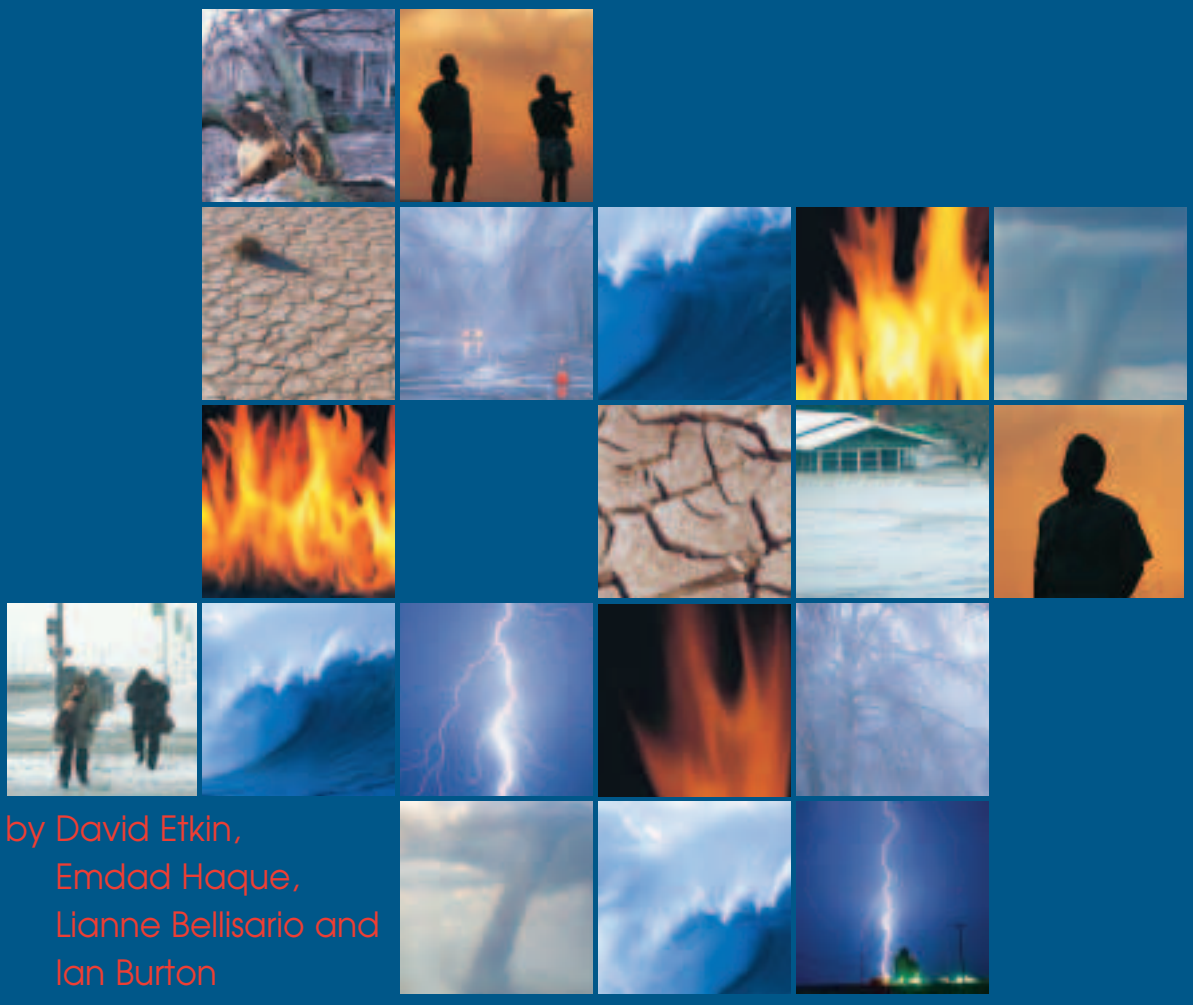
An Assessment of

Natural Hazards and Disasters in Canada

A Report for Decision-Makers and Practitioners



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A Report for Decision-Makers and Practitioners

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Vision

To develop a society more resilient to natural disasters, where sustained planning, investment and action results in more sustainable communities.

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EXECUTIVE SUMMARY

Canadians are more vulnerable to natural disasters than they could or should be. We have the knowledge and skills to make our communities safer. There are things we can do to reduce the potential for disaster, enhance preparedness for the disasters that do occur and improve our ability to respond to and recover from them. We can modify behaviours and policies that place us at risk and that increase our vulnerability to disasters.

Disaster losses in Canada are now measured in the billions of dollars and are expected to become even more expensive. The human toll, though less easily quantified, is increasing apace. The need for action is urgent because even more damaging events are predicted for the future as the climate changes. Indeed, it's possible that future disasters may far exceed anything we've experienced to date.

Protecting us against disasters demands increased awareness, co-operation and commitment from everyone – governments, corporations, community groups and individuals.

The term 'natural disaster' is somewhat misleading because it implies that disasters are the fault of nature. In fact, these events do not become disasters without human complicity – without humans creating vulnerability of where and how they build their homes, businesses and other critical infrastructures.

Natural events like hurricanes, floods, earthquakes or tornadoes are, in fact, hazards that have the potential to harm people and damage property. These hazards only become disasters when they intersect with vulnerable communities in a way that overwhelms their ability to cope.

Vulnerability refers to the likelihood that a community will suffer injuries, deaths or property damage from a hazardous event; it is a measure of how well prepared and equipped the community is to avoid or cope with such events. Some factors that increase vulnerability include population growth, increasing population density and concentration of wealth, poor land-use policies, aging populations and infrastructure, a lack of knowledge about local hazards and a lack of standards enforcement and effective monitoring systems. The degree to which communities allow themselves to be vulnerable to natural hazards defines their level of risk.

Different communities are adapted to different sorts of hazards. For example, Montreal handles heavy snowfall better than Vancouver simply because Montreal is used to winter storms and is therefore better prepared to deal with snow. But an event outside the range of normal experience – such as the 1998 Ice Storm – can even decimate the resources of communities that are generally well adapted to local conditions.

In recent years, many countries, Canada included, have experienced an alarming increase in natural disaster loss. In this country, Prairie droughts have been the most costly, accounting for some $16 billion in losses in the past quarter century. However, the 1998 Ice Storm was the single most expensive event for the Canadian insurance industry, which paid out about $1.8 billion – only about a third of the total estimated cost of $5.4 billion. Hailstorms in Calgary and major floods in Quebec and Manitoba also resulted in insurance claims in the hundreds of millions.

Since World War II, there has been an increase in the incidence of weather-related disasters – notably flooding – compared with geophysical disasters such as earthquakes. There is good reason to believe that even more devastating weather disasters will occur in the future because scientists anticipate that global climate change will be accompanied by increases in both the frequency and intensity of extreme weather events. This could greatly exacerbate losses to natural disasters since it's likely that future events will increasingly fall outside the traditional coping range of many communities.

Other trends will also amplify human vulnerability, most notably degradation of natural ecosystems and increasing population growth and development in risky areas such as coastal regions, floodplains, and earthquake zones. In recent decades, these types of activities have already enormously increased the risk that disasters will damage property and endanger humans.

There are four types of actions that can be taken to deal with the threat of natural hazards: **mitigation, preparedness, response, and recovery.**

Mitigation refers to long-term actions that reduce the risk of natural disasters, such as constructing dams and prohibiting people from building homes or businesses in high-risk areas.

Preparedness involves planning for disasters and putting in place the resources needed to cope with them when they happen. Examples include stockpiling essential goods and preparing emergency plans to follow in the event of a disaster.

Response refers to actions taken after a disaster has occurred. The activities of police, firefighters, and medical personnel during and immediately after a disaster fall into this category.

Recovery encompasses longer-term activities to rebuild and restore the community to its pre-disaster state. This is also a good time to engage in activities that reduce vulnerability and mitigate future disasters, such as strengthening building codes or modifying risky land-use policies.

In the past, most disaster-related efforts in Canada have focused primarily on preparedness, response, and recovery. These will remain important activities but there's an urgent need to shift the emphasis to mitigate risk and hazards with a more proactive approach. Increasingly, communities must undertake mitigation activities to increase their resilience and avoid the damages that future disasters could cause. Such activities can take many forms: legislation, land-use policies, educational programs, warning systems, establishing and enforcing building codes, and engineering activities such as building dams.

It's important, however, to ensure that people understand the limitations of such measures or they could defeat the purpose of these efforts by increasing risky behaviour in response. For example, building dykes in a flood plain may give people a false sense of security and encourage unwise development unless land-use policies prevent this from happening.

Similarly, risk-sharing measures such as insurance or government disaster relief programs can have the unfortunate effect of encouraging an increase in risk-taking behaviour because people may perceive that the consequences of this behaviour will be borne by others – specifically, the insurance companies or the government. In reality, everyone pays for risky behaviour through increased taxes and insurance premiums.

Mitigation need not be inordinately costly but even measures that are expensive – such as retrofitting buildings or buying out properties on flood plains – can be cost-effective in the long run, since they reduce the considerable social and economic costs associated with repeated response and recovery operations after disasters occur. By reducing vulnerability to natural disasters, a mitigation strategy will ultimately produce the greatest long-term benefits.

Unfortunately, such proactive disaster planning is often a "hard sell" because it requires decision-makers and the public to invest resources in events that may or may not happen at some undefined time in the future. It's hard for people to see immediate benefits from such a strategy and there are always other demands that are seemingly more urgent. This kind of thinking is a classic example of "penny-wise, pound foolish."

This is why disaster planners must take advantage of the window of opportunity that occurs in the aftermath of a major disaster, when the public and politicians are all too painfully aware of the price of disasters. It's when a hurricane or tornado has swept through or ice has crippled the power grid, that people are far more receptive to the idea of making precautionary investments in mitigation to reduce or avoid the kind of damages that have disrupted their lives.

Public Safety and Emergency Preparedness Canada (PSEPC) is currently developing a National Disaster Mitigation Strategy in consultation with the public and provincial and territorial governments. Shifting the emphasis from response/recovery to mitigation will require increased awareness, co-operation and commitment from all levels of government and the private sector as well as from individuals and community groups.

Implementing a proactive approach will also require a better knowledge and understanding of natural hazards in Canada. It's important to develop a comprehensive natural hazards database and a national, interdisciplinary institution or network that brings together scientists, planners and decision-makers responsible for studying and preparing for disasters. Communities must identify the range of specific hazards they face and assess their level of vulnerability and risk.

Better data on the costs and benefits of mitigation activities are also needed. Currently, these activities take place in many government departments and agencies; they are not well co-ordinated and there is little information on what benefits have resulted from such efforts.

More interdisciplinary research on mitigation is needed, particularly involving the social sciences, which have so far lagged behind the physical sciences. Social science research is likely to produce the greatest benefits since it may help to improve understanding of human behaviour that can defeat the best mitigation policies.

This is why increasing public awareness of hazards, risk and mitigation is also essential. Many people are in denial about the hazards they face, particularly those they believe may be devastating and beyond their control. They tend to discount the possibility of very high-risk, but rare, events.

For example, there are misconceptions about the term 'return period,' which is often used to describe the likelihood of an event occurring. If a certain magnitude of flooding is considered to have a 100-year return period, this means that it will occur, on average, every century. It also means that there's a one percent chance of it happening in any given year. It does not mean, as many people mistakenly believe, that if such a flood has happened this year, it won't happen again for another 100 years. These misconceptions must be rectified because they can lead to an increase in risk-taking behaviour that in turn increases a community's vulnerability.

It is also important to adopt mitigation strategies that reduce over-reliance on technological solutions. The technological approach that has been most favoured in the past is rooted in the philosophical belief that humans can and should control nature. It will be more beneficial in the long run to adopt measures that also include enhancing environmental sustainability.

One good example is how communities deal with heat waves, which have in recent years caused tens of thousands of deaths all over the world and are expected to increase with global warming. In the past, the primary response (in developed countries, at least) has been to crank up the air conditioning. But in some ways this just makes matters worse, since it puts extreme demands upon power generating facilities, increases the use of fossil-fuel energy, and results in even more greenhouse gases being emitted into the atmosphere. A better and more sustainable solution would be to develop strategies that also include rooftop and vertical gardens in urban areas, which would not only cool things down but also produce additional benefits such as reducing vulnerability to flooding and improving air quality.

Ultimately, developing an effective mitigation strategy requires that everyone, individually and collectively, take responsibility for acting in ways that reduce their vulnerability to disasters. We can have safer, more resilient communities if we truly decide that's what we want.

KEY MESSAGES

- Policies and measures that are available but not sufficiently used can substantially reduce the damage caused by extreme natural events (hazards).
- New steps and stronger actions are required if losses from natural disasters are to be effectively managed.
- In recent years, Canada has experienced a number of disasters that have caused unprecedented amounts of damage. Just six major events in the past quarter-century have cost over $22 billion (year 2000 dollars). Many smaller events that are not well-documented have raised the total cost of natural hazards and disasters to a much higher but unknown amount. These events are warning signs or precursors of what is likely to occur more frequently in the future unless more vigorous mitigation policies and measures are adopted.
- Worst-case scenarios of the damage, deaths and injuries that could result from Canadian natural disasters far exceed historical events.
- Experience in Canada and other countries confirm that precautionary expenditures to reduce disaster impacts before they occur produce favourable benefit-cost ratios and, therefore, are economically justified.
- The type and magnitude of natural disasters and community vulnerability vary considerably across Canada such that no generic, universally applicable measures can be developed. A broad policy framework is required to facilitate appropriate actions at different levels of government.
- Much disaster mitigation has to be community-based. It is important to provide technical and financial assistance to communities for hazard identification and risk and vulnerability analyses, to ensure that they are integrated into local planning and decision making.
- While there is no proof that recent disasters were caused by climate change, it is believed that such events will occur more frequently as global temperatures increase and the hydrological cycle intensifies.
- Policies required for natural disaster mitigation are compatible with current directions in sustainable development, community involvement and federal-provincial co-operation.
- There is a need for increased public education and awareness of opportunities for disaster risk reduction.

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PREFACE

In July of 1999, while attending the annual Natural Hazards Workshop organized by the Natural Hazards Research and Information Centre at Boulder, Colorado, a small group of Canadians involved in the field of natural hazards got together to discuss the state of hazards research in Canada and how well we manage risks from natural hazards as a nation. Recent disasters such as the 1996 Saguenay flood, the 1997 Red River flood, and the 1998 Ice Storm had demonstrated that natural disasters were becoming increasingly frequent and costly in Canada. Other reports from Munich Reinsurance, the United Nations' International Decade for Natural Disaster Reduction, and the second U.S. national assessment of natural hazards had also noted a disturbing global trend over the past several decades – a marked rise in the number and costs of natural disasters. Particularly damaging were recent earthquakes, droughts, floods, and hurricanes.

We all believed there were significant risks in Canada, but were also aware of large gaps in our understanding of these risks, especially hazard vulnerability. Both from a scientific perspective and from a desire to serve the public good, we felt a need to undertake the first-ever assessment of natural hazards and disasters in Canada to help fill these knowledge gaps. Consequently, Chris Tucker (Public Safety and Emergency Preparedness Canada (PSEPC)), Emdad Haque (Brandon University, now at the University of Manitoba) and David Etkin (Environment Canada) began the challenging task of engaging the Canadian hazards community in this assessment.

Courtesy of Geological Survey of Canada, Natural Resources Canada

Work on the Canadian Natural Hazards Assessment Project (CNHAP) was done on a volunteer and in-kind basis. The strategy of the assessment was to create three products targeting different audiences: 1) a set of background technical research papers covering a wide range of interdisciplinary topics; 2) a decision-makers report summarizing the literature and background reports; and 3) plain language summaries of a variety of natural hazards, intended for a general audience.

The background papers were published in a special issue of *Natural Hazards* (the journal of the Natural Hazards Society) (see *Appendix A*) and in the Institute for Catastrophic Loss Reduction (ICLR) research paper series (see www.iclr.org). These collections of interdisciplinary papers provide a useful reference for Canadians involved in the natural hazards field, both as researchers and as practitioners, in addition to transferring Canadian experiences to the international community.

The term 'natural disaster' is an unfortunate one as it gives the impression that disasters are primarily the fault of nature. Instead, natural disasters largely result from human-created vulnerability to known hazards in our environment. These vulnerabilities are typically a

consequence of the way in which we interact with our environment, organize our socio-economic systems, design and locate our infrastructure and concentrate our population geographically. The distinction between natural hazards and our vulnerability to them is well understood in the research community and increasingly so in government and non-government organizations but generally is poorly recognized by the general public.

With this in mind, it is hoped that through reading this document, decision makers will be able to better understand the risks associated with natural hazards and vulnerability and how to better mitigate against them. It should also provide a starting point for answering fundamental questions about natural hazards and disasters in Canada, including:

1. How big a problem are natural hazards and disasters for Canada?
2. What are their causes?
3. Are disasters likely to get worse in the future?
4. How much should we care?
5. How should the issue of natural hazards and disasters be addressed?

The answers to these questions are critical to making informed decisions, developing a Canadian approach to disaster mitigation, good planning based on sound information and the development of relevant policy. While it is unrealistic to expect universal or precise answers, this assessment nevertheless provides clarification of the issues, suggests solutions and highlights a path by which they might be further addressed.

The authors suggest that the answers are as follows:

■ **How big a problem are natural hazards and disasters for Canada?**

The problem is large and growing. Available data show that disasters have been a significant problem in many regions in Canada, though a few areas are at minimal risk due to a lack of exposure or vulnerability. The potential exists for disasters that far exceed what we have so far experienced, and they are, therefore, likely to become a much larger problem than historical data suggests.

There are two reasons for this trend. The first is that our areas of greatest vulnerability have not yet had a catastrophic disaster (such as a major earthquake in the Vancouver or Montreal regions). The second is that hazards and vulnerability are in many ways increasing.

■ **What are their causes?**

Natural disasters are caused when a hazardous event triggers community vulnerability. This vulnerability is enhanced by biased risk perceptions that discount risks associated with rare extreme events; by environmental degradation that exacerbates some hazards such as urban flooding; and by values that encourage, or ones that do not discourage inappropriate risk-taking behaviour.

■ **Are they likely to get worse in the future?**

Yes. Various factors act to make disasters worse, while others act to reduce them. Climate change in particular is liable to move our society out of its traditional coping ranges for some hazards and thereby worsen many disasters. Other trends, such as urbanization and lack of investment, also contribute significantly to the growing problem. It's not clear how they will evolve but if present trends continue, things may well get worse.

■ **How much should we care?**

We should care about natural disasters because they affect everyone. Indeed, since research suggests that people tend to discount risks associated with rare extreme events, we should probably care more than we currently do. The current assessment suggests that good disaster mitigation can be cost effective and can potentially provide a variety of co-benefits. It is a 'no regrets' strategy.

■ **How should the issue of natural hazards and disasters be addressed?**

This issue should be addressed through a national disaster mitigation strategy, from an all-hazards, holistic perspective, drawing upon the knowledge and talents of people from all disciplines and walks of life. Approaching this issue with a sense of humility and a willingness to learn from other people and other places will greatly enhance the chances of success. Actions can be taken to reduce disaster losses over the long term by applying what is currently known, but this requires a shift towards a more disaster-resilient culture, political will, and the allocation of resources.

DEFINITION OF **TERMS**

The terms risk, hazard, vulnerability, and disaster are often understood by different people to mean different things. In particular, the first two terms are often used interchangeably. Therefore, before discussing any of these issues in detail, the meaning of these terms, in the context of this report, must be clarified.

Natural Hazards are normally occurring events in the environment that can potentially harm people or damage property and assets (see *Box 1* for examples).

BOX 1

NATURAL HAZARDS IN CANADA

GEOLOGICAL:		BIOLOGICAL:	
Earthquakes	Tsunami	Infestations	
Landslides	Volcano	Epidemics	
METEOROLOGICAL/HYDROLOGICAL:			
Cold Wave	Hail	Storm Surges	Wildfire
Drought	Hurricane	Freezing Rain	Typhoon
Flood	Snow Avalanche	Tornado	Storms

Courtesy of Geological Survey of Canada, Natural Resources Canada

This harm occurs when an extreme or rare event lies outside of our coping range. For example, rain is an essential resource but when too much or too little falls, it can become a hazard, resulting in flooding or drought. Whether or not a potentially hazardous event is benign or becomes a disaster depends largely upon how we have designed our society, planned our communities, built our infrastructure, and adapted to our current environment. Adaptive capacity in Canada varies both geographically and temporally. For example, a winter snowstorm that is well within the coping capacity of Montreal could be a disaster in Vancouver. However, if the storm occurred unexpectedly in late spring, both cities could be negatively impacted.

Vulnerability refers to the propensity to suffer some degree of loss (e.g., injury, death, and damages) from a hazardous event. Whether considering a community, an individual, an economy or a structure, vulnerability depends upon coping capacity relative to the hazard impact. For example, a large ship may not be vulnerable to 2 m waves, but a rowboat certainly is. There are a number of different types of vulnerabilities to natural hazards (see *Box 2*).

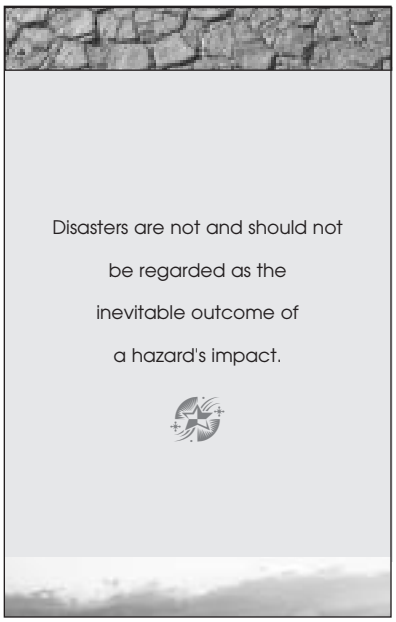
BOX 2

TYPES OF VULNERABILITIES

- Physical (living in a hazard-prone area)
- Personal (age, gender)
- Cultural (risk perception)
- Socio-political (limited or free access to information, control over resources and decision making)
- Structural (building standards and quality of materials)
- Economic (wealth distribution or diversity)
- Institutional (regulatory and jurisdictional: are codes and standards enforced/type of governance)

In practice, these vulnerabilities interact with each other to produce a cumulative effect. In particular, decisions that determine how and where we build communities and infrastructure are largely determined by cultural, economic and institutional factors.

Natural disasters occur when a hazard triggers vulnerability and the damage is so extensive that the affected community cannot recover through the use of its own resources (Cannon, 1994). Hazards are thus natural or expected events, but in general disasters are not and should not be regarded as the inevitable outcome of a hazard's impact. It is important to recognize that it is often the condition of society that creates the context for a hazard to become a disaster, which is a function of how well or how poorly we have adapted to the risks we face. The definition of a disaster is also closely tied to the size of the community being considered. For example, a flood may be a disaster for a town, though perhaps not for a province. Similarly, a freezing rainstorm may be a disaster for a province, but not for Canada.



The lines between natural and other types of disasters can be blurred. Many of the deaths resulting from the Barrie, Ontario tornado in 1985 were caused by building collapse. An engineering study by the National Research Council following the event found that many houses that did not survive were not built to National Building Code Standards (Allen, 1986). In this case, although nature created the tornado, the disaster was certainly exacerbated by human action, or rather, a lack of appropriate action. Generally, a disaster is considered 'natural' when its *trigger* is a natural event, no matter the role social factors played in creating the vulnerabilities.

Natural hazard risk incorporates the notions of both hazard and vulnerability and can be used to compare various hazards:

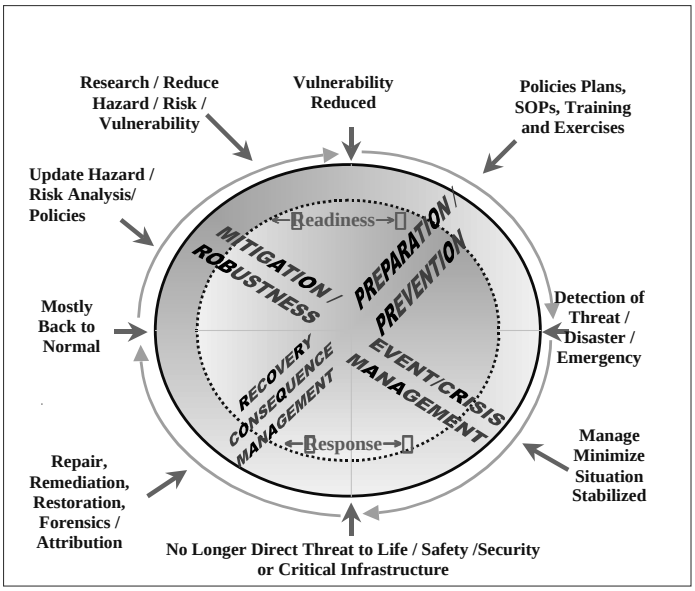
$$\text{Risk} = \text{hazard} \times \text{vulnerability}$$

Thus, a high probability hazard with small impacts can have the same risk as a low probability hazard with large impacts, even though people subjectively tend to view them as very different.

Emergency management activities enable individuals, communities, private sector organizations, and governments to assess the risks associated with natural hazards and to prioritize measures to reduce these risks. Although the level of sophistication and the degree to which emergency management activities are legislated varies greatly across Canada, the emergency management cycle offers one model through which natural hazard risk can be addressed (Figure 1). Emergency management activities include any action that helps to mitigate against, prepare for, respond to and recover from disasters, and thus reduces risk to society. These four pillars of emergency management (mitigation, preparedness, response, and recovery), while not the only framework for addressing risk, can clarify the many ways risk can be reduced and contribute to the development of sustainable, safer communities that are resilient to disaster effects.

Mitigation refers to long-term actions taken to reduce risk associated with natural hazards. They can be either structural (such as dams) or non-structural (such as land-use planning). Preparedness involves planning prior to a disaster to create the capacity to respond after it occurs. Examples are having emergency plans or stockpiles of essential goods. Response refers to actions taken after a disaster occurs, to save lives and minimize damage. Fire departments and police are examples of response agencies. Following an initial response comes recovery, which is the social and physical rebuilding that occurs as society works to bring the damaged communities back to their pre-disaster state. The distinction between these terms is not always clear since specific actions can sometimes fit into more than one category. For example, rebuilding during recovery, if done well, can reduce vulnerability and therefore be considered mitigation.

FIGURE 1
The Emergency Management Cycle
Note that the four pillars of emergency management (mitigation, preparedness, response and recovery) tend to be overlapping functions, as opposed to separate, sequential phases.



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INTRODUCTION

Policy and decision-makers responsible for community safety and well-being, as they relate to natural hazards and disasters in Canada, are the target audience for this report. It summarizes an assessment of the state and nature of knowledge, policy relevant observations, research and practice in this area. It is hoped that, through a process of engagement and information sharing, the trends towards increased vulnerability experienced in much of Canada and around the world can be reversed. Without action being taken to reduce these vulnerabilities, the probable result of these trends will be more frequent and increasingly severe natural disasters. Providing information that can be used to reduce the social cost and burden that these disasters impose is one of the principal objectives of this assessment effort.

This report is not intended to be a comprehensive review of natural hazards in Canada. Such a study would require many books. Rather, it is intended to outline the general nature of the problem, and to highlight potential coping mechanisms that would assist Canadians in reducing disaster losses. It is based upon the background papers written for this assessment (Appendix A), as well as the more general literature on the subject. It focuses on impacts upon people and society, but does not deal explicitly with ecological disasters.

Courtesy of Geological Survey of Canada, Natural Resources Canada

The human and economic loss generated by natural disasters can be reduced through informed planning and mitigation. Disasters are, however, complex phenomena, and approaches to disaster reduction that rely upon singular disciplines (such as only engineering or only insurance) or linear thinking address only one facet of the problem and tend to fail, sometimes with catastrophic results. Successful risk management for natural hazards requires broad-based engagement and a multi-disciplinary, systematic approach.

Why should reducing losses associated with natural hazards and disasters be important to decision-makers? The answer is that if we do not apply what we know about natural hazards, the risks we face from them will continue to threaten the lives and livelihoods of Canadians (Degg, 1992). We live in an unsafe world, although we often cling to illusions of control and safety. In recent years, Canada has suffered through a number of natural disasters that have resulted in large economic and personal losses. Some communities may be located in less hazardous places than others, but all Canadians face risks directly or indirectly related to the natural environment. We need to understand these risks and act to reduce them now. Otherwise, we may continue to follow the global trend of increasing human and socio-economic losses.

The extent of economic damage and personal loss caused by natural disasters prompted the United Nations to designate the 1990s as the International Decade of

Natural Disaster Reduction[1] (IDNDR). The goal was to reduce the likelihood and impact of these tragic events. However, according to analyses by Munich Re (2002), insured losses in the 1990s were actually 17 times larger than the 1960s, while estimated total economic losses were nine times larger. These dramatic increases can be largely attributed to economic growth and development policies, and the planning and implementation strategies of policies intended to reduce disaster losses that did not take adequate account of risk assessment and mitigation options. A smaller portion of the increase in losses may also have resulted from changing trends in the physical environment.

While the sizes of the Canadian population and its monetary and non-monetary assets have surpassed all historical records, we have simultaneously increased our risk from, and vulnerability to, various types of natural forces and their extremes. It is clear, unfortunately, that in many ways Canada and the world are becoming more vulnerable, and that this trend is likely to continue.

There are many forces driving this trend. Environmental degradation – for example, deforestation of slopes and more frequent extremes of some hazards because of climate change – is one. Socio-economic and demographic factors, such as urbanization and population growth, also play a role. Social progress and economic development should, in theory, bring concomitant safety and security. However, if appropriate policy, planning and implementation decisions are not taken, an inverse relationship can emerge, resulting in increased vulnerability and losses.

The importance of linkages between social, physical and political issues interwoven in natural disasters cannot be overemphasized. Natural disasters are fundamentally connected to social issues like development, poverty, globalization and human health (Lindsay, 2003). By being aware of existing and future hazards and of how individual and institutional decisions can increase our vulnerability, the human and economic toll they impose upon us can be greatly reduced.

"Disasters are, however, complex phenomena, and approaches to disaster reduction that rely upon singular disciplines (such as only engineering or only insurance) or linear thinking address only one facet of the problem and tend to fail, sometimes with catastrophic results."

However, awareness alone is not enough because it does not necessarily lead to effective action. Other efforts are needed to reduce disaster losses. These include having a broad-based systems approach[2] to problem solving, a vision for sustainable development, sensitivity to the importance of preserving the health of the natural environment, a concept of duty to future generations and the willingness to consider consequences resulting from the failure of systems designed to protect us.

Canadian decision-makers at all levels of government, private sector entities, and even individuals can and should plan for, mitigate against and respond to disasters. Canada has a long history of preparedness, response, and recovery activities in the face of natural disasters. As important as these activities are, it is becoming clear that we need to shift our efforts towards proactive rather than reactive risk and disaster management strategies. We should be placing greater

[1] This program has now been succeeded by the International Strategy for Disaster Reduction (ISDR) (www.unisdr.org).

[2] A systems approach emphasizes sets of relations between its different (sub)components and how they relate to and affect each other, in order to understand the system as a whole.

emphasis on disaster mitigation actions that reduce the likelihood or impact of future disasters, avoid damages, and reduce long-term costs.

Although there are some notable examples of disaster mitigation in Canada (see Box 3), efforts have largely been piecemeal, uncoordinated or under-funded relative to other activities. A greater effort is needed to understand natural hazard risk in Canada so we can plan effective and efficient mitigation programs based on reliable information. It is through directed mitigation efforts that Canadians stand to benefit the most, and receive the best return on investment by saving lives, property, and resources.

BOX 3

DISASTER MITIGATION IN CANADA

Disaster mitigation generally includes any sustained action that reduces or eliminates the impacts and risks associated with disasters.

EXAMPLES OF DISASTER MITIGATION

STRUCTURAL (engineering)	**NON-STRUCTURAL** (policies, plans, warnings, etc.)
Red River Floodway (Winnipeg)	National Building Code of Canada
Retrofitting buildings in high earthquake risk zones (Vancouver)	Legislation of buffer zones for coastal areas
Dams	Flood Damage Reduction Program
Dykes	Severe Weather Warnings

Enhanced mitigation actions in Canada can be tailored to specific regions and might include: local land use planning changes, hazard risk research such as hazard mapping and analysis, legislation requiring risk and vulnerability analyses for communities, changes to the national building code, the development and implementation of warning systems for extreme events, public education about risks, and information sharing. More concerted effort in any of these activities can improve the way in which communities cope with natural disasters and become safer and more resilient.

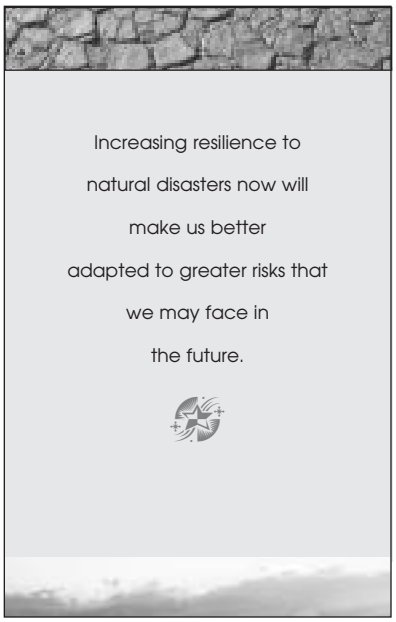
If disaster mitigation activities have clear benefits and can be tailored to local needs, why are they not more broadly supported? It is challenging to promote the idea of disaster mitigation because an investment made well in advance of the disaster may not produce visible and immediate results. This is in contrast to typical preparedness, response or recovery actions, which demonstrate their value immediately because they are imminent to, or directly follow, a catastrophic event. Mitigating the risks of natural disasters tends to have delayed payoffs, so it is tempting to focus on the short-term benefits that accrue from risk-taking behaviour rather than the long-term price of such behaviour.

Building resilience into social institutions or infrastructure in initial design or land-use planning stages may cost little or nothing, yet have an immense long-term benefit. Unfortunately, such mitigation strategies are often perceived to be very costly. Though one cannot be protected from all risks, not investing in mitigation is generally `penny-wise and pound-foolish.' Though some strategies and

measures, such as retrofitting buildings or buying out properties in flood plains can be expensive, they may still be very cost-effective since they are designed to reduce the impacts of disasters and the costs associated with repeated response and recovery efforts.

Understanding our vulnerability to natural disasters and reducing our risk through mitigation is a complex problem requiring complex solutions. A single approach will not suffice; what is needed is a co-ordinated effort on many fronts. Public education and outreach; policy review and development; physical, engineering and social science research; investigations into broader social issues; and a shared sense of responsibility for addressing hazards and disasters must all be part of an effective and co-ordinated program to reduce our vulnerabilities and mitigate risk.

Increasing resilience to natural disasters now will make us better adapted to greater risks that we may face in the future. Work is being done in Canada and elsewhere on this issue, but much more is needed. Nationally, Natural Resources Canada and Environment Canada are leading the development of a climate change adaptation framework. Internationally, natural disasters and climate change are being addressed through various forums, including the UN International Strategy for Disaster Reduction (ISDR) and the Kyoto Protocol of the UN Framework Convention on Climate Change. As new policies to address natural hazard risk are developed and implemented, the cross-linkages between natural disasters and other important issues such as climate change, ecosystem health, land use and changing economies cannot be forgotten.



2 DISASTER TRENDS

There is a lack of reliable data on disasters, especially those that receive less public attention and media coverage. There is no generally accepted methodology for assessing the direct and indirect economic impact of natural disasters (Dore, 2003). Measurements of intangible, non-physical assets or broader social and environmental costs are seldom factored into impact analyses since they are not easily quantifiable. For example, stress associated with the 1997 Red River flood tested marriages and family relationships, but these types of impacts are rarely measured. While many organizations in Canada gather some data on disaster costs and losses, no single institution is responsible for creating and maintaining an integrated, comprehensive database or network that links existing databases. In fact, each database typically uses its own definition of a disaster, making comparisons difficult.

Despite these methodological and data limitations, a number of national and international studies have attempted to standardize data and make comparative analyses. Munich Re[3] provides annual summaries of the number and costs of disasters worldwide. Costs are divided into insured costs (for which the data are reliable) and total economic costs, for which the quality of data is less certain (Figure 2). There is a clear trend: over the past several decades, global insured and uninsured costs due to disasters are rising. Moreover, these estimates should be considered very conservative, since many smaller events do not make it into databases like these, yet their cumulative costs may be quite large.

Courtesy of D. Mitchell

The United States National Climate Data Center[4] compiles and publishes a list of U.S. weather-related disasters that cost in excess of US$1 billion. One notable feature of these data is their 'top-heavy' nature: the top five disasters alone have a total estimated impact of about US$170 billion, while the next 42 disasters combined cost approximately US$110 billion (Table 1). This is significant because many people discount the likelihood that rare but high-consequence disasters will happen, particularly when the risk of the event occurring is assessed subjectively instead of quantitatively. This can result in flawed risk estimations and low building design thresholds that can lead to catastrophic failures when these thresholds are exceeded.

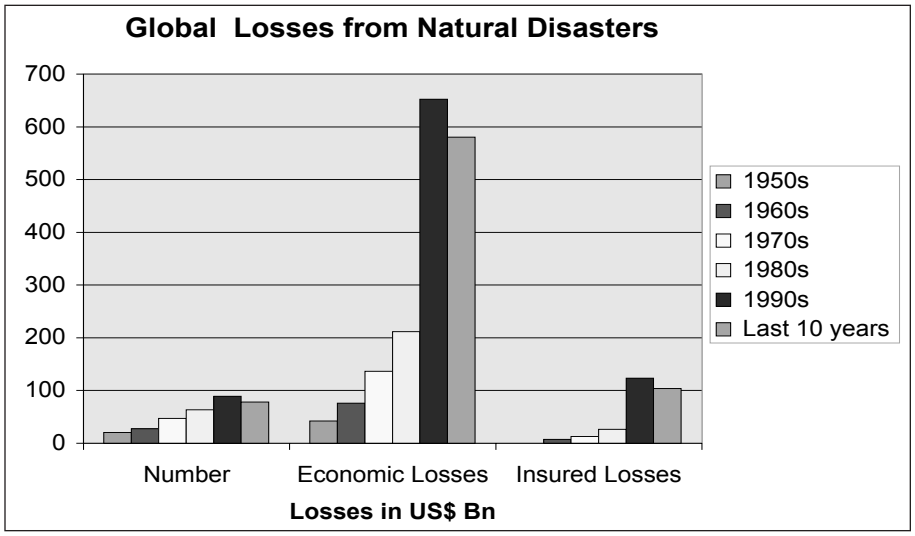
Public Safety and Emergency Preparedness Canada (PSEPC) maintains a database of Canadian disasters from 1900 to 2002.[5] The most costly Canadian disasters are shown in Table 2. Drought, freezing rain, and floods appear to be the most damaging and rank at the top of this list, although it must be recognized that ranking of disasters by direct cost is problematic because the disasters that have the most detailed cost records will appear first, although they may not have been

[3] www.munichre.com

[4] www.ncdc.noaa.gov/oa/reports/billionz.html

[5] www.psepc-sppcc.gc.ca

FIGURE 2
Trends of Natural Disasters by Decade (1950-2001)
(Source: Munich Re. 2001)



the disasters with the most significant socio-economic impacts. For example, severe drought events affecting farmers are tracked through crop insurance programs, so costs for these events are well documented, while other events with similar or perhaps greater indirect or uninsured costs (including loss of lives) might not be. Despite this, these data can be used to illustrate the relative impact of some historical disasters in Canada.

Disaster trends in developed countries like Canada have been towards fewer deaths but larger economic impacts. There continue to be significant health-related impacts which are not fully understood.

An analysis of this database shows some interesting trends in the frequency of weather-related disasters versus geological ones (Figure 3). The former shows a significant increase since WWII, driven mainly by an increased frequency of flooding (Figure 4). Another database of Canadian disasters, using different criteria than that used by PSEPC, shows that 51% of all Canadian disasters were weather-related (Jones, 2003). These data indicate that changes in weather hazards, such as those suggested by climate change projections, may play a significant role in exacerbating natural disasters in the future.

Disasters also have significant impacts on human health and well-being. In developed countries like Canada, the number of deaths tends to be small and the economic impacts large. In contrast, developing countries often experience large numbers of deaths and lesser economic impacts, in absolute, if not relative terms. As well, trends in developed countries like Canada have been towards fewer deaths and larger economic impacts, though important health-related vulnerabilities certainly exist. For example, the record-breaking European heat wave in August 2003 claimed more than 14,000 lives in France. This extraordinary event should prompt hazard and disaster practitioners and researchers to re-evaluate the vulnerability of communities to weather-related health hazards, especially within the context of climate change.

TABLE 1:
US Billion-Dollar Weather Disasters (NCDC)
Source: NOAA National Climatic Data Center (http://lwf.ncdc.noaa.gov/oa/ncdc.html)

HAZARD TYPE	YEAR	DAMAGE *(US$ billions) in 1998 dollars*
Drought/Heat Wave	1988	56
Drought/Heat Wave	1980	44
Hurricane Andrew	1992	32
Midwest Flooding	1993	23
Hurricane Hugo	1989	13
Southern Drought/Heat Wave	1998	9
Texas/Oklahoma/Louisiana/Mississippi Severe Weather and Flooding	1995	7
Storm/Blizzard	1993	7
Hurricane Floyd	1999	6
Hurricane Georges	1998	6
Hurricane Alicia	1983	5
Hurricane Fran	1996	5
Southern Plains Severe Drought	1995/96	5
Northern Plains Flooding	1997	4
Florida Freeze	1983	4
Hurricane Opal	1995	3
California Flooding	1995	3
Southeast Ice Storm	1994	3
Oakland Firestorm	1991	3

*Of a list of 47 disasters, the top five disasters (11% by number) cost $168 billion (60% of the cost) while the bottom 42 disasters (89% by number) cost $113 billion (40% of the cost). This illustrates the characteristic of disasters that impacts tend to be 'top-heavy'.

Data on Canadian disasters show that although they are infrequent and difficult to predict, they are very expensive and can result in great personal loss. These studies reveal with a reasonable degree of certainty an increasing trend in the number and relative costs of disasters, even when adjusted for population growth in the post World War II period (Dore, 2003).

More alarming is the discovery from case studies that many disasters might have been far worse had one more factor gone awry. Examples are: (1) The 1987 Edmonton, Alberta, tornado caused 27 deaths. Although it was rated as a violent tornado, it was only at moderate strength when it caused most of the deaths at a trailer park. Had it been at its strongest stage when it hit the trailer park, the devastation would have been much worse. (2) During the 1998 Ice Storm, the city of Montreal, Quebec, had one power transmission line that remained operational, while all the others collapsed under the weight of accumulated ice. Had the pattern of freezing rain been slightly different, it is very possible that all

Case studies have shown that many disasters might have been far worse had one more factor gone awry.

TABLE 2:
Most Expensive Canadian Natural Disasters, 1900–2002
(Major multiple-payment Occurrences)

DISASTER	YEAR(S)	LOCATION	ESTIMATED DIRECT COST *(billions of 1999 dollars)*
Drought	1931–1938	Prairie provinces	1.0
Flood	1950	Winnipeg, Manitoba	1.1
Drought	1979	Prairie provinces	3.4
Drought	1980	Prairie provinces	5.8
Drought	1984	Prairie provinces	1.9
Drought	1988	Prairie provinces	4.1
Drought	1989	Prairie provinces	1.0
Hailstorm	1991	Calgary, Alberta	1.0
Flood	1996	Saguenay region, Québec	1.7
Freezing Rain	1998	Ontario to New Brunswick	5.4

(SOURCE: PSEPC, 2003)

Climate scientists are well aware that the recent past is no longer an appropriate guide for the future, although knowledge of it is essential to understanding how risk is changing.

FIGURE 3
Historical Trends of Geological and Weather-related Disasters in Canada (1900-2002)
(Source: PSEPC, 2003 [updated from Dore, 2003])

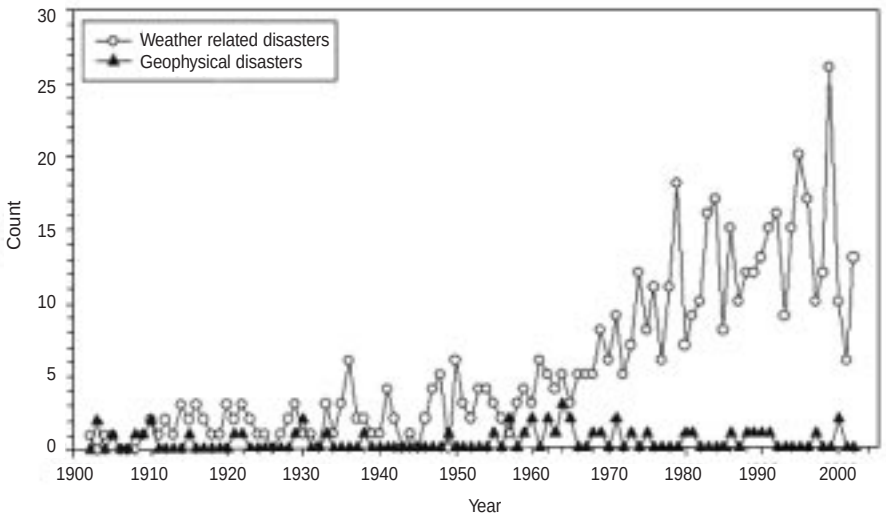
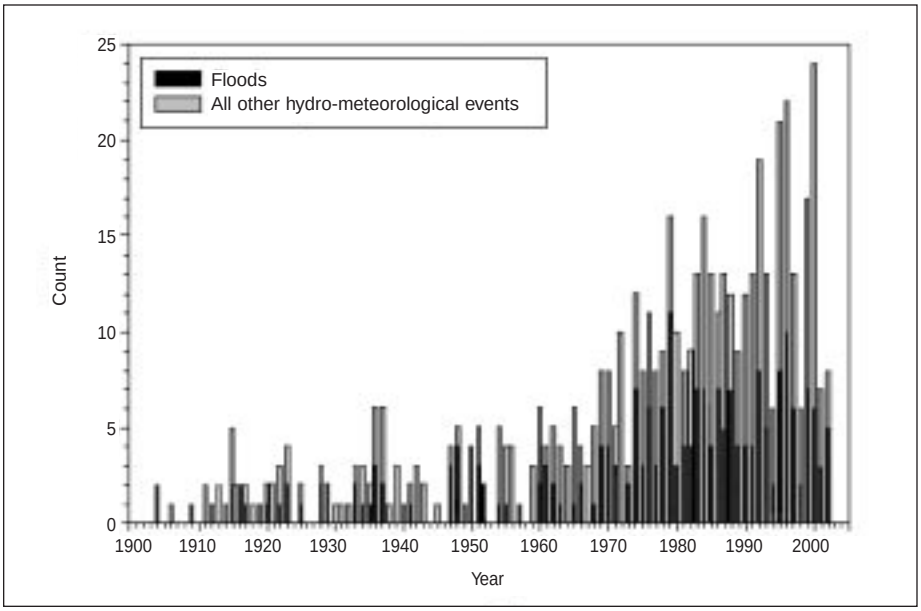


FIGURE 4
Comparison of Canadian Flood Disasters Frequency with other Hydro-meteorological Disasters
(Source: PSEPC, 2003.)



the lines would have collapsed, magnifying the disaster enormously. (3) The 1997 Red River flood in Manitoba came close to overtopping the dykes and inundating Winnipeg. Precipitation during the actual flood was only 70% of normal (Rannie, 1998). Had it rained slightly more, the city might well have been flooded, with a resulting cost of billions of dollars.

Given our current understanding of trends, it seems likely that Canada's disaster experience will change in two ways in the future:

1. Due to increasing vulnerabilities and increased frequency of some hazards from climate change, some types of disasters will likely occur more frequently, particularly flood and drought.

2. Because no worst-case scenario has yet been experienced, it is inevitable that at some time in the future, Canada will experience a disaster far more devastating than any we have seen in the past. It may be another ice storm, an earthquake, or the creation of a drought-ridden region as a result of climate change. There is no way of knowing which event will occur next, but it is certain that such a disaster will eventually occur. It makes sense to understand the risks better and take action to mitigate future damages.

Climate scientists are well aware that the recent past is no longer an appropriate guide for the future, although knowledge of it is essential to understanding how risk is changing. The insurance industry has noted that actuarial analyses may no longer provide reliable estimates of disaster risk, especially their future risk, due to complexities, uncertainties, and changes in social systems and climate. Other changes in the landscape lead physical scientists to similar conclusions. For

"Due to increasing vulnerabilities and increased frequency of some hazards from climate change, some types of disasters will likely occur more frequently, particularly flood and drought."

example, flood risks in watersheds shift over time as a result of land-use changes, development and waterway management. Thus there is a need to continually update flood risk maps and estimates of flood return periods (Robert et al., 2003; Roy et al., 2003).

Historical disasters must be understood in context in order to reach conclusions about changing patterns of risk and to develop scenarios of future disasters. That context includes increasing populations and the growth of mega-cities, changing demographics, land use, some social organizations and built structures that are increasingly less resilient, and a landscape of hazards affected by climate change that in all likelihood are progressively lying outside of our traditional coping range. In spite of this knowledge, we continue to rely on out-of-date and incomplete information when assessing hazard risk and not sufficiently communicate this risk to the public (Robert, 2003; Clague, 2003; Foo, 2003; Stethem et al., 2003).

To understand our changing risk environment, we must account for both negative forces that act to increase risk, and for many positive activities designed to increase coping capacity and mitigate risk. The latter include government policies related to emergency management and disaster mitigation, better science and engineering practices, and community engagement and sustainability initiatives. These twin sets of forces interact in a complicated way. Steering and influencing them is a challenge, particularly since the manner in which they will co-evolve is unclear. Though predicting the future is a formidable task (as any weather forecaster or economist can confirm), enough is known to make our society increasingly disaster-resilient, should we choose to do so.

"Because no worst-case scenario has yet been experienced, it is inevitable that at some time in the future, Canada will experience a disaster far more devastating than any we have seen in the past. It may be another ice storm, an earthquake, or the creation of a drought-ridden region as a result of climate change. There is no way of knowing which event will occur next, but it is certain that such a disaster will eventually occur. It makes sense to understand the risks better and take action to mitigate future damages."

3 HAZARDS/DISASTER CONCEPTS AND MODEL

To illustrate the relationship between hazards, disasters and vulnerability, a 'disaster model' is presented (Figure 5). It emphasizes how human decision making influences disasters. The central idea is that there is a series of social factors that create vulnerability, starting with *root causes* that create *dynamic pressures*, which ultimately result in *unsafe conditions*. This vulnerability is triggered by some external force, such as a natural hazard, which then results in a disaster (Hewitt, 2001; Blaike, 1994). This type of model is called a 'pressure-release' model.

This model suggests that the path to reducing disaster losses lies in the area of vulnerability reduction. For decision- or policy-makers, the issue is on how to intervene in the 'progression of vulnerability' to effect positive outcomes. These interventions could be made at any stage by addressing 'root causes', 'dynamic pressures' or 'unsafe conditions'.

An example of a root cause is the exploitation of natural resources, which can worsen some hazards or reduce the ability of the natural environment to act as a buffer, thereby creating unsafe conditions and aggravating some disaster impacts. Examples of this include slope failures triggered by deforestation, storm surges made worse by the loss of coastal dunes, flooding and land use change, and climate change resulting from the burning of fossil fuels.

Courtesy of
The Telegram (St. John's, Newfoundland)

Understanding the hazards model requires embracing a systems approach. In the natural hazard/disaster case, the different parts of the system (sub-systems) include the natural environment and the built environment, as well as social, cultural and economic human systems. Some relationships are hierarchical, where smaller systems are embedded within larger systems, while others are more parallel, working somewhat independently but still affecting each other through a series of inputs and outputs.

These systems and sub-systems interact and affect each other in complex ways, exchanging information, material and energy with each other. From these interactions, patterns of cause and effect emerge. These can be simple and unidirectional or circular, resulting in feedback loops that can have either positive or negative impacts. Within feedback loops, distinguishing between cause and effect can become complicated, as effects can become causes and generate their own sets of impacts.

Some systems, such as buildings, are 'hard', with well-defined boundaries; others, such as policy environments and cultural attitudes towards risk, are 'soft'. In complex systems like the one being described here prediction can be very difficult at times. Surprising behaviour (emergent properties) can often be observed that cannot be

understood only by considering individual system components. This is an example of the whole being greater than the sum of the parts.

Though the model shown in Figure 5 appears linear, in fact it represents a rather complex system in which the different parts interact in ways that are sometimes difficult to predict and occasionally perverse. An example is the well known `dyke effect', which refers to the tendency of people to place excessive faith in dykes built along rivers to protect them from floods. This unrealistic perception of safety often leads to development in risky areas along the dykes that are out of proportion to the safety the dykes actually provide. When the dykes are overtopped by a flood more extreme than their design limits, or when dyke failure occurs, the resulting flood can create a disaster, the magnitude of which has actually been exacerbated by over-reliance on the original structural mitigation effort.

Like most social problems, the problem of natural disasters is not subject to simple one-dimensional solutions. For this reason it is important for people from different disciplines and organizations who are concerned with disasters to interact and learn from each other. Within Canada, one of the barriers to coping better with disaster issues is the lack of networks or institutions to create such a dialogue.

By envisioning a future with safer and more sustainable communities, we can choose pathways that lead us in that direction. This requires the implementation of national networks and strategies devoted to disaster mitigation where people, communities, the private sector, and all levels of government work together to achieve a common goal.

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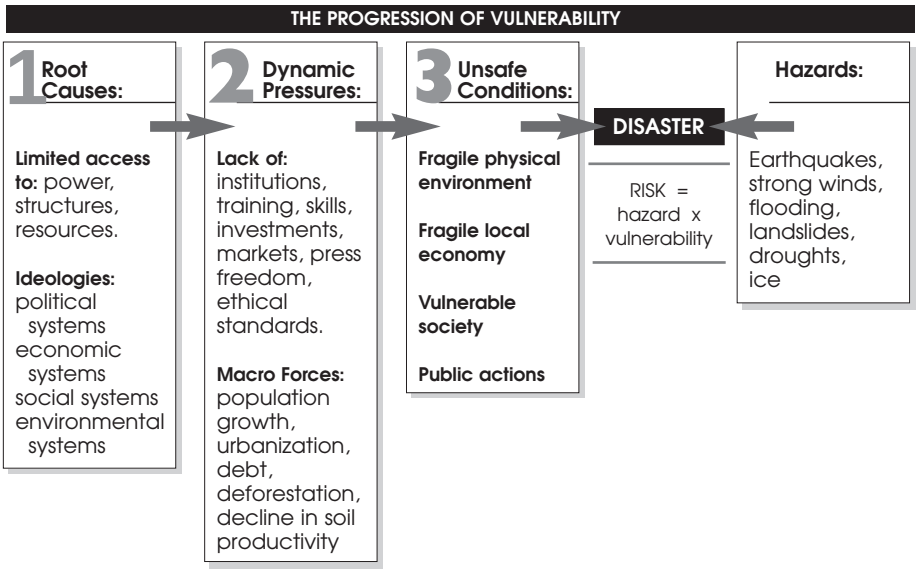
FIGURE 5
'Pressures' that Result in Disasters: the Progression of Vulnerability
(Source: modified from Figure 2.1, Blaike, 1994)



4 COPING MECHANISMS

Canadian society copes with and adapts to natural hazards and disasters through a variety of actions that can be grouped under the four pillars of the disaster management cycle: mitigation, preparedness, response, and recovery. Within each phase of the cycle, actions can be taken to decrease the threat from hazards and to minimize the potential impacts of a disaster. These risk management activities, which take place to a greater or lesser degree in every community across the country, typically increase in intensity after disasters happen. This post-disaster period is often referred to as a 'window of opportunity' when both public and political will is focused on the event's outcome and on reducing present and future vulnerability.

Generally, risk management activities fall into two groups: those that *reduce risk* and those that *transfer* or *share risk* (although the decision can simply be made to accept a certain level of risk).

(I) RISK REDUCTION

Courtesy of R. Bergeron, ministère de l'Energie et des Ressources, Quebec, and Canadian Armed Forces

Risk reduction can be accomplished by modifying a hazard (e.g. cloud seeding to reduce hail size, triggering controlled avalanches, or conducting prescribed burns) or by reducing vulnerability (e.g. enforcing building codes, zoning flood plains to restrict development, adoption of early warning systems). Many risk reduction activities are 'true' mitigation; they are actions taken well in advance of an emergency to change the likelihood of a hazardous event becoming a disaster. Others take place in the preparedness or response phases, which act to reduce losses and avoid further damages once an emergency is imminent or has occurred. This can include activities such as the release of severe weather advisories, road closings, or the activation of well-established and tested emergency plans. Regardless of when or where risk reduction activity occurs the objective is the same: avoid damages and loss of life.

When it comes to reducing risk through mitigation, a combination of approaches is often best. Historically, however, emphasis has been placed more on structural or engineering-based mitigation options, rather than on other types. Experience has demonstrated that this approach, while it plays an essential role in risk reduction, has been over-emphasized and that non-structural mitigation has been under-utilized. The result has been unnecessary damage and suffering, stemming from an incorrect belief that engineered structures alone can provide the optimum risk reduction available.

Increased public information about natural hazards and vulnerability is also critical to reducing future losses. Effective and rapid communication is key to reducing community vulnerability to an impending disaster. Non-structural mitigation actions – the development of early warning systems and data networks to support them, improving public understanding of risks, engaging community members in emergency management activities and ensuring appropriate responses to events – all serve to increase awareness and reduce a community's vulnerability (Stasiuk, 2003; Smoyer-Tomic et al., 2003). These activities, combined with structural mitigation projects such as retrofitting or relocating buildings and building dams or other barriers, can result in additional vulnerability reduction benefits.

The National Building Code of Canada[6] includes standards to protect structures against a variety of environmental risks including snow and rainfall, ground shaking, fire and wind. It is a model code that has no legal status until adopted by a province, territory or municipal government. Municipalities are responsible for enforcing the code, which is an important part of ensuring safe and resilient infrastructure. Poor quality of construction and lack of enforcement can exacerbate a disaster very significantly, as demonstrated by the damage caused by Hurricane Andrew in Florida, where 25% to 50% of the damage may have resulted from lax construction practices.

Some hazard reduction programs, such as weather modification, are generally considered to be ineffective by the scientific community (WMO, 1998). However, Canada's insurance industry has adopted at least one – seeding clouds in Alberta to reduce hail risk – and found it to be effective according to their analysis (Renick, 1997). Other programs have a more obvious benefit: for example, the floodway protecting Winnipeg, Manitoba, has been used at least 22 times since it was completed in 1968 (Shrubsole et al., 2003). The damage averted has already far exceeded the $63.2 million cost of construction, with estimated savings of between six and eight billion, and a benefit-cost ratio of at least 4:1, according to a 1982 analysis (Morris-Oswald et al., 1998). In 1997 alone it protected Winnipeg from the Red River flooding that created the worst economic per capita disaster in U.S. history further south at Grand Forks, North Dakota.

The floodway protecting Winnipeg, Manitoba, has been used at least 22 times since it was completed in 1968, with an estimated savings of between 6 and 8 billion dollars.

Prediction is another method of reducing risk. There are two kinds: warnings of imminent events and probability estimates that certain events will occur over a given period of time.

Warnings of imminent extreme events can be an effective way to protect people and to reduce losses. The Meteorological Service of Canada (MSC)

[6] www.nationalcodes.ca

provides weather watches and warnings to serve this end. These warnings cover a wide range of hazards, from severe summer thunderstorms to blizzards. The ability of the MSC to provide accurate warnings depends on several factors, the most important of which is the type of hazard and the time scale. Larger scale events such as major winter storms are much easier to predict than small-scale events such as tornadoes. Not surprisingly, long range predictions tend to be much less accurate than short range ones.

Forecasts for some geophysical hazards are also issued in Canada, although they are less well-known by the general public than weather forecasts. For example, the Geological Survey of Canada (Natural Resources Canada) issues long-term (up to 27 days) and short-term (one to 24 hour) geomagnetic forecasts to aid electrical power utilities cope with induced voltage swings during magnetic storms.

There is a warning system for tsunamis on Canada's west coast, but this is only useful when the source of the tsunami is located far from populated shores; otherwise there is insufficient time to warn and evacuate people. Although no long-term monitoring of potentially active volcanoes is undertaken in Canada, warning of an impending major eruption could be given by a large number (or swarm) of shallow earthquakes beneath a volcanic centre.

The effectiveness of a warning depends not only upon its accuracy and how it is communicated to the public, but also upon the ability of those at risk to respond in an appropriate manner. This response can be hindered by lack of knowledge, false beliefs, skepticism or apathy. Risk communication and public education, therefore, is an important part of reducing disaster losses.

The second type of prediction is probabilistic in nature; it provides estimates of the likelihood or chance of a particular type of event occurring over some period of time. Examples include data on or maps of flood or earthquake risk that can be used to make decisions regarding land-use planning and risk analysis. This sort of information, which requires long data sets that can be used to make statistical estimations of occurrence probability, is used by the National Building Code of Canada to set standards.

The concept of return periods is relevant to this category of prediction. Unfortunately, it is often misunderstood. For example, a 100-year flood refers to a flood of a particular magnitude that occurs on average once every 100 years, or that has a one percent chance of occurring in any one year. It does not mean, as many people mistakenly think, that it will not occur again for another 100 years, if it has just happened.

Mitigation actions, whether they modify the hazard or reduce vulnerability, deserve particular attention since they have the greatest potential to add incremental benefits to existing disaster risk reduction activities.

Mitigation as Risk Reduction

Mitigation actions, whether they modify the hazard or reduce vulnerability, deserve particular attention since they have the greatest potential to add incremental benefits to existing disaster risk reduction activities in Canada.

Mitigation activities to reduce the risk from natural hazards can include many different elements: legislation, policies (strategic and operational), standards (such as building codes) and enforcement, educational programs, warning systems, structures (such as dams), design of resistant or resilient systems, retrofitting (such as reinforcing buildings to ground shaking), and land-use planning and hazards assessment (such as identifying floodplains and restricting development within them, as per the Flood Damage Reduction Program FDRP).[7]

Such actions affect both the social and natural realms. Each community will have to decide which strategies and blend of approaches are possible and most appropriate, depending on their perspective, ethics, taken-for-granted assumptions, resources, capacity, politics, local hazards, previous experience with disasters and institutions.

In some instances, our best efforts at mitigation may not produce the intended results. For example, the FDRP has generally been considered a success as a cooperative federal-provincial program to reduce average annual flood damages (Watt, 1995). However, recent local studies have shown some counter-productive results (Robert et al., 2003; IJC, 1997; Roy et al., 2003); in some communities there has been continued development within floodplains because the presence of dykes and other structural measures may have provided a false sense of security. In any case, the appropriate jurisdictions have not been vigilant enough in ensuring that floodplains were zoned and regulated to prevent development or that flood-proofing standards were properly applied.

The reasons for this lack of expected results are many and complicated – some are political, some are cultural, and some are technical. For example, programs that are based in science and technology, but do not take account of the realities of human behaviour, are likely to fail. People need to know and understand the risks they face, and accept responsibility for making decisions that increase their vulnerability.

Therefore, while effective mitigation requires a supportive top-down policy and assistance, it should be accompanied by local community initiatives (Pearce, 2003). Partnerships between the various levels of government, the private sector, non-government organizations (NGOs) and local communities are essential. Through awareness, empowerment and well-formed legislation that forces action, better mitigation can become a reality. Historically, it has been a problem that community planning and disaster management planning are based in different professional communities with different ideologies and little communication between them. Some integration of these two groups is a requirement for the successful mitigation of disaster risk.

> We react very well, but we do not mitigate or plan properly for these events - we react to these events. I believe we must go through the process to find out how we can mitigate these events and minimize the damage to human lives. Fundamentally, that is what it is all about.
>
> *Senator Terrance R. Stratton, Chair of the Subcommittee on Canada's Emergency and Disaster Preparedness, 1999*

[7] More information on the FDRP can be found at www.ec.gc.ca/water/en/manage/flood/e_fdrp.htm.

A significant reduction in vulnerability to hazards, and a subsequent reduction in risk, can likely be achieved through more effective and concentrated efforts to reach out to the public and explain risk to natural hazards in an understandable and objective fashion. Pearce (2003) discusses the lack of "a comprehensive understanding of local government emergency management strategies and their effectiveness" and a lack of public participation as being significant obstacles, though a trend towards a more broad-based and inclusive strategy is evident. It is particularly important to dispel commonly held disaster myths that tend to impede progress and often accentuate the emotional and psychological distress which results from these events (see *Box 4*).

BOX 4

COMMON DISASTER MYTHS THAT IMPEDE EFFECTIVE RISK REDUCTION ACTIVITIES

- The public will panic if true risks are revealed to them;
- A belief that it cannot happen 'here' or 'to me';
- A 100-year return period means that a disaster only occurs once every 100 years, or that a community is safe for another 100 years if it has just occurred; and
- All risks are known with a high degree of accuracy and precision.

(II) RISK SHARING AND TRANSFERENCE

Transferring or sharing risk is mainly achieved through two mechanisms: 1) insurance, both private and government sponsored programs, such as crop insurance; and 2) disaster assistance programs administered through the government or other agencies such as the Red Cross.

Sharing risk through insurance and disaster assistance programs is a crucial component of disaster mitigation.

The Insurance Bureau of Canada tracks the insured costs of natural disasters (ICC, 2001) (Table 3 and Table 4), and has developed programs to reduce the risk of natural disasters, mainly through the Institute for Catastrophic Loss Reduction (ICLR).[8] The ICLR is an organization established by Canada's property and casualty insurers in cooperation with the Ontario and federal governments that engages in research, industry and public education, and networking.

Many provinces, but not all, have their own disaster assistance programs that assist individuals and communities to recoup losses after an event. For example, Ontario has the Ontario Disaster Relief Assistance Program.[9] These programs can be augmented by the federal Disaster Financial Assistance Arrangements (DFAA). The DFAA is a cost-sharing arrangement under which the federal government provides basic financial support to help provincial

[8] www.iclr.org

[9] www.mah.gov.on.ca

TABLE 3:
Costs of Natural Disasters to the Insurance Industry in Excess of $100,000,000*
(Major multiple-payment occurrences)

TYPE	DATE	LOCATION	COST *(millions of 2002 dollars)*
Ice Storm	Jan. 1998	Quebec / Ontario	$1,818
Hail	Sept, 1991	Calgary, Alberta	$ 412
Hail	Sept, 1999	Calgary, Alberta	$ 386
Flood	July 1996	Saguenay, Quebec	$ 218
Tornado	July 1987	Edmonton, Alberta	$ 215
Flood	July 1993	Winnipeg, Manitoba	$ 215
Flood/Hail	July 1996	Winnipeg, Manitoba	$ 164
Tornado	May 1985	Barrie Ontario	$ 133
Hail	July 1996	Calgary, Alberta	$ 133
Snowstorm	Jan. 1999	Southern Ontario	$ 130
Storm	May 2000	Southern Ontario	$ 107

* ranked by cost

Of this list, the January 1998 Ice Storm accounts for 51% of the total list costs of $3.6 billion. Like Table 1, it reflects the characteristic of disasters to be 'top- heavy'.

(SOURCE: ICLR, DATA 1983 – DEC. 2001)

governments meet the cost of disasters that exceed what they might reasonably be expected to bear on their own. The formula for determining federal financial assistance for a disaster is a function of per capita expenditures incurred due to the disaster. This means that provinces with smaller populations may request DFAA relief for events that a larger province could have recovered from on its own. Table 5 presents the total cost of disaster financial assistance (federal and provincial contributions combined), as documented under DFAA from 1970 to 2002.

The real costs of disasters far exceed those that are compensated for by insurance or disaster assistance programs.

The real costs of disasters far exceed those that are compensated for by insurance or disaster relief programs. Many costs are borne by municipalities and individuals. Non-monetary impacts on human health and social, cultural, and environmental welfare can be substantial. Nevertheless, risk sharing through both insurance and official relief programs provides an important tool for recovery.

Unfortunately, risk-sharing programs can be justifiably criticized for playing a role in increasing overall social vulnerability. This happens because the presence of a safety net like insurance or disaster relief can encourage dependence and/or risk-taking behaviour when people perceive that costs resulting from their risky behaviours will be borne by others (Wilde, 1994).

Some activities intended to lessen the impact of disasters have been found to be ineffective or, at times, even counterproductive. Examples include flood mapping and flood insurance programs intended to reduce development

within flood plains but which were, in some communities, unsuccessful and may in fact have even encouraged flood plain development (Robert et al., 2003; White, 1999). In part, this is because hazards are often examined singly, or from only one perspective; such efforts may not take into account the ability or willingness of the community to change, the local enforcement capacity or the complex interaction between policy development and implementation.

Recent experience of Canadian disasters has shown that, although communities possess some strong elements of resilience, critical deficiencies exist in coping mechanisms. Such shortcomings include a lack or ignorance of risk assessment at the local level; a heavy reliance on volunteers to prepare and respond to disasters; a lack of committed support to human resources and capital equipment from various levels of governments and other institutions; and a lack of meaningful involvement of stakeholders in hazard mitigation and management decision making. One way to address such issues is to develop a shared vision for strengthening the resilience of communities, and to create a partnership among stakeholders for further mobilization of knowledge and resources.

Legislation and policy play an important role in addressing these deficiencies, and Canada continues to make progress in these areas. The PSEPC-led National Disaster Mitigation Strategy, the Quebec Civil Protection Act (Bill 173)

TABLE 4:
Costs of Natural Disasters to the Insurance Industry by type
(Major multiple-payment occurrences)

TYPE OF EVENT	NO. EVENTS	CUMULATIVE COST *(in millions of 2002 dollars)*	PERCENT OF TOTAL
Ice Storm	1	$1,818	35%
Hail	18	$1,091	21%
Flooding	17	$758	14%
Storm	18	$506	10%
Tornado	7	$488	9%
Wind	8	$279	5%
Flood/Hail	1	$164	3%
Snowstorms	1	$130	2%
Windstorm	1	$15	0.3%
Wind/hail	1	$2	0.0%
Total	**73**	**$5,253,509**	**100%**

SOURCE: ICLR, DATA 1983 – DEC. 2001

Cost to the Canadian insurance industry of natural disasters.
Types ranked by cumulative cost.
Drought and residential flood costs are not included.
Commercial flood costs are insurable and included.

Legislation and policy play an important role in reducing disaster losses, and Canada continues to make progress in these areas.

and Ontario's Emergency Readiness Act (Bill 148) are excellent steps towards reducing the risk of natural hazards by emphasizing the role of disaster mitigation. However, legislation is not enough. Successful mitigation also requires political commitment and significant scientific input. Scientists from universities and within government organizations such as the Meteorological Service of Canada and the Geological Survey of Canada can help provide the methods and data required for community level hazard identification and risk assessments activities.

Shrubsole et al., (2003) noted that "past experience suggests that a lack of commitment by some or all levels of governments has been associated with the implementation of programs." This is a recipe for failure. Commitment, as noted in Danard et al. (2003), is a "hard sell" due to the rare occurrence of extreme events, no matter how great their impact. Should a national disaster mitigation strategy be developed, it would require adequate resources and the political will to ensure success in whatever form of governance that is chosen.

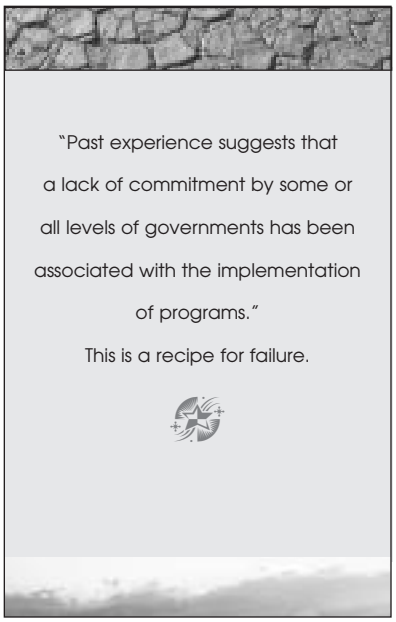


TABLE 5:
Disaster Costs under DFAA (1970–2002)

PROVINCE/TERRITORY	ESTIMATED TOTAL DFAA COSTS ($1000S) IN YEAR 1999 DOLLARS
Newfoundland	$53,202
Nova Scotia	$24,117
PEI	$4,631
New Brunswick	$145,119
Québec	$734,160
Nunavut	$0
Ontario	$342
Manitoba	$430,724
Saskatchewan	$60,978
Northwest Territories	$3,053
Alberta	$237,802
British Columbia	$231,580
Yukon	$5,592
Multiple province claims	$871,168
Total	**$2,802,468**

DFAA cost – amount by province/territory; estimates include both federal and provincial/territorial shares.

NOTE: drought is not included since it is covered under a different federal government relief program (crop insurance).

5 UNDERLYING THEMES

Canadians are exposed to many different natural hazards and are vulnerable in a variety of ways. This vulnerability develops through a progression of cause and effect relationships, beginning with *root causes* that create *dynamic pressures,* which then result in *unsafe conditions* (Figure 5). Assuming that poverty and lack of choice do not unduly restrict the options of most Canadians,[10] three main themes have been identified within which this progression occurs. The relative importance of these themes will vary from place-to-place and from hazard-to-hazard, and it is not possible to generalize as to which one dominates.

(I) THE ENVIRONMENT

The first theme has its source in how humans relate to the natural environment. We tend to view the natural environment as something to be tamed and utilized and consequently do not always think through the potential impacts of our actions. This can increase risk in two ways: first, by making hazards more severe; and second, by placing ourselves in harm's way.

Courtesy of Geological Survey of Canada, Natural Resources Canada

Environmental degradation caused by urbanization and resource development alters some hazards profiles. For example, paving over natural surfaces reduces water infiltration during rain events, leading to greater runoff and more flooding. De-vegetation of slopes also increases the chances of landslides. Some progressive communities require that subdivision developers incorporate measures to prevent an increase in urban runoff due to the development. This is certainly the contemporary best practice for subdivision design and is becoming a regulatory requirement. In addition to environmental degradation that can worsen hazards, communities are sometimes put at increased risk from development occurring in hazardous zones, such as in or near flood plains, coasts and fault lines.

These actions seem to be rooted in a notion that humankind can 'command and control' nature and a denial that its degradation can have negative consequences that affect us. Though these beliefs may be true some or even much of the time, our disaster experience demonstrates that development actions can fail to produce increased safety and security in some very important ways. In the decades to come, climate change has the potential to illustrate this lesson in costly ways by exacerbating the number and magnitude of some kinds of natural disasters, particularly those related to flood, drought or sea-level rise (IPCC, 2001).

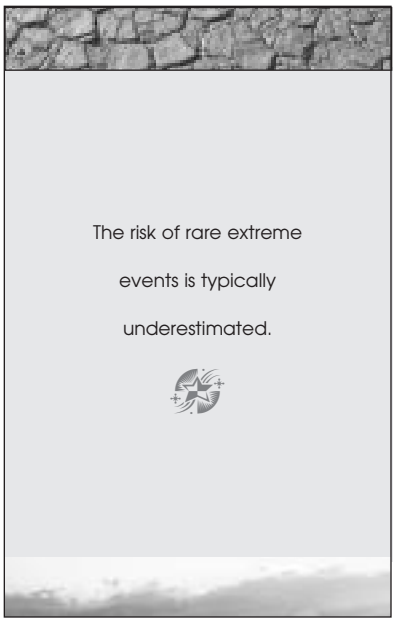
[10] Note that Lindsay (2003) argues that poverty, though not as significant a factor in Canada as it is in developing nations, is still an important determinant of vulnerability.

To reduce vulnerabilities that have their origins in our relationship with the environment, it is important to embrace a risk-reduction approach that goes beyond traditional thinking and challenges 'taken-for-granted' assumptions. The solutions to some problems are not primarily technological, though this tends to be the most common approach. Solutions may lie in the realm of values, ethics, social discourse, or in multidisciplinary approaches.

For example, examining how major cities have approached recurring heat wave problems illustrates the benefits of adapting to hazards using a multidisciplinary approach and more environmental thinking. A typical technological adaptation is increasing the use of air conditioners. This is an effective strategy that should be part of any program, but it has drawbacks: it's expensive, it consumes energy at a time when energy demands are high, it increases air pollution, and it increases greenhouse gas emissions.

An alternate approach is to increase urban green space by creating rooftop and vertical gardens. These have a significant cooling effect and also provide important co-benefits. For example, they can reduce flood peaks by acting as water storage reservoirs. They also improve air quality by filtering pollutants and provide a visual landscape that many find restful, thereby reducing stress (Smoyer-Tomic et al., 2003). Moreover, this approach emphasizes environmental sustainability.

(II) RISK ESTIMATION



The second theme deals with how we perceive and respond to rare but extreme risks. Many people have a bias toward discounting such events, which results in risk-taking behaviour that likely would not occur if they viewed these events more objectively (Etkin, 1999).

The risk of rare extreme events is typically underestimated for a number of reasons:

- **Statistics:** One difficulty with risk estimation is statistical in nature, and relates to the relatively short databases used to estimate the probability of rare events that have not yet been recorded.
- **Psychology/Risk Perception:** Research has shown that people tend to avoid dealing with risks that are devastating and over which they feel they have little or no control. This leads to avoidance, denial, and a gap between perceived and objective risk estimations. Other research has shown that people tend to increase their risk-taking behaviour (such as developing in areas prone to flooding or earthquake) when their perceived risk is less than their 'acceptable level of risk' (Wilde, 1994), especially when they expect to benefit from doing so, as in the case of urban development. When combined, these two factors – risk avoidance and underestimation – result in poor development decisions.

  As well, how people respond to natural disasters is very much determined by their recent experience; their attention is focused on these issues during and just after a disaster, but wanes greatly at other times. This psychological

response, known as the 'crisis effect', makes long-term planning problematic and focuses attention on response and recovery activities.

- **Faith in Technology:** People tend to believe that technology can and should protect them. In reality, any structural defence has a probability of failure; it is designed to cope with finite environmental loads that nature will exceed at some time. A tendency to put undue faith in technology as a safeguard leads to excessive risk-taking behaviour.
- **Discounting:** Benefit-cost analyses are likely to greatly discount the impact of extremes that may lie far in the future, devastating though they may be. Often, though, the analysis may not capture non-quantifiable costs, such as human suffering or benefits (such as cleaner air due to increased urban vegetation).

A consequence of this risk underestimation is that infrastructure tends to be built to given levels of resistance (fail-safe), but often not in a resilient way, so that recovery can be more easily achieved when failure does occur (safe-fail). An example is a hydro tower built with break away arms that collapse in the event of failure, but allow the main tower structure to remain standing.

In spite of this, it must be noted that a large proportion of deaths and economic impacts come from events that do not qualify as disasters, such as weather-related car accidents and lightning strikes. Because of their cumulative effects, these more common events are as if not more important than the large scale but rare disasters, but they often receive much less attention.

(III) ETHICS AND VALUES

The third theme has its foundation in ethics and values. Three main ethical perspectives are relevant: utilitarianism (i.e. the greatest good for the greatest number – though the concept of 'good' is sure to vary from person to person); libertarianism (focusing on rights and duties); and environmentalism (which considers human versus eco-centered approaches). While a detailed discussion on ethics is beyond the scope of this summary report, the main idea is that values that focus on a single ethic can result in practices that increase vulnerability or exclude ones that reduce it. Examples include cultures of dependence that can result from overuse of disaster assistance (utilitarian), over-development of risky areas because people feel that they have a 'right' to live where they wish (libertarian), or environmental degradation caused by a human-centered ethic that attributes a low value to nature. This can be exacerbated when there is a disconnect between those who make potentially risky decisions and those who suffer when disasters occur.

A consequence of risk underestimation is that infrastructure tends to be built to given levels of resistance (fail-safe), but often not in a resilient way, so that recovery can be more easily achieved when failure does occur (safe-fail).

One interesting discussion based on a scenario that emphasizes individual rights is the 'tragedy of the commons' (Hardin, 1968): "Ruin is the destination toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons. Freedom in a commons brings ruin to all." It seems likely that this scenario is now being acted out on a global scale. A good example is climate change and the Kyoto Protocol. Human-caused climate change is expected to adversely impact most of the world and make some

disasters worse. The Kyoto Protocol is a UN initiative designed to reduce the greenhouse gas emissions that cause this change. It enters into force when ratified by 55 nations accounting for at least 55% of total global carbon dioxide emissions in 1990. As of 2003, 110 nations have ratified it, but their emissions account for only 44% of the target, 11% below the necessary amount.

Most individual communities or states would benefit in the short term from not ratifying it but all would lose in the long-run. Unfortunately, while many countries have accepted the protocol, some that are major emitters of carbon dioxide have not done so – notably the United States, which accounts for 36% of global greenhouse gas emissions. Therefore, it seems likely that greenhouse gas emissions will continue to grow, creating increased risks from climate change for everyone.

Stefanovic (2003) in her discussion of philosophy and disasters notes that a contributing factor to poor decision making is the higher value placed upon 'things' that are quantifiable, such as the costs of rebuilding infrastructure, as compared to qualitative values that are harder to define in monetary terms. Examples of the latter include attachment to place, the value of wetlands or human suffering. This bias results in benefit-cost analyses and risk estimations that may not give appropriate weight to less tangible benefits or costs, or to measures that exemplify a 'no regrets'[11] approach or 'the precautionary principle.'[12] There is a growing body of literature on qualitative research that should receive greater emphasis when considering the real cost of decisions.

Socio-economic and development decisions that revolve around these three themes weave a web of vulnerability to rare extreme events. One challenge in achieving reductions in vulnerability reduction is a disconnection between driving factors and outcomes. Many decisions that affect vulnerability are driven by political or economic factors, but the emergency management sector has little or no influence on these driving forces or the decisions that are made. It is important to find ways to engage all potentially affected sectors.

Mitigating the risks of natural disasters means addressing all of the above processes, by strengthening existing mitigation programs and policies, by being inclusive, and by taking new actions that: (a) relate to the environment in realistic and positive ways; (b) do not underestimate risk; and (c) consider values and how they impact vulnerability from a broad perspective.

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[11] *No Regrets* – taking actions that have a positive outcome, no matter how the future evolves.

[12] *Precautionary Principle* – avoiding actions with possible negative outcomes, on the principle that the risk is intolerable.

6 DISTRIBUTION OF RISK ACROSS CANADA

Canadians are exposed to a wide range of natural hazards in Canada (see Box 1), but the extent to which someone will be exposed to each depends on where and how they live. For those who do not live on a coastline, storm surges will not be an issue, but severe rainstorms might be. The degree to which people are vulnerable to these events is highly variable and a function of many factors (see Box 2). Because of this, disaster risk is unevenly distributed across the country. Complicating this is the fact that some hazards vary seasonally, or on longer time scales, depending upon climate patterns such as El Niño. A few hazards, such as flood and drought, appear likely to get worse over time as a result of climate change (IPCC, 2001).

Geographically, risk tends to be concentrated where people live, along the southern boundary of the country – 85% of Canada's population lives within 300 km of the U.S. border – primarily in densely concentrated urban areas. Some lifelines, however, cover long distances to remote locations; examples include power lines that transport electricity from northern to southern Quebec or pipelines that transport oil and gas within, and outside of Canada. Interruption of these services can have severe impacts upon the socio-economic system.

Courtesy of Geological Survey of Canada, Natural Resources Canada

While a comprehensive description of hazards and vulnerabilities in Canada is *beyond* the scope of this paper, the following examples have been selected to illustrate some significant issues about the distribution of disaster risk in Canada.

(I) EARTHQUAKES

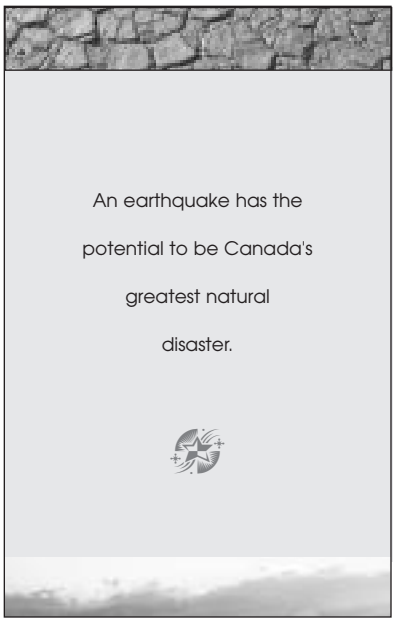
Earthquakes are unpredictable rapid onset events of short duration (seconds or minutes). They generally occur along boundaries where plates press against or slide past each other. In Canada, earthquake activity occurs along the west coast, southeastern Canada along the St. Lawrence and Ottawa valleys, areas offshore of Newfoundland and Labrador, Nova Scotia and in parts of Arctic Canada. The greatest potential impact of earthquakes is upon urban infrastructure and the people using it.

Since it is not currently possible to accurately predict when an earthquake will occur, warning systems are not helpful. However, using historical records of earthquake size and location and geophysical models, it is possible to create maps of earthquake probability that can assist the design and application of appropriate building standards or the avoidance of hazardous areas. Some of these hazardous regions are of little consequence to society since few people live there; however, Vancouver, Ottawa, and Montreal are all located in high earthquake risk zones, endangering many people and a great deal of valuable property.

Fortunately, Canada has experienced only one significant earthquake in the recent past. It occurred in 1929 off the east coast and triggered a tsunami that killed 28 people (Ruffman, 1997). However, the potential impacts of a future earthquake are far larger. A study of the economic impact of a hypothetical, magnitude 6.5 crustal earthquake with a focus 10 km beneath Vancouver concluded that the total economic loss would be between $14 and $32 billion (1992 dollars; Munich Reinsurance Company of Canada, 1992).

Such an event is probably Canada's greatest potential natural disaster, with the possible exception of a rapid switch to a new climate regime. Much of the damage is expected to be caused by fire following the actual shaking event. Reconstruction costs would be divided among the insurance industry (for those who have insurance), various levels of government, and affected individuals. Earthquake insurance market penetration in the Vancouver area is 80% to 90% for commercial property policyholders, while on the personal property side, 50% to 60% of policyholders buy earthquake shock insurance (Pang, 2003). By contrast, in Montreal, also an area of significant risk, only 40% to 50% of commercial property policyholders buy earthquake shock coverage while five percent of the personal property insurers have shock coverage. This means that a much greater proportion of reconstruction costs in Montreal would have to be borne by the public purse and by individuals.

The vulnerability of a community to earthquakes depends not only on its proximity to earthquake prone zones but also on the type of soil and bedrock in the region and the designs and materials used to construct buildings (Clague, 2001). For example, Montreal has many older brick buildings that are generally more susceptible (other factors being equal – the type of building foundation is also very important) to ground shaking than newer style houses that are more typical in Vancouver.



(II) DROUGHT

Meteorologists usually think of drought as a prolonged period of below normal precipitation, though others consider it in terms of reduced stream flow, water levels, soil moisture or runoff. There is no absolute definition of drought – it exists only relative to the needs of human and agricultural systems and ecosystems and how they have adapted to extreme local conditions.

Droughts are usually caused by disruptions to normal weather patterns that prevent rain-producing storm systems from moving through an area. Droughts can also be self-perpetuating since they cause drying soils, dying plants and dry water bodies. This means that little local water vapour is being added to the atmosphere and the area has to depend solely on moist air coming from other regions for its precipitation. This situation increases the probability that drought will occur and extends the lifetime of an existing one.

Drought, in contrast to earthquakes, is a slow onset event of long duration that can occur over large, diffuse regions. For this reason, many do not perceive it to be a potential disaster, though its economic and social impacts are larger than

many rapid onset disasters. It affects both urban and rural areas and can be particularly devastating to agricultural regions that do not have access to irrigation, affecting both crops and livestock. Droughts are often accompanied and exacerbated by insect infestations, soil erosion, and reduced hydroelectric generation.

Over 40 severe droughts have occurred throughout western Canada during the past 200 years. Other parts of Canada have also been affected. The area most prone to drought is the southern Prairies, because of the relatively low average precipitation and high climate variability found there. By contrast, droughts in eastern Canada are usually brief, covering a smaller area and are less frequent and severe. Drought is Canada's most expensive natural disaster in a cumulative sense. It is also one of the hazards likely to worsen as a result of climate change and may make agriculture in the Prairies much more challenging in the future.

Drought mitigation plans and actions of various types can reduce direct and indirect impacts. These include water conservation, soil conservation, grassland management and forest-fire watches. Though there is some skill in seasonal climate prediction, it is limited. Still, it may be one of the best future adaptation options, since it may allow the agricultural community to make better choices of which crops to grow – ones that are drought tolerant, or ones that thrive with more moisture.

(III) FLOOD

Floods are simply the result of too much water. They can be very rapid onset events, occurring over minutes to hours, such as flash floods from severe thunderstorms or they can come on slowly, occurring over days to weeks – as did the huge Red River flood of 1997. Often these slower events happen during spring melt. As a result, floods may or may not occur with much advance warning. They are Canada's most common, though not most expensive, type of disaster. The degree of flooding is very dependent upon conditions prior to rainfall. If the ground is saturated or water levels are already high, flooding is much worse. Recovery can be difficult; many people are not aware that residential flood insurance does not exist in Canada, though commercial coverage is available. Sewer backup insurance can be purchased in most places, however.

Drought appears to be Canada's most expensive natural disaster in a cumulative sense, while floods are Canada's most common type of disaster.

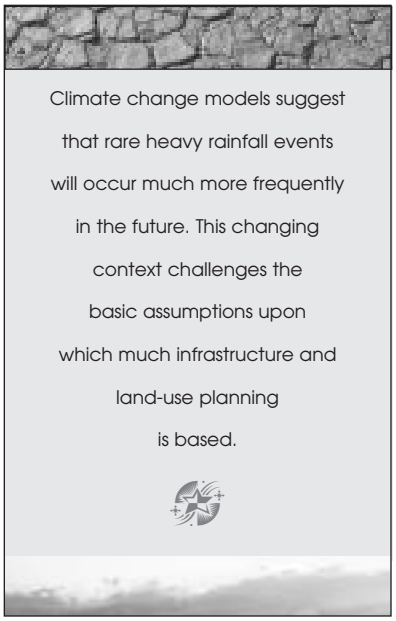
There are a number of different causes of floods in Canada, including:

- Snowmelt;
- Rainfall, both prolonged and occurring over a saturated surface or an intense localized one that can result in flash floods, riverine floods or sewer backup;
- Ice Jams and other phenomenon that obstruct stream flow;
- Jokulhaups (glacier outbursts);
- Coastal storms, tsunamis, cyclones, and hurricanes.

Of these, snowmelt runoff floods are the most common in Canada. About 40% of floods occur during April and May as a result of snowmelt, ice jams, and storm rainfall (Shrubsole et al., 2003). The most severe floods sometimes result from multiple causes, such as heavy rainfall during spring melt. Coastal areas tend to have a different set of hazard exposures than inland areas, being subject to storm surges and tsunamis, while avoiding many severe thunderstorms. The disaster database compiled by PSEPC (Figure 4) shows that in Canada, the rise in natural disasters in recent decades can be attributed mainly to more flooding, resulting from increased development in flood-prone areas.

Flooding in urban areas, especially from sewer backup, has been greatly exacerbated by paving (which reduces infiltration), aging sewer systems, and development in some flood plains. Urban sprawl along the Red River valley in Manitoba and Fraser River valley in British Columbia in recent decades are examples of such development. During the 1997 flood of the Red River basin, sewer backup created serious havoc for the citizens of Winnipeg. Heavy rains also cause urban flooding when they surpass the capacity of the storm sewer system. The frequency of these events may be low but their effects are often devastating.

Though some research suggests that a greater fraction of eastern Canada's rainfall during spring is occurring in heavy downpour events (Zhang et al., 2001), it is clear that an important cause of the upward trend of flood disasters is increasing vulnerability. This pattern is a familiar one, and has occurred in other countries such as the United Kingdom, United States and Switzerland. Gilbert White, the 'grandfather' of U.S. hazards research, once made the useful observation that "there is no solution (to flooding) if you live in a flood plain." In other words, people must face the reality of the risks they face living in such regions and realize that they can only achieve zero flood risk by moving elsewhere. Certainly there can be value gained by using flood plains, however within this context, flood plains should only be developed with the understanding that costs incurred from floods are balanced in the long-run by benefits accrued. Through the 'wise use' of flood plains, flood disasters are largely avoidable.



In spite of the knowledge that flooding in Canada causes severe damages, significant vulnerabilities to flooding still exist (Simonovic and Carson, 2003; Shrubsole et al., 2003; Roy et al., 2003; and Robert et al., 2003). For example, the International Joint Commission report on the Red River flood of 1997 noted the need for a number of improvements including flood plain location data, increased understanding of the environmental and social impacts of floods, and tools for sustainable flood plain management.

Historically, floods have been the second most expensive natural disaster in Canada, and research by climate scientists suggests they will probably occur more frequently in the future because of climate change. One study (Kharin and Zwiers, 2000) shows that a doubling of atmospheric carbon dioxide will cause what is now an 80-year rainfall to occur every 20 years on average – four times as often. This changing context challenges the basic assumptions on which much infrastructure and land-use planning is based. The return period of floods of some

given magnitude is an important factor in planning; in fact, it is used to define our acceptable level of risk – a critical threshold. When this threshold changes, much planning becomes invalid and more flood disasters are likely.

Forecasts and warnings are important, often crucial, tools to lessen the impact of flood events and to save lives when disasters are imminent. However, mitigation through the use of land-use planning and structural defences can be more effective because these approaches prevent the disaster from occurring in the first place. They complement preparedness activities in a way that reduces recurring damages and long-term losses.

(IV) VULNERABILITY

Throughout its history, Canada has experienced large physical, social and economic changes, some which have made us less vulnerable to natural hazards and others more so. While there are few in-depth studies to provide a detailed understanding of these changes, some factors that contribute to increasing the vulnerability of Canadians can be identified (Table 6).

Any community or individual's vulnerability is a balance between the factors that make them more and less vulnerable. In spite of the many ways available to reduce risk, overall, our vulnerability seems to be increasing. According to Statistics Canada, from 1951 to 2001 Canada's population grew from 14 to 30 million, an increase of 214%. The last census showed that 85% of Canadians live in urban centres.

Larger populations and the urban growth required to support them tend to be associated with the development of marginal lands such as flood plains. They can also lead to environmental degradation that changes hazard characteristics for the worse. In addition, extreme events that hit highly concentrated populations cause much more damage and suffering. In Canada, three major cities, Toronto, Montreal and Vancouver (census of metropolitan area), are growing rapidly[13] and account for 34% of the total Canadian population (Statistics Canada, 2003). All cities are exposed to significant hazards. Furthermore, many smaller urban centres areas are exposed to multiple hazards, such as earthquake, ice storm, hurricane and tsunami, making them subject to cumulative disaster impacts.

A lack of understanding of the hazards in the environment and a loss of traditional ecological knowledge or community history can increase a community's vulnerability by reducing its ability to make accurate risk assessments. Aging and marginalized communities also have specific needs that make them more vulnerable than others, sometimes related to aging infrastructure, but also to demographics and other social trends. Canada's population is also growing older; in 1921, about one person in 20 was over 65, but by 2001 this number was one in eight, and by 2026 it is expected to be one in five.

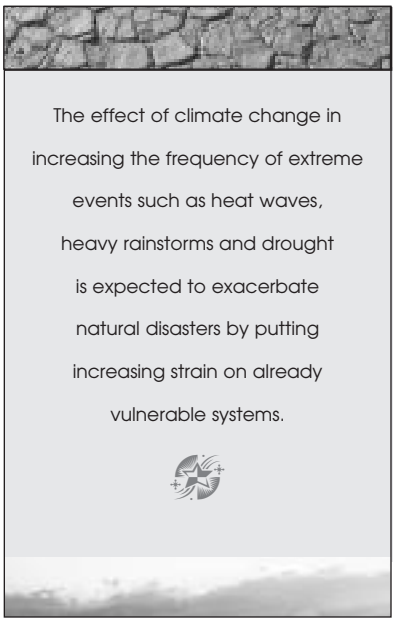
A loss of traditional ecological knowledge or local history of hazards can increase a community's vulnerability by reducing its ability to make accurate risk assessments.

[13] From 1951 to 2001, the population of Canada's five largest cities of Toronto, Montreal, Vancouver, Ottawa/Hull, and Calgary grew an average of 444%, with Calgary growing the most (670%) and Montreal the least (227%). These growth rates are much larger than that of Canada overall.

TABLE 6:
Factors that Influence the Vulnerability of Canadians to Natural Hazards

FACTORS WHICH INCREASE VULNERABILITY	FACTORS WHICH DECREASE VULNERABILITY
– Population growth	– Sustainable land use
– Increasing population density and concentration of wealth	– Increased public awareness and education and use of risk assessments
– Lack or loss of local hazard knowledge	– Improved health care and nutrition
– Aging population	– Scientific and engineering advances; investments interdependency research
– Aging infrastructure and system interdependencies	– Multidisciplinary approaches to risk reduction
– Under-use of non-structural mitigation options	– Development of improved polices and standards, reflecting lessons learned
– Lack of enforcement of standards	– Development of improved warning and emergency management systems
– Lack of effective monitoring systems	– Risk sharing of through disaster assistance programs and insurance
– Poverty	

Aging infrastructure (e.g., storm sewers) and a reliance on interconnected lifelines, such as power, water, transportation and communications systems, can all increase vulnerability to hazards. Though these systems contribute enormously to economic efficiency, their failure, and its potential to cascade through adjacent or interdependent systems, can magnify the size of a disaster. To date, infrastructure investments appear to be lagging behind the projected lifespan of current systems. The effect of climate change in increasing extreme events such as heat waves, heavy rainstorms and drought is expected to exacerbate this problem by putting increasing strain on already vulnerable systems.



Despite the complexity of the issue, there is a clear need for well-rounded and multidisciplinary approaches to reduce vulnerability. There are no national-level studies examining vulnerability issues in Canada, though a few community-level studies exist (Roy et al., 2003; Robert et al., 2003). They emphasize what many disaster researchers now believe – that most natural disasters occur, or are exacerbated, by human actions that create vulnerable communities, the inevitable result of which is a disaster.

The solution to reducing natural disasters does not lie within, or wholly within, the realm of science and technology. The answers must come primarily from politics, sociology, economics, psychology, ethics and philosophy because it is a human-centered problem. In the end, disasters are about impacts on people and resources. Reducing vulnerability is the key. Historically, though, disaster reduction has often been the subject of (primarily) technological problem solving. The result of such an approach ultimately tends to be spectacular failure (Vandenburg, 2000).

An all-hazards risk management approach is generally considered to be the most useful, since focusing on only specific hazards has been shown to put communities at risk. This is best done through probabilistic methods (Smith, 1996; Whyte and Burton, 1980) and an empirical scoring technique in which each potential event is scored based upon its historical incidence of local, regional and national occurrence (Ferrier and Haque, 2003).

Potential effects on the community are assessed and scored, and finally the level of concern the community attaches to these phenomena and resources are reviewed and scored. The final outcome provides a 'risk-rating' of potential events that helps communities mitigate and prepare for coping with the hazards they face. The cornerstone of any program to reduce disaster losses should be community-level hazard identification and risk and vulnerability analyses that are integrated into community planning and decision making.

The solution to reducing natural disasters does not lie within, or wholly within, the realm of science and technology. The answers must come primarily from politics, sociology, economics, psychology, ethics and philosophy because it is a human-centered problem. In the end, disasters are about impacts on people and resources. Reducing vulnerability is the key.

7 CREATING A SAFER SOCIETY

There is no simple prescriptive solution or set of rules that can be used to solve the disaster problem. To illustrate this point consider the analogy of war. From one point of view the solution to the problem of war is simple – all that is needed is for countries to stop fighting. But that is a complex and difficult task because there are human traits that drive us to fight. Similarly, the solution to disasters is complex, because there are human traits that drive us to live in unnecessarily risky ways. Very much like the notion of sustainable development, an important component of disaster mitigation, the *idea* of creating a safer society requires shifts in perspective, institutions, and culture. From these shifts, actions can flow that will result in decisions that make communities safer. To a great extent, the knowledge needed for these actions exists, but is not used or used effectively, largely because of "conflicting interests and lack of political will to resolve them" (White et al., 2001).

Public sector responses to large-scale disasters began in North America during and after the Dust Bowl and the Great Depression of the 1930s. For example, the Prairie Farm Rehabilitation Administration evolved from governmental intervention. Later, various government departments were established as society and the economy diversified; examples include the Department of Fisheries and Oceans and Environment Canada. Gradually, other similar departments were institutionalized, including Emergency Preparedness Canada under the Department of National Defence (now part of Public Safety and Emergency Preparedness Canada), and various post-event recovery programs that undertook responsibility to deal with emergencies and recovery efforts.

Courtesy of Geological Survey of Canada, Natural Resources Canada

Within Canada, there are currently no well-funded, interdisciplinary, national institutions or networks that regularly encourage the many people involved with natural hazards – be they academics or practitioners, in the private sector or government, physical or social scientists – to gather to exchange ideas, information and data. Cultural change and education is dependent upon such an exchange. Enhancing current institutions and/or creating a new one would encourage needed changes to take root and grow.

Creating a less vulnerable society requires adoption of the following principles:

- Think long term;
- Adopt an ecological perspective that integrates social and environmental systems;
- Avoid 'social traps' that lock people into counterproductive modes of behaviour;
- Link responsibility with risk in decision making;
- Develop sustainability;
- Examine 'taken-for-granted' assumptions upon which decisions are based and explore new approaches where desirable.

Historically, the responsibility for dealing with larger-scale natural hazards and disasters has shifted from individuals to institutional spheres, particularly to different levels of government. During the last century, considerable expansion of government sectors and departments has taken place to prevent and mitigate specific types of natural hazards. This sector-based or "specific-hazard" approach met with reasonable success when the scale and magnitude of disaster impacts were modest. As a result, threats to and loss of human life gradually diminished. The catastrophic events of the 1990s, however, have revealed that we are at risk of losing billions of dollars even from a single event, and that can put certain sectors of the economy under serious stress.

The terrorist attacks on September 11, 2001 elevated the level of engagement with emergency management planning to heights not previously imagined (Armstrong, 2002). Consequently, there are new budgetary opportunities, improvements to plans and more sophisticated approaches to communication and information gathering, but insufficient attention has been paid to ensuring these activities contribute to all-hazard risk reduction (Waugh, 2004). In light of this and because of financial trade-offs and constraints among the senior levels of government on the one hand and the need for institutions and individuals to take responsibility on the other hand, partnerships among concerned public, private and other types of institutions are still required to mitigate potential losses from the increasing incidence of natural disasters.

Reducing vulnerability is likely to result more from mitigation efforts taken in any point in the emergency management cycle. Within this context, 'no regrets' strategies and the 'precautionary principle' have received insufficient attention.

In Canada, mitigation activities are carried out by different levels of government in many departments and ministries. They tend not to be well coordinated and compiling a comprehensive list of these activities would be a significant task. This lack of coordination has resulted in strategies that are not broad-based. Our understanding of the costs of natural hazards and disasters is minimal; we do not have a good estimate of what is spent on mitigation and except for a few isolated activities, we do not know the savings involved.

Creating a safer society can be achieved by improving the four ways in which we can reduce risk – mitigation, preparedness, response, and recovery. In some ways, capacity in the first two categories has declined. For example, studies have shown that budget cuts to the Meteorological Service of Canada had a negative impact on their ability to monitor and predict weather (The National, 2001). In other ways, capacity has increased, particularly in emergency preparedness and response. Following the September 11, 2001, attack on the World Trade Center, many organizations took a hard look at their ability to prepare for and respond to a variety of hazards, some of which have not been considered before.

However, we must work harder and be more proactive if we want to reverse the trend of increasing losses from natural hazards and other threats. A policy

framework, the National Disaster Mitigation Strategy,[14] is being developed by PSEPC in consultation with the public, provincial, and territorial governments to advance these goals.

Involvement of the private sector in disaster mitigation has been hazard-specific. For example, the insurance industry in Canada is involved with earthquake and hailstorm hazards but less so with floods. This industry faces challenges because many weather and climatic hazards are expected to worsen in ways that are not yet clear as a result of emerging complexities and uncertainties related to climate change.

Lessons from the major recent natural disasters in Canada have shown that without adequate institutional partnership between governments and private sector, serious socio-economic drawbacks may emerge from sudden and catastrophic natural events. Since the private sector is a profit-seeking entity, its interest is primarily confined to certain types of risk sharing, mitigation, and response to natural hazards and disasters. However, not all types of hazards preparedness, mitigation, response, and recovery relate directly to generating profit, but rather to providing public safety and security; these aspects are the concern of public policy-analysts and decision-makers.

Research shows that a 'window of opportunity' to implement change opens after a disaster occurs but can close fairly quickly following recovery. Planners, policy-makers and others interested in building more resilience into their communities should take advantage of such opportunities by galvanizing the political and public will and translating it into meaningful action. We must also maintain momentum by ensuring a continuous level of support for research, emergency management activities, and public education.

Canadians have the capacity to create a safer society. With planning and commitment, it can become a reality.

[14] www.ocipep-bpiepc.gc.ca/NDMS/sum_e.asp

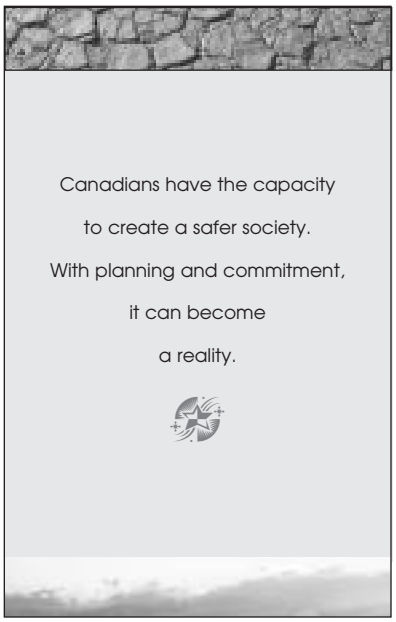
8 RECOMMENDATIONS AND CONCLUSIONS

Various sets of policy recommendations to reduce disaster risk have been published in recent years, including Mileti (1999), ISDR (2002) and Krimm (1998). Those listed in this section draw on both the background papers for this assessment and these other sources.

- Mitigation of risks associated with natural disasters should be strengthened and a national mitigation strategy, such as the one proposed by PSEPC, is needed for it to occur in a comprehensive way.
- There is a need for participation in and ownership of this issue by individuals, the private sector, NGOs and all levels of government.
- Institutions and/or networks that link hazard- and disaster-related researchers and practitioners from both the physical and social sciences should be strengthened and supported through the promotion of regular meetings, conferences and/or workshops.
- Encourage and support community hazard identification and vulnerability and risk assessment from an all-hazard perspective; encourage and provide support for holistic and ecological approaches to mitigation. In order to accomplish this, there is a need for baseline data to compare or assess the effectiveness of strategies and polices in amplifying or moderating vulnerabilities, exposure and risk. At present, this is a poorly addressed issue.
- Strengthen existing public education programs to increase awareness of hazards and disaster mitigation. These programs can provide knowledge that empowers individuals to reduce the risk of disaster in their communities.
- Support interdisciplinary research and knowledge transfer, both from the theoretical and applied sides. Emphasis should be on the social sciences, which in Canada have lagged the physical sciences to date. They are likely to produce the greatest benefits in mitigating risks.
- Support research and data collection initiatives that can lead to integrated or networked databases of impacts and costs. These can be used to enhance understanding of disasters and clearly demonstrate benefits that accrue from disaster mitigation.
- Ensure that political commitment underlies any disaster mitigation program. By being prepared for 'windows of opportunity' after disasters, policy-makers are more likely to succeed in enhancing community resilience.

Courtesy of Geological Survey of Canada, Natural Resources Canada

- Encourage a shift in emphasis from response and recovery to sustainable hazards mitigation, primarily through initiatives that reduce the vulnerability of socio-economic systems and infrastructure to all-hazards.
- Science-based organizations involved in hazard issues, such as Environment Canada and Natural Resources Canada, should increasingly bring risk and vulnerability assessments into their research and practice.
- Public safety and security should receive more attention and concomitant resources from all levels of government. Most Canadians view these as top priority issues. Public institutions must take more proactive roles and assume responsibilities to minimize risks and to aid in disaster recovery through partnerships with private citizens, organizations and economic sectors. Programs and projects that are built on strong institutional partnerships should be encouraged so that issues of accountability and responsibility are addressed appropriately.
- Governance through public involvement in decision making is an emerging trend of modern statehood and both governmental and non-governmental institutions ought to be exemplary in this regard. The state should protect citizens' right to be informed and allow them to participate in governing and implementing plans and programs concerning risks and hazards mitigation.
- Develop an information system, accessible to all segments of society, through which Canadians will be informed of the risks they face from natural hazards in their everyday lives.
- Support programs that will encourage citizens to take personal responsibility for acting in way that will reduce their risk to natural hazards, and thereby improve their quality of life.



To address the key messages that have been highlighted in this report, we must expand our efforts to ensure Canada can develop a hazard mitigation culture that emphasizes sustainability, resilience, and shared responsibility for reducing disaster losses. We must create an environment in which community-based disaster management activities are supported by all levels of government and are complementary to an all-hazards risk reduction approach. Accomplishing this requires a multi-pronged approach that addresses deficiencies in public education, policy, research, and cultural values that are currently contributing to increasing our disaster risk. Critical areas for action are outlined below.

Research

The need for both basic and applied research was a recurring theme in the background papers written for the assessment. Though much is known about hazard and disaster mitigation, there is still much to be learned, both in the social and physical sciences. Current knowledge gaps include but are not limited to:

- How social factors, climate change, urbanization, urban design and other factors alter hazard, risk and vulnerability;

- Hazard, risk and vulnerability assessments at the community level;
- Risk education, communication and management;
- The effectiveness of past programs and policies intended to mitigate disasters;
- Risk perception and human response;
- The application and development of new tools for natural hazard risk management, including:
    - Geographic Information Systems (GIS) and remote sensing
    - Telecommunication lifelines
    - Prediction techniques and models, particularly for extreme weather and climate related events and infrastructure interdependencies.

Community Development

Hazard mitigation should be linked to a healthy natural environment. Recent literature has emphasized the importance of an ecological approach to risk reduction. Unsustainable development can lead to environmental degradation that exacerbates some hazards and can make us more vulnerable by putting us in harm's way. By using planning approaches that sustain and take advantage of natural environments – such as allowing for natural infiltration of storm water in urban areas by increasing green space – we can make other hazard mitigation efforts more effective while providing co-benefits such as places for recreation.

Cultural Change

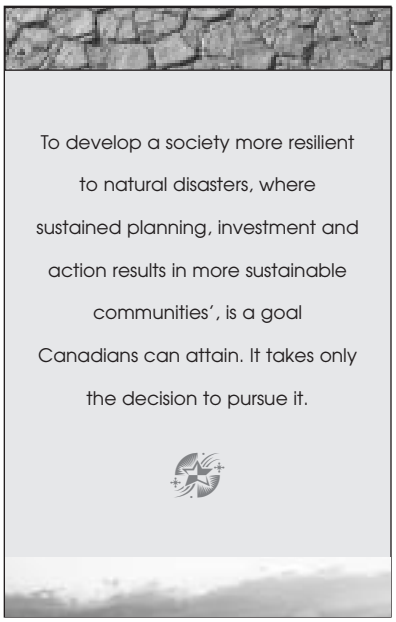
The need for cultural change is frequently called for in the hazards literature. Cultural change requires a cross-disciplinary approach to expanding our understanding of the risk environment we live in. In particular, researchers must engage and communicate with practitioners and policymakers. This lack of active exchange is a serious barrier to creating a more resilient society – one that must be addressed.

Existing institutions and/or networks should be strengthened to facilitate learning between disciplines and between academics and practitioners. We must educate a generation to understand that human decision making can be a contributor to disasters or a powerful mechanism for reducing them. A cultural shift cannot be achieved without an increase in public education and awareness of hazards. These two efforts go hand-in-hand and provide a framework within which all Canadians can contribute to reducing disaster impacts and building a more resilient society.

Commitment

In order to take any action commitment is required on many levels – from the public, from academia, from the private sector and from governments. One form of commitment relates to disaster relief and the incorporation of the principals of disaster mitigation into recovery processes (as recommended by Kumar et al., 2001). With commitment, Canadians can develop the knowledge and capacity to greatly reduce the damage and misery caused by natural disasters and work to ensure that knowledge is used effectively.

The vision stated at the beginning of this paper, 'To develop a society more resilient to natural disasters, where sustained planning, investment and action results in more sustainable communities', is a goal Canadians can attain. It takes only the decision to pursue it.



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