, not only for the Prairie region, but also on a sub-regional or local scale within the Prairies, for planning short-, medium-, and long-term adaptation strategies. This is likely best done through GCMs, which provide a powerful tool for modeling changes in Prairie climate under various conditions. However, GCM modeling on small areas is very uncertain, which is one barrier to climate change and human health research in the Prairie region, as noted in Section 2.4, General Discussion of Emerging Issues. In addition, a need was identified to define regional impacts according to eco-regional boundaries, rather than by geo-political boundaries. The questions which emerged was:

- What are the potential climate scenarios to which humans will have to adapt (positive and negative) in the Prairie region over the short-, medium-, and long-terms?

2.3.1.2 Linking Climate Scenarios to Human Health

We must establish and define the linkages, characteristics, and nature of the relationships between future climate scenarios and human health outcome variables at local and regional levels. We must address the questions:

- What are the probable direct and indirect impacts on human health of different climate scenarios? What are the consequences of these scenarios for the population in terms of biological threats, economic impacts on farmers, food production and safety hazards, and the associated health implications?

- How could socio-economic status (a well-established determinant of health) change in various population segments with respect to the future climate scenarios expected by GCMs?
- What health outcomes should be considered for effective surveillance and monitoring?
- What are the historical relationships concerning the effects of weather, climate and climate variability on human health? Does baseline scientific knowledge regarding these relationships exist for the Prairies?
- How will the health of individuals and populations be affected by hotter summers and milder winters in the Prairie region in the short-, medium-, and long-terms?
- How applicable to the Canadian Prairies is the research completed elsewhere (e.g., internationally)?

2.3.1.3 Partnering Between the Health and Physical Sciences

Climate change and human health research requires multidisciplinary, multi-sectoral and interdepartmental efforts. A concern raised was the lack of networking among sectors and between departments that: a) will be directly or indirectly affected by climate change; b) need to collaborate for basic research on the health effects of climate change and; c) have to plan and implement adaptation strategies, not forgetting the benefits to be derived from adopting appropriate medium-to-long term mitigation measures. In general, there is a split between the physical sciences and the health sciences communities.

In addition to these three areas, climate change and human health research topics and questions can be expanded to encompass more specific regional concerns. They are listed below as additional themes (numbered 4-10) in no particular order.

2.3.1.4 Water Quality and Quantity

All sectors recognized that water quality and quantity issues are and will continue to be extremely important for the Prairie region in many different ways. Some areas or regions may suffer from a lack of water resources, and others may have more flooding; all regions could experience large rainfall events within a short period of time, possibly overwhelming current infrastructure capacity. Questions that arose included:

- Will the Prairie region have safe potable water and in sufficient quantities to satisfy the Prairie region, the individual provinces, and small, localized areas within each province?
- Will the switch from grain production to more water intensive livestock operations (ILOs) be sustainable under various future climate scenarios with respect to water quantity?
- How will water quality change as a result of ILOs?
- What impacts will runoff from ILOs have on human health in terms of water quality and quantity?
- What might happen to water quality (i.e., potable water availability) with increased large precipitation events and flooding, especially areas serviced by aquifers? For example, during the Red River flood in Manitoba in 1997, water from aquifers mixed with that from the sewer systems.

2.3.1.5 Economic Effects of Climate Change on the Medical Services

Several participants felt it was important to put a dollar figure on how climate-induced changes will affect the provision of medical services (directly and indirectly). Specifically:

- What human and financial resources will be necessary to service an already stressed publicly funded health system (e.g., insufficient number of physicians)?
- What is our current economic capacity for emergency response to disasters?
- In addition to an economic impact from climate change on the publicly funded health system, what health resources (short- and longer-term, positive and negative) will be needed for health sector planning?
- Could new financial difficulties arise in any major employment sector (e.g., agriculture) adding new stresses to health?
- What will be needed in terms of socio-economic support and infrastructure to mitigate and adapt to the effects of climate change on health?

2.3.1.6 Air Quality and Other Pollutants

Air quality and the synergistic effects of pollutants on human health when combined with a changing climate were considered important. With heat, photochemical reactions convert fossil fuel emissions to secondary pollutants that amplify the already harmful effects of smog to respiratory health. Questions arising include:

- What is the relationship between climate change and pollutant levels, and what would be the human health effects of these levels (singly and in combination)?
- How will climate change affect common pollutants (e.g., industrial, fire smoke, pesticide application), and how will these pollutants affect human health?
- What are some of the synergistic effects between air quality (e.g., smog) and weather (e.g., more high/extreme heat days)?
- Will there be a need to implement higher standards for dealing with the cumulative fate and toxicity of pollutants that snowball over time and that may change in composition with higher surface temperatures?
- After shifting to a more energy efficient society in which homes become more airtight, will indoor air quality decrease? Could radon concentrations increase?
- If the environment becomes more humid, will there be a new challenge of mould toxicity?

2.3.1.7 Adaptation Capacity and Future Challenges

In order to adapt to climate change, it was felt that an inventory was needed of the present capacity of society to adapt, in addition to an estimation of what adaptation (and mitigation) measures would need to be implemented for the future. To have a vision of where society will be in 5 or 10 years time would be valuable for planning adaptation (and the associated mitigation) strategies. Questions that need to be addressed included:

- What is the current capacity of communities to adapt to climate change in terms of infrastructure, behaviours, emergency response, and the ability to cope with emerging infectious diseases?
- What additional infrastructure will be needed to help adapt to the future effects of weather on health? What associated mitigation measures would be appropriate?

- Can our current sewer systems and water treatment facilities cope with more frequent flooding events?
- How will costs of goods and services, livelihoods, and personal choice be affected by climate change?
- Historically, where have people been most vulnerable to high temperatures (e.g., top floors of brick buildings) and what adaptation measures have been successful in the past (e.g., lighter coloured buildings)?
- What characteristics of homes are pleasing to people, but are energy efficient and have a minimal impact on the environment?
- What are the new safety challenges that might arise from global warming in the transportation sector?

2.3.1.8 New Disease Burdens

Concern was expressed relating to the changes in the distribution of human, animal, and crop diseases (human- and animal-ecosystem health relationships) as temperature rises and international travel increases. Questions included:

- Does climate change have the potential to increase bacterial/insect populations, and what are the consequences along the food chain?
- Will warming allow for higher levels of disease and more bacterial growth in animals that may transfer to humans?
- How will climate change affect food safety?
- What changes in the frequency and severity of vector- and rodent-borne diseases are expected from climate change?
- What potential new populations of insects are expected?
- What is the historical relationship between vector-borne diseases and unusual concurrent weather patterns, and could this relationship be used to indicate whether extreme weather events are good predictors of outbreaks?
- Will Post Traumatic Stress Disorder and other mental health issues become more prominent?

2.3.1.9 Agriculture and Rural Health

The Prairie region has historical roots in agriculture, and this industry relies heavily on weather and climate for agricultural outputs and the livelihood of its residents. The unpredictability of climate can greatly affect crop yields and possibly force agricultural communities to change success strategies. Therefore, the health and welfare of farmers, the residents of rural communities, and the agricultural industry were noted as being important to participants. Questions arising included:

- How is climate change likely to affect the mental health and stress levels of farmers?
- What are the potential effects of the migration and the infestation of new insect species on crop yields?
- What are the health effects of a major shift in economy (from grain production to intensive livestock operations) or the need to change farm management (e.g. transportation costs, pesticide and fertilizer usage) on rural communities?
- Will rural communities experience more allergy/respiratory problems, and will pesticide residues, odours, dusts, and allergens be disseminated for longer periods?
- Could the warmer outdoor temperatures influence individuals to spend more time outdoors, and therefore increase skin cancer rates?

2.3.1.10 Risk Communication and Public Outreach

More effective risk communication and public outreach strategies must be developed in order to transfer scientific knowledge to the public and to successfully target populations for implementing both adaptation and mitigation measures. Questions arising included:

- What is the public's perception of the health risks and benefits from climate change?
- How do we target an aging population that may not be sensitive to these environmental issues?
- Where and how do people begin to educate themselves about climate change and human health issues (e.g., how do we simplify the massive amount of literature)?
- How can we provide accurate, easily understood information to the public that will change their ideas and behaviours in a positive, pro-health manner?

- How can research findings and adaptation and mitigation strategies be presented to society most effectively?
- How do we place global climate change and health issues in a context to which individuals can relate?
- How can the science of climate change and human health deliver a message that could influence health policy?
- What are the social and cultural barriers that prevent sincere and honest communication of science and health issues and how do we address them?
- Which populations are most vulnerable with respect to climate change and human health?
- What targeted messages will need to be developed for the various sub-populations with respect to age, gender, vulnerability and socio-economic status?

2.3.2 Question 2. What resources would your sector have available, or could be made available, for the conduct of relevant research and/or the dissemination of research findings?

The Prairie region is rich with expertise and information resources to conduct climate change and human health research. Each sector has available a number of resources to promote and support research in this area. (Please see Appendix B for a more detailed breakdown of the resources available from each sector. The sector affiliation of each participant is available in Appendix C.)

2.3.2.1 Government

- Various departments have money available to fund research projects either directly or indirectly.
- Existing networks and user groups can be utilized to disseminate research information.
- Considerable expertise in the physical sciences (e.g., climate, meteorology, extreme weather climate modeling, scenarios modeling, GIS applications, and hydrology).
- Health science expertise (e.g., toxicology, epidemiology, surveillance, data analysis, and experience in conducting health assessments).

-Maintenance of a wide variety of climatological (e.g., hydrometric, temperature, precipitation, and limited water quality data) and health databases (e.g. descriptive data, hospitalizations, physicians visits), in addition to air quality data.
- Workshops and presentations for stakeholders and in-reach programs for employees.
- Links to other organizations.
- Communication with public and media.

2.3.2.2 Industry

- Utilize existing modes of communication with employees and the community.
- Help leverage studies.
- Trade journals, newsletters, and websites.
- Time available for guidance in identifying epidemiological and weather records, writing or editing publications.
- Identify agencies likely to be interested in the topic from the point of view of risk management and scenario occurrence.
- Provide opportunities for education in training, by linking students with well-educated senior management.

2.3.2.3 Academia

- Networks available from current research in the area of climate change.
- List-serve participation for the dissemination of information.
- Ability to incorporate study results into university course curricula, assignments, and work-study programs.
- Availability of a database that overlays rural municipality boundaries over the Prairie Provinces.
- Socio-economic vulnerability/socio-economic adaptability modeling of the impacts of climate change at the local level (Regional Municipalities).
- Expertise in climate and health research, statistical modeling, multivariate air mass approach, weather data analysis and GIS.

2.3.2.4 Public

- Elaborate networking systems, print materials, and public education programs for the dissemination of research findings.
- Limited funds available for research that is of interest to their stakeholders.
- Links to various other NGOs/ENGOs, health organizations, and the government.
- Conferences.

2.3.3 Question 3. What is your sector doing to reach, educate, and extend public consciousness, mitigation or adaptation to climate change, and could these efforts be expanded? If so, how?

Please see Appendix B for a more detailed description of the various outreach and educational programs.

*2.3.3.1 Government**

- Conduct extensive education (K-12 and general public) outreach programs province-wide and local.
- Organize and promote workshops on understanding and use of climate scenarios.
- Provide presentations tailored to ecosystem health for their stakeholders on climate change science and impacts (e.g., industry, agriculture).
- Support activities and events (e.g., Special Weeks, Earth Day, and Commuter Challenge).
- Promote and coordinate education and outreach initiatives on climate change in Alberta (Climate Change Education Hub).
- Advertise on busses, print, TV, radio and billboards.
- In-reach opportunities for employees.

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* It was mentioned that without having answers to the core areas with a reasonable degree of certainty, it is often difficult to engage in outreach. Thus, within some departments a science communication strategy has not been full developed.

*2.3.3.2 Industry**

- In-reach programs for employees that explain the relationship between greenhouse gas emissions and energy use.
- Workshops available for the community on climate change (e.g., The ABC's of Climate Change).

2.3.3.3 Academia

- Development of a visual medium for health risk communication.
- Promote within University class materials and course curricula.
- Provide climate change workshops and conferences.
- Include projects that relate large-scale climate change issues to the local and individual level.
- Instruct university classes on how science can effectively communicate with the public.
- Provide expert opinion (climate variability/change and health) to community environmental campaigns.

2.3.3.4 Public

- Provide health education materials (websites, magazines, print material and maintenance of a library for public use).
- Promote educational programs.
- Answer calls from the public.
- Organize annual conferences and initiate regular contact with their member networks.

2.4 General Discussion and Emerging Issues

Discussions with Round Table Participants were informative and offered much more information than simply answers to the initial questions. Discussion included the *innovative* and creative use of interdisciplinary resources as possible solutions and how to enhance *adaptive and associated mitigative strategies*. In addition, discussion touched on the potential *barriers* that may need to be overcome for climate change and human health

* It was mentioned that because the message is a negative one, it might meet with some resistance.

research, adaptation, and the associated mitigation strategies that will need to be recognized and accepted by society.

2.4.1 Innovations

Innovations include new ideas, methods, resources, or tools available to aid the climate change and human health research process.

2.4.1.1 Piggyback one research project on another

Funding agencies could potentially acquire two studies from one by expanding the effort by an increment (e.g., 30%) and therefore ask potential researchers to add another relevant part, or question, to the initial experiment or questionnaire in order to promote climate change and heath research.

2.4.1.2 Educate students as they work

There are many well-educated senior managers that need and want to mentor. Some consulting firms invest in students as a means to confer the future direction of their businesses.

2.4.1.3 Novel ways to communicate with stakeholders

Public health is an excellent driver for raising awareness about climate change at the policy and societal levels. However, health research has to be presented to the public in an effective and innovative way to have the greatest impact on policy and societal adaptation. Using GIS and cartography techniques as a visual medium, health research and risk communication can be more effectively communicated to the public. The possibility of designing interactive video games with "what-if" scenarios for use by school-aged children would benefit education and outreach.

2.4.1.4 The socio-economic vulnerability and socio-economic adaptability (SEV/SEA) project at the University of Winnipeg

This project measures the impact of climate change on Prairie communities by taking large-scale information (e.g., future climate scenarios) and shrinking it to the community and even to the farm level (e.g., individual and community economic impacts). Thus, the impacts from climate change reach the level of the individual because the model details how climate change can affect each farmer economically. Attaching a dollar figure for losses and gains may be a powerful motivator for societal adaptation. In addition, this project has available a database that lays Rural Municipality boundaries over the Prairie Provinces (see Appendix B for web address).

2.4.1.5 Climate and Health Research Program (CHRP), Department of Earth and Atmospheric Sciences, University of Alberta

This ongoing research program and its affiliated researchers have been studying issues such as heat stress and health, the synergistic effects of air pollution and weather on human health, and the relationship between ENSO events, weather, and mosquito transmitted diseases. The innovative methods developed as part of CHRP can be used in research on climate-health relationships in the Prairies. These methods include air mass-based weather classification, air quality and health data time series analysis, statistical analysis including spatial analysis and methods for small areas and populations, and GIS for analysis and visualization (see Appendix B for web address).

2.4.1.6 Government initiatives to develop climate scenarios

Environment Canada is developing more representative future climate scenarios, mostly in terms of extreme weather. Research is mainly event driven and localized.

2.4.1.7 Bringing together the Ministries of Health and Environment

It has been uncommon for ministries of health and those of the environment to jointly discuss issues pertaining to health linkages related to environmental degradation. Great benefit could arise from organizing a workshop for health and environmental related fields for future networking and collaboration.

2.4.1.8 Gathering of PARC research teams

Advantage could be gained if each PARC research team could present their research to all other research teams in order to learn about, and possibly use, the linkages and networks built by other projects. In addition, this opportunity would allow for the evaluation of potential overlap and collaboration in research endeavours*.

2.4.1.9 Multivariate air mass approach

The external environment not only consists of precipitation, temperature, and solar radiation, it also includes humidity, pollen, dust, and particulates, which are housed within air masses. This unique approach better represents the holistic nature of the atmospheric environment. Air masses could be combined with GCM or regional climate model-derived climate scenarios for use in impact and adaptation research applied to the Prairies.

2.4.2 Adaptation and Mitigation

Possible long- and short-term adaptive and mitigative solutions for both the direct and indirect health effects associated with climate change are presented below.

2.4.2.1 Governments setting the standards for energy efficient building designs

Presently, individual customers are demanding energy efficient building designs such as those that promote a sense of well-being and comfort without compromising the environment. Natural lighting and solar energy within energy efficient buildings may actually enhance well-being and health owing to the tendency of these building types to be brighter and more airy. Because the Government occupies most building space, they set the standard for spending on technology, innovation and energy efficiency. Therefore, the Government at all levels must lead the way for future building design standards.

2.4.2.2 A 5-10 Year Strategic Outlook

Forward movement in adaptation and the associated mitigation strategies require having an end goal in sight. Working towards the objective will require starting at the end and working backwards using a time line to organize the steps in which the goal is to be achieved. Climate change and human health research and policy should incorporate this strategy into research designs and decision-making processes.

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* In between the writing of this document "A Feasibility Assessment to Study Societal Adaptation and Human Health Impacts under Various Future Climate Scenarios Anticipated in the Canadian Prairies: Report on Prairie Round Table Discussions" and this thesis, there have been two gatherings of the PARC projects.

2.4.2.3 Educating K-12

Education of school-aged children is an adaptation and mitigative strategy that could have a substantial impact in the long-term. Governments and NGOs have targeted many outreach programs specifically to school-aged children. However, attempts should be made to introduce climate change education more formally into school curricula.

2.4.2.4 Historical Data Analysis

Understanding how individuals and society have adapted to climate variability in the past may uncover some short-term adaptations for the future. Learning from mistakes and triumphs could decrease adaptation costs and the time spent between inventing and implementing adaptation measures.

2.4.3 Barriers

Although many resources, innovations, and ample expertise are available for climate change and human health research, and for adaptation and mitigation strategies, there are barriers that may need to be overcome for their eventual integration into society.

2.4.3.1 Media

The media is important for relaying human health and climate change research findings and adaptation measures to the public. However, the media can distort images, print partial stories, or even miss the entire message. It was noted at each discussion that the interface between science/research and the media should be utilized. However, a sound strategy must be adopted in order to communicate the climate change and human health adaptation message effectively. Consultation with editors was noted as being one potentially effective strategy.

2.4.3.2 Fear mongering

Health is a useful vehicle and a potentially powerful tool to bring climate change issues into the forefront of the public consciousness. But, health also has the potential to scare society. Using fear tactics is a poor way to attempt to change societal behaviour. While it serves to gain the attention of the public, recidivism rates are high. Climate change research on human health must consider both the positive and negative aspects if credibility is to be maintained. Trustful and honest communication that does not instill panic or use fear as the driving force for change is essential.

2.4.3.3 Future climate scenarios

An important aspect of adapting to future health impacts from climate change is to have reliable and credible climate scenarios. However, there are limitations on the ability of large-resolution GCMs to provide precise projections of potential climate futures in the Prairie region. Temperature projections are most reliable; however, precipitation and extreme weather event projections are more uncertain.

2.4.3.4 Human health indicators

Finding and utilizing good human health indicators with which to measure the health effects of climate change may be difficult. For example, asthma may seem to be a good indicator of respiratory health, but people sometimes treat themselves, thus leaving no record for research purposes. In addition, "diagnostic creep" and confusion of asthma with other respiratory ailments may further devalue asthma as a quality indicator of changing respiratory health as it relates to climate change. Another health indicator could be mortality, which involves fewer uncertainties than cause-specific morbidity. Other possible health indicators are infectious diseases. Climate change is likely to affect the distribution and frequency of infectious diseases because in many cases they are connected to biological and ecological systems, which are expected to change through climate change. These diseases could be more likely recorded, have incidence rates that can change over the short- and longer-terms, and will not likely be misdiagnosed or have their definition change.

2.4.3.5 Networking

Networking activities inevitably increase the demand on an individual's time. Most people already have busy schedules. A lack of incentives to justify the extra time to participate in a network makes establishing networks a very difficult task. Therefore, incentives need to be provided to motivate and make participation possible for the various stakeholders and increase interaction across traditional academic disciplinary boundaries. In addition, incentives could be viewed as a mechanism that would help stakeholders to regard climate change and human health issues as part of their agenda. The nature of incentives does not need to be only monetary.

2.5 Recommendations and Conclusions

Health and well-being factor into all aspects of human life. Thus, it is difficult to view human health and climate change research as distinct from all other ongoing climate change research. This research endeavour attempted to incorporate the various perspectives from four main sectors (Government, Industry, Academia, and Public) in order to gain a balanced perspective on the feasibility of human health adaptation research in the face of climate change on the Canadian Prairies.

According to the IPCC (2001)*, climate change appears inevitable and likely to be greater than previously thought. Thus, residents in all regions of Canada must become focused on adapting to future climate scenarios specific to their geographical area or eco-region.

Networking among the four sectors proved to be much more difficult than asking for participation in Round Table Discussions. Only 12 of the original 26 committed participants attended a Round Table Discussion; 5 individuals attended from the open invitation; 3 individuals attended from the FYI copy list; and, 7 responded through e-mail.

A limitation of this report is that certain groups were not represented because of sampling methods and the potential cost associated with a larger search effort. For example, farmers and industries in the agriculture and livestock production business could have been included. Despite these challenges, our research was able to engage in a meaningful exchange of information with what seems to have been a reasonable representation of

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* Intergovernmental Panel on Climate Change, Working Group I. *Third Assessment Report: Climate Change 2001: The Scientific Basis, Summary for Policy Makers.* IPCC [online] 2001 [cited June 2001]. Available at URL: http://www.ipcc.ch

individuals and organizations from each of the four sectors. Certainly, excellent discussions and ideas were generated which are documented in this report.

From the RTDs and e-mailed responses, it was noticed that almost all sectors had similar concerns regarding the priority research questions and topics with respect to human health and climate change. Through analysis of the proceedings it became apparent that several research areas needed better definition before other research topics could be investigated. The first question is one of acquiring an understanding of the possible future climate scenarios in the Prairie region. Second, from the scenarios, health scientists and other related scientists (e.g., ecologists and entomologists) could begin to define the nature of the relationships, linkages, and characteristics between climate change and human health. This could be accomplished by examining historical records where the scenarios have played out in the past, or by using current literature comparing health outcomes from similar scenarios that have occurred in other regions in the world. Third, and finally, the need to address the split between the health sciences and physical sciences communities was noted.

Defining these initial three domains is important for several reasons. First, climate change and health scientists need to have a good understanding of what future climate scenarios are most likely to arise with warmer global temperatures in order to promote the best adaptive strategies with respect to direct human health impacts (e.g., more severe weather events). Second, how the various future climate scenarios could affect human health indirectly (e.g., if vector-borne diseases move northward, or if increased stress-related disease occurs in farmers) is important in planning for future possible disease burdens that current health care strategies may need to incorporate. Finally, networking the various departments and sectors intimately involved in climate change research is fundamental for the advancement of human health and climate change adaptation research.

This report classifies the possible domains in which future climate scenarios could affect human health into seven thematic categories (see Section 2.3 themes numbered 4-10). These themes are: water quality and quantity, economic effects of climate change on the public health system, air quality and other pollutants, adaptation capacity and future challenges, new disease burdens, agriculture and rural health, and risk communication and public outreach. Within each theme, research questions associated with regional and local issues of the stakeholders within each sector were identified. Although research questions within each of the themes were identified by the participants, these are not necessarily exhaustive. The hope is for additional research that will build on the insights provided here. During the RTDs, many innovative suggestions were put forward because participants were able to generate new ideas based on interactive discussion.

Finally, participants recognized the need to overcome potential barriers to climate change and human health research. Barriers also were noted concerning adaptation and associated mitigation strategies (see Section 2.4: General Discussion and Emerging Issues, for a more detailed description of innovations, adaptation and mitigation, and barriers). They also need to be overcome.

2.5.1 Recommendations

As a result of the networking endeavour and the information collected from the RTDs, five recommendations emerge:

1. Climate change and human health research needs to be based on solid principles. Therefore, it is recommended that the initial three thematic areas (future climate scenarios, linking future climate scenarios with human health, and the partnering between the physical sciences and health sciences) be defined more adequately.

This research endeavour has attempted to identify the various individuals and organizations that could be directly or indirectly affected by climate change. Therefore, partnering between the physical sciences and health sciences has begun in the Prairie region. However, future proposed research should include a coordinator capable of devoting time to facilitating networking and the ongoing dissemination of results to stakeholders for feedback and re-incorporation into the research process. In this regard incentives are needed for academics, institutions, and stakeholders to interact across traditional disciplinary boundaries, to encourage inter-disciplinary and also transdisciplinary research, and make climate change and human health issues a part of their agenda. Solutions to systemic problems are not going to be found through exclusive adherence to the reductionist paradigm.

Meaningful climate change and human health research needs to be based on sound climate scenarios and plausible human health outcomes. There is a real need to couple global and regional models, and for climate scientists to: 1) provide usable, appropriately-scaled climate projections to climate impacts and adaptation researchers; and 2) suggest the "best" scenarios to end users who rarely have the needed background to distinguish between models in terms of accuracy, robustness, and reliability. Thus, increased interaction with climate modelers and end users is necessary. In this regard, the nature of the relationship between future climate scenarios and human health could then be defined more adequately, and more specific research questions could be investigated. For example, with an increase in surface temperatures of 3°C, what vector-borne diseases should the Prairie region need to plan for? Once these linkages are understood, more effective and efficient human health research should be piggybacked onto the physical science research of climate change wherever possible.

Uncovering the link between future climate scenarios and human health could be accomplished by examining historical records where the scenarios have played out in the past, or by using current literature that compares health outcomes from similar scenarios that have occurred in other regions in the world. Historical climate variations or extremes (e.g., drought, heatwaves, extreme weather events, or flooding) have been recorded and, where possible, these scenarios could be linked to health databases during the same time period. Outcome variables then could be used for surveillance and monitoring of health conditions, in addition to providing a framework for the allocation of health care resources in the future.

2. Mitigation is an important component of, and often not easily separated from, adaptation. A good example of this in terms of human health is emissions reductions. They are an important element of adaptation to climate change (e.g., smog), but also play a

role in long-term mitigation (e.g., GHGs promote long-term climate change). Thus, adaptation is necessary for the short-, medium-, and long-term, but it should include mitigation measures whenever possible to lessen the need for adaptation in the future (medium- and longer-term outlooks). This may be especially important to convey with respect to outreach, educational opportunities, and media relations.

We recommend that both adaptation and mitigation be incorporated into educational efforts, whether it is the education of the general public, or the promotion of climate change in the K-12 program agendas. Education that is targeted, standardized and consistent with best available knowledge, based on the most current information, would be optimal. For the general public, a science communication strategy on climate change adaptation and mitigation options should be developed, and delivered. Periodic evaluation and revision would be essential in the face of ever-changing information and realities.

3. We recommend that a workshop should be organized that presents all PARC research projects. This would provide an opportunity to learn from other research projects, collaborate with research teams, and share the knowledge and experiences of conducting climate change research. A workshop would allow for the networking of expertise in areas that are crucial to human health and climate change research (e.g., scenario development and prediction). For example, in October 2001 a workshop for PARC research teams was held in Calgary, Alberta.

The gathering of research agendas would allow for the possibility of linking human health research or data collection with other climate change research projects for little additional cost. For example, questionnaires regarding the economic impact of climate change on farming practices may effectively introduce several health-related questions. In addition, innovations developed by other research projects could be made known to human health researchers, and be effectively implemented in the human health research agenda (e.g., GIS, air mass classification, spatial statistics, small area analysis).

4. Possibly through C-CIARN, a national forum for health and the environment, centering on adaptation to climate change and related issues, should be organized. This would provide the opportunity to merge the health and physical science fields nationally. Again, a forum of this type would identify new resources and innovations to make human health and climate change research more efficient. Networking and collaboration of expertise in the various fields would be facilitated.

In addition, better awareness, integration, and partnership of existing resources and agencies is needed to prevent duplication. This is because organizations often are not fully aware of other agencies and the resources they can provide.*

5. A strategy by which research findings, adaptations, and possible mitigation strategies should be disseminated to the public should be developed by PARC for use by all of the research teams funded under PARC. In other words, the need exists for media advocacy, or the conscious use of the media to move the climate change agenda forward. Health is a powerful tool that brings the global phenomenon of climate change into focus for the individual.

2.5.2 Conclusions

Round Table Discussions were effective in achieving their three objectives. However, only 27 individuals and organizations contributed to the attainment of the objectives. Other methods such as media advertisements could have increased the number of participants. However, this would have substantially increased the cost with no guarantee that it would increase the representativeness of the sample. In addition, our initial sample design was targeted towards certain organizations and institutions with expertise and experience in climate change and/or human health. It was therefore not our intention to provide an information session for climate change and human health, but rather meaningful idea generation and capacity building.

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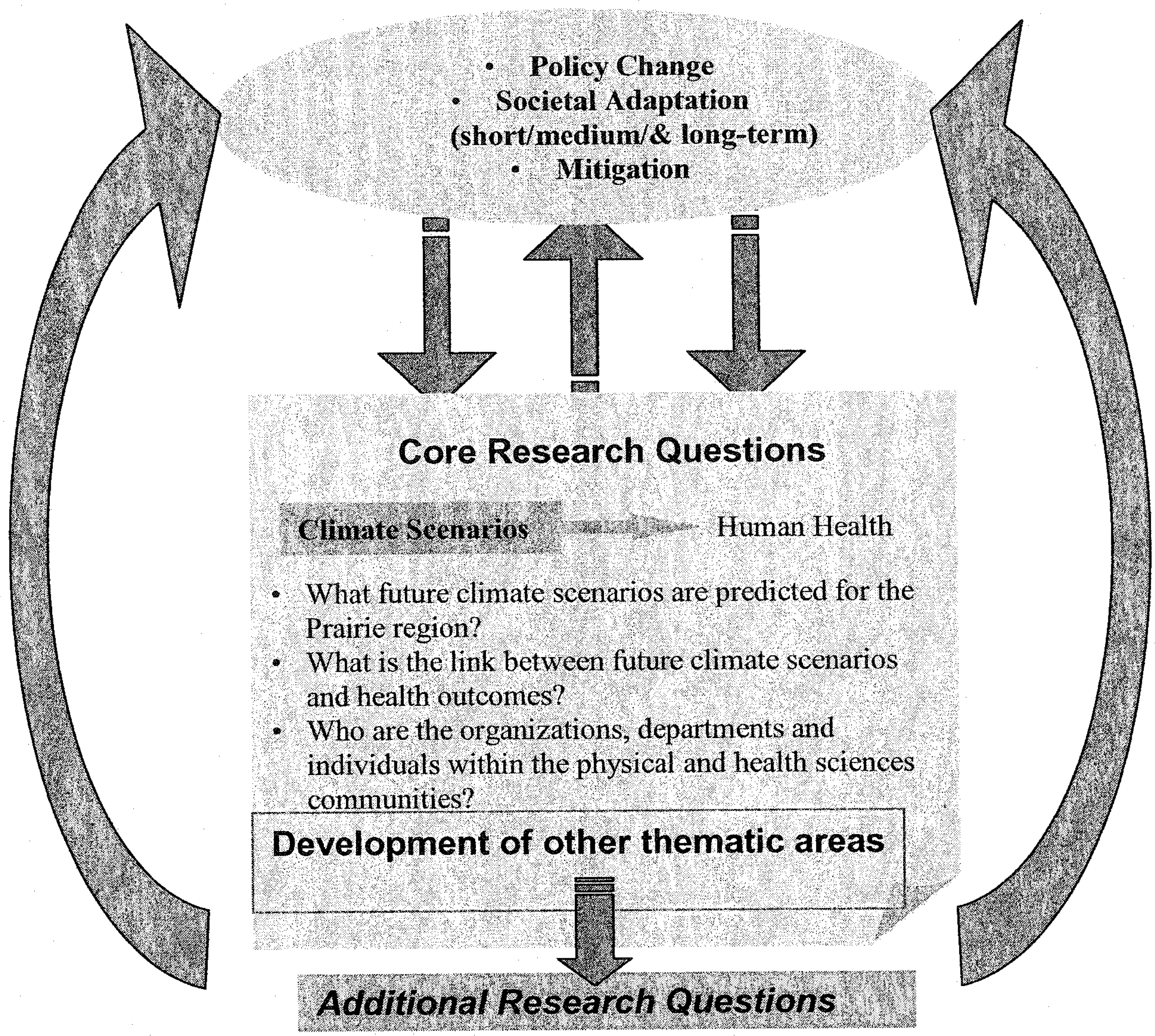
* Since producing the document: "A Feasibility Assessment to Study Societal Adaptation and Human Health Impacts under Various Future Climate Scenarios Anticipated in the Canadian Prairies: Report on Prairie Round Table Discussions" and this thesis, this work has been initiated by Health Canada's Climate Change and Health Office and is well under way.

Results indicate that there is a need for greater collaboration between physical sciences and health sciences, a need to have a better understanding of the future climate scenarios and how these scenarios could affect the health of human populations on the Canadian Prairies. In addition, water quality and quantity, economic effects of climate change on public health, air quality and other pollutants, adaptation capacity and future challenges, new disease burdens, agriculture and rural health, and risk communication and public outreach were of high priority to Prairie stakeholders.

Several innovations, and adaptation and mitigation opportunities/strategies were identified that could benefit and further future climate change and human health research. Some of these include: piggybacking a research question on an already funded research question for only a marginal incremental cost; the SEV/SEA project currently being completed at the University of Winnipeg; on-going climate/air quality/health research with the Climate and Health Research Program at the University of Alberta; Environment Canada being motivated to understand how climate change may affect the frequency of severe weather events; and, a need to focus on K-12 education. However, barriers must also be overcome or at least be considered when initiating human health and climate change adaptation research. Barriers include: media distortion of climate change and human health issues; fear mongering as a driver of societal adaptation; limitations of GCM modeling; selection of appropriate human health indicators; and, the difficult task of networking.
Final recommendations were based on the results of the RTD results and the conclusions drawn from the general discussion and emerging issues. Final recommendations include: a clearer definition of the three primary research themes; consideration of a mitigation commitment with adaptation; the need for PARC research teams to present research projects for one another to generate resource sharing, networking, and collaboration; the suggestion that C-CIARN organize a research forum between the health and physical sciences communities; and the need to develop a media advocacy strategy by PARC.

Appendix A

How the three core areas of priority research could provide answers to climate change and human health research questions.



Appendix B

Resources, Dissemination of Findings, and Outreach Opportunities

Each sector and departments within each sector have their own networks, linkages, public outreach, employee in-reach strategies, educational programs, and funding sources for climate change research. As discussed in this report, it is important to share information and program development or innovation so that research dollars and energy is used optimally. Below is a list of some of the resources available to Prairie-based climate change researchers. It should be noted that only items for which specific contact information could be provided have been included below; other resources are known to be available. Therefore, the reader should treat this Appendix simply as a starting point. More effort than available under the current PARC grant would be needed to provide a more complete listing.

National:

1. Environment Canada (EC). Environment Canada has considerable expertise in meteorology, climatology, hydrology, and GIS applications. They also maintain climate databases (hydrometric, temperature, water quality databases (limited), and precipitation) and the weather network.
Climate and weather:
Jim Ross, Head, Climate Archives Section, Environment Canada, Edmonton, AB.
ph (780) 951-8875, fax (780) 495-3529, email jim.ross@ec.gc.ca
Water quantity:
Merle Moore, Applications Coordinator, Water Survey of Canada, Prince Albert, SK.
ph (306) 306-953-8574, fax (306) 953-8542, email merle.moore@ec.gc.ca
Water quality:
Bing Chu, QA/QC Coordinator, Water Survey of Canada, Regina, SK.
ph (306)780-5333, fax (306) 780-5311, email bing.chu@ec.gc.ca
http://www.ec.gc.ca/envhome.html or http://www.ec.gc.ca/climate/index.html.

2. Climate Change Action Fund (CCAF). There are four components to CCAF. Individuals or organizations interested in submitting proposals for funding under the CCAF should contact the appropriate CCAF component directly.
http://www.climatechange.gc.ca/english/actions/action_fund/index.shtml

3. Transport Canada (TC). TC is well-aware of its role in global climate change issues and takes a very proactive approach to the mitigation of climate change. TC provides funding support through their Moving On Sustainable Transport (MOST) program.
http://www.tc.gc.ca/envaffairs/MOST/Main_e.htm.

4. A useful international site, which is the United Nations Framework Convention on Climate Change http://www.unfccc.int/. This link provides information on the Kyoto Protocol.

Provincial or Regional

1. Alberta Heritage Foundation for Medical Research (AHFMR). Each year AHFMR awards over $40 million in grants and awards in five program areas. http://www.ahfmr.ab.ca/frames1.html

2. Alberta Agriculture, Food, and Rural Development. This website features pests and diseases that affect agriculture, and ranching operations which include vertebrate pests, plant diseases and insects and livestock diseases, among others. Through *Land, Water and Climate* link there is a variety of links including environmentally sustainable agriculture, and climate and air quality.
http://www.agric.gov.ab.ca/

3. Alberta Environment and the Bureau of Climate Change. These two websites offer an overview of the Government of Alberta's rationale for their involvement in climate change issues, the challenges of emissions reductions in Alberta, and involvement in initiatives mitigating or adapting to climate change. Mitigation and adaptation includes: alternative energy, education and outreach, and effective action in agriculture, among others. http://www.gov.ab.ca/env/climate/index.html and http://www.gov.ab.ca/env/

4. Alberta Environment. Alberta Environment offers formal education programs targeted to K-12, pre-service and in-service teachers, in addition to environmental education and educational resources on climate change. Some materials are to be used in a classroom setting and other resources are available to the general public. http://www.gov.ab.ca/env/resedu/edu/ee_res.html

5. Alberta Lung Association (ALA). Their mandate is to raise funds to support respiratory research, community health education programs and professional education in Alberta and NWT. The ALA's greatest strength is communication with the public. In addition, they have an extensive network with other lung associations and have excellent public education outreach programs. http://www.ab.lung.ca or Canadian Lung Association: http://www.lung.ca and in French: http://www.lung.ca/fr/

6. Clean Air Strategic Alliance (CASA). CASA is a not-for-profit partnership, its memberships include representatives from government, industry and non-government organizations. CASA has been actively involved in climate change issues and has initiated a multi-stakeholder Climate Change Project Team in November, 1998. http://www.casahome.org/

7. City of Regina. The City of Regina has a climate change education program called 'Cool Down the City' which revolves around special events. In addition, the city has a 'Green Ribbon Community Climate Change Advisory Committee' that focuses on a strategy that will move Regina closer to their GHG emission reduction targets. http://www.cityregina.com/content/info_services/environmental/climate.shtml

8. Climate Change Central. Climate Change Central is a private-public partnership between Alberta businesses, governments and the environmental community. It offers climate change partnership opportunities, intelligence, and funding.
http://www.climatechangecentral.com/

9. Community Animation Program (CAP). CAP is a joint initiative of Health Canada and Environment Canada that involves the Prairie and Northern Region. Its focus is to contribute to the sustainability and health of Canadian communities.
http://www.mb.ec.gc.ca/community/ecoaction/cap/ba02s00.en.html

10. Dr. Colin L. Soskolne. Dr. Soskolne is from the University of Alberta, Department of Public Health Sciences, Epidemiology Program. Dr. Soskolne has interest in the implications for public health from a decline in ecological integrity from several different standpoints. Dr. Soskolne was instrumental in producing the "Discussion Document" on Ecological Integrity and Human Health, for the World Health Organization in 1999 accessible at: http://www.euro.who.int/document/gch/ecorep5.pdf A summary of this document is at: http://www.elements.nb.ca/theme/health/colin/who.htm
Dr. Soskolne's home page is at: http://www.phs.ualberta.ca/staff/soskolne/

11. Dr. Ed Cloutis, University of Winnipeg, Department of Geography. His areas of interest include remote sensing, Geographic Information Systems (GIS), planetology, and spectroscopy. Currently Dr. Cloutis is working on the SEV/SEA (Socio-Economic Vulnerability or Socio-Economic Adaptability) impacts of climate change on Prairie Communities at the Regional Municipality level, which is funded by PARC. The project has also generated a network of approximately 160 contacts, which have provided advice and/or guidance with climate change research.
http://www.uwinnipeg.ca/~geograph/faculty.html

12. Dr. Karen Smoyer Tomic. University of Alberta. Dr. Smoyer Tomic has been researching the relationships among climate, air quality, human health, and socio-economic factors in Canada and the U.S. since 1989. In addition to her research into the health impacts of and potential for adaptation to climate change, she is active in the Science/Policy/Media interface, which focuses on how science can effectively communicate with the public through the media. She also is involved in various list serves and has expertise in air mass-based weather classification methods, multivariate and spatial statistical modeling (including small areas/populations), and the use of large weather, air quality, health, and census datasets.
http://www.ualberta.ca/~eas/People/profs/smoyer.htm
Climate and Health Research Program (CHRP) webpage
http://www.ualberta.ca/~ksmoyer/chrp/home.htm
Situating Place in Health Research (SPHR) webpage
http://www.ualberta.ca/~ksmoyer/webpage/home.htm

13. ECOMatters. ECOMatters is an environmental consulting company that specializes in detailed understanding of basic processes in terrestrial and aquatic environments. An ongoing project is addressing the concern of manure management and the possible impacts of the phosphorus in the manure on streams and rivers.
www.ecomatters.com/

14. Innovation and Science Research Investments Program (ISRIP). This is a competitive funding program offered by the Government of Alberta in the amount of $30 million. Three distinct funding streams will allocate money that will support selected science and research initiatives of strategic importance to Alberta.
http://www.gov.ab.ca/is/research-grant/

15. Institute of Health Economics (IHE). The IHE is an independent, not-for-profit organization that delivers health economics, health outcomes and health policy research and related services.
http://www.ihe.ab.ca/index.htm

16. Manitoba Conservation (Energy) Program Division: Climate Change Branch. There is funding information (through MCCAF) and published material on climate change. In addition, there are free energy efficiency workshops for new homebuilders and current homeowners.
http://www.gov.mb.ca/natres/energy/index.html

17. Manitoba Climate Change Action Fund (MCCAF). Priority areas for funding include education and outreach, impacts and adaptation, technical innovation and energy efficiency. http://www.gov.mb.ca/natres/energy/mccaf/mccaf-brochure.html

18. Prairie Adaptation Research Collaborative (PARC). http://www.parc.ca

19. RL&L Environmental Services Ltd. RL & L is a professional consulting firm specializing in aquatic biology and research on large rivers and in remote environments. They offer comprehensive project services in the fields of water quality analysis, environmental engineering and hydrology, and reclamation planning.
http://www.rll.ca

20. Saskatchewan Research Council (SRC). A branch of the SRC focuses on the assessment of climatic hazards and the development of strategies that reduce the negative impacts from climatic variability and allow for benefit from the positive impacts.
http://www.src.sk.ca/climatology.html

21. Solar Energy Society of Canada Inc (SESCI). SESCI promotes the increased use of solar and other renewable energies in Canada. To promote these goals SESCI has developed programs in three broad areas: education, technical development, and public policy. SESCI also has a network of approximately 600 members.
www.solarenergysociety.ca

22. Syncrude Ltd. ABCs of Climate Change. Syncrude Ltd. invests in employee education, training, and on-the-job development. Every fifth employee has attended a workshop explaining the relationship between climate change and GHG emissions and energy use. Syncrude Ltd. also has participated in the *ABC Program: Action by Canadians on Climate Change.* The ABCs include seminars, personal action exercises and tools that provide climate change information to help staff of Canadian organizations reduce greenhouse gas emissions.
http://www.syncrude.com/enviro/action_plan00/education.html

23. Toma & Bouma Management Consultants. Toma & Bouma are Western Canada's leading management consulting practice, specializing the food and agricultural industry. www.tomaandbouma.com

Appendix C

List of participants and their affiliation within the four sectors.

The following organizations and/or departments participated directly and/or by e-mail and are acknowledged for their significant contribution to the content of this report.

Government:	
Transport Canada	Mr. Tim Johnson (Edmonton)
	Mr. Bill Ferguson (Winnipeg)
Environment Canada	Mr. Ross Herrington (Regina)
Manitoba Transport	Mr. Terry Zdan (Winnipeg)
Alberta Environment	Dr. Raymond Wong (Edmonton)
	Mr. Goldie Edworthy (Edmonton)
	Ms. Beverly Yee (Edmonton)
Alberta Health and Wellness	Mr. Alex MacKenzie (Edmonton)
	Ms. Margaret King (Edmonton)
Alberta Agriculture, Food and Rural Development	Ms. Jilene Sauvé (Edmonton)
	Dr. Shane Chetner (Edmonton)
Saskatchewan Resource Council	Ms. Virginia Wittrock (Saskatoon)
City of Regina	Ms. Kim Sare (Regina)
Industry:	
RL & L Environmental Services Ltd.	Dr. Rob Anderson (Edmonton)
Toma and Bouma Management Consultants	Mr. Darrell Toma (Edmonton)
Atmospheric Service and Management Associates	Dr. Harby Sandhu (Edmonton)
Syncrude Canada Ltd.	Mr. Kees Versfeld (Fort McMurray)
ECOMatters Inc.	Dr. Marsha Sheppard (Pinawa)
Academic:	
University of Winnipeg	Dr. Ed Cloutis (Winnipeg)
	Ms. Jillian Golby (Winnipeg)
	Mr. Grant Wiseman (Winnipeg)
University of Alberta	Dr. Karen Smoyer Tomic (Edmonton)
	Dr. Colin Soskolne (Edmonton)
	Ms. Justine Klaver (Edmonton)
University of Regina	Dr. Dave Gauthier (Regina)
Public:	
Alberta Lung Association	Dr. Mary Carson (Edmonton)
PARC	Dr. Dave Sauchyn (Regina)
Solar Energy Society	Mr. Terry White (Regina)

Chapter 3

Prairie-Focused Literature Review and Integrated Assessment Framework

3.1 Introduction

The four objectives of the PARC research proposal were outlined at the beginning of Chapter Two. Chapter Two concentrated on the first three objectives, whereas the focus of this chapter will be the fourth. The fourth objective is based on a paper written by Chan et al., (1999) which proposes an integrated assessment framework (IAF) for climate change and vector-borne diseases. Within the context of the proposed framework, Chan et al. (1999), review the published literature uncovering what is currently understood with respect to the various linkages that connect a changing climate to vector-borne disease, as well as identifying the knowledge gaps in the literature.

This chapter is divided into four sections and combines IAF with a critical review of the literature. First, the background section will set the stage for the relevance of IAF within the context of a literature review, and will subdivide the Prairie climate change problem into climate change scenarios predicted under atmospheric conditions. The second section outlines the general search strategy and inclusion/exclusion criteria for peer-reviewed research articles. The third section is divided into four subsections, each corresponding to a Prairie climate change scenario. Each subsection will initially provide an overview of the human health issues associated with each climate change scenario, proceeding with the depiction of an IAF (with exception of changing ecosystems), and review of the peer-reviewed literature as it pertains to the IAF. The concluding section will provide recommendations for and insights into future research hypotheses.

3.2 Background

Several review articles detail the health effects associated with climate change by dividing the indirect consequences (as opposed to direct, like heat) by disease outcome (Duncan et al., 1999; Martens, 1999; Patz et al., 2000). However, another way to partition the health consequences (direct and indirect) of climate change is to understand them according to climate change scenarios. In this way, it becomes less complicated for policy and the general public to adapt to the current weather or climatic conditions, rather than trying to identify how a certain health consequence may be linked to any number of climate or weather phenomena.

The four climate change scenarios most likely to occur in Canada, and in the Prairie region, are drought (Herrington et al., 1997; Beaudoin, 1999), increased heat (Etkin, 1999; Hengeveld, 2000), extreme hydrological events (Etkin, 1999; Francis and Hengeveld, 1998), and changing ecological systems (Duncan et al., 1999; Herrington et al., 1997). These scenarios can be linked to a number of direct and indirect human health consequences. Within each scenario, an IAF can be proposed to integrate current knowledge from the various disciplines and to aid in the development of an IA for each scenario with respect to human health.

Thus an initial task of IAF is to design a framework or model, outlining the key plausible links and interactions with respect to the biological, physical, and social modules of each climate change scenario and human health. The next step is to assess current knowledge regarding each module and its links to other modules by employing peer-reviewed literature search techniques. A future endeavour would be to quantify the linkages in order for comparison of various outcomes, based on risks and input of biological, physical, and/or social responses into the system (Aron et al., 2001).

Because there is a vast amount of literature available in each area, it is beyond the scope of this chapter to cover all dimensions of climate change and, thus, it will only investigate the possible climate change scenarios relevant to the Canadian Prairie region. However, within each scenario all relevant published literature (global to regional) will initially be considered for its applicability to the Canadian Prairie climate change situation.

3.3 Search Strategy

Based on the information gleaned from review articles and expertise from the Round Table Discussions (RTDs) detailed in Chapter One, an IAF for each climate change scenario (with exception to changing ecosystems) was proposed with ecologic, sociologic, health, and adaptation modules. All IAFs are specific to the Canadian Prairies Provinces.

Using a planned search strategy devised with the aid of a qualified librarian, an extensive search of the published literature, in the English language, was conducted separately for each scenario. The "grey literature" has not been included in this review.

Within each scenario aspects of each module were used in a keyword search of four literature databases: a) EMBASE; b) MEDLINE; c) PubMed; and d) Web of Science. The main inclusion criteria were that all papers must have an ecological module or climate change component, and a health, sociological, or adaptation component. The main purpose of the criteria was to emphasize the linkages between climate and one or more human component. In addition, papers that linked ecologic change with a sociologic model (e.g., political, economic, vulnerable populations) vastly different from that of Canada (e.g., developing nations) were not included.

Some areas covered in this review have been well researched (e.g., air quality and respiratory effects), and do not need to be reviewed again. Therefore, additional restrictions were placed on these subtopics. On the other hand, some topics are associated with very little original research and often only descriptive or positional papers are available. These were included at the discretion of the author. The inclusion and exclusion criteria for each scenario literature search are provided within each scenario subsection. The primary objective of this chapter is to describe current knowledge of climate change and human health as it pertains to Prairie climate scenarios, identify the gaps in knowledge, and explore directions for future research in the Canadian Prairie Provinces.

3.4 Prairie Climate Change Scenarios: IAF

Three of the stated four climate scenarios (drought, heat, and extreme hydrological events) were subjected to in-depth investigation of the literature with respect to IAF. The last scenario (changing eco-systems and vector-borne disease) was only reviewed.

3.4.1 Drought

Perez and Thompson (1996:71) defined drought as "any lack of water for the normal needs of agriculture, livestock, industry, or human population". Drought is expected to be one of the most significant markers of climate change on the Canadian Prairies (Herrington et al., 1997).

3.4.1.1 Farming and Mental Health

Farming is one of the most stressful occupations in society (Robertson, 1980), and drought conditions will only exacerbate the problem. Droughts have caused substantial decreases in crop yields and large export losses of agricultural products, leading to an increased need by farmers and cattle producers for assistance and crop insurance payouts. In the Prairie region, drought has the potential to decrease the average crop yield by 10-30% and move agriculture northward (Herrington et al., 1997). While large corporate agricultural enterprises have greater resources to buffer themselves against agricultural losses associated with drought-like conditions, family farmers do not, and a changing climate thus will have a disproportionately higher impact on family farmers and ranchers (NAST, 2000).

Current agricultural policy favours high-yield, monoculture crops, which makes farmers more vulnerable to crop disease and place them at higher risk of economic hardship (Wilhite and Smith, 1996). Risks associated with decreased yields are held personally, and many families rely on off-farm incomes to make ends meet (Wilhite and Smith, 1996).

Several studies have documented the quality of life of farmers and defined what aspects of farming lifestyles tend to increase personal stress and distress levels. Most of the literature concludes that financial concerns are highly associated with the stress felt by farmers

(Olson and Schellenberg, 1986; Walker et al., 1986; Geller et al., 1988; May, 1990; Ehlers et al., 1993; Deary et al., 1997; Simkin et al., 1998; Booth and Lloyd, 1999). Although financial concerns—stemming mainly from government policy/bureaucracy, market prices, and farm expenses coupled with unpredictable incomes—are a major source of increased stress in farmers, weather is also a source of stress (Deary et al., 1997; Walker et al., 1986). It was also found that farmers in Manitoba had self-reported significantly higher stress symptoms than non-farmers (Walker and Walker, 1988). Another study also found that farmers had more depression and anxiety than controls (non-agricultural workers), but the results were inconclusive (Eisner et al., 1998).

Stress contributes to the appearance of many health problems. In a study in rural populations in southern Saskatchewan, Masley et al. (2000) found stress to be one of the most commonly reported health problems among men aged 18-55 years. Some international studies have documented that farmers had higher suicide rates than the general population (Stallones, 1990; Malmberg et al., 1997). In contrast, within Canada the suicide rates among farmers are lower than Provincial rates (Pickett et al., 1993; Pickett et al., 1999).

Suicide in farm owners, managers and tenants is highly correlated to depression in the year before death, which in turn is correlated to financial pressures (Malmberg et al., 1997). With this in mind it becomes apparent that suicide could possibly increase under the condition of climatic change (drought, uncontrollable weather), where farmers are dealing with decreased yields, greater financial pressures, and stress. However, Pickett et al. (1993) failed to find support for the hypothesis that recession years were accompanied by overall higher suicide rates.

Stress in agricultural occupations not only affects the farmers that experience financial difficulties, it cascades into family life (Plunkett et al., 1999). Farmwives also experience a great deal of stress (Walker and Walker, 1988; Deary et al., 1997). However, the stress felt by women encompasses not only the financial difficulties of farm life, but also interpersonal relations, conflicts, and family concerns (Walker et al., 1986). Adolescents were also found to perceive greater family stress in times of farm economic crisis (Plunkett et al., 1999).

3.4.1.2 Dust and Respiratory Health

Dust generation is very sensitive to climatic processes. Drought conditions and dry periods have been associated with peak intensity of global dust and haze patterns (Prospero, 1999). The Prairie Provinces are often dry and windy; when combined with large-scale agricultural practices, atmospheric dusts result. On the most extreme scale, dust storms can cause significant economic and environmental damage, wiping out buildings, destroying vegetation, decreasing the viability of soils, and causing injuries from debris or traffic fatalities (Wheaton, 1998).

Studies in the United States noted short-term health effects from dust storms include minimal increases in morbidity (Hefflin et al., 1994) and yet no increase in mortality (Schwartz et al., 1999). However, Kwaasi et al. (1998) noted that during sandstorms in Saudi Arabia there were 100% and 40% higher agar plate counts for bacteria and fungi, than non-sandstorm dust. In addition, IgE reactivity for sandstorm dust in humans was demonstrated in both normal and atopic individuals (Kwaasi et al., 1998).

Particulate matter is anything that can be filtered from the air and can be added to our atmosphere from both natural and man-made sources (Last et al., 1998; Duncan et al., 1999). Particulate matter derived from soils is comprised of organic and inorganic components and its composition is a function of the crops and vegetation in the area (Green et al., 1990).

Most land use on the Canadian Prairies is devoted to agriculture and ranching operations, with approximately 70% of the land under cultivation (Environment Canada, 1991). Farming activities constitute the source for the majority of aerosolized particulate matter in south-central farming regions of Alberta (Green et al., 1990). Relative humidity has also been inversely correlated with particulate matter during periods of high temperature in the summer (Haller et al., 1999). Therefore during drought conditions soil moisture will decrease in the Prairie region, giving rise to increased concentrations of particulate matter in the air.

Within Alberta farming communities, Green et al. (1990) found that there was bimodal peaking of total suspended particulates (TSP) that coincided with spring and fall maximal farming activities. The mean respirable mass fraction in districts that were either predominantly forage-crop or cereal grains was 76% and 62% respectively. Particles that are respirable are dangerous because they can reach the terminal end of the bronchioles, causing airway inflammation, and can eventually manifest into respiratory illnesses such as rhinitis, bronchitis, and asthma (Lang, 1996). The major component of the dust within Alberta farming communities was mineral (e.g., silicates), but depending on the type of crop grown, organic material was also found to be present (Green et al., 1990). Inhalation of silicates can increase the risk of silicosis (Silicosis and Silicate Disease Committee, 1988).

The major constituents of organic dust include moulds, pollen, plant material, animal derived particles, bacteria, fungi, mites, insect fragments, and dusts generated in barns, silos, and grain elevators (do Pico, 1992; Lang, 1996). The biological activity of organic dusts in the atmosphere depends on the type and concentration of the dust (mainly owing to the industry type), in addition to the regional weather conditions, product source, state of decomposition, and temperature (do Pico, 1992). In addition, feed additives and pesticide particulate matter, also found within agricultural generated dust (do Pico, 1992; Lang, 1996), may exacerbate existing health problems or create new ones.

In general, the major health effect from inhaling particulate matter is airway inflammation, which can manifest (acute or chronic forms) as asthma, allergic rhinitis, bronchitis, hypersensitivity pneumonitis (Rylander, 1986; do Pico, 1986; Lang, 1996; Simpson et al., 1998), and organic dust toxic syndrome (Rylander, 1986; do Pico, 1992; Simpson et al., 1998). These respiratory diseases often begin as acute attacks of respiratory distress and with continued exposure to a particular dust, the disease may become a chronic condition. Over time, these lung conditions can lead to irreversible lung damage (Rylander, 1986).

Although, windblown dust may be most noticeable in rural communities, urban populations may also experience added atmospheric dust of rural origin (Haller et al., 1999).

3.4.1.3 Fires and Respiratory Health

Drought in the Prairie region is also expected to increase the number of forest fires in the Prairie Provinces. Using GCMs to project forest fire danger levels in Canada under a 2 × CO_2 scenario, there will be an increase in area under extreme fire danger, a lengthening of the fire season, and more frequent and severe fires (Natural Resources Canada (NRCan), 2000). The seasonal severity rating (SSR) in a doubled CO_2 atmosphere would place the southern Prairie region at a score of 6-7, and the more northern Prairie region at a score of 3-5 (according to the SSR scale, a score of 7 is most severe, and 0 is the lowest severity) (NRCan, 2000).

The direct consequences of wildfires (e.g., evacuation and loss of property/lives) will inevitably cause more discomfort and need for social assistance, plus raising insurance costs. The indirect health consequence of fire is smoke haze and smoke inhalation. Wildfire smoke has a composition mainly resulting from combustion of natural products and biomass (Liu et al., 1992; Aditama, 2000). Emmanuel (2000) found that electron microscope scanning of haze particles showed that 94% of the particles were below 2.5 μm in diameter ($PM_{2.5}$). This is important because at this size they are inhalable and can aggravate the respiratory tract. The severity of human exposure to wildfire smoke depends on the proximity of the fire, time span of the burning, and prevailing wind conditions (Aditama, 2000).

Two studies in Asia concluded that the haze experienced in 1997 in Singapore caused significant levels of respiratory ill health in the general population and an increase in accidents and emergency room attendance (Aditama, 2000; Emmanuel, 2000). Some of the haze related conditions included conjunctivitis, acute upper respiratory tract infection, allergic rhinitis, acute bronchitis, asthma, eczema, exacerbations of chronic obstructive pulmonary disease (COPD) and ischaemic heart disease, pneumonia, or emphysema (Emmanuel, 2000).

In California during a 1987 forest fire, significantly more patients were treated for asthma in the emergency department (in the counties most affected by smoke or fires) than would have been expected (Duclos et al., 1990). Although, individuals with pre-existing asthma and COPD were found to be susceptible to the effects of the wildfire smoke exposure, the overall short-term public health impacts from the exposure were deemed moderate (Duclos et al., 1990).

With respect to the seasonal burning of agricultural residues one study found an association between a smoke haze episode and respiratory ill-health in a susceptible population Long et al., (1998). Another study found that self reports of asthma to be higher in Spokane than the national average (Roberts and Corkill, 1998). Spokane experienced long-term periodic exposure to agricultural residue smoke.

It is noted that an analysis of the frequency and severity of fires on the Prairies is beyond the scope of this thesis. Anecdotally, however, the frequency of fires has increased over the past two years with the severe drought in this region.

3.4.2 Drought Integrated Assessment Framework

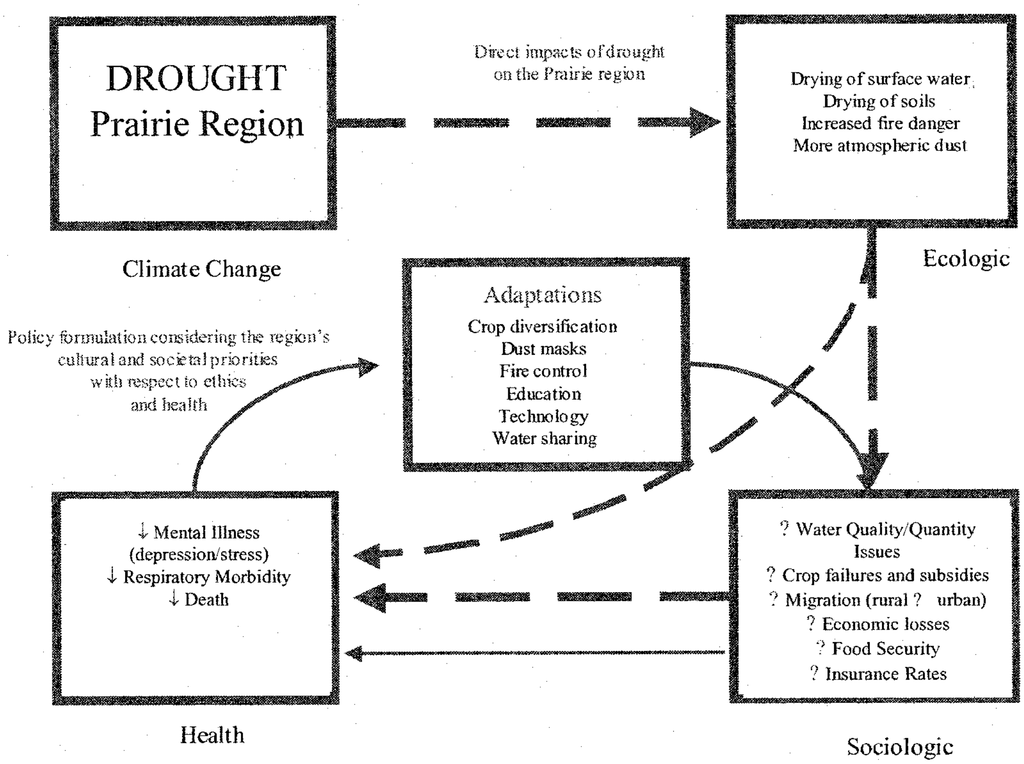
Figure 3.4.1.1 depicts the proposed IAF of the ecologic, sociologic, health and adaptation modules associated with drought. It identifies the key plausible links (direct and indirect) between a climate scenario predicting drought and the possible health impacts. As well it takes into account feedback loops that involve adaptation, providing insight to policy makers about how to adapt to increased pressure associated with drought.

Some factors within the IAF may play larger and more important roles in the determination of health outcomes, and some adaptations may be more costly and infrastructurally intensive to implement than others. In addition, health impacts from drought-like conditions are likely to affect certain populations and aspects of Prairie society differently.

For example, farmers and rural populations that are agriculturally dependent may be the hardest hit overall. However, if substantial decreases in water quantity occur, urban populations can also be greatly impacted.

Although the IAF are divided by scenario, it is important to point out that several scenarios could work synergistically and compound the health impacts from any one scenario. Other considerations are the role of climate variability and possible weather 'surprises' that are expected to become more frequent and variable with climatic change.

Figure 3.4.2. Integrated assessment framework of the direct and indirect pathways drought can impact the health of Prairie residents



Blue depicts the direct and indirect pathways, and red exemplifies how adaptations could lessen any negative impacts.

3.4.3 Drought: Review of Current Knowledge and Knowledge Gaps

Among the excluded literature were those that were indoor, occupational in nature (e.g., confined swine buildings), as well as those studies that investigate respiratory health outcomes associated with specific farm-related exposures (e.g., wheat, hay, moulds, pesticides). These types of studies were only included if they had an ecological component consistent with what is predicted to occur under conditions of climate change in Prairie region.

Table 3.4.3 depicts the IAF associated peer-reviewed literature and their links to the various modules, and it also provides details on the study designs and the statistical analyses. The table is broken into four aggregations of studies according to logical breaks in the literature for better comparison. In general, there were very few research articles originating in the Canadian Prairie region. The majority of studies were conducted in the United States or the global arena. Research studies were dated as far back as 1978.

Because the included research is not specifically about drought *per se*, but rather can encompass other ecological conditions or terminology, the ecological change module was further subdivided into: dust and/or soil dryness; water quantity; uncontrolled natural disaster; air quality issues; wild fire; and other (e.g., sandstorms). Depending on the section of the table, one or more ecologic changes were dominant.

3.4.3.1 Dust

Eight studies investigated the health outcomes associated with dust and/or soil dryness, and only one specifically investigated drought. Respiratory illness was a theme in five studies, death in one study, two studies investigated morbidity other than respiratory illness (i.e., coccidioidomycosis), and one study included in the 'other' category looked at health outcomes associated with windblown dust such as aeroallergens.

Seven studies were original research linking dust and health outcomes. However, only one originated in the Prairie region. Gomez et al. (1992) investigated the potential adverse respiratory health effects from blowing alkali salt and dust in residents living near the desiccated Old Wives Lake in Saskatchewan. The study concluded that cough, wheeze, nasal and eye irritation symptoms were significantly greater in Old Wives Lake residents, than the control group.

Table 3.4.3 Peer-reviewed literature associated with the direct and indirect health impacts of a drought scenario IAF

		Region					Ecological Changes							Sociological Changes										
First Author	Year	G	NA	CND	CP	DffG	DRT	S/D	WTR	UND	AQ	FIRE	Oth	CWN	$$	AL	ADP	MGR	EP	CLT	GP/B	Vpop	PopH	Oth
DUST																								
Fisher MC	2000		✓				✓						✓											
Gomez SR	1992				✓	✓	✓	✓			✓													
Hefflin BJ	1994		✓				RF	✓			✓		✓											
Kwaasi AA	1998	✓						✓					✓											
Pappagianis D	1978		✓				RF	✓					✓		✓									
Prospero JM	1999	✓	✓					✓			✓		✓											
Rutherford S	1999	✓						✓			✓		✓											
Schwartz J	1999		✓					✓			✓		✓											
Unger DL	1985		✓					✓					✓											
MENTAL HEALTH																								
Deary IJ	1997	✓								✓					✓	✓					✓			✓
May JJ	1990		✓							✓					✓									
Olson KR	1986		✓							✓					✓						✓			✓
Simkin S	1998	✓				✓				✓					✓			✓			✓			✓
Walker JL	1986				✓					✓					✓						✓			✓
FIRE																								
Aditama TY	2000	✓				✓					✓	✓												
Duclos P	1990		✓								✓	✓												
Emmanuel SC	2000	✓									✓	✓					✓							
Jacobs J	1997		✓								✓	✓												
Layon AJ	2001		✓									✓						✓	✓			✓		
Long W	1998				✓						✓	✓												
Mims FM	1996	✓										RF	✓											
Roberts RA	1998		✓								✓	✓											✓	
Smith MA	1996	✓					RF				✓	✓												
Torigoe K	2000	✓									✓	✓												
OTHER																								
Anonymous	1988		✓				RF		✓															
Burr ML	1978	✓					✓		✓													✓		
Jackson LA	1993		✓				✓						✓											
Pavelchak N	1999		✓				RF										✓							
Raymond CA	1988		✓				RF		✓															
Samples P	1989		✓				RF		✓															
Stehlik D	2000	✓					✓																	✓
Wood GE	1992		✓			✓	RF						✓											✓

TABLE LEGEND

G – Global
NA – North America
CND – Canadian
CP – Canadian Prairies
DffG- compares different geographical regions

DRT – drought
S/D – soil or dust only
WTR – water quantity/quality
UND – uncontrolled natural disaster
AQ – air quality
FIRE - fire
Oth – other

CWN – community water needs
$$ - money difficulties
AL – agricultural losses
ADP -adaptation
MGR – migration
EP – emergency planning
CLT - culture
GP/B – government policy & bureaucracy
Vpop- vulnerable populations
PopH – population health variables
Oth - other

Additional Notation:
RF – Risk Factor
$ - Economic Component

Table 3.4.3 continued

		Health Effects							Data Coll		Model Type		Study Design	
First Author	**Year**	**RSP**	**MNT**	**DTH**	**INJ**	**MRB**	**CD**	**Oth**	**QNT**	**QLT**	**IAF**	**Oth**	**Paper Type**	**Statistics**
DUST														
Fisher MC	2000					✓			✓	✓			S	MR
Gomez SR	1992	✓							✓	✓			P	MH
Hefflin BJ	1994	✓							✓				S	OER/MR
Kwaasi AA	1998							✓	✓				P	D
Pappagianis D	1978					✓							PSN	
Prospero JM	1999	✓											R	
Rutherford S	1999	✓							✓	✓			P/S	OER
Schwartz J	1999			✓					✓				S	PR
Unger DL	1985	✓							✓				S	D
MENTAL HEALTH														
Deary IJ	1997		✓						✓				P	PCA
May JJ	1990	✓	✓	✓	✓	✓		✓					R	
Olson KR	1986		✓										R	
Simkin S	1998		✓							✓			P	
Walker JL	1986		✓							✓			P	MA/NP
FIRE														
Aditama TY	2000	✓		✓					✓				S	D
Duclos P	1990	✓							✓				S	OER
Emmanuel SC	2000	✓		✓					✓				S	D
Jacobs J	1997	✓							✓				S	MR
Layon AJ	2001									✓			Oth	
Long W	1998	✓								✓			P/S	MR
Mims FM	1996	RF				RF	RF		✓				P/R	MR/OER
Roberts RA	1998	✓							✓	✓			S	OER
Smith MA	1996	✓							✓				S	PR
Torigoe K	2000	✓							✓	✓			P/S	MR
OTHER														
Anonymous	1988				✓					✓			S	D
Burr ML	1978					✓			✓				P	D
Jackson LA	1993							✓	✓	✓			P	MA/D/NP
Pavelchak N	1999					✓			✓	✓			CR	D
Raymond CA	1988				✓								PSN	
Samples P	1989				✓								PSN	
Stehlik D	2000							✓		✓			P	Narratives
Wood GE	1992								✓				P	D

TABLE LEGEND

RSP – respiratory diseases
MNT – mental illness
DTH – Death
INJ - Injuries
MRB - Morbidity
CD – Communicable diseases
Oth – Other illnesses

Data collection method (data coll)
QNT - Quantitative
QLT - Qualitative

IAF –Integrated Assessment Framework
Oth - others

Paper Type
P-primary data collection
S-secondary data collection
CR-case reports
R-review
PSN-position paper
MA-meta analysis
E-ecological
CBA-cost benefit analysis
SUR-surveillance
EA- Economic Analysis
Oth- other

Statistics
OER-observed expected ratio
D-description
MH-Mantel Haenszel test
MA- measures of association
MR-multiple regression
MV- multivariate statisitic
PCA-principle component analysis
B-bivariate statistics
NP-nonparametric
PR-Poisson reqression
MC-Monte Carlo
PC-partial correlation
MLM- multi-level modeling
SP- spatial statistics
OR-other ratio type
EE- effect estimate
PA- path analysis
FA- factor analysis
RA- risk analysis
Oth- other

Organic dust exposures associated with soil and agricultural practices may become more common under conditions of drought, and possibly within urban areas surrounding extreme drought-prone agricultural areas. Based on 1.5 years of continuous monitoring in Seattle, Haller et al. (1999) found that windblown dust enhanced both the $PM_{2.5}$ and PM_{10} (particle size < 10μm) under dry conditions. Intermodal particulate matter ($PM_{1.0-2.5}$) (particle size between 1.0and 2.5 μm) was also inversely correlated with relative humidity and positively correlated with temperature. These data also indicate the dependence of the soil fraction on relative humidity, suggesting that these fugitive dusts may enhance the $PM_{2.5}$ and PM_{10} in the city (Haller et al., 1999).

Because there is a lack of original research that acknowledges the impact drought and soil dryness have on air quality, there is a need to determine baseline information regarding dust, specifically those organic in nature, in rural and surrounding urban areas during drought and non-drought conditions. Although Green et al. (1990) and Haller et al. (1999) have made the connection between weather variables, farming activities, and aerosolized PM, the connection to health outcomes is lacking. Thus, these data should be collected in conjunction with information on respiratory disease, allergy-related health outcomes, and drought-related morbidity or rural and urban populations. In addition, biological activity and how the different fraction of each dust affects respiratory health should be taken into consideration.

3.4.3.2 Mental Health

Mental health outcomes such as depression, stress and anxiety as they relate to the drought climate scenario were not well studied, thus the inclusion criteria were broadened to include those papers that identified uncontrolled natural disasters or forces (drought or otherwise) as a study risk factor. May (1990) wrote a review article outlining many potential health and safety hazards associated with farming. These hazards include mortality, injury (respiratory, acute, chronic, and cutaneous), and stress factors. However, May (1990) only touched the issues associated with the causes of stress in farming, such as weather and economic pressures.

Deary et al. (1997) used principle component analysis and grouped highly correlated variables (bad weather, machinery breakdown at busy times, unplanned interruptions, unpredictability of weather, and production losses from disease/pests/weeds) into one factor termed 'acts of God' or uncontrollable natural forces. After the initial factorization of the variables, further analyses were then conducted on males and females, farm type, farm size, and age. The findings include that women reported significantly higher levels of stress from uncontrollable natural forces than men.

Olson and Schellenberg (1986) reviewed questionnaire surveys of general farm stressors. Their work indicated that financial difficulties or events associated with financial loss are most often reported by farmers to be integral to their stress levels. However, financial stress is compounded by addition familial and extrafamilial (namely policy and market forces) stressors, which are unique to each farm family and situation.

There were three original research articles that investigated the possible direct or indirect mental health outcomes associated with ecological changes. However, no studies were identified that took into account changing weather, drought periods, or water accessibility as a possible correlate of increased financial pressures and hence, mental health of farmers or rural communities that directly or indirectly rely on the agricultural economy for their livelihoods.

Because of this lack of research there is a need to investigate the possible connection between drought and mental health. Thus several questions could be asked: is there a difference in financial problems in farmers during drought years versus non-drought years, and is there a corresponding increase in suicides or symptoms of depression?; How do periods of drought affect bankruptcy, farm loss, or farm buy outs?; and, Are there general increases or decreases in depression, stress, or anxiety during years of drought and successful crop year?

3.4.3.3 Fire

With respect to fire, a sufficient number of studies investigated the respiratory health effects associated with wildfire or agricultural smoke. Three studies (Aditama, 2000; Emmanuel, 2000; Duclos, 1990) investigated the general health effects associated with forest fires or agricultural burns at the population level. Three other studies investigated the association between asthma and wildfire smoke (Smith et al., 1996; Jacobs et al., 1997; Torigoe et al., 2000), and two studies investigated the respiratory symptoms in a susceptible population from agricultural burning (Long et al., 1998; Roberts and Corkill, 1998).

In Indonesia, the most significant immediate health effects from the haze produced by a large uncontrolled forest fire in 1997 were acute respiratory infection, bronchial asthma, diarrhoea, eye irritation, and skin disease (Aditama, 2000). In Singapore, suffering the effects of the same fire, there was a 30% increase in outpatient attendance for haze related conditions (Emmanuel, 2000).

The only study specific to the Prairie region was a Winnipeg-based study by Long et al. (1998). They based their study on individuals with pre-existing mild to moderately severe chronic airflow obstruction whose lung function and chronic respiratory status was known prior to the burning residue episode. They found that individuals with underlying phlegm production, dyspnea, wheezing or asthma were more likely to have increased symptoms of cough, wheeze, chest tightness, and/or shortness of breath, associated with the agricultural residue burning episode.

Another study investigated the effects of seasonal exposure to seasonal burning of Kentucky bluegrass over more than 30 years found that the city of Spokane self-reported levels of asthma, emphysema, and chronic bronchitis to be higher than the national average, and state-licensed hospitalization rates for asthma higher than the state average (Roberts and Corkill, 1998).

There were no studies that investigated the impact of death or economic cost to society from infrastructure losses in areas devastated by fire. This may primarily be because of fire suppression capability and the ability of vulnerable populations to be evacuated at times of danger. However, in one study, Layon et al. (2001) did describe the evacuation of a Florida County threatened by forest fire danger, and the pitfalls encountered along the way.

Mims (1996) found that biomass burning in Brazil significantly reduced UV-B intensity from the sun. Through a review of the literature Mims (1996) describes the possible biological and health implications of reduced UV-B. For example, a reduction in UV-B could decrease its bactericide capabilities, decrease photosynthesis, and provide better survival conditions for mosquitoes that can carry human disease.

Based on the studies which explored the health effects associated with episodic or chronic exposure to wildfire or agricultural smoke, there is evidence to support the link that intense smoke exposure can be harmful to the health of populations that experience them. Because of the vast expanse of Canada and the Prairie Provinces, populations in the Prairie region may not experience exceptionally smoky conditions from a single fire. However, in the future under conditions of climate change, regions may be exposed to forest fire haze stemming from several fires for the greater part of a summer, and research needs to be conducted on the health effects of several months of continuous haze.

Forest fires can be associated with other health effects, such as mental health. Fire can be thought of as a natural disaster and can inflict great loss on personal belongings and infrastructure. Further research should be conducted on the mental health aspects of communities affected by fire.

3.4.4 Extreme Heat Events

Higher global surface air temperatures could increase the frequency and severity of heatwaves, the number of extremely hot days, and extend the summer season on the Canadian Prairies. These events may be especially important in cooler climatic regions, where extremely high temperatures occur infrequently or irregularly. Therefore, these regions may also experience the greatest increase in heat-related morbidity and mortality in response to increased summer temperatures (Kalkstein and Smoyer, 1993).

3.4.4.1 Heat and Excess Mortality and Morbidity

When unusually high temperatures for a geographic area and population occur, heat-related deaths and morbidity ensue. It is well known that heatwaves increase the number of patients presented to hospitals and emergency departments (Semenza et al., 1999) and are associated with 'excess' deaths (Kalkstein and Smoyer, 1993; Kilborne, 1999). The most common heat-related illnesses giving rise to hospital admissions and excess deaths are heat exhaustion, heat stroke, and dehydration (Faunt et al., 1995; Kilborne, 1999; Semenza et al., 1999). Of the spectrum of heat-related illnesses, heat stroke and heat exhaustion are the most severe in terms of outcome and demands on medical resources (Tek and Olshaker, 1992; Faunt et al., 1995). Extreme heat exacerbates many pre-existing conditions leading to elevated mortality from multiple causes (Kalkstein and Smoyer, 1993).

Heat-stress can affect anyone, but there are particular segments of the population that are at higher risk of having an adverse outcome from high temperature days. Patients needing medical attention or who died from heat-related illnesses in hospital were more likely to be elderly, be of lower socio-economic status, be unable to care for themselves, have an alcohol or drug problem, be on drug therapy (especially diuretics), have pre-existing cognitive impairment, and have underlying cardiovascular, cerebrovascular, or respiratory illnesses (Kilborne et al., 1982; Kenney and Hodgson, 1987; Faunt et al., 1995; Semenza et al., 1999; Kilborne, 1999; McGeehin and Mirabelli, 2001). The elderly may be most at risk for heat-related illnesses and death owing to the association of aging with decreased heat tolerance, alterations in thermoregulatory capacity (Kenney and Hodgson, 1987), and the presence of associated risk factors (e.g., pre-existing medical condition, taking drug therapy, and unable to care for themselves). The elderly is the most rapidly growing portion of the population, and thus heat-related morbidity and mortality cases are expected to increase because of demographic changes, even with a change in climate.

Place-based studies of disparities in health outcomes focus not only on the health of people, but on how health outcomes correlate to the places in which people live. Living spaces can amplify risk or exacerbate pre-existing health conditions in extreme weather events (Smoyer, 1998a). The characteristics of places that put individuals at higher risk of adverse outcomes from heat-related illnesses include living on the higher floors of multi-story buildings (Kilborne et al., 1982), and living in urban areas. Urban areas are more vulnerable to the effects of extreme heat than rural areas owing to the urban heat island effect (WMO, 1999). This is because asphalt and buildings tend to absorb and retain more heat than vegetation.

The external environment not only encompasses temperature, precipitation and solar radiation, but various thermal, moisture, visibility, and cloud cover variables that comprise air masses (Kalkstein et al., 1996). A past study showed that the offending air mass type associated with excess deaths in the Toronto, Montreal and Ottawa areas exhibited certain characteristics. Of note were high temperature (with respect to Canadian standards), high dewpoint temperature (or high humidity), southwest wind direction, and high pressure (Kalkstein and Smoyer, 1993). However, increased summer mortality was not noted for any particular air mass approach or maximum temperature in the Prairie cities of Calgary, Edmonton, and Winnipeg. Possible reasons are that the air mass type harbouring the heat event (lower humidity and drier conditions) was less offending, or that the population sizes were too small to identify a meaningful relationship (Kalkstein and Smoyer, 1993).

3.4.4.2 Heat and Air Pollution

Rising temperatures from climate change can increase human exposure to urban air pollution in two ways: 1) by affecting the weather, which affects regional and local pollution concentrations; and 2) by affecting human-induced pollutant sources from adaptation to changes in the weather. Some of these adaptations may increase fossil fuel combustion for power generation (e.g., air conditioners).

The primary end products of fossil fuel combustion are mainly carbon dioxide (CO_2), carbon monoxide (CO), oxides of nitrogen (NO_x), sulfur dioxide (SO_2), hydrocarbons or volatile organic compounds (VOCs), and airborne particulates composed of primarily particulate matter (e.g., PM_{10} and $PM_{2.5}$) (Last et al., 1998; Guidotti, 1999). Secondary pollutants may become a bigger concern for human health in the Prairie region with climate change. Warmer temperatures enhance the production of secondary pollutants (e.g., ozone, acid aerosols, and complex organic particles) which are formed from primary pollutants via photochemical reactions (reactions with water vapour and sunlight) or reactions between VOC and acid aerosols (Last et al., 1998; Bernard et al., 2001).

In general, adverse health outcomes from air pollution include: exacerbation of pre-existing respiratory conditions (e.g., asthma, hay fever, COPD); increased mortality from respiratory or cardiovascular distress, increased morbidity and hospital admissions for patients with cardiac or respiratory disease (Burnett et al., 1995; Burnett et al., 1999); initiation of respiratory diseases (especially in children) like asthma or hay fever; headaches; fatigue (Last et al., 1998); and, premature mortality (Burnett et al., 1998).

It has been emphasized that ozone and particulate matter (PM) may be the important urban pollutants, which are positively correlated with temperature (Delfino et al., 1994), and thus concentrations are anticipated to increase with global warming (Bernard et al., 2001). Particulate matter (e.g., PM_{10} and $PM_{2.5}$) is described as any matter that can be filtered from the air (Duncan et al., 1999) and can be primary or secondary in origin (Bernard et al., 2001). Delfino et al. (1994) found a 2.7% increase in asthma hospital admissions for respiratory illnesses in Montreal over mean levels for every 13 $\mu g/m^3$ increase in PM_{10}. Another study found cardiac and respiratory hospital admissions to increase by 1.4% and 2.55% for each 10 $\mu g/m^3$ increase in PM_{10} and $PM_{2.5}$ respectively (Burnett et al., 1999).

Ozone, the major component of smog, (Duncan et al., 1999), is one of the most difficult air pollutants to control and has been found to be associated with respiratory morbidity (Beckett, 1991; Delfino et al., 1997; Bernard et al., 2001) and hospitalizations (Burnett et al., 1997c). In Saint John, New Brunswick, there was a 33% increase in emergency department visits when the daily one-hour maximum ozone concentration exceeded 75 ppb (Stieb et al., 1996a). For the Prairie cities of Edmonton, Calgary, Regina and Winnipeg, ozone has been recorded to be above the 82 ppb one-hour average maximum Canadian Ozone objective for 0.7 to 2.3 days per year, respectively (Duncan et al., 1999). Burnett et al (1998) found that the cities of Winnipeg, Calgary and Edmonton had low ozone risks.

Human exposure to primary and secondary air pollutants can affect certain sub-populations disproportionately. The elderly (Burnett et al., 1997a; Delfino et al., 1997), children (Delfino et al., 1997), and individuals with underlying medical problems (especially respiratory or cardiovascular diseases (Burnett et al., 1997b)) are at greater risk of adverse health effects from air pollution than are healthy adults (Last et al., 1998).

3.4.4.3 Heat and Food-borne Diseases

Food- and water-borne illnesses are defined as those maladies that are caused by pathogenic microorganisms (bacteria, protozoa, parasite, or viruses), microbial toxins or chemicals, or naturally occurring plant or animal toxins, ingested, inhaled or absorbed (through the dermis) by humans (Shewmake and Dillon, 1998; Patz et al., 2000). Food and water-borne diseases are similar in that they both stem from ingesting contaminated material. However, the differences lie in the environmental and climatic conditions under which humans become exposed and are most likely to become ill from food- or water-borne pathogens. The key climatic variables associated with water- and food-borne diseases are temperature and precipitation (Rose et al., 2001).

There are three main ways in which humans can be exposed to food- and water-borne diseases. The first is by the consumption of food contaminated with food-borne pathogens. The second is by consumption of water contaminated with water-borne pathogens or food-borne pathogens that find their way into drinking water supplies. The last is by consumption of foods contaminated by water-borne pathogens from irrigation water, or by the ingestion of shellfish from contaminated marine waters (Rose et al., 2001). In this section, exposure to food-borne pathogens will be discussed as it relates to temperature.

The most common pathogens of food-borne illnesses of concern are *Salmonella, Clostridium perfringens, Staphylococcus aureus, Bacillus* spp., *Escherichia coli, Vibrio parahaemolyticus, Campylobacter jejuni, Listeria monocytogenes,* and some viruses (Roberts, 1990). These food pathogens are normally found in animal products such as raw foods and ingredients (Roberts, 1990), but can be introduced to non-animal food products by irrigation processes using contaminated water (Rose et al., 2001). Environmental cross-contamination is another means of food contamination with pathogens. This includes not washing hands between handling cooked and uncooked meat and using the same tools (e.g., cutting boards, knives, and storage containers) for both raw and cooked foods (Park et al., 1991).

The method of food processing directly before food consumption (e.g., prepared in commercial or institutional establishments or at home) is often identified as the primary risk factor associated with a food-poisoning episode or outbreak (Roberts, 1990; Health Canada, 1998). For example, the four most common reasons for food poisoning are: 1) leaving prepared food at temperatures that allow for bacterial growth; 2) inadequate cooking or reheating; 3) cross-contamination (from contaminated raw to cooked foods, usually on surfaces); and 4) infected food handlers (Shewmake and Dillon, 1998).

Food poisoning outbreaks occur more often in the summer months (Bentham and Langford, 1995). Several factors may play an important role in increased food-poisoning during warmer temperatures. These include: 1) warmer temperatures, which are more conducive to accelerated growth of bacterial species in animal faeces (Rose et al., 2001), raw animal products, and prepared foods; 2) longer summer periods, which will increase the time period during which bacterial species and their carriers (e.g., flies) can survive in the environment (Rose et al., 2001); and, 3) different methods of food preparation and patterns of food consumption in the summer months (Bentham and Langford, 2001). All could be enhanced with global warming.

Other factors that already play a significant role in food-borne disease outbreaks could also be affected by warmer temperatures and should be assessed for their role in food poisoning outbreaks. There is a trend to promote intensive livestock and poultry rearing (Bentham and Langford, 2001). Farther distances for animal travel between ranch and slaughter will increase soiling of animals and consequently raise the bacterial content of their meat (Bentham and Langford, 2001). There is a population trend towards consumption of more ready-to-eat foods that depend on others for correct handling and storage, in addition to chicken, which has been the most important source of *Salmonella* outbreaks in the last 5 years (Potter, 1992). Finally an aging population is more susceptible to food-borne illnesses (Potter, 1992, Lacey, 1993; Anonymous, 1999; Bentham and Langford, 2001; Rose et al., 2001). However, it should be noted that these factors could work in synergy, making it more difficult to identify the effect of global warming on the incidence of food-borne diseases.

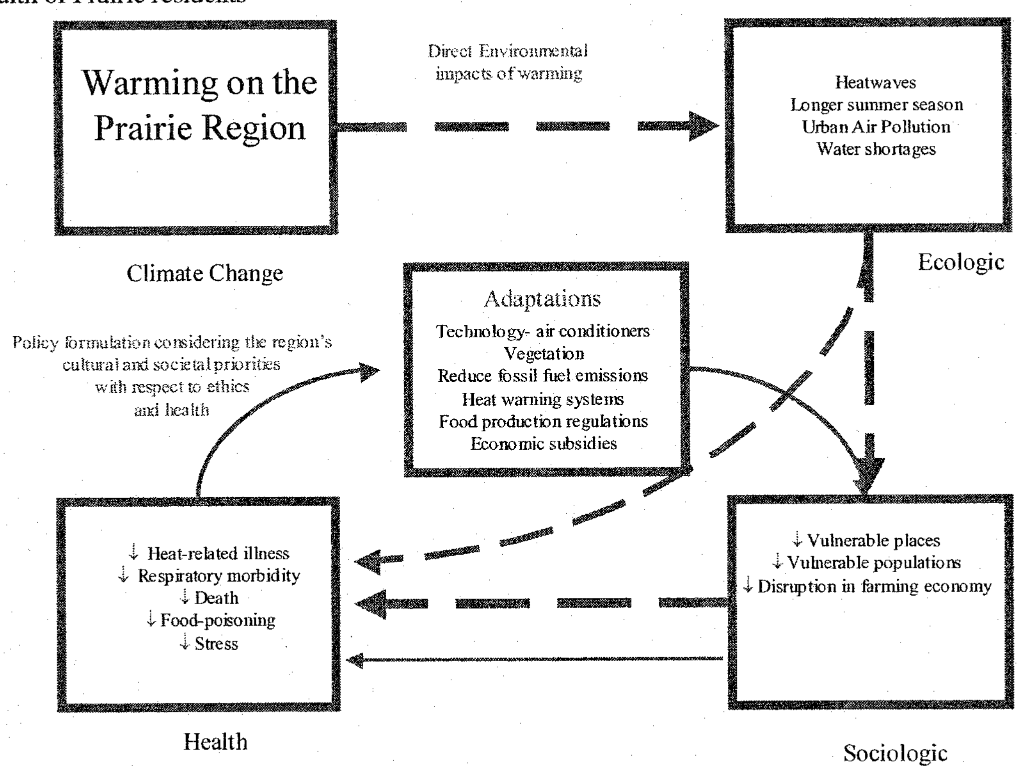
According to Statistics Canada (2001), the Prairie Provinces are home to 69% of Canada's cattle and calves, 39% of pigs, and 17.2% of chickens. In Canada, intensive livestock operations (ILO) are becoming more concentrated. In 1992, the Province of Alberta and British Columbia (combined data) had 15 cattle slaughter plants and the average kill per plant per year was 193,156. The top four plants were responsible for 89% of the slaughter. In comparison, in 1999 only nine slaughter plants were remaining, with average kills of 260,779 cattle per plant per year, and the top four plants were responsible for 98% of the slaughter (Agriculture and Agri-Food Canada (AAFC), 2001a). In addition, in 1999, 74% of all cattle slaughtered in Federally or Provincially inspected slaughter establishments in Canada occurred in the Prairie Provinces, with 68% in Alberta alone (AAFC, 2001b). However, there is little literature pertaining to the role of primary processing plants in food-borne diseases, and none to our knowledge in the Prairie region.

3.4.5 Heat and Integrated Assessment Frameworks

Figure 3.4.2.1 depicts the proposed IAF of the ecologic, sociologic, health and adaptation modules associated with heat. It identifies the key plausible links (direct and indirect) between a climate scenario predicting heat and the possible health impacts. As well it takes into account feedback loops that involve adaptation, providing insight to policy makers about how to adapt to increased pressure associated with heat.

Some of the key links include: heatwaves and heat-related death or morbidity; urban air pollution, heat and respiratory illness; and longer summer seasons that, through a variety of pathways, can promote increased incidence of food-borne illness. Adaptations to reduce the short-term effects of heat include identification of vulnerable populations and places, reduction of fossil fuel emissions, heat-weather warning system, and additional food-processing regulations.

Figure 3.4.5 Integrated assessment framework of the direct and indirect pathways heat can impact the health of Prairie residents



Blue depicts the direct and indirect pathways, and red exemplifies how adaptations could lessen any negative impacts.

Some modules and linkages will play a larger and more visible role in determining health outcomes, and less complicated solutions are available for adaptation. For example, smog and respiratory morbidity in Toronto are being combated by a smog warning system to alert vulnerable populations and the general public when atmospheric conditions may become dangerous to their health.

However, other aspects of heat are more difficult to link to warmer ambient temperatures, as the outcomes come about from multi-factorial and indirect pathways. This is evident in food-borne disease outbreaks, where ambient temperature may factor into the equation at a number of places. These include intensive livestock operations, transportation to slaughterhouses, and the slaughterhouse itself. In addition, consumer habits, food preparation, and food processing also can play roles in the indirect effects.

3.4.6 Heat: Review of Current Knowledge and Knowledge Gaps

The health outcomes of interest in this section have been well studied (with exception to food-borne disease outbreaks) in the peer-reviewed literature. Thus, additional restrictions were placed on heat and morbidity/mortality, and urban air pollution and respiratory health literature searches.

With respect to heat and heatwaves and their association with morbidity and mortality, restrictions placed on the search strategy were that the original research or review article had to either: a) employ a novel study design and/or go beyond descriptive, bivariate, and in some cases, observed-expected statistical analysis; b) identify vulnerable populations, places, or adaptation; or c) have a specific relevance to the Canadian Prairie region. Table 3.4.6 shows the peer-reviewed literature associated with a heat scenario.

There is a large body of literature that reviews the health effects of primary and secondary combustion particles (Beckett 1991, Committee of the Environmental Health and Occupational Health Assembly of the American Thoracic Society 1996). Also there is extensive air quality research originating in Canada and all around the world. A comprehensive review of this literature is not within the scope of this paper. Thus, studies were included only if they: a) were primary research or review articles originating in, or had relevance to, the Canadian Prairies; or b) explicitly employed heat variables or climate change as part of the research hypothesis.

3.4.6.1 Heat

Twenty-four* articles met the inclusion criteria for heatwave or heat-related morbidity and mortality section of the literature review. The vast majority dealt with death as the health outcome of interest. The cause and effect relationship between ambient heat, and mortality has been well investigated. Currently the trend is to investigate this relationship on a geographical level, hence the large amount of original research taking place all around the world.

Three studies (Kalkstein and Smoyer, 1993; Kalkstein and Greene, 1997; Martens, 1998) used future climate change scenarios to aid in the prediction of future deaths from climatic change: two were global and one was set in the United States. Only one study was found that directly addressed the heat and mortality in the Prairie region (Kalkstein and Smoyer, 1993). The study included three Prairie cities (Edmonton, Calgary, and Winnipeg) in an international study, involving four countries: United States, Canada, the People's Republic of China, and Egypt.

Kalkstein and Smoyer (1993) initially estimated the heat-related mortality threshold, as well as high and low mortality associated with the daily synoptic air mass classification of each city in the four countries (data permitting). Each outcome was then entered into separate climate change scenarios, adjusted for acclimatization, for future estimates of the impact of climate change on the human mortality. Although Prairie cities suffered from periodic heatwaves (harboured within hot air masses), there was no significant relationship between mortality and any synoptic category of weather conditions. It was thought that the lack of relationship could be attributed to the continental source of the hot air masses.

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* One article was included based on reading the abstract only (Alberdi, 1998) as the paper was not available. However, it was not categorized into the different fields presented in the table.

Table 3.4.6. Peer-reviewed literature associated with the direct and indirect health impacts from a heat scenario IAF

		Region					Ecological Changes								Sociological Changes						
First Author	**Year**	**G**	**NA**	**CDN**	**CP**	**DffG**	**HW**	**HAM**	**UAP**	**PII**	**SMM**	**Temp**	**CC**	**Oth**	**IFD**	**VPL**	**Vpop**	**ADP**	**MIT**	**FDP**	**Oth**
HEAT																					
Alberdi JC oo	1998																				
Ballester F	1997	✓									✓						✓				
Bark N	1998	✓					✓										✓	✓			
Braga ALF	2001		✓			✓					✓	✓						✓			
Ellis FP	1972		✓				✓										✓				
Ellis FP	1976		✓				✓										✓				
Huynen MM	2001	✓					✓														✓
Kalkstein LS	1993	✓	✓	✓	✓	✓		✓				✓									✓
Kalkstein LS	1997					✓		✓													✓
Keatinge WR	2000	✓				✓					✓		✓	✓							
Kilborne EM	1982		✓								✓					✓	✓				
Marmor M	1978						✓										✓	✓			
Martens WJ	1998	✓				✓							✓								
Marzuk PM	1998		✓									✓					✓				
McGeehin MA	2001		✓			✓	✓	✓				✓	✓			✓	✓	✓			
Rogot E	1992		✓			✓						✓						✓			
Saez M	2000	✓									✓	✓					✓				
Sartor F	1995	✓					✓		✓												
Semenza JC	1999		✓				✓										✓				
Semenza JC	1996		✓				✓									✓	✓				
Smoyer KE	1998a		✓				✓									✓	✓				
Smoyer KE	1998b		✓				✓										✓				
Smoyer KE	2000a			✓			✓						✓			✓	✓				
Smoyer KE	2000b		✓					✓	✓		✓										
AIR POLLUTION																					
Aunan K	1998	✓							✓				✓	✓					✓		$
Bernard SM	2001		✓						✓	✓			✓								
Burnett RT	1997a			✓	✓	✓			✓								✓				
Burnett RT	1997b			✓	✓	✓			✓												
Burnett RT	1998			✓	✓	✓			✓										✓		
Cifuentes L oo	2001																				
D'Amato G	2001	✓							✓	✓			✓								
Davis DL	1997	✓							✓				✓						✓		
Garty BZ	1998	✓							✓	✓		✓					✓				
Guo YL	1999	✓				✓			✓			✓					✓				
Hales S	2000	✓							✓			✓									
Hall JV	1992		✓			✓			✓										✓		$
Holberg CJ	1987		✓			✓			✓	✓	✓	✓									
Jones G	1994		✓						✓			✓					✓				
Katsouyanni K	1993	✓					✓		✓			✓									
Kleinman LI	1996		✓						✓				✓					✓	✓		
Piver WT	1999	✓					✓		✓			✓									
Sartor F	1997	✓							✓		✓	✓					✓				
Steib DM	1996b			✓		✓			✓									✓			
Ye F	2001	✓							✓		✓	✓					✓				
FOOD-BORNE																					
Health Canada	1999a		✓			✓					✓										
Aserkoff B	1970		✓			✓					✓									1 & 2	
Bentham G	1995	✓											✓								
Bentham G	2001	✓											✓								
Frost JA	2001	✓									✓									2	✓
Hancock D	2001		✓			✓					✓									1	✓
Katzenell U	2001	✓				✓					✓									2	
MacGowan AP	1994	✓									✓									1	✓
OTHER																					
Beggs PJ	2000	✓											✓								
Harrington WZ	1995		✓								✓	✓									

TABLE LEGEND

G – Global
NA – North America
CND – Canadian
CP – Canadian Prairies
DffG- Compares different geographical regions

HW – heatwave
UAP – urban air pollution
PII – pollen
SMM – summer months
Temp – heat variable + weather variable
CC – warmer ambient temps or climate change

HAM – heat air mass
Oth - other

Additional Notation:
$ - Economic Component
1 = Primary
2 = Secondary

IFD – infrastructure damage
VPL – vulnerable places
Vpop – vulnerable populations
ADP – adaptation
MIT – mitigation
FDP – food processing
Oth – other

oo- on order inclusion into table is based on abstract only

Figure 3.4.6 continued

		Health Effects								Data coll		Model Type					
First Author	**Year**	**RSP**	**MNT**	**DTH**	**INJ**	**MRB**	**CD**	**FDB**	**Oth**	**QNT**	**QLT**	**IAF**	**Oth**	**CCS**	**FTD**	**Paper Type**	**Statistics**
HEAT																	
Alberdi JC oo	1998																
Ballester F	1997			✓						✓						S	PR
Bark N	1998			✓						✓						S	MA/D
Braga ALF	2001			✓						✓						S	PR
Ellis FP	1972			✓												R	
Ellis FP	1976			✓		✓										R	
Huynen MM	2001			✓						✓					✓	S	PR
Kalkstein LS	1993			✓						✓				✓	✓	S	MR
Kalkstein LS	1997			✓						✓				✓	✓	S	MR
Keatinge WR	2000			✓						✓						S	D
Kilborne EM	1982					✓				✓	✓					P/S	MR
Marmor M	1978			✓						✓						S	MA/D
Martens WJ	1998			✓						✓				✓	✓	MA	EE
Marzuk PM	1998			✓						✓						S	NP
McGeehin MA	2001			✓		✓										R	
Rogot E	1992			✓						✓	✓					P/S	MH/NP
Saez M	2000			✓						✓						S	MR
Sartor F	1995			✓						✓						S	MR
Semenza JC	1999					✓			✓	✓						S	MR/NP
Semenza JC	1996			✓						✓	✓					P/S	OER
Smoyer KE	1998a			✓						✓						R/E	MA/MR
Smoyer KE	1998b			✓						✓						S	SP
Smoyer KE	2000a			✓						✓						S	MR
Smoyer KE	2000b			✓						✓						S	OR
AIR POLLUTION																	MR/oth
Aunan K	1998	✓		✓					✓				IA			CBA	
Bernard SM	2001	✓		✓		✓			✓							R	
Burnett RT	1997a					✓				✓						S	
Burnett RT	1997b	✓								✓						S	MR
Burnett RT	1998			✓						✓					✓	S	MR
Cifuentes L oo	2001																MR
D'Amato G	2001	✓														R	
Davis DL	1997			✓										✓	✓	S	
Garty BZ	1998	✓								✓						S	MR
Guo YL	1999	✓								✓	✓					P/S	MR
Hales S	2000			✓						✓						S	MR/PCA
Hall JV	1992					✓							REHEX			EA	
Holberg CJ	1987	✓								✓	✓					P/S	
Jones G	1994	✓								✓	✓					P/S	PCA/FA/PA
Katsouyanni K	1993			✓						✓						S	MR
Kleinman LI	1996	✓		✓		✓								✓	✓	R	MR
Piver WT	1999					✓				✓						S	
Sartor F	1997			✓						✓						S	PR
Steib DM	1996b										✓					P	MR
Ye F	2001					✓				✓						S	MR
FOOD-BORNE																	
Health Canada	1999							✓		✓						SUR	D
Aserkoff B	1970							✓		✓						SUR	D/
Bentham G	1995							✓		✓					✓	S	MR
Bentham G	2001							✓		✓						S	MLM
Frost JA	2001							✓								R	
Hancock D	2001							✓								R	
Katzenell U	2001							✓								R	
MacGowan AP	1994							✓		✓						P	D
OTHER																	
Beggs PJ	2000								✓							R	
Harrington WZ	1995				✓					✓						P/S	D

TABLE LEGEND

RSP – respiratory diseases
MNT – mental illness
DTH – Death rate
INJ - Injuries
MRB - Morbidity
CD – Communicable diseases
FDB – Food borne diseases
Oth – Other illnesses

Data collection method (data coll)
QNT – Quantitative
QLT – Qualitative

IAF – Integrated Assessment Framework
Oth - others

CCS – Climate Change Scenarios
FTD – Future Trends Estimation

** refer to Table 3.4.3 for description of annotations used for paper type and statistics.

REHEX- Regional Human Exposure model
IA- Integrated Assessment

The lack of a significant relationship in the Prairie region could also be attributed to smaller size of the cities, which contributes to more noise within the mortality data, for example traffic fatalities also increase in the summer (Kalkstein and Smoyer, 1993). However, this insignificance between mortality and heat outcomes may indicate that morbidity associated with heat might play a larger role in the determination of health in Prairie populations.

There were only four morbidity studies associated with heat; none included the Prairie region. Two studies were review articles and two were original research. One research article (McGeehin and Mirabelli, 2001) focused on the impact of climate change. None of the morbidity studies employed climate change scenarios, or attempted to assess future trends of heat-related morbidity under warmer climatic conditions.

As found by Kalkstein and Smoyer (1993), heat events in the United States had a larger impact in cities where high temperatures occur irregularly. Therefore, cooler regions may experience the greatest increase in heat-related morbidity and mortality in response to increased summer temperatures. However, Prairie cities have smaller populations, which may decrease a researchers ability to uncover the trends associated with heat-related morbidity and mortality. This may be especially true for heat-related morbidity as it relates to underlying or co-morbid conditions. Although morbidity trends associated with heat may initially not be statistically significant, or even distinguishable from the larger morbidity picture, it is important to note that health-effects, associated with increased heat from climate change, will be encountered in the future. Thus, as temperatures rise, the effects may become more apparent as Prairie populations are exposed to hotter conditions for longer periods of time.

Thus, in response to climate change, the best defence for the Prairie region would be to have a good surveillance system and a respectable understanding of the baseline health status of Prairie populations with respect to temperature sensitive morbidities and co-morbidities. However, in order for surveillance to occur, the climatic conditions most offensive to Prairie residents must be better understood. Although the results were inconclusive regarding offending hot air masses and the role of maximum temperature on mortality, they provide a baseline for future research. In addition, future research should be conducted to identify morbidity associated with hot air masses.

Currently, there is a significant amount of information associated with vulnerable populations. It is well-known that if the duration, intensity and frequency of heat events in the Prairie region increase as a consequence of global warming, vulnerable populations will require more care. Place-related risk factors that tended to decrease the risk of heat-related illness were living in residences more shaded by trees and shrubs (Kilborne et al., 1982), and low-mortality rates were associated with more affluent and stable sections of St. Louis (Smoyer, 1998a). Also in St. Louis heat-related mortality was associated with the warmer, less stable and more disadvantaged areas of the city during the 1980 heatwave (Smoyer, 1998a). However, infrastructure and vulnerable places may not have the same adaptive qualities as a smog advisory program and may take longer (if ever) to implement, mainly from costs associated. Thus, as suggested in Chapter Two (RTDs) it is important to assess and document the vulnerable or potentially vulnerable places (e.g., retirement homes without air conditioning, lower income neighbourhoods) in order to document the current adaptive capacity and the cost associated with future infrastructure adaptation.

3.4.6.2 Air Pollution

The ill-health effects associated with air pollution have also been well studied in Canada and all around the world. However, what distinguishes general urban air pollution studies from those applicable to climate change is the heat or weather component. This is because under conditions of increased average global atmospheric temperatures, air pollution from the combustion of fossil fuels is expected to worsen, mainly from the formation of temperature dependent secondary pollutants.

Only three studies (Burnett et al., 1997a; Burnett et al., 1997c; Burnett et al., 1998) investigated the health affects associated with air pollution in the Prairie region, although none employed temperature variables, except for controlling confounding. In addition, the three studies only examined Prairie cities as part of a larger study design involving 10, 11, or 16 Canadian cities.

The three Prairie-related studies investigated: the effect of carbon monoxide on the elderly for congested heart failure hospitalizations (Burnett et al., 1997a); the effect of urban air pollution mix on daily mortality rates (Burnett et al., 1998); and the association between ozone and hospitalizations for respiratory diseases (Burnett et al., 1997c). A need exists to more fully understand how weather and climate will interact with air pollution as it pertains specifically to the Prairie region.

Five studies included a climate change premise within their study design: three are review articles (Kleinman and Lipfert, 1996; Bernard et al., 2001; D'Amato et al., 2001); one is a cost-benefit analysis of the health and environmental benefits from air pollution reduction (Aunan et al., 1998); and, one used climate change scenarios to investigate the health benefits from a reduction in fossil fuel combustion emissions (Davis et al., 1997). One study employed an IA model (Aunan et al., 1998); however, the study was conducted in Hungary where economic stagnation considerably decreased fossil fuel consumption. Another study employed a modeling technique, but not specific to climate change, called the Regional Human Exposure (REHEX) model (Hall et al., 1992). The purpose of the study was to assess the economic value of clean air in California.

Many studies investigated heat or temperature as an added risk factor, coupled to urban air pollution. These studies are useful as they can provide insight to appropriate study designs and statistical analysis procedures for studies initiated in the Prairie region. However, some methodological considerations must be mentioned for research in the Prairie region. First, the incidence of health occurrences (e.g., hospital admissions for asthma, increased emergency department visits, mortality) may be too small, in some areas, to detect significant trends (clinically or statistically) associated with the daily concentration of air pollutants. This limitation is detailed more specifically in Chapter Four, section 4.4.5.

Second, because of possible low reported disease, it becomes difficult to link air pollution levels to health effects, and even more difficult to link them to climate change. Third, Prairie cities occupy large geographical areas (urban sprawl), on relatively flat landscapes, and, thus, pollutants are less likely to be 'locked in' by surrounding mountains. In addition, Prairie cities also have lower density populations (as compared to Vancouver, Montreal or Toronto), creating less pollution. Last, the Prairie region is continental in geography and will be associated with different air mass types than those that have shown an association with mortality elsewhere (i.e., coastal areas). For these reasons, Prairie cities may be less prone to the health effects of urban pollution, and trends may be more difficult to detect.

3.4.6.3 Food-borne Diseases

Food-borne disease outbreaks are the most ambiguous health affect associated with a rise in global atmospheric temperatures. This is because temperature can play a role in food-borne disease outbreaks at many points along the food processing chain, from the intensive livestock operation to home preparation and consumption. In table two, where possible, it was noted whether primary (intensive livestock operations to the supermarket shelf) or secondary (from purchase of food product to consumption) food production was discussed. The majority of the studies included in the literature review indicated a seasonal pattern of food-borne disease outbreaks in the summer months.

Only two studies included a climate change premise for food-borne disease outbreaks (Bentham and Langford, 1995; Bentham and Langford, 2001), both studies were conducted in England. Bentham and Langford (1995) found that monthly fluctuations in food poisonings are related to environmental temperatures. A later study (Bentham and Langford, 2001) found stronger associations between environmental temperatures 2-5 weeks before the food poisoning event and the outbreak of food poisoning. The authors hypothesized that factors associated with earlier food production or the distribution system may play a larger role in increased food-related illnesses under conditions of increased atmospheric temperatures (Bentham and Langford, 2001).

Because the Prairie region is responsible for the majority of cattle rearing and slaughter, the need exists to determine the magnitude of food-borne pathogens within slaughter plants and the subsequent distribution of the meat products. With rising temperatures, the burden of food-borne disease on Prairie residents (and even the other locales that import our meat products) may increase. Studies should incorporate temperature as a factor when testing for concentrations of pathogens in meat and meat products, and investigate the possibility of an association between temperature, pathogen levels and type, and cases of enteric disease within the general population.

Other studies could investigate the pathogen concentrations over varying transportation and distribution distances, during the various seasons (as a control for temperature). For example, an animal from livestock operation to supermarket shelf or restaurant freezer could be tracked and tested for concentrations of pathogens, therefore providing an understanding of how temperature and transportation distances can affect pathogen levels/types and possibly the incidence of food-borne illness.

Modeling of the pathways associated with the food-borne disease outbreaks and atmospheric temperature was not attempted in the peer-reviewed literature. Because of the complex nature of food-borne disease and the multiple possible entry points for temperature into the food-borne disease incidence, it is important to model these pathways. However, modeling can proceed only after more is learned about the component parts (mentioned above).

3.4.7 Extreme Hydrological Events

Extreme weather is defined as infrequent or rare weather that lies outside a locale's normal range of weather intensity (Francis and Hengeveld, 1998). Extreme weather includes natural hazards and disasters. Natural hazards include heat, convective storms (i.e., severe thunderstorms accompanied by heavy rain, lightening, hail or tornadoes), snowstorms, and windstorms (Etkin, 1999). A hazard can turn into a disaster when significant loss of life and/or property occurs beyond the capacity of the community to recover on its own (Francis and Hengeveld, 1998; Etkin, 1999). Some of the most destructive extreme events are those that are the result of a chance union of less extreme events (Francis and Hengeveld, 1998). For example, the 1997 Manitoba Red River flood was the combination of higher than normal snowfall and heavy rain in the spring (International Joint Commission (IJC), 2000). Nevertheless, both natural hazards and disasters can have impacts on human health in many important ways.

It is certain that with global warming there will be an increased volume of water moved throughout the hydrological cycle, and consequently more moisture will be available to fall as rain or snow (Francis and Hengeveld, 1998). The Intergovernmental Panel on Climate Change (IPCC, 2001) predicts that it is likely that intense precipitation events will increase in frequency over many areas. Canadian records depict a trend towards heavier precipitation since 1940, but the increase is mainly in the northern region (Francis and Hengeveld, 1998).

Precipitation trends for the Canadian Prairies are inconclusive and difficult to predict. Since 1950, precipitation in Canada's southwestern region (defined as the Prairie Provinces and British Columbia) has experienced a decrease in winter precipitation (Akinremi et al., 1999; Stone et al., 2000). One study found that between 1950 and 1995, precipitation of lighter intensity decreased, whereas heavier intensity events increased for southwestern Canada (Stone et al., 2000). However, other studies found that the increase in precipitation in the Canadian Prairie region was the result of increased low-intensity rainfalls (Akinremi et al., 1999; Akinremi and McGinn, 2001). Predictions for future precipitation levels in the Prairie Provinces, with respect to the 1975-1995 average, by 2080-2100 include: 0-10% increase in winter precipitation, except in the northern half Manitoba; and, a 0-10% increase in summer precipitation, except for parts of east-central Alberta and small areas in northern Manitoba and Saskatchewan (Hengeveld, 2000).

Although Canada and the Prairie region generally are expected to experience an increase in severe weather (Etkin, 1999); when, where, or how severe weather will increase cannot be reliably predicted (Last et al., 1998). However, these severe weather events will have important repercussions to the health of residents in the Prairie region. This section focuses on the health impacts of extreme hydrological events with respect to intense rainfall events and large-scale flooding as they pertain to the Canadian Prairie region.

3.4.7.1 Intense Rainfall Events and Water-borne Diseases

Extreme rainfall events, being associated with flash floods in rural and urban areas, can have both direct and indirect effects. Direct effects include injury or mortality associated with the event (Greenough et al., 2001). These direct health risks could become more common if intense precipitation events increase. Indirect health risks associated with intense rainfall events are water-borne diseases and mental health illnesses (Greenough et al., 2001; Rose et al., 2001). Mental or emotional health, such as post-traumatic stress disorder, that are associated with intense precipitation events will be discussed more fully under flooding.

Water-borne diseases are associated with water quality, defined by the physical [suspended solids], chemical, and bacterial content of the water (Cooke et al., 2000). Water quality can be affected differently by a precipitation event depending on the location of the event (rural versus urban areas). Industrial agriculture (e.g., intensive livestock operations) often overuses fertilizers and permits the effluents from livestock operations associated with tens of thousands of animals to be released into the environment, posing a potential problem to water quality (Schindler, 2001). In urban areas, it is often the overflow of a combined sewer system technology (one that carries both storm water and sewage wastes in the same pipe to the treatment plants) that poses a problem to water quality. In this circumstance, when rainfall exceeds the capacity of the system, raw human waste may be discharged into surface water bodies and contribute to water contamination (Rose et al., 2001).

As noted the Prairie Provinces are home to 69% of the nation's cattle, which are reservoirs for various gastrointestinal disease-causing organisms (e.g., the bacterium *E. coli* 0157, and the protozoa *Cryptosporidium* and *Giardia* (Kocagil et al., 1998; Rose et al., 2001)). Although, in Alberta, guidelines for manure disposal and water quality state that surface water runoff contaminated with manure cannot leave the owner's property (Alberta

Agriculture, Food and Rural Development (AAFRD), 2000), under conditions of extreme rainfall events, this guideline could easily be breached.

Given the large number of livestock present in the Prairie Provinces and the link between the presence of pathogens in receiving waters and rainfall/runoff events (Millson et al., 1991; Kocagil et al., 1998; Health Canada, 2000a) little research has been conducted exclusively in the Prairie region. A study by Wallis et al. (1996) investigated *Giardia* cysts and *Cryptosporidium* oocysts in surface water, raw sewage, and drinking water in 72 municipalities across Canada. However, of the 1700 samples taken less than 10% were from the Prairie Provinces. In addition, the study did not mention how many municipalities were represented in each Province and it is possible that, for example, all samples in Alberta (totalling 39) could have come from one municipality.

Many rural residents rely on well water from underground aquifers for drinking, and for a long time this water was considered safe for consumption and naturally protected against pathogenic microbes (Robertson and Edberg, 1997). However, in a mixed farming area one town endured a heavy snow accumulation in the previous winter, as well as heavy spring runoff and rain, a temporal relationship was found between heavy rainfall, detection of well water contamination, and an outbreak of gastrointestinal illness from *Campylobacter jejuni* (Millson, et al., 1991). Other studies also concluded that contaminated well water is a possible source of gastrointestinal infections (Jackson et al., 1998; De Serres et al., 1999) and can contain viruses from seepage of contaminated groundwater into wells (Robertson and Edberg, 1997; De Serres et al., 1999).

Another example of contamination of water supplies was seen in the Canadian water contamination tragedy that occurred recently in the hamlet of Walkerton, Ontario. Human bacterial pathogens (*E.coli* and *Campylobacter* spp.) were identified in animal manure on 11 of 13 livestock farms within a four-km radius of the three wells providing the town with drinking water. A combination of several factors led to the contamination of *E. coli* in drinking water. These included heavy rains accompanied by flooding, bacterial pathogens present in the environment, wells that supplied a town with drinking water being subject to surface water contamination, and a water treatment system that may have been overwhelmed by increased turbidity (Health Canada, 2000a), plus human error.

Intense precipitation events and water quality issues in urban areas arise when storm water combines with sewage wastes, overwhelming sewage treatment plants allowing raw sewage to be released into the receiving water body. Depending on the discharge protocol for wastes upstream, water can become increasingly more polluted with faecal wastes for the townships or of urban centres downstream (Payment et al., 2000). Most rivers in the western Prairie Provinces begin in the Rocky Mountains and wind their way through many agricultural and urban areas as they head east to internal drainage basins (Herrington et al., 1997). Each agricultural field, intensive livestock operation, processing plant, municipality, or city is a possible water contaminant source (Coleman et al., 1974; Vanderpost and Bell, 1977; Menon 1985) and can be the origin of the parasites or bacteria in drinking water.

Although all urban centres are equipped with water treatment plants that destroy bacteria, some parasites (e.g., *Cryptosporidium* and *Giardia*) are more resistant to water treatments and can still be found in drinking water (Payment et al., 2000). A randomized trial found that even though the urban area's treatment plant (water mainly contaminated by human sewage) met the biological and physico-chemical water quality standards, there was a significant excess of gastrointestinal illness symptoms in tap water users when compared to persons that used an additional water filter in the home (Payment et al., 1991).

Chlorination and settling of water in treatment plants reduce both *Giardia* cyst and Cryptosporidium oocyst concentrations in water, and although cysts and oocysts may still be present, protozoan infection also depends on their concentrations, their viability, and virulence against humans (Wallis et al., 1996). However, byproducts from chlorination have also been implicated as a cause of health problems (Mills et al., 1998; Reif et al., 1996; Magnus et al., 1999).

3.4.7.2 Flooding and Mental Health

The majority of rivers in the Prairie region have dams or other man-made structures to reduce the risk of flooding for populations living on floodplains. Despite this, flooding disasters do occur. Health issues surrounding flooding can be short-term, such as the threat of infectious diseases from water-borne pathogens, or from accidental ingestion or dermal exposure, injury, and other types of mortality (drowning, heart failure). Slow-rising riverine floods have a low potential for mortality, and the major health effects from floods may be longer-term, such as mental-health issues (Post-Traumatic Stress Disorder (PTSD)), and moulds/mildew and the associated respiratory conditions from extremely wet conditions, during and after a flooding event (Square, 1997; Greenough et al., 2001).

In 1997, the Manitoba Red River flood resulted in approximately 28,000 Manitobans being evacuated from their homes (Square, 1997). The total cost to society was US$5 billion for the United States and Canada combined (IJC, 2000). Although infectious diseases were a concern, the threat of bacteria such as *Cryptosporidium*, *Salmonella*, and *E. Coli*, was estimated as low to moderate (Square, 1997). There have been reports linking floods with rare outbreaks of disease (e.g., Leptospirosis, vector-borne diseases, Western equine encephalitis), but the reports have been from the United States.

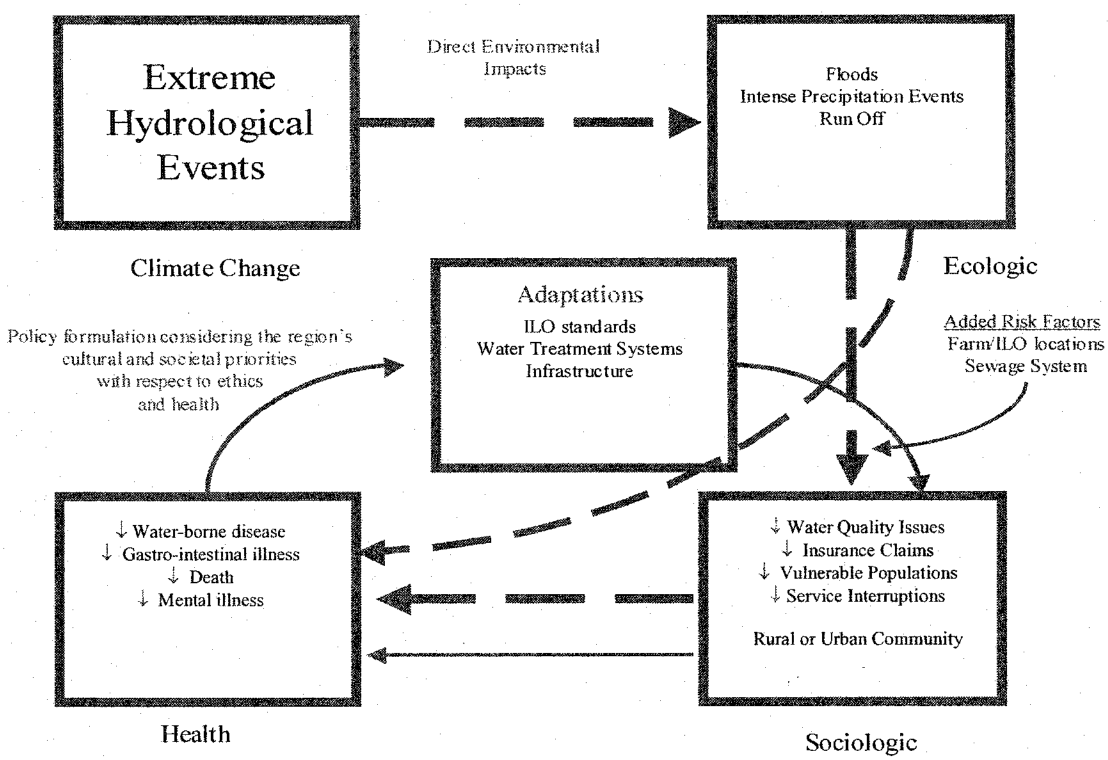
During and after (and possibly before, if there is warning) a flooding event, stress and discomfort levels in humans are elevated. But the long-term health impacts after a disaster, even once the community is on the way to recovery, may consist of lingering psychological problems. For example, a natural experiment in Bangladesh that measured selected behavioural problems before a flooding event, found that a significant number of children increased in aggressiveness and developed enuresis (i.e., involuntary passing of urine, especially at night) five months after the flooding event (Durkin et al., 1993).

3.4.8 Extreme Hydrological Events and Integrated Assessment Frameworks

Figure 3.4.8 depicts the proposed IAF of the ecologic, sociologic, health and adaptation modules associated with extreme hydrological events. It identifies the key plausible links (direct and indirect) between a climate scenario predicting more intense rainfall events and/or floods and the possible health impacts. As well it takes into account feedback loops that involve adaptation, providing insight to policy makers how to adapt to increased pressure associated with extreme hydrological events.

As mentioned above extreme hydrological events are associated with adverse mental health reactions and water-borne disease outbreaks. However, other adverse health outcomes include vector-borne disease outbreaks, gastrointestinal illness, death, injury and respiratory ailments as well. Within the proposed IAF there are also added risk factors such as type of sewage system, and proximity of a farm or intensive livestock operation to a drinking water source. These are important components as often it is contamination of drinking water with human or animal waste, in conjunction with an intense precipitation event, run off, or flood that causes a water-borne disease outbreak.

Figure 3.4.8. Integrated assessment framework of the direct and indirect pathways of how extreme hydrological events can impact the health of Prairie residents.



Blue depicts the direct and indirect pathways, and red exemplifies how adaptations could lessen any negative impacts.

Some linkages and modules will play a larger and more visible role in determining health outcomes associated with extreme hydrological events; for example, a water-borne disease outbreak that causes widespread morbidity and even death. Geographical regions and time will also need to be addressed, as certain places are more vulnerable (e.g., flood plains) and over time as technology is employed to adapt to previous disasters or if multiple disasters plague a particular region.

3.4.9 Extreme Hydrological Events: Review of Current Knowledge and Knowledge Gaps

There were no additional inclusion criteria imposed on extreme hydrological events. In general, studies needed to have both an ecological component and either a sociological, health or adaptation component. Other aspects or added risk factors associated with precipitating floods and intense precipitation events, or their undesirable health outcomes were also included under the category of ecological change, to provide additional information. These include: climate variability and El Niño; other natural disasters such tornadoes or hurricanes; run off of water from flooded areas; and a climate change premise. Table 3.4.9 shows the relevant peer-reviewed literature associated with the IAF.

3.4.9.1 Flooding

There was a range of health outcomes investigated in the peer-reviewed literature with respect to flooding. There was also a good distribution of rural and urban locations, and vulnerable populations were indicated in six articles. Added risk factors were mentioned in three articles, one of which had a climate change premise. This indicates that research has directly or indirectly investigated many of the linkages between health and flooding.

There are many studies that investigate the mental health effects associated with flooding. However, the majority originate in the United States or in the global arena. Only two papers (Square, 1997; Simpson-Housley, 1989) had a Prairie regional focus. Both were position papers and only referenced mental health as a health outcome or concern.

Five studies were prospective in nature, such that measurements of mental health were measured prior to the flooding event, thus allowing for more meaningful comparisons after the event. This study design provides good information about the mental health impacts of severe flooding. However, vulnerable populations such as children in a developing nation (Durkin et al., 1993) and older adults (e.g., age 55 or older) (Phifer, 1990; Phifer et al., 1988; Tyler and Hoyt, 2000) were the subjects of four of the five studies.

Phifer (1990) measured the pre-flood mental health of exposed and non-exposed older adults (55+ years), and found that the flood had effects on anxiety, depressive and physical symptoms that were present 16-18 months post-flood. The study also revealed that flooding had differential effects on anxiety levels and well-being on the basis of socio-demographic status (e.g., age, gender, occupational status, SES). For example, low-income individuals were more vulnerable to the adverse effects of a disaster than those with higher socio-economic status, and older adults (65+ years) were less susceptible to adverse impacts of floods than younger adults (55-64 years). In addition, men experienced a greater decline in well-being than women after the flood (Phifer, 1990).

Another prospective study was conducted by Ginexi et al. (2000), which randomly measured depression in Iowa one year prior to and 60-90 days following a flooding event in 1993. Results of the study found that pre-disaster depressive symptoms and diagnoses contributed to post-disaster distress. Although this paper investigates floods as a type of disaster relating to climate change that could affect the residents in the Prairies, other disasters may also occur (e.g., fire) or even work in synergy (e.g., drought and fire), possibly eliciting diverse psychological responses in the population.

Table 3.4.9 Peer-reviewed literature associated with the direct and indirect health impacts from an increased hydrological events scenario IAF

		Region					Ecologic Change								Sociologic Change								
First Author	Year	G	NA	CND	CP	DffG	FLD	IR/E	RO	OND	CV/EN	CC	ARF	Oth	IFD	VPL	Vpop	ADP	MIT	WQ/O	INS	R/U	Oth
FLOOD																							
Anders J	1994		✓				✓							✓									
Burke JD	1986		✓				✓										✓					U	
Cotton P	1993		✓				✓							✓									
Duke C	1994		✓				✓	✓		✓					✓								
Durkin MS	1993	✓					✓										✓					R	
Earls F	1988		✓				✓															R	
Fullilove MT	1996	✓								✓													✓
Fuortes L	1994		✓				✓																
Ginexi EM	2000		✓				✓																
Krug EG	1988		✓			✓	✓			✓													
Kukkula M	1997	✓					✓		✓				SS/LS							✓		R	
Kunkel KE	1999		✓			✓	✓			✓	✓	✓			✓						✓		$
Meier PA oo	1998																						
Miettinen IT	2001	✓					RF		RF						✓					✓			
Melick ME	1985		✓				✓										✓						
Morgan IA	1995	✓					✓								✓								
Phifer JF	1990		✓				✓			✓							✓					R	
Phifer JF oo	1989																						
Phifer JF	1988		✓				✓								✓		✓						
Schmidt CW	2000		✓				✓			✓			LS		✓	✓				✓			
Shippee GE	1982		✓				✓																
Simpson-Housley	1982				✓		✓									✓						R	
Smith BW	1996		✓				✓																
Smith BW	2000		✓				✓	RF															
Square D	1997				✓		✓						LS		✓	✓						R/U	
Stout CE	1990		✓				✓										✓						
Tobin GA	1996		✓					RF							✓								✓
Tyler KA	2000		✓				✓	RF							✓		✓					R/U	✓
RAIN EVENTS																							
Atherholt JL	1998		✓					✓	✓					✓						✓		U	
Bridgeman SA	1995	✓						RF	✓				LS							✓		R	
Bickford G	1999	✓						✓	✓				SS	✓						✓		R/U	
Casman E	2001		✓				✓	✓	✓			✓	LS/SS	✓				✓		✓		R/U	$
Christoffel KK oo	1985																						
Colford JM	1999		✓					✓					SS									U	
Curriero FC	2001		✓			✓		✓				✓								✓			
Dulcos P	1991	✓					✓	✓								✓						U	
Ebi KL	2001		✓								✓	✓		✓								U	
Greenough G	2001		✓			✓	✓	✓		✓	✓	✓						✓	✓		✓	R/U	
Health Canada	2000a			✓				✓	✓				LS							✓		R	
Kovats RS	2000	✓				✓				✓	✓	✓				✓	✓						✓
Kremer C	2000		✓				✓	✓		✓													
Laursen E	1994	✓						✓	✓				SS		✓					✓		R	
Mattson A	2000			✓				✓	✓				SS	✓		✓				✓		U	
Millson M	1991			✓				✓	✓				LS							✓		R	
Quinn NWT	2001		✓					✓		✓	✓	✓						✓					✓
Rose JB	2001		✓					✓	✓			✓	SS/LS							✓		R/U	
Rose JB	2000	✓	✓					✓				✓								✓			

TABLE LEGEND

G – Global
NA – North America
CND – Canadian
CP – Canadian Prairies

FLD – flood
IR/E – intense rainfall / event
RO – runoff
OND – other natural disaster
CV/EN – climate variability / El Niño
CC – climate change
ARF – added risk factor

IFD – infrastructure damage
VPL – vulnerable places
Vpop – vulnerable populations
ADP – adaptation
MIT – mitigation
WQ/O – water quality or disease outbreak
INS – insurance
R/U – rural / urban
Oth - other

Additional Notation:

RF – Risk Factor
$ - Economic Component
LS – Livestock
SS – Sewer System

oo- on order inclusion into table is based on abstract

Table 3.4.9 continued

		Health Consequence										Data coll		Model Type					
First Author	Year	RSP	MNT	DTH	INJ	MRB	WBRN	VBRN	PTSD	GI	Oth	QNT	QLT	IAF	Oth	CCS	FTD	Paper Type	Statistics
FLOOD																			
Anders J	1994							✓				✓						P/SUR	D
Burke JD	1986		✓										✓					P	MV
Cotton P	1993							✓										PSN	
Duke C	1994			✓								✓						S	D
Durkin MS	1993		✓								✓		✓					P/S	MR
Earls F	1988		✓						✓				✓					P	B
Fullilove MT	1996		✓															R	
Fuortes L	1994										✓		✓					CR	
Ginexi EM	2000		✓										✓					P/S	MR
Krug EG	1988			✓								✓						S	OER
Kukkula M	1997						✓						✓					P	D
Kunkel KE	1999			✓														R	
Meier PA oo	1998																		
Miettinen IT	2001											✓						S	D
Melick ME	1985		✓										✓					P	B
Morgan IA	1995								✓				✓					P	PC
Phifer JF	1990		✓										✓					P/S	MR
Phifer JF oo	1989																		
Phifer JF	1988					✓					✓		✓					P/S	MR
Schmidt CW	2000																	PSN	
Shippee GE	1982		✓										✓					P	B
Simpson-Housley	1989		✓								✓		✓					P	B
Smith BW	1996		✓								✓		✓					P	MR
Smith BW	2000		✓								✓		✓					P	B/PA
Square D	1997		✓				✓		✓		✓							PSN	
Stout CE	1990										✓		✓					P	D/B
Tobin GA	1996		✓		✓				✓				✓					P	MR
Tyler KA	2000		✓										✓					P/S	MR
RAIN EVENTS																			
Atherholt JL	1998												✓					P	MR
Bridgeman SA	1995						✓					✓	✓					P/S	MR
Bickford G	1999										✓	✓	✓					P/S	RA
Casman E	2001						✓								IA	✓	✓	Oth	
Christoffel KK oo	1985																		
Colford JM	1999										✓	✓						S	MR
Curriero FC	2001											✓						S	MC
Dulcos P	1991			✓	✓	✓	✓			✓	✓	✓	✓					P/S	D
Ebi KL	2001										✓	✓						S	PR
Greenough G	2001	✓	✓	✓	✓	✓		✓	✓		✓							R	
Health Canada	2000a			✓						✓		✓						P/S	D
Kovats RS	2000							✓		✓	✓							R	
Kremer C	2000			✓								✓						S	D
Laursen E	1994									✓	$	✓	✓					P/S	NP
Mattson A	2000											✓						P	D
Millson M	1991									✓			✓					P/S	D
Quinn NWT	2001														IA	✓		Oth	
Rose JB	2001						✓				✓							R	
Rose JB	2000											✓						S	D

TABLE LEGEND

RSP – respiratory diseases
MNT – mental illness
DTH – Death rate
INJ - Injuries
MRB – Morbidity
WBRN – water-borne diseases
VBRN – vector-borne diseases
PTSD – post-traumatic stress disorder
GI – Gastrointestinal disorders
Oth – Other illnesses

Data collection method (data coll)
QNT - Quantitative
QLT – Qualitative

IAF – Integrated Assessment Framework
Oth – others
CCS – climate change scenarios
FTD – Future Trends Estimation

** refer to Table 3.4.3 for description of annotations used for paper type and statistics.

The information gained from the above-mentioned prospective studies is important to assess the general mental health impact from flooding. However there are external validity concerns when applying these results to Canada or the Prairie region, as coping with the health effects of climate change depends the underlying social structure of the country. Papers reporting flooding disasters and the mental health effects are situated in the United States or Europe. Because both areas have different coping mechanisms (e.g., social support structure and health care access/facilities), populations may actually experience the disaster differently than in Canada. Thus, there is a need to conduct health-based studies with a Prairie regional focus.

Future studies should also investigate the sociologic impacts from floods at population and individual levels of analysis. In the past Prairie communities have had to cope and adapt to flooding disasters, however no studies have examined community adaptation strategies. This may be because a community cannot adapt readily to disaster, other than moving or building higher levees and dams. It is possible, therefore, that adaptation occurs at an individual level, such as buying a water pump or re-designing house structures to lessen the impact of the next flood. Thus, health impacts from flooding disaster, coping mechanisms, and economic costs associated with rebuilding and adaptation are also important to measure at an individual level.

3.4.9.2 Rainfall

There is a broad knowledge base for the linkages between the different modules in the proposed extreme hydrological events IAF, as 24 research articles met the inclusion criteria. Again the main gap lies in the lack of Prairie specific research. One third of the research articles are associated with either or both of the added risk factors: livestock and sewage system overflow. Nine articles were associated with a water quality issue or disease outbreak at the population level (sociologic module). Studies were then classified within the health consequence module only if disease or health outcome was identified at the level of the individual. Rural and urban locations were fairly evenly distributed between those studies that mentioned location. However, not a single study was Prairie specific.

As mentioned in the RTD, water quality issues are of major importance to Prairie stakeholders. With respect to extreme hydrological events, water-borne disease and water-related gastrointestinal illness are the primary concern. Individual water-borne disease outbreaks when investigated with epidemiological methods have been shown to be associated with intense precipitation events and/or flooding and run off within areas that contain agricultural livestock (Millson, 1991; Bridgeman, 1995; Health Canada, 2000a).

Although a point source of water contamination can be sometimes identified, often the source of contamination and reason for the water-borne disease outbreak cannot be found. This may be because the source of contamination has occurred in a place far removed from the outbreak location. A unique study conducted by Curriero et al. (2001) investigated the geographical distribution of reported water-borne disease outbreaks within the different watersheds throughout the United States and their association with extreme precipitation events. The results indicated that 51% of water-borne disease outbreaks were preceded by precipitation events above the 90^{th} percentile, and 68% above the 80^{th} percentile (Curriero et al., 2001). This study emphasized the need to conduct climate change and human health research on an ecosystem level, as opposed to a geo-political level.

Seven studies had a climate change premise, three of which were review articles (Rose et al., 2001; Greenough et al., 2001; Kovats, 2000). However, only two of these studies attempted to model the health or sociological impacts associated with extreme hydrological events. Quinn et al., (2001) investigated the affect that floods (and multi-year droughts) could have on crop production in the San Joaquin River Basin in California, as the economy is agriculturally dependent, thus dependent on the river. However, at the same time the basin is a complex, fragile water-dependent ecosystem, and the source of drinking water for over 20 million people. Casman et al. (2001) used an influence diagram to cover a broad range of influences that affect cryptosporidiosis outbreaks, including medical, engineering, environmental, and psychological factors.

Water quality issues are not only important in times of extreme precipitation, but also at times of drought. In conjunction with intense rainfall events, other more complex environmental situations may be brought about by climate change that could affect water quality. For example, an intense rainfall event could increase bacterial contaminants in surface waters. However, in drought like conditions, evaporation could potentially increase the concentrations of pathogens in surface waters as well as increase the temperature of the water. Therefore it would be necessary to not only investigate and monitor the baseline concentrations of parasites in surface waters, but also how they could change with warmer temperatures and less water. In addition, how could warmer surface waters affect the survival and virulence of parasites in the Canadian Prairies at normal and decreased water levels?

3.4.10 Changing Ecosystems

Although it would be ideal to tabulate the peer-reviewed literature and propose an IAF for changing ecosystems and associated vector- or rodent-borne disease as it was done for heat, drought and extreme hydrological events, it is a far more complex issue. This endeavour would require a large interdisciplinary team including biologists, ecologists, entomologists as well as epidemiologists to integrate the various component parts into a single model and is beyond the mandate of this thesis. Thus, below is a summary of some of the vector-, and rodent-borne diseases predicted to be of importance under warmer atmospheric conditions in the Prairie region.

When considering rodent- or vector-borne diseases as a human health threat, there are usually four key players: reservoir (often mammals or birds); vector (insect or rodent); pathogen (bacteria, virus, or protozoa); and, host (humans). All must be able to interact, survive and propagate to perpetuate the cycle. Unlike humans, capable of escaping adverse weather and unfavourable climate, pathogens, reservoir, and vector are susceptible to changes in weather and climate variability. Weather events and climate variability can help or hinder insect or rodent reproduction, behaviour, and survival, and consequently influence the reproductive capacity of their pathogens within. The three climatic factors that are especially important are temperature (all year round), rainfall, and humidity (Gubler et al., 2001).

Human activities and behaviour can also play an important role in the ability of vectors to pass disease to humans. International travel will likely facilitate the introduction of foreign diseases, and possibly their vectors from other parts of the world, but the threat will be relatively small in developed countries (Gubler et al., 2001). However, rising temperatures, increased use of air conditioners and indoor living could decrease the likelihood of vector-borne disease outbreaks.

Using the Canadian Climate Impacts Scenarios (CCIS), CGCM1 climate model, the summer (JJA months) daily minimum and maximum temperatures in the Prairie region are expected to increase (from the 1961-1990 baseline*) by 2-3°C and 2-4°C by 2050. Spring (MAM months) daily minimum and maximum temperatures are expected to increase 2-7°C and 1-6°C by 2050. The derived relative humidity is expected to change in both the summer and spring months with the southern portion of the Provinces becoming drier, and the northern portions becoming slightly wetter (CCIS, 2001). Another possibility not explored in this section is how fall/winter temperatures may affect pathogens within the reservoirs (e.g., rodents and birds).

Vector-borne diseases are classified as those that result from infections transmitted to humans by blood-feeding arthropods (e.g., mosquitoes, ticks, fleas). Transmitted pathogens include viruses, bacteria, protozoa, worm parasites, and rickettsiae; they spend part of their life cycle within a cold-blooded arthropod vector, making them susceptible to environmental influences. Rodent-borne diseases are less dependent on temperature, and transmission relies more heavily on rodent population density and behaviour, which is dependent on climate and climate variability (e.g., El Niño) (Guber et al., 2001). In Canada, and more specifically in the Prairie region, the vector-borne diseases of most concern are: Western equine encephalitis (WEE), Lyme disease, Rocky Mountain spotted fever (RMSF), and hantavirus pulmonary syndrome (HVP) (Last et al., 1998; Duncan et al., 1999).

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* Baseline minimum and maximum temperatures: spring –8 - 2°C, -2 - 8°C; summer 10 - 15°C, 15 - 25°C. Temperatures become cooler towards the north and mountain parks. Summer relative humidity is lowest in the south central Prairie region.

3.4.10.1 Western Equine Encephalitis

Western equine encephalitis is transmitted to humans mainly via the mosquito, *Culex tarsalis* (McLintock et al.1970). *Cx. tarsalis* is indigenous to the Prairie region (Darsie and Ward, 1981), and its main animal hosts are birds (Shemanchuck and Morgante, 1968; Waters, 1976). Reported outbreaks of WEE in horses and humans have occurred sporadically in the past (Medovy, 1976).

Wild birds are found to be the natural carrier of the WEE virus (Burton et al., 1966). However, in the summer months, the WEE virus spends most of its existence in the vector mosquito where the viruses are subject to temperature variation (Reeves et al., 1994). Weather conditions are a major determinant of sufficient mosquito populations needed for outbreaks of WEE, although having large mosquito populations does not necessarily mean an outbreak will occur (McLintock, 1976). The climatic conditions most conducive to the adult *Cx. tarsalis* in Manitoba are precipitation (above the 1976 average reported in the study) followed by warmth (2°C above the 1976 average reported in the study), with temperature being the more important factor (Fraser and Brust, 1976). With climate change, the temperature requirements for *Cx. Tarsalis* may become more optimal. But, decreased humidity and precipitation may make for less favourable conditions. One possible consequence of these types of conditions on human WEE outbreaks could be more seasonal or variable patterns.

In the laboratory setting, the time between mosquito infection with WEE and first transmission from the mosquito decreased with increasing temperatures. However, the transmission rates of mosquitoes (their ability to transmit the virus) declined at temperatures greater than 20°C (Reisen et al., 1993). In California, the survivorship of *Cx. tarsalis* declined with increasing temperature; it will become a less competent vector for WEE when temperatures exceed 30°C (Reeves et al., 1994). Other factors, such as flooding that leaves stagnant water sources or pools for mosquitoes to breed, followed by hot dry weather, could amplify the health threat from encephalitis, but if the flood were followed by cool dry weather, the threat could also diminish (Cotton, 1993).

Heat, drought, and decreased precipitation can enhance the capabilities of mosquitoes and their pathogens in several ways. Mosquitoes can have increased survival and longer season length at higher latitudes. The susceptibility of some mosquitoes to pathogens can be altered and the feeding rates of mosquitoes can be changed. Low rainfall can create habitats by creating pools in rivers, and by increasing container-breeding mosquitoes. Finally, temperature can decrease the time between mosquito infection with a pathogen, and its ability to infect humans with disease. The main summer limiting factor for mosquito-borne diseases would be the decrease in humidity, which decreases vector survival (Gubler et al., 2001).

It has been suggested that mosquito-borne diseases, such as malaria, dengue, and yellow fever, could possibly move northward into Canada (Last et al., 1998; Duncan et al., 1999). How these diseases will evolve in the Prairie region under climate change is not known. It is possible that because of the predominance of drought, predicted by climate change and the cold winters, these diseases may not pose as great a threat to Prairie residents as is predicted for Eastern Canada (Duncan et al., 1999).

3.4.10.2 Lyme Disease

Ticks are second to mosquitoes in their importance as vectors of disease to humans and animals (Green and Costero, 1993). Lyme disease is a major public health concern in the United States, with approximately 8,000 cases diagnosed each year; however, in Canada, the tick vectors are not well established. The causative organism of Lyme disease in humans is *Borrelia burgdorferi* and is maintained in mammalian reservoirs – the white-tailed deer, the white-footed mouse, and the dusky-footed woodrat (Hamilton, 1996).

The main species of ticks that are responsible for the transmission of the *B. burgdorferi* to humans are: *Ixodes dammini* (now recognized as *I. scapularis* (Health Canada, 1999b)), *I. pacificus,* and *I. scapularis* (Gubler et al., 2001). Currently, the only known established populations of *I. scapularis* in Canada are on the Long Point peninsula and Point Pelee National Park, both located on Lake Erie, Ontario (Health Canada, 1999b). Although *I. scapularis* has been detected in all the Prairie Provinces (Health Canada, 1993; Health

Canada, 1999b), they are in low numbers and were possibly transported as larvae or nymphs, on birds migrating from endemic areas to the south (Klich et al., 1996).

Because of international travel, the nearness of Canada to endemic areas in the United States, the expanding geographical range of the various tick species (Landquist and Hill, 1991; White et al., 1991) and this possible link to climate change, Lyme disease may become a threat to Prairie residents. Thermal requirements for the females to begin to lay eggs in Long Point, Ontario, were 82.4-168.3 degree days (DD) over 6.0°C*, and 650 DD above 11°C for the emergence of larvae (Lindsay et al., 1995). According to a study by Lindsay et al. (1995), northwestern and southern Ontario are the most likely areas for *I. scapularis* expansion because they meet the thermal regulations and support white-tailed deer populations.

With climate change, increased thermal temperatures may allow for the establishment of the *I. scapularis* in the Prairie Provinces, because all Provinces have populations of white tailed deer. A study by Estrada-Peña (1998) employed satellite imagery to access the habitat availability for *I. scapularis* in both Canada and the United States, on the basis of temperature and vegetation data. This study noted that the arid region of North America has restricted the western distribution of *I. scapularis*. This is plausible given the need for high relative humidity by the species. However, the study concluded that habitat suitability for *I. scapularis* in Manitoba and southern Saskatchewan were medium to high, and low-medium suitability for parts of northern Alberta (Estrada-Peña, 1998). This suggests that given the right circumstances (which could be attained under climate change) the Prairie Provinces may eventually host the tick species responsible for the spread of Lyme disease to humans.

3.4.10.3 Rocky Mountain Spotted Fever

Rocky mountain spotted fever (RMSF) is also transmitted by tick species, principally *Dermacentor andersoni* and *Dermacentor variabilis* (Fishbein and Dennis, 1995). It is the

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* Cumulative degree-days (DD) are calculated by subtracting the threshold temperature from the mean temperature for each day (e.g., a day with a mean temperature of 25°C has 19 degree days above the threshold of 6°C) (Lindsay et al., 1995).

vector for the disease causing bacterium *Rickettsia rickettsii* (Reed, 1993), and has a death rate in humans of over 20% if left untreated (Harden, 1990). Its mammalian reservoirs are rodents and other mammals, including dogs (Gubler et al., 2001). Both tick species are endemic to the Prairie Provinces. *D. andersoni* occupies the region east of the Rocky Mountain foothills and the grassland zone of Alberta and part of Saskatchewan. It is then replaced by *D. variabilis*, which is adapted to the more humid summers of the eastern deciduous forest ecozone of eastern Saskatchewan and Manitoba (Wilkinson, 1967).

With the discovery of a vaccine and antibiotics in the first part of the 20th century, the number of reported cases and human deaths in the 1950's from RMSF were greatly decreased. However, in 1970s there was an unexplained resurgence in the rates of disease in the United States (Harden, 1990). How climate change will affect the tick species responsible for the transmission of RMSF to humans and *R. rickettsii* in the Prairie region needs to be investigated more fully. However, it is noted that the transmission season for RMSF is longer in warmer regions (Gubler et al., 2001).

3.4.10.4 Hantavirus Pulmonary Syndrome

Hantavirus Pulmonary Syndrome (HVP) is the newest zoonotic disease to present itself in North America; the first case was reported in the United States in 1993. The hantavirus (genus *Bunyavirus*) is carried by many rodent species and transmitted to humans via the inhalation of aerosolized hantavirus from rodent excreta and saliva (Health Canada, 1994; Gubler et al., 2001). The rodent most often associated with HVP is the deer mouse, which has a wide and diverse range throughout North America (Health Canada, 1994; Glass et al., 2000), making the reservoir for the hantavirus quite dynamic.

The first three Canadian cases of HVP recognized during active surveillance were in British Columbia in 1994 (Health Canada, 1994). However, HVP was not made a nationally notifiable disease until January 1, 2000 (Health Canada, 2000b). As of December 31, 1999 there have been 32 confirmed cases, all from western Canada, with a fatality rate of 38%. The majority of cases have been from Alberta (numbering 20), but Saskatchewan and Manitoba have also reported cases, with rural, less densely populated areas experiencing the greatest burden of disease. Research on potential exposures to hantavirus prior to the onset of illness suggests that infection likely occurred during domestic and farming activities for 70% of the cases (Health Canada, 2000b).

It has been suggested that human cases of HVP may reflect the yearly and seasonal patterns of high rodent population densities (Mills et al., 1999). This is mainly because of a greater chance of human exposure to the hantavirus. Large increases in population numbers of rodents have been observed at specific locations over time. In addition, varying population densities have been seen over short distances (Glass et al., 2000). The 1993 outbreak in the United States was associated with a 20-fold increase in rodent populations from the previous year. Also, once the rodent population densities decreased to normal levels, hantavirus infection rates within rodents also decreased (Engelthaler et al., 1998). Large increases in rodent populations have been linked to mild wet winters, and to above average rainfall followed by drought and higher than average temperatures (Engelthaler et al., 1999).

In Canada, the human HVP infection cases occurred in all months except March (Health Canada, 2000b). In the United States Four Corners region, the seasonality of HVP cases varied by location, elevation, and biome, with most grassland, Great Basin scrub, and montane conifer cases occurring in spring and summer (Engelthaler et al., 1999). All cases of HVP occurred below 2,500m, with 66% between 1,800 and 2,500m (Engelthaler et al., 1999). Vegetation type was also linked to hantavirus antibody-positive deer mice. Sites that had at least one positive-antibody deer mouse were associated with higher elevations, and more dense, but less uniform vegetation (Boone et al., 2000).

El Niño Southern Oscillation (ENSO) is the periodic warming of surface waters in the eastern half of the equatorial Pacific and is the best known example of natural variability, which occurs in a somewhat regular cycle (Kovats, 2000). In Canada, it is associated with drier and warmer winter conditions (Francis and Hengeveld, 1998) and has been more frequent and persistent since the mid 1970s (Bruce et al., 1999). Research has indicated that climate change may be increasing the frequency, intensity, and persistence of ENSO events (Bruce et al., 1999). ENSO is thought to be somewhat predictive of the climatic conditions to be expected under climate change.

The number of cases of HVP was negatively correlated with the number of months from the end of the El Niño period, meaning that as the El Niño event becomes more distant, less cases per month of HVP occur (Engelthaler et al., 1999). Using satellite imagery combined with epidemiological surveillance, environmental conditions were shown to have varied with the presence of ENSO. These observations support the view that El Niño may increase the likelihood of HVP outbreaks (Glass et al., 2000).

The environmental risk factors for HVP infection in humans can be divided into those that are endemic and those that are epidemic (Engelthaler et al., 1999). Endemic factors are those static habitat structures that support populations of rodents (e.g., deer mice) that are reservoirs for hantavirus in a particular geographic area. Epidemic environmental factors are mainly dynamic events associated with large-scale environmental changes (e.g., precipitation followed by drought and increased temperatures, El Niño) that support increased rodent populations in the geographical area (Engelthaler et al., 1999).

3.5 Conclusions

The social, demographic, economic, and environmental conditions within of the Prairie Provinces make them a unique and important region in Canada. This region plays a key role in the production of primary foodstuffs (e.g., beef and grain), has a relatively small population base, and consists of the grassland and boreal forest eco-regions. Because the Prairie residents are reliant on these conditions for their way of life, disruptions in the environment from climate change will make theses populations vulnerable. For example, intensive livestock operations and heavy rain can affect water quality; rural populations may experience more stress during times of drought and decreased agricultural production; and drier climates may make forest fires in the boreal region more common and thus increasing respiratory distress.

Although each IAF has specific gaps in knowledge that need to be addressed, two specific themes ran through all three IAF: 1) the lack of Prairie specific research; and 2) the lack of modeling of the health effects. Both of these deficiencies in knowledge can be partially reversed through the use of what is already known and through the establishment and innovative use of baseline health status.

It was evident that Prairie specific research was rare or even non-existent with respect to the linkages between the different modules in the proposed IAF. However, in some areas a lot of information was known about the different linkages. This was most evident in the heat scenario IAF. Although it is important to undertake more investigation into the linkages, this will take both time and money.

The above critique of the individual IAF points to the gaps in knowledge of possible primary importance for continued investigation by disciplinary sciences in order to further the above IAF. However, at this point it may be more feasible, with respect to time and money, to begin investigation into baseline health status of Prairie populations. Baseline refers to the health status of populations under normal or non-extreme climatic conditions for a particular location. Baseline status will promote Prairie-specific research in addition to advancing knowledge, and it is feasible for three reasons: 1) statistical power; 2) money; and 3) time.

As mentioned above, the Prairie region is both small in population and has a spacious geography. Both of these reasons make it difficult for epidemiologists and others to find statistically significant relationships between climate or weather and human health. However, there are ample studies (as the literature suggests) that point to weather and climate sensitive health outcomes. Investigating the baseline health status of Prairie populations with respect to these weather sensitive outcomes will allow climate change and human health researchers to detect changes in health status with weather variability resulting from climate change. Thus, over time, as the climate changes, so will the health status of Prairie residents, and baseline will provide a measure against which to compare deviations.

Money is also a concern, as there is not an infinite amount of funding at the disposal of research to study climate change and human health. Using current knowledge regarding the links between modules in the IAF and then monitoring these changes into the future with respect to weather and climate changes will save money, as independent climate change and human health research groups will not have to repeatedly start at the beginning. This will also aid in comparing results across studies.

Last is time because climate is changing. Even if money were available, meaningful, valid, and high-quality research takes time. If baseline health status information were available, monitored, and regularly updated, researchers would not have to go through the data gathering and processing phases for every new study. As will be discussed in Chapter Four, a major limitation of climate change and human health research is actually acquiring and using the data.

The second underlying limitation was the lack of modeling of the various social, economic, and biophysical, components that together can affect the health of populations. Modeling uses expertise, current research, and mathematical formulae to estimate future impacts on health, associated with different decisions, or physical, biological or social inputs into the model. The range of outcome possibilities is employed to aid decision-makers in adaptive and mitigative decision strategy.

The more complicated the models become, the more uncertain model elements become. For example, social adaptations and economic fluctuations may affect the trends seen in the health data, and a researcher may not know how to statistically compensate for the confounding event. This is where baseline health status and monitoring of Prairie populations will become an important asset. Monitoring populations over a geographic area over time will allow for comparing adaptations or periods of economic decline, and new rates can be incorporated into a new model. Other information that is already known, such as Statistics Canada demographic data, previous applicable and high quality studies, and Environment Canada climate data can supplement models. However, it is important to note that IAF should not be used as the sole resource for decision-making, but rather aid in the decision-making process.

In addition to health baseline data, baseline data are needed for describing environmental quality and ecosystem health (to address problems regarding disease-bearing rodents and vectors). This is important because both are expected to change under climate change. Environmental quality and ecosystem health data need to be collected simultaneously with climatologic data in order to identify changes in baseline levels with changes in weather and climate variability.

This chapter addresses the effects from climate change that will negatively impact the health of Prairie residents, thus motivating the need for the current health care system to adapt to anticipated health burdens. However, it is necessary to mention that climate change could also lead to positive changes in the health of Prairie residents. For example, less extreme winters would likely lead to decreases in excess mortality associated with cold weather. Also, injury from slipping and falling during winter months likely would decrease, having the greatest impact on the elderly.

In addition, larger agricultural outputs likely would be attained in the Northern portions of each of the Provinces from extended growing seasons. Summer recreation and associated economic opportunities also likely would increase, and certain diseases associated with cold temperatures may become less of a threat to populations. These examples are backed more by extension from the published literature on the negative effects (likely owing to publication bias) than on anything published in support of positive effects at the time of writing.

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Chapter 4

Climate Change and Human Health in the Prairie Region: An "Ideal" Study Design

4.1 Setting the Context

Research into climate change and human health involves a great variety of resources, expertise, and data. There are many questions to be investigated and numerous barriers to be overcome in order to embark on meaningful and productive climate change and human health research. As in all frontiers of research, climate change and human health research requires a starting point. Guidelines for assessing the health impacts from climate change were drafted by the World Health Organization (WHO), Health Canada, and the United Nations Environment Programme (UNEP) and can be regarded as such a starting point (WHO, 2001). In the winter of 2001, the Organizations mentioned above gathered in Victoria, Canada, to agree on the outline and the format of climate change and human health assessment guidelines.

The discussions at the WHO workshop documented two components for a successful assessment of health impacts from climate change: *knowledge assessment* and *integrated assessment methods*. Knowledge assessment includes: conducting a thorough literature review, monitoring and archiving data, being involved in the peer-review process, and developing a communications strategy. More specific needs of the knowledge assessment include:

- Involve a variety of sector stakeholders from the beginning to guide priority setting;
- Involve multiple disciplines;
- Include shifts in social, demographic, and economic arenas in climate scenarios;
- Identify baseline health information from which changes will be monitored;
- Balance empirical analysis with scenario-based methods; and,
- Identify vulnerable groups within populations (WHO, 2001).

The second component, the integrated assessment method, includes:

- Employing an array of climate scenarios to use for the assessment of potential health consequences of climate variability and change;
- Identifying indicators (e.g., environmental health indicators) and conceptual frameworks;
- Applying comparative risk assessments to evaluate global public health;
- Using integrated assessment (IA) to understand the interactions and feedbacks within an entire system; and
- Utilizing economic assessments for cost estimates of resource investment (WHO, 2001).

Previous chapters represent the commencement of the knowledge assessment process, as well as the integrated assessment methods for Prairie climate change and human health research. In Chapter One, discussion on environmental health indicators, risk assessment, and integrated assessment (IA) was initiated. In Chapter Two, networking and involving stakeholders from the beginning was begun to guide priority setting by establishing a Prairie-wide stakeholder network in various sectors and disciplines, and by initiating Round Table Discussions; these identified priority research questions. In Chapter Three, a literature review was conducted within the context of an IAF, assessing potential health consequences associated with various climate change scenarios expected in the Canadian Prairie Provinces. Within these Prairie-relevant climate change scenarios, Chapter Three also identified the gaps in knowledge, as well as what is known about the health effects from climate change. The IAF provided a conceptual framework for a more specific IA. The chapter emphasized the need to begin accumulating baseline health information on Prairie populations from which changes in health status could be monitored.

Based on the recommendations in Chapter Three and the findings from the WHO (2001) workshop, in this chapter, an 'ideal' proposal is presented to begin the estimation of the baseline health status of populations in the Prairie Provinces, as well as to investigate possible weather-health relationships. In an 'ideal' world, there would be ample standardized health data, spanning long time periods over large geographical areas and at high resolutions; however, this is not usually the case. Thus, this 'ideal' research proposal is an exercise to underscore the challenges and the barriers associated with identifying the baseline health status of populations, and of weather-health relationships, as well as to identify the constraints under which research would be bounded in the 'real world'.

Chapter Four is divided into four sections: rationale, proposal, limitations and barriers, and recommendations and conclusions. The rationale section will provide the reasoning for drafting an 'ideal' proposal, and for the chosen study boundaries. The proposal section outlines the 'ideal' proposal objectives and methods for investigation. In brief, the two objectives are:

- Historical data collection and analysis of climate data; and
- Identifying weather-health relationships and the baseline health status of rural and urban Prairie populations.

For a more detailed description of the objectives, see section 4.3.1.

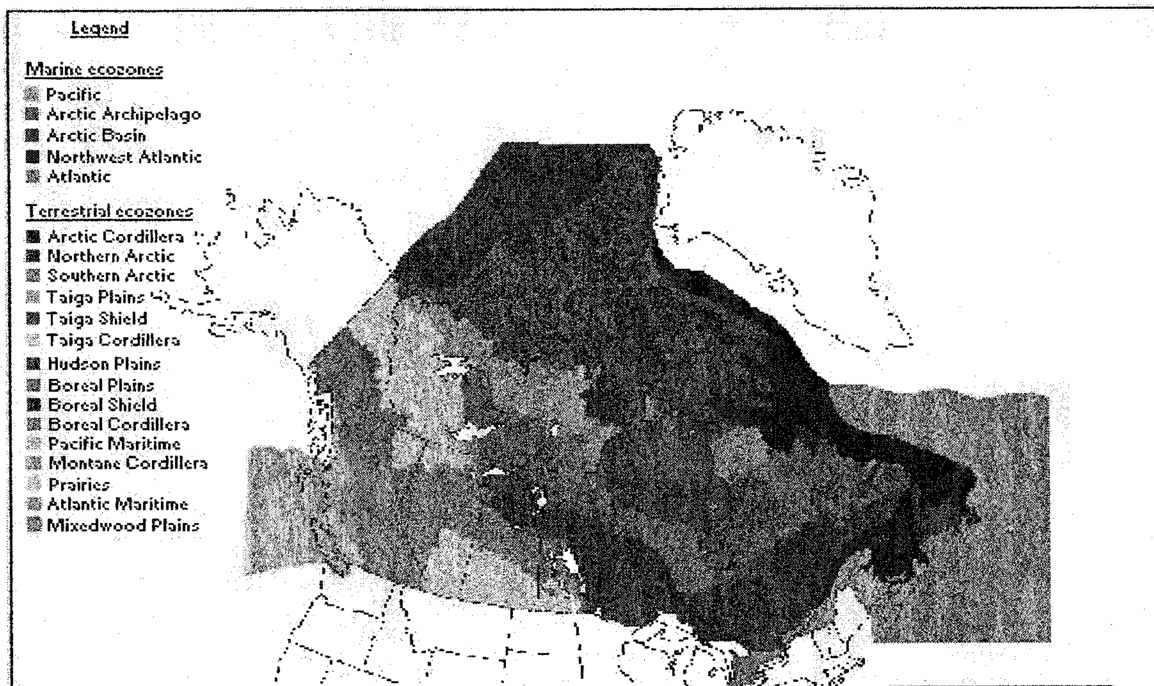
The limitations and barriers section identifies the 'real world' pitfalls associated with the investigation of weather-health relationships and the identification of baseline health status. This section focuses on the procurement of health data, the limitations with the use of health data, and the linking of health data to weather data. In addition, scenario-based power tables are discussed. Power tables provide insight into the ability of a study to detect a change in the prevalence or the incidence of diseases when, in fact, such a difference does exist. Power considerations are essential, particularly when comparisons involving smaller regions such as rural regions comprising relatively small population sizes. The final section presents recommendations.

4.2 Rationale for an 'Ideal' Proposal

Although an increasing amount of climate change and human health research is being conducted on a global scale, national- and regional-level research is increasing in importance. This is so because the health effects of climate change depend on two interdependent factors: (a) the local environment and how it will change under climate change; and (b) the underlying social context of populations experiencing the change. These factors vary across Canada.

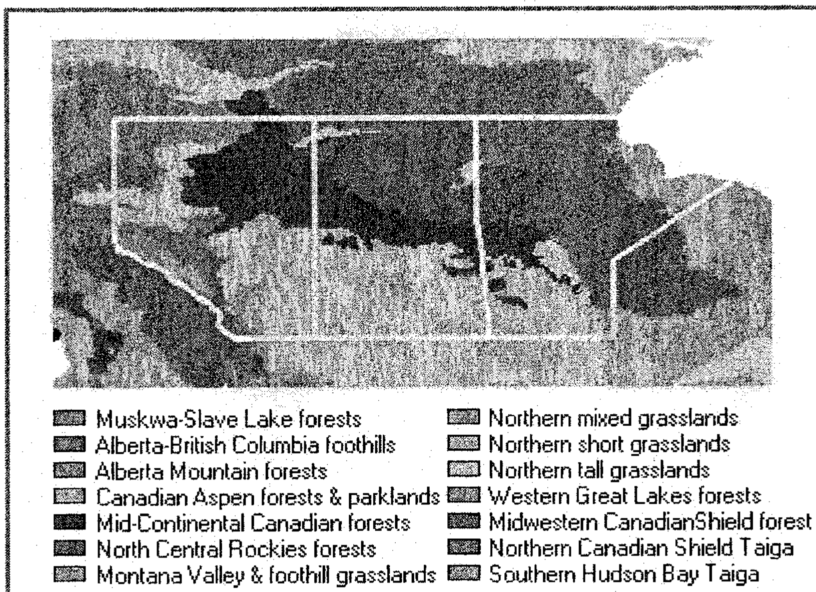
Canada is large geographically, including 15 different terrestrial eco-zones (Environment Canada (EC), 1996). Figure 4.2a depicts the various terrestrial and marine eco-zones of Canada. Seven eco-zones expand into the Prairie Provinces, and these include: the Prairies, the Boreal Plains, the Boreal Shield, the Montane Cordillera, the Taiga Shield, the Taiga Plains, and the Hudson Plains. Each eco-zone can be further subdivided into smaller units, such as eco-regions (Figure 4.2b), based upon similarities or dissimilarities in ecological characteristics, such as climate, soil or water properties, and wildlife (EC, 1996). One important geographical area that will be faced with a unique set of challenges with respect to climate change is the Prairies Provinces because they dominate Canada's agricultural sector (Herrington et al., 1997). In addition, these provinces have a significant investment (especially Alberta) in the extraction of fossil fuels (Herrington et al., 1997), which are a primary source of greenhouse gases responsible for much of the human-induced climate change. Figure 4.2b represents the eco-regions of the Prairie Provinces. There are 14 different eco-regions in the Prairie Provinces, each having its own specific set of climate change issues.

Figure 4.2a. The eco-zones of Canada



Source: State of the Environment Directorate, Environment Canada, 1996
www.ec.gc.ca/soer-ree/English/1996Report/Doc/1-6-2-4-1.cfm

Figure 4.2b. Eco-regions of the Prairie Provinces



Adapted from National Geographic Society, 2001

As previously stated, the environmental changes expected in the Prairie region under conditions of climate change include: more frequent and prolonged drought; longer and hotter heatwaves; more extreme hydrological events; and, changing geographical ranges of vectors and their pathogens. Although health impacts from climate change are situated within an environmental context, changes in population health often result from complex pathways that are embedded within society. This includes social support structures, culture, urban-rural populations, economics, and health resource availability, all of which, when associated with extreme weather and a changing climate, play a part in determining the underlying health status of populations.

Because social factors often differ between rural and urban populations, this study will differentiate between rural and urban locations in its identification of baseline health status and weather-health relationships. For example, health resource availability may differ between rural and urban populations because rural populations are often too small to support the same health services.

As mentioned previously, one objective of this 'ideal' study is to investigate the baseline health status and the relationship between weather variables and health outcomes in the Prairie Provinces. Because climate change scenarios depend on the underlying environment, it is natural to investigate health while respecting environmental boundaries. However, geopolitical boundaries do not respect environmental boundaries, and the pertinent geopolitical boundaries associated with human health in this study (i.e., Regional Health Authorities (RHAs), overlap both the Prairie and Boreal Plains eco-zones.

Despite this limitation, it was decided to investigate primarily the Prairie eco-zone (even though there will be some overlap into the Boreal Plains eco-zone for Rural Health Authorities (HAs), because the majority of the Prairie Provinces' population resides within the Prairie eco-zone (all major cities are within this eco-zone). Larger populations will make it easier to observe weather-health relationships, as well as changes in baseline health status. However, an improvement for climate change and human health research would be eco-regional-based health studies.

4.3 The 'Ideal' Proposal

There are two objectives associated with the 'ideal' proposal.

4.3.1 Objectives

The two objectives are:

4.3.1.1 Historical Data Collection and Analysis of Climate Data

To investigate historical climatic data, between the years 1961 and 1999, as it pertains to: 1) extreme weather events; and 2) particular extreme or unusual climatic years or seasons. The focus will be on the six major cities in the Prairie region (Urban Health Authorities), and four Rural Health Authorities.

4.3.1.2 Identifying Weather-Health Relationships, and Baseline Health Status of Rural and Urban Prairie Populations

Known or suspected weather-sensitive health outcomes will be extracted from various health databases: hospital admissions, physician visits, and Ambulatory Care Classification System (ACCS), and mortality. These health outcomes will be linked to the weather events identified under the first objective. Baseline rates for each health outcome will be determined for the study populations during periods of normal climatic conditions, and compared to observed health outcomes during times of extreme conditions.

4.3.2 Project Scope

Climate change is a concern for Canada because it will alter the environment in ways never experienced in human history before. Because we cannot predict the future, analogue studies are commonly used to provide insights. Thus, the goal of the first objective is to investigate historical climate data for extremes in weather and anomalous seasons or years, in the Prairie region. These extremes can be thought of as analogous to scenarios predicted under conditions of climate change (i.e., heat, drought, and extreme hydrological events).

The second objective builds upon the first, such that a relationship between weather and health will be determined. Weather-sensitive health indicators will be examined, and the baseline health status of Prairie populations under normal climatic conditions will be established. Baseline will be equivalent to the rate of disease prevalence or incidence under 'normal' climatic conditions. It will be compared to observed health outcomes during times of extreme conditions. Deviations of health outcomes from baseline during extreme weather events and anomalous years or seasons will provide insight into weather-health relationships. Analyses will be conducted with a view to rural and urban populations, and to eco-zone boundaries.

4.3.3 Methods

In general, each data type requires different collection, structuring, and analytical methods.

4.3.3.1 Data Collection

We will use daily meteorological data from EC and four sources of health data (physician claims, ACCS, hospital admissions, and mortality). Unless otherwise specified, physician claims, ACCS, and hospital admissions will be referred to collectively as health morbidity data, and the term "health data" is used to refer to all four data sources collectively.

4.3.3.1.1 Regional Health Authority Locations for Analysis

The six urban Health Authorities (HAs) were chosen as the HAs containing the largest cities in each Province (i.e., Edmonton, Calgary, Saskatoon, Regina, Winnipeg, and Brandon). The selection criteria for rural HAs were: the rural HA's proximity to any single urban HA or large urban centre (e.g., Lethbridge, Red Deer), and the size of the rural HA major population centres.

Rural HAs sought were those that were not directly adjacent to large urban centres in order to minimize the crossing over of rural to urban usage of health services. In addition, within each rural HA the largest towns or cities were less than or equal to 15,000 people, in order to maximize the rural and urban disparities in health services available and utilized. Rural HAs in the Northern portion of the Prairie Provinces were not considered because of issues associated with poor statistical power of studies that expand over large areas and have small populations.

Because of the size of rural HAs, it was difficult to locate rural HAs that adhered to the selection criteria and were entirely within the Prairie eco-zone. Thus, in order to obtain at least one rural HA from each Province, it was deemed necessary to have some overlap of rural HAs into the Boreal Plains eco-zone. The four rural HAs chosen were: (a) the Aspen Health Region – Alberta*; (b) Region 3 – Saskatchewan; (c) Region 5 – Saskatchewan**; and (d) the Parkland Regional Health Authority – Manitoba**.

4.3.3.1.2 Meteorological Data

Daily meteorological data from EC will be acquired for each of the 10 Regional Health Authorities (RHAs) chosen for the 1961-1999 period of analysis. The number and location of the stations used in the analysis will depend on the size of the RHA and number of stations within it. The meteorological variables to be investigated for extremes are: daily temperature; daily precipitation; and days with freezing rain, hail, smoke/haze, blowing sand and snow, and wind speed ≥ 28 knots.

4.3.3.1.3. Health Data and Health Outcomes

Four types of health outcome data will be acquired: a) hospital admissions; b) physician claims; c) ACCS; d) and mortality. These data will be obtained for each RHA between the years 1961 to 1999.

a) Hospital Morbidity Data will be obtained from the Canadian Institute for Health Information (CIHI). This database provides a count of cases separated through discharge or death from a hospital, by primary diagnoses. Variables of interest are: primary diagnosis, admission date, discharge condition, total days stayed, age, sex, and first three digits of residential postal code. Daily information is sought from each hospital in the study area, excluding rehabilitation hospitals and extended care facilities.

b) ACCS and Physician Claims will be obtained from each of the Provincial Ministries of Health for daily records. Variables of interest are: physician specialty, date of service, primary diagnosis or procedure, age at service, sex, and first three digits of residential postal code.

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* RHA is entirely within the Boreal Plains eco-zone.
** RHA partially within the Boreal Plains eco-zone.

c) Mortality Data will be accessed from Statistics Canada (Vital Statistics). All-cause daily mortality data will include: ICD-9 code (or equivalent) of death, date of death, age at death, sex, first three digits of residential postal code, and place of death.

4.3.3.2 Data Structuring

Each data source will need various levels of formatting or structuring.

4.3.3.2.1 Meteorological Data

Temperature and precipitation data from each RHA will be analyzed according to methods used by Bellisario et al. (2001), to identify the extreme weather conditions. We will identify the percentiles of extreme low (1^{st}, 5^{th}, and 10^{th}) and extreme high (90^{th}, 95^{th}, and 99^{th}) for temperature; and for precipitation, the top percentiles. Days will be coded as with or without the occurrence of the following: freezing rain, hail, smoke/haze, blowing sand or snow, and wind speed = 28 knots.

4.3.3.2.2 Health Data

Health experts and peer-reviewed literature were consulted to determine which health outcomes are most likely to change with climate change. These were then converted into ICD-9 codes and re-evaluated by a physician. Each morbidity and mortality data source will be structured separately, using the appropriate statistical methods. Because the study time period spans several ICD coding changes, techniques will be used to convert lower ICD codes to ICD-9.

4.3.3.3 Statistical Analysis

Morbidity and mortality data will be subjected to statistical analysis.

4.3.3.3.1 Human Health Indicators

Each health database will be statistically analyzed separately using SPSS 11.0®. Initial descriptive statistics will be calculated on the health data before linking it to weather data.

a) Determination of Baseline Rates for Health Outcomes

Monthly, standardized age-sex adjusted rates for each health outcome, for each year and database will be calculated from each data source, and for all health outcomes. These will provide baseline health status. No less than ten years will be included in a baseline rate calculation. Each RHA will be considered individually, and the baseline rates will then become age-standardized monthly expected values for each health outcome.

It is important to note that baseline health outcome rates may not be appropriate to use for all extreme events. For example, baseline rates can be used to compare health outcomes before and after heatwaves, drought periods, and extreme precipitation days or seasons because background events likely exist. However, they would not be useful for events like tornadoes where background rates would not exist; sudden disasters would need to be analyzed differently.

b) Examination of Extreme Events

Date, location and type of extreme event as calculated in section 4.3.3.2.1 will be matched to dates and locations of health outcomes in each database. Appropriate statistical analysis methods will be used to conduct descriptive, bivariate, and multivariate analyses, and the observed minus expected ratios where appropriate for each extreme event.

4.3.3.4 Interpretation

Interpretation will be conducted with a view to: a) defining weather-health relationships as they pertain to the Canadian Prairies; and b) providing baseline scientific knowledge regarding traditional health outcomes of rural and urban Prairie populations as they relate to extreme weather or anomalous climatic seasons or years.

4.4 Barriers and Limitations

This section will discuss the 'real world' barriers to such an ideal proposal, focusing on the use of health morbidity data. Four themes will be discussed: a) the procurement of health data; b) the limitations of using the different types of health data; c) the linkage of health data to weather data; and d) the issues associated with statistical power when detecting changes in baseline health status.

Although the above proposal details the need for health data from the three Prairie Provinces (Alberta Health and Wellness (AHW), Saskatchewan Health, and Manitoba Health), and two national agencies (i.e., CIHI and Statistics Canada), the barriers presented in this section will focus on AHW data. This is because the expertise needed for an in-depth examination of the barriers is readily available*. However, attempts will be made to include CIHI and the other Provincial Provinces in the discussion where possible. In-depth discussion of all aspects is beyond the scope of this thesis.

4.4.1 Types of Health Data

There are three general types of health data collected on the health of individuals. The first type is information collected for a specific health problem or research question, usually in the form of survey or questionnaire data. The second type are data collected by other agencies or organizations that have relevance to health, such as when school boards collect data on children and visits to the school nurse. The last type of data, and which are of most interest to the epidemiologist, are those relating to the provision of medical treatment, the focus of this section.

Data related to the provision of medical treatment have three basic sources of information. The first is physician visits. When a patient visits the doctor for an ailment, a physician keeps a record of the person, the reason(s) for the visit, and the service(s) provided. Each procedure (e.g., wart removal) or diagnosis (e.g., viral pneumonia) is coded using an ICD-9-CM and a bill is sent to the Government for physician payment for the services provided. In Alberta, up to three ICD diagnostic codes can be recorded for a single visit. This provides a means of recording information about conditions for which individuals might seek the help of a physician.

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* The expertise used for section 4.4 (with exception of section 4.4.5) was based on personal communication with Dr. Donald Schopflocher, Biostatistician, Health Surveillance, Population Health Division, Alberta Health and Wellness.

The second source of medical treatment data is hospital admissions. When a patient is admitted to a hospital (for a stay that lasts at least one night), a paper or computer record is initiated for that patient. Attending physicians and allied health care professionals then add information to this record every time the patient is seen. When the individual patient is discharged, a medical records coding expert, using ICD codes, will transfer information from the paper record to a computer record according to the various diagnoses and/or procedures the patient undergoes. This is done for tracking purposes. A hospital record allows up to 16 different ICD diagnostic codes.

All hospitals in Canada must forward hospital admission records to the CIHI. CIHI formats and standardizes the information, and relays it back to the Province. It is also made available to researchers to purchase. Data formats have changed markedly over the years, making longitudinal studies difficult. As a result, hospital admission records are most often used only since 1994.

The third type of medical treatment data is ambulatory care data, collected in Alberta through the Ambulatory Care Classification System (ACCS). This data set contains information regarding patients that have had contact with a health professional in a non-office setting, but not in association with a hospital admission. This includes individuals that have day surgery, visit a clinic within the hospital, or visit the emergency department. This information is available only in Alberta, beginning on April 1, 1997. CIHI is spearheading an initiative to establish a national ambulatory care data reporting system. It was piloted in Ontario in 2001.

4.4.2 Limitations to the Procurement of Health Data

The main limitation is that the needed data may not exist. ACCS data are available only for the Province of Alberta, and starting in April of 1997, and hospital admissions from CIHI are generally available beginning with the 1994-95 fiscal year. Other limitations in attaining data stem from the fact that data are generated for accounting purposes. Because the data are structured for internal accounting purposes, it can be difficult for outside agencies to acquire the data in a format amenable to their purposes.

As evident in the 'ideal' proposal, climate change research requires a sufficiently long time-series (which is a single group research design, in which measurements are made at different times enabling trends to be detected (Last, 2001)) in order to delineate the signal from the noise. The noise includes seasonality, anomalous years, social issues, media coverage of a medical subject, or even a subtle change in physician diagnostic criteria and/or a diagnostic bias. All these trends, or potential confounders, need to be controlled so as not to bias the results.

Cost is another factor in the procurement of data. Data are expensive and may cost tens of thousands of dollars to obtain. For a research proposal, such as the one mentioned in section 4.1, processing of over 35,000,000 records per year for Alberta alone might be required. Thus, it is important to obtain a cost estimate for the data required for research. Currently, cost is estimated on a case-by-case basis, and an estimate may take several weeks to obtain.

Stringent rules and regulations are placed on the use of health data for research purposes because of confidentiality and privacy issues. Generally, to apply for health data, researchers first need a letter from a Research Ethics Board (REB) stating that the research process has been approved. An application, in the form of a proposal, must then be completed by researchers and submitted to AHW to secure their approval of the provision of data (AHW, 2001), which can sometimes take several months.

In addition to the application process, there is often a general misunderstanding between AHW, which owns the data, and the researchers who attempt to acquire them. The Health Information Act (2001) specifies that data may be released only to the level of specificity required to answer a research question. This requires that the researcher be extremely specific about the use of the data at the time of submitting the data request. This includes at minimum ICD codes, dates, postal codes, facility numbers, and physician specialty.

Developing these detailed specifications must become a collaborative process between AHW and the researcher because the researcher has little idea about the structure or format of the data, and because very limited public documentation exists about the nature of the data. Without close collaboration, this could be viewed as a "Catch 22" situation because specifications must be complete and precise in order for that request to be processed. Yet, no public information exists to allow the researcher to compile precise and complete specifications.

4.4.3 Limitations to the Use of Health Data

The most fundamental weakness in using health data for epidemiological research is that it is collected for economic and accounting purposes, not for research. Physician claims and hospital billings are done so that physicians can be paid and the Government can keep track of health care spending. This reality has implications for the use of health data for climate change and human health research.

There are several doctor-patient interactions that can artificially increase health outcome counts. In one, prior to ACCS data, the physician examines a patient and advances the patient to the emergency department because of a serious medical condition. Once at the emergency department, the patient may be seen by another physician, and then admitted into the hospital. This creates an overlap of physician claims data by generating two separate physician claim records for the same patient for the same problem.

Another interaction is in follow-up care. A physician may see a patient in the clinic for a medical problem and then request the patient to come back in a week for follow-up. Often, these diagnoses are coded identically at both visits (Kibria, 2002 PC). This could artificially introduce a lag time, inflate physician claims for a certain health outcome, or bias the results towards that of no effect for a weather-health relationship. For example, a patient visits a physician after a heat event for symptoms associated with exhaustion and this diagnosis is made. However, the physician asks the patient to return for a follow up visit one week later, and again codes the visit as heat exhaustion. This example illustrates how follow-up care can result in inflating physician claims (i.e., more than one claim for the same patient), artificially introducing a lag time (i.e., the average time between event and diagnosis increases), and suggests that heat exhaustion occurs at times when no heat event has occurred (i.e., one week later), indicating a no-effect relationship.

Physician billing, however, may also underestimate health outcome statistics. When physicians first see patients in their clinics, they can use up to three ICD-9 codes for the visit, but they are paid for only one (Kibria, 2002 PC). Thus, if a physician sees a patient for more than one problem, the physician may decide to code and bill for only the first item of concern during the visit, leaving the other spaces empty. On the other hand, a physician may choose to fill in all three positions for ICD-9 codes. However, often the researcher may request the primary diagnosis, leaving secondary diagnoses or procedures uncounted.

A similar underestimation of health outcome statistics may occur with hospital admissions data. When CIHI data are sold back to researchers, only the primary diagnosis (of 16) is available. This creates the problem of under-reporting co-morbidities that might be the underlying cause of the hospital admission. For example, an elderly person may be primarily diagnosed with an ischemic heart problem, but a secondary diagnosis could be heat exhaustion or stress.

Climate change and human health research must examine data in at least two dimensions: time and space. However, each dimension presents its own barriers and limitations.

4.4.3.1 Time

A time barrier to the use of health data is that data are sorted by the date the bill was received, not the date of the service. Physicians have up to six months to bill for their services. Reformatting of the data according to date of service can be done. However, there is a major cost involved because there are 35 million records for Alberta alone to sort per year.

Time-series analysis of data has several statistical limitations. Exposing all the details is beyond the scope of this thesis, but they do deserve mention. Data over time need to control for issues such as day of the week, monthly fluctuations, and season. One study analyzed the relationship between physician claims for asthma and daily ambient pollution rates in Fort McMurray, Alberta, and found that patients seek physician help mainly between Monday and Friday, and there were statistically significant monthly and seasonal fluctuations in physician claims for asthma (Schopflocher, 2001, unpublished data). Changes in health policy, diagnostic criteria, public awareness of certain illnesses (e.g., asthma), administration accounting reshuffling, and the development of new coding procedures (e.g., ICD-7 to ICD-8) will also have to be taken into consideration when analyzing data over time.

Although some types of data (mainly mortality) have been collected over the time period suggested for this study, ICD coding and the health care system have changed over this same period. Both will introduce quality issues into the data. For example, Medicare (the universal health care system for Canadians) was not in place for physician services or in-hospital care until 1971 (Health Canada, 2001).

ICD coding has also changed significantly since its inception. This is because of medical advancement, diagnostic technology, and extended life expectancy. Although using revised ICD coding improves the quality of data, matching ICD coding from an earlier version to a newer one (sometimes several times e.g., ICD-7 to ICD-9) may introduce some degree of misclassification.

4.4.3.2 Space

One future goal of climate change and human health research is to be able to study health within the confines of eco-regions, which do not respect geo-political boundaries. Geo-political boundaries make is difficult to study eco-regions that are not confined to one Province, let alone those that cross national boundaries. Data are traditionally organized within administrative borders, and to achieve eco-regional analyses would require an addition to the way that data are presented across administrative and political boundaries. Various kinds of cooperation would be needed to achieve this.

The only way to connect individual health data to eco-regional geographical location is through postal codes. Statistics Canada uses geocoding, where census households and postal codes are linked to block-faces (one side of a city street between two consecutive intersections) or enumeration areas (the geographic area canvassed by one census representative) (Statistics Canada, 1999a). Postal codes have been created for the postal service for delivering mail and are not static in nature. Postal codes are being created, retired and even moved to different locations over time, Canada Post updates these changes regularly throughout the year (Canada Post, 2002). As of November 2000, there were 122,962 postal codes in the Prairie Provinces (Statistics Canada, 1999b).

Considering the limitations of using postal codes for connecting health data to geographical location, adding eco-regional or geopolitical issues adds other dimensions of complexity. As cities and towns expand outwards from their centre, they may cross into different eco-regions, eco-zones, or geo-political boundaries. Once this occurs, eco-regional analyses become confounded by social and political processes such as: people traveling across eco-regional boundaries for health services; differing socio-economic status as richer individuals may choose to live in different eco-regions; and differing health care practices across the province, RHA, or municipality.

One example of this already exists in Lloydminister, a town of approximately 18,000 people that straddles the Alberta-Saskatchewan border. If a patient is a resident of Saskatchewan, he/she is covered by the Saskatchewan health care plan, and likewise for Alberta residents. However, both the Alberta and Saskatchewan sides are governed by two different Provincial standards, and within two different RHAs. It could be possible that physicians will bill differently, depending on the patient's resident province, or groups of similar people may choose to live in a certain province because of other forces like taxation or socio-economic opportunities.

4.4.4 Limitations to Linking Health Data with Climate Data

Time-series is only one dimension of the analysis phase of health data and, as noted above, there are several real and potential questions of compatibility and consistency that must be considered. In addition, space adds one or more dimensions on top of time in the analysis phase. The space dimensions of interest in the proposal outlined above are rural and urban, extending across RHAs, and extending over several Provinces. However, we still need to add the most fundamental variables in climate change and human health research, the weather variables, adding another dimension to the research.

Weather variables, like health data, are multidimensional in scope. Many studies have employed only one variable like temperature, or solar radiation. However, others have used a synoptic approach (e.g., air masses) or multiple variables like temperature, humidity and wind speed. The number of additional weather variables entered into the study design will dictate the following: the complexity and interpretability of the analysis and results; the ability to explain the unknown variance; the number of potential confounding variables; and the number of confounding trends needing to be controlled.

The first problem encountered with linking health and weather data is with linking weather data to geographically defined health outcomes. Weather stations are often concentrated in the southern portion of Canada, near population centres. In addition, not all weather stations measure all weather variables; some may measure only the most basic variables like temperature and precipitation. For example, in Alberta, there are 1,287 stations measuring daily minimum and maximum temperature, and daily precipitation (EC, 2002a). Volunteers are mainly responsible for the collection of these data (EC, 2002b). In contrast, only seven stations measure air quality, 144 stations measure hourly data (of which 12 are stationed in Edmonton and area), and 154 stations measure the rate of precipitation (EC, 2002a).

In the above 'ideal' proposal, it was suggested that there be both rural and urban accounting of weather variables, in order to study weather-health relationships. Most urban areas, especially those with airports, have hourly readings of weather variables for the purposes of supporting aviation and weather forecasting operations (EC, 2002b). Not only do urban areas usually have the most sophisticated and accurate weather records, urban

HAs also cover the smallest geographic areas. Thus, within urban areas, there is greater confidence that the majority of people are experiencing the same weather phenomenon.

In contrast to urban areas, rural areas have a different set of circumstances pertaining to the location and distribution of weather recording stations. First, the weather stations are not evenly distributed over space, such that there are fewer stations in remote areas. Second, rural and remote areas can cover larger areas of land, with smaller residential populations. Last, rural areas also may not have the same number of weather variables monitored as do larger centres; for example, only precipitation and temperature may be recorded. Thus, to investigate whether a population is experiencing the same weather event, researchers will have to rely on fewer weather stations spread over larger geographical space that measure fewer variables.

Weather variables change from day-to-day and hour-to-hour. Thus, there will always be a lag time between weather and the presentation of a health outcome to any health care facility. For some heat-related diseases, the lag time is quite short, maybe only 1 to 2 days. However, for other health-weather relationships, the time lag can be quite long, like in the temperature and food-borne disease outbreaks study conducted by Bentham and Langford (2001), which showed that outbreaks of food poisoning were more closely associated with temperature 2-5 weeks before the outbreak. This is problematic because health researchers often do not know this lag time, nor do they have enough information to make an educated guess.

4.4.5 Issues Associated with Statistical Power: Detecting Changes in Baseline Health Status

One objective of the above 'ideal' research proposal was to identify weather-health relationships and baseline health status of Prairie populations. However, detecting and monitoring changes or deviations from baseline health status is also important for climate change and health impact assessments. As discussed in Chapter Three, several illnesses likely will become more common with climate change in the Prairie region and will need to be monitored.

Epidemiological studies begin with an hypothesis (H_a), which is "a supposition, arrived at from observation or reflection, that leads to refutable predictions" (Last, 2001; 89). There are two types of error associated with the statistical testing of an hypothesis: Type I and Type II errors. A Type I error (α) refers to a conclusion that there is an association between exposure and disease when, in fact, there is no association. This is called a "false positive" finding. A Type II error (β) refers to a conclusion that there is no association between exposure and disease when, in fact, there is (Kleinbaum et al., 1998).

With respect to climate change and human health studies, where health information is at the population level, we are not only interested in determining the baseline health status of Prairie populations, but also what statistically significant change in disease can be detected, taking into consideration changing denominators (from the immigration and out-migration of populations). Thus, the study might posit H_a: 'the prevalence or incidence in disease will vary with changes in weather or climate patterns'. Like with the Type I error, we can "detect" a change in prevalence, when, in fact, there is none. Or, the opposite such that we do not "detect" a change in the prevalence when there really is one. By minimizing as much as possible, both Type I and Type II errors, researchers are attempting to maximize the power of a study, which is the ability of a study to demonstrate an association if one exists (Last, 2001). It is calculated as $1-\beta$.

Because it is impossible to avoid all error, epidemiologists often choose an acceptable amount of error. It is common practice in epidemiology to use a Type I error of 5%. That is, at least 95 times out of 100 we should conclude the right results, and a Type I error (or false positive) should occur only 5 times out of 100. Given a desired Type I error, and the size of the population within the study, we can calculate the power that a study would have to detect a change in disease prevalence or incidence (Kleinbaum et al., 1998). As the power of a study increases, it will better ensure that the difference detected is resultant from a change in the exposure. Furthermore, using a desired Type I error and study power, we can calculate the minimum sample size or population needed to detect a given change in prevalence or incidence of disease.

Although hypothesis testing is often associated with determining causation, it is important to note that correlation, not causation, is the objective of this section. Causation implies the relation of causes (exposures) to their effects (health outcomes), whereas correlation implies the degree to which variables change together (Last, 2001). There are several criteria that need to be met in order to reason that an exposure causes a health outcome. These are: the magnitude of the observed association; known biologic mechanism by which the exposure can plausibly increase the risk of disease; consistency of the study findings with other similar studies; the exposure should precede the outcome; and the presence of a dose-response relationship (Hennekens and Buring, 1987). Based on these criteria, it is clear that thinking about causality would be premature in this proposed study.

The next two sections use hypothetical climate scenarios and the known prevalence or incidence of a diseases to illustrate the power of a study to detect changes in weather-sensitive health outcomes, as well as population sizes needed in order to detect this change. Although, the ideal study proposes to investigate prevalence on a RHA level, the relevant data were not available at this level. Thus, health data from the Province of Alberta (only on a province-wide scale) were used because Alberta was the only province to have prevalence and incidence rates for certain weather-sensitive diseases aggregated by sex and age, available in the public domain. However, the conclusions derived from this section will be applicable to rural and urban populations, RHAs, as well as the other Prairie Provinces.

Tables 4.4.5.1 and 4.4.5.2a in the following section require some prior-mention as they aim to illustrate the relationship between the prevalence or incidence of disease, the population size, the Type I error, the power of a study, and how these relationships have implications for detecting change in weather-health relationships in rural and urban populations. From these tables, it is apparent that large populations enable the detection of very small changes in prevalence. However, these differences may not be clinically significant. Clinical significance refers to the difference in effect size that is considered by experts to be important for policy or clinical decisions (Last, 2001). Despite the possible lack of clinical significance for small changes, using large or moderate changes in prevalence would reveal only maximum power for all cells within the power table. Thus, these small changes in prevalence serve to illustrate how changes in population size can affect the power of a study to detect overall changes in prevalence. Calculations for determining power and sample size used for Tables 4.4.5.1 and 4.4.5.2a are supplied in Appendix A of this chapter.

4.4.5.1 Drought and Depression

As mentioned in Chapter Three, drought could lead to depression and mental health problems in Prairie farmers and rural communities. Climate can indirectly affect depression, mainly through increased financial difficulties and stress, especially for people whose livelihoods are weather dependent. If we were attempting to measure a change in the prevalence of depression in a population during a drought period, or over a series of drought years, would need to know two things: 1) what change in disease prevalence from baseline would be considered anomalous or statistically significant; and 2) if the study population had the necessary power to detect a change in prevalence.

Table 4.4.5.1 provides information on the power needed to detect small changes in prevalence, and the minimum population needed to detect a change in probable depression using maximum power, and a Type I error of 5%. For the population size, the use of larger changes in the prevalence of probable psychological depression were chosen to exemplify more realistic changes in prevalence that might be necessary in order to correlate a change in depression with other external factors, including changes in weather variables. For example, it may be possible to detect a 0.1% change in the prevalence of probable depression within an age-sex study population group with maximum power. However, we cannot say with any certainty that this change results from drought, as opposed to another confounding factor. Thus, larger changes in prevalence (e.g., 3.0%) as well as large populations, may be necessary in order to factor in the social context, such as market forces and government infrastructure that support drought-affected people, as well as climate variables into a statistical framework. It must be noted that causation is not the objective, but rather correlation between drought in conjunction with other social forces, and probable psychological depression.

Table 4.4.5.1 Power to detect a change in prevalence, and population size needed to detect a change in prevalence of probable psychological depression in Alberta, by sex and age .[1, 2]

	Population[3]	% Depressed[4]	Power[5]			Pop. Size (1000s)[6]		
			0.1%	0.2%	0.5%	0.5%	1.0%	3.0%
Females								
15-64	1 040 819	6.88	0.8106	0.9999	1.000	170.9	44.1	5.5
65+	172 785	2.35	0.4841	0.9673	1.000	65.4	17.9	2.7
Males								
15-64	1 085 679	3.60	0.9755	1.000	1.000	95.6	25.4	3.5
65+	138 259	0.95	0.7524	0.9993	1.000	30.6	9.3	1.8
Total								
15-64	2 126 498	5.24[7]	0.9959	1.000	1.000	133.9	34.9	4.5
65+	311 044	1.65[7]	0.8622	1.000	1.000	48.1	13.6	2.2

[1]Alberta was the only province to have prevalence rates of probable psychological depression aggregated by sex and age available in the public domain. Prevalence rates are 1996 values.
[2]Calculations for power and population size were conducted by PS- Power and Sample Size Calculation ® software, Version 1.0.17.
[3]The entire population of Alberta was employed. Statistics Canada, CANSIM II, table 051-0001.
[4]Percent probable depressed was estimated from *Health Trends in Alberta 2000*, figure F.2.1; pg 105.
[5]For a 0.1, 0.2, or 0.5 percent increase in the prevalence of probable depression within a predetermined age-sex group of the Alberta population, and a Type I error of 5%, what is the power of the study to detect this change?
[6]Minimum population size needed to detect a change in prevalence of 0.5, 1.0, and 3.0 percent increase in probable depression at maximum power (i.e., 99.99%), and a Type I error of 5%. All estimates are rounded up to the nearest 100 people.
[7]This was calculated as the average probable psychological depression between males and females.

Furthermore, eco-regional analysis of the health effects from climate change should be a next step in the research process. At these levels of analysis, the population base may not be sufficient to detect relatively small changes in prevalence. For example, in Alberta, both RHAs that contain the major cities each have in excess of 800,000 people. However, the Aspen RHA contains only 82,595 people, and the Northwestern RHA, which covers the largest land area, serves only 19,000 people (HEALNet, 2000).

4.4.5.2 Food-borne Disease and Warmer Temperatures

It has been estimated that, in the United States of America, there are as many as 9 million cases of food-borne illnesses every year (Buzby and Roberts, 1997), and most go unreported (Shewmake and Dillon, 1998). This may be because of the nature of most of the common food-borne illnesses. These lend themselves to relatively quick onset, general-type symptoms (diarrhea, nausea, vomiting, and fever) (AHW, 2000), and full recovery. Thus, many cases are not reported to health authorities. Because food-borne illnesses are temporary, it is the incidence of cases that is of interest.

Exact numbers of food-borne illnesses are unknown, and with the recent onset of climate change, these numbers are expected to increase. Very few numbers are actually recorded and the incidence rates of Campylobacter enteritis are much lower in the Alberta population than psychological depression (e.g., 5.24% prevalence of psychological depression versus 0.0435% reported incidence of Campylobacter enteritis in the age group 15-64 years). Campylobacter enteritis is an acute enteric disease caused by the *Campylobacter* bacterium, and is normally contracted by ingesting the bacterium in unpasteurized milk, in undercooked pork or chicken, or in other contaminated food and water (AHW, 2000). In order to illustrate the study power relationship with population size, it is necessary to use very small changes in incidence of Campylobacter eneteritis.

Table 4.4.5.2a depicts the incidence rate of Campylobacter enteritis per 100,000 for the various age-sex groups in Alberta for the years 1996 to 1998. There is sufficient power to detect relatively minute changes (0.05 of a percent) in the incidence of Campylobacter enteritis in the Alberta population as a whole, as well as in the other age-sex groupings (Table 4.4.5.2a). However, the same power and population size issues arise for food-borne disease as psychological depression with respect to eco-regional, and rural and urban analyses, and does not need to be repeated here.

Table 4.4.5.2a Power to, and population size needed to, detect a change in incidence of Campylobacter enteritis in Alberta, by sex and age.[1,2]

Age-Sex	Pop[3]	CE Incd. Rt[4]	% CE Incd.[5]	Power[6] 0.001	0.01	0.05	Pop. Size (1000s)[7] 0.5	1.0	3.0
Females									
0-14	304 458	48.75	0.0488	0.0535	0.3907	1.0000	7.7	3.6	1.1
15-64	1 040 819	40.50	0.0405	0.0646	0.9225	1.0000	7.5	3.5	1.1
65+	172 785	26.80	0.0268	0.0536	0.3777	1.0000	7.2	3.4	1.1
Males									
0-14	322 249	58.75	0.0588	0.0531	0.3556	1.0000	8.0	3.6	1.1
15-64	1 085 679	46.40	0.0464	0.0633	0.9015	1.0000	7.7	3.5	1.1
65+	138 259	32.40	0.0324	0.0524	0.2745	0.9998	7.3	3.5	1.1
Total									
0-14	626 707	53.75[8]	0.0538	0.0566	0.6364	1.0000	7.9	3.6	1.1
15-64	2 126 498	43.45[8]	0.0435	0.0781	0.9968	1.0000	7.6	3.5	1.1
65+	311 044	29.6[8]	0.0296	0.0559	0.5636	1.0000	7.2	3.4	1.1

[1] Alberta was the only province to have incidence rates of Campylobacter enteritis aggregated by sex and age available in the public domain. Incidence rates are calculated from 1996 – 1998 data.
[2]Calculations for power and population size were conducted by PS- Power and Sample Size Calculation ® software, Version 1.0.17.
[3] Statistics Canada, CANSIM II, table 051-0001.
[4] Campylobcter enteritis incidence rate/100,000 for the years 1996-1998, estimated from *Health Trends in Alberta 2000*, figure E.4C.3; pg 92.
[5]Percent incidence of Campylobacter enteritis.
[6]For a 0.001, 0.01, or 0.05 percent increase in the incidence of Campylobacter enteritis within a predetermined age-sex population in Alberta, and a Type I error of 5%, what is the power of the study to detect this change?
[7] Minimum population size needed to detect an increase in incidence of 0.5, 1.0, and 3.0 percent of Campylobacter enteritis at maximum power (i.e., 99.99%), and a Type I error of 5%. All estimates are rounded up to the nearest 100 people.
[8] This was calculated as the average male and female combined incidence of Campylobacter enteritis.

Expressing the incidence rate as a percentage, less than 0.06 percent of the population is inflicted with and seeks medical attention for Campylobacter enteritis in any given three year period. Because of this small incidence, it is useful to illustrate how many more cases of food-borne illness need to be reported in order to detect a change in incidence, providing a meaningful reference point.

Table 4.4.5.2b expresses the number of cases of Campylobacter enteritis for the given percentage of incidence, as well as the number of new cases that need to be reported to realize a 0.05 percent increase (this value is carried over from Table 4.4.5.2a) in Campylobacter enteritis for each age group in Alberta. For example, for the years 1996 to 1998, there were 925 cases of Campylobacter enteritis reported in individuals aged 15 to 64. However, in order to detect a 0.05 percent increase in incidence, 1 064 new cases (in a three year time span, like 1996-1998) would need to be presented to health authorities in this same group of individuals.

Table 4.4.5.2b Number of new cases of Campylobacter enteritis needing to be reported to increase the incidence of disease by 0.05% in Alberta, 1996-1998. [1].

Age Group	Population	% Incidence[2]	No. of Cases[3]	% I + 0.05%[4]	No. of Cases[5]	New Cases[6]
0-14	626 707	0.0538	338	0.1038	651	313
15-64	2 126 498	0.0435	925	0.0935	1 989	1 064
65+	311 044	0.0296	92	0.0796	248	156
Total Cases			**1 355**			**1 533**

[1] Calculations for the first row of this table are supplied within the footnotes.
[2]Total population incidence of Campylobacter enteritis taken from Table 4.4.5.2a.
[3]Number of cases of Campylobacter enteritis reported for the 1996-1998 incidence rate. All estimates are rounded up to the nearest case. Population × %Incidence/100 = 626 707 × 0.0538/100 = 338.
[4] % incidence column plus 0.05%. = 0.0538% + 0.05% = 0.1038%.
[5]Number of cases of Campylobacter enteritis reported for the increased incidence rate. All estimates are rounded up to the nearest case. Population × (% incidence + 0.05%)/100 = 626 707 ×0.1038%/100 = 651.
[6]Number of new cases to be reported in order to realize the 0.05% increase in incidence of Campylobacter enteritis in the Alberta population. New cases – number of cases = 651 – 338 = 313.

The number of new cases needed to detect a change in incidence is less in smaller populations, as would be the case in rural communities. However, because of power issues (studies with larger populations will have greater ability to detect smaller changes in incidence rates) the percent change in incidence for smaller populations will have to be greater in order to detect this change. Hence, smaller populations will need to report a greater percent of new cases than larger populations.

4.5 Recommendations and Conclusions

The use of health data from physician claims, hospital admissions, and ACCS data has both strengths and weaknesses. There is a vast amount of information on general interactions of individuals with the health care system, where public money is being spent on various procedures or diagnoses. However, as pointed out in the previous section, there are some fundamental costs, and statistical and methodological concerns, associated with using this information for research purposes.

The first major issue is the use of data for health research that was originally collected for other purposes: delivering mail, accounting, or documenting weather patterns. These data are appropriate for their intended use, but may be less suitable for health research. In a period of increasing research costs, limited funds available for research, and the need for ever-more detailed and retrospective data, the use of administrative health data may be more cost-effective and feasible than large-scale cohort or case-control studies. Indeed, there is a long tradition of using such records to the advantage of public health.

Because of the major limitations presented in the previous section, extreme caution must be taken when designing the methods, attempting statistical analysis, and interpreting results. It may be possible to provide basic descriptive statistics about weather and human health relationships to aid in informing policy decisions, and in creating new hypotheses to be tested by disciplinary sciences. However, these data should not be used to make definitive decisions, or infer casual relationships regarding climate change and human health.

A second issue is the quality and availability of the data from ACCS and physician claims for research purposes. As mentioned, their purpose is for accounting, and therefore there is no real way of knowing if these data can accurately represent the information researchers are trying to collect from them, or if the data are complete. Paper records are potentially the best way to delineate the true reasons behind health care utilization, but for logistical and confidentiality reasons, this is not an option on a population scale.

Thus, it is recommended that when collecting data for administration purposes, that governments and other agencies should keep in mind the uses of these data for research interests, promoting resource sharing and advancing the public health agenda. This is important because funding for research often comes from the government, the same agency that collects the data. Possibly through the future implementation of a computerized Health Information System, multi-user data collection could become more of a priority.

Although the shortcomings of using population scale and medical treatment data as a source for climate change and human health research seem daunting, the data used are far from useless. There is a vast amount of information within these databases that can be used, provided that caution is taken with the methods and analysis. The strongest studies that use these data sources may be those that relate most closely to their collection purpose (e.g., studies of health economics).

This chapter has identified the difficulties associated with linking weather, human health, and geographic (eco-zones, eco-regions, and postal codes) data together for the purpose of climate change and human health impact assessment. Thus, it is recommended that better data sources be established, or designed, to more easily link the three components. This may provide a more valid way to proceed to an eco-regional level of analysis.

Finally, because the social context plays a large role in determining the health effects that a population will experience from climate change, it is recommended that future research engage in evaluating the values, ethical principles and costs associated with a changing environment from the perspective of the people experiencing it. This will aid policy decision-making on initiatives that respect the needs and values of Prairie residents, as well as provide insight to Prairie-relevant adaptations and mitigation measures for climate change and human health problems.

In summary, climate change and human health research is emerging on the Canadian Prairies. As in all pioneering fields of study, climate change and human health research requires a starting point. Thus, based on the WHO, UNEP and Health Canada recommendations and findings from the Spring 2001 workshop in Victoria, Canada, an 'ideal' proposal was drafted as the basis for initiating research projects in the Canadian Prairie region. This chapter was an exercise undertaken to identify what data, time, and cost might be associated with a 'perfect world' research project. Above all, this chapter has presented what limitations would need to be considered as constraints to present study design options.

This 'ideal' proposal investigated the measurement of baseline health status as a way to compare the health status of Prairie populations under normal and extreme weather conditions. Such baselines are critical if change is to be assessed under various future conditions predicted by climate change. To measure baseline and change from baseline, mortality and morbidity data that have been collected on a population scale, namely physician claims, hospital admissions, and ACCS data, could be useful. However, not all the morbidity data needed are available. In line with drafting an ideal proposal, it is important to understand the boundaries and limitations of such a proposal, for the drafting of a more feasible proposal for eventual funding. Thus, some of the limitations of the 'ideal' proposal included those limitations associated with procuring health databases, the difficulty associated with using morbidity data to measure a human health response to extreme weather and anomalous years, and the difficulties that arise with linking health data to weather and climate data.

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Appendix A

Power and Sample Size Calculations for the First Rows of Tables 4.4.5.1 and 4.4.5.2a*

Study Design: Independent Prospective Cohort
Test Statistic: Uncorrected X^2
Outcome Variable: Dichotomous

F = cumulative probability distribution for a standard normal random variable
z_a = critical value that is exceeded by a standard normal variable with a probability of a.
d = effect size
s = standard deviation of the null (o) or alternative (a) hypothesis
n= observed response on n patients.

Basic Equations

Power: $1 - ß = F\,[d\sqrt{n} - (s_o/s_a)z_{a/2}]$

Sample Size: $n = [(s_o/s_a)z_{a/2} + z_ß]^2/d^2$

- Power and sample size formulas for a study design can be obtained by substituting the appropriate definitions of s_o, s_a, and d.

Prospective Cohort

- Probability (p) of outcome is employed to calculate the values of s_0, s_a, and d.
- Null Hypothesis: $p_o = p_1 = p$
- Alternative Hypothesis: $p_1 - p_o = \Delta$

Calculations (Table 4.4.5.1; females 15-64):
Power (of 0.1% increase in prevalence):

$$1 - ß = F\,[d\sqrt{n} - (s_o/s_a)z_{a/2}]$$

p_o = probability of the event at baseline
p_1 = probability of the event under conditions of climate change
Δ = the change in prevalence or incidence
q_1 = $1 - p_1$
q_o = $1 - q_o$
m = ratio of control to experimental subjects

$s_o^2 = pq(1 + 1/m)$
$= (0.0688)(0.9312)(2)$
$= 0.12813$
$s_o = 0.35796$

$s_a^2 = (p_oq_o)/m + (p_1q_1)$
$= (0.0688)(0.9312)/1 + (0.0698)(0.9302)$
$= 0.12899$
$s_a = 0.35916$

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* Calculations for the PS- Power and Sample Size Calculation® software and the above hand calculations is based on the paper by Dupont and Plummer (1990).

$d = \Delta/s_a$
$= 0.001/0.35916$
$= 0.0027843$

$1 - \beta = F\,[d\sqrt{n} - (s_o/s_a)z_{a/2}]$
$= F\,[(0.0027843\sqrt{1\ 040\ 819}) - (035796/0.35916)1.96]$
$= F\ 0.8913$
$= \mathbf{0.81}$

Sample Size (of a 0.5% increase in prevalence):
$n = [(s_o/s_a)z_{a/2} + z_\beta]^2/d^2$

Power = 0.9999
$z_\beta = 3.72$

$s_o^2 = pq(1 + 1/m)$
$= (0.0688)(0.9312)(2)$
$= 0.12813$
$s_o = 0.35796$

$s_a^2 = (p_o q_o)/m + (p_1 q_1)$
$= (0.0688)(0.9312)/1 + (0.0738)(0.9262)$
$= 0.13242$
$s_a = 0.36390$

$d = \Delta/s_a$
$= 0.005/0.36390$
$= 0.013740$

$n = [(s_o/s_a)z_{a/2} + z_\beta]^2/d^2$
$$= \frac{[(0.35766/0.36390)1.96 + 3.72]^2}{(0.013740)^2}$$

$=$ **168 876** (difference from table calculation because of rounding error).

Chapter 5

Discussion, Recommendations, and Conclusions

In the previous chapters, discussion about how climate change will have adverse effects on the health of Prairie populations is provided. Epidemiologists and other public health professionals are only now beginning to understand the potential magnitude of the problem, as well as to identify possible research avenues and solutions (i.e., mitigation and adaptation). This chapter will discuss the reoccurring themes and their importance when considering climate change and human health research. In addition to the discussion, this chapter makes several recommendations for furthering climate change and human health research in the Prairie region.

5.1. Discussion

In undertaking the above exercises, several themes recurred throughout. These include: time, space, data, complexity, interdisciplinary research teams and inter-sectoral knowledge, and the underlying importance of the social context.

5.1.1 Time

Climate fluctuates over hundreds of thousands of years, whereas manually recorded climate and weather variables have been regularly recorded for approximately the last 150 years. It is difficult then to draw conclusions regarding the natural cycles of climate based solely on manual records. Thus, proxy records have been used to provide a clearer picture of pre-industrial climatic fluxes. However, since the industrial revolution, human activity has begun to impact the climate system.

Time enters the climate change problem on two fronts. The first is with respect to weather and climate records (proxy and instrumental/manual), and their ability to represent climate change. The second relates to health data. As discussed in the previous paragraph, precise instrumental records of weather and climate have been available for only a relatively short time span. Although proxy records extend back in time thousands of years, they are less precise. These conflicting elements of weather data, in addition to uncertainty of the entire set of variables that produce climate, make climate modeling into the future difficult, as well as separating natural climate variability from human-induced climate change.

Time also plays a large role in being able to link health outcomes to changes in weather. Because of the subtle nature of climate change and the time it takes climate to change substantially in conjunction with the adaptability of human society, it becomes very difficult to link any particular health outcome to climate change *per se*. Thus, climate change research often focuses on climate variability (e.g., ENSO and vector-borne diseases).

In addition, as Chapter Four exemplified, time plays a large role in the availability of the health records needed to measure changes in health outcomes. These data may be non-existent or do not extend far enough back in time. Because of the limited scope of the health data with respect to time, controlling for confounding influences, such as economic influences becomes problematical. In addition to looking for general trends in the health data, analyzing these data will need to control for issues such as day of the week, monthly fluctuations, and season, as these may change over the long-term.

5.1.2 Space

Climate change is a global phenomenon where warmer average global temperatures will change the climate all around the globe. However, each of the Earth's regions will be affected differently as climate change alters each regional landscape individually. In Canada, there are 15 different eco-zones, and the Prairie Provinces are home to 14 different eco-regions. Each region will have its own climatic challenges associated with climate change.

Because climate change will have differential effects on a regional basis, it becomes important to employ these areas as the unit of analysis in studies. However, eco-regions or eco-zones can cover vast geographical areas that do not respect geo-political boundaries; in addition, weather data recording stations are not evenly distributed across space with remote areas having little instrumental data. As evident in Chapter Four, health data are already difficult to procure, without the added complexity of crossing RHA, Provincial, and national borders, and the location-specific linking health outcomes to weather data.

5.1.3 Complexity

Climate change and human health research is a complicated research field. At its very basic level, climate change and human health research must intertwine sociologic, health, and ecologic components. Each component can be broken down into smaller parts; for example, sociologic into economic, political, adaptation, SES, and societal values; health into public and individual health, as well as the determinants of health; and ecologic into ecosystems, scenarios, and eco-regions. Each of these parts needs to be thought about on various spatial and temporal scales as mentioned above. IA is one research and predictive modeling method that attempts to link social, environmental, and health factors together for the purpose of examining policy and making decisions.

This thesis exemplifies the complexity of climate change and human health research. First, the problem was broken into its component parts: sociological (Chapter Two), and ecological and health (Chapter Three), as well as addressing space and time components (Chapters One and Four). Then, it attempted to combine all these aspects into the 'ideal' proposal (Chapter Four). However, the 'real world' pitfalls and complexity associated with bringing these components together under a single proposal presented major barriers to realizing climate change and human health research in the Prairie region.

5.1.4 Interdisciplinary Research Teams and Inter-Sectoral Knowledge

The complexity of climate change and human health research lends itself to interdisciplinary research teams and inter-sectoral knowledge sharing. Chapter Three best exemplifies the requirement to have inter-disciplinary research teams, where IAFs were proposed for three climate scenarios expected to occur under conditions of climate change in the Prairie region. Within each scenario, ecological, sociological, health and adaptation modules were joined using direct and indirect pathways to illustrate how changes in climate could affect human health. Each module had a number of items within that could change as a result of a change in any of the other modules, and could directly or indirectly affect human health.

Because any one module, and the items within it, for a single scenario can be defined as an area of academic expertise, multi-disciplinary teams are needed to ensure that there is adequate knowledge to address the many questions and assumptions that will undoubtedly arise while conducting research. Interdisciplinary research teams also will need to include statisticians and medical personnel.

As illustrated in Chapter Two, teams must not be exclusive to academia, but also should include stakeholders such as government, industry, and public (i.e., civil society) sectors. These individuals and organizations play a key role because: 1) they are directly or indirectly affected by climate change and therefore can provide alternative value-added (e.g., societal and cultural) perspectives on the potential health effects from climate change; 2) they have valuable resources and expertise, and are part of other networks useful for the dissemination of knowledge and research results; and 3) each sector can aid in adaptation and mitigation processes.

5.1.5 Importance of the Social Context

The social arena in which the Prairie people live is the pervasive characteristic that will underline how a society will react to not only climate change, but also to adaptation and mitigation processes. These things include adaptive capacity of the region, market economy, the region's economic structure or primary economic drivers (e.g., oil and gas, agriculture), societal values, and the political construct of the region. The social context in which climate change plays out can positively or negatively affect the health of individuals.

Canada and the Prairie region have a high adaptive capacity to climate change and a considerable ability to mitigate GHG emissions, as we are part of a wealthy and technologically advanced nation. However, the social context of the various regions play a large role in Canada's ability to mitigate and adapt to climate change on a national, and even on a global level.

For example, Alberta is highly dependent on the exploration and sale of fossil fuels as a primary source of economic wealth. Societal values in this Province hold this sector in high regard, as it employs many people and generates provincial wealth. Thus, the political will to mitigate GHG emissions may be much lower than in the rest of Canada. In addition, how the government expects to adapt to the health effects associated with climate change may be very different from that of the rest of the nation, or even the global community.

Consideration of the social context is also important when conducting research. For example, studies have shown that mental health effects in farmers are highly correlated with financial pressures. These financial pressures are highly dependent on market forces and bureaucratic red tape (e.g., applications to qualify for subsidies and filling out the appropriate forms). In addition, trends in societal awareness of health issues (e.g., asthma) and the subsequent change in the provision of health services and diagnoses may change how we measure any particular outcome.

5.2 Recommendations and Conclusions

The discussion highlighted the major themes and commonalities that pervade this thesis. Although much has been learned in this pioneering stage of climate change and human health research, where do we go from here? Several solutions or considerations have continuously surfaced in the previous chapters and are the basis for the recommendations in this section. These are: determination of baseline health status of Prairie populations with respect to health outcomes that are climate/weather sensitive; investigation of health at the eco-regional level; inclusion of stakeholders in the research process; and, importance of networking.

5.2.1 Baseline Health Status of Prairie Populations

The need for determining the baseline health status of Prairie populations has been mentioned throughout this thesis. Climate change is something that is deemed to occur in the future and is generally quite subtle; changes in the health status of populations will most likely be subtle as well. Especially in areas with small populations, it is important to monitor health status changes and have a baseline against which to compare the changes.

As mentioned in Chapter Three, baseline information could save time and money, and increase the statistical power associated with Prairie-specific research. In addition, baseline information will help compensate for the inadequate time span of health data recognized in Chapter Four. However, with the determination of baseline health status, it must be recognized that continuous monitoring and surveillance are major components.

5.2.2 Eco-regional Analysis

Because climate change directly affects the environment in which populations live and to which they are adapted, eco-regional analysis of health outcomes is an important next step for climate change and human health research. As depicted in Figure 4.2b in Chapter Four, there are fourteen different eco-regions in the Prairie Provinces, none of which respect geo-political borders.

Several climate change and human health review articles have reported the health effects associated with climate change by disease outcome. However, when dealing with a defined geographical area, it may be more appropriate to partition the health consequences of climate change according to climate change scenario. In this way, it becomes easier for policy and the general public to adapt to the current weather or climatic conditions, rather than trying to identify how a certain health consequence may be linked to any number of climate or weather phenomena. As such, eco-regional analysis lends itself to scenario-based research.

5.2.3 Inclusion of Stakeholders

The complexity and need for interdisciplinary research teams make it essential to include stakeholders from a variety of sectors from the beginning during the research process. This is important because stakeholders will be affected by climate change, as well as policy change. Stakeholders have unique and valuable perspectives on the climate change problem, in addition to insight into possible solutions that could best serve the community they represent.

Stakeholders also can contribute greatly to the research process. As was outlined in Chapter Two, stakeholders in the four sectors of society (government, academia, industry, and public (i.e., civil society)) have a great amount of expertise and resources to aid in the research process. In addition, because each individual represents a larger societal interest group, he/she is then able to communicate results, information, and concerns between researchers and the larger segments of society.

5.2.4 Networking as an Important Part of the Research Process

As mentioned in the previous section, stakeholder involvement is a crucial part of climate change and human health research. However, networking is also a fundamental component of the research process. Networking was the focus of Chapter Two. It allowed for the pooling of resources and expertise. The network also was crucial for the dissemination of knowledge to the larger community.

Also mentioned in Chapter Two was that networking had some limitations in that there was a lack of incentives for individuals to donate their time and energy, under ever-increasing busy schedules. In addition, a challenge lies in maintaining a network after the research project has been completed. These challenges can be very costly and time consuming to a research project. In order to address these challenges, climate change and human health research projects could tap into one or more of the regional or national networks already in existence; for example, the Canada Food/Waterborne Contaminants (FWC) Climate Change and Health Research Network initiated by Health Canada, or the Canadian Climate Impacts and Adaptation Research Network (C-CIARN).

5.3 Summary

In summary, the main objectives of this thesis were to: (1) identify priority research questions and stakeholder expertise and resources for Prairie-specific climate change and human health research (Chapter Two); (2) objectify the potential scope of the climate change and human health problem in the context of IAFs, and to identify current knowledge as well as knowledge gaps in the Prairie region (Chapter Three); and, (3) further the climate change and human health research agenda by proposing an 'ideal' research proposal, and then identify the 'real world' barriers associated with realizing the proposal (Chapter Four).

This thesis also contributes to climate change and human health understanding and research in several ways. First, it is the first research endeavour, to the knowledge of the author, to focus specifically on climate change and human health issues in the Canadian Prairie region. It outlines Prairie-specific scenarios, in addition to health consequences associated with each scenario. This is important because the health consequences of climate change will be regionally-specific. Second, this research endeavour has effectively established a Prairie climate change and human health network, and will continue to build and fortify the network with other research projects. Network building is important for involving stakeholders, for identifying resources and expertise, for adapting to and mitigating the health consequences from climate change, and for enhancing dissemination capabilities and understanding of climate change and human health issues.

The third way that this thesis contributes to climate change and human health research is through providing new perspectives into our current knowledge base, in addition to where gaps in knowledge occur with respect to research already conducted. Last, based on the findings of the various components, this thesis recommends how Prairie climate change and human heath research could be advanced. Important additional research questions are proposed where further research is needed, in addition to noting that baseline health information will be needed for monitoring and surveillance purposes.

5.4 Postscript

As important as climate change is to the health of global populations, it is only part of the entire picture, which is global change (Soskolne and Bertollini, 1999). Global change is the interaction of natural and anthropogenic dynamics that cause change in the natural environment (Feulner, 2001). These include processes like deforestation, industrialization, natural disasters, drought, and migration; each can further exacerbate global change, and render the ecosystem less resilient in its response or adaptation to future threats.

However, since the industrial revolution, the drivers of global change have shifted from being mainly natural in origin (e.g., glaciation) to anthropogenic (e.g., collapsing fish stocks, climate change, pollution of oceans, lakes and rivers, and decreasing biodiversity). These factors can work in synergy, eventually producing human suffering of great proportion.

The bigger picture thus becomes the health of the environment that humans depend on for life. Whether it is pesticides on our lawns, acid rain, or creating demands for environmentally destructive commodities, as humans continue to pollute and degrade the environment's components, it will have negative direct and indirect impacts on our health. Thus, with each passing day, humans must tread more lightly on our Earth, as we are part of our natural world since we breathe it, drink from it, and eat its products.

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