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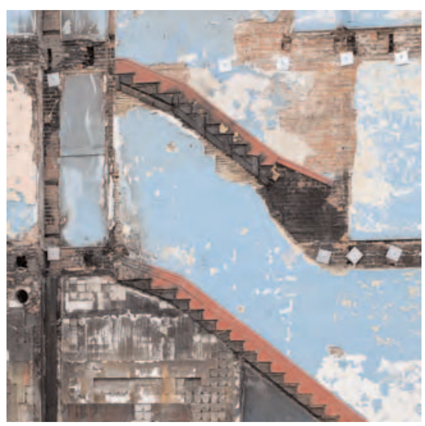
Canadians at risk: Our exposure to natural hazards

Canadian Assessment of Natural Hazards Project

February 2010









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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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INTRODUCTION

1.1 Preface

We live in an unsafe world, one that's filled with risks of various kinds. This book deals with those that result from natural hazards such as earthquakes, floods and tornadoes.

It's the third part of a project conducted by many of Canada's leading scientists in the field of hazards research and is meant to inform people about the risks they face, some of the ways we adapt to them and actions we can take to reduce our vulnerability to them.

The reader of this book will find much information on the hazards themselves, though it really just scratches the surface of our current knowledge. Perhaps the most important message, however, is that we are not just passive victims of natural hazards that are beyond our control; instead, we often make ourselves victims by our own actions. How vulnerable we are to the environment we live in is largely determined by the choices we have made in the past and will make in the future.

The authors of this book hope that this information will enable people to make more informed choices and thus create a safer society.

Dave Etkin, Editor

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Etkin, D., Haque, C.E. and Brooks, G.R. (2003). An Assessment of Natural Hazards and Disasters in Canada. Natural Hazards. Kluwer, Vol. 28, No. 2-3.

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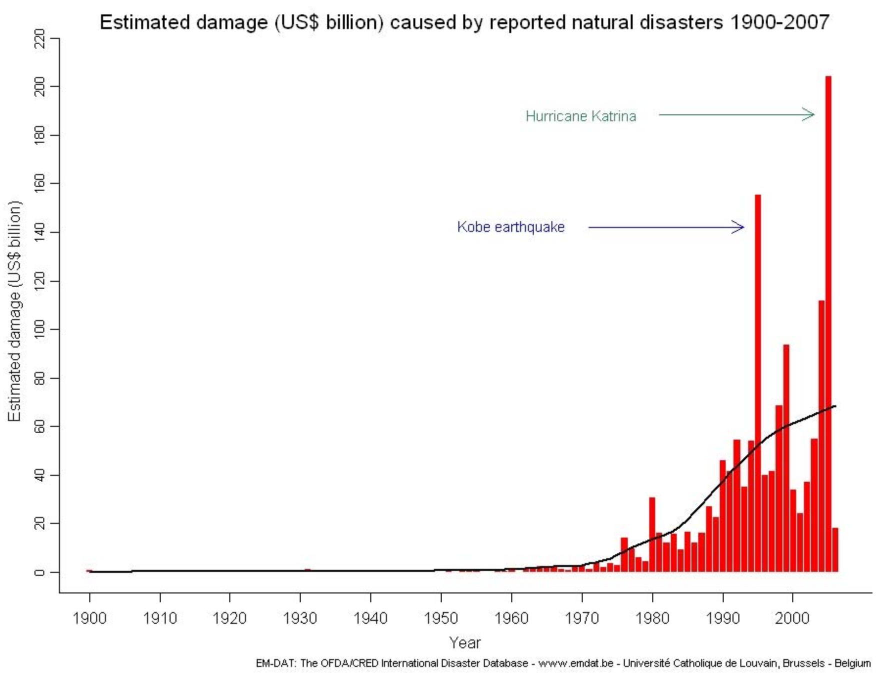
1.2 Disasters through History

Global Disasters

Natural disasters have plagued humanity throughout history. We find disaster stories in our earliest records and they form the basis of many myths, such as the destruction of Atlantis. Not all people agree on exactly what constitutes a disaster[1], but the most generally accepted definition is that a disaster is a damaging event that overwhelms the coping capacity of a community, such that it must seek outside aid in order to recover.

Over time, we've done much to protect ourselves from disasters but recent data suggests that their impacts have been rising. According to the Centre for Research in the Epidemiology of Disasters the cost of natural disasters has risen 14-fold since the 1950's (See Figure 1). Certainly, as the world's population grows and we accumulate more wealth, it's not surprising that disasters are becoming more expensive.

Figure 1: Economic Costs of Natural Disasters



Source: Centre for Research on the Epidemiology of Disasters (CRED)

Grappling with the threat of future natural disasters is an important exercise for all

[1] For more discussion on this topic, the reader is referred to 'What Is a Disaster?: Perspectives on the Question' by E. L. Quarantelli (Routledge Press, 1998)

countries, but particularly for those that have not developed resilient societies because of poverty or other issues. For example, Hurricane Mitch, which hit Central America in 1998, had a devastating impact on Honduras, rendering one-quarter of the population homeless. When disasters hit poor countries, the economic or insured losses may not be as large as disasters that affect richer ones, but the impact on the population can be much worse because of their greater vulnerability

Canadian Disasters

Canada is a huge land – the second largest country in the world. Its diverse geography and climate means that we're exposed to many natural hazards and therefore experience a variety of natural disasters, including floods, droughts, ice storms, tornadoes, hail, wildfire, heat and cold waves, hurricanes, earthquakes, tsunami and landslides (See Table 1).

In 2003 alone, Canada experienced seven significant disasters; four were natural disasters and three were biological or technological disasters. These included an east coast hurricane, a major power blackout and a communicable disease (Severe Acute Respiratory Syndrome or SARS) in central Canada and, in the West, floods, wildfires, droughts and mad cow disease. It was an onslaught that forcefully reminded Canadians that disasters do happen here—and they cost us dearly, both economically and emotionally.

Table 1: Most Expensive Canadian Natural Disasters (Total Estimated Economic Impact)

Date of occurrence	Event	Location	Estimated Total Cost (billion 2000$)
1980	Drought	Prairie provinces	$5.8
January 4-10,1998	Freezing rain	Ontario to New Brunswick	$5.4
1988	Drought	Prairie provinces	$4.1
1979	Drought	Prairie provinces	$3.4
1984	Drought	Prairie provinces	$1.9
July 19, 1996	Flood	Saguenay region, Québec	$1.6
May, 1950	Flood	Winnipeg, Manitoba	$1.1
October 15, 1954	Hurricane Hazel	Toronto and southern Ontario	$1.1
1931-1938	Drought	Prairie provinces	$1.0
1989	Drought	Prairie provinces	$1.0

Source: Public Safety Canada

In Canada, natural disasters have not killed many people, unlike some in developing countries that have caused up to hundreds of thousands of deaths. Biological hazards have been the most deadly; in 1918, the Spanish influenza epidemic may have killed as many as 50,000 Canadians, while smallpox epidemics in 1862 and 1885 killed at least

20,000 and almost 6,000 people respectively.

Human-caused disasters have also caused many deaths. The Halifax Explosion of 1917 killed almost 2,000 people and the collision of two ships in fog near Rimouski in 1914 killed about 1,000. The most tragic weather-related disaster occurred in 1775, when a hurricane off the east coast destroyed a fleet of ships, causing about 4,000 deaths.

As with most developed countries, the use of modern warning systems and improved standards in Canada has reduced the loss of life. However, the economic cost of disasters has been rising. Much of the cost is covered by insurance, but some hazards are not covered, including residential flooding from overland water flow and crop damage from drought.

The insured costs of disasters by type is shown in Table 2. Notably, a single event—the 1998 ice storm (which is counted as 2 events as it went through Ontario and Quebec)—accounts for 23.8% of the payouts between 1983 and 2006.

Table 2: Costs of Natural Disasters to the Insurance Industry, by Type*

(Major multiple-payment occurrences)

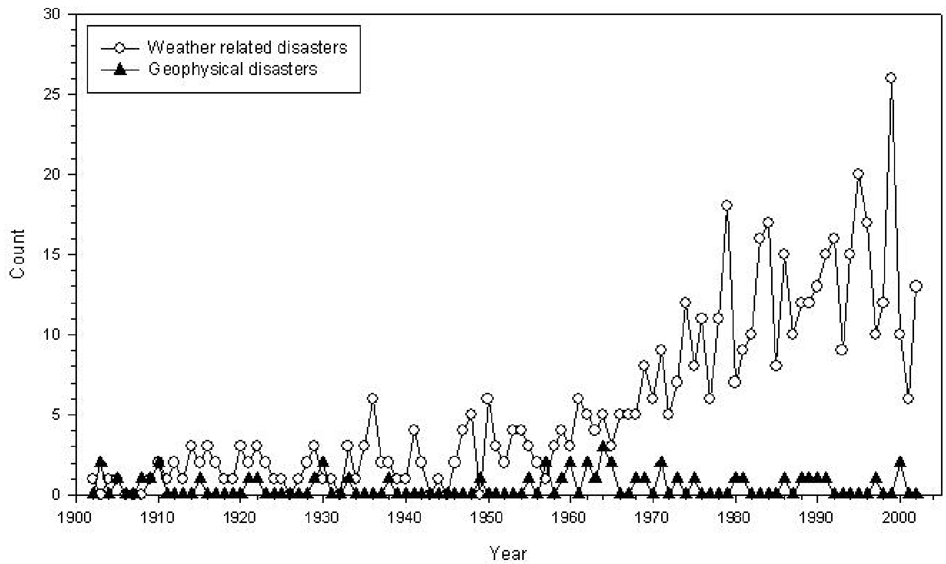
Event Type	**No. of Events**	**Cost in Millions (2006 $)**	**Percent of Total**
Flood/Hailstorm	1	180,187	2.2
Flooding	27	1,382,153	16.8
Forest Fires	1	212,257	2.6
Hail	8	691,360	8.4
Hailstorm	13	714,691	8.7
Hurricane	2	147,875	1.8
Icestorm	2	1,961,658	23.8
rainstorm	2	118,139	1.4
Snowstorm	2	156,285	1.8
Storm	26	1,037,023	12.6
Tornado	7	544,122	6.6
Wind	8	306,388	3.7
Wind/Hailstorm	3	68,386	0.8
wind/rainstorm	1	509,813	6.2
Windstorm	4	211,490	2.6
windstorm/hail	1	4,628	0
TOTAL	**108**	**8,246,455**	**100%**

*Cost to the Canadian insurance industry of natural disasters. Types ranked by cumulative cost.

Source: Institute for Catastrophic Loss Reduction, data 1983 - Dec. 2006 (Drought and residential flood costs are not included. Commercial flood costs are insurable and included.)

Public Safety Canada (PSC) offers an online Canadian Disaster Database which shows that the number of disasters has been increasing, mainly as a result of more floods (See Figure 2).

Figure 2: Historical trends of geophysical and weather related disasters in Canada (1900-2002)



Source: Public Safety Canada (PSC) Canadian Disaster Database (CDD).

Note: Weather related disasters from the CDD include: cold waves, droughts, floods, hail/thunderstorms, heat waves, hurricanes/typhoons, avalanches, storms (storm surges, freezing rain, winter storms), tornados and wildfires. Geophysical disasters from the CDD include earthquakes, landslides and tsunamis.

Disclaimer: *Where there has been no finding of fact by a court of law in criminal, civil or administrative proceeding, the facts set out in this database are alleged facts. The Canadian Disaster Database continues to be a work in progress. While entries are checked, and every effort is made to use reliable sources, the data presented here may contain errors and/or duplications. As a consequence, revisions to the database are ongoing*

Most interestingly, this graph shows a rising trend in weather-related disasters since the 1960s that is not matched by a similar increase in geophysical disasters. It's been suggested this is due to climate change, but it appears that increased development in flood plains is more likely the cause. However, climate change is expected to make flooding worse in the future.

Another online listing of Canadian disasters has been put together by Bob Jones at. His analysis found that about half of the 204 disasters listed were weather related.

A series of maps and summary maps (See Figure 3) showing the location, history and frequency of many natural hazards and disasters can also be viewed and downloaded from the Public Safety Canada website, as well as the Atlas of Canada.

Figure 3: Natural Hazards Map of Canada

Source: Public Safety Canada

Coping with natural disasters is one of the greatest challenges Canadians will face in the future, particularly in light of growing evidence that extreme events may occur more frequently as Earth's climate warms. It's important for all Canadians—political leaders and bureaucrats, business leaders and the public—to better understand the nature of the risks we face and to prepare for disasters. Only by making communities and individuals more resilient can we reduce the likelihood of suffering devastating losses when disaster strikes.

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1.3 Vulnerability

On a warm summer's day in July two men - Jones and Smith - ventured out separately from Mahone Bay, Nova Scotia, for a day of pleasure boating. Two hours later and several miles from shore, a severe thunderstorm unexpectedly developed. Each man tried to return to shore but was unsuccessful because heavy rains, strong winds and high waves made navigation difficult.

Adrift at sea, both boats were at risk of capsizing during the storm. Each man's circumstances, however, influenced his outcome. Jones was in a multi-million dollar yacht; Smith was in a canoe. It was Smith who never returned to shore.

This story illustrates the concept of vulnerability—the propensity to suffer some degree of loss such as injury, death or damage. It is vulnerability that determines whether things at risk from a hazardous event—a person's life, the integrity of a building, national security—will actually experience a loss when that event occurs. In the story above, Smith was more vulnerable than Jones and, as a result, he suffered a much greater loss.

Types of Vulnerability

There are six main types of vulnerability: physical, social, structural, cultural, economic and institutional.

Physical vulnerability

People who live in proximity to hazard-prone locations, such as on floodplains, along active fault zones and near industrial plants, are vulnerable because they're more exposed to hazards than others. Even within these areas, the level of vulnerability varies and those closest to the hazard are likely to suffer the highest losses.

Urbanization can increase exposure to hazards by concentrating people and property geographically. Nearly one-third of the world's population lives along active fault lines and flood-prone coastlines and that number is growing quickly. In North America, the populations of hurricane-prone communities along the U.S. east coast continue to increase rapidly, as do populations in British Columbia, Colorado and California that are exposed to bush fires.

Urban growth also leads to new development in previously restricted areas. Demand for land often encourages encroachment onto floodplains, unstable slopes, barrier islands and former landfill sites. Residential development on ravines and steep hillsides in Vancouver and in many towns in the Okanagan Valley, for instance, is exposing more people to landslides

Social vulnerability

Different people experience disasters differently. People suffer different degrees of loss and have varying experiences recovering because of differences in the resources available to them and their ability to access aid. Thus, those who are less capable of dealing with hazardous events are often labelled as being vulnerable, and their vulnerability can vary greatly depending on the types of hazards they face and their social circumstances. Some groups have a limited ability to adapt and they often suffer greater losses than others. These vulnerable groups often include the young, the elderly, women, the disabled, immigrants and/or ethnic minorities, the poor, the homeless and single-parent families. They contain a disproportionate number of less educated, lower income and unemployed or underemployed people who are often unaware of safety-net programs and lack resources that would improve their ability to adapt to and cope with hazardous events.

Age influences vulnerability. Both children and the elderly are usually dependant on others during disasters. Many elderly people live on fixed incomes, which makes it difficult for them to move to a better location or upgrade their homes. Women are more vulnerable than men because they typically have fewer financial resources and less autonomy. They're often primarily responsible for the care of children or elderly parents. Family structure can also increase vulnerability; single-parent households often operate on the economic margin and are less flexible in adapting to hazards. Larger families often have financial burdens that limit their choices.

People with mental and physical disabilities tend to take longer to recover from disasters largely because of their lack of economic resources. They often have limited employment opportunities and those with low incomes usually live in poor-quality housing, are uninsured and often lack personal transportation for evacuations.

Ethnic and racial minorities are also vulnerable during disasters. Cultural and language barriers may hinder their ability to understand or trust warnings. They may not be well represented among community decision-makers and their limited economic resources often create the need for long-term aid.

Vulnerability has a psychological component as well. People who are stressed or have experienced previous disasters, for example, are more likely to have difficulty coping. People's psychology can also play an important role in how they perceive and respond to threats, risk, and crucial aspect of social vulnerability.

Structural vulnerability

The structural integrity of the built environment and critical infrastructure play an important role in determining the number of deaths and injuries and the financial losses caused by a hazardous event. The built environment includes buildings and their surrounding property; critical infrastructure includes transportation, communications and utility systems, hospitals and other emergency services.

Building codes and structural regulations define standards that buildings and critical infrastructure must meet. The degree to which they can withstand the impact of a hazardous event is referred to as structural vulnerability, which is influenced by three important and cumulative factors:

- *Standards*: It's important to apply structural design criteria and standards consistent with the nature of local hazards. In some countries such as Iran and Turkey, many communities at risk of earthquakes do not enforce earthquake-resistant construction standards for buildings, despite the threat. Cape Cod-style gabled homes remain popular in many U.S. coastal towns despite being highly prone to losing their roofs in a hurricane unless they are strapped down. Cedar shakes, which ignite easily, are still permitted in many western Canadian and American suburbs located in heavily forested areas prone to drought and fire.

- *Enforcement*: Although stronger standards are usually recommended after a disaster, it is inadequate enforcement of existing codes that often contributes significantly to the losses. Take, for example, the case of a town vulnerable to hurricanes where the performance standard for shingles is being able to withstand wind speeds of 120 km/hr for three hours. A house that uses shingles that last only an hour under those conditions will suffer substantially more structural damage than one that meets the standard. Lax enforcement of building codes, whether it is the result of insufficient and poorly trained staff, corruption or naive perceptions of the hazard, can result in poor construction practices and failures to follow the codes—and, ultimately, larger losses in a disaster.

- *Maintenance*: A building that is structurally sound won't necessarily remain so through its lifetime. Structures that are neglected and do not receive sufficient upkeep can be compromised by the natural process of degradation. Maintenance of the built environment is expensive and requires substantial investment from all levels of government, but the money is often diverted to other uses.

Cultural vulnerability

Culture is defined as the customs, beliefs, values and knowledge that guide society's behaviour. Ideology, social organization and biases regarding the use of technology, for example, collectively contribute to cultural vulnerability, which can in turn influence exposure to hazards.

Differing views about the relationship between humans and the environment strongly influence the ways in which different cultures protect themselves from hazards. Some cultures, for example, believe that humans have little control over nature and that hazardous events are a matter of fate or even a form of punishment. They often do little to reduce their vulnerability.

Others believe that human ingenuity can overcome nature and they build stronger dykes, bigger dams and anti-seismic foundations for their houses. However, while technology can help reduce risk, it can also increase exposure. In many places in Canada and the United States, development has intensified behind dykes because people perceive that the risk of flooding has decreased. But, as a result, more people and property become exposed and when a flood large enough to overcome the dyke occurs, the losses will be much greater.

Different forms of social organization also influence cultural vulnerability. In some cultures, women are subservient and are restricted to their homes; they are highly vulnerable to hazards such as earthquakes, fires and floods that may require evacuation. In North America, social fragmentation can increase vulnerability. Ghettos and walled communities are enclaves of people with similar characteristics, such as income and ethnicity. In many cases, services formerly provided by municipal governments have been privatized. These fragmented social arrangements often deter local governments from investing in hazard management for these areas, largely because the money is spent elsewhere (*e.g.,* crime prevention).

Technology also influences vulnerability. In North America, technology is an integral part of day-to-day life; it facilitates access to everything from bank machines and gas pumps to the phone system and the Internet. It’s also a key element in industrial operations, surveillance of utility grids and national security. And during a disaster, technology is essential to the work of emergency services.

But we pay a price for our heavy reliance on technology—it if fails during a disaster, we are all the more vulnerable. We can’t complacently assume that our technologies will always be available. The 1998 Ice Storm was a case in point; many organizations, including utilities, critical care and emergency services, did not have back-up generators and had neglected to consider large-scale power failures in their emergency plans.

Economic vulnerability

Some communities are less likely to cope with hazards and more likely to suffer losses because of the nature of their economic systems.

Three key factors influence economic vulnerability:

- *Diversity*: A one-factory town is more vulnerable than a town with multiple factories. The same could be said of a place dependent on multiple industries of one type (e.g., high tech or manufacturing) compared with those that have a diversified economy.
- *Global connections*: The interdependence between a place and foreign markets strongly influences its economic stability and vitality. Disasters do not affect only the country in which they occur, but also those economically linked to it. The 9/11 terrorist attack in the United States, which made many people afraid to fly, had a

devastating impact on the travel industry and tourist-based economies around the world.

- *Investment choices*: Hazard management requires a substantial financial commitment but it usually has a very long return on investment and thus is often relegated to the back burner. In Canada, there have been budget cuts to both large-scale programs such as floodplain mapping, shoreline protection and water quality monitoring, and small-scale programs, such as municipal tree-trimming (which contributed significantly to power line damage during the 1998 Ice Storm). This disregard can lead to the development of hazardous areas and the inability to enforce regulations, zoning and management plans. Ultimately, it undermines the adaptive capacity of the economic system.

Institutional vulnerability

Institutional vulnerability refers to the capacity of the governing system to adequately protect society from hazards. In some countries, corruption, war and civil unrest cause a breakdown in governance that significantly undermines their capacity to withstand and deal with hazards. Money and resources that would otherwise be used to reduce disaster vulnerability are frequently diverted to military and security operations.

In more stable governments, complexity can increase institutional vulnerability. The ability of governments to develop and enforce policies to protect society is at least partially influenced by the number of stakeholders involved and their interests, and the bureaucracy responsible for making decisions. For example, in Florida, it's private developers who favoured profit over safety, rather than local planners, who have historically controlled coastal development in parts of the state.

Governments that have the flexibility to change policies to reflect changing circumstances are more resilient in coping with hazards and reducing disaster losses. On the other hand, competing interests and inflexible policies can lead to unsafe operations, poor development and construction practices and incompatible protection strategies among different jurisdictions—all of which increase vulnerability to hazards. Examples of competing interests can include economic development versus environmental protection, or profit versus resilience.

Tools Used in Assessing Vulnerability

There are people whose job it is to assess the vulnerability of individuals and communities to natural hazards. They do these assessments using tools that incorporate information about hazards and the different types of vulnerability.

One such tool is a checklist—a detailed list of people and structures considered vulnerable and their characteristics. Each item can be weighted to indicate its level of importance. The HIRV (Hazard-Impact-Risk-Vulnerability) model, a checklist developed by Laurie Pearce (Pearce, 2001), is used by the Province of British Columbia to identify vulnerable groups in local communities.

The second type of tool involves computer-assisted programs designed to model the effects of hazardous events and estimate their impacts. For example, a program called NHEMATIS, developed by Public Safety Canada, helps officials quantify the number of people and buildings that will be affected in Vancouver by earthquakes of different magnitudes. A similar program used by the U.S. Federal Emergency Management Agency (FEMA), HAZUS, focuses on floods and earthquakes.

Other programs help identify the people, buildings and critical infrastructure that are located in hazardous areas. This information can then be used to increase public awareness of hazards and encourage the development of long-term plans to increase resilience. The Community Vulnerability Assessment Tool, developed by the U.S. National Ocean and Atmospheric Association, contains guidelines for conducting such an exercise.

Ultimately, governments, communities and individuals make choices about how vulnerable to hazards they allow themselves to be. Unfortunately, in many cases, they make poor choices that increase either the exposure to the hazard or the likelihood of suffering damaging losses when the hazard occurs. But there are ways to turn this around. We can’t eliminate the hazards we face but we can make ourselves less vulnerable to them.

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1.4 Ethics and Disasters

> "*Ethics is a reasoned account of how people should live their lives*."
> - Peter Wenz, *Environmental Ethics Today*

A major flood has occurred and everyone in the community has been affected. The most damaged area is a flood plain that was zoned for residential development by the city. As the cleanup starts, so do the questions:

- *should tax dollars be used to compensate for all losses or should payouts be capped?*
- *should the rich and the poor be equally compensated or only those who don't have the personal resources to pay for damages?*
- *should those who built in a high-risk area—the flood plain—be compensated or should they have to pay for their risky behaviour? Does it make a difference if they weren't aware of the level of flood risk?*
- *Some people were flooded because water was diverted to protect a larger number of homes in other areas of the city. Should these residents receive special consideration?*
- *should compensation be contingent on building more floodproof homes—or moving out of high-risk areas altogether?*

Webster's dictionary defines ethics as the "branch of philosophy which studies the principles of right or wrong in human conduct." Issues of right and wrong, and of fairness, inevitably arise in the wake of natural disasters, as they do in many other social and economic decisions we make.

Decisions about who to compensate and how much to give them after a disaster have pragmatic consequences—for example, they influence the future vulnerability of the community and its residents and the probability of suffering further damage in the next disaster.

But these decisions, and others related to risk-taking, also involve value judgments about what is the right thing to do. Ethical evaluations therefore play an important role in shaping our decisions. For example, a community may decide to allow development on a flood plain and, in doing so, take certain risks. Some people may believe this is the right thing to do, feeling that the benefits outweigh the risks. Others may feel it's better to be safe than sorry.

However, in some cases, those who gain the benefits may not be the same as those who take the risks. A developer may benefit from selling homes on a flood plain, but it's homeowners who suffer the consequences when flooding occurs. It's not unusual for people who end up living in high-risk areas not to be the ones who made the initial decision to build there. In some cases, they may not even be fully aware of the risks they face.

Who, then, should pay the price for this risk-taking behaviour? Should all residents be required to pay for it, through their tax dollars?

Sometimes, decisions are also based on taken-for-granted worldviews or “paradigms.” These worldviews are so much a part of us that we rarely notice them, almost like a fish that doesn’t notice the water in which it swims. For instance, many people feel that technology is the best protection against natural disasters. If there’s a danger of flooding, build a dyke.

Other worldviews are less technocentric. Some people may believe that dykes cause unnecessary ecological disruption and upset natural river cycles—a paradigm that might lead to the conclusion that it’s best not to develop towns and cities in flood-prone areas in the first place.

This approach would not only preclude building dykes, but would also minimize the ecological impact of heavy-handed technological interventions of various kinds. Someone who holds such an “eco-centric” worldview might put greater weight on preserving natural habitats than someone with a more human-centered worldview, who places greater importance on the needs of people.

Canada is a diverse society, with people from many different cultures, backgrounds and philosophies so it’s not surprising there are different perspectives on right and wrong. In this country, as in most of western society, there are two dominant approaches to making ethical decisions. The first involves the concept of “the greatest good for the greatest number.” The second approach involves principles relating to “rights” and “duties.”

The first category emphasizes efficiency: the idea is to obtain the most “bang for the buck” by maximizing the overall, positive consequences of our actions. On the other hand, people can argue that they have certain rights that must be respected, even if this means that resources are used less efficiently.

Consider, for example, people who, knowingly or not, take the risk of living in a floodplain and have consequently suffered flood damages. Some may feel they have a “right” to government compensation, even though they engaged in risky behaviour and are wealthy enough to cover their losses. Their view is that, in principle, every citizen has an equal “right” to financial compensation and that governments have a “duty” to their citizens to help them recover their losses.

Others would argue that government resources should be spent more efficiently. The principle of “the greatest good for the greatest number” might involve compensating only the needy and saving the tax dollars that would have gone to wealthier people for other important social needs.

There is also the ethical issue of whether those who knowingly took risks should be held accountable for such actions, particularly if they gained some benefit or did not take reasonable precautions to reduce the risk.

When we make choices in allocating resources, both as individuals and as a society, we are in fact making ethical decisions. Examples of natural hazard-related planning decisions include how we design and build essential infrastructure—buildings and communications, transportation and energy systems—and what policies our politicians create to deal with disaster management and land-use planning. Deciding what percentage of our tax base will be spent on health care and daycare as opposed to safe dams and dykes requires balancing human and economic costs and has a major impact on people's lives.

Ethical choices also come into play before natural disasters strike. Every day, both as individuals and as members of society, we're forced to make sometimes difficult choices about how to allocate scarce resources. In many cases, these choices are, at their core, based on ethical considerations. The cost of building stronger homes and more resilient communications, transportation and energy systems must be weighed against the costs of improving health care, education and other social programs that benefit many people. The trade-off is never easy. The issue is complicated by the political process that tends to emphasize short-term thinking and benefits as compared to the long-term benefits accrued by mitigation. As well, mitigation benefits future potential victims; this can be a hard sell when there are important existing needs. The reality is that mitigation tends to get attention in relatively short windows of opportunity, normally following a disaster when public attention is focused on the event.

Unfortunately, too often, issues related to natural disasters are not framed within an ethical perspective. Being explicit about the ethical values that drive our decisions is important because it forces us to debate the wisdom of our choices and helps us to make better judgments.

Values are, however, only one component of the decision-making process. It's also essential for people to understand the nature of the risks they face; only then can they make informed decisions about how much to invest in measures that reduce their vulnerability to risks and increase resilience in coping with disasters when they happen.

The remainder of this project summarizes some of the knowledge scientists have acquired about the hazards Canadians face, in the hope that this will better arm them to deal with sudden and extreme events that may threaten their property and their lives.

Chapter 2:

WEATHER HAZARDS

2.1 Climate Change

June 2002: Severe drought plagues much of the Prairies for the second year in a row, resulting in some of the worst crop yields in more than a decade. Where patches of green used to be, brown dust holds sway. Cattle and other livestock have little to feed on and hay is being shipped from eastern Canada to save them.

Crop planting is slow and the outlook is bleak. The acute lack of soil moisture means that many areas must receive higher than normal rainfall during the next growing season to have a chance at normal yields.

The emotional and economic toll on farmers has been enormous; not even recent rains have been able to lift their gloom. No drought like it has been seen since the 1930s. Worse, this might be the harbinger of a changing climate that will bring repeated disasters of this sort in the future.[1]

Prairie droughts are only one of many significant consequences of climate change that Canada will likely face. As the Earth warms, high latitude countries like Canada are expected to experience the strongest impacts, including an increase in the frequency and intensity of extreme weather events.

This means that Canadians can expect to be confronted more often with natural hazards, such as storms, forest fires, heat waves, floods and droughts that will test their resilience and challenge their ability to adapt to the new climatic conditions.

Weather and Climate

Climate is different from weather. Weather refers to our day-to-day experience of precipitation, temperature, winds, atmospheric pressure, relative humidity and other factors that vary with atmospheric conditions.

Climate, on the other hand, refers to the average weather that occurs in a region over an extended period, usually 30 years. It includes long-term temperature, rainfall and wind patterns.

Climatic conditions can change over time and this change can be caused by both natural forces and human activities.

[1] How Weather Works: :Record drought plagues Prairies:. CountryRoads Network website - AgJournal. June 3, 2002.
InDepth Agriculture - "Drought of 2002". CBC News Online. August 6, 2004

The Changing Climate

Although climate varies naturally, recent changes are unprecedented and do suggest that something more than nature is at work. Most climate experts believe that human activities are having an impact on global climate. Burning fossil fuels to heat our homes, run our cars, produce electricity and manufacture products is adding an accelerating burden of greenhouse gases to the atmosphere —more than would have occurred naturally. The accumulation of these gases causes the earth to heat up more rapidly.

The Greenhouse Effect

- Earth receives a constant flow of energy from the sun.
- About 30% of this energy is immediately reflected back into space.
- Most of the remaining 70% is absorbed to warm the earth's surface.
- Some of the heat from Earth's surface is radiated back into space.
- However, this outgoing heat is trapped by certain gases in the atmosphere, including water vapour, carbon dioxide, nitrous oxide, methane and ozone, causing the earth to heat up. This is known as the greenhouse effect.
- Some greenhouse gases—notably water vapour—are natural in origin and keep the earth 33˚C warmer than it would otherwise be. Without this natural greenhouse effect, Earth's average temperature would be –18˚C, too cold for life to survive.
- Human activities also add greenhouse gases to the atmosphere, including carbon dioxide, methane, nitrous oxide and artificial chemicals like CFCs, which enhance the greenhouse effect.

Scientists from the Intergovernmental Panel on Climate Change (IPCC) have predicted that the average global temperature will rise by about 1.4 to 5.8°C by 2100 if current greenhouse gas emission trends continue. This might not seem like much, but history has shown that small changes in average temperature can have significant impacts. During the last ice age, for instance, average global temperatures were only 5^{o}C cooler than they are today and yet most of Canada was covered by thick glacial ice. The IPCC is an intergovernmental body set up by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP). The body does not conduct research or monitor climate itself, but rather is meant to comprehensively assess the global literature and other data produced regarding climate change. However, it should be noted that there is increasing controversy with the nature and consequences of global warming, as well as the legitimacy of the IPCC.

Since the beginning of the industrial revolution, humans have added an enormous burden of greenhouse gases to the atmosphere, increasing concentrations to the highest levels in about 400,000 years. Most of this burden remains in the atmosphere, literally hanging over our heads. And we're adding more each year, as emissions from fossil fuels continue to rise. The rapid rate of climate warming is one of the greatest challenges we face as a society.

It would take a long time to reduce atmospheric concentrations of greenhouse gases even if we were to stop all emissions today. Consequently, Earth's climate will continue warming for many decades. The longer emissions continue rising, the longer it will take to stabilize or reduce climate warming.

Expected Changes in Climate

Using computer models, scientists are able to project patterns of climate change on the scale of continents. Predicting how climate change will affect weather at regional or local levels is much more difficult, but they have made some projections of the potential effects of climate change on Canada:

- Canada's annual mean temperature may increase between 5˚ and 10˚C over the next century. Temperatures in parts of the Arctic could increase between 10˚ and 20˚C.
- In this scenario all seasons would be warmer, though the warming would be unequally distributed across the country and with the larger warming occurring in spring and winter. By 2050, hot summer days in excess of 30°C are projected to occur on average about once every two days in southern Ontario and once every four in Calgary. This frequency is more than four times current rates.
- More precipitation is likely to fall as rain, as opposed to snow, than at present.
- A sea level rise of up to 95 centimetres is expected in some coastal areas.
- Over the next half-century, average fire weather severity in western and central Canada is projected to increase by 50% and the fire season is expected to lengthen by three weeks. However, fire risk in north-eastern Canada may be moderated as a result of increased precipitation.

Climate Change and Extreme weather Events

In general, climate change is expected to affect the frequency, severity and duration of extreme weather events. We may experience:

- more extreme heat waves and fewer extreme cold snaps
- more heavy rainfalls, thunderstorms, hailstorms and tornadoes
- more droughts
- more intense winter storms
- major changes in atmospheric circulation which could influence storm tracks and rainfall distribution
- large storm surge events of over four metres. These events, which currently occur less than once per century, are expected to return about once per decade as the climate warms.

Scientists claim to be fairly confident of the changes in heat waves, cold snaps, heavy rainfalls and droughts. Other changes are more uncertain. As well, climate change is expected to vary greatly from region to region. The consequence of these changes in hazards is likely to be more frequent natural disasters. This is particularly worrisome since in some ways the vulnerability of Canadians is increasing (See Section 1.3: Vulnerability). As a result, it is important for Canadians to consider how to deal with this issue. Additional information can be found on the Environment Canada and Natural Resources Canada websites.

Responding to Climate Change

Because of the large amount of greenhouse gases already in the atmosphere, some global warming will occur during this century no matter what we do. However, there are steps we can take to reduce emissions[2] and slow the rate of climate warming, and to make our communities more resilient to hazards that may increase.

The United Nations, in response to the risk of climate change, developed what is called the 'Kyoto Protocol'. In the Kyoto Protocol developed nations agreed to limit their greenhouse gas emissions by 6% relative to the levels emitted in 1990 between 2008 and 2012[3]. Canada is a signatory to this agreement; however the federal government has been seriously criticized for failing to meet its own targets. Nevertheless, there are several provinces (British Columbia, Manitoba and Quebec) along with several states in the US which have formed their own collective agreement to reduce greenhouse gas emissions as outlined in the Western Climate Initiative.

The Government of Canada has at least nominally made climate change a national priority, and is working closely with Canadians and the global community to meet this challenge. In the 2006-2007 period the government spent over 1.5 billion on clean air and climate change initiatives[4]. The government has also created an "EcoAction" website listing their initiatives and incentives for greenhouse gas reduction.

Cities such as Toronto also work towards these emission reduction goals. Their program, '20/20 The Way to Clean Air' promotes individual and collective actions to create a 20/20 vision for a cleaner and healthier city. Taking actions to reduce home energy use and personal vehicle kilometres traveled will lessen climate change and make a difference to the air we breathe. Fewer emissions means protecting our climate and having cleaner air and healthier communities for all Canadians. And saving energy puts more money in your pocket.

The following organizations provide information about what individuals and communities can do to reduce emissions and cope with the consequences of climate change:

- Environment Canada
- Natural Resources Canada
- The David Suzuki Foundation

[2] There are numerous other benefits to reducing emissions, such as less urban air pollution and lower fuel costs. These are called co-benefits.
[3] The United States agreed to reduce emissions from 1990 levels by 7 percent during the period 2008 to 2012.
[4] The Budget Plan 2008: Responsible Leadership. http://www.budget.gc.ca/2008/pdf/plan-eng.pdf

There are opportunities in different sectors of the economy to reduce greenhouse gas emissions, to make adaptive planning decisions that reduce a community's vulnerability to natural hazards and to create a healthier environment. The tables below summarize many of these actions.

Energy Use	Examples / Further Information
Space heating and cooling • Reduce air leaks in your home; install an energy-efficient furnace. Purchase an energy efficient home. • Plant trees around your home to reduce demand for space heating and cooling; maximize the use of passive solar energy. • Install cool, reflective roofs	Government of Canada Office of Energy Efficiency PositivEnergy – Community Energy Conservation, in Oakland California
Household electricity use • Purchase energy-efficient equipment, appliances and light bulbs. (Replacing one frequently used regular light bulb with an energy efficient compact fluorescent bulb will save 225 kg of CO_2 per year.) • Demand "green" power from your utility.	
Water heating and use • Purchase water-efficient equipment (e.g., shower heads, toilets). • Lower the thermostat on your hot water tank and use a solar hot water heater to reduce demand on your current system. • Use cold water in washing machines where possible. (Ninety-two percent of the energy used by washing machines goes to heating water; using cold water to wash and rinse clothes save 150 kg of CO_2 per year.)	Toronto Deep Lake Water Cooling Project Community energy systems in Charlottetown, PEI use pipes to carry hot water from a waste wood and garbage incinerator to buildings around the downtown area.
Alternative Energy sources • Switch from fossil fuels that produce the most carbon dioxide (coal and oil) to fossil fuels that produce the least carbon dioxide (natural gas) • Where possible, replace fossil fuels with renewable energy sources like the sun, wind, biomass and falling water	Alternative Energy Programs exist in The Yukon and NWT: waste- heat recovery in Holman, wind turbines in Sachs, Harbour& Solar Wall in Fort Smith
Green Roofs: • Absorb heat, reduce energy use and costs, provide food, jobs and biodiversity amidst the	Toronto City Hall green roof public tours Tree Canada

concrete and cement of the city.	
Tree Planting • Plant trees to cut down energy costs and improve air quality. • Planting deciduous shade trees on the west and south sides of buildings can reduce air conditioning costs by up to 40%. • Planting evergreens on the north side of buildings can reduce winter heating costs by up to 10%.	

Land Use	**Examples / Further Information**
• Change zoning regulations to prevent development on lands vulnerable to floods, which are expected to worsen in the future. • Upgrade sewer systems to reduce flood vulnerability. • Check urban sprawl. Reduce the number of parking lots. • Reduce the need for travel by encouraging mixed residential and commercial development and high-density housing. • Use pavements that encourage air circulation and water infiltration to reduce heat retention. • Encourage the development of green cities through tree-planting, rooftop gardens etc.	Coastal communities, especially in the Atlantic Provinces, have built dikes and other sea defences, but these may have to be strengthened. Information on the role of pervious pavements can be found at: Cool Communities Examples of storm water management options including water retention tunnels can be found through the Government of British Columbia Environmental Protection Division, and others.

Transportation	**Examples / Further Information**
• Encourage more use of public transit • Provide support for transportation options such as autosharing, carpooling, walking or biking. • Purchase fuel-efficient vehicles. Consider new technologies, like hybrid gas/electric cars or those that use fuel cells.	Autosharing: i.e. CarTool School walking programs: i.e. Active and Safe Routes to School, in Ontario. AutoSmart and Energuide for vehicles Prius hybrid car Ballard fuel cells

Solid Waste Management	Examples / Further Information
• Reduce, reuse, and recycle • Encourage gas-to-energy programs such as recovering methane from landfills to be used for power generation.	Toronto's methane recovery program

Sources and Further Reading

- Inter-governmental Panel on Climate Change (IPCC), 2001.*IPCC Third Assessment Report: Climate Change*, IPCC, Geneva, Switzerland.

- Koshida, G. and W. Avis (1998) (eds.) *Canada Country Study: Impacts and Adaptation, Volume VII, National Sectoral Volume*, Environment Canada, Downsview, Ontario

- David Suzuki Foundation

- Environment Canada

- Natural Resources Canada

- Sierra Club

- U.S. Environmental Protection Agency (USEPA)

- World Meteorological Organization

- Country Roads Network

2.2 Severe Cold Snaps

The winter of 2002/2003—the coldest in nearly a decade—sent chills through the Canadian economy as energy prices spiraled toward record highs. The subzero temperatures led to skyrocketing energy demand for heating, compared with the very warm previous winter. Energy consumption was up nearly a third in Toronto, and only slightly less in Ottawa, Montreal and Saint John.

On Monday, March 3, 2003, Ontario consumers were asked to turn off lights and limit the use of electrical appliances as bone-chilling temperatures caused a shortage of power in the province. With late winter and early spring in Eastern Canada remaining comparatively cold, the high demand for natural gas and heating oil continued, creating a growing strain on the economy.

Introduction

The actual temperatures reached during a cold snap depend specifically on the nature of the cold air mass and where it originated. Extreme cold temperatures are associated with continental Arctic air masses, so Canada's northern location greatly increases its exposure to cold weather events. All regions in Canada have experienced temperatures below -40°C except for Prince Edward Island. Sometimes unusually cold weather may persist over a large area for a few days or even weeks (See Table 1). Such extended periods are referred to as cold snaps.

Every region in Canada has one or two periods a year with unusually cold weather. Cold spells are relatively common on the prairies. Eastern Canada usually experiences prolonged deep freezes each winter, but they're rarely as long or severe as in the Prairies. Of course, the size of the impact depends upon how adapted people and communities are, and in the Prairies and far north they can deal much better with extreme cold than in other areas.

Table 1: Significant Canadian Cold Snaps

Location	Date	Conditions
Snag, YK	3 February, 1947	Lowest recorded Canadian temperature (-63°C)
Edmonton, AL	7 January to 1 February, 1969	Temperatures below -18°C for 26 days
Most of Canada	January, 1982	Coldest winter month on record; most provinces reached –40°C minimum temperatures
Parts of British Columbia	30 January, 1989	Freezing caused $2.5 million in damages

Source: Dave Phillips, 1990

Windchill

Cold temperatures are dangerous in their own right, but strong winds make them even more deadly. The cooling sensation caused by the combined effect of temperature and wind on bodies is known as the wind chill factor.

Environment Canada defines windchill as how the combined effect of wind and temperature would feel on your face if you were walking at a normal pace (4.8 km/h). Under a new Canadian index (See Table 2 for Canadian records), wind-chill is expressed in temperature-like units, but because it's not the actual air temperature, it's given without the degree sign. For example, if the outside temperature is -10°C and the wind is blowing at 30 km/h, the wind-chill is -20. It means that your face will feel as cold as it would on a calm day when the temperature is -20°C.

Windchill quickens the rate of body heat loss and thus worsens the health impacts of prolonged exposure to cold weather. Other factors also affect how fast the body loses heat— body build, for example. People who are tall and slim lose heat faster than those who are shorter and heavier. On the other hand, wearing layered and/or insulated clothing traps body heat and protects against freezing.

Table 2: Highest recorded Windchill (over a 30-year period)

City	Date	Wind Chill	Wind Speed (km/h)	Temperature (^{o}C)
Victoria	Dec. 16, 1964	-25	39	-13.3
Whitehorse	Jan. 9, 1963	-58	51	-36.1
Yellowknife	Jan.26, 1960	-61	32	-41.7
Iqaluit, NU	Feb. 16, 1979	-66	61	-40.9
Alert, NU	Jan. 6, 1958	-65	58	-40.6
Edmonton	Dec. 15, 1964	-57	55	-35.6
Calgary	Dec. 15, 1964	-55	55	-33.9
Regina	Jan. 17, 1962	-59	39	-38.9
Saskatoon	Jan. 15, 1954	-59	32	-40
Winnipeg	Jan. 9, 1982	-54	56	-32.7
Thunder Bay	Jan. 10, 1982	-58	54	-36.3
Ottawa	Jan. 23, 1976	-48	35	-30.8
Toronto	Jan. 4, 1981	-44	30	-29.1
Quebec City	Feb. 12, 1967	-52	43	-33.3
Montreal	Jan. 23, 1976	-49	45	-30.6
Fredericton	Jan. 17, 1982	-43	37	-27.3
Halifax	Feb. 13, 1967	-41	48	-24.4
Charlottetown	Jan. 18, 1982	-50	37	-32.4
Goose Bay, Lab.	Jan. 21, 1975	-54	55	-33.3
Gander, Nfld.	Feb. 8, 1959	-43	72	-23.9

Source: Environment Canada – Wind Chill Program

Exposure to Cold

In Canada, exposure to extreme cold directly causes on average about 80 deaths a year—more than any other weather extreme. However, more deaths are attributed indirectly to things like weather-related car accidents and air pollution.

Prolonged exposure to cold temperatures can cause injuries to both humans and animals. The two most serious include frostbite and hypothermia.

Frostbite occurs when body tissues are frozen. Table 3 shows how frostbite risk changes with windchill. Symptoms include numbness and a white or pale appearance in the extremities, such as fingers, toes, ear lobes, or the tip of the nose, due to lack of circulation. Extreme frostbite may lead to amputations. Frostbite victims should seek immediate medical attention. They should lay down, avoid rough handling and be gradually warmed.

Frostnip is a milder form of frostbite where only the skin freezes. The skin appears yellowish or white, but feels soft to the touch. The victim will feel a painful tingling or burning sensation at the affected site.

In either case, don't rub or massage the affected area. Instead, use blankets and other forms of clothing to gradually generate body heat. You can also use warm water (40º-42ºC) to achieve the same result. In the absence of warm water or another body to keep you warm, conserve your own body heat by pulling your legs together beneath you. In any case try to avoid direct heat that can burn the skin.

Hypothermia is another major form of cold injury. It's characterized by a considerable drop in core body temperature below its normal temperature of 37ºC. Warning signs include uncontrollable shivering, memory loss, disorientation, incoherence, slurred speech, drowsiness, and apparent exhaustion. When shivering stops and there's a loss of consciousness, hypothermia can become life-threatening, possibly due to cardiac arrest. The elderly are particularly vulnerable to hypothermia.

Mitigating Risk from Cold Snaps

Both communities and individuals can take actions to make themselves safer during periods of extreme cold. Homeless, the elderly, children, people with circulatory problems, people taking certain prescription medications, outdoor workers, people with disabilities who live alone and newcomers to Canada are particularly vulnerable. Programs to assist the homeless through shelters, outreach workers and community resource centres can greatly reduce their vulnerability by providing shelter, food, warm clothes or sleeping bags [1]. The Region of Peel, Ontario provides guidelines to agencies and organizations (see list below) of guidelines to follow when engaging in different activities in extreme or prolonged cold temperature. Municipalities can also expect high usage of electricity, oil and gas due to large heating requirements, with a possible need to conserve energy if supplies run low. Service stations and the Canadian Automobile Association are likely to have to make numerous service calls to start cars with dead batteries.

[1] Any time the temperature drops below -15ºC in Toronto, efforts are made to create more emergency spaces in shelters to protect homeless people from the cold.

Example of Agency Recommendations (Region of Peel)

- Establish both a policy and plan to deal with potential consequences of extreme temperatures and winter storms (e.g. power outage, lack of transportation). Have an emergency kit available.
- Reduce the amount of time staff spend outdoors or consider postponing outdoor work when the temperature is -25°C or colder, with or without wind chill. Some medical conditions may increase sensitivity to cold.
- Educate staff on how to prevent, recognize and treat cold injuries.
- Ensure that all staff have adequate winter gear, including insulated coats and boots (slip resistant/waterproof), hats, mittens and neck warmers (adhering to Health and Safety Guidelines in the workplace).
- Ensure that workers have access to plenty of warm beverages. Smoking and consumption of caffeinated beverages should be avoided when working in cold environments.
- Schedule shorter periods of work outdoors during extreme temperatures.
- Ensure that all staff take regularly scheduled breaks when needed in a heated environment or provide an on-site source of heat (adhering to Health and Safety Guidelines in the workplace). A vehicle is considered a heated environment. A shed or a tent can add protection against the wind.
- Establish a buddy system which allows a close observation of co-workers.
- Educate staff to take precautions to prevent frostbite from contact with cold surfaces (adhering to Health and Safety Guidelines in the workplace).

Canadian occupational health and safety regulations specify a minimum temperature for indoor work environments in buildings that are normally heated (See Canadian Centre for Occupational Health and Safety (CCOHS)). No such limits are specified for outdoor work in cold weather. As an example, Saskatchewan Labor has developed guidelines for working in outdoor weather, (See Cold Conditions Guidelines for Outside Workers – Saskatchewan Department and Advanced Education, Employment and Labour) specifying a maximum work period and a minimum number of breaks in a warm environment.

The main responsibility for protection, however, lies with the individual – actions people can take themselves are listed below.

Avoiding Cold Injuries:

1. Listen to the weather forecast

Even moderate wind chills can be dangerous if you're outside for long periods. You can minimize the risk by checking the weather forecast before going out. Environment Canada offers periodic weather warnings, including windchill warnings, to alert the public about hazardous weather conditions. Windchill warnings are provided when very cold temperatures combined with wind are expected to create outdoor conditions hazardous to human activity. Cold wave advisories are issued when temperatures are expected to drop by 20ºC or more within 18 hours. You can check the Government of Canada "Weather Office" website or listen to weather radio or local TV or radio stations for regular updates.

2. Plan ahead

Prevention is better than a cure. Reducing the amount of time spent outdoors is an important coping strategy. Organizations such as schools and construction companies should plan ahead during severe cold spells to minimize interruptions and prevent discomfort, injury and deaths. For example, schools can hold recess indoors, while outside workers should schedule warm-up breaks when wind-chill is severe. Have a candle and warm blanket in your car and park inside if possible.

3. Dress Warmly

Dressing warmly is one of the most effective ways of dealing with cold weather. Wear layers of warm clothing, covered by a wind-resistant outer jacket. Make sure you have mittens (which are much warmer than gloves), hats, scarves and boots. Cover as much exposed skin as possible and always cover your head, which loses a large proportion of body heat.

If it's extremely cold, cover your mouth to protect your lungs from the cold air. Check for signs of frostbite so that you can take the necessary precautions immediately.

4. Seek Shelter

If the cold become unbearable, and particularly if you find signs of frostbite, get out of the wind and find shelter.

5. Keep active

If you are at risk from wind-chill and can't find shelter, moderate physical activity will help generate body heat to keep warm. However, you should avoid strenuous exercise. In extremely cold temperatures, the heart is already working much harder than normal to pump blood through constricted vessels in arms and legs; strenuous activity only adds to the stress.

6. Stay Dry

Wet clothing chills the body rapidly. If you find yourself sweating, remove just enough layers of clothing (or open your coat) so that you don't overheat.

7. Know your limits

Some people, especially children, the elderly and those with circulation problems are more susceptible to cold than others. Also, using tobacco, alcohol and certain medications can increase susceptibility to cold.

Table 3: Wind Chill Hazards and Risk of Frostbite

Wind Chill	Risk of frostbite	Health Concern	What to do
0 to -9	Low	- Slight increase in discomfort	- Dress warmly, with the outside temperature in mind.
-10 to -27	Low	- Uncomfortable - Risk of hypothermia if outside for long periods without adequate protection	- Dress in layers of warm clothing, with an outer layer that is wind-resistant. - Wear a hat, mittens and scarf. - Keep active.
-28 to -39	Increasing risk: exposed skin can freeze in 10 to 30 minutes	- Check face and extremities (fingers, toes, ears and nose) for numbness or whiteness - Risk of hypothermia if outside for long periods without adequate protection	- Dress in layers of warm clothing, with an outer layer that is wind-resistant. - Cover exposed skin: wear a hat, mittens and a scarf, neck tube or face mask. - Keep active.
-40 to -47	High risk: exposed skin can freeze in 5 to 10 minutes*	- Check face and extremities (fingers, toes, ears and nose) for numbness or whiteness (frostbite) - Risk of hypothermia if outside for long periods without adequate protection	- Dress in layers of warm clothing, with an outer layer that is wind-resistant. - Cover all exposed skin: wear a hat, mittens and a scarf, neck tube or face mask. - Keep active.
WARNING LEVEL** -48 to -54	High risk: exposed skin can freeze in 2 to 5 minutes*	- Check face and extremities frequently for numbness or whiteness (frostbite) - Serious risk of hypothermia if outside for long periods	- Be careful. Dress very warmly in layers of clothing, with an outer layer that is wind-resistant. - Cover all exposed skin: wear a hat, mittens and a scarf, neck tube or face mask. - Be ready to cut short or cancel outdoor activities. - Keep active.
-55 and colder	High risk: exposed skin can freeze in less than 2 minutes	DANGER! - Outdoor conditions are hazardous	- Stay indoors.

Source: Environment Canada – Wind Chill Program

* In sustained winds over 50 km/h, frostbite can occur faster than indicated.

**In parts of the country with a milder climate (such as southern Ontario and the Atlantic provinces except Labrador), a wind chill warning is issued at about -35. Further north, people have grown more accustomed to the cold, and have adapted to the more severe conditions. Because of this, Environment Canada issues warnings at progressively colder wind chill values as you move north. Most of Canada hears a warning at about -45. Residents of the Arctic, northern Manitoba and northern Quebec are warned at about -50, and those of the high Arctic, at about -55.

Sources and Further Reading

- Meteorological Service Canada website:
    - Wind Chill Calculation Chart
    - Wind Chill Fact Sheet
- Phillips, Dave. (1990). The Climates of Canada. Canadian Government Publishing Centre

2.3 Drought

It's mid-July 2001, and a thin band of lush, green grass circles Ron Cannon's farmhouse. Cannon regularly waters the two-metre-wide green space that breaks up an unending expanse of brown grass, black dirt and dying, stunted plants.

"I water the grass 'cause it's nice to have something green to look at when I'm sitting on the deck,… thinking about this mess" .

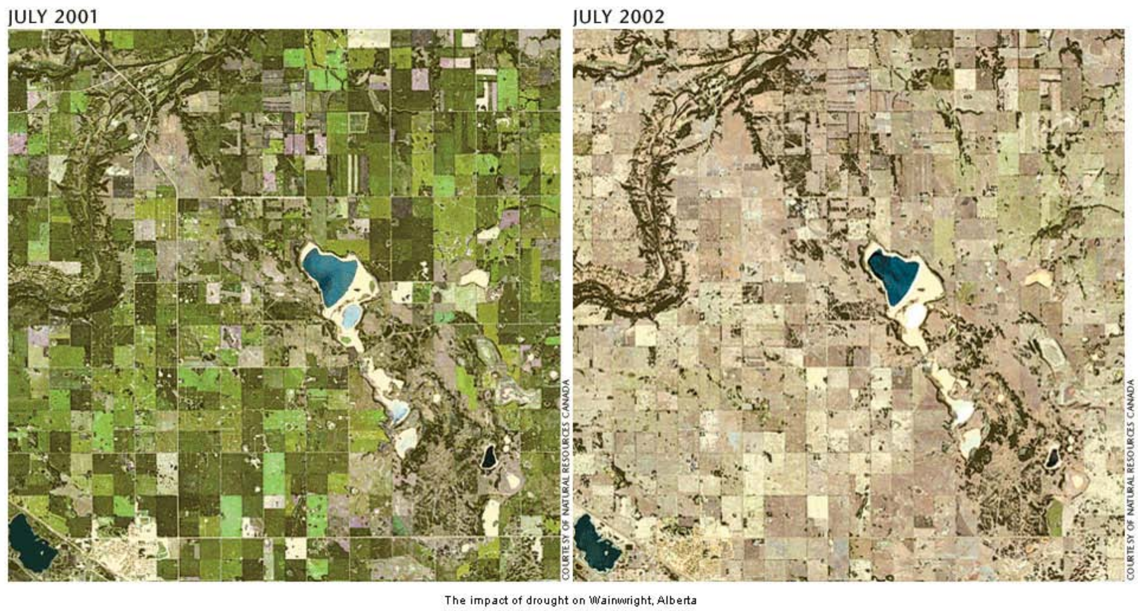
His farm sits in the middle of a vast drought zone that stretches from Calgary to Saskatoon and beyond. Like thousands of farmers in the Prairies, Ontario and Prince Edward Island, most of Cannon's planted seed has died without even sprouting from the soil.

An unprecedented series of droughts that started in 2000 and covered most parts of Canada cost an estimated $5 billion in economic losses in 2001 and 2002. The only harvest Cannon and other farmers saw that year was a harvest of despair.

Figure 1: Effect of Drought

Source: Food and Agricultural Organization of the United Nations – Regional Office for the Near East

Figure 2: Impact of 2001 Drought on Wainwright Alberta



Source: Natural Resources Canada

Droughts differ from other natural hazards in several ways. They tend to develop slowly and their existence is often ignored until human activity is markedly affected. Droughts can cover large areas and can last for months or even years. The huge economic losses caused by severe droughts make them one of Canada's most costly hazards.

Understanding the cause of droughts

One challenge associated with studying droughts is that they're defined differently by different people. Meteorologists typically refer to drought as a long-term period of below-normal precipitation. Water resources experts consider drought as a prolonged period of reduced streamflows, groundwater levels or runoff. A farmer often defines drought as a period during which soil moisture is insufficient to support crops.

Droughts are usually caused by prolonged disruptions in normal weather patterns. For example, large, high-pressure cells can dominate a region, resulting in shifts in the jet stream that prevent storm systems from reaching an area.

Droughts can also be self-perpetuating because they cause soils, plants and water bodies to dry, greatly reducing the amount of local water vapour being added to the atmosphere. The area then has to depend for precipitation on moist air coming from other regions. This situation increases the likelihood that a drought will occur and also extends the life of existing droughts.

Drought impacts

Droughts have economic, environmental and social impacts. In Canada, reductions in crop yields and livestock production account for the most significant drought-related economic losses. Other agriculture-related sectors, including forestry and fisheries, are also affected because of their reliance on surface water and groundwater supplies.

Droughts are often associated with increases in insect infestations (e.g. grasshoppers) and soil erosion caused by blowing winds. They also substantially increase the chance of forest and range fires that put both human and wildlife populations at risk.

The reduced water supply associated with droughts makes rivers less navigable, resulting in increased transportation costs. Ships may have to reduce their loads and make more trips to carry the same amount of cargo, or the cargo must be transported by alternate means, such as rail or truck. Hydroelectric power generation may also be significantly affected by reduced river flows.

Environmental impacts include the loss of wetlands, lakes and vegetation, which can affect wildlife habitat and water quality for waterfowl and fish. Fortunately many species can eventually recover when the water returns.

Social impacts can include health problems and conflicts among water users. For example, in 2002, there was controversy over watering an Alberta golf course for Wayne Gretzky's charity golf tournament; local farmers were outraged when water was diverted from a lake while their cattle and crops were dying.

Weather events associated with droughts can also cause health problems. For example, heat spells and poor air quality caused by wind erosion and dust storms can exacerbate respiratory or cardiac problems.

Drought occurrence and frequency

Droughts can extend from small areas of one province to very large regions covering several provinces. Although they can happen anywhere in Canada, the most severe and widespread occur on the Prairies.

Located on the northern extremity of the North American Great Plains, the Prairies are a semi-arid to sub-humid area that experiences highly variable weather. Over 40 severe droughts have occurred throughout western Canada during the past 200 years. By contrast, droughts in eastern Canada are usually brief, cover a smaller area and are less frequent and severe (See Table 1).

Table 1: Historical droughts in Canada

Date	Location / Impact
1805	Scorched potato crop in the Red River (Manitoba area)
1816-1819	Almost continuous drought and hordes of grasshoppers on the Prairies
1846	Complete crop failure in the Red River area
1862-1864	Low river levels on the Red River
1868	Prairie crop fails; grasshopper plague
1890s	Nine years of drought force farm abandonment on the Prairies
1929-1931	Severe British Columbia interior drought
1933	Grasshopper plague and drought result in smallest wheat crop in Saskatchewan since 1920
1936-1938	Recurrence of drought on prairies cause a national emergency
1961	Worst drought year this century for prairie wheat
1963	Severe Ontario drought drastically cut soybean and corn production; low Great Lakes water levels
1967	Extensive drought from Peace River to southern Manitoba
1973	Record warm summer and local drought hurt potato and apple production in Ontario
1977	Severe winter drought in southern Alberta and western Saskatchewan
1978	Extensive central Ontario drought
1979-1980	Two years of agricultural drought devastate prairie forage and wheat production
1983	Southern Ontario and Quebec drought
1984-1985	Southeastern Prairies got 50% of normal rain; insect infestations; drought in southwestern Nova Scotia dried up many streams and wells
1985	One of the worst forest fire seasons in British Columbia’s history due to drought
1987	British Columbia interior got 60% of normal rain; summer drought in Atlantic provinces affect crops and water supplies
1988	Extensive drought across the Prairies, Ontario and Quebec; worst interior British Columbia drought in 60 years
1991	Worst summer drought in Nova Scotia in over 40 years affects water supplies, increases number of forest fires
1997-2001	Prolonged Ontario drought affect Great Lakes water levels
2001	Drought affects Canada coast to coast; driest in Prairies since the 1930s; driest summer in over 50 years in Great Lakes-St. Lawrence Region; PEI potato yields down by 35-40%

2002	Prairie drought; grasshopper infestations

Courtesy: Grace Koshida

Infamous Prairie droughts

The most severe Prairie droughts of the 20th century occurred during the 1930s and 1980s and in 1961. The latter was the most severe single-year drought in the region. The multi-year droughts of the 1930s and 1980s covered large areas and caused devastating socioeconomic and environmental impacts.

The 1930s dry period began in 1929 and reached severe drought proportions by 1933, when central parts of Alberta and Saskatchewan experienced crop failures. A period of extreme heat and no precipitation from 1936 to 1938 literally changed Canada's wheat belt into a "dust bowl". Grasshoppers, weeds, wind and blinding dust storms known as "black blizzards" lasted for days. Crops were devastated, livestock starved and farmers suffered great hardship. This drought was the principal cause for the migration of over a quarter of a million people from the Prairies.

The 1980s are remembered for the widespread persistence and severity of drought. Droughts occurred in parts of the Prairies in 1979-80, and 1984-85. One of the worst droughts in North American history occurred in 1988. It extended throughout southern Canada and the United States, affecting 24 states and three provinces.

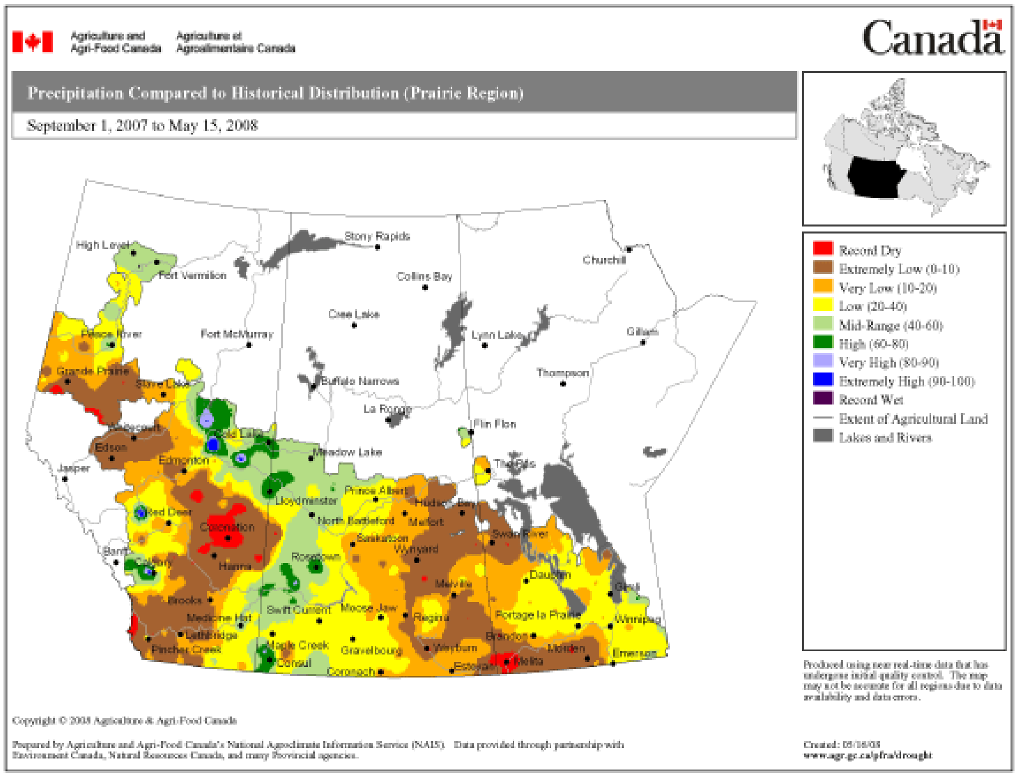
Agricultural impacts were severe; for example, crop production in Saskatchewan was reduced to less than 50% of average yields. However, economic bankruptcy was averted to a great extent due to a variety of technological improvements, cultural practices and government support programs, such as crop insurance. Though similar in intensity, the droughts of the 1930s had more severe socioeconomic consequences because of a lack of social programs and a poor adaptive capability.

Detecting and monitoring droughts

Various indices have been developed to detect and monitor droughts. However, unlike other natural hazards, a drought is a creeping phenomenon that develops over weeks and months. In fact, experts often know better when droughts end than when they start.

Because a lack of precipitation is often the first sign of an impending drought, this is the most widely used measure. Figure 1 shows an example of a map used in drought monitoring – maps showing areas of greater and lesser precipitation over an extended period of time (12 months in this case) as compared to normal values. Areas of brown and red are experiencing drought conditions.

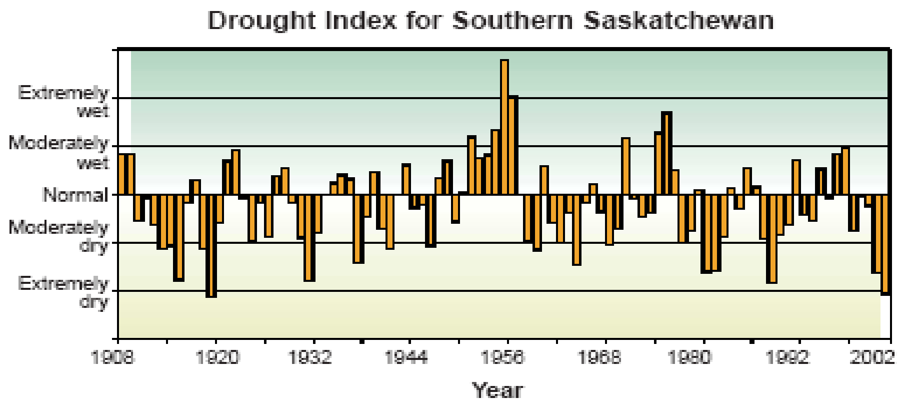
Figure 3: Prairie Precipitation Compared to Historical Distribution, September 2007- May 2008.



Source: Agriculture and Agri-food Canada

Soil moisture estimates are used to evaluate crop stress and yield and are also used in computer models that project water runoff and supply. The Palmer Drought Severity Index (PDSI), an index commonly used in North America, represents degrees of soil wetness and dryness with numerical values. The PDSI includes many factors in its calculations, including precipitation, evaporation, transpiration, soil moisture conditions and runoff. The distribution of the average June PDSI for southern Saskatchewan for the period 1908-2002 is shown in Figure 2. Downward running bars indicate dry conditions which, at the extreme, can lead to drought.

Figure 4: Trend of Drought Severity Index from 1908 to 2002 for Southern Saskatchewan



Source: Meteorological Service of Canada, Regina (2002)

Climate change and future droughts

Although no one can predict the date of the next drought, it's certain they will recur, especially in the Prairies. In fact, more frequent and more intense droughts are expected to occur as the Earth warms. Various climate change scenarios project a decrease in the number of rain days; this means that during dry summers, higher temperatures will increase evaporation and intensify drought conditions.

Drought mitigation

Droughts are infrequent enough in most parts of Canada that they're usually not included in long-term disaster management plans. When a drought is detected, drought mitigation plans of various types—crop management, water conservation, soil conservation, and grassland management—should be started or enhanced to lessen impacts. Mitigating drought—taking actions in advance of drought to reduce its long-term risk—can involve a wide range of tools. This helps reduce the cost of droughts and our vulnerability to them. Community or organizational strategies can be divided into 9 categories:

- Assessment Programs
- Legislation/Public Policy
- Water Supply Augmentation

- Public Awareness/Education Programs
- Technical Assistance
- Demand Reduction/Water Conservation Programs
- Emergency Response Programs
- Water Use Conflict Resolution, and
- Drought Contingency Plans

Specific crop management measures that individuals can adopt include:

- Planting crops that use less water, withstand dryness, hold water and reduce the need for irrigation.
- Water conservation measures include choosing irrigation systems that lose less water to evaporation, percolation, and runoff.
- Soil conservation measures include providing ground cover to protect soil from wind, and allowing fallow periods so that soil nutrients will not be depleted.
- Grassland management includes using tillage (crop residue left on the field after harvest) to increase soil moisture and reduce evaporation and reducing livestock herd size that graze the land.

Droughts can also affect urban areas, and are considered to occur when supply cannot meet demand. Most cities do not have drought plans, since water reservoirs or other engineering devices ensure a fairly stable water supply. However, they do occur from time-to-time and can require mitigation. Actions taken are usually temporary and include voluntary water conservation measures by individuals and communities, water storage and diversion, mandatory restrictions using city by-laws if necessary, and urban reforestation or greening projects.

Droughts are among Canada's most expensive type of disaster, perhaps the most expensive when they are considered in total, because they affect the viability of the country's multibillion-dollar agricultural sector. Although most Canadians are not directly affected, they still pay for the consequences through crop insurance, aid to farmers as well as the price and availability of food.

Sources and Further Reading

- Drought Watch on the Prairies (Canada)
  - Agriculture and Agri-Food Canada: Drought Watch

- Drought Monitor (USA)

- Koshida, G., B. Mills and M. Sanderson 1999. Adaptation lessons learned (and forgotten) from the 1988 and 1998 southern Ontario droughts, in I. Burton, M. Kerry, S. Kalhok and M. Vandierendonck (eds.), Report from the Adaptation Learning Experiment. Environment Canada, Environmental Adaptation Research Group, Downsview, Ontario. pp.23-36.

2.4 Forest Fires in Canada

"Kelowna Counts the Cost: Raging forest fires destroyed hundreds of homes in Kelowna yesterday, leaving others unscathed. For the lucky ones, there was relief as they've never felt. But hundreds of others left a Kelowna church grim-faced and in tears, clutching maps that delivered final proof that their homes had been destroyed by a forest fire."[1]

"A whole stretch of country for 100miles in northeastern Ontario is laid bare by the fire element. Nothing remains but a bleak outlook of charred trunks of trees and desolation reigns supreme."[2]

Introduction

Most Canadians are familiar with the devastating British Columbia wildfires of 2003, which burned hundreds of homes at the forest/urban interface with losses totaling hundreds of millions of dollars. Most Canadians would not be aware, however, that large wildfires caused widespread devastation and significant loss of life across Canada as this country was being settled. The large 1916 Matheson firestorm in northeastern Ontario burned 24 townships, killing at least 243 people and destroying numerous small towns. It was one of three major fires during this period —the Porcupine Fire of 1911, and the Temiskaming Fire of 1922 were others—that galvanized government and public opinion into developing organized forest fire protection in Ontario.

Forest fires have played a dominant role in disturbing Canadian forests since the last Ice Age about 10,000 years ago. Fire is a natural and essential phenomenon that, along with insects, disease, wind, and natural regeneration, has helped to shape the character of Canadian forests before the country was settled.

Fire is particularly important in Canada's vast boreal forest region, where trees such as pine, spruce, birch, and aspen have adapted to fire to the point where it is essential to their existence. In fact, the high-intensity crown fires (involving both surface and tree crown fuels) that occur in this region are required to regenerate these tree species. Fire affects the physical and biological characteristics of the boreal forest environment, shaping the nature and diversity of the landscape. It also influences cycles of energy and chemicals—particularly the carbon cycle, which is particularly important in climate change.

Canadian forests are therefore strongly connected to the fire regime; their nature is dependent on the frequency, extent and severity of forest fires. In Canada, and other similar countries with large forests, maintaining their natural state and the

[1] Toronto Globe and Mail, August 25, 2003
[2] The Globe, Toronto, August 2, 1916

environments that support their existence is crucial to preserving a balanced global natural environment.

At the same time, forest fires are an increasing threat to lives and property, and their incidence and severity are expected to increase as the earth's climate warms. In northern regions like Canada, which will be disproportionately affected by climate change, even sophisticated fire management organizations will be hard-pressed to meet the challenge.

Protecting Canada's forests

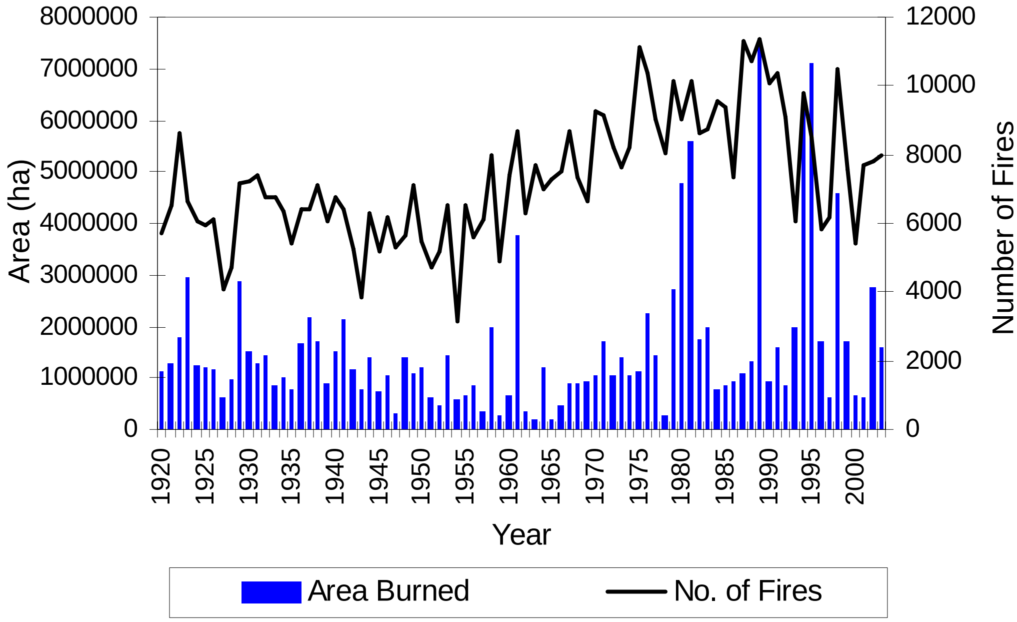
In Canada, the industrial use of forests is intimately linked to the country's cultural, economic and social development. Over the past century the forest sector has become the largest contributor to Canada's economy. In 2007, the forest industry directly employed almost 300,000 people and the industry was worth $78.3 billion to the Canadian economy. Forest recreation is also expanding.

Clearly, such extensive utilization of the forest requires protection from fire. Reconciling the need to protect forest lands that are valuable for industry and recreation with the natural role of fire in maintaining forest ecosystems has been a priority in developing fire management in Canada over the past century.

Throughout the 1800s, as Canadian settlements expanded westward, numerous devastating wildfires, often associated with land clearing, caused much loss of life and property. Some prominent examples include the Miramichi Fire of 1812 in New Brunswick and the Lac St-Jean Fire of 1870 in Québec. This trend continued into the early 1900s, with major fires in northeastern Ontario, east-central Alberta, and central British Columbia that resulted in the burning of complete towns with substantial loss of life. This, along with the need protect an expanding forest industry, prompted the development of fire control organizations in Canada.

Forest fire statistics have been archived since 1920 in Canada (See Figure 1). It is believed that many fires in remote regions were not detected or monitored prior to the advent of satellite coverage in the early 1970s, so the record for this period is somewhat incomplete. Bearing this in mind, fire occurrence in Canada has increased rather steadily from about 6,000 fires a year in the 1930-1960 period to almost 10,000 fires annually during the 1980s and 1990s, most likely the result of a growing population and expanded forest use, along with an increased detection capability.

Figure 1: Number of fires and area burned in Canada 1920 - 2003



*** Unofficial Data from 2004-2007**
2004: 3,277,183 ha and 6630 fires
2005: 1,706,445 ha and 7438 fires
2006: 2,079,554 ha and 9713 fires
2007: 1,661,174 ha and 6324 fires

Source: Brian Stocks, Natural Resources Canada

From Figure 1 it is also evident that the area burned by Canadian forest fires fluctuates greatly from year-to-year, from under 0.5 million hectares to more than 7 million hectares in extreme years. In comparison to the 1950s and 1960s, average annual area burned has been increasing over the past three decades, with major fire years in 1980, 1981, 1989, 1994, 1995, 1998 and 2003. Lightning is responsible for 35% of Canadian forest fires, yet lightning fires account for 85% of the total area burned. This is because lightning fires occur randomly over large areas and are often harder to detect and reach than human-caused fires. As a result, firefighting efforts are often delayed, allowing the lightning-caused fires to grow larger.

Weather is the most important factor affecting the occurrence and growth of forest fires; it creates lightning, largely determines the moisture content of forest fuels and greatly influences fire growth through wind action. Although long-term droughts contribute to major fire years, they are not a necessary requirement; just a week or two without precipitation can reduce forest fuel moisture enough to allow easy ignition and extreme fire behavior. The Canadian fire season generally runs from April through October, although it is shorter at higher latitudes. The occurrence of fires and the amount of area burned reach their peak from June through August.

Fire management responsibilities

Since the 1920's, Canadian fire management agencies have grown in size and sophistication to address expanding responsibilities in protecting Canadian forests from unwanted fires. Operational fire managers and fire scientists in Canada have worked together closely to develop highly sophisticated systems to predict the occurrence, behavior, and impact of forest fires in various ecosystems across the country.

Two key objectives in successfully controlling fires are early detection and initial attack when fires are small, as the chance of early control diminishes quickly as a fire grows in size. Fire management agencies predict the most likely locations where both lightning and human-caused fires will start and then fly aircraft detection patrols focusing on those areas. When fires are detected, initial attack forces are deployed by land or helicopter and are often supported by water bombing aircraft.

In Canada, most forested land is public and owned by the 13 provinces and territories, which are responsible for fire management. The federal government, in addition to conducting a large share of forest fire research, is also responsible for fire management in National Parks. In the parks, prescribed burns and wildfire monitoring are used periodically to maintain the ecological integrity of the forests.

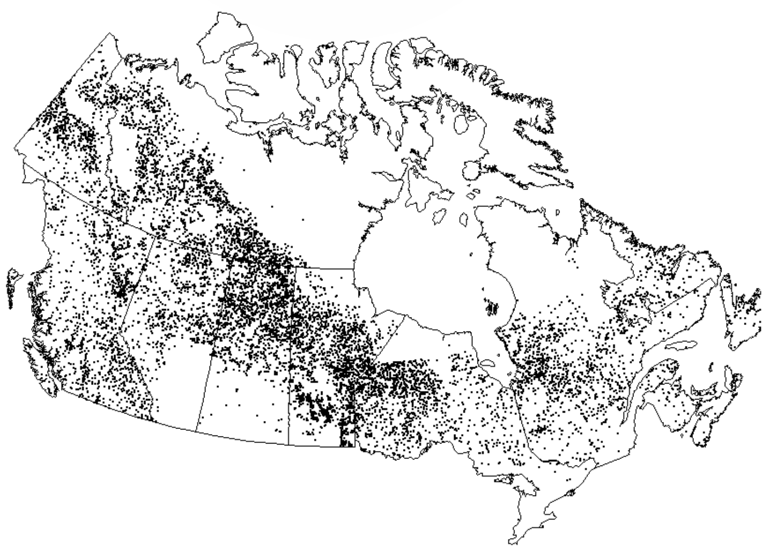
Fire suppression costs are constantly rising in Canada for several reasons, including changes in fire weather, the use of more costly equipment, the expansion of fire protection zones northward to match growing forest operations, and increased costs associated with protection of an expanding wildland-urban interface. Annual suppression costs, not including public and industrial losses, are averaging about $300 - $500 million. The three provinces with the largest fire management organizations, British Columbia, Ontario, and Alberta, generally account for about 60% of total Canadian expenditures.

Canadian fire management agencies have been largely successful in controlling a high percentage of the fires that occur in high-value areas. However, extreme fire danger conditions—often coupled with multiple fire starts usually associated with lightning storms—occasionally overwhelm fire suppression resources and large areas burn. This is particularly true in the boreal zone, where high-intensity crown fires are most common and can cover large areas very quickly.

The sophisticated fire management systems in place are largely successful and the vast majority of fires are contained at an early stage. However, about 3% of fires grow larger than 200 hectares in size and these account for about 97% of the total area burned. While severe burning conditions and multiple ignitions cause a number of large fires in the intensively protected areas of Canada, there are many areas in northern Canada where fires are allowed to burn naturally, provided they do not threaten anything of economic or social value.

Northern regions of Québec, Ontario, Manitoba, and Saskatchewan, along with much of the Northwest and Yukon Territories, are areas where fires are monitored but not necessarily fought. Over the past four decades, nearly half of the roughly 2 million hectares burned annually in Canada have been in these remote “modified suppression” zones. The contribution of these fires to the total area burned in Canada can be seen in Figure 2, which shows the distribution of large fires across Canada from 1959 to1997.

Figure 2: Distribution of large Canadian fires (>200 hectares) 1959 - 1997



Source: Brian Stocks, Natural Resources Canada

Clearly, the largest areas burned occurred in west-central Canada, in a band running from northwestern Ontario through northern Manitoba and Saskatchewan into the Northwest Territories. These regions contain large areas where values-at-risk do not warrant aggressive fire suppression and fires most often are left to burn naturally. Most forested regions of southern Canada sustained fewer large fires as a result of intensive protection, although large fires are still a factor in these areas.

Forest fires threaten urban areas

Over the past decade forest fires have had a growing impact on residential communities, as municipalities expand into surrounding forests. The threat to life and property that forced the development of organized fire suppression in Canada is once again a growing concern. During the 1980s and 1990s communities were often evacuated due to threatening wildfires, and in some cases residential structures were burned. Some primary examples are the 1994 Penticton Fire in B.C., the 1995 Parent Fire in Québec, the 1998 Salmon Arm Fire in B.C., and the 1999 Shelburne County Fire in Nova Scotia.

The threat of wildfires in the wildland-urban interface became common knowledge to all Canadians in the summer of 2003, when continual extreme fire danger conditions and multiple ignitions in the interior of BC overwhelmed suppression capabilities and fires destroyed homes in a number of communities including Kelowna, B.C. A total of 334 homes and 10 businesses were destroyed and over 50,000 people evacuated. The total economic impact to the province of BC is thought to have been over 700 million dollars.

Increased awareness of potential fire impacts in the wildland-urban interface has prompted research into better ways to protect communities and homes. Suggested strategies include modifying fuels near homes by thinning or pruning tress or planting less flammable tree species) and using more fireproof construction materials.

Climate change a growing threat

Managing forest fires will likely become even more of a challenge in the future because of climate change. Northern latitudes are predicted to experience the most significant degree of climate change and associated impacts. Recent research indicates that the warming predicted by many global meteorological models would result in a significant increase in the frequency and geographical extent of severe fire danger conditions across western and central Canada. In addition, fire seasons are expected to become longer, and increased lightning activity is predicted.

Clearly, Canadian forests will be exposed to more frequent and severe fire under these conditions and fire management agencies will be forced to adapt their protection policies. Increased fire impacts associated with climate change pose a very real social and economic threat to Canadians.

Despite the fact that Canadian forest fire management programs are among the most sophisticated and expensive in the world, forest fires continue to have a profound impact on the Canadian landscape, with growing social and economic consequences. As fire incidence and severity are expected to increase in the near future, fire management organizations in this country will face new and daunting challenges.

Mitigation

Community Level:
A variety of tools are available to communities to manage fire risk. These include planning tools, engineering tools, policy tools and public education. Some steps a community can follow are:

- Develop a Strategic Forest Management Plan.
- Integrated Landscape Planning, including the identification of broad areas available or not for forest development; strategies for reducing or eliminating significant negative effects on other resources and values.
- Harvest Development Planning that designs the general harvest activities consistent with the outcome of landscape planning.
- Operating Plans that field check and engineer harvest block boundaries, landings, volumes and exact road location consistent with higher level plans

Individual Level:

- Move your firewood pile out of your home's defensible space.
- Perform a FIREWISE assessment of your home. Clean your roof and gutters of leaves and pine needles (best done in October).
- Clear the view of your house number so it can be easily seen from the street.
- Put a hose on a rack and attach it to an outside faucet.
- Trim all tree branches if they overhang your house.
- Trim all tree branches from within 20' of all chimneys.
- Remove trees along the driveway to make it 12' wide.
- Prune branches overhanging the driveway to have 14' overhead clearance.
- Maintain a green lawn for 30' around your home.
- If new homes are still being built in your area, talk to the developer and local zoning officials about building standards.
- Plan and discuss an escape plan with your family. Have a practice drill. Include your pets.
- Get involved with your community's disaster mitigation plans.
- Check your fire extinguishers. Are they still charged? Are they easy to get to in an emergency? Does everyone in the family know where they are and how to use them?
- Clear deadwood and dense flammable vegetation from your home's defensible space.

- Remove conifer shrubs from your home's defensible space especially if your home is in a high-risk area.
- Review your homeowner's insurance policy for adequate coverage. Consult your insurance agent about costs of rebuilding and repairs in your area.
- Talk to you children about not starting fires or playing with matches.
- If you have a burn barrel that you use for burning trash, STOP !
- Compost leaves in the fall, don't burn them.
- If you burn your brush piles or grass in the spring, get a burning permit.
- Always have a shovel on hand and hook up the garden hose BEFORE you start the fire.
- Never burn if the smoke and flames are blowing towards your home (or your neighbour’s home).
- Be a Firewise advocate.
- Install metal screens on all attic, foundation, other openings on your home to prevent accumulation of leaves and needles.
- Replace conifer and evergreen shrubs with low-flammable plants in your home's defensible space.
- Thin and prune conifer trees for 30' to 100' around your home.
- Replace vinyl gutters and downspouts with non-flammable, metal gutters and downspouts.
- Install a spark arrestor or heavy wire screen with opening less than 1/2" on wood burning fireplaces and chimneys.
- Treat flammable materials like wood roofs, decks, and siding with fire retardant chemicals
- Enclose decks to prevent accumulation of leaves, needles, and debris. Include a metal screen with a 1/8" mesh opening to prevent sparks from getting under the deck.
- Replace your roof with fire-resistant materials such as Class A shingles.
- Install a roof irrigation system to protect your home's roof.
- Install an independent water supply for a sprinkler system with a non-electric (e.g., propane) powered pump capable of running unattended for 24 hours.
- Replace wood or vinyl siding with non-flammable material.
- Replace single-pane glass windows and plastic skylights with tempered, double-pane glass.
- Box in eaves, fascias, and soffits with aluminum or steel materials with metal screens to prevent entry of sparks.
- Relocate propane tanks inside the defensible space but at least 10' from the house. Have non-flammable ground cover such as gravel around them for 10'.

Sources and Further Reading

- Government of British Columbia: Firestorm Provincial Review, and Forests and Range – Protection Branch.

- Government of Saskatchewan: Saskatchewan Environment

- Wildland Fire Lessons Learned Center

- Natural Resources Canada/Canadian Forest Service: Forest Fire Facts and Questions.

2.5 Floods

On July 19 and 20, 1996, Quebec's Saguenay Valley experienced an unusual torrential rainfall that caused the most damaging flash floods in Canadian history. Rising waters overtopped dams in the area and at the Lake Ha! Ha! Reservoir, an earthen saddle dike was overtopped and breached. The resulting deluge swept down the Ha! Ha! River valley flooding the hamlet of Boilleau with churning mud and uprooted trees. Near the river mouth, flood waters devastated the City of La Baie.

Fearing breaching of the dams impounding the Lake Kenogami Reservoir, engineers were compelled to ease lake levels by releasing water. The resulting floods spilled along the Sable and Chicoutimi rivers through the cities of Chicoutimi and Jonquiere causing widespread flooding and the breaching of four small dams. Overall, the flooding in the Saguenay area destroyed or damaged 1718 houses and 900 cottages, and forced 12 000 residents to flee their homes. Many bridges and roads were washed away and power water supply systems failed. The event cost a staggering $1.5 billion in economic losses. In southern Quebec, 10 people were killed as a result of the storm.

Introduction

Floods can occur in any region of Canada, in the countryside or in cities, and at virtually any time of the year. Between 1900 and 1997 at least 168 flood disasters occurred in Canada, causing billions of dollars in property damages and at least 198 deaths.

In coming decades, flooding problems may get even worse. Climate change is expected to increase the frequency and intensity of flood events, and changing patterns of population growth and infrastructure development will likely increase the economic losses that result from them. We can avoid, or at least minimize, these losses by taking precautionary measures and avoiding development in flood prone areas.

Floods

Floods result when natural or man-made channel courses cannot carry all the water supplied to them or when drainage is blocked by the formation of some natural dam. Then, water overtops the channel margins and inundates adjacent low-lying areas such as floodplains. Flooding also occurs along lakes and coastal shorelines when strong winds or storm surges produce higher than normal water levels that inundate surrounding areas.

In natural areas, such spillovers aren't of great concern; in fact, they keep wetlands and marshes alive and replenish groundwater aquifers. However, in developed areas, floods threaten lives, homes, industry and critical infrastructure such as roads, bridges, and power sources when they occupy flood prone lands.

Types of Floods

In Canada, flooding is caused by any of the following factors:

- Snowmelt
- Rainfall, both prolonged and occurring over a saturated surface, or an intense localized one.
- Rain on snow – the combination of snowmelt and storm rainfall runoff together can cause very severe flooding.
- Ice jams.
- Natural dam failures (landslide, glacier or moraine dams).
- Coastal storms, tsunamis, cyclones, and hurricanes.

The actual intensity of flood is determined by a number of factors, including rate of rainfall or snowmelt and the shape of the land - mountainous or hilly terrain make floods worse by channeling water into valleys.

Snowmelt
Snowmelt runoff floods are the most common type in Canada, accounting for about 40% of flood events. One of the worst, Manitoba's Red River flood in May 1997, resulted from the melt of a thick spring snowpack.

Storm-Rainfall Runoff
The amount, intensity and duration of a rainstorm affects the ability of the land to absorb water. Intense and/or prolonged rainfall reduces the amount of absorption and produces runoff that swells the volume of streams and rivers.

In small watersheds, a torrential downpour can cause sudden, severe flooding called a flash flood. A flash flood is one in which peak flooding occurs within six hours of the onset of rainfall. Mountainous areas are especially prone to flash flooding because steep slopes increase runoff velocity and concentrate the water into channels.

Eastern Canada is the region most affected by tropical storms and hurricanes, which produce heavy precipitation that can cause flooding. In October 1954, Hurricane Hazel deposited over 100 millimeters of rain on the Toronto area in less than 12 hours. More than 80 people died and over $100 million in damages was recorded (See Section 2.9: Hurricane).

Some notable Canadian flash floods include:

- May 26, 2005: Bridgewater, Nova Scotia: 383mm of rain fell in the region and a local state of emergency was declared.
- July 3, 2002: Vanguard, Saskatchewan had one of the most intense rainfall events ever recorded in Canada when as much as 375 mm fell in eight hours. The town's 200 residents had to use boats to get around.
- July 19 & 20, 1996: Red River, Manitoba: Over 270mm of rain fell in a few hours, which was equivalent to the amount in a normal month.
- July 1989: Harrow, Ontario: over 400 mm of rainfall fell in 30 hours.
- July 14 1987: Montreal, Quebec: over 86mm of rain recorded in a one hour period. Two people were killed.
- May 30 1961: Buffalo Gap, Saskatchewan: over 254mm of rain fell in less than hour, making it the greatest high-intensity short-duration rainfall event in Canada.

Ice Jams

Ice jams occur where floating ice, slush or blocks pile up within a channel behind a stable ice cover or obstructions such as bridge piers, islands or bends. Jams can form both during fall freeze-up and spring breakup. However, more severe flooding is likely to happen during the latter because the upstream ice cover starts to break up and water levels start rising due to snow melt. Ice jam flooding can also occur during a sudden mid-winter thaw accompanied by substantial rainfall.

The majority of floods in Yukon and the Northwest Territories follow spring ice break-up. They're common in the Mackenzie River Basin; broken ice and warmer waters from the southern part of the basin move north on the river to where water is still frozen, leading to severe ice jams and flooding. Ice jam floods also occur in other locations though, for example in the Saint John River.

The sudden release of a major ice jam can also produce damaging floods downstream of the jam. Flow surges can move as fast as 10 meters per second (36 kilometers per hour). The water flows so quickly that there's little time to implement emergency measures.

Ice-related floods are common in most of southern and Atlantic Canada. In May, 1986, massive floating ice debris demolished the northern Ontario village of Winisk. Houses were floated off their foundations and moved kilometers away. One person was crushed by ice, another carried away by the flood waters.

Outburst Floods

Outburst floods are formed by the rapid failure of actual dams, which can form behind glaciers, moraines (soil and debris deposited by stagnating or retreating glaciers) and landslides. Flooding caused by the failure of a glacier dam are known by the Icelandic term 'jökulhlaup'.

Outburst floods can also occur when man-made dams fail, as was the case at Lake Ha! Ha! during the 1996 Saguenay Flood. Because they happen so suddenly and can cause enormous flows, outburst floods can cause catastrophic damage. They can rip trees and sediments from valley floors and transform them into destructive debris flows. In 1978, debris flow triggered by a jökulhlaup from Cathedral Glacier near Field, British Columbia, destroyed three levels of Canadian Pacific railway track and buried sections of the Trans-Canada Highway.

Coastal Storms

People living along Canada's coasts and the shores of the Great Lakes are occasionally exposed to the threat of flooding caused by high winds, wave action, or an interaction between high estuarine flows and tides. Storm surges, usually the result of hurricanes or their remnants, produce abnormally high water levels that inundate low lying areas (See Section 2.10: Storm Surge). In coastal regions, severe storms can produce surges of up to 2 meters. Great Lakes shorelines, particularly those of Lake Erie, also experience significant surges.

Besides hurricane-induced surges, the most spectacular coastal flooding event is the tsunami, which is a wave set in motion by an undersea earthquake, volcano or landslide (See Section 3.5: Tsunami).

Urbanization and Flooding

The characteristics of a drainage basin, such as its size, shape, terrain, vegetation cover and degree of development, determines whether it will flood or not. In a natural area, vegetation cover and reduce the speed, rate and amount of runoff that reaches the drainage channel. A large proportion of the rainfall will be intercepted by the vegetation or infiltrate into the soil. However, in urban areas, natural channels are paved over and sewers and ditches are built to quickly evacuate surface runoff. This reduces the level and rate of soil infiltration while increasing the volume and velocity of runoff. When runoff exceeds the drainage capacity of the sewer system streets and homes are flooded, often as a result of sewer backups.

A spectacular urban flood occurred in Montreal on July 14, 1986 when a storm dumped between 100mm and 150mm of rain within a three-hour period. Thousands of basements and several major underpasses were inundated. The Decarrie Expressway was turned into a canal as the water rose 3.6 meters. The subway system was paralyzed, and two people lost their lives. Property damage exceeded $40 million.

Spatial Distribution of Floods

Most populated areas of Canada can be affected by flooding. Flood plains, valleys, urban areas with inadequate sewer systems and some coastal areas are much more vulnerable. During the 20th century about 62% of flood disasters in Canada occurred in four provinces: Ontario (37 events), New Brunswick (26 events), Québec (23 events) and Manitoba (18 events). Recurrent flood disasters have occurred in the Saint John River basin, New Brunswick, (16 disasters) and the Red River basin, Manitoba (15 disasters, including the Assiniboine River)

Seasonal distribution of Floods

The seasonal distribution of floods is mainly controlled by the timing of snow melt, storms and hurricanes (See Table 1 for a list of Canada's worst flood disasters). Floods that occur between January and March can be caused by rain-on-snow during mild winter spells. About 40% of flood disasters occur in April and May, which coincides with the snowmelt period of most rivers in much of Southern Canada. In May, delayed snowmelt and ice jams lead to flooding in the north. Between May and September the major cause of frequent flooding is heavy rainfall from storms. In June, flooding can occur in mountainous regions as a result of high mountain snow and glacier melt. Hurricanes or their remnants sometimes cause flooding in eastern Canada in the late summer or fall (for example, in August, September and October 2001, 11 of the 20 flood disasters in Eastern Canada (Ontario to Newfoundland) were caused by these types of events). The smallest number of flood disasters has occurred in the months of November and December.

The human and monetary costs of floods in Canada

Floods have caused misery and hardship in many Canadian communities over the last few decades. Between 1975 and 1999, 63 floods resulted in payments of about $720 million through federal Disaster Recovery Financial Assistance Arrangement programs. Between 1984 and 1998, insurance claims for the flooding (excluding residential losses) were above $750 million.

Table 1: Canada's most significant floods and their costs

Year	Region	Estimated damages ($million) in year 2000 dollars
1999	Maritime Provinces (NF,NS,NB)	12
1999	Melita, MB	103
1997	Red and Assiniboine River Valleys, MB	815
1996	Saguenay river valley, QC	1500
1995	Southern Alberta	156
1993	Winnepeg ,MB	406
1986	Edmonton,AB and Prince Albert,SK	67
1985	Northwest Territories	1.1 (amount represents compensation paid)
1983	Newfoundland	62
1974	Saskatchewan	23
1974	Quebec	359
1973	New Brunswick	127
1956	Nova Scotia	214
1954	Ontario (Hurricane Hazel)	1030
1950	Manitoba	1090
1948	British Columbia	427
1923	New Brunswick	75

Source: Public Safety Canada (2007)

Recent floods, such as the Saguenay Flood (1996) and the Red River Flood (1997), resulted in significant losses. Flood-related losses are expected to increase in the future for three reasons.

- More people will be exposed because of increasing population and urbanization.
- Climate change is expected to increase the frequency and intensity of storms that cause floods.
- Much of Canada's infrastructure is aging, particularly urban sewer systems.

Mitigating the Impacts of Floods

Both structural and non-structural measures can be used to reduce the impacts of floods. Structural measures that can be undertaken by communities include building protective dikes, reservoirs, channels, levees, raised roads and stormwater detention ponds to regulate the flow of water, protect low-lying areas and elevate infrastructure and buildings.

However, structural measures alone have proved insufficient since:

- they tend to give residents a false sense of security, which in turn encourages more development on river floodplains. This results in increased vulnerability.
- once the memory of a flood disaster fades, communities often fail to adequately maintain existing flood protection infrastructure and allow new development, thereby increasing the likelihood of future flood damage
- Nonstructural measures communities can adopt include:
- floodplain mapping to identify flood-prone areas
- land use regulation to prohibit or restrict floodplain development
- watershed management—upstream land management practices that protect downstream communities
- flood-proofing structures to reduce their vulnerability
- commercial flood insurance
- land acquisitions: buying out homes and business in vulnerable areas and reverting to a more natural environment; removing and/or relocating flood-damaged structures
- flood emergency response: flood forecasting, monitoring and warning systems, evacuation and rescue plans, shelter and emergency relief
- public education regarding flood risk and mitigation.

The most effective way to minimize flood damage is to avoid developing in areas prone to flooding.

Individual actions before, during and after flood events can also minimize impacts.

Before a Flood

- Move people and valuables to higher locations
- Disconnect downspouts if they are connected to the house sewer
- Move snow away from the house's foundation
- Keep water out of window wells.
- Prepare appliances for flooding.
- Shut off electricity to areas of the home that might flood
- Move hazardous materials to higher locations.
- Plan an escape route.
- Plan for pets.
- Assemble supplies in case the electricity goes off.
- Assemble supplies for a possible evacuation.
- Use sandbags or polyethylene barriers to protect homes

During Evacuation

- listen to the radio for evacuation instructions. Check Environment Canada – Weather Office for details.

- evacuate your home immediately when you are told to do so
- take your emergency survival kit with you
- follow approved routes; shortcuts may lead you to blocked areas
- don't try to drive your car through flood water; abandon it if it stalls
- don't try to walk through flood waters; instead turn around and seek higher ground. A stream as shallow as 15 cm could carry you away

After a Flood

- take precautions, especially against electric shock, by wearing rubber boots
- make sure your building is structurally safe before entering
- boil or purify water before drinking if you suspect contamination
- assemble equipment, such as gloves and pails, that will be needed in clean-up
- store all damaged documents (including those for insurance purposes) in a freezer until needed
- remove water from your flooded home slowly; rapid disposal may cause walls to buckle
- do not heat your home to more than 4ºC until all water is removed
- remove all dirt and debris and thoroughly rinse materials with water
- carpets must be dried within the first two days. Seek professional help where necessary

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2.6 Fog Hazard in Canada

In the early hours of May 29, 1914, the Canadian passenger steamship Empress of Ireland and the Norwegian coal ship Storstad crossed paths by the south shore of the St. Lawrence near Rimouski. However unlike most days, this morning was mired in a creeping surge of fog. Though both crews cried to interpret the others' signals their attempts were were quashed by a lack of visibility and by 14 minutes after the crash, the ship had sunk and 1,012 of the 1,477 on board the Empress had been plunged into the water, to eventually lose their lives.[1]

Introduction

Fog is a common hazard in Canada, one that often makes air, sea, and land travel a treacherous affair. It is simply a cloud at ground level, containing millions of tiny, visible water droplets that make it difficult to see very far.

The more droplets, the denser the fog. A thin fog is known as mist. A thick fog is one that reduces visibility to one kilometre or less. When thick fog occurs for part or all of a day, it is known as a fog day.

Fog forms when air is cooled to the saturation point—the temperature at which invisible water vapour begins to condense into minute liquid droplets. Several different processes can produce fog:

- when night-time radiation of heat from the earth's surface cools the air near the ground, it creates radiation fog.
- when humid and relatively warm air moves across a colder land or water surface, it creates advection fog.
- when cold air flows over a relatively warm lake or water body, it creates steam fog. Over the sea this type of fog is often called "arctic smoke".
- when moist air moves up and over higher terrain, it creates upslope fog.
- fog is also created when cold rain falls through a mass of relatively dry air, thereby increasing the amount of water it contains while lowering its temperature at the same time.

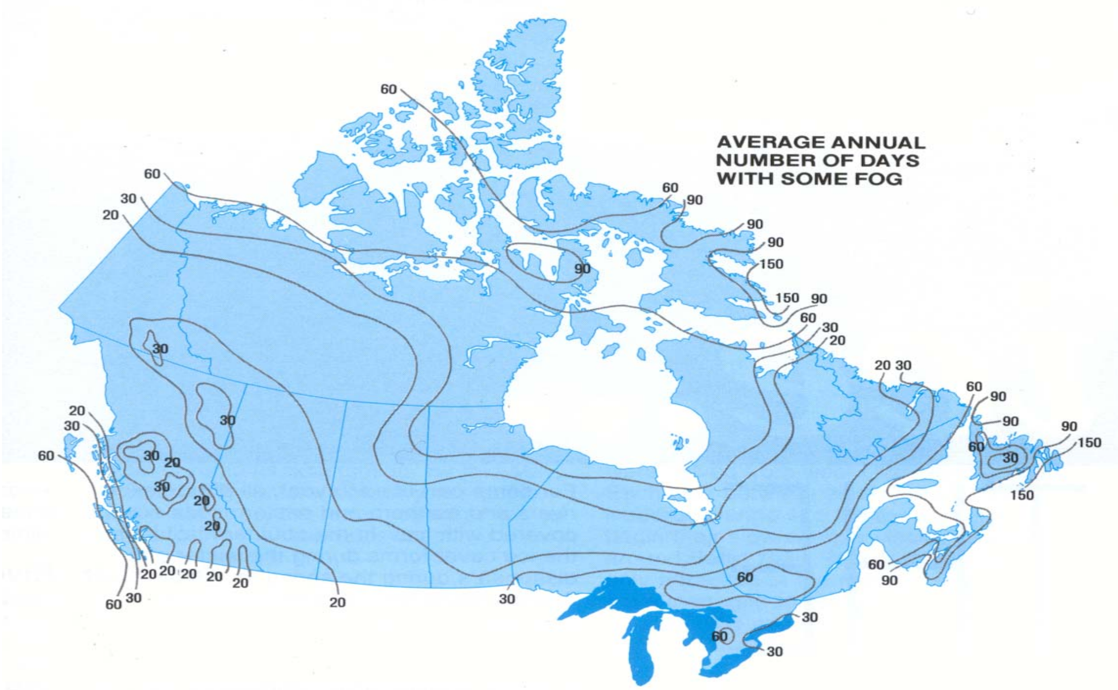
Fog frequency and distribution

Almost every region of Canada experiences foggy conditions at least a few times a year. The least foggy area is in the dry B.C. interior; Penticton, for example, is the least foggy of all Canadian weather stations, with an average of just one to four fog days a year. The central region of Canada, from Labrador in the east,

[1] Public Broadcasting Service (PBS) website –Empress of Ireland

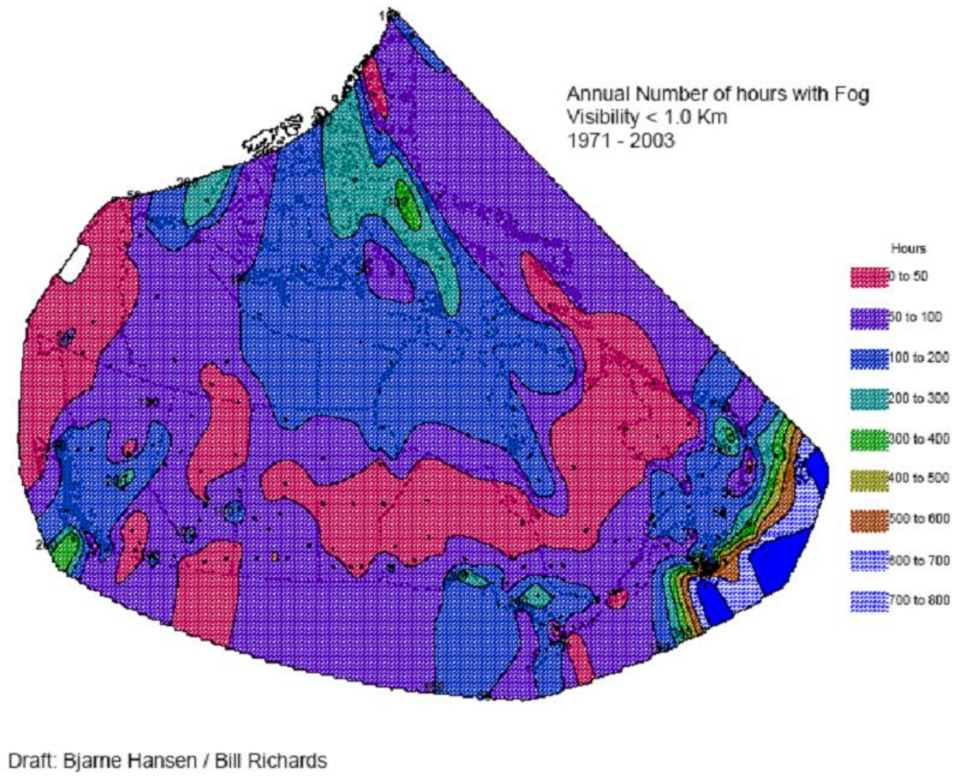
across central Quebec, northern Ontario, and the Prairies to the Yukon, is also relatively fog-free. (See Figure 1).

Figure 1: Distribution of Fog Days.



Source: Environment Canada (1990)

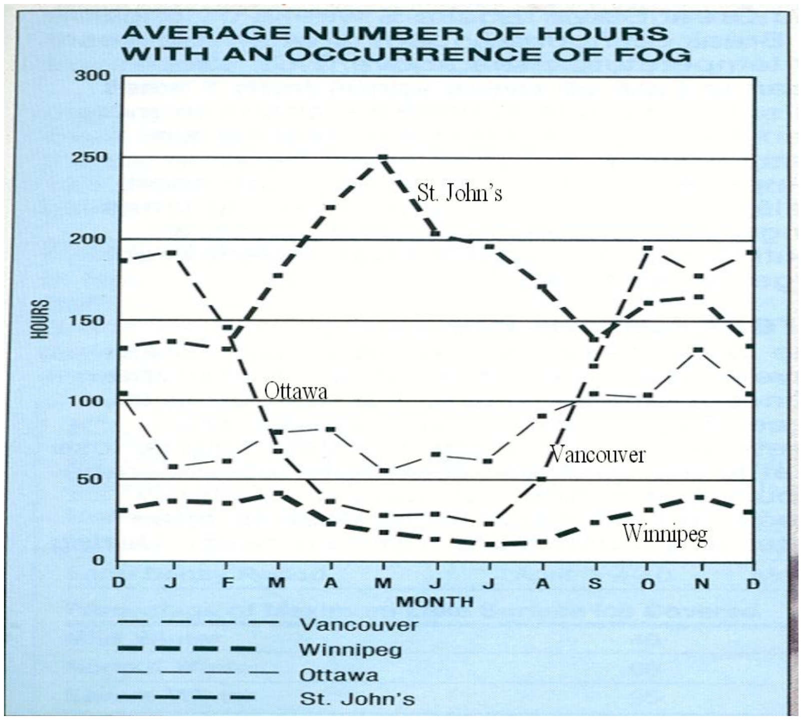
Figure 2: Distribution of Fog Hours per Year



Source: Bill Richards – Environment Canada

Figures 1 and 2 show the distribution of fog in Canada. Figure 1 maps the distribution of days with some fog (even if it is only a few minutes), while Figure 2 more importantly maps the average number of hours of fog per year. This figure shows that the foggiest areas are along the east coast of Nova Scotia and Newfoundland, parts of the Arctic and the west coast of Vancouver Island, as well as some areas adjacent to the Great Lakes. Figure 3 shows how fog varies through the year at four Canadian cities. Note that St. John's experiences more fog in the summer, as compared to the other three cities. This is because it is the only one that experiences advection fog, when warm moist air from the south moves north over cold waters (the Labrador Current).

Figure 3: Annual Trends of Fog at Four Canadian Cities



Source: Environment Canada (1990)

Communities in the Yukon and the western Arctic experience a different kind of fog called ice fog, which can linger for days. This is formed at temperatures below -30°C when it is too cold for water droplets to form and ice crystals form instead.

Social and Economic Impacts

Transportation

Fog causes major disruptions in all forms of transportation, ranging from delays and inconvenience to extreme danger. On land, reduced visibility routinely creates traffic delays and congestion—and, far too often, horrendous collisions with deadly consequences. In March 17, 2003, heavy morning fog in Barrie, Ontario, led to a series of pile-ups on Highway 400 that injured two dozen people and involved more than 200 vehicles. A 20-kilometre stretch of the highway was closed for hours in both directions (See Figure 4).

Figure 4: Car Accident Caused by Fog

Source: The Toronto Star

Fog also disrupts marine operations. In foggy weather, ships can run aground on the shoreline or ram into one another, often with a loss of cargo or lives. On August 11, 1993, 'TAN 1', a whale-watching cruise, departed from Les Escoumins, Quebec, in fog and restricted visibility. The owner/operator and 12 passengers were on board. The operator soon became disoriented and couldn't read the compass. He decided to return to the departure point by following the shoreline closely at reduced speed but the boat ran aground on a large rock. Modern radar and GPS technology have minimized these dangers but have not completely eliminated them.

Foggy conditions are particularly dangerous for air travel and often lead to cancelled or delayed flights. This not only inconveniences passengers but also causes major financial losses for airlines and other businesses dependant on aviation. Anything that can reduce the impact of fog-related delays produces major economic benefits.

Fog and health

When fog coincides with cold temperatures, it can cause health problems. For instance, it can increase the chances of catching a cold or pneumonia. Children, the elderly and those with asthma are particularly vulnerable. Fog and mist can irritate asthma patients, who have hyper-reactive airwaves sensitive to atmospheric irritants.

Positive impacts of fog

Despite the dangers it represents, fog can serve useful purposes. In some parts of the world that lack fresh water but are near oceans, fog can actually be harvested, using mesh screens and gravitational flow, to provide badly-needed water for drinking and agriculture. Areas where fog harvesting is common include Cape Verde, Chile and the Canary Islands.

Fog forecasting

Accurate forecasting of weather conditions can help reduce fog-related accidents and transportation delays. Pilots, sailors and drivers all require timely information to plan and adjust their travel schedules and routes. In particular, marine and aviation forecasts produced by Environment Canada help people understand their risks.

Mitigation

Of course, forecasting is of no value unless people use the information, heed the warnings and take steps to reduce the risks associated with travelling in foggy weather. Communities can do little to respond to the fog hazard – it primarily lies with individual people. Boats and ships can be equipped with radar that can greatly reduce the risk associated with fog, if the expense is warranted. If you must drive through fog in a car or truck:

- drive slowly, using dipped headlights
- use fog lights, if you have them
- be especially alert for others who may be driving without headlights
- use windshield wipers to keep windows clear
- be aware that fog drifts quickly and can be patchy. If you enter a clear patch, don't assume the fog has lifted
- create a greater margin of safety by maintaining greater distances from vehicles in front of you
- if fog appears suddenly, double check the location of other vehicles around you
- slow down gradually, as fog can make roads wet and slippery
- be extra cautious at intersections and crossroads

Sources and Further Reading

- Environment Canada (1990) *The Climates of Canada*, Minister of Supply and Services Canada, Ottawa.

- USA Today Weather

2.7 Hailstorms

Figure 1 – Severe hail in Lismore, New South Wales

Source: ABC News. Cars, homes damaged in Lismore hailstorm. Oct. 9, 2007

Ezekiel 13:11,13 "*say to those who plaster it with untempered mortar, that it will fall. There will be flooding rain, and you, O great hailstones, shall fall; and a stormy wind shall tear it down. Therefore thus says the Lord God: I will cause a stormy wind to break forth in My fury; and there shall be a flooding rain in My anger, and great hailstones in fury to consume it.* "

On September 7, 1991, Calgary, Alberta, experienced an intense thunderstorm accompanied by golfball-sized hailstones that smashed windows and dented cars all over town. In just half an hour, the storm caused $343 million in insured losses and nearly $885-million in total damage - ultimately generated more than 100,000 insurance claims. It was the most costly hailstorm in Canadian history.

Calgary was also hit by severe and expensive hailstorms in 1996 and 1981, giving it the dubious distinction of being the Canadian city that has suffered the greatest losses to hail.

The formation of hailstones

Figure 2 – *Hail shaft downburst near Hondo, TX*

Source: Columbia Weather Systems – Spring 2007 Newsletter (online)

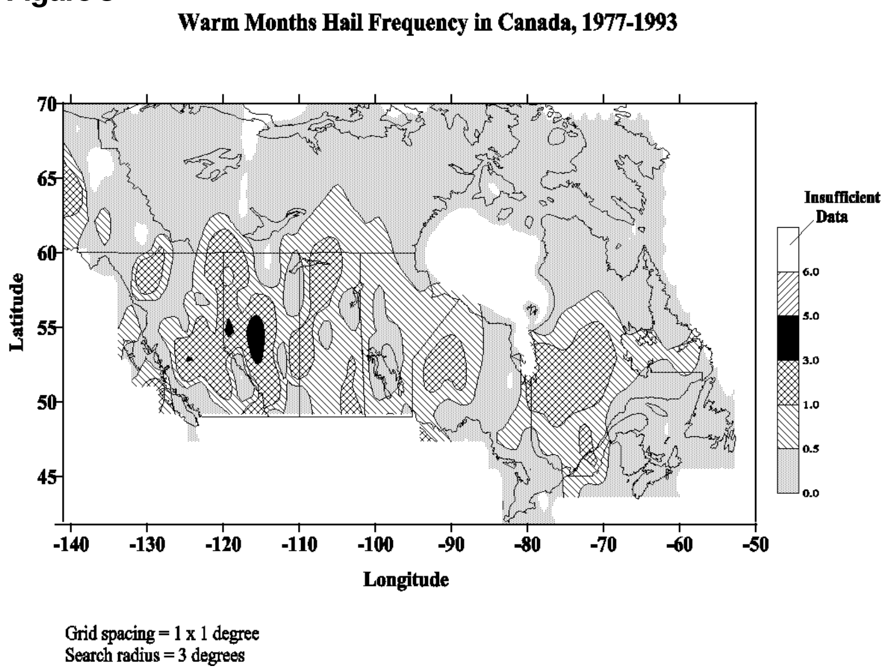
Hailstones form inside severe thunderstorms when supercooled water droplets collide with dust particles or other hailstones and freeze to them. (Supercooled water is water that remains liquid below zero degrees Celsius, the temperature at which water normally freezes.)

If updrafts within the storm are strong enough (greater than about 40 km/hr), hailstones will be carried up and down within the cloud, picking up more layers of ice until they get so heavy that they finally fall to the ground. This usually occurs during the dissipating stage of the thunderstorm, when the updrafts are weakening. Hailstones can reach speeds of 100 km/hr before they hit the ground. As the thunderstorm speeds along hail falls in long narrow swaths, typically 10-20 km in length, though they can be much longer.

The largest hailstone on record was observed at Aurora, Nebraska, on 22 June, 2003. It measured 17.88 cm in diameter with an 47.6 cm circumference.

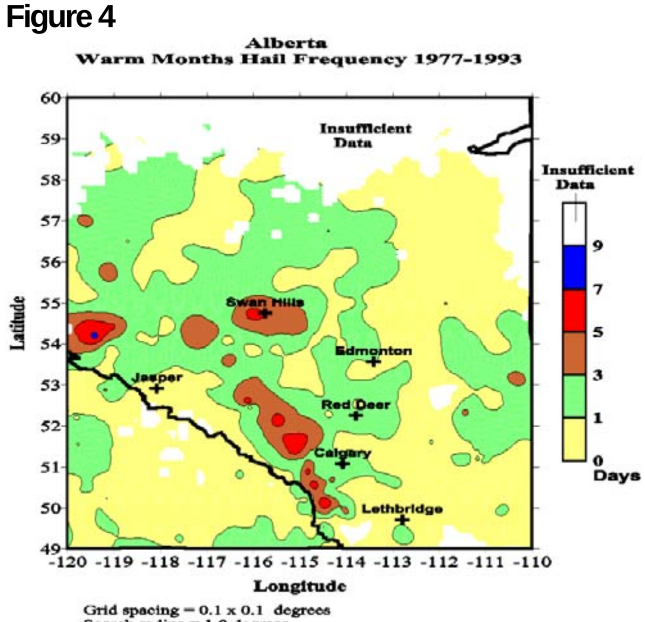
Where hailstorms occur

Figure 3



Source: Etkin and Brun (1999)

Figure 4



Source: Etkin and Brun (1999)

Hailstorms are most common in the Prairie Provinces and in parts of British Columbia. Alberta is well known for having Canada's worst hailstorms. Calgary seems to be particularly exposed and has experienced many of Canada's most expensive hail disasters (See Table 1). This is because the city has grown into areas that typically lie in path of severe thunderstorms forming in the foothills of the Rocky Mountains.

In fact, hail is more prevalent in the Prairies even though other regions of Canada get more frequent thunderstorms. Figures 3 and 4 show patterns of hail occurrence for the months of May to September. Southern Ontario, for example, gets more tornadoes, which also form from severe thunderstorms (See Section 2.12: Tornado). The reason is that atmospheric temperatures in the Prairies tend to be cooler, so falling hailstones are less likely to melt before hitting the ground.

When hailstorms occur

Since they come from severe thunderstorms, hailstorms are mainly a warm-season phenomenon. The hail season begins in May, peaks in mid-summer, and ends in September. The number of hailstorms can vary considerably from one summer to the next because of natural weather variability.

Since most thunderstorms occur during the late afternoon or early evening, this is also when hail is most likely to fall, though it can and has occurred at all hours of the day and night. Thunderstorms are expected to become more common in the future because of climate change and some scientists have suggested that the frequency of hailstorms may increase as a result. However, this remains to be proven.

Canada's worst hailstorms.

In Canada, hailstorms rarely hurt people but they can cause considerable property and crop damage. Damage to houses and cars is usually covered by insurance. Table 1 below lists Canada’s worst hail events in terms of insured damages.

The most destructive hailstorm in North America, and possibly the world, occurred in Texas, in May, 1995, causing an estimated $2 billion (US) in damages. Hail has been known to cause fatalities as well. On April 30, 1888, the deadliest hailstorm on record killed 246 people and 1,600 domestic animals in India.

Table 1: Major Canadian Hailstorms

Location	Date	Insured Damages (million $)
Drummondville Quebec	June 5, 1999	20
Calgary, Alberta	July 4-9, 1998	65
Calgary, Alberta	24/25 July, 1996	75
Calgary, Alberta	16-18 July, 1996	103
Winnipeg, Manitoba	16 July, 1996	105
Calgary, Alberta	13-15 July, 1995	52
Southern Alberta	10 July, 1995	26
Edmonton, Alberta	4 July, 1995	15
Southern Manitoba	27 Aug., 1994	7
Southern Alberta	18 June, 1994	8
Alberta	29/30 July, 1993	8
Alberta	1 Sept. 1992	7
Alberta	28 Aug. 1992	5
Calgary, Alberta	31 July, 1992	22
Calgary, Alberta	7 Sept., 1991	343
Calgary, Alberta	9 July, 1990	16
Calgary, Alberta	16 Aug., 1988	37
Montreal, Quebec	29 May, 1986	65
Southwestern Ontario	30 May, 1985	30–40
Calgary, Alberta	28 July, 1981	100
Montreal, Quebec	5 June, 1979	extensive property damage
Cedoux, Sask.	27 Aug., 1973	10
Western prairies	23 July, 1971	20
Edmonton, Alberta	4 Aug., 1969	17
Lambeth, Ontario	19 Aug., 1968	extensive crop and property damage
Central Alberta	14 July, 1953	unknown
Okanagan Valley, BC	29 July, 1946	2
Edmonton, Alberta	10 July, 1901	extensive damage

As is evident from the above table, Calgary receives the largest proportion of hail in Canada. Almost one third of the events noted in the table occurred in Calgary, including the 1991 Calgary hailstorm which caused close to $350 million in insured damages, making it one of Canada's largest and most costly disasters.

Vulnerability and Risk Reduction

There are four approaches to reducing hail risk:

(1) **Reducing the Hazard: Weather modification**. Thunderstorm clouds can be "seeded" by airplanes to reduce the amount and size of hail. This involves

injecting clouds with large numbers of particles of dry ice or silver iodide that water droplets and hailstones can form around. The idea is that this will cause more but smaller and less damaging hailstones to form, or that more water droplets will fall out of the clouds before reaching higher altitudes where they become hailstones.

There have been various attempts to do this. The insurance industry currently funds a cloud-seeding program in Alberta each summer, which they feel has been successful in reducing hail damage. Scientific studies, however, have produced mixed or unclear results.

(2) **Reducing Vulnerability: Buying insurance**. Insurance can provide funds to help recover losses due to hail damage. Most standard homeowner policies include hail risk as part of an all-hazards insurance policy. Farmers can buy crop insurance that will cover hail damage.

(3) **Reducing Vulnerability: Smart building methods**. Building to reduce hail damage—by using hail resistant shingles to roof houses, for example—can greatly reduce losses resulting from severe thunderstorms. Shingles that have an Underwriters Laboratories Class 4 impact-resistance rating are claimed to be substantially hail resistant. More information is available from the Institute for Business and Home Safety.

(4) **Reducing Vulnerability: Awareness and action**. Listen to weather watches and warnings. If you’re indoors when a storm with large hailstones strikes, stay there. If you’re outside and unprotected, seek shelter immediately. (However, don’t shelter in an isolated structure if it’s exposed to lightning.) Move cars, pets, livestock and people into protected shelters when a hailstorm approaches.

Large hailstones can shatter windows; close drapes, blinds or window shades to prevent the wind from blowing broken glass inside. Stay away from skylights and doors.

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- Environment Canada: Prairie and Northern Region - Hail
- Institute for Business and Home Safety - Protect Your Home Against Hail Damage
- Canadian Disaster Database

2.8 Heat Waves: The Silent Killer

In early August, 2001, much of Canada sweltered in the grip of an intense heat wave. Montreal broke a 52-year record with a temperature of 36.1˚C. Toronto, which reached 37˚C, issued a heat emergency warning and, for the first time, implemented its Heat Health Alert System, the first of its kind in Canada.

It extended the hours of four cooling centers and sent out paramedics and volunteers to check on and, if necessary, transport vulnerable people to hospitals or cooling centers. The Ontario Ministry of Labour was swamped with calls from workers complaining about working in overheated conditions. In Barrie, Ontario, a bakery worker died of heat stroke.

Heat waves

When abnormally warm conditions—usually temperatures at or above 30ºC—persist for a prolonged period, typically three or more successive days, it's called a heat wave.

What constitutes a heat wave depends on what's considered "normal" weather conditions in a particular locality and the ability of people who live there to adapt to warm weather. People who live in Florida are more heat tolerant than those who live in a cooler climate like that of Halifax.

Heat waves are dangerous in several ways. They can cause serious illness and death. They affect animals and plants and can exacerbate drought conditions that can devastate crops and vulnerable ecosystems. They increase the risk of forest fires and making battling such fires more difficult.

Heat waves also increase energy demand, which stresses power grids and produces additional greenhouse gases that contribute to global warming. Canada will likely experience worse heat waves in the future because the climate is warming (See Section 2.1: Climate Change).

One trend that may increase the impact of heat waves is the fact that night-time temperatures are rising faster than daytime temperatures. This means there may be little respite at night, which can greatly increase the human health risks associated with heat waves.

European heat wave

The summer of 2003 was hot and deadly throughout much of Europe. Record temperatures were recorded from June through August, causing US$13 billion in economic losses and a staggering death toll in excess of 20,000 people. The mortality rate was second only to a December earthquake in Iran.

France was the hardest hit, with nearly 15,000 deaths. Air conditioning is not common in France; most of the victims were elderly people living alone or in nursing homes who succumbed to temperatures that reached 40˚C during the peak of the heat wave in early August. Germany, Spain and Italy also suffered several thousand deaths. Many European countries also experienced extreme drought and raging forest fires during the weeks of record-breaking heat.

Measuring heat waves

There are several methods of measuring a heat wave. An example of a heat stress index is the humidex, which combines relative humidity and temperature values. The degree of danger varies with humidex level, as shown in the second box

THE HUMIDEX- A GUIDE TO SUMMER COMFORT

The humidex is a Canadian innovation, first used in 1965. It combines temperature and humidity to describe how hot, humid weather feels to the average person. An extremely high humidex reading can be defined as one that is over 40. In such conditions, all unnecessary activity should be curtailed.

Temperature in Celsius	Relative Humidity								
	25%	30%	40%	50%	60%	70%	80%	90%	100%
38	42	43	47	54	57	*	*	*	*
37	40	42	45	49	54	55	58	*	*
36	39	40	43	47	51	56	57	58	*
35	37	38	42	45	48	51	54	57	*
34	36	37	41	43	47	49	52	55	58
33	34	36	38	42	44	47	50	52	55
32	33	34	37	39	42	45	47	50	52
31	31	33	35	38	40	43	45	48	50
30	31	31	34	36	38	41	43	46	48
29	29	30	32	34	37	38	41	44	46
28	28	29	31	33	35	37	39	41	45
27	27	28	29	31	33	35	37	39	41
26	26	27	28	29	31	33	35	37	39
25	25	26	27	28	30	32	33	35	37
24	24	25	26	27	28	30	32	33	35
23	23	23	24	25	27	28	30	32	33

* = Beyond the Earth atmosphere's ability to hold water vapor.

Humidex - General Heat Stress Index

Danger Category	Humidex	Heat Syndrome
Extreme Danger	> 55+	Heatstroke imminent with continued exposure.
Danger	40 - 54	Great discomfort. Avoid exertion. Seek a cool shady location. Heat cramps or heat exhaustion likely. Heat stroke possible with continued exposure and / or physical activity.
Extreme Caution	30 - 39	Some discomfort. Heatstroke, heat exhaustion and heat cramps possible with prolonged exposure and / or physical activity.
Caution	< 29	Little discomfort. Fatigue possible with prolonged exposure and / or physical activity.
NOTE: Degree of heat stress may vary with age, health and body characteristics.		

Almost all regions in Canada can be affected by extreme heat events as shown in Table 1 below. However, they are more common in mid-continental regions of southern Canada.

Table 1: Number of heat waves where temperatures exceeded 30ºC that occurred in Canadian cities and their duration in days

Location	Province	Number of years on Record	Heat wave counts				# Events/years of Record
			2 days	3 days	4 days	5+ days	
Vancouver	BC	63(1937-1999)	2	0	0	0	0.03
Whitehorse	YT	56(1943-1998)	6	0	0	1	0.13
Yellowknife	NT	56(1946-1998)	3	2	0	0	0.09
Iqualuit	NU	50(1946-1996)	0	0	0	0	0.00
Edmonton	AB	83(1916-1998)	48	10	0	2	0.72
Calgary	AB	104(1895-1998)	84	21	12	10	1.22
Saskatoon	SK	104(1895-1998)	165	70	30	29	2.83
Winnipeg	MB	104(1895-1998)	170	92	40	34	3.23
Ottawa	ON	60(1939-1998)	103	48	27	29	3.45
Toronto	ON	61(1938-1998)	105	78	33	33	4.02
Quebec	QC	100(1895-1995)	84	36	18	5	1.43
Montreal	QC	53(1942-19-1994)	61	29	20	17	2.40
Saint John	NB	104(1895-1998)	6	2	0	0	0.62
Halifax	NS	54(1945-1998)	4	1	0	0	0.09
Charlottetown	PE	98(1895-1992)	17	3	0	3	0.23
St John’s	NF	104(1895-1998)	4	0	0	0	0.04

Source: Smoyer-Tomic et al. (2003)

Heat waves and human health

Extremely hot, humid days can cause serious heat-related illnesses and even death, as Table 2 shows.

Table 2: Common Heat-Related Illnesses and Their Symptoms

Illness	Description and Symptoms	Treatment
Heat cramps	Painful spasms, usually in leg muscles and abdomen due to heavy exertion, which in turn triggers heavy water loss through heavy sweating.	Stop activity and rest in a cool place. Lightly stretch or gently massage muscle to relieve spasms. Give sips of cool water.
Heat Exhaustion	A mild form of shock, marked by heavy sweating, weakness, cold, clammy skin, a weak pulse, fainting and vomiting. This usually occurs when people have been exercising heavily or working in a warm humid place. The blood flow to the skin increases - in an attempt to cool the body - causing the blood flow to the vital organs to decrease.	Get victim to a cool place. Lay down and loosen clothing. Apply cool wet cloths. Give sips of cool water
Heat Stroke	A truly life-threatening condition in which the body's internal thermostat has ceased to work High body temperature of 39°C to as high as 41°C. This can cause brain damage and death may occur in less than ten minutes unless medical help is immediate. Hot, red, dry skin. No sweating, as the ability to do so ceases. Rapid pulse, fast and shallow breathing, headache, nausea, dizziness, confusion. Possible unconsciousness	Heat stroke is a severe medical emergency. Summon emergency medical assistance or get the victim to a hospital immediately. Delay can be fatal. Move the victim to a cooler environment. Reduce the body temperature with a cool bath or sponging. Use air conditioning or fans. Do not give fluids.

Vulnerability

During heat waves, the most vulnerable people are the elderly, the very young, those who are sick or confined to bed, and those who have weakened immune systems, such as HIV/AIDS and transplant patients. Also vulnerable are pregnant women, overweight people, the poor, people who live without air conditioning and people who work outdoors.

Factors that increase vulnerability

The duration of excessive heat is important in determining the impact of a heat wave. Studies have shown that there’s a significant increase in heat-related illnesses when excessive heat lasts more than two days, particularly if night-time temperatures do not drop low enough to provide relief.

The conditions in which people live also determine how severely they will be affected. Those living on the top floor of apartment buildings and/or lacking access to air-conditioning are more vulnerable. People who live alone, especially in crime-ridden neighborhoods, are also at increased risk; in the 1995 Chicago heat wave that killed more than 500 people, many poor and elderly people living alone refused to open their windows because they feared violence.

Living in cities is another risk factor because urban areas tend to retain heat more than outlying suburban areas—a phenomenon known as the urban heat island effect. Vehicles, factories and air conditioners give off heat that further enhances the heat island effect, in addition to producing greenhouse gases and pollutants that only make matters worse.

When high summer temperatures interact with some air pollutants, such as ozone, they create unhealthy smog conditions in many cities. The health consequences include severe coughing, shortness of breath, pain when breathing, lung and eye irritation. Smog also increases susceptibility to respiratory illnesses such as bronchitis, pneumonia, asthma attacks and heart problems.

Heat Waves affect plants and animals

Excessive heat affects the leaves and roots of plants, reducing their ability to photosynthesize food. Many plants wilt at temperatures above 40°C and die if these conditions persist. In cereal crops like maize and wheat, high temperatures may decrease crop yields, kernel density and grain quality.

During heat waves, beef cattle do not grow as fast or as efficiently and dairy cattle don't produce as much milk. Production goes down even more when temperatures remain too warm at night for the animal to recover from daytime heating.

When extreme heat events coincide with drought, the economic impact on farmers can be devastating; this scenario has caused substantial losses in Western Canada in recent years.

Heat Waves and infrastructure

Materials used in buildings, vehicles and infrastructure such as bridges, railways and roads are designed for average local weather conditions. They can be compromised or degraded by prolonged high temperatures, leading to increased maintenance costs. For example, heating can increase rutting on paved highways and cause flushing or bleeding of asphalt surfaces, which can increase vehicle skidding.

Increased use of car air conditioners is a good coping strategy, though it increases fuel consumption and the cost of operating a vehicle. The same is true for other forms of energy such as electricity when demand skyrockets during heat waves. At the same time, high temperatures reduce the efficiency of transmission lines because power lines sag as they expand with heat.

Heat waves and climate change

In Canada, the frequency, duration and intensity of heat waves will likely increase as a result of climate change. It doesn't take much of a change in average temperatures to cause a disproportionate change in the frequency of extremes like heat waves (See Section 2.1: Climate Change).

The regions most likely to suffer significantly—for example, southern Ontario—also have the highest population densities and the most productive agricultural zones. Extreme heat waves that now occur once every 80 years are projected to occur at least once every 10 years by 2050. In many Canadian cities, heat stress during "average" summers in 2050 could result in several hundred additional deaths. This makes it all the more important for individuals and communities to prepare for extreme heat events in advance.

Ultimately, it's vitally important to make a serious effort to use energy more efficiently, so as to reduce greenhouse gas emissions that contribute to climate warming. Otherwise, measures we use to cope with the immediate impact of heat waves—such as using air conditioning—will, in the long run, only make matters worse.

Coping strategies during heat waves

Community Strategies:

- Disseminate heat information to citizens and community groups, particularly the elderly.
- Work with meteorologists, local media and community groups to provide a consistent message on the dangers of heat, precautions, treatment and emergency management.
- Have a "Heat Awareness Week" early in the warm season to inform citizens about the dangers of heat waves and to provide information on city services available
- Open cooling centres in public buildings such as schools, libraries, park district field houses or recreation centres.
- Extend hours of public swimming pools.
- Provide free bus or taxi transportation to cooling centres.
- Work with government emergency management and weather authorities and private meteorologists to give the public a simple, unified heat-warning message through the media.
- Use nursing homes, Department on Aging, and informal support networks such as churches, block clubs, and ethnic organizations to reach senior citizens.
- Have mail carriers, metre readers, home care workers etc. check on vulnerable people, especially elderly or sick people living alone.
- Install low pressure, shower/sprinkler caps on fire hydrants to allow people to take impromptu street showers
- Monitor hospitals for heat related morbidity and mortality.

Strategies by Individuals:

- spend some time in air conditioning, if possible. Cooling down for even just two hours a day can significantly reduce the risk of heat-related illness.
- avoid dehydration by drinking plenty of water and natural juices, even if you don't feel thirsty.
- slow down. Avoid strenuous activity. People who exercise outdoors should adjust their programs to reduce the risk of heat-related illness.
- wear loose-fitting, lightweight, light-colored clothing.
- avoid going out in the blazing heat, if you can; if you must be out in the sun, use sunscreen and wear a wide-brimmed hat.

- keep shades drawn and blinds closed, but open windows slightly. Turn lights down or off.
- take cool baths or showers periodically and use cool wet towels.
- eat small meals and eat more often. Avoid high-protein foods, which increase metabolic heat (energy from digestion).
- avoid using ovens.
- avoid alcoholic beverages and caffeinated beverages such as coffee, tea and colas.
- do not leave children or pets in a closed vehicle, where temperatures can reach 60ºC to 80ºC within 30 minutes on a hot day.
- don't let infants or young children play or sleep in the sun for long, even when wearing a sunscreen
- schools should restrict strenuous outdoor athletic activity when a heat advisory is in effect. All physical education and athletic activity should be cancelled when a heat warning is in effect.
- stay informed about the heat wave by listening to local weather warnings on radio and television.
- check on elderly, ill or disabled people living alone.

As a long-term effort to mitigate heat waves cities can be cooled passively using strategically-placed vegetated spaces and green roofs or walls, and reflective surfaces, such as light-coloured roofs, roads and parking lots that reflect rather than radiate heat. These measures can reduce energy use and the cost of air conditioning.

There are normally legal requirements under provincial Occupational Health and Safety Acts to protect employees from too much heat stress. This can include reducing the amount of time spent in hot conditions or reducing the physical demands of the job. The Ontario Ministry of Labour, for example, uses standards recommended by the U.S. Occupational Safety and Health Administration (OSHA). Part of this process involves education; the Workers' Compensation Board of British Columbia requires that employers must provide adequate information and training to all workers at risk, their immediate co-workers and their supervisors.

Sources

- Smoyer-Tomic, K.E., R. Kuhn and A. Hudson (2003 Heat Wave Hazards: An Overview of Heat Wave Impacts in Canada, *Natural Hazards,* Vol. 28, Nos. 2-3, pp. 463-485
- Canadian Centre for Occupational Health and Safety:
- Red Cross: Heat Safety Tips
- National Weather Service (U.S.):
- City of Toronto website

2.9 Hurricanes

In the early hours of September 29, 2003, Hurricane Juan slammed into the coast of Nova Scotia, causing widespread power outages, extensive damage and eight deaths. At landfall, it was a Category 2 storm.

Halifax Harbour took a direct hit from the eastern eyewall, the part of the storm with the strongest winds. Sustained winds reached as high as 158 km/hr with gusts to over 185 km/hr. Maximum wave heights of nearly 20 metres and a storm surge higher than 1.5 metres were recorded. The strongest winds, the highest surge and the highest waves all arrived at the same time but, fortunately, they did not coincide with the highest tides, which would have made the flooding even worse.

According to the Canadian Hurricane Centre, it was the worst event of this type to hit the region in more than a century.1

Introduction

The word hurricane comes from the Caribbean Indian word "Huracan' meaning the god of stormy weather. Hurricanes are made up of masses of warm, humid tropical air with high winds exceeding 118 km/hr and torrential rains. Hurricanes have a life span of 1 to 30 days and occur most often during August and September though the season runs from June 1 to November 30.

Even though hurricanes are generally associated with tropical regions, Canada is not immune. Sometimes these powerful storms or their remnants remain strong enough as they track up the Atlantic coast from the Caribbean to reach parts of eastern Canada.

In fact, Canada is threatened by three to four tropical storms or hurricanes each year and it has experienced significant losses to such events. The Maritimes experience the most frequent events, but Ontario and Quebec are also at risk even though these storms typically lose strength as they move over land.

Hurricanes deserve our attention because they are powerful and deadly. However, they bring copious rainfall, which can be beneficial. The risks are sufficiently large that Environment Canada established the Canadian Hurricane Centre (CHC) in Dartmouth, Nova Scotia, in the mid-1980s. Working with the U.S. National Hurricane Center, CHC gathers information about approaching storms, evaluates their potential effect on Canadian territory and issues

[1] Environment Canada. (2007). Hurricane Juan September 28 & 29, 2003.

warnings. They also engage in public education activities to make Canadians more aware of the risks of hurricanes and tropical storms.

Characteristics of a Hurricane:

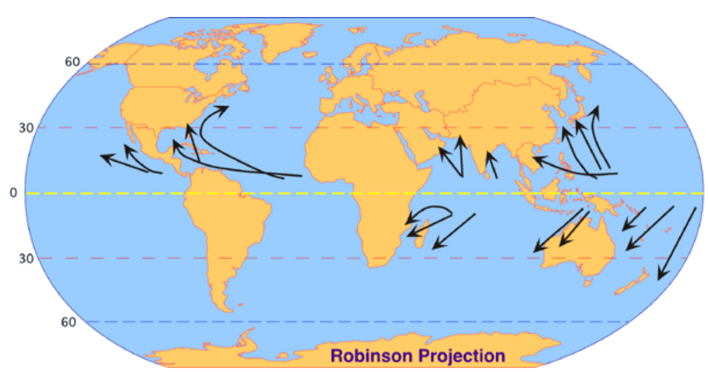
- 100's of kilometres in diameter and about 15 km high
- High wind speeds –118 to 400 km/hr
- High precipitation: 2.5 cm/hr
- Low pressure: typically 950 mb though pressures as low as 888mb have been measured (1000 mb is normal)
- Very destructive: destruction caused by winds, rain and flooding, and storm surges
- The pressure decreases and the wind speed increases toward the center of the storm, except in the very center where winds are light.
- The temperature within the storm rises relative to that of the surrounding air.

Conditions for hurricane formation

The process by which a hurricane system forms and subsequently strengthens requires at least three conditions:

- The ocean should be at least 26oC in the upper 60 meters
- The air must be warm and humid and the atmosphere unstable
- The upper level winds should be weak and generally blowing in the same direction as the surface winds

Fig 1: Areas where hurricanes normally begin their development and the common paths of storm movement.



Source: Okanagan University College

Hurricane Formation

A hurricane that affects North America begins initially as a disorganized storm system over warm tropical waters in the Atlantic. When the storm system becomes more organized, it is first classified as a "tropical depression" and given a number by the U.S. National Hurricane Center.

As they encounter seawater warmer than 26°C, the winds begin to circle, air rises, condenses, and a tropical storm begins to form. If the winds increase to 63 km/hr, a tropical depression is reclassified as a tropical storm and given a name. Tropical storms gain energy from the condensation of water vapour (what's known as the latent heat of condensation). When the winds in these storms reach 118 km/hr, they're upgraded to hurricane status.

Hurricanes are classified on a scale of 1 to 5 (known as the Saffir-Simpson Scale (Table 1) based on their wind speed and destructive potential.

Table 1: Hurricane classification

Category	**Wind Speed (km/hr)**	**Storm surge (metres)***	**Description**
1	118 - 153	>1.2	little damage
2	154 - 177	>1.8	damage to shrubbery, mobile homes, small craft
3	178 - 210	>2.7	damage to trees, roofs, mobile homes, some flooding
4	211 - 249	>4.0	damage to all signs, roofing, major flooding, evacuation
5	>249	>5.5	major damage to vegetation, buildings, complete building failure, massive evacuation.

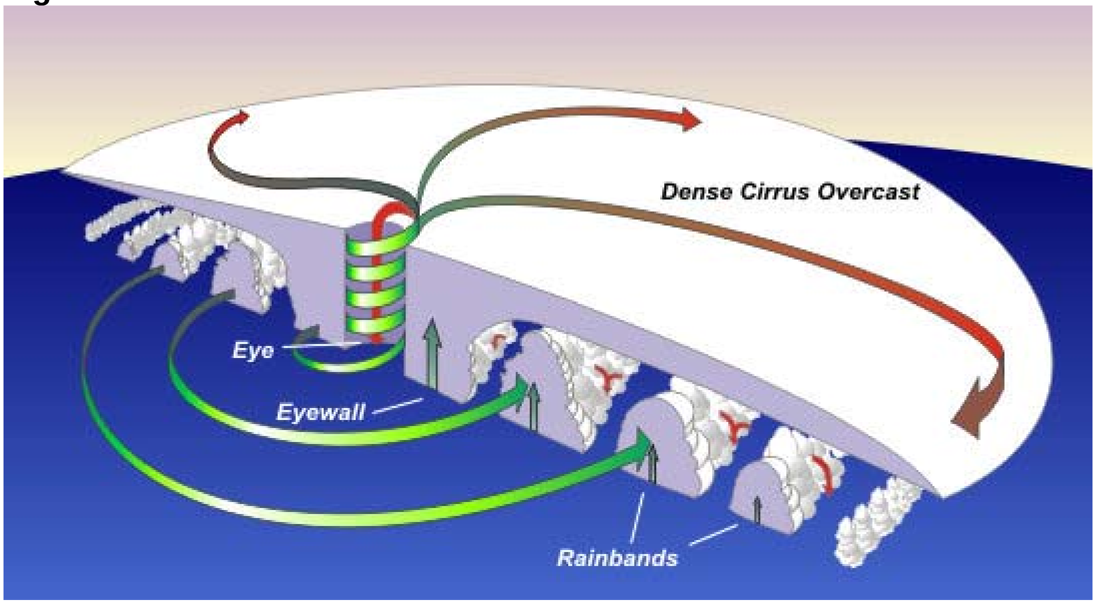
Hurricane Structure

A well-developed hurricane has four main components:

- Eye: This is the centre of circulation and the area of lowest pressure within a hurricane. It may be 20 to 50 kilometres in diameter. The eye of a hurricane has clear skies and calm winds but this is a deceptive calm, because after the eye comes the eyewall.

- Eyewall: This is a narrow area of intense thunderstorms surrounding the eye. It's the most ferocious part of the storm, with the highest and strongest horizontal winds, the heaviest rains and the strongest updrafts.
- Spiral Rain Bands: These are long, narrow bands of clouds and precipitation that swirl in toward the storm centre, where they wrap themselves around the eyewall. In a classic hurricane, these bands are symmetrical.
- Outflow: The extent of the outflow of air at the top of a hurricane determines the outer fringe of a hurricane.

Fig 2a: Hurricane Structure Cross Section



Source: The National Weather Service

Fig 2b: Hurricane Structure Top View

Source: COMET – Cooperative Program for Operational Meteorology, Education and Training

Hurricanes in Canada

Canada is relatively lucky when it comes to hurricanes. In fact, no category 4 or 5 hurricane has made landfall in Canada in the last 150 years. This has been attributed to the cold climate and the country's northern location, which weaken the storms that reach our borders. As the storms travel over large expanses of land or cold water, the energy source on which they feed—warm surface waters—is removed.

Some storms, however, occasionally reach eastern Canada—from the Atlantic Provinces to Lake Superior in Ontario—still possessing hurricane-like characteristics, including strong winds and heavy rains. The Canadian Hurricane Centre lists 59 tropical storms that have affected Canada from 1887 to 2002. Landfalling hurricanes that have reached Canada include not only Juan in 2003, but Hortense in 1996 and Gustav in 2002. The strongest was Luis that hit Newfoundland in 1995 (See Environment Canada "Canada's Top Landfalling Tropical Cyclones (winds of 50 knots or above; 1886 - 1998)".

The east coast is the area most prone to experiencing tropical storms. On average, 3 to 4 tropical cyclones affect Atlantic Canada each year (See Table 2).

Table 2: Frequency of Hurricanes by Province

Province	Frequency
Newfoundland	One tropical cyclone every 1.4 years
Nova Scotia	One every 2.4 years
New Brunswick	One tropical cyclone every 3.4 years.
Quebec	One tropical storm every 6.6 years
Ontario	One tropical storm every 11.1 years

Source: Environment Canada – Canadian Hurricane Centre

British Columbia has very rare encounters with Pacific hurricanes.

Ontario and Quebec also experience tropical storms that usually arrive in a weakened state as a result of moving over land, but they're still capable of doing a lot of damage. Sometimes, these 'dying storms' can be re-energized up by the jet stream if it is in the right location, and intensify the storm. Then they can be devastating, as they combine the characteristics of tropical storms (copious precipitation) and mid-latitude storms (strong winds). Hurricane Hazel[2], which hit southern Ontario in 1954, was such a storm. Fortunately, they're rare.

Because hurricane intensity is directly related to the warmth of ocean waters, it's possible that global warming may increase the frequency and intensity of

[2] a description of Hurricane Hazel can be found at Environment Canada – The Management of Water: Flooding Events in Canada – Ontario.

hurricanes by affecting ocean temperatures. Changes in other climatic factors, such as winds and El Ninos, will certainly affect hurricane formation and movement as well.

Impacts of Hurricanes

The damage that hurricanes inflict is caused by four factors:

- High winds: Winds cause damage by blowing down objects, creating choppy waves and high seas, and by inundating coastal areas with seawater.
- Heavy rainfall: Rainfall within a hurricane can often exceed 60 centimetres in a 24-hour period. If this rainfall occurs on land, flooding normally occurs. In 1971, hurricane Beth dropped a record rainfall of nearly 300 millimetres in Halifax, washing out bridges and flooding farmland.
- Storm surge: Strong winds associated with hurricanes can create storm surges of several metres above the normal mean water level (See “Storm surges.”) When this happens, affected coastal areas can experience severe flooding and significant loss of lives and property. In 1900, 6,000 people were killed in Galveston, Texas, mainly as a result of a hurricane-related storm surge in the Gulf of Mexico.
- Weak tornadoes: Hurricane-generated tornadoes can also cause considerable damage. About 25% of the hurricanes that make landfall have tornadoes because tremendous energy and instability are created when a hurricane moves over land. Most of these types of tornadoes are relatively weak and in Canada, are extremely rare.

Hurricane Prediction and Response:
Predicting the speed and track of a hurricane is difficult, but it has been improving. People who live in exposed regions prone to tropical storms should be aware of alerts issued by Environment Canada and learn what precautions to take.

Communities can plan for hurricanes by:

- Performing a hazard and vulnerability assessment
- incorporating appropriate response strategies into their emergency plan
- designating or zoning floodplains,
- estimating potential damage to coastal infrastructure, like wharves, water access points, and boardwalks
- protecting critical infrastructure
- educating residents in exposed areas
- enforcing building codes for strong winds
- protecting against storm surge through the use of forested green spaces or engineering controls such as breakwaters.

Individuals can reduce their risk by doing the following:

Listen for alerts

- a WATCH means that a hurricane is possible within the area, usually within 36 hours.
- a WARNING means that a hurricane is expected in the area, usually within 24 hours.

Prepare a personal evacuation plan

- determine whether you live in a potential flood zone
- plan in advance where you'll go if an evacuation is ordered—e.g. a friend's place out of town or a designated shelter
- keep the phone numbers of these places with you
- take a road map in case the weather forces you onto unfamiliar roads
- listen to radio and TV for regular updates on weather and evacuation conditions
- if advised to evacuate, do so immediately

Assemble a disaster kit that contains

- a first aid kit and necessary medications
- canned food that can last for long periods without refrigeration; a can opener
- plenty of water. The Red Cross recommends three gallons of water per person, enough for last three days.
- flashlights, a battery powered radio and extra batteries
- rain gear, sleeping bags and protective clothing

Prepare for high winds

- make your house hurricane proof by boarding up windows, etc. See the Red Cross website for tips on how to protect your house.
- prune trees by removing branches and damaged limbs

What to do when a hurricane watch is issued

- continue listening to weather updates from the Canadian Hurricane Centre or local radio and TV stations
- stow trash cans, lawn furniture and other items that can be carried away by winds
- make sure vehicles are in good shape and filled with gas
- check if your disaster kit is well stocked and board up your house with plywood

What to do when a hurricane warning is in effect

- keep abreast of road conditions through the news media
- stay alert and watch for tornadoes associated with the hurricane
- if you're not told to evacuate, remain indoors; stay in the center of your home, in a closet or bathroom without windows
- when asked to evacuate, do so immediately. It's important to move to a safe area before access is cut off by floodwaters

- do not drive over standing water; floods may have damaged the roads beneath and you don't know how deep the water really is
- if you're caught on a flooded road and waters are rising rapidly, get out of the car and climb to higher ground

What to do after the hurricane

- continue listening to Canadian Hurricane Centre's advisories on radio, television or on the internet.
- if you're returning home after an evacuation, enter your house only when local officials say it's safe to do so
- inspect your home; watch for live electrical cables and crumbling walls and other sources of danger
- use flashlights and not candles as gas leaks could spark fires

Sources and Further Reading:

- Lugo, A.E. (2000) Effects and Outcomes of Carribean Hurricanes in a Climate Change Scenario, The Science of The Total Environment, Vol. 262, pp. 243-251

- The Canadian Hurricane Center:

- National Weather Service (US): National Hurricane Centre:

- Geophysical Fluid Dynamic Laboratory:

- Institute for Catastrophic Loss Reduction:

- University of Illinois At Urbana –Champaign

- The American National Red Cross:

2.10 Storm Surges

On September 29, 2003, Hurricane Juan, a Category 2 hurricane, made a direct hit on Halifax, Nova Scotia. The eastern eyewall of the storm moved directly over Halifax Harbour, with sustained winds of more than 150 km/hr and gusts to 176 km/hr. Pushing ocean waters ahead of it, the hurricane created storm surges ranging from 1 to 1.5 metres around Halifax. In the harbour, water levels reached an all-time high of 2.9 m, causing extensive damage to coastal properties.[1]

Figure 1: Storm surge causes wharf damage in Halifax Harbour - Maritime Forces Atlantic

Source: Environment Canada – Hurricane Juan Photo Gallery

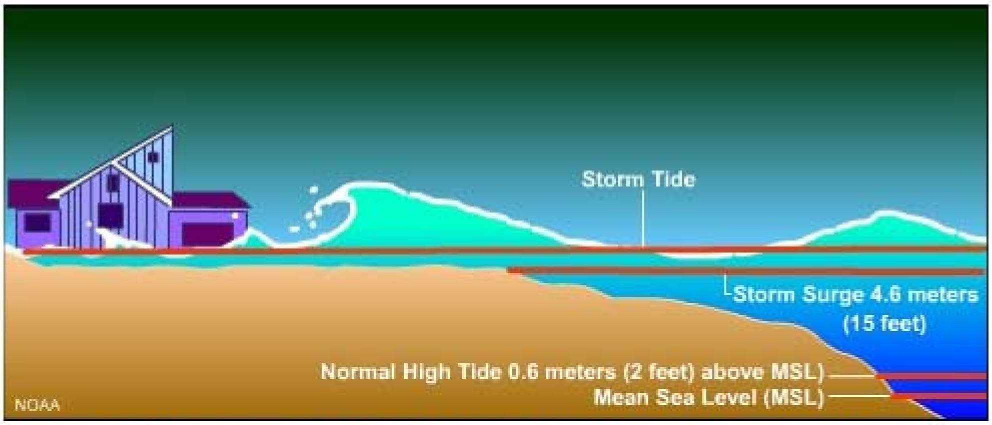
Storm surges

Storm surges are elevated water levels due to (1) a combination of water pushed by winds and (2) as a result of low atmospheric pressure due to a storm. They can occur over the ocean as a result of this second effect, but are not hazard unless they affect sensitive structures like gravity-based drilling platforms or bridge piers. The high water or positive storm surges is normally considered the main hazard, but low water or negative storm surges can also be a hazard in coastal areas, particularly in areas where big ships navigate shallow waters. Strong onshore winds or winds parallel to the shore, where the shore is to the right of the

[1] Environment Canada Hurricane Juan summary

wind flow, cause positive storm surges Offshore winds or winds parallel to the shore, where the shore is to the left of the flow, cause negative storm surges.

Figure 2: Nature of Storm Surges



Storm surge is a large dome of water, often 50 to 100 miles wide, that sweeps across the coastline where a hurricane makes landfall. The storm tide is the combination of the storm surge and the astronomical tide.

Source: HPC Wire - July 19, 2007: From Katrina Forward: Producing Better Storm Surge Forecasts

Storm surge formation

Surges are larger when winds blow over long stretches of open water. They are also magnified by gently sloping, shallow continental shelves or shorelines since these concentrate the energy of the surge along the coast.

The size of the surge depends on several factors:

- wind strength and duration: stronger winds that last longer periods of time cause higher storm surges.
- the presence of low atmospheric pressure which results in higher than normal water levels.
- wind direction: onshore winds push water inland, while offshore winds push water away from the coastline.

The impact of a surge is affected by:

- elevation of the coastline: low-lying areas are easily flooded during storm surges and also make it possible for water to flow further inland.
- high tides at the time of a storm surge. Storm surges at such times can be 50% higher than normal high tides.

Occurrence

In Canada, storm surges are common along the along the Atlantic and Pacific coasts and along shores of large lakes, such as the Great Lakes. The hazard is greatest along the Atlantic coast, mainly because of the intensity and frequency of storms, the low-lying nature of the coastline, land subsidence (the gradual sinking of the land) and sea level rise.

Other areas where storm surges are relatively common are the Gulf of St. Lawrence, St. Lawrence Estuary, Bay of Fundy, Hudson Bay, James Bay, Lake Winnipeg, the Northwest Passage and the Beaufort Sea. Among the Great Lakes, Lakes Erie and St. Clair are the most susceptible to storm surges because they are the shallowest. Significant surges are less common on the deepest lakes, Superior and Ontario. Southern Lake Huron and Georgian Bay also experience storm surges. The area with the lowest risk is the Arctic.

Storm Surge impacts

Storm surges are destructive and those that coincide with high tides are even more devastating. They flood and damage houses, wharves, warehouse facilities, bridges and ships. They wash out roads and runways by scouring and eroding the soil beneath them. They inundate drinking water sources with saline water. They cause loss of life and personal injury.

Figure 3: Wave Damage at Souris, Prince Edward Island

Source: Natural Resources Canada

Many communities along Canada's Atlantic coast have been hard hit by storm surges in recent years, for example:

- October, 2000: The remains of a tropical storm hit the Gulf of St. Lawrence coast of New Brunswick with wind gusts of 120 km/h, creating waves of 7-11 meters and a surge of about 1.6 meters above the high tide mark, causing massive damage to coastal infrastructure
- January 2000: An intense winter storm hit the Maritimes during a period of very high tides. This storm was accompanied by heavy snow and strong winds that created storm surges of 1.2-2.0 meters. This caused coastal flooding in the Gulf of St. Lawrence affecting Prince Edward Island, New Brunswick and Nova Scotia. Damages were estimated at $20 million.
- February, 1976: Hurricane force winds accompanied by storms in the Maritimes inundated and damaged wharves, coastal buildings, boats and power lines in places like the Bay of Fundy, southwestern Nova Scotia and southern New Brunswick. Damage was estimated in the tens of millions.
- January, 2001: A storm hit Prince Edward Island and other Atlantic Provinces, plunging several communities into darkness as utility poles were knocked down by strong winds. Wharfs and coastal roads were submerged as storm surges coincided with high tides.
- September, 2003: Hurricane Juan hit Halifax Harbor. It was the highest recorded storm surge sine 1940. This, combined with high winds and high waves contributed to a great deal of flooding in the area.
- February, 2006: A Storm Surge hit Louisbourg, NS revealing 30 metres of a Louisbourg fortress wall that was long thought destroyed, as well as the foundation of a house, a burial plot and a soldiers' outpost.

Storm surges can also destroy wildlife. In the Yukon region, storm surge floods during early summer have, at times, destroyed 80 to 90% of the production of nesting ducks.

Implications of changing climate

Climate change may increase the storm surge hazard for several reasons. It may alter the tracks of weather systems, exposing new areas to storm surge activity. In addition, the warming of ocean waters and the melting of land-based ice is expected to raise global sea levels over the next century by an estimated 15 to 90 cm. Finally, the frequency and/or intensity of storms may increase as the climate warms. This will likely increase erosion and the risk of storm-surge flooding and dyke overtopping in coastal areas, especially in the Atlantic provinces.

Mitigation Issues

A lot of development and degradation has occurred along most of Canada's natural beaches and dune systems. Consequently, vegetation and wetlands that acted as buffers have virtually disappeared, making many coastal and lake settlements more susceptible to being damaged by storm surges. Over the next 50 to 100 years, projected increases in sea level and coastal development will worsen these problems.

Storm surges can't be prevented, but there are both structural and nonstructural measures that can reduce their impacts. Nonstructural measures include land use controls, emergency preparedness and public education. Structural measures include dykes, flood proofing, and surge-resistant construction.

Nonstructural Systems

Land use controls involve restricting development in high-risk areas through zoning regulations or relocation to higher ground. Such restrictions can reduce exposure to storm surges and limit the economic damage they cause.

Vulnerability assessment involves defining and mapping storm surge-prone areas for effective management. It's particularly important to maintain the integrity of natural protective zones along coasts and beaches through vegetation cover or creating buffer or hazard setback zones. Vegetation works in two ways: below–water, it retards the water current, while above-water, it reduces wind speed and wind stress at the water surface.

In cities, minimum floor levels for new development in flood prone areas should take surge risk into consideration. In New Zealand, for instance, some houses have been built on piers to elevate their floors between 0.5 and 2.0 metres above ground.

Automated warning systems should be established in vulnerable sites to quickly notify local emergency agencies once pre-determined water levels are exceeded. Such a warning system should consist of a tide gauge as well as instruments to measure wind speed and direction, barometric pressure and wave heights. In the hands of skilled people with a good understanding of the local environment, these data can be used effectively to reduce vulnerability to storm surges.

Education: Information on storm surges should be made part of primary and secondary school curricula in provinces on the Pacific and Atlantic Coasts, as well as in the lake districts of Ontario and Manitoba. Travelers to storm-surge prone areas should also be targeted by public awareness campaigns.

Structural Measures to Reduce Hazards

Structural measures, such as dikes, barrages or sea walls, are designed to prevent storm surges from inundating low-lying areas or reaching high-risk areas inland, and to reduce their impact on buildings and other structures such as highways. Areas where such shoreline protection measures are common include Pictou County, Nova Scotia, and most parts of Prince Edward Island.

Preparedness and Response by Individuals:

The impact of extreme weather events can be reduced by taking precautions before, during and after an emergency.

- ***Listen: to storm surge warnings or public weather warnings*** issued by Environment Canada. These warnings are carried by the media, including Newswire Services, Environment Canada's Weatheradio and Automated Telephone Answering Devices. If a significant storm surge is forecast, Environment Canada will issue a statement informing the public of the potential for high surf, high water levels and coastal flooding. These are issued up to 48 hours in advance of any anticipated storm surge. If forecasters estimate a storm surge to be large in scale, they will also issue a public weather warning.

- ***Be prepared:*** have kits ready both at home or in your car. (See Table1)

- ***Take appropriate action:***
    - check your supplies (See Table 1)
    - make an inventory of property items and personal items, including a list and a video or photographs that can be supplied to your insurance company. These and other important documents (i.e., birth certificates, insurance policies, contract deeds, passports, social insurance numbers, immunization records, marriage and death certificates and other legal documents) should be stored safely in a waterproof area or box. Many people store these and other valuables in the basement but if you live in a flood-prone area, they should be placed at a higher level
    - close basement windows
    - fuel your car. If evacuation is needed, it will be hard to stop for gas along the way
    - if a storm surge occurs, stay inside your house where you are protected from the water
    - stay on the downwind side of the house, away from windows
    - if family members are not all together, they should try to make contact frequently
    - monitor the storm's progress and listen for further warnings or instructions from local officials

- o floodwaters can be dangerous to drive through. Before driving anywhere, listen carefully to rescue officials who are coordinating evacuation plans

Table 1: Emergency Equipment:

At Home • Flashlight: in case of power failure • Radio and batteries: Battery-powered radios are preferable due to possible power failure • First-aid kit • Candles and waterproof matches or lighter • Extra car keys and cash • Important documents for identification • Food : canned foods and soups generally preferred • Bottled water: at least one liter per adult per day • Clothing and footwear: one change of clothes per person • Blankets or sleeping bags: one per person. • Personal supplies: toothpaste, soap, toilet paper, etc • Stove that does not require electricity. Follow the manufacturer's instructions and never use a barbeque indoors • Medication **In your car** • Shovel, ice scrapper and brush; sand, salt or kitty litter; traction mats • Booster cables, Methyl hydrate for fuel line & windshield de-icing • Tow chain, first-aid kit, fire extinguisher, flashlight, road maps, warning light or road flares • Emergency food pack • Extra clothing and footwear; cloth or roll of paper towels; blanket (special "survival" blankets are best) • Compass; axe or hatchet; matches and a "survival" candle in a deep can (to warm hands, heat a drink or use as an emergency light)

- if an evacuation order is given, take small valuables and important documents with you but travel light
- establish an out-of-area contact such as a relative in a nearby city where your family can meet after it evacuates
- make sure you take your emergency preparedness kit with you
- if you are evacuating your home, leave a note stating your whereabouts and register at any local registration and inquiry centre so you can be contacted when it is safe to return

Sources and Further Reading

- Danard, M., A.Munro and T. Murty (2003): Storm Surge Hazard in Canada, *Natural Hazards* , Vol. 28, Nos. 2-3, pp. 407-431

- University Corporation for Atmospheric Research: Hurricane Basics - Damage Hurricanes Cause--Winds and Storm Surges

- Natural Resources Canada: Climate Change Impacts and Adaptation Program

2.11 Thunderstorms

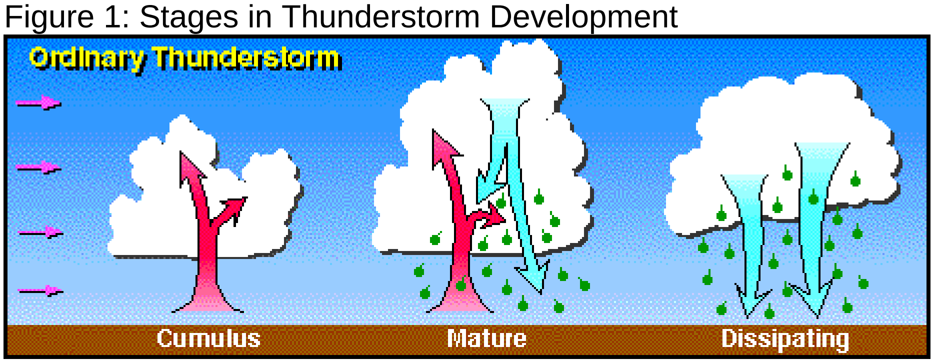
On July 14, 2000 a tornado-bearing thunderstorm bore down on the Pine Lake Trailer Park, Alberta, killing 12 people, injuring hundreds more and leaving a 25 kilometre path of destruction. On June 8, 1999, a stationary thunderstorm suddenly flooded the town of White Rock, B.C. On July 17, 1996, in a 15 minute period, a hail storm hit Winnipeg and caused $250 million of damage. On the same day, another hail storm hit Calgary and left another $200 million in damage. On July 15, 1995, a wind storm swept through cottage country in Ontario creating a 100 kilometre wide swath of damage stretching from Georgian Bay to Kingston. On July 19/20, 1996, heavy localized rains created flood conditions that swept the Saguenay Valley in Quebec, causing $1.5 billion in damage. Ten people died and 12,000 were evacuated.

Thunderstorms are one of nature's wonders. They are mesmerizing to watch as the clouds boil and change in front of your eyes. They contain the energy equivalent to an atomic bomb and spawn all kinds of destructive weather, including tornadoes, hail, lightning and heavy rain.

They're also hard to predict, both in terms of exactly when and where they will occur, because the processes that create them are hard to detect and measure. There's is a fine balance among the various atmospheric influences that determine the character of a thunderstorm. Though weather forecasters can predict generally where they might occur, being more specific is like trying to predict which kernel of corn on a hot skillet will pop first.

The ingredients of a thunderstorm

Figure 1: Stages in Thunderstorm Development



Source: EarthStorm website: Severe Weather Graphics

Thunderstorms come in many different types. They can be isolated, towering cumulonimbus storms several tens of kilometres in size. They develop from cumulus clouds which go through a process of development and dissipation (See Figure 1). They can be organized in squall lines hundreds of kilometers in length. They can be embedded in low clouds or within broad areas of light rain. They can move quickly or slowly. Some last just a few minutes and others for hours. At any given moment, nearly 1,800 thunderstorms are in progress over the surface of the earth.

Thunderstorms are the parents of localized severe weather—strong winds, tornadoes, downbursts, hail, lightning and heavy rains. All of these severe weather elements can be present together or separately.

The basic ingredients that create a thunderstorm include moisture and the vertical temperature and wind profile of the atmosphere. The relative balance of these ingredients determines the type of thunderstorms that can form.

Moisture is created near the ground by evaporation from bodies of water or by transpiration from trees and vegetation. If moisture-laden air starts rising or is forced to rise, it will condense to form clouds. When condensation occurs, heat is released from the water vapor into the air, causing the warm air to rise even more quickly. The main difference between thunderstorms and other less damaging weather systems is that the vertical motions are very strong inside the thunderstorm, about 20 to 40 metres per second.

If the air aloft is dry, the temperature contrast between the cloud and surrounding air is large and a very buoyant cloud is formed. This results in explosive growth of the cloud and the development of a strong updraft. As the air rises, the cloud droplets collide and coalesce to form rain, graupel (icy pellets) and often hail. When the precipitation particles are large and heavy enough, they fall through the updraft, reaching the ground as rain.

If the winds aloft are strong—a situation called wind shear—the precipitation will fall away from the updraft. Falling precipitation creates a downdraft and if this occurs in the updraft region, the updraft and therefore the storm will be destroyed. Thus, in a wind shear environment, a long lived updraft can develop and this leads to the development of strong and intense storms. The combination of rising air and strong winds aloft can also create rotating storm clouds that can spawn tornadoes.

The balance between the various factors that create thunderstorms is very delicate. For example, if there's too little moisture near the ground, the thunderstorm may never get started. If there's too much moisture, then small short-lived thunderstorms are formed because the precipitation particles get large and heavy quickly, and fall back into the updraft, destroying the storm. If the updraft is too strong, precipitation particles don't grow large enough before they're transported away from the moisture-rich updraft and encounter dry air aloft that causes them to evaporate.

The factors that influence the development of thunderstorms can be very small, short-lived and hard to detect. The most difficult aspect of the process is understanding the initial kick that starts the air rising. There are several possibilities. The presence of an atmospheric front, a boundary between warm and cold air, is one. Because cold air is heavy, it pushes underneath warm moist air and causes it to rise. Similarly, cold drafts from an existing thunderstorm can push along the ground, creating a mini-cold-front that can kick off a new thunderstorm.

Lake breezes can also set up conditions conducive to thunderstorm development. The circulation associated with a lake breeze, where air sinks over the cooler water of the lake and rises over the warmer land, creates a boundary where there is rising air that can trigger thunderstorm activity. Other possible triggers include solar heating of bedrock, which causes unstable conditions favorable to thunderstorm development.

Geographic distribution of thunderstorms in Canada

Thunderstorms can occur in all parts of Canada (See Figure 2), but their preferred locations are in Alberta east of the mountains, in southern Prairies and southeastern Ontario. The relative contributions of the various factors and processes just described determine the type, occurrence and frequency of these storms. In the coastal areas of British Columbia, thunderstorms are infrequent and tend to be short and small because there is little wind shear and the low-level air is moist. In the B.C. interior, thunderstorms tend to form in and travel along mountain valleys since low level moisture pools in the valleys.

Figure 2: Number of Days with Thunderstorms (1951-1980)

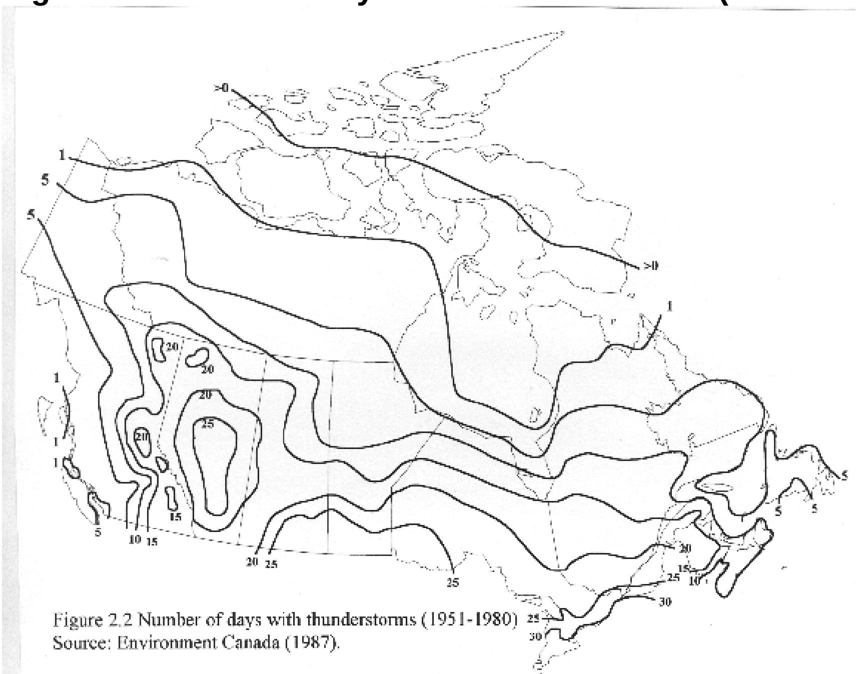


Figure 2.2 Number of days with thunderstorms (1951-1980)
Source: Environment Canada (1987).

Source: Environment Canada

In the Prairie provinces, various factors converge to form the largest thunderstorms in Canada. Much of the region can be affected by low-level moist air that originates from the Gulf of Mexico, while the winds aloft coming from the west create tremendous wind shear. The air aloft is also dry, the result of ascending and raining over the west side of the Cordillera. The east-facing mountain slopes heat up from the sun, creating the rising air needed to kick off the development of thunderstorms. It also creates a slowly developing updraft and precipitation growth environment that leads to the development of very large hail.

Farther east in the Prairies, transpiration from agricultural crops creates another source of moisture to feed thunderstorm development. Transpiration is a process where plants draw moisture from the ground and release it out to the atmosphere as water vapour. The amount of moisture that transpires from crops is equivalent to that produced by evaporation from lakes.

When green crops lie next to dry, fallow fields, transpiration can create moisture boundaries very similar to lake or sea breeze boundaries. These boundaries are areas of enhanced moisture and form preferred locations that trigger thunderstorm building processes.

The air in Ontario is generally moisture-laden due to the influence of the Great Lakes, the warm, moist Gulf of Mexico and sometimes the Atlantic Ocean. The distant Rocky Mountains play a much lesser role than in the Prairies. The Great Lakes provide a moderating influence on daytime heating, but also create lake breezes that can initiate or enhance the formation of thunderstorms. Widespread rain often develops from large scale storms, shrouding thunderstorms and making them difficult to see from the ground. This is called embedded convection; it can sometimes be seen from the air, where tall thunderstorms rise up from extensive low clouds.

Conditions in Quebec are similar to those in Ontario except that the Atlantic Ocean is the most important source of moisture. This is also true in the Atlantic provinces, where thunderstorms are short-lived and heavy with rain. There's so much moisture that rain forms quickly and the lack of strong wind shear from the Cordillera influence causes the rain to form lower in the atmosphere and fall back into the updraft, destroying the thunderstorm.

Since heat is a key ingredient in thunderstorm formation, they exhibit a strong day/night pattern. Maximum daytime heating occurs around two o'clock, so thunderstorms frequently develop in the late afternoon and early evening.

However, one type of thunderstorm tends to occur at night. As air aloft cools at night, it becomes heavier and can create a top-heavy system, turning over the air and creating a long-lived nocturnal thunderstorm system. In this overturning air process, moist low or mid level air is forced to rise, which can initiate convection. On July 15, 1995, such a system formed in Ontario, extending from Georgian Bay to Kingston and causing widespread wind damage.

Thunderstorms can contain any or all of several damaging severe weather elements – strong winds including tornadoes, downbursts, straight line winds called derechos, hail, heavy rain and lightning. The damage can be sudden, extensive and substantial.

Thunderstorm watches and warnings

Environment Canada issues severe weather watches as a heads-up that severe weather is likely to develop. The lead time is normally two to six hours, but may be less than two hours at times because thunderstorms often form quickly.

There are two types of watches

1. A Severe Thunderstorm Watch is issued when severe thunderstorms are expected to develop.

2. A Tornado Watch is issued when severe thunderstorms are expected to develop and there is a good possibility that one or more may spawn tornadoes.

Environment Canada issues severe weather warnings only when severe weather is occurring or is about to occur and tries to provide lead times of 15 minutes to two hours. The Department usually issues watches first, then warnings. But when severe thunderstorms develop quickly, Environment Canada skips the watch stage and issues warnings directly. There are four types of warnings:

- *Severe Thunderstorm Warning*: When one or more of the following is expected to occur:
    - Wind gusts of 90 km/h or more
    - Hail of two cm in diameter or larger
    - Rainfall of 50 mm or more within one hour or 75 mm or more within three hours
- *Tornado Warning*: When a tornado has been reported or when a tornado is likely to form and touch down.
- *High Wind Warning*: When winds are forecast to reach sustained speeds of 60 km/h or more for three hours or more and ‘or when wind gusts of 90 km/h or more are expected.
- *Heavy Rain Warning*: When 50 mm or more of rain are expected to fall within 12 hours.

What do in a Thunderstorm

Communities can mitigate their risk by engaging in the activities listed under mitigating flood, hail and tornado hazards (sections 2.5: Flood, 2.7: Hail and 2.12: Tornado). These include land-use planning to control development in flood-prone areas and building standards or codes to reduce vulnerability to hail and strong winds.

Individuals can also take effective actions to reduce their risk. If severe weather is imminent, seek shelter. If no shelter is available, seek a low-lying area. The objective is to avoid being hit by projectiles—or worse, becoming one yourself. If you are in your house, go to the basement or to the most central part of the house. If a tornado is imminent, avoid collapsing walls by seeking shelter in a closet or bathroom or bathtub.

Stay away from flooded roads, rising streams and storm drains. The power of moving water could sweep you into trouble. Do not drive on flooded roads; you do not know how deep the water actually is. Your car may become buoyant and float away. Stay away from downed power lines and other harmful debris

The 30/30 rule is good way of knowing when you're in danger. If the time between seeing lightning and hearing thunder is 30 seconds or less, the lightning is close enough to be a threat and you should seek shelter immediately. Wait 30 minutes after seeing the last lightning flash before leaving shelter. More than half of lightning deaths occur after the storm has passed.

Sources and Further Reading

- Environment Canada: Prairie and Northern Region – Thunderstorms
- USA Today website - Resources: Thunderstorms
- Red Cross - Disaster services

2.12 Tornadoes

On July 31, 1987, a violent tornado tore through Edmonton, killing 27 people and injuring hundreds. Among them was 18 year old Kelly Pancel, who died protecting Meagan, her four week old daughter. Fifteen of those who died lived in a trailer park; the trailers and mobile homes offered little or no protection to their inhabitants.

The tornado remained on the ground for an hour and cut a path 40 kilometres long and up to a kilometre wide in places. With wind speeds of up to 460 km/hr, it caused more than $330-million in property damage at four sites, making it one of Canada's worst natural disasters.

Introduction

Tornadoes have taken a considerable human and economic toll in Canada, which is second only to the United States in the number of tornadoes it experiences. On average, there are about 60 tornadoes in Canada each year, although only a very small number actually cause disasters.

The 1987 Edmonton tornado caused the most damage while the Regina "cyclone" of 1912 caused more deaths (28). Other tornadoes that caused significant deaths, injury and property damage are listed in Table 1. None of these cases represents a worst case scenario. If a severe tornado were to strike an area with many mobile homes, a sporting event, or school portables – none of which has occurred so far - the resulting impact could be disastrous.

Between 1985 and 1997, there were six tornado disasters that cost the insurance industry about $289 million (1995 dollars) in payouts.

Table 1: Worst Canadian Tornadoes (by death toll)

1. Regina "Cyclone", Saskatchewan; June 30, 1912. Twenty-eight dead and hundreds injured. Damage of $4 million.
2. Edmonton, Alberta; July 31, 1987. Twenty-seven dead and 300 injured. Thousands homeless. Damage of $300 million (see Charlton et al, 1998, for a comprehensive review of this storm).
3. Windsor to Tecumseh, Ontario; June 17, 1946. Seventeen dead and hundreds injured. Damage conservatively estimated at $1.5 million.
4. Hopeville to Barrie, Ontario; May 31, 1985. Twelve dead and 155 injured. More than 1000 buildings damaged. Damage of $100 million. A description of this event follows in the case study.
5. Pine Lake, Alberta; July 14, 2000. Twelve dead and hundreds injured. Six hundred and thirty-five trailers and RVs severely damaged or destroyed.
6. Lancaster Township, Ontario to St-Zotique to Valleyfield, Quebec; Aug. 16, 1888. Nine (possibly 11) dead and 14 injured. Extensive property damage.
7. Windsor, Ontario; Apr. 3, 1974. Nine dead and 30 injured. Damage of $500 thousand.

8. Sudbury, Ontario; August 20, 1970. Six dead, 200 injured. Damage of $10 million or more.
9. St. Rose (Montreal) Quebec; June 14, 1892. Six dead and 26 injured.
10. Buctouche, New Brunswick; August 6, 1879. Five to seven dead and 10 injured. Damage of $100 thousand and 25 families homeless.
11. Portage La Prairie, Manitoba; June 22, 1922. Five dead and scores injured. Damage of $2 million.

The anatomy of a tornado

Strong tornadoes form from a type of severe thunderstorm called a supercell, which can occur when the atmosphere is very unstable and wind shear is strong. Supercells are also associated with heavy rain, hail and strong straight-line winds. Weak tornadoes can form from weaker thunderstorms systems, on low level boundaries associated with thunderstorm outflows or on lake breeze fronts.

The tornado itself is a whirlwind varying in width at the ground from a few tens of metres to more than a kilometre for some monsters. When they form over water, they're called waterspouts. If they do not touch down, they're called funnel clouds.

Some tornadoes are not composed of a single funnel, but break down into several smaller funnels or vortices that can form and dissipate rapidly. These vortices rotate around the central tornado core. A tornado can be quite erratic, weakening and strengthening during its life cycle. Some last for only minutes but severe tornadoes can last up to an hour or so.

The damage caused by these storms reflects their erratic behaviour and wind speeds, which vary greatly over their damage area; they can completely destroy some places while leaving nearby areas virtually untouched.

The vast majority of tornadoes spin counter-clockwise in the northern hemisphere and clockwise in the southern hemisphere as a result of the earth's rotation. In Canada, they generally move from west or southwest to east or northeast.

The intensity of tornadoes is measured by to how much damage they cause, rated on the Fujita scale from F0 to F5 (Table 2). Though they produce strong updrafts and abrupt drops in pressure as they pass, it is the intense winds that create the greatest damage.

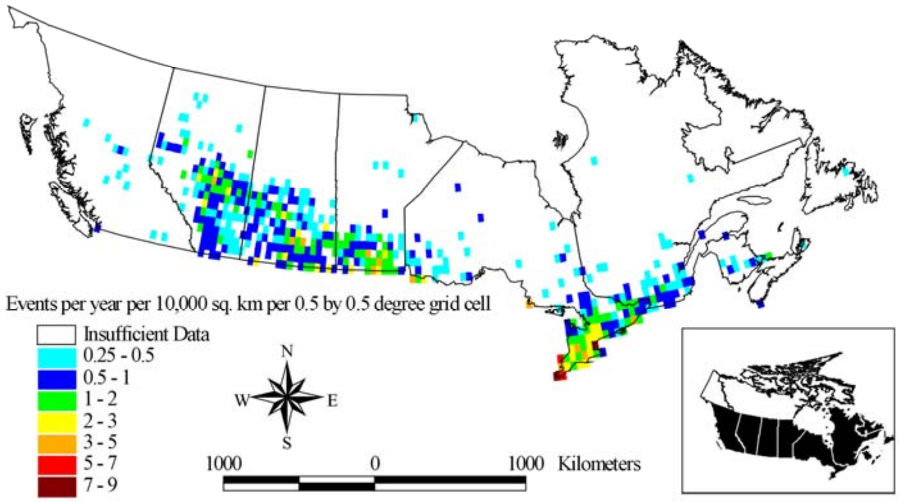
Table 2: The Fujita Scale

F0 - light winds of 64 to 116 km/hr; some damage to chimneys, TV antennas, roof shingles, trees, signs, and windows and accounts for about 28 percent of all tornadoes.
F1 - moderate winds of 117 to 180 km/hr; automobiles overturned, carports destroyed, and trees uprooted. F1 tornadoes account for about 39 percent of all tornadoes.
F2 - considerable winds of 181 to 252 km/hr; roofs blown off homes, sheds and outbuildings demolished, and mobile homes overturned. F2 tornadoes account for about 24 percent of all tornadoes.
F3 - severe winds of 253 to 330 km/hr; exterior walls and roofs blown off homes, metal buildings collapsed or severely damaged, and forests and farmland flattened. F2 tornadoes account for about six percent of all tornadoes.
F4 - devastating winds of 331 to 417 km/hr; few walls, if any, left standing in well-built homes; large steel and concrete missiles thrown great distances. F4 tornadoes account for about two percent of all tornadoes.
F5 - incredible winds of 418 to 509 km/hr; homes leveled or carried great distances. F5 tornadoes can cause tremendous damage to large structures such as schools and motels and can tear off exterior walls and roofs. Tornadoes of this magnitude account for less than one percent of all tornadoes and have never been officially recorded in Canada. However, recent research suggests that as many as two may have occurred in Saskatchewan, regardless, F5 tornadoes are possible in Canada every summer.

Where and when tornadoes occur

Tornadoes have occurred in all parts of Canada, but the areas of greatest occurrence are the southern Prairie provinces and southwestern Ontario (Figure 1). This figure only reflects tornadoes that have been observed and reported; many tornadoes occur where people do not live, but these one are not shown.

Figure 1: Observed Tornado Frequencies in Canada



Source: Etkin et al 2001.

It may come as a surprise that Ontario and Saskatchewan—not Alberta—get the most tornadoes, as Table 3 shows. Most deaths from tornadoes also occur in these two provinces. The Maritime provinces rarely experience the severe types of thunderstorms that can spawn tornadoes, mainly because they don't have the dry conditions high in the atmosphere that are needed to create the necessary unstable conditions.

Tornadoes are most common in flat terrain and in areas with little water. Mountainous terrain tends to break up the circulation that creates tornadoes and the cooling effect of water tends to stabilize the atmosphere.

Table 3: Frequency of Tornadoes by Province, 1980-1997

Province	No. Events	% Events
Nfld	1	0.1
PEI	2	0.2
NS	2	0.2
BC	9	0.8
NB	12	1.1
Que	58	5.3
Man	148	13.6
Alta	241	22.2
Sask	268	24.7
Ont	345	31.8

Source: Etkin et al 2001.

The conditions that create tornadoes occur mostly during warm months, so it's not surprising that more than three-quarters occur in June (32.5%), July (30.3%) and

August (14.4%) (Table 4). Tornado occurrence is not the same in the prairies as it is in eastern Canada however, where the tornado season lasts about a month longer, lasting into September.

They are most likely to occur in the late afternoon or early evening when the heating effect of the sun has warmed the surface of the earth to it's maximum temperature. However, they have occurred at all hours of the day or night; during the night, they can be triggered by fronts, for example, which provide the lift needed for severe thunderstorms, even when the earth's surface is relatively cool.

A typical tornado day would be hot and muggy with strong southerly surface winds and lots of sunshine.

Table 4: Frequency of Tornado Observations by Month

Month	% Frequency
January	0.3
February	0.2
March	0.2
April	2.8
May	11.3
June	32.5
July	30.3
August	14.4
September	6.3
October	1.6
November	0.1
December	0.0

Source: Etkin et al 2001.

Vulnerability to tornadoes

Canadians are vulnerable to tornadoes because they're so rare that our homes and buildings are not constructed to withstand them and because most people don't know how to respond when they strike. The number of deaths per province from tornadoes is shown in Table 5.

In the Barrie, Ontario, tornado disaster of May 31, 1985, seven of the twelve deaths occurred in homes not properly anchored to their foundations. In the 1987 Edmonton tornado, 15 of the 27 people who were killed lived in a trailer park. Mobile homes --the phrase takes on a new meaning in the presence of a tornado -- or school portables are at great risk because they have so little ability to withstand strong winds.

Weather warnings can help reduce risk, but the people potentially affected often do not hear or heed the warnings before the tornado strikes. This is because it's still very hard to predict precisely where tornadoes will touch down and because they strike so rapidly. It's important for people who live in vulnerable regions be aware of weather watches and to then be vigilant and to know how to respond when a tornado is seen.

Table 5: Tornado Deaths by Province (1879-1999, all known events)

Province	No. of Events	No. of deaths
Saskatchewan	34	85
Ontario	26	84
Alberta	16	65
Quebec	9	28
Manitoba	6	9
New Brunswick	2	6

Source: Etkin et al 2001.

Mitigation

Tornado risk can be reduced in several ways.
Community Actions:

1. Ensure that organizations have emergency plans in place, and that they can rapidly be put into practice when needed.

2. Avoid building vulnerable structures such as school portables or mobile homes in areas where tornadoes are more likely. If they must be used, make sure they are strapped down or anchored to their foundations.

Individual Actions:
1. Listen to weather forecasts, watches and warnings. Be alert. Signs of an approaching tornado are[1]:

- A green or greenish-black colour to the sky.
- If a watch or warning has been issued, then hail should be considered a real danger sign. (However, hail is common in some regions and usually has no associated tornadic activity.)
- A strange quiet that occurs within or shortly after the thunderstorm.
- A sound like a waterfall or rushing air at first, turning into a roar as it approaches. Tornadoes have been described as sounding like railroad trains or jets.
- Debris dropping from the sky.
- A rotating cloud with an obvious funnel shape, or debris such as branches or leaves being pulled upwards, even if no funnel cloud is visible.

[1] The Tornado Project Online

2. When a tornado strikes, take immediate shelter. *Do not open windows*. If the tornado gets close to your home, it will break all the windows anyway. Houses do *not* explode from pressure differences. They break up due to high wind speeds that lift off roofs and blow down walls. Flying debris, particularly glass, injures most people. .

3. Take shelter in a safe well-protected location, preferably a basement. Crouch under a strong table if possible or lie down in your bathtub and pull a mattress over you.

4. If you're in your car and a tornado is headed towards you, you might escape by driving south or north, traffic permitting. Tornadoes usually, though not always, travel from west to east, or southwest to northeast. Otherwise buckle up, and cover up to protect yourself from flying glass in case the windows get broken.

The wisdom of leaving a car is still debated, but recent research has shown that this may ultimately be more dangerous than staying in it. In most situations, it's probably not a good idea to seek shelter in an outside location such as a ditch or an underpass. Ditches are uncommon in many areas and they tend to fill up with water and hail. Underpasses offer little protection against the strong winds and flying debris that accompany tornadoes and they may collapse.

Sources and Further reading

- Environment Canada: Prarie and Nothern Region – Tornadoes

- Edwards, Roger.The Online Tornado FAQ. Storm Prediction Center.

- The Tornado Project Online

- Etkin, D., Brun, S., Shabbar, A. And Joe, P. (2001). Tornado Climatology of Canada Revisited: Tornado Activity During Different Phases of Enso. International Journal of Climatology. Vol 21, pp. 915-938.

2.13: Winter Storms

For more than a week in January 1998, a relentless downpour of freezing rain blanketed western Quebec and eastern Ontario with a coat of ice so thick and heavy that hydro towers, power lines, telephone, and cable TV wires came crashing to the ground under its weight. Trees and hydro poles snapped like matchsticks, showering the streets with broken limbs and shards of ice.

The scene was like a war zone —and, indeed, some 14,000 Canadian troops were called out to help with the devastation. In most parts of Montreal, there was no heat, no light, no drinkable water and no water pressure. Backup generators failed and fires ignited from heaters, but firefighters had few accessible roads to reach the fire scenes.

By Friday, January 9th 1998, Montreal had only one serviceable electricity line. If it had failed, the city would have been totally without power, turning what was already an enormous disaster into a catastrophe.

Figure 1 – Broken tree limbs after the 1998 Ice Storm in Montreal

Source: CTV.ca. Canadians remember 'storm of the century'. Jan 4, 2008. Picture courtesy Ryan Remiorz / THE CANADIAN PRESS

Introduction

Canadians are well acquainted with winter storms—at times, far too well. From the Maritimes to the west coast, we battle wind, cold and various forms of precipitation. Since these storms are so common, Canadians are, overall, well adapted to them, but they nevertheless cause great inconvenience as well as injuries and death.

Bitter cold and winter storms kill more than 100 people in Canada every year—more than the number killed by the combined effects of tornadoes, thunderstorms, lightning, floods, hurricanes and heat waves.

Types of Winter Storms:

There are several types of winter storms. A common type, referred to as mid-latitude storms, depends upon fronts and the jet stream for their energy and can cover much of the North American continent. They often have a mixture of precipitation types, ranging from rain (often produced by thunderstorms) to freezing rain, ice pellets and snow.

The patterns of precipitation—both the type of precipitation and where it falls geographically—depend on where the centre of the low pressure system and where the cold and warm fronts are located. For example, areas of freezing rain occur north of a warm front and are sometimes called ice storms, especially if large amounts fall over a large area.

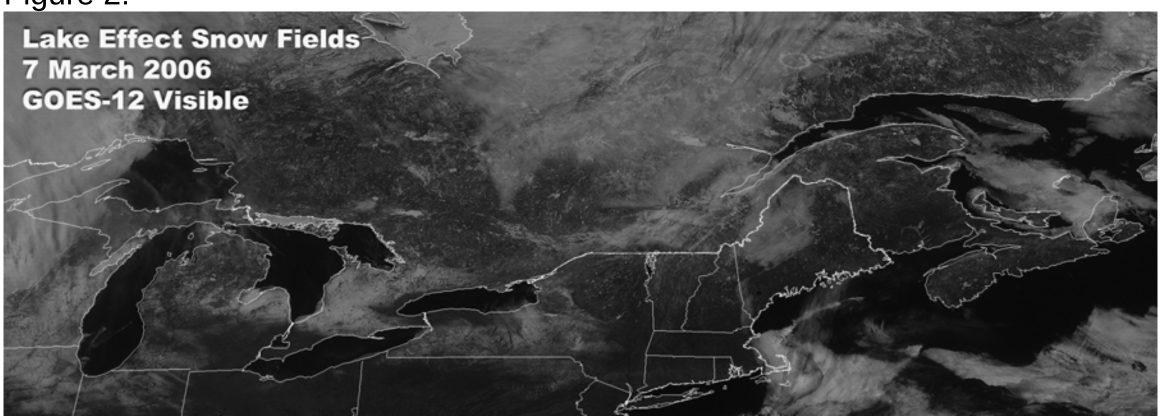
Figure 1: Summary diagram of types of Winter Storms and their common locations

Source: Modified from Stewart et al (1995)

Occasionally, severe storms develop along the east coast of North America and move northeastward towards the Atlantic Provinces. Since winds blow counter-clockwise around a low pressure system, the winds are typically from the northeast along the coast, and therefore these storms are called *nor'easters*. They can have very strong winds and drop large amounts of precipitation because they carry moisture from the Atlantic Ocean. Sometimes they are accompanied by storm surges (See Section 2.10: Storm Surge).

Some winter storms, such as snowsqualls, depend upon the presence of bodies of water for energy and moisture. When cold air blows over the Great Lakes, for example, there is a transfer of heat and moisture from the lakes into the atmosphere, which results in lines of clouds that can drop huge amounts of snow, creating snowbelts.

Figure 2:

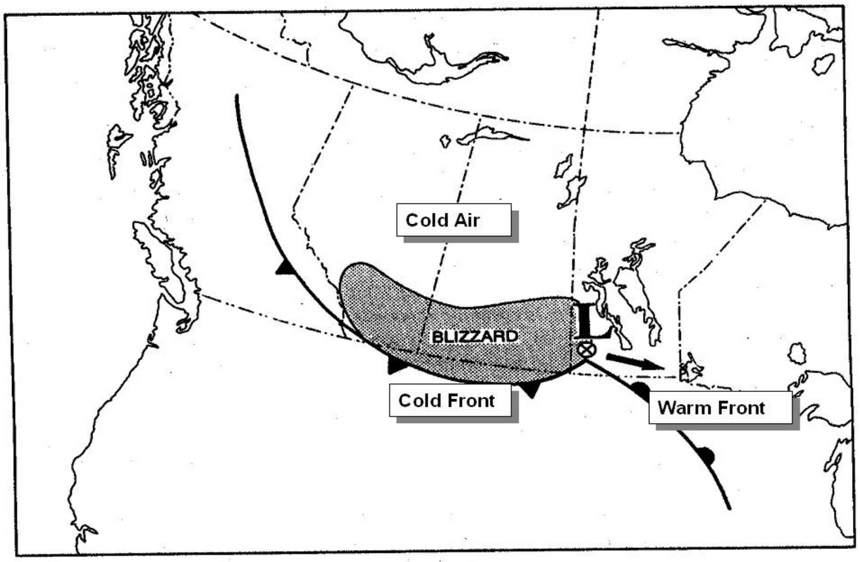


Source: NASA-Goddard Space Flight Center, data from NOAA GOES

Blizzards occur when several conditions occur simultaneously: cold temperatures, strong winds and low visibility due to snow and blowing snow. These conditions typically occur after the passage of a cold front and are common on the prairies (Figure 3) and in the Arctic. They usually last for about 18 hours, after which the winds die down and visibility improves, though cold temperatures continue to persist.

Mountains lying in the path of storms can funnel winds along valleys into local storms with devastating impacts. The regions most susceptible to this kind of activity are Atlantic Canada, the Arctic Islands, and the West Coast.

Figure 3: A summary sketch showing the region that typically experiences blizzard conditions within an overall low system over the Prairies. The arrow indicates the track of the low pressure center**.**



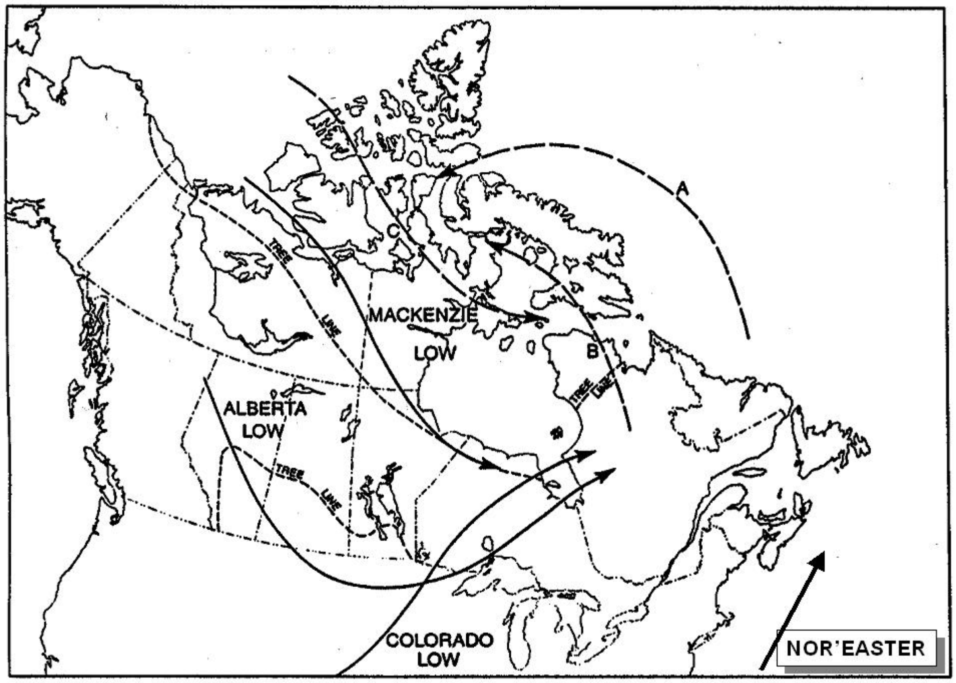
Source: Modified from Stewart et al (1995)

The alignment of mountain ranges along the west coast of Cape Breton Island and Newfoundland causes winds to move in a southeasterly direction, bringing severe downslope windstorms to the lee of the mountains. These winds occur several times a year. In Newfoundland, they're called "wreckhouse winds" and Acadians in Cape Breton refer to them as "Les Suetes."

Storm Paths

Storms can occur pretty much anywhere, mostly traveling in an eastward or northeastward direction. However, there are several types of storms that follow well-worn storm tracks or paths (Figure 4): (1) the nor'easters along the east coast, (2) "Colorado lows" that originate in the U.S. southwest and move northeastward toward Ontario, Quebec and the Maritimes and (3) "Alberta Clippers" that develop east of the Rocky Mountains and move eastwards.

Figure 4: Typical Tracks of weather systems producing blizzards over the Prairies and the Northwest Territories with arrows indicating the systems' directions of motion



Source: Stewart et al (1995)

Impacts

Winter storms are associated with cold temperatures, slippery conditions from ice and snow, and interruptions in communications and power supply.

Ice storms produce a hard glaze that coats all surfaces and makes roads and sidewalks treacherous. Driving becomes extremely dangerous; stopping distances on glaze ice are about double that on packed snow and 10 times greater than on dry pavement.

Ice storms can also down power and communication lines and break trees. Weighed down by ice, cables will often sag almost to the ground until they break. Those that don't snap under the direct weight of the ice may succumb to the combined forces of ice and wind, or trees and branches falling across them.

People will often turn to alternative energy sources such kerosene, propane and charcoal briquettes but these fuels can be deadly because they emit carbon monoxide gas, which can cause asphyxiation in closed in areas without proper ventilation.

Mitigation and Preparedness

Canadians adapt to winter storms in part through the use of weather forecasts and warnings put out by Environment Canada that enable communities and people to plan activities taking the risks into account.

Watches and Warnings:
When severe weather approaches, Environment Canada alerts the public by issuing special weather statements, winter storm watches and winter weather warnings. These are broadcast over regional and local radio and television stations as well as Environment Canada's Weatheradio. For specific weather information about your part of the country, see the regional websites provided at the end of this paper.

Special Weather Statements
Environment Canada issues special weather statements to flag the approach of significant or severe weather. If there has been a significant accumulation of snow, the snow loads on roofs may exceed the building code and even moderate forecast snowfalls may result in special weather statements.

Winter Storm Watch
Environment Canada issues a winter storm watch as a "heads up" that conditions are favorable for the development of severe and possibly dangerous weather or that an existing winter storm is approaching. The approaching weather may affect your safety or at least be inconvenient.

Winter Weather Warnings
Winter weather warnings are issued when severe weather is either occurring or is highly probable. The weather service tries to provide lead times of 3 to 18 hours.

Environment Canada's warnings are quite specific about the type of weather approaching and provides 10 different types of warnings:

1. Heavy Snow Warning
2. Snow Squall Warning
3. Blizzard Warnings
4. Wind Warning
5. Freezing Rain Warning
6. Heavy Rain Warning
7. Flash Freeze Warning
8. Windchill Warning
9. Cold Wave Warning
10. Winter Storm Warning

Community Response

Communities can mitigate risk by designing buildings, roads, towers and other infrastructure to withstand the strong winds and heavy loads of snow and ice that occasionally accompany these storms. These loads are prescribed in the National Building Code of Canada. They should also have plans in place for snow removal services and the closing of non-essential services.

Individual Response

Before The Storm

- Store drinking water, first aid kit, canned/no-cook food, prescription drugs, non-electric can opener, fuel, battery-operated radio, flashlight and extra batteries where you can get them easily, even in the dark.
- Keep cars and other vehicles fueled and in good repair, with a winter emergency kit in each.
- Listen for the latest severe weather warnings from Environment Canada.
- Get to know how the public is warned (siren, radio, TV, etc.) and understand warning terms for each kind of disaster in your community.
- Know how to turn off the gas, electric power and water, in case you need to leave your home.
- Know ahead of time what you should do to help elderly or disabled friends, neighbors or employees.
- Keep plywood, plastic sheeting, lumber, sandbags and hand tools on hand and accessible.
- Make sure your house, barn, shed or any other structure that may provide shelter for your family, neighbors, livestock or equipment is suitable for winter conditions. Install storm shutters, doors and windows; clear rain gutters; repair roof leaks; and check the structural ability of the roof to sustain unusually heavy weight from the accumulation of snow—or water, if drains on flat roofs do not work.
- Ensure animals are sheltered, and provide them with plenty of food and water before the storm reaches full force.

During The Storm

- Monitor radio or other local media for information and emergency instructions. Ensure you have a battery-operated radio in case the power goes out.
- Have your emergency survival kit ready to go if you're told to evacuate.
- Stay indoors. If you must go outside, dress for the season and expected conditions
- If you must go outside, and you live in an isolated location, to avoid getting lost in blinding snow, tie one end of a long rope to your house, and grasp the other end firmly.

- Conserve fuel, if necessary, by keeping your house cooler than normal. Temporarily shut off heat to less-used rooms.
- If you're using kerosene heaters, maintain ventilation to avoid the build-up of toxic fumes. Keep heaters at least three feet from flammable objects. Refuel kerosene heaters outside.
- If advised to evacuate, tell others where you are going, turn off utilities if told to do so, then leave immediately, following routes designated by local officials.

If A Blizzard Traps You In Your Car

- Pull off the road, set hazard lights flashing, and hang a distress flag from the radio aerial or window. Remain in your vehicle; rescuers are most likely to find you there.
- Conserve fuel. Run the engine and heater for about ten minutes each hour to keep warm, cracking a downwind window slightly to prevent carbon monoxide poisoning.
- Do not set out on foot unless you see a building close by where you know you can take shelter.
- Once the blizzard is over, you may need to leave the car and proceed on foot. Follow the road if possible. If you need to walk across open country, use distant points as landmarks to help maintain your sense of direction

After The Storm

- Report downed power lines and broken gas lines immediately.
- After the storm, check to see that no physical damage has occurred and that water pipes are functioning. If there are no other problems, wait for streets and roads to be opened before you attempt to drive anywhere.
- Check on neighbours, especially those who are particularly vulnerable and might need help.
- Beware of overexertion and exhaustion. Shovelling snow in extreme cold causes many heart attacks.

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GEOPHYSICAL HAZARDS

3.1 Earthquakes

At 4:31 a.m. on January 17, 1994, more than seventeen kilometres beneath Northridge, California, the earth suddenly moved. A violent earthquake jolted residents awake in this residential community of northern Los Angeles. The magnitude 6.7 quake proved to be the strongest in the greater Los Angeles area since the San Fernando earthquake of 1971.

Although the earthquake was smaller than some in California's past, the damages were the highest in US earthquake history, with estimated economic losses of up to US$44 billion. The earthquake occurred in a heavily built-up area with a dense population and costly infrastructure, much of which was damaged. The Antelope Valley Freeway collapsed onto the Golden State Freeway, as well as an intersection of the Santa Monica Freeway.

Fifty-seven people died, there were over 9,000 injuries and 20,000 people were displaced from their homes. The toll could have been much higher, were it not for the fact that the earthquake occurred early in the morning and on a national holiday, Martin Luther King Day.

Figure 1: A span of the Antelope Valley Freeway collapses onto the Golden State Freeway below.

Source: U.S. Department of Transportation – Federal Highway Administration. Public Roads Online - Summer 1994, Vol. 58. No.1

Figure 2: A supporting column of the Santa Monica Freeway collapses.

Source: U.S. Department of Transportation – Federal Highway Administration. Public Roads Online - Summer 1994, Vol. 58. No.1

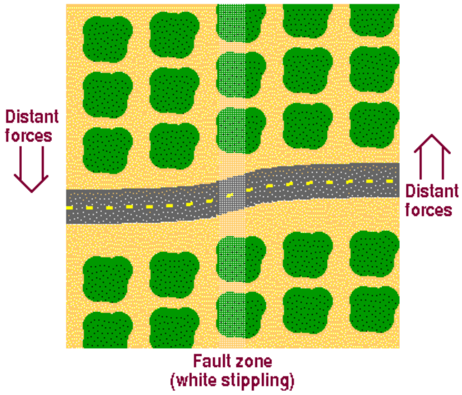
Introduction

Beneath the surface of the Earth are a number of large tectonic plates, the basic building blocks of the planetary crust. They have many fractures or faults where the blocks slide past each other and these areas generate earthquakes.

Plate movements are not steady and continuous, but rather sudden and abrupt. Earthquakes occur when these sudden movements release large amounts of energy, producing seismic waves (from the Greek *seismos*, meaning 'earthquake'). It is these waves that produce the destructive ground motions that cause earthquake damage.

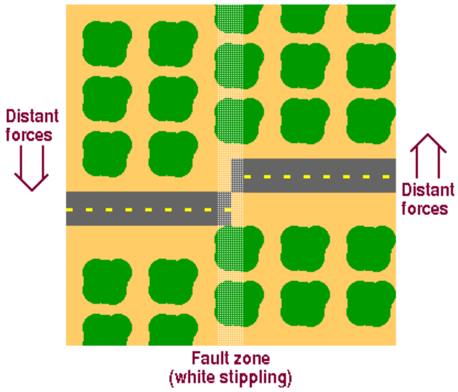
Earthquake motions are infrequent because the rocks are essentially 'locked' until they suddenly slip along a fault or fracture zone. As pressures or stresses on the rocks build, they deform until they suddenly move. This relieves the stress, and the rocks return to their original shape though they are now displaced.

Figure 3a: Stresses building on the fault prior to an earthquake deform the rocks.



Source: Institute for Crustal Studies: University of California at Santa Barbara – Understanding Earthquakes.

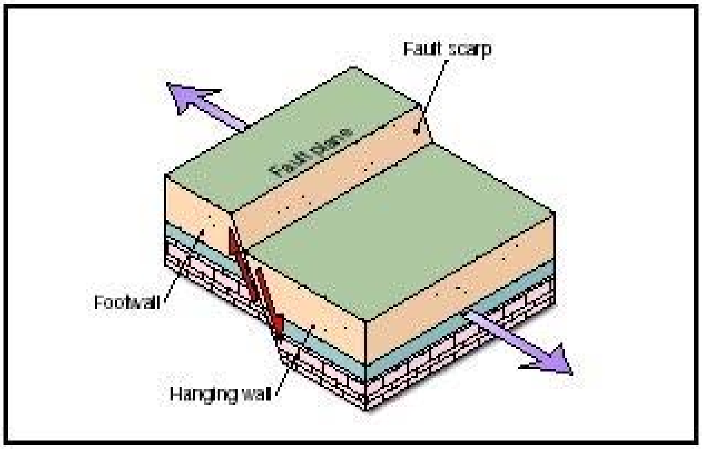
Figure 3b: After the earthquake, the rocks are no longer stressed, so they return to their original shape. The rocks, however, are now offset.



Source: Institute for Crustal Studies: University of California at Santa Barbara – Understanding Earthquakes.

There are different types of faults, some causing vertical ground motions, and others causing horizontal motions. Some cause both.

Figure 4: Two crustal blocks and a normal fault. The crustal blocks pull apart, causing a generally vertical motion. Note that the fault slips at the focus while the epicentre is on the surface.



Source: Science Clarified website – Fault.

The strength of an earthquake is estimated by its magnitude, an indirect measure of the energy released. Magnitude is measured on the Richter scale, named after its inventor seismologist Charles Richter. This scale is logarithmic, meaning that an earthquake of magnitude 5 is ten times larger then a magnitude 4, while a magnitude 6 is 100 times greater than a level 4 event. However, the Richter scale does not measure damage resulting from the earthquake. Instead, a 12-level damage scale called the modified Mercalli intensity scale is used to evaluate the degree of destruction (See Table 1).

Table 1: Earthquake Magnitude and Intensity

Richter Magnitude	Modified Mercalli Intensity	Characteristic Effects
less than 3.4	I	Recorded only by seismic instruments
3.5 to 4.2	II and III	Felt by some people who are indoors
4.3 to 4.8	IV	Felt by many people; windows rattle
4.9 to 5.4	V	Felt by everyone; dishes break, doors swing
5.5 to 6.1	VI and VII	Slight building damage; plaster cracks, bricks fall
6.2 to 6.9	VIII and IX	Much building damage; chimneys fall, house foundations move
7.0 to 7.3	X	Serious damage; bridges twisted, walls fractured, many masonry buildings collapse
7.4 to 7.9	XI	Great damage; most buildings collapse
more than 8.0	XII	Total damage; waves seen on ground surface, objects thrown into the air

Earthquake Hazards in Canada

Canada is fortunate to have experienced very few destructive earthquakes. Between 1,500 and 2,500 earthquakes occur annually in Canada, but only about 100 of these are greater than magnitude 3[1].

The largest Canadian earthquake in the past century was in 1949, when a magnitude 8.1 earthquake struck the Queen Charlotte Islands on the northwestern coast of British Columbia. The earth motion was strong enough to knock cows off their feet. A more recent magnitude 5.9 earthquake struck Quebec's Saguenay region in 1988, causing tens of millions of dollars in damage.

The most earthquake-prone area in Canada is the Pacific coast. There, tectonic plate boundaries near western British Columbia and in the Pacific Ocean immediately offshore create numerous fault zones with significant earthquake potential. In the past 70 years, over 100 earthquakes with magnitudes exceeding 5 have occurred offshore in the Pacific Ocean west of Vancouver Island.

Earthquakes also occur in eastern Canada along the St. Lawrence lowland and Ottawa Valley areas in southern Quebec and eastern Ontario. They also occur in the Artic Islands and offshore adjacent to the Maritime provinces. (Figure 6) Canada's deadliest earthquake occurred in 1929 when a magnitude 7.2 event triggered a tsunami that killed 28 people in southern Newfoundland (See Section 3.5: Tsunami)

[1] Public Safety Canada

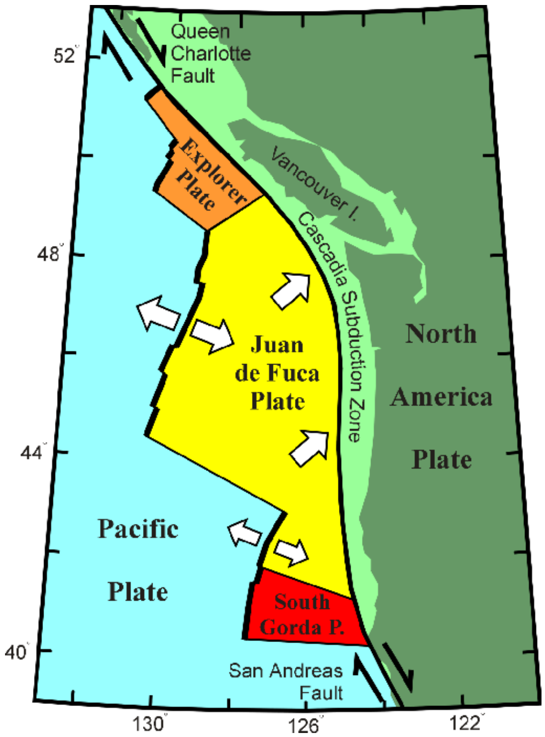
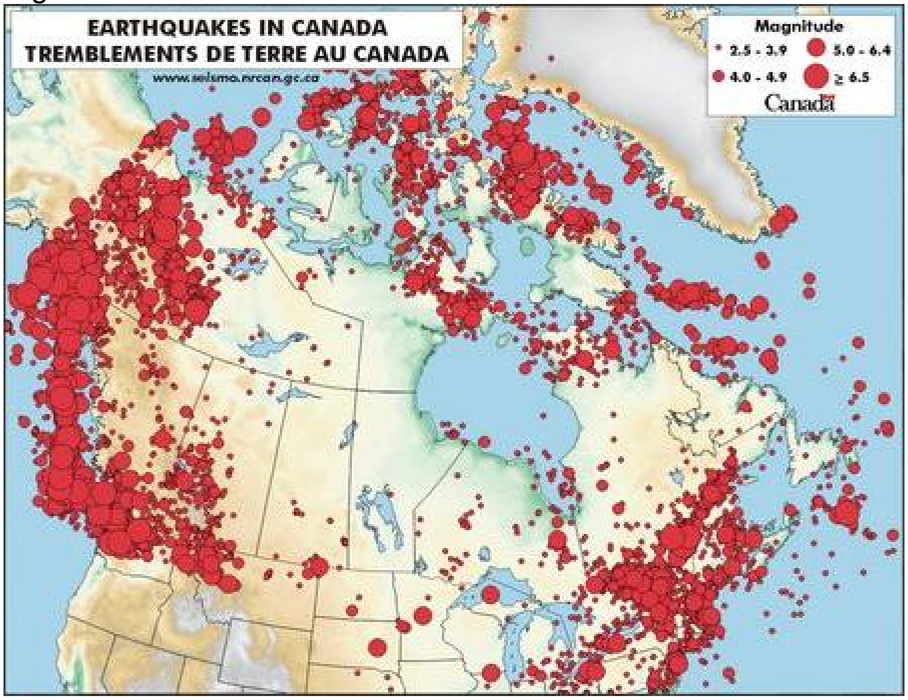


Figure 5: This diagram of tectonic plates off the west coast shows three types of margin activity. **Divergent margins** are spreading apart (opposed white arrows). **Convergent margins**, or **subduction zones**, are where an ocean plate moves below a continental plate (single white arrows). A **transform boundary** is where one plate moves past another in a generally horizontal direction (paired black arrows). Western Canada is one of the places where all three types of margins occur.
Source: Geological Survey of Canada.

Earthquakes can result in a variety of hazards:

- Ground shaking (both horizontal and vertical, depending upon the type of fault). This is the hazard that causes buildings to collapse, which is one of the main causes of death, injury and damage during these types of disasters.
- Tsunamis (if the earthquake occurs under water)
- Liquefaction (some types of soils take on properties similar to liquids when shaken. When this occurs buildings can fall over)
- Landslides
- Dam rupture
- Land level changes (See Figure 4)
- Amplification. In certain situations the ground shaking or building motion can be amplified in specific locations. This can occur due to particular soil and rock formations
- Building resonance. When the earthquake waves have a frequency similar to the natural swaying period of some buildings – as occurred in the Mexico City earthquake of 1985) – the effect of the ground shaking on those buildings can be magnified many times.
- Surface ground ruptures
- Fire following. It is common for earthquakes to rupture gas lines and other critical infrastructure. This can cause fires following the earthquake, and is one of the main concerns of the insurance industry to earthquake hazard. Damage from fire following can be greater than that from ground shaking.

Figure 6:



Source: Geological Service of Canada

Earthquake Mitigation

Earthquakes cannot be prevented but deaths, injuries and property damage can be. The risk from earthquakes can be reduced both at government / community and at individual levels.

Governments can establish and enforce building codes that increase the ability of buildings and other structures, such as bridges, lifelines and freeways to withstand earthquakes of a given magnitude. Older buildings can be retrofitted to become more resistant to ground shaking, though this can be expensive. The ultimate aim of retrofit is to stabilize a building or structure by connecting and reinforcing the understructure so that it will remain as secure as possible during an earthquake. The particular techniques used will depend upon the type of building and construction (e.g. wood frame, brick etc). In particular, bolting a building to its foundation is important.

Building codes depend upon knowledge of earthquake hazard, so it is important for governments and communities to have programs that increase our understanding of where earthquakes might occur, what kind of ground shaking and related hazards are likely to accompany them and how severe they are liable to be. It's important to remember, however, that failures may still happen if the quake is more powerful than allowed for in the building standards

For individuals, preparedness means planning to survive for at least 72 hours without any assistance.

- Know areas in your home that are safe and dangerous

Safe areas include:

  - Under heavy desks or tables
  - In hallways and archways
  - In corners of rooms
  - Dangerous areas include:
  - Near windows or mirrors
  - In doorways where doors can hit you. Unlike older structures, modern houses often have doorframes that are no stronger than anywhere else. (See "Earthquake Myths" below)
  - In the kitchen, where appliances and cupboard contents can be thrown about

- Take a first-aid course
- Consider purchasing earthquake insurance
- Understand the safe use of fire extinguishers, as fire is a very common occurrence in earthquake events
- prepare an earthquake toolkit with emergency supplies for your home. (See "Personal Preparedness" below)
- Note locations of emergency supplies, tools and equipment
- Develop an emergency plan that includes evacuation measures if needed. Share your emergency plan with your neighbours.
- Prepare a pack of emergency supplies for evacuation for your home, car and office.
- Practice evacuation and ensure that all family members understand their roles
- Ensure that children know what to do at home and at school. Familiarize yourself with your school's Earthquake Plan
- Plan what to do if the family gets separated during an earthquake; arrange an out-of-area contact for each family member and have them carry the contact information with them
- Make sure that all family members understand how to turn off gas, electricity, and water. Don't shut the gas off unless there is a fire. If the gas is shut off, don't turn it on again—let a qualified technician do so
- Make sure family members know when and how to request emergency assistance
  - know that emergency telephone numbers are inside the front cover of the telephone directory
  - know that emergency services (fire, police, ambulance/ EMS) are to be used only in extreme emergencies, as such services will be under extremely high demand
  - know to follow emergency broadcast instructions and look to authorities for guidance

Reducing Earthquake Vulnerability

Individuals can take measures to make their homes less vulnerable to damage during an earthquake. For example, anchoring file cabinets and bookcases to walls and restraining heavier items like water heaters, computer monitors and appliances, can prevent injuries or property loss. It's also a good idea to attach picture frames and mirrors to long-shank, open-eye hooks that penetrate walls and are less likely to fall out.

The federal emergency preparedness agency, Public Safety Canada (PSC) offers self-help information on how Canadians can prepare for an earthquake in their community. Information is available on the PSC "Get Prepared" website, as part of 72 hour preparedness initiative.

Sécurité publique Québec offers information for Québec youth on how to prepare for earthquake hazards, available in both French and English. Information is available on the Sécurité publique website concerning "Civil Protection for Youth".

The Government of British Columbia makes earthquake preparedness information available through the Provincial Emergency Program. Information is available on the BC Provincial Emergency Program website, under the heading of "Earthquake Preparedness"

Personal Preparedness

The Canadian Centre for Emergency Preparedness (CCEP) is a not-for-profit organization devoted to raising awareness of the risks of natural hazards such as earthquakes. CCEP encourages and promotes preparedness to individuals, communities and organizations, in both government and the private sector. Their aim is to reduce the risk, impact and cost of natural, human-induced and technological hazards and disasters. CCEP provides a variety of information on all aspects of preparedness, such as how to create an Emergency Plan, or how to prepare an Evacuation Pack or an Earthquake Toolkit. Information is available on the CCEP website.

Earthquake Myths

Popular myths suggest that earthquakes…

1. …happen in the morning. Even in earthquake-prone California, evidence of this is nonexistent. Many events, including the Northridge earthquake, have happened early in the day, but a similar number have happened at other times.

2. …can be caused by tides. Some believe that the same planetary forces that cause tides can cause earthquakes. In fact, careful analysis of tides and earthquake occurrence shows no significant relationship between the two.

3. …occur when it's hot and dry. Earthquakes happen in all types of weather.

4. …which are small and frequent protect you from big ones. Some people feel that frequent small earthquakes release the stresses that would otherwise be released in a single catastrophic event. In fact, small earthquakes can sometimes be precursors of bigger ones.

5. …are safer if you stand in a doorway for the duration. This is true for an old-fashioned adobe house with reinforced doorframes, but not for a modern house. Modern houses frequently have doorways that are no stronger than the rest of the structure. In fact, by standing in a doorway you could be injured by a swinging door or panicked people trying to exit.

6. …are becoming more frequent. The number of earthquakes of magnitude 6 to 7 and greater has actually been fairly constant over the past century. What has changed is the ability to detect and be aware of earthquakes, especially weaker ones, due to improved technology and increased dissemination of information through the media. However, the impacts from these earthquakes may be increasing due to urbanization.

7. …are not dangerous where modern building codes exist. This is not true for two reasons. Firstly, older buildings are generally not retrofitted as a result of new codes. Secondly, nature can produce earthquakes stronger than any codes will generally design for. In addition, sometimes earthquakes produce ground motions that act in unexpected ways. Examples of this include the 1995 Kobe earthquake in Japan and the 1994 Northridge earthquake in California.

8. …are when the earth splits open and swallows people, cars and houses. This is generally not true, although movement and settling of the earth can cause fractures or fissures that can open up. But fire is a much more common danger; earthquakes frequently upset stoves and fireplaces, rupture gas mains and interrupt electrical power. Fires are often difficult to put out because of the damage and chaos caused by the quake, interruption of water supplies, and the extreme demands placed on emergency services. Earthquake damage will usually include a number of structures partially or totally destroyed by fire.

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- Geological Survey of Canada

3.2 Geomagnetic Storms

March 6, 1989. The sunspot was dark and large enough to hold 70 Earths. As astronomers watched it through their specialized instruments, another spot suddenly appeared in its middle, glowing white-hot against the orange-yellow sun and growing ever larger until it spanned several hundred thousand square kilometres on the solar surface. Suddenly, the white spot exploded outward, ejecting billions of tonnes of solar material into space in an explosive eruption known as a solar flare.

Most of this material missed Earth because the sunspot was directed away from the planet on March 6. Four days later, it was a different story. With the sun's rotation, the sunspot was now aimed directly at Earth. The flare, 36 times the size of the planet, ejected a flood of radiation and dangerous high-energy particles that showered down on Earth over the next three days.

When these particles arrive in such tremendous quantities, they generate a **geomagnetic storm**. On March 13, the largest such storm in at least 30 years occurred as the massive wave of solar radiation swept over the planet.

The storm wreaked havoc on a grand scale. The uppermost fringe of Earth's atmosphere, heated by the blast of solar radiation, expanded like a balloon and came into contact with low-flying satellites. The resulting drag caused the satellites to fall into lower, faster orbits, creating tracking and control problems for many satellites including Skylab, the first space station.

The March 13 geomagnetic storm also damaged spacecraft such as the GOES-7 weather satellite. A US Department of Defense satellite began a fatal fall to Earth. Meanwhile, astronauts aboard the Space Shuttle Discovery, which was launched that morning, were forced to delay spacewalks that would have exposed them to higher radiation levels outside the spacecraft.

On Earth, the electrically-charged particles interacted with the magnetic field to produce transient electric currents that affected pipelines and electrical transmission systems, particularly those closer to the north magnetic pole. Communications systems also suffered and the transient currents even paid house calls: alarmed residents reported electric garage-door openers opening and closing on their own.

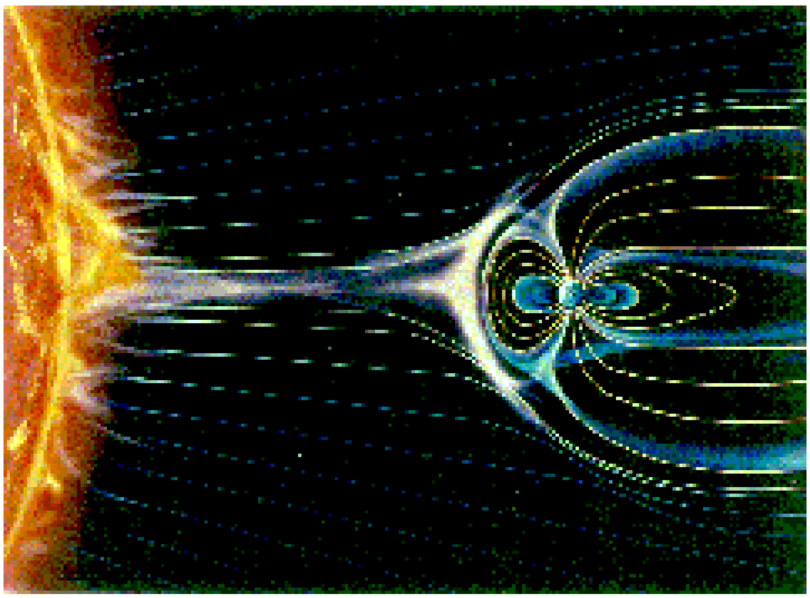
The largest impact occurred in Québec, which experienced a massive system failure of Hydro-Québec's transmission lines, plunging six million residents into cold darkness for nine hours. Most of the failure took only fifty-nine seconds to occur.

Introduction

A solar flare is an explosive ejection into space of hot gaseous matter from inside the sun. The plume of ejected material can extend hundreds of thousands of kilometres out into space and result in discharges of solar radiation and energized particles that can affect the earth. These flares are often associated with sunspots, which appear and disappear from the sun's surface in unpredictable ways, but generally follow an 11 year cycle. Their main impact on the earth is due to geomagnetically induced currents (GIC). Though some particles can reach the earth in as little as 10 minutes, magnetic storms on earth will generally begin from one to two days after the flare, depending upon the speed of the solar wind.

Fortunately, Earth is largely protected from solar flares by its sphere of magnetism or *magnetosphere*, which deflects much of the solar material around the planet (See Figure 1).

Figure 1: Due to its electrically-charged state, ejected solar material is deflected by the Earth's magnetosphere, shown here as bubble-shaped zones around the Earth.



Source: NASA.

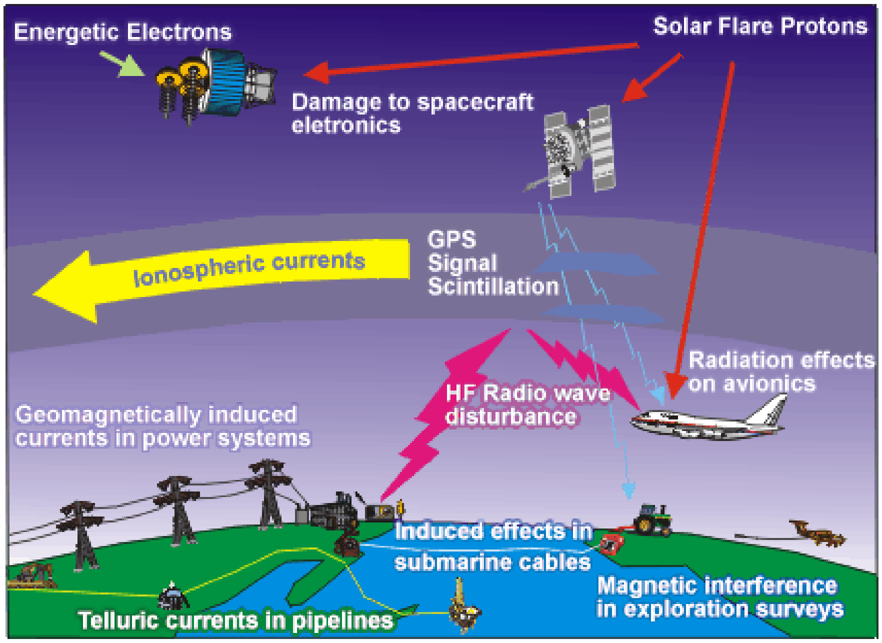
The most visible evidence of this process is the aurora borealis or northern lights in the Northern Hemisphere and the aurora australis in the Southern Hemisphere. These beautiful dancing lights are caused by the collision of high energy solar particles with the magnetosphere. The 1989 geomagnetic storm produced some of the strongest and most beautiful auroras in decades; they were seen as far south as Mexico, Jamaica, and the Caribbean Island of Grand Cayman (See Figure 2).

Figure 2: An enormous aurora appears as a white band in this image of the eastern United States, taken by the US Department of Defense F9 meteorology satellite on 14 March 1989.

Source: US Department Of Defense.

GICs sometimes wreak havoc with technological systems, such as those depicted in Figure 3. GIC impacts reach a peak during the equinoxes in March and September. At these times, the auroras are brightest and most visible, but adverse effects are also most likely to occur.

Figure 3: Some of the technological systems that can be disrupted by geomagnetic activity.



Source: Canadian National Geomagnetism Program, Geological Survey of Canada.

Impacts of Geomagnetic Storms

Society is becoming increasingly vulnerable to geomagnetic storms, due to its increasing reliance upon, complexity of, and use of technological systems that can be affected by these events. For the public, the most significant effects of geomagnetic storms are those that impact electrical transmission systems. Transmission lines provide long conductors on the surface of the Earth that allow GICs to flow. In Québec, for example, there are thousands of kilometres of electrical power lines spanning the province from northern James Bay to southern cities like Montréal.

During the 1989 geomagnetic storm, electrical utilities across North America reported abnormal electrical effects, as currents produced in the atmosphere were interfering with power transmission. This produced wide voltage fluctuations, causing line-protection devices to 'trip-out,' or deactivate, resulting in numerous failures. There were also electrical blackouts in some locations. Transformers were particularly susceptible: powerful eddy currents created 'hot spots' that caused them to burn out.

Pipelines are also long conductors and thus are affected by geomagnetic storms. The main concern in these cases concerns pipeline corrosion caused by electrochemical reactions. This weakens the pipes, making them more vulnerable to breaking. Pipeline breaks are unsafe, costly and environmentally harmful.

Orbiting satellites are also vulnerable to geomagnetic storms. The Canadian communications satellites Anik E1 and Anik E2 both suffered damage during a strong geomagnetic storm in January 1994. It took eight hours for engineers at Telesat Canada to regain control of Anik E1 and many months to regain control of Anik E2.

Coping with Geomagnetic Storms: Preparedness

The 1989 geomagnetic storm cost Hydro-Québec tens of millions of dollars in direct damages and loss of sales. The loss in gross domestic product for the province as a whole was much more.

Preparedness is the key to reducing the impact of geomagnetic storms. Changing the design of technical systems is one important way to reduce vulnerability. For example, in the aftermath of the 1989 event, Hydro-Québec installed devices called *capacitors* on their power lines to block the flow of GICs.

Importing electrical power from other utilities to compensate for unreliability on the power grid during a geomagnetic disturbance is another possibility. But since such disturbances usually affect entire continents, other utilities may be dealing with problems of their own and may not be able to offer much assistance.

Advance warnings also play an important role in coping with geomagnetic disturbances because they allow people to implement short-term strategies that minimize system vulnerability. For example, system operators can alter patterns of electrical generation and routing, or defer maintenance shutdowns on equipment that might be needed in the event of failures.

Public Awareness of Geomagnetic Storms

Individuals should be aware that, regardless of preventative measures taken by electrical utilities, electrical failures can still occur during a geomagnetic storm. Outdoor and marine enthusiasts who use a Global Positioning System (GPS) receiver should be aware that geomagnetic disturbances can impair the reliability of GPS information. Aircraft navigation systems may be similarly affected.

People who depend on technological systems such as radio, GPS, satellite communications or aircraft avionics should keep themselves informed about geomagnetic conditions. This is also important for those whose activities require an uninterrupted supply of electrical power.

Further Information

The Canadian National Geomagnetism Program, operated by the Geological Survey of Canada, maintains a watch on geomagnetic hazards in Canada. Its goal is to study and understand solar conditions in order to provide warnings to interested parties. It issues hourly forecasts of geomagnetic conditions across the country.

A simplified version of the Space Weather Forecast is issued online through Space Weather Canada

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3.3 Landslides

On the evening of May 4, 1971, a resident of Saint-Jean-Vianney, Québec, calls a friend to say she's felt an earthquake. She notes that she can see the lights of Chicoutimi, a town normally hidden from view by a hill, but oddly hidden no longer.

Meanwhile, a bus driver stops and watches in horror as the ground collapses under his bus. It continues collapsing farther and farther up the street. As the passengers run out of the bus, and away from the sinking terrain, they and the driver begin banging on the doors of houses sitting in the path of looming destruction.

In just five minutes, the bus, many cars, and 34 homes are consumed in the landslide. Thirty-two people lie dead, many of them children, in one of the most destructive landslides in Canadian history.

Introduction

A landslide is a downward movement of rock and soil under the influence of gravity. Though frequently unexpected, landslides are quite common in Canada. There are several different types involving different kinds of earth materials, and they display a wide range of behaviours.

Rock avalanches are a type of landslide that involves mass movements of greater than one million cubic metres of rock. They are fast, often moving hundreds of kilometres per hour. This term was first used to describe the 1903 Frank slide in the Crowsnest region of Alberta, the worst landslide disaster in Canadian history. (See sidebar: "The Frank Rock Avalanche.")

Rapid rockslides are similar to rock avalanches but smaller; they occur when a mass of rock slides along a surface below the ground, such as another rock layer.

Rockfalls occur when small rock masses and fragments break away from slopes and tumble down. They often create a hazard to motorists on roads and highways that are downslope of the fall.

Debris avalanches and *debris flows* occur when large boulder and gravel-sized rocks are transported across terrain within a finer-grained volume of material; they can appear to flow like a fluid. Such events occur frequently in the dry terrain of the Cordillera of western Canada, as well as in the Appalachian and Laurentian Mountains in eastern Canada.

Not all landslides are fast moving; in fact, the most common types in Canada are slow slides of both rock and soil. These occur when a mass of material slowly moves downslope at speeds on the order of centimetres per year. They can occur beneath the surface in mountainous areas, deforming mountain surfaces in a process called *sagging*.

As blocks of earth involved in slow slides break, internally deform and disintegrate, they can form slow or rapid *earthflows*. These commonly occur in areas where the soil is rich in smectite, a type of clay that is weak and prone to instability.

Rapid earthflows are common in areas rich in sensitive marine sediments such as *Leda clay*, found in the Ottawa area and the St. Lawrence Lowlands. Other types of sensitive marine sediments can be found in British Columbia. Sensitive sediments are unusual because they can rapidly lose strength when the material has been abruptly shaken or otherwise physically disturbed causing it to flow like a thick fluid.

Failures in sensitive sediments can cause retrogressive slumps, where the ground collapses in the direction opposite to that in which the debris is flowing. It's like an 'upstream' progression of collapsed slopes; as one 'upstream' block of earth collapses and flows rapidly in the 'downstream' direction, it in turn destabizes the next upstream block, causing the latter to fail, and so on. This is what happened at Saint-Jean-Vianney, Quebec, where 'upstream' houses were progressively engulfed as the ground surface collapsed beneath them in a rapid series of failures.

Landslides can also occur in *permafrost* (permanently frozen ground), which is common in northern regions of Canada.

Landslide hazards in Canada

Landslides such as those at Saint-Jean-Vianney, Quebec and Frank, Alberta may seem like entirely natural phenomena with little human input, but human activities often influence the degree of risk from landslide hazards. Often these risks are increased, directly or indirectly, by human modification of the landscape or by building in the path of potential landslides. For example, landslides can be triggered by building on unstable slopes, by construction or mining activity that undercuts or overloads dangerous slopes, or by modifications that redirect the flow of surface water or elevate groundwater levels.

Landslides can also occur in man-made slopes such as mining pits, landfills, embankments and excavated slopes. Some of the largest landslides in Canada have occurred in such places, although they are often thought of as engineering failures.

Landslides can also occur underwater, causing destructive waves. In 1929, an offshore earthquake in the Grand Banks area of Newfoundland triggered an enormous submarine landslide that, in turn, caused a *tsunami*, a massive water wave that destroyed villages and killed 28 people (See Section 3.5: Tsunami).

Coping with Landslides

The main strategies for mitigating landslide risk are:

1. Avoidance
- Hazard identification through geotechnical assessment of sites
- Zoning of landslide hazards
- Slope management to reduce hazard

2. Prevention / stabilization
- Preventing destabilization of marginally stable slopes
- Stabilizing unstable slopes

3. Protection
- Construction of physical barriers to protect roads and buildings[1]
- Implemented when it is either impossible or too expensive to stabilize slopes

4. Expropriation
- Physical removal of threatened structures from hazardous areas
- Can be expensive and controversial

Landslides frequently cause deaths, injuries and property damage. A single landslide can affect communities, forests, roads, dams, fisheries, water sources, or other valuable resources for years to come. This is why numerous mitigation projects have been started to prevent losses of life and property, chiefly in Quebec and British Columbia.

One protective strategy is building defensive dykes to protect communities, such as was done in Port Alice, British Columbia. Others include changing surface water drainage routes and planting vegetation on vulnerable surfaces to stabilize the ground.

Relocating communities at risk is another option. The town of Lemieux, Ontario, was relocated when geological studies demonstrated it was at serious risk of a landslide because of underlying sensitive sediments. A landslide did indeed occur at this location in 1993, so the move avoided potentially serious consequences.

[1] After damaging debris flows in 1973 and 1975, the town of Port Alice on Vancouver Island built defensive dykes to protect itself. Defensive structures have also been built along Howe Sound, north of Vancouver.

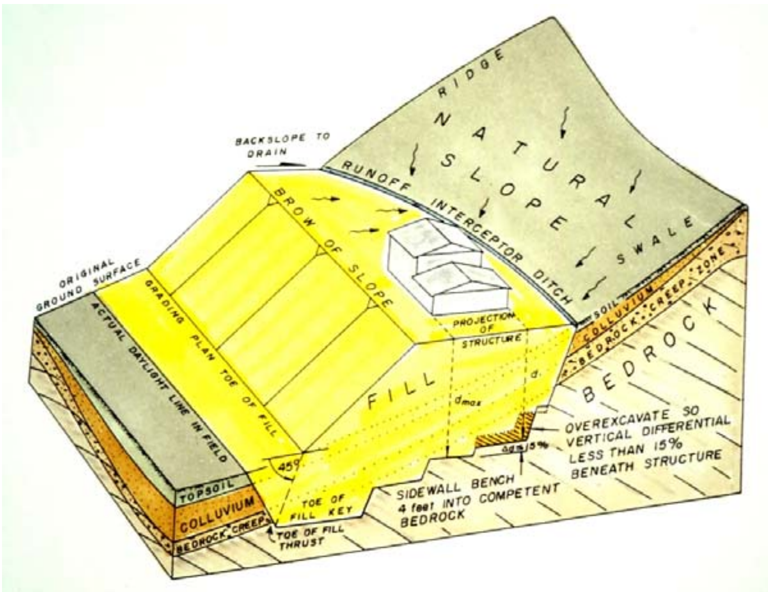
It was a different story in Garibaldi, British Columbia. In 1980, the town was ordered vacated by the provincial government because geological studies indicated there was a landslide risk from a geological feature called 'The Barrier.' This action was contested in the courts, and thus far there has been no landslide. However, although the risk remains, many area residents are advocating re-opening the site to development, citing the high value and attractive nature of the land[1].

Figure 1: This 1991 rockslide closed British Columbia's Sea-to-Sky Highway for 12 days and cost $7 million for repairs and many landslide-prevention geotechnical structures

Source: British Columbia Provincial Emergency Program

Decreasing vulnerability to landslide risks may also require taking precautions during the construction of buildings. Some slopes require careful design for road or building development in order to avoid instability problems. If this is not done the chances of landslide occurrence can actually increase (See Figure 2 and Table 1). Indicators of possible slope stability problems are listed in Table 2.

Figure 2: This house was built on a slope in such a way as to increase landslide risk. Soil excavated from upslope was placed downslope as fill, creating a flat pad for the house. This increased both the angle of the slope and the weight on it. Soil-stabilizing vegetation was also removed, which could lead to more water being absorbed in the ground, thus further destabilizing the slope.



Source: Science vs. Advocacy

Table 1: Construction Factors influencing Landslide Risk	
Construction factor	- Excavation or undercutting a slope base
	- increasing slope angle
	- adding fill material or buildings to the top of a slope
	- changing surface water drainage patterns
	- adding excess water to soil/ rock
	- removal of competent (solid) rock
	- removing vegetation

***Table 2*: Possible Indicators of Slope Instability**	
Physical Indicators	- saturated soils/ seeps springs where none were known to exist
	- growth of wetland vegetation on lower parts of slopes
	- fresh cracks/ breaks in soil surface
	- ground surface bulges in the lower parts of a slope
	- structural defects: misaligned roads/ sidewalks - cracked foundations/ doorframes/ walls
	- tilted retaining walls/ trees/ telephone poles
	- leaking water/ sewer lines

Mitigation:

Communities can reduce their risk by:

- educating the public about landslide risk and how to reduce it
- conducting landslide risk assessments and either zoning high risk sites such that they can not be developed, or
- by ensuring that other mitigation measures are used.

Individuals can reduce their risk if they:

- learning about and understanding the nature of local geology and geological hazards

- consulting a professional: discuss potentially hazardous locations and building plans with an earth scientist or geological engineer

- requesting landslide hazard information from a municipal/ regional/ district planner prior to land purchase; ask for assistance in understanding this information if necessary

- proceed with land purchases, property subdivisions, and construction activities only when all relevant questions concerning the hazards have been answered

- consult a provincial geological survey or the Geological Survey of Canada:

Sidebar: The Frank Rock Avalanche

4:00 a.m. April 29, 1903. Frank, Alberta. In the cold early morning air, the trainmen steadily went about their work, loading coal from the Turtle Mountain mine. Soon they would be on their way, leaving the sleeping town of Frank behind.

Towering over 900 metres above the town of 600 inhabitants, Turtle Mountain was the stuff of legends. Aboriginal Blackfoot and Kutenai lore held that the old mountain had a mind of its own -- and that it sometimes moved of its own accord. So powerful was the legend that local natives refused to camp at its base. That night the mountain was cold, dark, and quiet. Or so it seemed.

High above, an enormous rock boulder teetered and fell over, bounding down the mountainside. Hearing the noise, the train engineer was instantly alert; his experience in the Crowsnest Pass made him acutely aware of the hazards of the rugged countryside. Numerous snow avalanches, broken rails and rock falls had made this section of the Canadian Pacific Railway notoriously troublesome.

As the train moved out of the mine siding at walking speed, trouble was brewing again. Another boulder toppled free and crashed down the mountain-then another and another. The engineer yelled to his crew to jump aboard the locomotive and forced the throttles wide open, trying to outrun the danger. The train hurtled toward the railway bridge on the Oldman River.

At that moment, the quiet of the night was broken by an enormous thunderclap of sound. Eighty-two million tonnes of rock broke away from the mountain, forcing a wall of icy air ahead of it as the enormous mass began its descent. A rock avalanche of mammoth proportions was underway.

The mine entrance at the base of the mountain was obliterated. So was the boiler plant that provided power to the community. A livery stable, a small dairy farm, a cemetery, a construction camp, a boxcar of mining dynamite, as well as houses and bunkhouses with their occupants asleep in their beds-all were buried, some 30 metres deep. A blacksmith shop and a railcar were thrown more than three kilometres across the valley. Moments after the speeding locomotive and its crew had safely crossed the Oldman River bridge, the rock avalanche destroyed one of its abutments, sending it into the river.

The explosive blast of frigid air blew away houses, temporary shacks, buildings, and tents. People were hurled hundreds of metres. The rock avalanche traveled 3.1 km and came to rest 150 metres above the valley floor on the opposite valley side. The air was filled with choking dust. The greatest landslide disaster in Canadian history was over in less than 100 seconds. Fourteen hours after the slide, 17 trapped coal miners dug their way to freedom. At least 70 men, women, and children lay dead, most buried under tonnes of rock. Only 12 bodies were ever recovered. The disaster might have been much worse, had not a Canadian Pacific Railways brakeman clambered over the debris to flag down a passenger train, thus keeping it from slamming into the fallen rocks.

See Frank Slide Interpretive Centre website for more information

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- Geologie Quebec

- New Brunswick Department of Natural Resources

- Nova Scotia Department of Natural Resources – Mineral Resources Branch

- Newfoundland & Labrador Department of Natural Resources - Geological Survey

3.4 Snow Avalanches

Just before 2:00 a.m. on January 1, 1999, a party in the northern Quebec community of Kangiqsualujjuaq was coming to a close. It was a couple of hours after the traditional Inuit shaking of hands to welcome in the new year. Between 400 to 500 of the community's 650 residents were enjoying each other's company in the school gymnasium, with games, music and Scottish-style dances.

Within seconds, their world was literally buried. Without warning, the wall of the gymnasium collapsed, burying many inside under two metres of snow. The force of the impact was devastating, even driving a parked snowmobile into a classroom.

Stunned by the sudden tragedy, many began to frantically dig through the snow to free trapped victims, their efforts lit by the glow of the still-burning gymnasium lights. For some, rescue would not come in time. Several suffocated – the most common cause of death associated with avalanches. Nine people lost their lives and 25 were injured.

Introduction

Dozens of damaging snow avalanches occur annually in Canada and the United States, and the death toll is rising. Many are as large as the Kangiqsualujjuaq event but public awareness of avalanche risk has lagged behind the increasing fatalities they cause.

For many Canadians, heightened awareness was triggered by the avalanche-related drowning in British Columbia of Michel Trudeau, the youngest son of former Prime Minister Pierre Trudeau, only a few months before the Kangiqsualujjuaq tragedy. However, there have also been other avalanches that resulted in large losses of life that have also captured public attention.

In January 2003, seven heli-skiiers lost their lives in the Selkirk Mountains of British Columbia, killed by an avalanche on the Durrand Glacier (see Sidebar: Avalanche Deaths). Twelve days later, seven children from the Strathcona-Tweedsmuir School in Alberta died in another tragic avalanche. The Strathcona-Tweedsmuir avalanche occurred in Glacier National Park, located between Revelstoke and Golden, and home to Canada's famous Rogers Pass. In fact, Rogers Pass itself has a history of deadly avalanches, which have resulted in the deaths of over 200 Canadian Pacific Railway employees between 1885 and 1916. It was also the site of a particularly deadly avalanche in 1910 that destroyed a train, taking 62 lives. Ironically, the 1910 avalanche occurred while railway employees were clearing away snow from a previous avalanche on

Mount Cheops -- the same mountain that 93 years later would take the lives of the students of the Strathcona-Tweedsmuir School.

Avalanche Geography and Risks

Snow avalanches pose a threat to human lives, property, transportation corridors and infrastructure, and resource industries. There are approximately 1.5 million potentially destructive avalanches in Canada every year, but only 2% to 5% of these occur near communities, transportation routes or recreational areas.

Most Canadian avalanches occur in western Canada, primarily in British Columbia, the Yukon Territory, and Alberta, where the most mountainous regions of Canada are located. However, there have also been avalanche fatalities in Newfoundland, Quebec, Ontario, Nunavut and the Northwest Territories.

In the past, avalanche fatalities were largely related to transportation and mining activities. Today, most deaths are recreation-related, accounting for 109 of the 125 Canadian avalanche fatalities from 1990 to 2000. In Canada, an average of 8.5 fatalities occurred annually from 1970 to 1996; however, during the 1990s the fatality count rose to 12.5 per year. There have been more than 600 deaths from this hazard since the mid-1800s. Given this trend, it’s important for the public to understand the causes of avalanches and how to avoid them or to reduce avalanche risk.

The Causes of Avalanches

Snow avalanches occur when a snowpack loses its grip on an inclined surface, such as a hillside. The snowpack slides downward under the influence of gravity, entraining air and more snow as it moves downslope. It can reach speeds as high as 125 km/h in wet snow and 250 km/h in dry snow.

There are two major types of avalanches. Loose snow avalanches start at a single point on a slope, usually at or near the surface of a snow cover. As the snow moves downslope, more snow is entrained in a spreading triangular pattern. Far more dangerous are slab avalanches, which occur when a large slab of snow starts to slide downslope.

In either case, a triggering mechanism must start the snow moving. It could be a natural source, such as a rapid temperature change, rain or snow precipitation, wind, or an earthquake or earth tremor. But artificial triggers can also start an avalanche, including skiers, snowboarders, and snowmobilers, as well as vibrations or shock from explosives used to deliberately set off controlled avalanches. A rating system for snow avalanches are shown in Table 1.

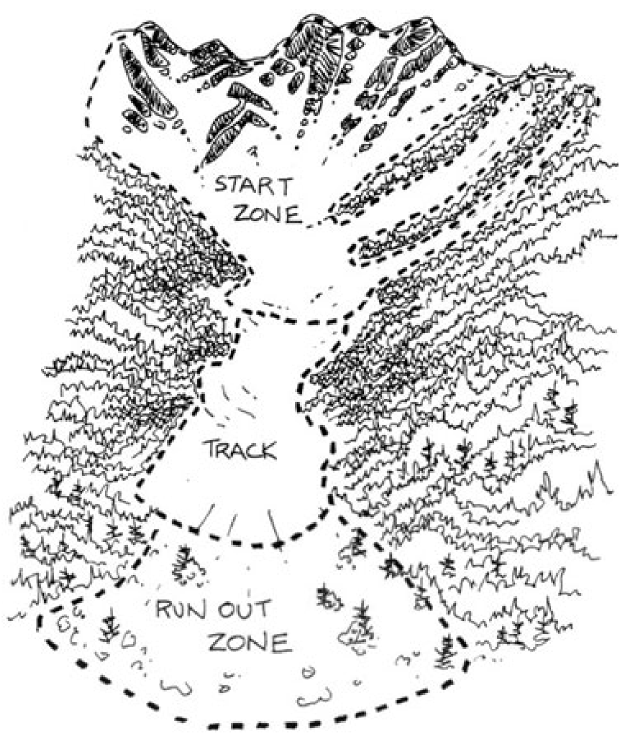
Anatomy of an Avalanche

Avalanches have three parts: the *start zone,* where snow breaks away and begins its slide downslope; the *track*, the downslope pathway that the avalanche travels; and the *runout zone,* where the snow and debris finally come to a stop (See Figure 1).

Avalanches come in various sizes (See Table 1) but smaller ones occur more frequently; the vast majority contain less than a hundred to a few thousand tonnes of snow. The largest avalanche on record was at Rogers Pass, with a mass of 404,000 tonnes.

The main factor influencing the development of an avalanche is the angle of the slope or incline on which snow starts its descent. Most avalanches occur on 30° to 45° slopes. However, a June 1970 avalanche that destroyed a tank farm in Ungava Bay, Quebec, began on only a 16° incline. Runout zones of a kilometre or can be present where inclines are up to 10°.

Figure 1: Anatomy of an Avalanche. Diagram shows the start zone, the track, and the runout zone.



Source: Canadian Avalanche Association.

Table 1: Canadian Snow Avalanche Size Classification System

Size	Description	Typical Mass (tonnes)	Typical Path Length (metres)	Typical impact Pressures (kPa)
1	Relatively harmless to people	Less than 10	10	1
2	Could bury, injure, or kill a person	100	100	10
3	Could bury a car, destroy a small building, or break a few trees	1000	1000	100
4	Could destroy a railway car, large truck, several buildings or a forest with an area up to 4 hectares	10 000	2 000	500
5	Largest snow avalanche known; could destroy a village or a forest of 40 hectares	100 000	3 000	1 000

Source: *McClung and Schaerer, 1981*

Controlling Avalanches

In Canada, control techniques that can be undertaken by communities involve artificially triggering avalanches. This is commonly used in controlled ski areas and along some transportation corridors. Avalanche control personnel use explosives to produce the vibration and shock needed to start minor avalanches, thereby relieving smaller snow buildups before they become very large, heavy, and dangerous.

Reducing the Risk of Avalanche Accidents

Understanding the factors that contribute to snow avalanche accidents can help minimize danger for outdoor recreationists. Avalanche hazard is weather-related. Changes in precipitation and temperature, particularly if they've occurred rapidly and recently, can greatly increase avalanche risk. Danger increases with heavy snowfall, rain, drifting snow and/or warm/ warming conditions.

The surface crust on a snowpack provides much of its strength and stability; as sunshine and warmer temperatures melt this crust, dangerous instability results. Therefore daytime temperatures and the amount of sunshine the surface is exposed to are critical considerations. Warm nights can also result in instability that increases the avalanche danger.

Stable snow conditions typically result from a series of clear days and clear nights, with overnight lows below freezing. By contrast, unstable snow conditions typically result from a series of warm days with cloudy and warm nights; these warm conditions often prevent the overnight formation of a frozen surface crust needed for snowpack stability.

Sun-exposed, low-elevation areas are more hazardous; high-elevation, north-facing areas that face away from the sun are less so. Visual clues to avalanche danger may be as obvious as recent fresh avalanche deposits. There are also less visible clues, such as weak layers of older snow buried deep in the snowpack that may remain hazardous – even several weeks or months after the snow has fallen.

*Trip planning***:** Get as much advance information as possible. Maps, guidebooks and information sources such as the Canadian Avalanche Association (CAA) can help recreationists better prepare for their trip. It would be a good idea to speak with people who've had experience in the areas you plan to visit.

Information on snow stability in western Canada is provided by recorded telephone messages, posted notices at stores or information centres, as well as on the Internet. For example, the CAA operates the Canadian Avalanche Centre in Revelstoke, British Columbia, which publishes the Public Avalanche Bulletin.

Avalanche safety courses are also a good idea. The CAA has established nationally recognized avalanche course standards and maintains a list of qualified avalanche safety instructors.

*Selecting routes and understanding terrain***:** Route selection is important, particularly in the spring. Evidence from avalanche accidents shows that many recreationists are ignorant of basic rules regarding how to evaluate terrain for avalanche risk.

For example, they should be aware of not just the overlying snowpack, but also the underlying terrain. Entering terrain traps such as gullies when the snowpack is unstable can result in deep burial if an avalanche should occur. And being buried is not the only risk: unstable slopes that suddenly release have been known to carry people over cliffs, into rocks, or into trees. Michel Trudeau, mentioned earlier, was swept into a lake. If the runout zone is inaccessible, then so is anyone caught in it. Rescuers cannot help a person they cannot reach, regardless of how shallow the snow is.

Human/ Psychological Factors: When groups of people travel in snowy terrain without a designated leader, they often make poor decisions. Those with less experience may find themselves making decisions about snowpack stability and the safety of chosen routes. Yet, while leadership is important, the entire group should understand and feel comfortable with the decisions made.

Warm, sunny weather in snowy country is beautiful and picturesque but it can also distract attention from the task of evaluating avalanche hazards. Often the goal of reaching the day's objective can override good judgment when confronted with deteriorating weather and increasing avalanche risk. Being aware of these psychological factors can help recreationists avoid these pitfalls.

Safety and Search & Rescue: There are ways to increase safety in avalanche country. For example, crossing possibly unstable slopes one at a time, or while well spaced apart, can reduce the likelihood of setting off an avalanche. Removing ski-pole straps tends to reduce the tendency to get buried if one does happen to be caught. Recreationists should always carry safety items such as portable shovels, probes and avalanche transceivers, which are electronic devices that can be used to locate a person buried under snow. Air filtration systems, avalanche buoyancy systems, and newer technological advances are also available for recreationists looking to increase their chances of avalanche survival.

Motorists driving through avalanche-prone areas should heed posted avalanche hazard warning signs as a matter of course. Some roads and highways remain active avalanche zones even in the summertime, so motorists should always heed signs that warn them not to exit their vehicles.

The Changing Nature of Avalanche Risk

Between 1870 and 1979, there were at least 114 fatalities in Canada caused by snow avalanches related to mining activities. In 1965, an avalanche that killed 26 at the Granduc Mine in British Columbia entirely changed the way in which avalanche hazards are addressed in mining operations in Canada. Modern avalanche control methods adopted in the wake of this event reduced mining-related avalanche fatalities significantly, and there have been none since 1972.

Today, it is skiers, snowboarders, and particularly snowmobilers who are at the greatest risk of avalanche fatality. Of 125 avalanche fatalities in Canada between 1990 and 2000, 109 were recreation-related. The number of deaths among those who choose to ski outside of controlled ski areas has been increasing as well. In addition, snowmobilers make up an increasing percentage of avalanche victims. The proportion of snowmobile victims has increased from 12% to 20% from the 1980s to the 1990s, while the percentage of ski victims has declined from 61% to 47% in the same period.

Because modern snowmobiles can conquer terrain that was once inaccessible, snowmobilers are increasingly capable of getting themselves into remote and dangerous areas with a higher avalanche risk. Whether by underestimating the degree of hazard, overestimating their ability to cope with an incident, or by triggering an avalanche with their snow machines, some snowmobile enthusiasts are unwittingly bringing disaster upon themselves.

Sidebar: Avalanche deaths

On January 20, 2003, seven heli-skiers were killed on the Durrand Glacier in British Columbia's Selkirk Mountains. All had experience, and one was a professional championship snowboarder. The group was led by a guide considered to be an expert, who was knowledgeable about snowpack conditions and avalanche safety.

On February 1, 2003, seven Calgary high-school students, one girl and six boys, were killed in the Rogers Pass area of Glacier National Park while on a school outdoor expedition. All had outdoor and backcountry experience. An avalanche of size 3.5 released across a 500- to 800-metre start zone on Mount Cheops in Glacier National Park, running approximately one kilometre, and burying some of the victims as deep as three metres.

These deaths suggest that even people with knowledge and experience can be surprised by unexpected events. Backcountry recreation in avalanche areas always carries a certain degree of risk that cannot be completely eliminated.

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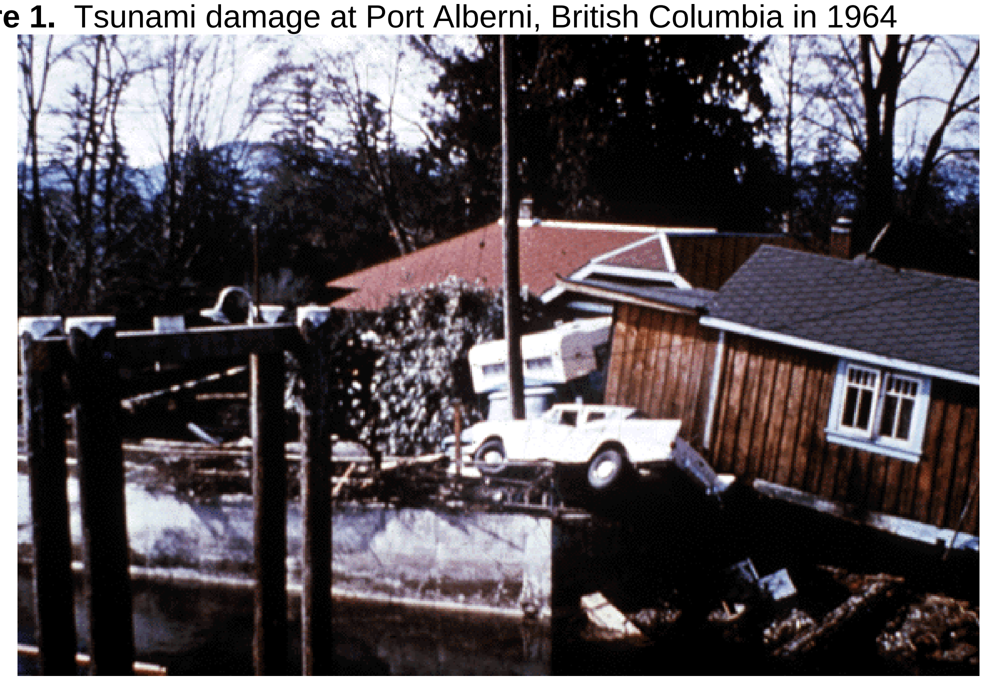
3.5 Tsunami

On the evening of Good Friday, March 29, 1964, an 8.4 magnitude earthquake, the largest ever recorded in North America, struck near Prince William Sound, Alaska. It generated enormous waves along the Pacific coast of the U.S. and Canada—the most destructive tsunami ever to hit those regions.

Southeastern Alaska suffered the most devastation (see Sidebar: The (Bad) Good Friday) but many British Columbia communities were also impacted, suffering about $5-million in damage. The worst effects occurred along the southwest coast of Vancouver Island. Charles Ford, a seaplane pilot living in the town of Zeballos at the time, returned to find half a metre of water in his home but "a couple of holes in the floor with my .308 Winchester hastened its departure -- it wasn't much of a house anyway."

The tsunami even travelled deep inland through an inlet to Port Alberni, which was hit by six waves. The first caused extensive flooding and the second—the highest at 2.4 metres above high tide—caused widespread damage. Some homes were swept off their foundations and moved 300 metres inland. It was the middle of the night and the residents had no warning, but miraculously, no one was killed -- although there were a few close shaves[1]

Figure 1. Tsunami damage at Port Alberni, British Columbia in 1964



Source: British Columbia Provincial Emergency Program.

[1] British Columbia Civil Defense Circular: 1964 Summer Edition – Special Report on Alberni Tidal Wave Disaster and Ford, Charles. Tidal Wave. British Columbia Provincial Emergency Program

Introduction

Tsunami is a Japanese word meaning harbour (*tsun*) and wave (*ami*). Tsunamis are waves generated by any process that causes a sudden displacement of water. One example, on a very minor scale, is when a stone is thrown into a puddle, creating a series of outward-radiating waves. The edge of the puddle experiences a succession of wave fronts as each wave passes, eventually diminishing until the water is once again still.

Tsunami are sometimes referred to as “tidal waves” but this is incorrect. Tsunami have little if anything to do with tides, other than having their impact modified by the tide, as they’re not as destructive at low tide as they are at high tide. Tsunamis can travel thousands of kilometres and cross oceans. In deep water, tsunami move very fast; they regularly reach 450 to 500 km/hr and can even go as high as 1,000 km/hr. In deep water they also have low wave heights of one metre or less. This means that tsunami, when crossing the deep ocean, are practically harmless and difficult to detect. The danger arises when a tsunami approaches a shoreline where the water is shallow. With decreasing water depth the speed of the wave decreases while its height increases, often to many tens of metres. Most likely a tsunami will generate a series of waves.

Tsunami hazard is related to run-up -- the horizontal or vertical distance that the water travels ashore. Horizontal run-up depends on many factors, including offshore water depth and shoreline shape, that vary considerably along a shoreline. Consequently, vertical run-up is more frequently used as a guide to the destructiveness of a tsunami.

Tsunami-prone areas have been inhabited for millennia. One theory suggests that a giant tsunami caused by the eruption of the Mediterranean volcano Santorini destroyed the Minoan civilization.

Causes of Tsunami

Most tsunami are caused by sudden movements of the earth’s surface, such as during an earthquake. The Alaskan earthquake of 1964 produced a tsunami that crossed the Pacific Ocean. In 1755, the city of Lisbon, Portugal was devastated by a tsunami that killed between 30,000 and 50,000 people.

On December 26, 2004 a magnitude 9.3 earthquake in the Pacific Ocean, the world’s largest since 1962, generated tsunami waves reported to be as high as 30 metres. This event is thought to have killed more than 230,000 people in 11 countries including Thailand, India, Malaysia, Bangladesh, Sri Lanka and Somalia and many people were left homeless for over a year after the incident. The response of the international community was generous with over $7 billion in donations by various governments and estimates reaching close to $6 billion in donations by citizens and NGOs.

Tsunami can also be generated by a submarine landslide, as was the case in 1964 in Valdez, Alaska and southern Newfoundland in November 1929. These can be very destructive locally, but are less so as the distance from the landslide increases. In 1958 in Lituya Bay, Alaska, a large earthquake-generated rockslide entering the bay pushed water up the shoreline to an incredible height of over 500 metres on the opposite side of the fjord -- almost the same height as Toronto's CN Tower, and causing the largest wave in recorded history. Large waves travelled around the bay for 25 to 30 minutes afterwards. A landslide-generated wave at Notre-Dame-de-la-Salette, Quebec killed 33 people in 1908.

Undersea volcanoes can also trigger submarine landslides. In addition, volcanoes at or above sea level can eject massive amounts of material that can cause tsunami when they rapidly flow into the sea. Other, much rarer, causes of tsunami include the escape of trapped gases from beneath undersea sediments and comet or asteroid impacts.

Finally, tsunamis can be generated by human activities. In 1917, the infamous 'Halifax Explosion' occurred when the ship *Imo* collided with the munitions ship *Mont Blanc*, causing the latter to explode. This is believed to be the largest human-generated explosion in history prior to the atomic bombs of 1945. The resulting tsunami drowned approximately 200 people, more than any other in Canadian history.

Areas of Tsunami Risk

In Canada, the tsunami threat mostly exists on the Pacific Coast. This is because the Pacific Ocean has many subduction zones where moving geological plates collide, generating subduction-type earthquakes and volcanoes. (see summary on Volcanoes).

Tsunamis are rare in the Atlantic Ocean, but they can occur. An earthquake-generated submarine landslide caused a tsunami that impacted the Burin Peninsula (Placentia Bay) in Newfoundland in 1929. The probability of tsunami in the Arctic Ocean or the Great Lakes is quite low.

The areas in Canada most prone to tsunami are the west coasts of the Queen Charlotte Islands and the west coast of Vancouver Island. Towns such as Ucluelet, Zellabos, and Port Alberni have historically been damaged by tsunami, but fatalities have been minimal because their populations are small.

Tsunami Warnings

There are major tsunami warning systems with administrative jurisdiction over the west coast of North America.

1. ***The Pacific Tsunami Warning Centre (PTWC).*** The PTWC operates the International Tsunami Warning System (ITWS). Its tsunami warnings may be accessed via a subscription to their Internet listserverv.

2. ***The West Coast and Alaska Tsunami Warning System (WC/ATWC).*** The PTWC cannot be used to warn against local events and related tsunami phenomena, so the WC/ATWC was established to provide warnings of local tsunami affecting coastlines. Warnings are available via e-mail and also through Alaska Public Broadcasting, Inc.

   The British Columbia Tsunami Warning and Alerting Plan. This information, as well as other hazard preparedness and awareness information, is on the Provincial Emergency Program (PEP) website.

Reducing Tsunami Vulnerability

Communities can mitigate their risk by engaging in programs of:

- Public Education
- Inundation Mapping
- Harbour Survivability
- Local Tsunami Warnings

Emergency managers of coastal communities subject to tsunami should incorporate its risk into their emergency response plans. In some cases this may include land-use guidance, to reduce development in identified areas at risk.

The impacts of flooding and high velocity water flow caused by tsunamis are strongly dependent on construction and land use/planning in the inundation area. Wood-frame structures that perform well in strong ground shaking are likely to collapse when hit by rapidly moving water. Reinforced concrete structures may provide havens for vertical evacuation. Consideration of both the effects of moving water and strong ground shaking need to be included in construction codes. Vegetation may dampen the water velocity in some cases, but in others, add to the debris and projectile force of the flow. No guidelines addressing these issues are available to coastal communities[2].

[2] Executive Office of the President of the United States of America – National Tsunami Hazard Mitigation Program

Tsunami cannot be prevented, but vulnerability to them can be reduced. Providing warnings is the main approach that can be used, however this can be difficult since most tsunami have little warning time. It is believed that almost all Pacific Ocean tsunami deaths over the past century have occurred in areas where the tsunami reached shore within 30 minutes of being generated. However, tsunamis generated by distant earthquakes may have a travel time of many hours, making warnings more practical.

Once people are inundated by a tsunami their survival chances are slim. Many are drowned as they are swept out into deep water with the return flow. Impact with floating debris is another killer; this was believed to be the cause of most of the deaths that occurred during the 1993 Hokkaido-Nansei-Oki tsunami in Japan.

In the aftermath of a tsunami, public health issues may become a concern. Tsunami frequently destroy infrastructure, which may result in contamination by sewage, with its attendant health risks.

Compared with deaths from other types of natural hazards, comparatively few people have been killed by tsunami in Canada. Nevertheless, residents in areas at risk should be aware of the danger and how to respond. Telephone directories in B.C. coastal communities already contain some tsunami information. It might also be helpful to make tsunami awareness part of the school curriculum.

Understanding tsunami and minimizing the risk requires some basic knowledge:

1. **If you live near the ocean**, you are at risk from a tsunami.

2. **In the event of a tsunami warning, seek higher ground** and stay away from the shoreline. In 1964, 10,000 spectators crammed San Francisco's cliffs to view the Good Friday tsunami. Luckily, it had little impact on that part of the coast, but it did kill eleven people in nearby Crescent City.

3. **Tsunami are not a single wave**, but rather a series of waves that strike in succession. Often the strongest wave is not the first. In Tofino, B.C. in 1964, the third wave was the strongest, but the second did the most damage; the tide had fallen by the time the third wave arrived, blunting its effect.

4. **Rapid withdrawal of water from the shoreline**, exposing the sea floor, is a sign of an approaching tsunami, which could arrive in a minute, or even as long as 50 minutes later.

5. **Tsunami can become trapped in harbours**, particularly those with narrow harbour mouths and long foreshores. Unable to return to the sea, the tsunami dissipates its energy in the harbour, causing widespread destruction.

6. **Tsunami can also travel up rivers and fjords**, as was the case in Port Alberni.

7. **Cliffs will not save you**. Some tsunami only 1 to 2 metres high just offshore have surged up cliffs to 30 metres or more.

8. **The effects of tsunami tend to be magnified** at headlands, gullies, and in the lee of circular islands. These are areas to avoid.

Sidebar: The (Bad) Good Friday

4:12 pm. Good Friday, March 27, 1964. The freighter *Chena* arrived in the tiny coastal town of Valdez, Alaska, located in the northeastern reaches of Prince William Sound. A crowd of people gathered to watch and crewmen tossed candy to children scampering about the dock.

5:36 pm. Approximately 23 km beneath Unakwik Inlet in northern Prince William Sound, a powerful earthquake occurred, eventually causing dramatic vertical ground motion over an area of more than a half-million square kilometres.

5:36:08 pm. Eight seconds later and 64 kilometres away at Valdez, the ground surged like an ocean wave, repeatedly moving up and down by a metre or more for 3 to 5 minutes. The heaving motion caused people to feel physically seasick. It was low tide in Prince William Sound and the water in immediately withdrew from the beaches. This exposed the delta sands underlying much of Valdez; subsequent ground shaking caused the surface to "flow" like a semi-liquid slurry. A large area of the delta, over a kilometre in length and 200 metres in width, slid into the sea carrying a portion of the town of Valdez with it.

The earthquake produced a catastrophic tsunami; as well as secondary local tsunami from earthquake-induced landslides. These localized tsunami were enormous and highly destructive. They threw boats and ships around like toys. The water surged up to 30 metres above sea level near Shoup Bay and up to 50 metres at Cliff Mine. The tsunami was higher than the tops of spruce trees in the area and many trees, some as large as 60 centimetres in diameter, were broken like matchsticks.

In Seward, Alaska, entire sections of the waterfront slid into the bay, causing a 10-metre local tsunami. Fuel tanks ruptured from the ground motion and erupted in an enormous fireball. A ship discharging fuel rolled violently, breaking its transfer hoses and spewing burning oil. The tsunami carried this burning fuel across the harbour to another petroleum facility, setting it ablaze.

Shortly thereafter the first tectonic tsunami, related to the earthquake itself, arrived. A 12-metre wave, carrying flaming fuel from ruptured storage tanks thundered ashore, destroying homes and setting buildings ablaze. The fiery wave threw a 109-tonne locomotive 30 metres across a rail yard, while a 68-tonne engine was thrown 90 metres. Forty railway cars containing gasoline and oil began to explode as well.

Back in Valdez, the *Chena* rose ten metres on an incoming wave and violently rolled 50 degrees to one side. The warehouse and dock next to the ship both collapsed, throwing their human occupants into a cauldron of broken buildings, water, mud, and debris. The *Chena* then slammed down on the dock, killing all 28 people who had been standing there.

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3.6 Volcanoes

On May 18, 1980, at 8:32 a.m., the destruction began. Within 5 minutes, the upper 400 metres of the volcano's summit was destroyed in a series of 3 massive landslides, and billions of tonnes of rock immediately swept down adjacent valleys. In a picturesque part of central Washington state, the largest volcanic eruption in modern American history was finally and decisively underway. After two months of local earthquakes and steam eruptions, Mount St. Helens finally began an explosive rampage.

Releasing more energy than the Hiroshima atomic bomb, a sideways-directed blast emanated from the volcanoes failing north flank, causing an avalanche of debris. With internal temperatures reaching 350 degrees Celsius, the blast wave thundered down the slope at 480 kilometres per hour – a speed faster than many aircraft can fly.

The blast flattened an adjacent forest, destroying enough wood to build 300,000 homes. Wildlife in the area met instant death as a **pyroclastic surge** *(hot, fragmented rock) rushed down the flanks of the volcano. It consisted of a rolling, boiling, ground-hugging cloud of tiny rock particles called* **volcanic ash** *and hot volcanic gases with internal temperatures many times that of boiling water.*

A monstrous column of erupted debris rose through the sky to an altitude of almost 25 kilometres – over twice the height that commercial jet aircraft fly. The volcanic ash it contained spread halfway across the United States in three days; within 15 days, it had circled the earth.

Figure 1: Mount St. Helens, May 18, 1980.

Source: United States Geological Survey.

In addition to the cataclysmic physical destruction 57 people lost their lives that fateful morning. Most of these people were outside of the identified 'red' zone while those inside had permits. A lack of incorporating extreme blast scenarios into planning resulted in these deaths.

Introduction

Volcanic eruptions are rare events in North America, compared with other parts of the world such as Japan and Indonesia. But the seemingly rapid awakening of Mount St. Helens, and the strength of the 1980 eruption, demonstrated that such events, though infrequent, can be catastrophic enough to warrant serious attention.

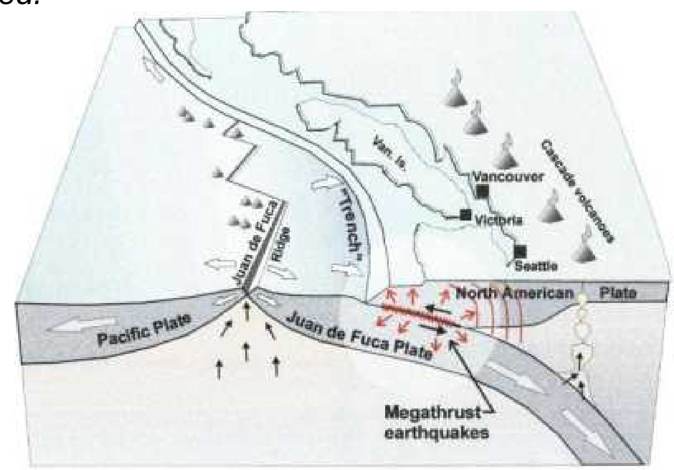
Canada, too, has volcanoes — wrongly assumed by many people to be extinct. They have the potential to cause serious damage, but unfortunately, in many cases we lack sufficient knowledge of their history to accurately assess how much of a threat they represent.

Anatomy of a Volcano

Understanding volcanoes begins with *tectonic plates*—the slabs of rock, often the size of continents, that make up the earth's crust. These slabs 'float' on the earth's underlying *mantle*, similar to the way a cracked eggshell sits on top of a hard-boiled egg. They move around, colliding and grinding against one another over time scales of millions of years.

Continental plates that collide can buckle, thrust upward, and form enormous mountain chains such as the Himalayas in Asia. However, when an ocean plate, consisting of heavy oceanic rocks, collides with a continental plate made up of lighter continental rocks, the oceanic plate often slides beneath the continental plate. This forms a *subduction zone*, an area where one plate is driven beneath another plate.

Figure 2: Cascadia Subduction Zone. *The east-moving Juan de Fuca tectonic plate meets the west-moving North American plate off the west coast of Canada in what is called a subduction zone. The Juan de Fuca plate attempts to slide beneath the North American plate, causing the rocks along the edges of the plates to be compressed or squeezed and uplifted.*



Source: Geological Survey of Canada.

As the oceanic plate is driven downward, it begins to melt from the intense heat within the earth. The melted rock—called *magma* (or *lava* when it spills onto the earth's surface)—forces its way upward, forming volcanoes that are essentially mounds on the surface where melted rock has escaped from below. Lines of volcanoes, known as *volcanic belts*, often occur near subduction zones.

What happens when a volcano erupts depends on the nature of the magma. The volcano will *extrude*, or forcefully emit, molten rock at the surface, but may do so in various ways. An *effusive* eruption is one in which lava seeps from the earth without explosive behaviour, such as occurs in Hawaiian volcanoes. In these cases, the magma contains little of the common mineral component *silica* and may appear on the surface as a thick liquid.

On the other hand, magmas rich in silica are often very thick, like plastacine; they are more likely to explode in globs of lava and fine ash and other types of particles, known as *ejecta*. This is known as an *explosive* eruption—the type that occurred at Mount St. Helens, May 18, 1980.

Volcanoes are one of the few natural hazards that provide reasonable advance warning. Impending eruptions are signaled by detectable *precursor activity* generated by rising magma. As it makes its way to the surface, the magma exerts great forces on the overlying rocks, causing fractures and producing detectable *foreshocks*—essentially small earthquakes. Additionally, melting of snow and distortions of the surface due to rising magma may also provide diagnostic clues.

At Mount St. Helens, the period from peaceful quiet to explosive eruption was just two months—very short in geological terms, even though adequate for warning purposes. And while such precursor activity does indicate an increase in risk, it's still not possible to predict exactly when a volcano will erupt or how large the eruption will be.

Volcanic Hazards

Volcanoes produce a number of dangerous physical hazards. They frequently produce fragmented volcanic rock called *tephra*, with particle sizes ranging from fine-grained *ash* to larger *blocks* and *bombs*. Higher-silica magmas such as those at Mount St. Helens frequently produce great quantities of ash that can be carried airborne for hundreds or thousands of kilometres; for example, ash from Mount Meager, British Columbia has been identified in Alberta, and airborne ash from Mount St. Helens circled the globe.

Pyroclastic flows, and the faster, lighter and more chaotic *pyroclastic surges*, are hot, dense avalanches of volcanic debris—rock material that gets carried along in an extremely hot, buoyant plume of air. They move along the ground at very high speeds, incinerating everything in their path.

Lahars (*mudflows originating from a volcano*) are a type of volcanic debris flow, an extremely destructive slurry-like mixture of water and volcanic particles that flows rapidly downhill. The largest are associated with eruptions of volcanoes covered with snow or ice; the history of Mount Rainier in Washington is filled with examples of lahars.

Lava flows are flows of liquid or semi-solid rock along the ground. Contrary to popular perception, they are usually slow, and hence usually the least dangerous volcanic hazard. However, they are relentless in their destruction of vegetation, built structures, and other objects in their path.

When groundwater contacts hot rocks, it can rapidly form steam and result in explosive *phreatic* (steam) eruptions, leading to fracturing of overlying rocks. Finally, hot, toxic *volcanic gases* can incinerate, as well as create acid rain.

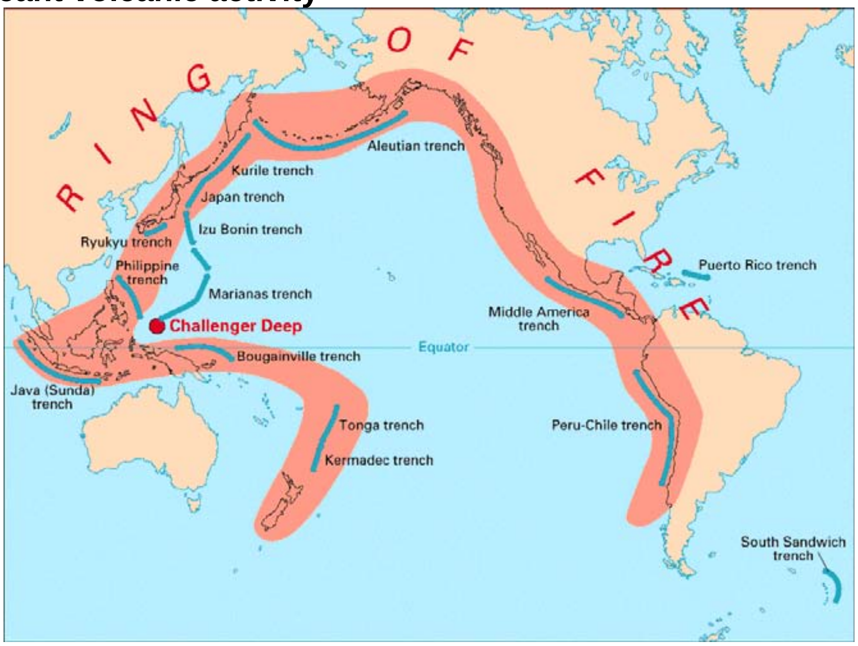
Volcanic hazards can threaten cities and towns, as well as related infrastructure such as highways, roads, and railways. Rivers and lakes can be severely affected by lahars. Agriculture, forestry, and other important resource sectors can also fall victim to the damage caused by volcanic hazards. Airborne ash clouds can adversely affect aircraft corridors and the routing of flights. (See sidebar entitled *Aircraft Impacts*) Heavy ashfall may reduce sunlight, causing a sudden demand and possibly brownouts of electrical power. Ash can clog water systems, sewage plants, and all kinds of machinery, cause roofs to collapse and electrical short circuits. Fine ash can be extremely slippery, hampering driving and walking. Ash can also damage the lungs of small infants, elderly, and those having respiratory problems[1].

[1] Source: http://www.ak-prepared.com/plans/mitigation/volcano.htm

Volcanoes in Canada

Canadian volcanoes are located in the Cordillera of western Canada, in British Columbia and the Yukon Territory. There are numerous subduction zones in the Pacific Ocean just off the coast of British Columbia and the state of Alaska, part of a zone of active volcanism known as the *Pacific Ring of Fire*.

Figure 3: The Pacific Ring of Fire. This "ring" around the Pacific Ocean is known for its significant volcanic activity



Source: United States Geological Survey.

Most people incorrectly assume that Canadian volcanoes are extinct. In fact, many are very young (only hundreds of years old), such as Tseax Cone, Lava Fork, and Ruby Mountain (103 years) within the Stikine Volcanic Belt of British Columbia. This, coupled with the fact that no eruption-related fatalities have occurred in recent Canadian history, may foster a false sense of security. But given the lack of a comprehensive history of volcano activity in Canada, there is insufficient knowledge to accurately assess how much risk Canadian volcanoes represent. The locations of volcanoes in western Canada are shown in Figure 4.

Figure 4: Volcanoes in Western Canada

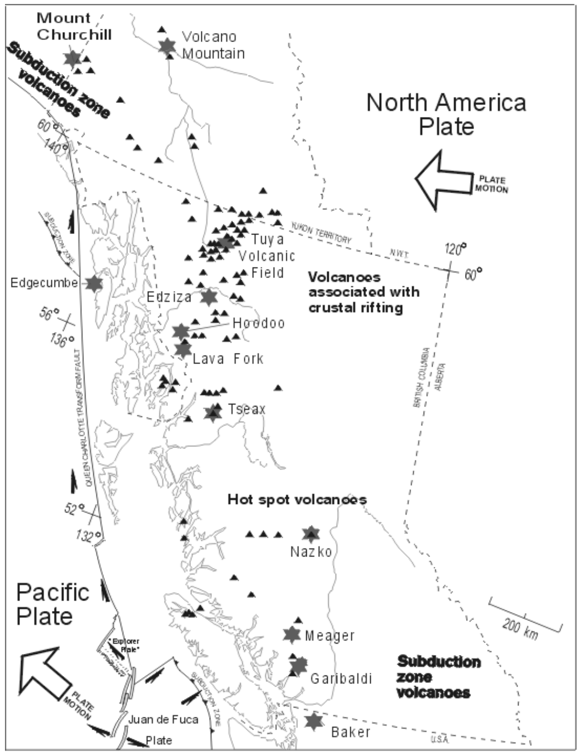


Figure 1. Quaternary volcanoes in western Canada and their tectonic settings.

Source: Canadian Geophysical Union

Response

- Know in advance what to expect and how to deal with it; that will make it manageable.
- If exposed to ash, use dust masks and eye protection. If you don't have a dust mask, use a wet handkerchief.
- As much as possible, keep ash out of buildings, machinery, air and water supplies, downspouts, storm drains, etc.
- Stay indoors to minimize exposure -- especially if you have respiratory ailments.
- Minimize travel -- driving in ash is hazardous to you and your car.
- Don't tie up phone line with non-emergency calls.
- Follow the evacuation order issued by authorities.
- Avoid areas downwind of the volcano.
- If caught indoors:
    - Close all windows, doors, and dampers.
    - Put all machinery inside a garage or barn.
    - Bring animals and livestock into closed shelters.
- If trapped outdoors:
    - Seek shelter indoors.
    - If caught in a rockfall, roll into a ball to protect head.

    - Avoid low-lying area where poisonous gases can collect and flash floods can be most dangerous.
- If caught near a stream, beware of mudflows.

- Protect yourself:
    - Wear long sleeved shirts and pants
    - Use goggles to protect eyes.
    - Use a dust-mask or hold a damp cloth over face to help breathing.
    - Keep car or truck engines off.
- Stay out of the area.
- A pyroclastic surge and flow from a volcano can travel many kilometres from the mountain. Trying to watch an erupting volcano could be deadly.
- Mudflows: Mudflows are powerful "rivers" of mud that can move faster than people can walk or run. Mudflows occur when rain falls through ash-carrying clouds or when rivers are dammed during an eruption. They are most dangerous close to stream channels. When you approach a bridge, first look upstream. If a mudflow is approaching or moving beneath the bridge, do not cross the bridge. The power of the mudflow can destroy a bridge very quickly.

Figure 5: Hoodoo Mountain (left) and Mount Edziza (right). Hoodoo Mountain is an ice-covered volcano, while Mount Edziza is a heavily eroded stratovolcano. Both are found in the Stikine Volcanic Belt of British Columbia.

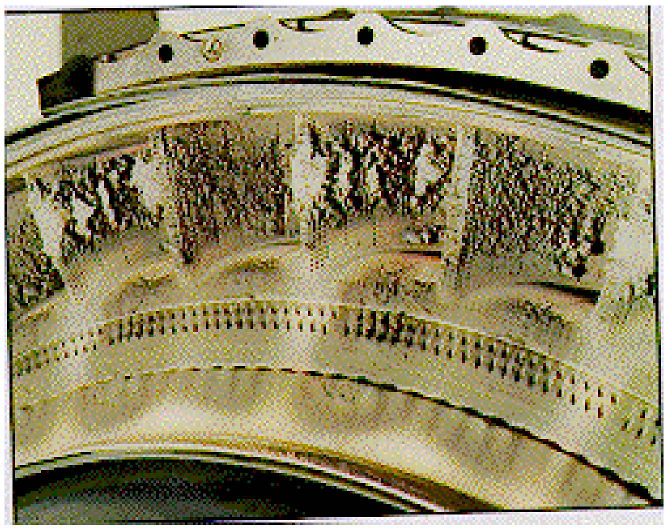
Sources: M. Stasiuk (left) and C.J. Hickson (right), Geological Survey of Canada.

Sidebar: Aircraft Impacts

Aircraft that fly into clouds of volcanic ash are at great risk. Jet engines operate at temperatures high enough to melt the ash, so it can coat and destroy engine turbine blades. In 1982, a British Airways Boeing 747 aircraft encountered an ash cloud from the Galunggung volcano in Indonesia. All four engines failed, forcing the pilot to make an emergency landing at Jakarta.

This was not an isolated incident, as other aircraft have lost engine power due to volcanic ash. Incidents such as these have resulted in improved response plans and warning systems.

Figure 5: Aircraft engine damage due to volcanic activity. A component removed from a Rolls-Royce aircraft engine shows heavy deposits of re-solidified ash after an airborne ash encounter. This assemblage was removed from the British Airways Boeing 747 aircraft that flew through an ash plume from Indonesia's Mount Galunggung on 24 June 1982.



Source: Airline Pilot, vol. 59, no. 6, June/July 1990.

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- Information on Canada's volcanoes is available online through Environment Canada. Both the Catalogue of Canadian Volcanoes and the Map of Canadian Volcanoes are available at the geological Survey of Canada page “Volcanoes of Canada”

Chapter 4:

COPING STRATEGIES

4.1 Risk Assessment

Introduction

Risk is a normal part of daily life. It's everywhere—in school, at work and at home. Some risks can be avoided, but many cannot, although we can often reduce their impacts by following safety guidelines or taking precautionary measures, such as getting a flu shot.

However, taking action to minimize risk presupposes knowledge of the risk in the first place. This is the objective of a risk assessment exercise—to identify hazards, their probability of occurrence, their severity and location, and the vulnerability of life and property exposed to such hazards (See Section 1.3: Vulnerability).

There are two general approaches to dealing with risk; one is called 'all-hazards' and the other 'risk-based'. The former is based upon developing a set of generic or common responses that could apply to any hazard (such as evacuation). The latter looks at risks individually and considers how to mitigate or prevent their impact, using a risk-ranking approach that emphasizes the greatest risks first. The following discussion emphasizes a risk-based approach, but it makes good sense to consider generic responses in any plan. The two approaches mesh well with each other.

Defining Risk

The term risk has several meanings in everyday usage. It may mean chance or probability—the likelihood that an event will happen. It can also be used to mean a consequence or impact—e.g. the risk of using a pesticide.

Risk is different from hazard. A hazard is any naturally occurring or human-induced process or event that has the potential to cause fatalities, injuries, or damage. An example would be a tornado.

The concept of risk embraces both the chance of a hazard occurring and its consequences. To illustrate this difference, take the example of two people building a house in an area exposed to flood. One person raises his house on a pad and builds his house with flood resistant materials. The other builds a standard house without raising it. The hazard is the same for both but the risk is much greater for the second person.

Risk is associated with uncertainty; we can never be sure of the level of risk we face. That's why risk is often stated as a probability—the chance that a given event will occur. For example, a weather forecaster might report a 70% chance of rain for a given region (See Section 4.2: Prediction).

A disaster is an event that results in widespread losses to people, infrastructure, or the environment that the affected community cannot recover from without outside assistance.

What is risk assessment?

Risk assessment involves examining activities or processes that can cause harm or damage in the environment you live in. It has three related components:

- Identifying hazards you're potentially exposed to
- Determining the chance of the hazards occurring and the vulnerability of the community
- Assessing potentially harmful impacts should the hazardous event occur

A hazard identification and risk assessment (HIRA) is often used to facilitate this process. Tables similar to Figure 1 (also called a risk matrix) are used as a basis for it. Most emergency management organizations (an example is Emergency Management Ontario) base their risk assessment on this process.

Figure 1: HIRA Table

Hazard Index Ranking				
Impact → / Frequency of Occurrence ↓	Catastrophic	Critical	Limited	Negligible
Highly Likely	5 *(Highest)*	4 *(High)*	4 *(High)*	3 *(Medium)*
Likely	5 *(Highest)*	4 *(High)*	3 *(Medium)*	2 *(Low)*
Possible	4 *(High)*	3 *(Medium)*	2 *(Low)*	2 *(Low)*
Unlikely	3 *(Medium)*	2 *(Low)*	1 *(Lowest)*	1 *(Lowest)*
Highly Unlikely	2 *(Low)*	1 *(Lowest)*	1 *(Lowest)*	1 *(Lowest)*

Hazard maps and land use planning

The findings or results of a risk assessment study can be used to create hazard and vulnerability maps that depict the most risk-prone areas in a given community. These maps can be helpful for pre-disaster planning and developing an emergency response capability.

They can also be used to develop better land use plans and policies that identify the location and nature of hazards and enable policymakers, potential investors and the public, to understand the limitations of hazard prone areas. Good land use plans help educate the public about where to settle and what structures to build to mitigate the impacts of disasters.

Based on risk assessment exercises, many governments provide hazard maps, set aside forests and protect watersheds. They implement zoning regulations that bar development in risk-prone areas and, in fact, sometimes buy back properties already located in such areas. With the right mix of land-use management measures, local governments can reduce disaster losses while accomplishing environmental and other community goals, including the protection of wildlife and water bodies.

Many people and communities seem willing to go for the immediate economic benefits of building in hazard-prone areas hoping that the flood or earthquake won't happen for a long time. However, such wishful thinking is dangerous and nature often crushes it in devastating ways. When buying or developing property, it's far more prudent to be guided by an understanding of the long-term risks.

Building Codes and Design

Local officials, planners and designers can use the information from risk assessment projects in many ways, including:

- developing and refining building codes
- designing safer highways, bridges, buildings, and utilities
- estimating the stability and landslide potential of hillsides
- setting insurance rates for properties
- establishing construction standards to help ensure the safety of waste-disposal facilities
- planning earthquake mitigation practices and emergency response procedures

A building's ability to withstand a natural hazard depends on its design and where it's located. It's important for communities to not only establish building codes that take local hazard probabilities into account, but to enforce them as well. It's believed that about 40% of the losses to Hurricane Andrew in Florida could have been avoided with proper enforcement of existing building codes. These codes have since been toughened, but critics say they're still not strong enough.

In Canada, the provisions of the National Building Code (NBC) have been widely adopted by provincial, municipal and other authorities responsible for local building by-laws and code requirements. The NBC is meant to prevent structural collapse during major natural disasters and to protect human life. Since Canada is more prone to winter storms than other natural hazards, many of the regulations refer to heavy snow and high winds. Canadian building codes appear to be stringent enough for the different weather extremes that occur in this country.

The NBC also provides seismic calculations and zoning maps that identify earthquake-prone areas. Seismic hazard calculations provide information not only on the size of a probable earthquake but also on the nature of the ground motion most likely to occur at given sites within a given 50 year period. The NBC also contains earthquake load guidelines to assist in designing and constructing buildings. These maps, calculations, and guidelines are designed to ensure that buildings and structures in Canada are made as earthquake safe as possible.

Insurance policies

Risk assessment studies are used by insurance companies to establish rates for properties and to determine coverage policies. For example, insurers may set higher premiums for properties deemed to be in high-risk areas—or refuse coverage altogether to limit their exposure to large losses. Following Hurricane Andrew, many insurance companies refused to renew homeowners' contracts in Florida and, in fact, revoked thousands of existing policies.

In Canada, reports indicate that some insurance companies have scaled down their business in vulnerable areas, such as the low-lying community of Richmond, south of Vancouver, for fear of a flooding event from the Fraser River.

Sources of Information for Risk Assessment

For communities and researchers planning to undertake a risk assessment exercise, the lack of adequate and reliable data on hazards can be frustrating. Chapters 2 and 3 in this volume provide information or information sources that can assist in this process. There is also quite a bit of information available on the net including the Atlas of Canada and hazard maps published by Public Safety Canada. Provincial ministries often have hazard related information, such as Understanding Natural Hazards, which is available for download by the Ontario Ministry of Natural Resources. Table 2 provides some sources for information on various hazards.

Table 2: Selected Hazard Data Sources[1]

Hazard	Source	Variables
Tornadoes Thunderstorm Hail Lightning	Environment Canada - summer severe weather	Date, time , latitude, longitude, deaths, injuries and damage
Meteorological events	Environment Canada - National Climate Archive - Weather Office	Current climate data and archival information including atlases, maps and satellite images
Hurricanes	Environment Canada - Canadian Hurricane Centre	Date, time, wind speed, pressure, deaths
Floods	Dartmouth Flood Observatory: Environment Canada - Freshwater Website : floods	Year, location, death, damage
Earthquake	Public Safety Canada Natural Resources Canada - Earthquakes Canada	Data, maps, history, research, FAQs
Landslide	Natural Resources Canada	Data, maps, history, research, facts
Winter storms	Environment Canada - Meteorological Service of Canada (MSC)	Current conditions, local forecast and data on past events

Disaster information can also be obtained from online databases such as:

- The Canadian Disaster Database, which contains accurate historical information on Canadian disasters free from the federal department of Public Safety.
- The U.S. Geological Survey main page, or the “Ask USGS” site.

Other more general sources of information, referenced in more detail in chapters 2 and 3, include:

- scientists and researchers with expertise in specific hazards. A list of contacts for various hazards is available in Etkin et al (2004), which can be accessed on the internet at www.crhnet.ca under information sharing
- published materials: local newspapers, articles, journals such as Canadian Geographic or “Natural Hazards” that are typically available at public or university libraries, hazard maps
- historical records, including photographs and maps, in local libraries or municipal records
- long-time residents (especially native communities) are a vital source of information on historical events in the community

[1] Over time the internet addresses are likely to change, however a search using appropriate keywords is likely to find the relevant web page.

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4.2 Prediction

At 5 a.m. on July 31,1987, a forecast was issued for Edmonton, Alberta, predicting an 80% probability of thunderstorms, heavy at times. At 11 a.m., the forecast was revised, calling for thunderstorms with hail, damaging winds and heavy downpours. Phrases such as "vicious thunderstorms" and "extremely strong and violent thunderstorms" were used in Weatheradio and media reports. A weather watch was issued.

Less than an hour later, this was amended to a "severe weather watch." Just before 3 p.m. Environment Canada issued a "severe weather warning" as the rapidly intensifying storm was observed moving towards Edmonton at 70 km/h. Ten minutes later, a tornado touched down in the eastern part of the city and parts of neighbouring Strathcona County. A call from a member of the public reporting the event prompted Environment Canada to issue a tornado warning for Edmonton.

The tornado killed 27 people, injured hundreds, destroyed more than 300 homes, and caused more than $330 million in property damage at four major disaster sites. It was one of Canada's worst weather-related natural disasters.[1]

What is Prediction?

Hazardous events cause the most damage when they occur suddenly and unexpectedly. With advance notice, it's often possible for communities and individuals to minimize or prevent loss of life and property. This is why efficient and reliable early warning systems are an important component of emergency preparedness and disaster reduction programs.

Prediction specifies, in advance, the expected place, time, nature and impacts of an event. Accurate and timely warnings and forecasts provide critical information about what is likely to happen, as well as advice on how to respond in order to save lives and protect property.

There are two main types of predictions:

- Forecasts/outlooks/advisories/warnings that specify in advance the location, time and nature of hazardous events. An example is a tornado warning that provides specific information about when a tornado may occur in a given region.
- Statements of risk that include the probability of a hazard occurring in a given area, without specifying when the event will actually occur. An example is a

[1] Environment Canada

statement that says a particular location is subject to flooding on average once every 50 years without specifying particular dates or times when flooding will occur.

Each type of prediction elicits a different response. A warning leads to immediate response, while statements about long-term risks lead to activities related to mitigation and preparedness. (See Section 4.8: Mitigation and Section 4.4: Emergency Preparedness and Response).

Predictability

The main objective of disaster management is to make communities less vulnerable. Predictions help define the risks that communities face years to decades ahead of actual disaster events that may occur. This helps decision makers and community members to develop programs, such as land use plans, that reduce their vulnerability and increase their resilience when faced with disasters.

The degree to which warnings can reduce a community's vulnerability depends on the interplay several factors:

- the accuracy of the warning
- the length of time between when the warning is issued and the expected event occurs
- the state of pre-disaster planning and readiness and the extent to which the public hears and responds to the warning and takes precautionary action

The accuracy of predictions

Predicting natural events is always difficult but it is particularly daunting to predict extreme events, especially far in advance. There are several reasons for this. First, natural systems are inherently full of uncertainties that make accurate prediction very difficult. Second, sometimes there is not enough data on natural systems to provide a solid basis for prediction. Finally, current technologies have limitations that prevent them from providing the accurate observations needed to predict natural events. Prediction is more challenging for events that are of smaller scale (such as tornadoes). As well, the accuracy of predictions drops rapidly with time (that is, short range predictions are much more accurate than long range predictions)

Lead time and Disaster response

The amount of time between prediction of an event and its impact is crucial. With adequate lead-time for prediction, effective and timely communication is possible.

Lead time also largely determines the disaster management strategy that will be adopted. If a flashflood is expected within the next 30 minutes, it's important to issue a warning advising people to take immediate action, such as moving to less vulnerable locations like hills.

On the other hand, if the forecast is that a river might overflow its banks within the next few days because of heavy rainfall, there's time to prepare for evacuation or to implement emergency procedures such as strengthening dikes or fortifying riverbanks with sandbags. Residents of Winnipeg and southern Manitoba could take such action during the 1997 Red River flood because they knew a couple of weeks ahead of time that a severe flood was coming.

On longer time scales, if floods are expected to become increasingly likely, communities can review building codes or develop land use plans that make allowances for these changing risks. These sorts of issues arise from consideration of climate change or other environmental changes.

Unfortunately, it's not always possible for scientists to issue timely warnings because some hazardous events, such as earthquakes and tornadoes, can occur very suddenly.

Disaster response and reduction of vulnerability

All disasters cannot be prevented, but being alert and prepared can reduce one's vulnerability to such events. Responding to warnings proceeds in several stages: (1) hearing the warning (2) believing the warning is credible (3) confirming that the threat does exist (4) understanding the extent to which the hazard will affect you or your community (5) determining whether protective action is needed, (6) determining whether protection is feasible, and (7) determining what action to take and then taking it.

Many people have become skeptical of forecasts and warnings because not all events occur as predicted. This skepticism sometimes translates into apathy or indifference—people or communities often just ignore warnings and go about their normal activities as they are not at risk. For example, many people in Halifax didn't take warnings about Hurricane Juan seriously because their previous experience hadn't prepared them for a hurricane of that magnitude.

Being complacent about warnings can be dangerous. Despite the uncertainties, warnings from the appropriate authorities do save lives and property, so it's important to take them seriously.

WEATHER WARNINGS

Forecasts and weather watches and warnings are predictions made by the Meteorological Service of Canada about present and future hazardous weather conditions.

Table 1: Types of Weather Warnings

• Severe thunderstorm watch: • Severe thunderstorm warning	• Blizzard warning • Heavy snowfall warning • Winter storm warning
• Tornado watch • Tornado warning	• Windchill warning • Cold wave advisory
• Freezing rain warning • Heavy rain warning • Frost warning	• Storm Surge Warning
• Wind warning • Marine wind warnings • Dust storm advisory	

Different thresholds determine when watches or warnings are issued for different hazards and it's important understand these thresholds in order to respond appropriately.

A WEATHER ADVISORY means actual or expected weather conditions may cause general inconvenience or concern but do not pose a serious enough threat to warrant a weather warning. An advisory may also be used when conditions show signs of becoming favorable for severe weather but the situation is not definite enough, or too far in the future, to justify a warning.

A WEATHER WATCH is an alert that conditions are favorable for the development of severe weather. Watch the skies and listen for updated watches and warnings.

A WEATHER WARNING is an alert that severe weather is occurring or that hazardous weather is highly probable. Severe thunderstorm or tornado warnings may be issued less than one hour in advance. Other weather warnings may be issued six to twelve hours in advance.

Variation by region

The conditions that precipitate weather watches and warnings vary somewhat across Canada because different regions have different climates and people's ability to deal with adverse weather is quite variable. For example, people living in the far north are better adapted to and have different expectations of very cold temperatures than those living in the mild climate of Victoria B.C. It doesn't make sense, therefore, to use the same criteria for issuing watches and warnings in all regions.

The standards for each region are available for viewing on the local Environment Canada website.

WARNINGS OF GEOPHYSICAL HAZARDS

Geophysical hazards, such as earthquakes and volcanoes, are even harder to predict than weather hazards and it's therefore more difficult to issue warnings long in advance.

Earthquakes

Earthquakes occur suddenly; they come without warning and cannot be prevented. Thus far, Canada hasn't experienced a catastrophic earthquake disaster, but the chances of one occurring within the next 50 years is uncomfortably high in southwestern British Columbia or the St. Lawrence Valley area of eastern Canada (See Section 3.1: Earthquake).

Earthquakes have been measured at permanent seismograph stations in Canada since 1897. The Geological Survey of Canada (GSC) maintains a network of about 125 seismograph stations across the country. It also has seismicity maps based on data about the locations and sizes of over 39,000 measured and historically-recorded earthquakes dating back to 1568.

This information is used to produce seismic risk maps by the GSC for the National Building Code. Though scientists can't predict the occurrence of future earthquakes in Canada, these maps do provide an idea of how often and where they can occur.

Landslides

Landslides are generated when rock or soil moves down a slope. They can be as small as a few boulders falling from a rockface to the collapse of an entire mountainside. They can be fast (hundreds of metres per second) or slow (centimeters per year.)

Many different types of landslides occur in Canada, reflecting the diversity of the landscape. They can also occur underwater (See Section 3.3: Landslide). Although areas of high landslide risk can be mapped, it's not currently possible to predict precisely when landslides will happen or how severe they will be. For the purposes of risk avoidance through land-use zoning, however, this information is quite good.

Geomagnetic hazards

High-speed clouds of charged particles from the sun bombard Earth's upper atmosphere and interact with its magnetic field to generate large electric currents. Periodically, intense eruptions known as solar flares produce 'magnetic storms' that can damage equipment such as satellites and telephone and power systems (See Section 3.2: Geomagnetic Storms).

The impact of geomagnetic storms can be reduced by designing equipment to cope with the induced voltage swings and adjusting operating procedures during magnetic storms. Based on the monitoring of precursor phenomena on the sun, the Geological Survey of Canada issues both long-term (up to 27 days) and short-term (1 to 24 hr) geomagnetic forecasts to aid utility operators.

Volcanoes

Different types of volcanoes have different styles of eruption. Collecting data on the nature, timing and impacts of past eruptions can be used to assess the potential future hazard associated with specific volcanoes (See Section 3.6: Volcano).

Unfortunately, it is not possible to make accurate predictions of volcanic eruptions, though there are precursors that can indicate high risk situations. Because there have been no major eruptions for the past several hundred years, no long-term monitoring of potentially active volcanoes is done in Canada.

Warning of an impending major eruption could be given by a large number or "swarm" of shallow earthquakes beneath a volcanic centre, generated by the upward movement of magma (molten rock) from deep in the Earth. The seismic network operated by the Geological Survey of Canada can detect moderately sized earthquakes within such a swarm.

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4.3 Adapting to Natural Hazards and Disasters

Throughout history, natural disasters have been part of the human experience. They've played a pivotal role in defining who we are and how we relate to nature. We find them in myths (the sinking of Atlantis) and in religion (Noah's Ark.) For good or ill, they've sometimes intervened at key moments in human affairs; for example, typhoons destroyed Mongol fleets and saved Japan from invasion in 1274 and 1281.

Societies have continually adapted to the risks associated with natural hazards and disasters. Perhaps the first recorded example of this is in Hammurabi's Code of Laws, circa 1750 B.C. His Rules Governing Contractors included the following instructions:

> *229. If a builder build a house for some one, and does not construct it properly, and the house which he built fall in and kill its owner, then that builder shall be put to death.*
> *232. If it ruin goods, he shall make compensation for all that has been ruined, and inasmuch as he did not construct properly this house which he built and it fell, he shall re-erect the house from his own means.*
> *233. If a builder build a house for some one, even though he has not yet completed it; if then the walls seem toppling, the builder must make the walls solid from his own means.*

Laws today are much less harsh, but their intent is similar—to use building codes and other measures to ensure that citizens and their property are protected.

Figure 1: Forest Fire

Source: Canadian Forest Service - Frontline Express Bulletin No. 34

What is a disaster?

An event becomes a disaster when a community's ability to cope with the damage caused by an event is overwhelmed and it must seek outside assistance to recover.

Disasters have different scales; a disaster to a town may not be one to a province and a provincial disaster may not be a national one. Some disasters have overwhelmed nations, as was the case when Hurricane Mitch hit Honduras.

It's important to distinguish between the event that caused the disaster and the disaster itself. A tornado by itself is not a disaster until it strikes a vulnerable community.

Nature's victims or self-destruction?

Figure 2: Flood Damage in the Saguenay Area, Quebec

Source: Natural Resources Canada

If people live in a flood plain, they should not be too surprised if they get flooded from time to time.

How we view natural disasters has changed over time. The traditional view sees nature as the perpetrator of tragic events and assigns humans the role of victim. More recently, we've moved toward a different mind set, one that puts far more responsibility for natural disasters on humans. This theory suggests that we create our own disasters by making ourselves vulnerable to the hazards that surround us (See Section 1.3: Vulnerability).

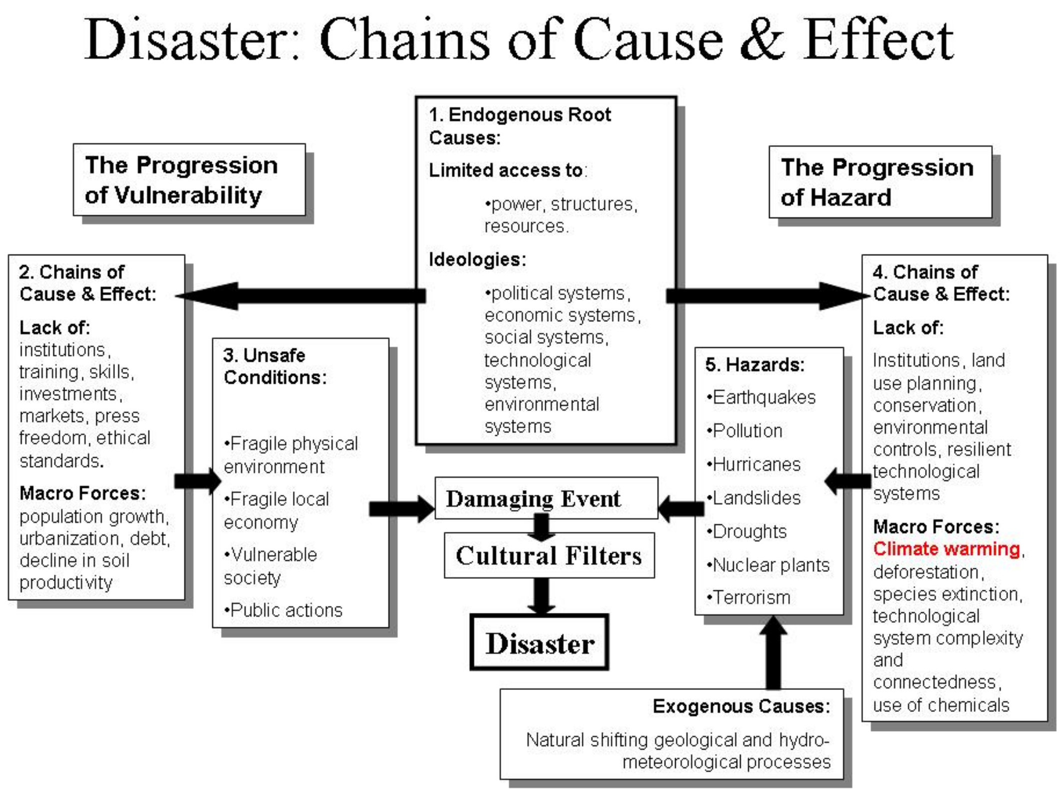
We create vulnerability in many ways, both in the built environment and our social structures. By choosing to live in flood plains or close to fault lines, we make ourselves vulnerable. When we build infrastructure, such as buildings, transmission towers or pipelines, that are not resilient, we make ourselves vulnerable. When our social and political strategies do not encourage communities to prepare for disasters or provide hazard awareness and education, we make ourselves more vulnerable.

Disaster costs are rising and the grim truth is that this trend will likely continue because we build vulnerability into our society (See Section 1.2: Disaster History).

Of course, there are times when we're totally unaware that a hazard exists, such as an unknown fault line that can cause an unexpected earthquake. In such cases, we cannot say we created our own vulnerability. However, studies of disasters around the world show this to be the exception, not the rule.

Risk, hazard and vulnerability

Figure 3



Source: David Etkin

We live in a hazardous world. Nature provides a host of natural hazards, including:

- Hydrometeorological threats: those dealing the atmosphere and water, such as storms and tsunami;
- Geolophysical threats: those dealing with the earth, such as earthquakes, volcanoes and landslides;
- Biological threats: those dealing with living organisms, such as bacteria and viruses

This document deals only with the first two categories.

If the event that triggers a disaster is natural in origin, the disaster is considered a natural disaster. However, even in these cases, human actions or technology can play a strong role. For example, in 1994, many homes in Florida were destroyed by Hurricane Andrew (a naturally occurring event) because building codes were not enforced.

When a disaster stems from technological or human-caused events, it's not considered a natural disaster but natural forces may still play an important role. For example, winds can disperse dangerous chemicals that have been released and tides can influence which areas of the ocean are damaged by oil spills. The distinction between natural and human-caused disasters can be quite blurry.

A hazard by itself—e.g. flooding near a river caused by heavy rainfall—will not necessarily create a disaster. Two more ingredients are needed:

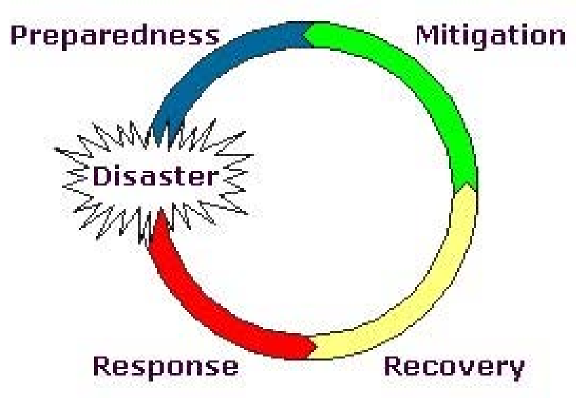
- there must be some part of society present to be affected, and
- there must be some vulnerability that can be triggered.

This is illustrated in Figure 1.

The RISK we face depends on both the frequency and intensity of the HAZARDS that we're exposed to, and the degree of VULNERABILITY of our community. For example, building a community within a flood zone puts its residents at risk. The community can make itself less vulnerable by employing flood resistant measures such as building levees or flood-proofing houses with elevated floors, but often this is not done until after disaster strikes**.**

Adaptation: a response to disaster

Figure 4: Traditional Model of Disaster



Adapting to natural hazards involves four types of activities[1]:

- response
- recovery
- mitigation
- preparedness

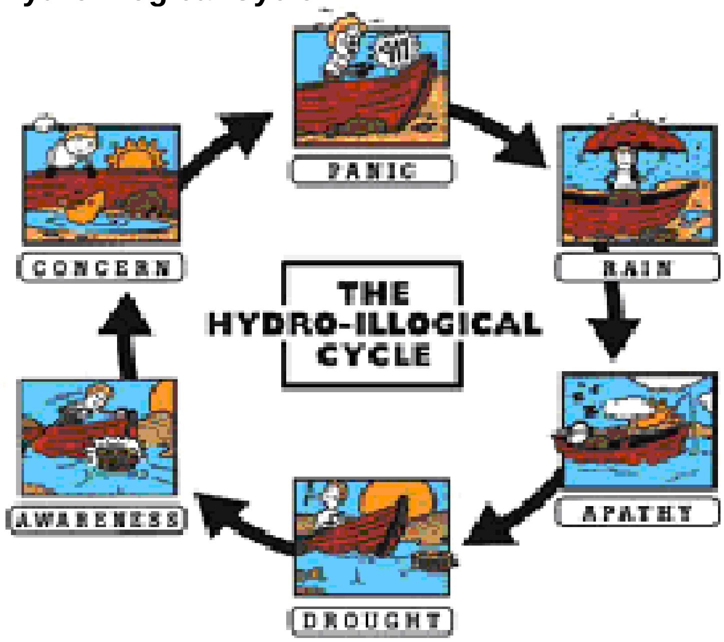
Sometimes it's hard to distinguish between them. Response and recovery are the things we do right after a disaster has occurred, such as locating and helping victims and rebuilding what's been destroyed. Mitigation refers to long term planning, such as implementing strong building codes or land use planning that prevents development in hazardous areas such as in flood plains. Preparedness means having emergency plans in place and emergency services and supplies in a state of readiness so we can respond effectively when disaster strikes. (See Section 4.4: Emergency Preparedness and Preparedness and Section 4.8: Mitigation)

It's generally after a disaster that we change how we do things. This period often provides a "window of opportunity when people are most likely to stop and look at how they've designed their communities and how prepared they were. Each new disaster, ironically, is an opportunity to make our world safer, as we learn what mistakes not to repeat.

1 Sometimes prevention is added as a fifth category

This is illustrated in the bottom half of the disaster adaptation figure. After the disaster, the cycle of human activity alters our vulnerability. Unfortunately, as time passes, we sometimes forget these hard lessons and pay the price by suffering through repeated disasters. (See "Lessons Learned or Lessons Forgotten: The Canadian Disaster Experience" by Joe Scanlon on the Website for the Institute for Catastrophic Loss Reduction)

Figure 5: The Hydro-Illogical Cycle



Source: National Drought Mitigation Center

When we change our level of vulnerability, we also change our level of risk, thus altering future natural disasters for better or worse. The decisions we make about how and where our communities are built, in fact, *design* future disasters. This is why a recent U.S. assessment of natural hazards, led by Prof. Dennis Mileti of the University of Colorado, was called Disasters by Design.

How well adapted are we?

Canadians have done a reasonably good job of adapting to the more common natural hazards. Yet we're still overcome by large disasters—as our recent history with ice storms, floods, forest fires and drought attest. Clearly, we remain vulnerable and must do more to protect ourselves. In fact, although our risk to the more frequent but less severe of nature's extremes has diminished, many argue that we are *more* exposed and vulnerable to rare but extreme events.

This is true for several reasons:

(1) **Urban development**. The destruction of forests and paving of green areas has reduced Earth's natural ability to absorb heavy rainfalls, resulting in more overland water flow and flooding. Increasing population densities in large cities make them more vulnerable to hazards.

(2) **Reduced self-reliance**. Our dependence on electricity, gas and oil and transportation and communications systems makes us more vulnerable. The 1998 Ice Storm is a good example of an event that hit us hard, but would have had a much smaller impact a century ago when people were less reliant on technology.

(3) **The belief that technology can always protect us**. Sometimes it's just better to move out of harm's way than to try to control nature**.** But in our technologically advanced world, we believe so much in the saving power of technology that we put ourselves in danger. For instance, instead of avoiding development in a flood plain, we build dams to control river flow. This intervention provides a false sense of security that often results in additional development, thus exposing even more people to the risk of flooding.

In fact, when technology protects communities from small disasters, it often makes them far more vulnerable to much larger ones that can overwhelm their resources. A dam, for example, may prevent minor flooding but if it's breached by a large event, a massive disaster may ensue. The fact that many more people are living on the flood plain because of the presence of the dam only makes matters worse.

Technological systems designed to protect people and their built environment can fail for two reasons. The first is the occurrence of a natural event beyond the design criteria of the technological system. The second stems from human activities, such as a lack of maintenance, inadequate quality of construction or human error.

The 1996 Saguenay flood in Quebec is a spectacular example of a system failure that demonstrated the limitations of human control over nature, despite engineering ingenuity. A complex system comprised of 45 watercourses and about 2,000 flood control structures (mostly dykes and embankments) owned by 25 different organizations was simply unable to deal with the extreme amount of rain that fell over two days in July. The Saguenay River broke through an earthen dam, creating a cascading wave of destruction downstream along its natural pathways.

(4) **Increased development in hazardous areas**. Despite the risks, places like flood plains and coastal regions are in great demand for economic, agricultural and leisure activities. As a result, more people and property are exposed to hazards than ever before. Examples include some communities near Montreal such as Rosemere

and Saint-Eustache, as well as others in Manitoba's Red River Basin and some low-lying areas near Vancouver, B.C.

Of course, many people perceive benefits to be gained by living in these low-lying areas, which must be balanced against the risks. A community might well decide to accept occasional floods as part of the 'price' they pay for living there.

Becoming better adapted

Becoming better adapted mean reducing vulnerability. This can be done through strategies to improve response, recovery, preparedness or mitigation. We've generally done a better job on the first three categories than on the fourth.

However, mitigation offers the greatest "bang for the buck" in terms of reducing the costs of future disasters. This is why the federal government, under the leadership of PSC (Public Safety Canada), has crafted a national mitigation strategy. This strategy was launched on January 9, 2008 with a goal "to protect lives and maintain resilient, sustainable communities by fostering disaster risk reduction as a way of life." The key elements in this strategy are: leadership and coordination, public awareness, education and outreach, knowledge and research and federal-provincial-territorial cost-shared mitigation investments. It is hoped that through greater integration of research endeavors and dissemination of that knowledge to households throughout Canada citizens will become more resilient to the increasing number of natural and technological disasters in Canada.

Becoming better adapted to hazards and disasters requires a different way of thinking—one that's sensitive to the natural environment and our relationship with it, and that considers and designs for the potential consequences of failure. Not all disasters can be prevented, but with good planning, their numbers and impact can be reduced.

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4.4 Emergency Response

August 1, 2003. In the interior of British Columbia (B.C.), 328 wildfires raged across 28,000 hectares of prime forested land. The McLure Lake fire was forcing residents of McLure and Louis Creek to evacuate and threatening the town of Barriere. With 44 new fires beginning since the previous midnight, the situation was critical.

Premier Gordon Campbell declared a Provincial State of Emergency, initially confined to the Thompson-Nicola regional district. In the next 24 hours, with another 25 fires started and, with an additional 10,000 hectares burning or already destroyed, the State of Emergency was extended provincewide. It lasted six weeks.

Ultimately, there were 2,400 fires burning in B.C. that summer. They caused the largest forest fire-related evacuations in decades and destroyed an enormous amount of valuable trees and property, including historic railway trestles and bridges, a sawmill in Louis Creek and over 200 houses in suburban Kelowna.

Managing Emergencies and Disasters

The State of Emergency is a legislative instrument that was used to provide extraordinary powers to the B.C. Fire Commissioner, the Ministry of Forests, the RCMP and the Provincial Emergency Program. It gave these officials authority under the Emergency Program Act to draw resources from across the province and to take the actions necessary to support evacuation efforts, fight the fires and protect residents and communities. Their responsibilities included establishing emergency reception centres, co-ordinating efforts with organizations such as the Canadian Red Cross, and communicating with the public.

While the B.C. wildfires were indeed a disaster, not all emergencies necessarily become disasters, if they are efficiently and safely managed in a manner that takes their unique characteristics into account.

Emergency preparedness and response (EP&R) refers to activities of individuals, organizations and communities undertaken to anticipate and prepare for emergencies and to respond effectively to those that occur. An important aspect of preparedness is public information—ensuring that people understand the risks they face and take steps to protect themselves. Emergency response refers to activities undertaken to manage the event itself and its immediate aftermath.

However, there's more to EP&R than dealing with events immediately before, during and after an emergency. It's becoming increasingly important to plan further ahead—to develop a sustained program of measures to reduce impacts and risks associated with emergencies and disasters over the long term. This is called mitigation, also known as prevention. (See Section 4.8: Mitigation)

Mitigation goes hand in hand with recovery, the actions taken after an emergency or disaster to restore or rehabilitate society to its pre-emergency condition. In fact, the recovery phase often provides the best opportunity to undertake mitigation efforts. It's the ideal time to restore social systems and infrastructure to a safer and more sustainable level, which helps to ensure resilience against future events. This creates a society better adapted to withstand the shocks of emergencies and disasters.

Taken together, mitigation/prevention, preparedness, response, and recovery form the four fundamental components of an effective emergency management program. These programs are run by an Emergency Measures Organizations (EMO) in every Canadian province and territory. Two notable examples are Emergency Management Ontario and the British Columbia Provincial Emergency Program.

Provincial and territorial EMOs carry out their mandates by:

- playing the lead role in assisting provincial and municipal/community officials in developing and implementing community Emergency Management Plans and Programs;
- providing training for emergency management personnel;
- providing advice, technical expertise and support and general assistance to community officials during emergencies and disasters;
- co-ordinating and, if required, integrating the emergency response between provincial/territorial governments and the federal government;
- providing information products and services and related public education.

If an emergency exceeds the ability of a province or territory to manage it, or involves areas of federal jurisdiction, provincial or territorial EMOs may request assistance from the federal Public Safety Canada (PSC), which has the mandate for federal emergency management, co-ordinates national efforts in mitigation/prevention, emergency preparedness, response, and recovery. PSC maintains comprehensive databases of human and material resources and their locations throughout Canada so it can respond quickly to requests for assistance from the provinces and territories.

PSC also manages the Ottawa-based Government Operations Centre (GOC) and funds programs like the Joint Emergency Preparedness Program (JEPP) and the Disaster Financial Assistance Arrangements (DFAA).

Public education is also part of PSC's mandate. Its 72 Hour program provides Canadians with useful information on emergency preparedness.

PSC also sponsors Emergency Preparedness Week, an annual effort to increase public awareness of emergency preparedness principles and reinforce Canada's system for managing emergencies. This program is a collaborative effort with provincial and territorial EMOs, various levels of government and other organizations with similar missions and mandates. Events are held throughout the country to inform Canadians of the types of emergencies they may face and what steps they can take to lower their level of personal risk and prevent emergencies from becoming disasters.

In addition, PSC provides information and services related to public safety and security. It offers specialized training and education in critical infrastructure protection and emergency preparedness through the Canadian Emergency Management College in Ottawa.

Individual Preparedness

When disaster strikes, people cope in different ways. Some may be fully self-sufficient, able to take care of their own needs without outside assistance. Others are less so and may require help from first responders such as police, firefighters and paramedics. However, first responders and others responsible for emergency management and response are in great demand and under enormous stress, so citizens should avoid summoning them unless absolutely necessary.

In fact, Canada's national emergency response strategies expect individuals to attend to their own needs for a minimum of 72 hours during a major disaster. Material and human resources are simply not sufficient to help everyone during this critical period. In fact, experience with the Ontario-Quebec Ice Storm of 1998 suggests that individuals may have to rely on themselves for even longer than 72 hours.

The following are some basic steps individuals can take to be better prepared for emergencies:

1. Find out about your community's emergency management programs

a) Learn who's responsible for emergency management programs
b) Get copies of community plans and guidelines
c) Search libraries, emergency preparedness organizations and the Internet for Personal Preparedness Plans such as these:

2. Determine which emergencies/disasters may occur in the areas where you live and work

a) Major natural disasters such as earthquake, flood, and severe weather events

b) Other lesser-known disasters such as power failures, fires due to faulty wiring, and proximity to hazardous materials storage areas or hazardous facilities

3. Take steps to prevent or reduce the impact of these emergencies/disasters

a) Create an emergency plan including:
   - a list of essential contacts
   - the layout of your home/office
   - places to meet if you're required to evacuate
   - where to shelter in an earthquake, flood, or storm
   - how to turn off gas, water and electricity at the main connections
   - a detailed checklist of things to do in a crisis

b) Store copies of essential documents, including the emergency plan, at another location such as the home of a family member or friend

c) Make sure everyone in the house or office is familiar with the plan and discuss it with your neighbours

4. Prepare an emergency survival kit

a) Food and water
b) Essential tools and supplies
c) Flashlights or other emergency lighting; spare batteries of the proper size and number
d) A first aid kit and a first aid manual or handbook
e) Appropriate emergency clothing and footwear, blankets and suitable outdoor clothing
f) Special supplies for babies, children and seniors

5. Practice the emergency plan

a) Test the plan with reasonable frequency—at least once or twice a year.
b) Keep it up-to-date
c) Revise the plan if testing reveals deficiencies.

Certain groups such as seniors, children and people with mobility impairments or other special needs often are not well accommodated in the planning process. Pets also require consideration. A good emergency plan will make allowance for the special needs of these vulnerable groups.

Community Preparedness

Many municipalities are required by law to have community emergency programs or plans and residents should become familiar with them. In communities that do not have such programs, residents should encourage local governments to develop them.

Community Emergency Management Plans and Programs

To enhance their safety, communities should develop emergency management programs that are appropriate to local conditions, allow for a wide range of emergencies, risks and hazards, and consider the needs of vulnerable groups with special needs. These plans should be tested and revised frequently.

The essential components of a Community Emergency Management Program include the following:

- a documented Community Emergency Plan that defines the following goals and objectives of the Plan
- roles and responsibilities of key figures and the established management structure
- key priorities
- vital resources
- communications
- procedures for restoration of services
- a plan for continuity of essential operations
- an Incident Management System (IMS) that defines the framework for managing any emergency and includes an Emergency Operations Centre (EOC)
- reliable communication systems, both internal and external
- a crisis communications plan that includes adequate measures for public information and education related to the emergency
- a logistics system appropriate to the anticipated task that includes adequate facilities
- regular and consistent training of those responsible for maintaining and implementing the plan
- periodic testing of the plan and the Emergency Management Program. These tests should be reasonably frequent, comprehensive and full-scale

An excellent example of a Community Emergency Management Plan is that of Brampton, Ontario, a community strongly supports emergency preparedness at the municipal level. This plan is a good model for other communities to emulate and can be found on the city's website.

Neighbourhood Preparedness: The SPAN Initiative

A community-based initiative entitled Strengthening Preparedness Among Neighbours (SPAN) takes an even more localized approach to emergency preparedness. Its goal is to ensure that neighbourhoods are self-sufficient during disasters for a minimum period of 72 hours. It does this by promoting personal

preparedness, establishing neighbourhood response teams and making good use of resources and skills that exist within the neighbourhood.
(See Canadian Centre for Emergency Preparedness)

Volunteer Training: The CERT Initiative

Volunteers can be an important resource in an emergency. Several Canadian communities have implemented the Community Emergency Response Team (CERT) concept, which trains residents to understand, prepare for, and meet their own needs during an emergency or disaster, as well as helping others to help themselves, their families and their neighbours.

During the September 19, 1985 earthquake in Mexico City, civic volunteers saved hundreds of lives. Unfortunately, about 100 volunteers lost their lives while helping to save others. To avoid such tragedies, CERT training aims to teach volunteers the skills necessary to help others while protecting themselves from injury and death.
(See Canadian Centre for Emergency Preparedness)

In Ontario, Community Emergency Response Volunteers Ontario (CERV) is a province-wide grass-roots network of teams of volunteers trained in basic emergency management principles and skills. In British Columbia, Community Emergency Resource Teams British Columbia (CERTBC) is a CERT initiative and also provides training so that civic volunteers can help others safely and skilfully.

Emergency Management Organizations in Canada

- Public Safety Canada
- Canadian Centre for Emergency Preparedness
- British Columbia Provincial Emergency Program
- Saskatchewan Emergency Management Organization
- Alberta Emergency Management Agency
- Manitoba Emergency Measures Organization
- Emergency Management Ontario
- Sécurité Publique Québec
- New Brunswick Emergency Measures Organization
- Nova Scotia Emergency Management Office
- Prince Edward Island Emergency Measures Organization
- Newfoundland & Labrador Emergency Measures Organization
- Yukon Emergency Measures Organization
- Northwest Territories Emergency Measures Organization

4.5 Remote Sensing

In July 1996, the Saguenay region of Quebec was affected by one of the worst floods in the province's history. The severity of this event made it urgent for all levels of government to map the extent of the damage and act to reduce the impact on residents.

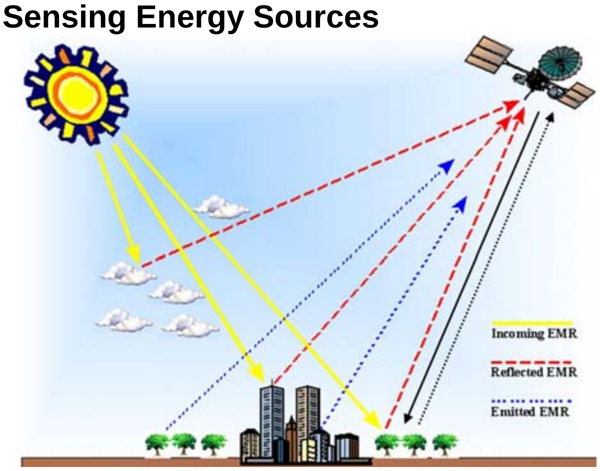
To this end, the Canada Centre for Remote Sensing (CCRS) acquired satellite images from before and after the event to estimate the costs of the flood for the entire Saguenay region. Two weeks after the event, CCRS scientists visited the site to document the effects on a local scale. Aerial images were digitally processed to produce a mosaic over several of the flooded rivers that drain into the Saguenay River, which was used to assess the extent and cost of the flooding.

Introduction

Advances in space and satellite technologies offer new options for reducing hazards and managing disasters. One increasingly useful technique is remote sensing—the process of getting information about objects of interest without being in physical contact with them. The technologies used in remote sensing include cameras, infrared scanners, and Laser Imaging Radar (LIDAR).

Some remote sensors can be hand-held, but most are put on platforms such as balloons, cherry pickers, aircraft, satellites or the space shuttle. These vantage points allow remote sensors to detect and measure the energy (electromagnetic), sound (acoustic) or force (gravitational or magnetic) emitted by objects such as water bodies, wind and vegetation. (See Figure 1). These data are then converted into useable information, such as images, for forecasting and planning purposes.

Figure 1: Remote Sensing Energy Sources



Modified from: University of Utah – GIS: CVEEN Remote sensing

Remote Sensing Applications in Canada

Remote sensing has been applied in various aspects of disaster management. (See Table 1).

Table 1: Remote Sensing Applications in Disaster Management

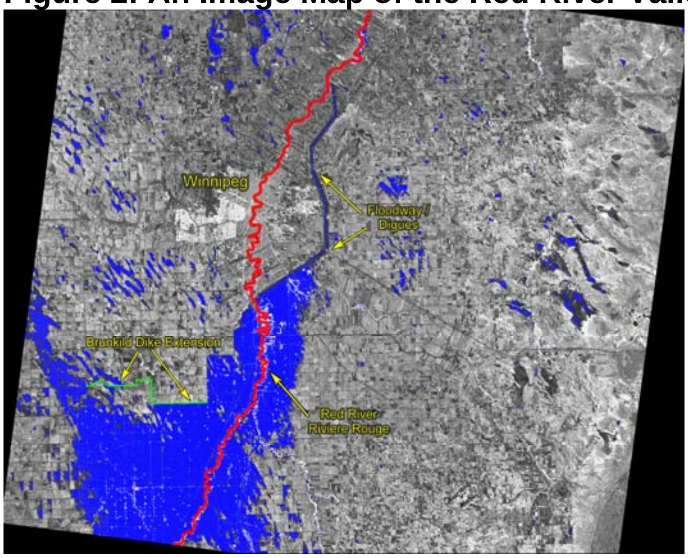
Disaster Type	Prevention	Preparedness (Warning)	Relief
Earthquakes	• Mapping Geological Structures and Land use	• Ground movements, • Surface expansion of faults	• Locate Stricken Areas, • Map Damage
Volcanic Eruptions	• Topographic and Land use Maps	• Detection/ Measurement of Gaseous Emissions, • Ground movements	• Mapping Lava flows, lahars and ashfalls, • Map Damage
Landslides	• Topographic and Land use Maps	• Level of soil saturation, • rainfall, • slope stability, • slope movement	• Mapping Slide Area
Flash Floods	• Land use Maps: • Determination of water boundaries and surface water areas	• Local rainfall measurements, • determination of aerial extent of snow and ice, • estimating snow melt runoff	• Map Flood damage
Major Floods Storm Surge	• Land use & flood plain maps, water bodies inventory, • Land Cover Maps, Mapping shallow areas & shoreline changes, tracing beach erosion	• Regional rainfall, • Evaporation and transpiration rates, • Measurement of sediment and turbidity patterns • Ocean Surface Wind velocities	• Map extent of Floods, • Map extent of Damage
Hurricanes		• Weather Forecasts	• Map extent of Damage,
Tornadoes		• Nowcasts, • Local weather Observations	• Map cost & extent of damage
Ice storm	• Land Cover maps	• Weather Forecasts	• Map of extent of damage
Drought	• Forest cover type maps, • Fire danger monitoring, • Crop drought monitoring	• Measurement of crop and timber acreage, • Estimating crop stress and yields, • Regional rainfall, • Evaporation and transpiration rates, • drought warning	• Monitoring Vegetative Biomass, • Station communication, • Map extent of fires

Disaster Prevention

Some remote sensors can measure soil and canopy moisture and discriminate effectively between water and dry land. This makes them useful in flood management and in fire/drought management.

During the 1996 the Red River Floods, enhanced images from the RADARSAT satellite were used to monitor the flood and to define its extent once it receded. These images also assisted Canadian Forces personnel during relief efforts. Figure 2 is an map of the Red River Basin created from a RADARSAT image acquired on May 1, 1997. The flood extent (blue areas) and dikes are clearly shown.

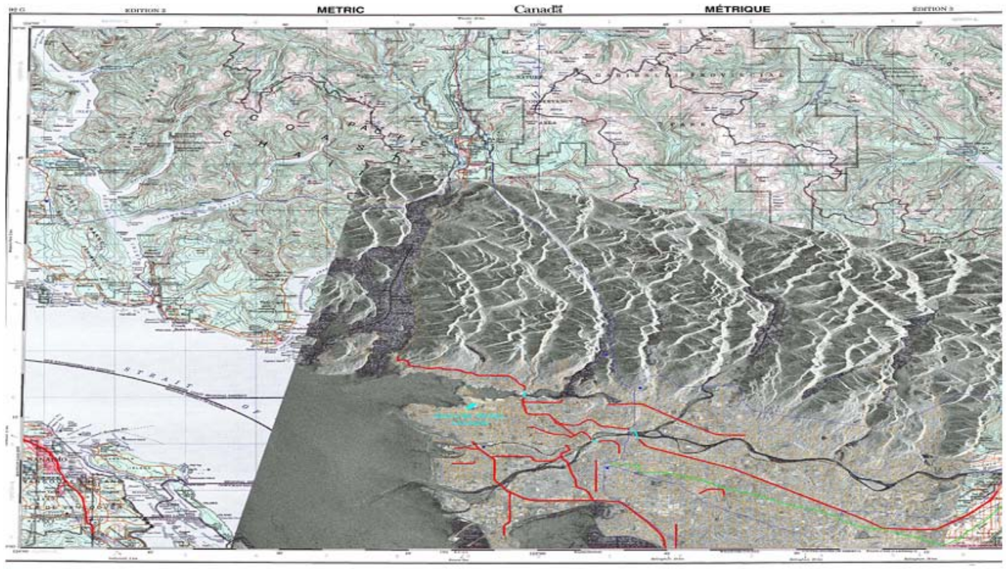
Figure 2: An Image Map of the Red River Valley showing 1996 Flood extent



Source: Canadian Space Agency – Red River image taken by RADARSAT

Remote sensing data can be combined with other geographic information, such as land use, slope, transportation and infrastructure networks, to identify high-risk areas that may be subject to damage from disasters (see Figure 3). These hazard zoning maps are useful in developing land use regulations to reduce future vulnerability.

Figure 3: A satellite image of Vancouver, taken on July 29, 2000 and integrated with cartographic information from a 1:250,00 national topographic map



Source: Canadian Centre for Remote Sensing

Disaster Preparedness

Operating high above Earth's surface, remote sensing devices on satellites can monitor events, often in real time. Satellites revolve around the earth and, in some cases, provide continuous day and night all-weather coverage, so they can send real-time data to weather monitoring stations that analyze and create forecast models for tracking storms and other weather events.

On the ground, Canadian meteorologists use weather radar to determine the motion, location, intensity and structure of precipitation inside and outside of storm systems. The detailed information provided by these radar systems enable weather forecasters to identify and more precisely define the areas where severe weather, such as tornadoes, is likely to occur. (See Section 2.12: Tornado)

Remote sensing images are also used to evaluate risks associated with landslides and avalanches especially in mountainous areas of Canada (See Section 3.3:Landslide and Section 3.4: Snow Avalanche) Researchers from CCRS and Natural Resources Canada use remote sensing techniques to monitor landslide stability at selected stations along two of the most strategically important transportation corridors in the country—the Fraser Valley and the Crowsnest Pass, which link the Prairie provinces with metropolitan Vancouver. They've been gathering information about slope gradient, soil porosity and drainage-vegetation patterns to develop an inventory of landslides in high-risk mountainous regions.

Remote sensing is also proving useful in monitoring glaciers, sea ice and icebergs. The Canadian Ice Service uses such data to analyze and forecast sea ice and iceberg conditions for shipping and marine safety in five regions: the Great Lakes, the St. Lawrence River, the Gulf of St. Lawrence, the East Coast and the Arctic. They provide ice hazard bulletins and special warnings, as well as free real-time ice information on their website.

Remote sensors used to detect gaseous emissions that precede volcanic eruptions can provide data for early warning purposes. They can also track emissions once an eruption has occurred.

For decades, scientists have used remote sensing data to develop long-range climatic models for drought management. They've also used long-term satellite monitoring of crop areas and yields to create crop hazard maps. In Canada, RADARSAT data are used for assessing cultivated areas, forecasting yields, measuring soil moisture, monitoring poor growth areas, determining the need for fertilizer or pesticides and evaluating the damage caused by tornadoes, hail or pests.

Remote sensing aids in the detection, damage assessment, and risk evaluation aspects of forest-fire disaster management. Aircraft observations and satellite data are used to supplement traditional approaches involving visual observations and forest observation towers. Natural Resources Canada has a Fire Monitoring, Mapping and Modeling System (Fire M3) that monitors actively burning large fires in real time, estimates annual area burned and models fire behaviour. Other pilot research projects have been undertaken to develop a fire danger monitoring system based on the estimation of fuel moisture using remote sensing (Leblon and Pultz, 2005)

Response and Recovery

It's important to respond quickly when disaster strikes to minimize the loss of life and property, but affected regions are often cut off by the failure of transportation and communications links in the wake of the disaster. In these circumstances, remote sensing is useful for locating stricken areas and disaster victims and for mapping the extent of the damage. With just one pass, satellites can provide high-precision images of wide areas of the disaster zone. In addition, those that have radar instruments, such as Canada's RADARSAT-1, can image the Earth's surface night and day in all weather conditions.

By comparing pre- and post-disaster images, civil authorities can detect areas where the disaster has changed conditions in the affected region—crucial information for those charged with rescuing people and restoring services.

Remote Sensing Information for the public

Individuals and communities can access remote sensing data to identify their level of risk. For example, RADARSAT images are available, usually on a commercial basis. Images for research and public awareness purposes can be purchased a special price.

Under the auspices of the International Charter on Space and Major Disasters, communities in crisis can have access to timely, high-quality satellite data for rescue and recovery purposes at the request of the Charter partner agencies, the Canadian Space Agency, the European Space Agency, the U.S. National Oceanic and Atmospheric Administration and the Indian Space Agency.

For communities concerned about flooding, the Dartmouth Flood Observatory provides updated information on global floods that can be used to create hazard maps, assess vulnerability and develop disaster plans.

Municipal archives and libraries may also have pictures of past disasters that can help in assessing vulnerability.

Further information

- Dartmouth Flood Observatory:
- Canadian Center for Remote Sensing:
- University Corporation for Atmospheric Research: Remote Sensing Using Sattelites
- Canadian Space Agency
- University remote sensing laboratories websites
- Various university research departments

Sources and Further Reading

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4.6 Insurance

Between January 4 and 10, 1998, the worst ice storm in Canadian history spread a wide swath of disaster throughout eastern Canada and adjacent parts of the United States. The region around Montreal and Ottawa were hardest hit. More than 100 millimetres of icy rain fell in areas south of Montreal, while Ottawa received about 85 millimetres—more than double the amount that had fallen during the worst previous ice storms in these areas.

The damage was devastating. Thousands of kilometres of electrical power and telephone lines were knocked out. More than 1,000 transmission towers toppled, as did 30,000 utility poles. A massive power blackout ensued, affecting more than 1.6 million people in Ontario and Quebec. About 100,000 people took refuge in shelters.

It was Canada's most expensive natural disaster to date, costing a record $5.5 billion, of which more than $1.4 billion was paid out in insurance claims.[1]

The Growing Damage from Natural Disasters

Natural disasters have caused misery and suffering throughout human history. Globally, they kill about one million people per decade and cost the world's economy about US$50-billion a year and rising. With global climate change, increasing urbanization and aging urban infrastructure, the social and economic costs of natural disasters are expected to continue rising.

Canada has had a fair share of natural disasters. (See Table 1.) Between 1983 and 1987, they cost Canadians about $500 million. Over the subsequent five years, these costs increased to about $750 million and they more than doubled to over $1.5 billion between 1993 and 1997.

[1] Statistics Canada: "The Storm" Catalogue no. 16F0021XIB

Table 1: Costs of Natural Disasters to the Insurance Industry, by Type

(Major multiple-payment occurrences)

Event Type	No. of Events	Cost in Millions (2006 $)	Percent of Total
Flood/Hailstorm	1	180,187	2.2
Flooding	27	1,382,153	16.8
Forest Fires	1	212,257	2.6
Hail	8	691,360	8.4
Hailstorm	13	714,691	8.7
Hurricane	2	147,875	1.8
Icestorm	2	1,961,658	23.8
rainstorm	2	118,139	1.4
Snowstorm	2	156,285	1.8
Storm	26	1,037,023	12.6
Tornado	7	544,122	6.6
Wind	8	306,388	3.7
Wind/Hailstorm	3	68,386	0.8
wind/rainstorm	1	509,813	6.2
Windstorm	4	211,490	2.6
windstorm/hail	1	4,628	0
TOTAL	**108**	**8,246,455**	**100%**

*Cost to the Canadian insurance industry of natural disasters. Types ranked by cumulative cost.

Source: Institute for Catastrophic Loss Reduction, data 1983 - Dec. 2006 (Drought and residential flood costs are not included. Commercial flood costs are insurable and included.)

Strategies to Deal with Natural Catastrophes

There are two basic ways to deal with disasters: risk reduction and risk transfer.

Risk reduction involves implementing strategies before the event, with the aim of either reducing exposure or increasing the ability of structures or communities to withstand its impact. These activities could be structural (e.g. constructing dikes and floodways) or non-structural, such as restricting development on floodplains.

Risk transfer, on the other hand, enables people to cope with or recover better from a disaster. It involves shifting much of the loss from individuals to society at large (including the government), using mainly financial mechanisms. In Canada, risk transfer is mainly done through insurance and a federal disaster assistance program (See Section 4.7: Disaster Financial Assistance).

Insurance as a risk transfer strategy

Insurance is an agreement between an insurance company (the insurer) and their client (the insured), which states that if the insured suffers a loss, they will be compensated for it, as long as certain conditions are met. Insurance policies differ and it's important to understand what is or is not covered. Besides providing a safety net for victims, insurance also provides resources to rebuild damaged property.

Public Insurance

In Canada, both governments and the private sector provide insurance. An example of a public program are the crop insurance programs run by the provinces, but assisted with federal financial contributions. The program provides production risk protection to farmers by minimizing the economic effects of crop losses caused by natural phenomena such as drought, flood, hail, frost, and insects. There's also a provision for crop damage caused by protected migratory waterfowl such as Trumpeter Swans and Snow Geese.

By sharing the costs of damage among farmers and the federal and provincial governments, the crop insurance program minimizes the risks involved in farming. Crop loss protection is available to farmers in the form of a production guarantee based on their probable yield. If production falls below that expected yield due to a natural hazard, farmers are eligible for compensation.

Generally, the maximum coverage available is 80% of the historic average yield in an area, or the individual farmer's average yield. Crops or producers who are considered to be at low risk can get up to 90% coverage. Although the federal and provincial governments provide most of the funds for this program, producers also contribute by paying premiums.

Sometimes, the federal government enters into crop reinsurance agreements with provinces. Under this scheme, the federal government provides provincial governments with funding when costs incurred exceed accumulated premium reserves due to severe crop losses.

Both federal and provincial governments have paid significant amounts under the Crop Insurance Program (See Tables 2 and 3.)

Table 2: Crop Insurance Costs by Province (1986-1996)

Province	Amount (million $CDN)
British Columbia	34
Alberta	1,048
Ontario	72
Manitoba	528
Saskatchewan	1,996
Quebec	36

Between 1972 and 1992, federal government payments to Canadian farmers directly related to climate (e.g. drought assistance, crop loss compensation, crop insurance) totaled $5 billion, or an average of $250 million per year. Some years are much worse, however; in 2001, crop insurance paid out some $1 billion while in 2002 drought payments exceeded $2.0 billion.

In 2002 a National Water Supply Expansion Program was created in order to allow agricultural areas of Canada the technical and financial assistance necessary for developing sustainable water supplies. Through a series of Federal, provincial and territorial agreements those in need apply for assistance for a variety of projects. This program was originally scheduled to end on March 31, 2008 but was extended on year further in order to allow the federal government time to create and implement the next phase of agricultural policy and programming.

Table 3: Crop Insurance Costs: 1986-1996

Year	Amount (million $CDN)
1986	202
1988	1,047
1989	990
1990	617
1991	147
1992	581
1993	377
1996	58

Private Insurance

In Canada, more than 230 companies actively compete in the Property and Casualty insurance industry, along with about 40 reinsurers, most of which are foreign owned. Reinsurers are companies that insure insurance companies.

Over the years, insurance companies have made substantial payouts to disaster victims. For instance, the 1996 Saguenay floods, which were among the top 10 insurance disasters in Canada, cost the industry about $207 million. In 1997, the Red River floods in Manitoba cost private insurers over $200 million. The 1998 ice storm in Quebec and Ontario set a record of $1.4 billion in insured losses.

Sewer backup insurance in Canada

In Canada, residential insurance policies do not cover water damages attributable to overland flooding. However, depending on the community, residents may be eligible to be covered for losses due to sewer backup through a standard policy or for an extra premium. Sewer damage can be considerable. In 1993, $213 million (2003 dollars) was paid to Winnipeg residents for damages caused by sewer backup following intense rainstorms. Afterwards, however, many insurance companies stopped offering this provision to Winnipeg residents.)

Private insurers will usually provide coverage for commercial losses due to closures and damages. Following the 1997 Red River flood, insurance companies paid $2-million for sewer backup up, out of a total of more than $200 million for all damages. After that event, the few companies that still provided sewer back-up coverage withdrew this clause. In the future, residents of Winnipeg will have to bear their own losses.

Since 1983, Canadian insurance payouts for damages caused by natural disasters have been doubling every five years. Rising property values and aging infrastructure may further aggravate the situation. While the expectation of more disasters in the future may convince more people to take out insurance policies, excessive disaster losses could cripple the insurance industry. Therefore many insurers in Canada believe that pro-active measures such as public education, use of better building materials and codes and restricted development in risk-prone areas are needed, not just because it's good for society, but because it's good for business.

Unless such measures are taken, insurance companies may be forced to either increase premiums or limit their exposure to losses by avoiding coverage of property in vulnerable areas. In fact, some companies have already scaled down their business in areas like the low-lying community of Richmond, south of Vancouver, for fear of a flooding event from the Fraser River. If this trend continues, many people will have to live without insurance, thus increasing their vulnerability.

The ability of the insurance sector to continue playing its traditional risk-spreading role depends on the actions of both its policyholders and all levels of government. By reducing vulnerability through better development choices and regulations, the impacts of disasters would be reduced and so would the cost burden of the insurance industry. This would benefit everyone. Increased insurance payouts translate into increased premiums or limited coverage. In both cases, it's the policyholder or the taxpayer who pays the price.

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- Agriculture and Agri-Food Canada

- Environment Canada

- Federal Emergency Management Agency

- Disasters, a deadly and costly toll around the world, continued

- International Federation of Red Cross and Red Crescent Societies

- Disaster Data: key trends and statistics

- World Meteorological Organization

- Institute for Catastrophic Loss Reduction

4.7 Federal Disaster Financial Assistance Arrangements (DFAA)

Introduction

Large scale disasters can be enormously costly. Responding to and recovering from such events can overwhelm the resources of provincial and territorial governments. This is why the federal government has put in place the Disaster Financial Assistance Arrangements (DFAA) to provide financial assistance in times of extreme need. This program, administered by Public Safety Canada (PSC) was begun in 1970 to replace an ad hoc method of dealing with disasters to a more organized one. It should be recognized that the fundamental responsibility for dealing with disasters lies with the provinces and territories, and that the federal government, though it provides assistance, is not required to do so.

Emergency preparedness in Canada is based upon a philosophy that responsibility begins with the individual, and then moves to higher levels of government as the capacity of people or communities to cope is overwhelmed.

- Individuals, family units, small businesses (including farms) are expected to prepare for any emergencies and disasters that might occur, to take initial response measures and to provide for post disaster clean up and restoration to the limits of their capabilities. This would include maintaining prudent levels of insurance that are reasonable and readily obtainable through public and private sources.

- The municipal government or local authority as the most immediately involved government, prepares response plans, initiates second level response actions and is closely concerned with clean up and the restoration of essential services. Municipalities are also the first level involved in post-emergency or disaster restoration and recovery. Where appropriate they also should maintain prudent levels of insurance that is available at reasonable cost and readily obtainable through public and private sources.

- Provincial and territorial governments are involved in the response regime, overseeing large-scale operations, providing specialised resources and co-ordinating support from other governments. In the recovery phase for emergencies and disasters, they design and implement recovery programs and are responsible for providing financial assistance to affected individuals and local government authorities.

- The Government of Canada provides response resources when requested by a province or territory, when Government of Canada jurisdictions are involved in emergencies or disasters, and/or when several provinces or territories are affected. For large-scale events, the Government of Canada shares the cost of eligible disaster response and recovery expenses when requested by the affected province or territory. Government of Canada financial assistance is administered and delivered through the province's or territories' disaster financial assistance mechanisms.

The DFAA defines the roles and responsibilities of both the federal government and provincial governments in disaster response and recovery. Under the arrangement, the federal government offers financial assistance to provincial and territorial governments (not individuals) when disaster response and recovery expenditures exceed what an individual province can bear on its own. In turn, provincial governments deliver financial assistance directly to disaster victims. They have the power to decide how much and what types of assistance can be provided.

In certain instances, a provincial/territorial government may request that the federal government share the cost of responding to disasters. In such cases, the level of federal assistance is determined using a formula based on a province's population size. The system is designed so that the federal government pays a proportionately greater amount the bigger the disaster.

Provincial Disaster Financial Assistance (DFA) Program:

Each province has its own disaster assistance program tailored to respond to suit their unique conditions**.** As an example, some details of Manitoba's program are given below.

In Manitoba, when disaster creates an unreasonable financial burden, assistance is provided to help local governments, individuals, full-time farmers, small businesses and some non-profit organizations using the cost-sharing formula below.

Table 1: Province of Manitoba's cost-sharing formula

Expenditures Per Capita of the Municipal Population	**Provincial Share**	**Municipal Share**
$0.00 to $1.00	0%	100%
$1.01 to $3.00	50%	50%
$3.01 to $5.00	75%	25%
$5.01 plus	90%	10%

Disaster Financial Assistance Policy

The Manitoba Emergency Measures Organization (EMO) administers the assistance programs offered under the DFA Policy.

Purpose

- To assist local authorities financially when eligible costs incurred during a disaster exceed what any one local authority may reasonably be expected to bear on its own.
- To ensure that, as much as possible, the provincial disaster assistance program is consistent with the federal program, so that claims are handled in a consistent manner regardless of which government level provides financial assistance.

Qualifying for Assistance

Eligible Costs

Assistance is generally available for:

- **Pre-emptive costs:** costs incurred for constructing temporary dikes (berms or sandbags); costs of operation and/or removal of water pumps
- **Evacuation costs:** "reasonable expenses" when evacuation is necessary
- **Restoration to a pre-disaster condition**
- **Loss or repair of essential items:** Loss of uninsurable harvested or stored crops; livestock fencing; farm machinery and trapping equipment
- **Structural damage**
- Principal residences
- Farmland restoration (erosion) but not loss of market value of land
- Farm buildings or buildings essential to the operation of a farm
- Buildings essential to the operation of a small business
- **Clean-up and debris removal,** including allowances for applicants who undertake their own clean-up

Ineligible Costs

Assistance is *not* available for:

- **Insurable losses:** Items that are, or could have been insured at a reasonable and available rate.
- **Costs recoverable through an existing government program**
- **Losses recoverable at law**
- **Non-essential items:** Luxury items; recreational property and private roads; lawn and garden damage; fences (non-farm)
- **Loss of income and opportunity or inconveniences**
- **Normal operating costs**
- **Upgrading of existing facilities**
- **Damages that are a normal risk of trade, occupation, or enterprise**

The Process
Before, during and after the disaster, keep track of your expenses and costs. Documenting losses with photos or videos is useful.

Before individuals can apply for assistance, the municipality must, with 30 days following the disaster, pass and forward a resolution to EMO requesting financial assistance.

Once a program is in place, individuals have 90 days to apply for assistance. Applications forms are obtained from local municipal offices, which collects the completed forms and forwards them to EMO.

Inspection of damages
An EMO recovery advisor visits applicants with eligible costs to examine and report on the damages. Following this inspection, claims are evaluated and a payment is made, based on eligible costs. It's important for applicants to keep receipts, time sheets and invoices for all repair work or replacement of items eligible for assistance.

Appeals
Those who feel they have not received the assistance to which they're entitled, can appeal their assessment by contacting the Disaster Assistance Appeal Board.

Limitations
- The maximum assistance on private claims is 80 per cent of eligible costs to a maximum of $100,000.
- Claims are based on net costs. Recovered costs must be reported to EMO and will be deducted from the overall claim.
- No claim should exceed the estimated cost of repair or replacement.

General Administrative Procedures of Federal DFAA

It takes a big enough disaster and a request from the affected province to trigger federal assistance under the DFAA. The request is sent to the federal Minister responsible for emergency preparedness. It's a good idea for provinces to send this request as quickly as possible; this enables an early assessment of the damages and a determination of the provincial expenditures on response and recovery that are eligible for federal assistance.

According to the guidelines, federal assistance is given when eligible provincial expenditures exceed an amount equal to $1 per person of the provincial population. Since the inception of the DFAA, over $1 billion in post disaster federal assistance has been given to provincial governments.

Federal Disaster Financial Assistance (per capita sharing formula)	
Provincial Eligible Expenditures	**Federal Share**
First $ 1 per capita	Nil
Next $2 per capita	50%
Next $2 per capita	75%
Remainder	90%

Eligible and Ineligible Costs

Not all provincial costs are eligible for federal assistance under the DFAA guidelines. Those that are include restoring public works and essential individual property to their pre-disaster condition.

- *Provincial/territorial expenses eligible for federal cost sharing*
- Cost relating to rescue, transportation, emergency health arrangements, emergency medical care, emergency feeding, shelter and clothing
- Costs relating to the shelter and feeding of livestock
- Emergency provision of essential community services
- Security measures, including the removal of valuable assets and hazardous materials from a threatened area
- Communications costs, extraordinary monitoring and control expenditures
- Costs of measures taken in the immediate pre-disaster period intended to reduce consequences

- *Provincial/territorial expenses not eligible for federal cost sharing*
- Damage to non-primary dwelling (cottage, ski chalet, hobby farm)
- Damage for which costs could be recovered through insurance
- Damage costs covered in whole or in part by another government program, such as crop insurance
- Damage to property or facilities for which assistance was previously available to prevent such damage (such as a government-assisted diking program)
- Assistance to large businesses and industries
- Normal operating expenses of a municipal or provincial government department or agency

The federal government does not give financial assistance to individuals or communities directly. They may receive assistance from their provincial and territorial governments to cover eligible costs and these provincial payments are then retrieved from the federal government under the cost sharing arrangement.

Examples of eligible individual costs include:

- Restoration, replacement, repairs to houses and other dwellings (principal residence only)
- Restoration, replacement or repairs to essential furnishings, appliances and clothing

- Assistance in the restoration of small businesses and farmsteads, including buildings, stocks and equipment, when an individual's livelihood has been destroyed
- Costs of damage inspection, appraisal and clean-up

Individuals receive the provincial minimum wage for their clean-up efforts. Assistance for reconstruction of buildings will be given only once, unless action to avoid repeated losses is not possible or practical.

Costs not paid for include anything that could be covered by insurance such as vehicles, loss of income, normal operating expenses and restoration of property owned by large businesses.

DFAA Costs

The number of disasters eligible for DFAA support has risen over the past several decades. In the decade of 70's there were 31 events, in the 80's 32 events, in the 90's 49 events, and from 2000 to the end 2004 30 events[1].

Floods are a major cause of property damage in Canada (See Table 2.)
Once an area is designated as a high flood risk, no DFAA assistance will be provided to repair or replace structures subsequently built or installed in these designated areas that are damaged by flood.

Table 2 of DFAA payouts (1970-1995)

Event	Audited Total (Millions of Dollars)	DFAA Payout	Percent of Audited Total
Flood	$307.2	$150.2	73.7%
Storm	$48.7	$22.8	11.7%
Fire	$41.8	$23.3	10.0%
Sleet/Ice	$11.1	$6.1	2.7%
Windstorm	$4.1	$2.1	1.0%
Hurricane	$2.4	$0.8	0.6%
Snowstorm	$1.6	$1.3	0.4%
Totals	$416.9	$206.6	100%

DFAA costs vary from province to province (See Table 3). This variation depends upon how exposed communities in the province are to hazards, their vulnerability, to what extent the hazards fall within DFAA parameters and the size of their population. Provinces with large populations, such as Ontario, require much larger disasters to qualify for DFAA due to the nature of the funding formula.

[1] Note: Since the financial threshold of $1 per capita has not changed over entire period, more events would be expected as a result of inflation.

Table 3: Federal DFAA payouts to provinces from 1970-1995.

Province	Adjusted Total Payouts (1995 dollars)
QUE	$133.0
MAN	$81.6
ALTA	$54.1
BC	$37.5
NB	$48.2
NFLD	$23.5
SASK	$17.3
NS	$13.2
YT	$3.9
PEI	$4.3
GNWT	$1.4
ONT	$0.3
Total	$418.1

*Dollars are adjusted to FY 95/96 values

Trends

DFAA assistance to provinces has been rising (Figure 1). This trend would be expected as a result of population increase and the constant financial threshold criteria of $1 per capita. However, some analyses suggest that the frequency of flood disasters has also been increasing as a result of continued development within some flood plains in Canada, and that the increase in costs also results from this exposure. In addition, Canada has suffered some rare and major disasters within the past decade, such as the 1998 Ice Storm, which affect the statistics.

Figure 1: Trends in DFAA Payouts to Provinces

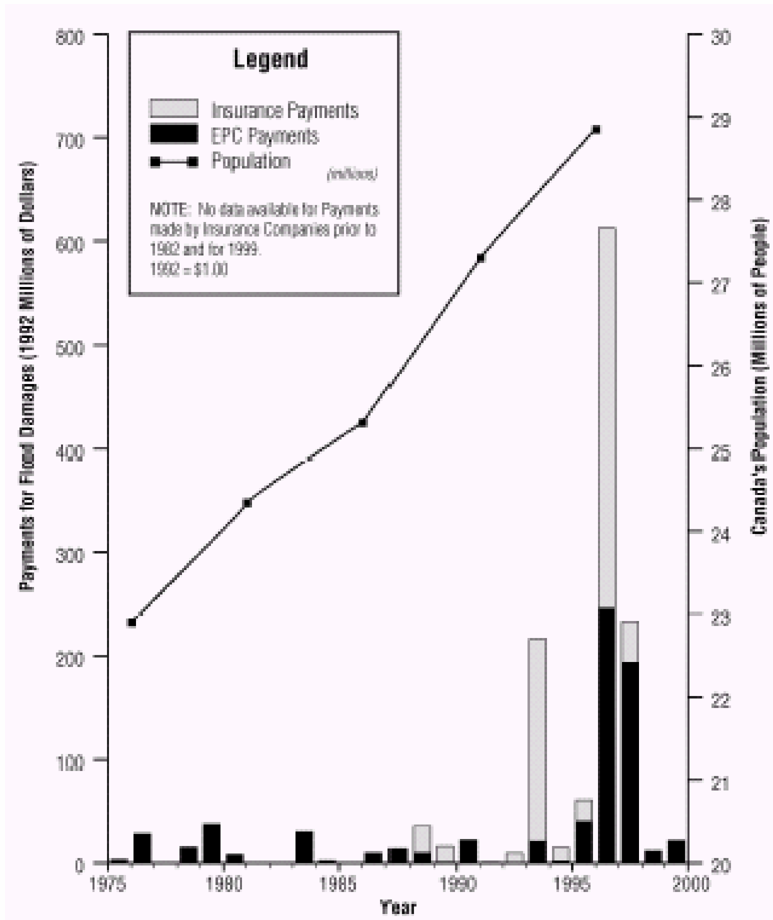

Figure 2.2 – Flood damage payments from Disaster Financial Assistance Arrangements (DFAA) and the insurance industry along with Canada's population since 1975. Costs standardized to 1999 dollars and show both federal and provincial/territorial contributions. Note that these figures do not include costs of provincial assistance to sub-DFAA threshold events (i.e., less than $1 per capita provincial population) (Shrubsole, 2000).

Sources and Further Reading

- Public Safety Canada - Disaster Financial Assistance Arrangements (DFAA)
- Manitoba Disaster Financial Assistance (DFA)
- Ontario Disaster Relief Assistance Program

4.8 Disaster Mitigation

In 1950, the city of Winnipeg suffered its worst flood in a century and vowed never to allow it to happen again. In direct response to the disaster, the Manitoba government spent the next 18 years completing a floodway to divert the waters of the Red River around the city.

Costing over $63 million it has saved Winnipeg from disastrous flooding many times, with an estimated savings of over $10 billion in flood-related damages. In 1997 an expansion project was commenced with funding of $665 million, in order to keep all communities protected from further flooding events[1]

Because it reduced the impacts and costs of future flooding, the Winnipeg floodway is a prime example of a successful disaster mitigation project.

Introduction

Disasters, whether natural or human in origin, are a major cause of misery and property damage. When disaster strikes, businesses are interrupted, essential infrastructure is damaged and peoples' lives and livelihoods are affected. Communities are faced with often monumental repair tasks and their sometimes huge costs.

Disaster costs have been rising steadily in recent years as a result of increasing population, urbanization, rising property values and changing climatic conditions. Growing populations and increasing population densities in urban areas increase the number of people at risk. Higher property values translate into higher costs when destruction occurs. As climatic conditions become more erratic, there are fears that the frequency and severity of climate-related disasters might increase.

The changing face of disaster management

In times past, disasters were mostly considered acts of God or Nature, beyond the ability of humans to prevent or contain. Humans were portrayed as victims and nature as the perpetrator. In this context, the usual response was merely to pick up the pieces after the disaster and start over.

Over time, this mindset has largely changed as we came to recognize that human activities play a key role in creating disasters out of natural events. The rising costs of post-disaster response and recovery measures have also motivated us to find ways to reduce vulnerability.

[1] Manitoba Floodway Authority – History of the Floodway

It's important to understand that a natural hazard, such as a flood or an earthquake, does not become a disaster unless there is some part of society that can be affected and some vulnerability that can be exploited. A flood is not a flood disaster if it occurs where nobody lives; when it affects a vulnerable community it can become one.

This suggests that actions taken both before and after a disaster can go a long way to reduce its severity or prevent its reoccurrence. Disaster experts now accept that if human activities can aggravate the destructive effects of natural phenomena, they can also reduce or eliminate them.

Actions taken prior to a disaster are categorized as disaster preparedness while those taken immediately afterwards to locate and help victims and rebuild what's been destroyed are classified as response and recovery.

Although these actions help reduce the impacts of disasters, disaster-related costs have continued to increase. This has shifted the focus towards more long-term, sustained actions to reduce or eliminate the impacts and risks associated with natural and human-induced disasters. These actions are known as disaster mitigation, and include such measures as long-term planning (e.g. good building codes), community awareness programs and land use policies that prevent development in hazardous areas.

Disaster Mitigation at Work

Mitigation occurs through activities that reduce risk or transfer/share risk.

Risk reduction can be accomplished by modifying the hazard or reducing vulnerability. An example of hazard modification is a hail suppression program that attempts to prevent or reduce the severity of damaging hailstorms. Building floodways to protect communities from damaging floods or revegetating slopes to prevent landslides are measures designed to reduce vulnerability.

Within Canada, risk transfer is achieved mainly through insurance—both private and government-sponsored, such as crop insurance—and through government disaster assistance programs. Internationally, the World Bank and International Monetary Fund (IMF) provide grants and loans to assist developing countries recover from disasters.

Disaster Mitigation Tools

A number of disaster mitigation techniques and practices are employed to increase the resilience of communities and reduce future damage and losses. These include: land use planning tools to avoid habitation in hazardous areas;

engineering and building codes to build disaster-resistant structures; educational programs to inform the public about the risks they face; warning systems to aid rapid evacuation or preparedness and insurance to fund recovery after a disaster.

Although each of these techniques can play a role in mitigating disasters, the choices individuals and communities make about which measures to use depend on several factors, including available resources, adaptive capacity, disaster history and socio-political institutions.

1. Land use Planning

When a disaster causes extensive destruction of property one of the questions most frequently asked is: “Why were they allowed to build there?” The answer lies in the kind of land use planning available within the community and/ or the extent to which land use regulations are followed and enforced.

Land use planning is the decision-making process that determines where development takes place or where structures are built. A good land use plan identifies hazardous areas and restricts or prohibits development there. This keeps property and businesses out of harm’s way. It also increases the resilience of a community by ensuring that protective natural features such as sand dunes, wetlands, forests and vegetated areas are maintained as buffers against disasters. A community that plans before acting can spare itself a lot of misery and expense.

2. Building Codes and Standards

A land use plan determines where development takes place but how structures are built is determined by building codes and standards. The number of deaths and injuries and the costs resulting from a disaster can be significantly influenced by the quality of buildings and other structures in a community.

Structures that are fortified and built to the highest standards obviously stand a better chance of surviving a disaster than those that are haphazardly built. It’s even better when structures are designed and built to suit local conditions including geology, climate and known hazards. For example, in hurricane-prone areas, where high winds pry open vulnerable cracks in homes and turn debris into missiles, it may be best to build a concrete home or one with thicker than normal walls.

In Canada, the National Building Code contains provisions for determining the seismic forces which a building must be designed to withstand. Key to this are two seismic zoning maps prepared by the Geological Survey of Canada (GSC), based on the earthquake record and geological factors controlling earthquake activity. One map, which shows peak ground acceleration, is relevant to short, stiff buildings; the other, showing peak ground velocity, applies to tall, flexible buildings. The maps are updated every 10 to 15 years.

Good building codes are only the first step in reducing the impacts of disasters. To be effective, the codes must be rigorously enforced. Enforcement failures have resulted in significant property damage that could have been avoided.

3. Insurance

Even with the best preparation, it's often impossible to completely avoid suffering damages during a disaster. This is where insurance comes in. Its role is to compensate policyholders for losses suffered, as long as certain conditions are met. In Canada, both governments and the private sector provide insurance for many risks—although some, such as residential flooding, are not insurable (See Section 4.6: Insurance).

Insurance does not prevent disasters but can minimize the severity of their impacts. It provides a safety net for victims and resources to rebuild damaged property. This enables people to better cope with or recover from a disaster.

By putting a price tag on risk and creating financial incentives such as rate discounts and higher coverage limits, insurance policies can also encourage people to take steps to reduce risk. For example, insurance companies can make coverage contingent on a property being built in a less hazardous area or retrofitted to an acceptable standard. These measures minimize potential losses by proactively reducing the number of people or the amount of property put in harm's way. Individuals who take such steps may be offered lower premiums than those who do not.

However, limiting insurance coverage may not be enough. It's also important to educate the public to be aware of the risks they face and what they can do to reduce their chances of loss. In Canada, this is done by organizations like the Institute for Catastrophic Loss Reduction (ICLR), which offers publications and seminars for both officials and the general public.

4. Prediction and Warning Systems

Accurate and timely warnings and forecasts are critical to saving lives when disaster strikes. They provide information about the nature of impending events as well as advice on how to respond. They help define the risks that local communities face years to decades ahead of potential hazards, thus assisting decision makers and community members to anticipate and design programs that

reduce vulnerability and increase resilience. By limiting property damage and minimizing disruptions, timely warnings and forecasts also enable communities to recover more quickly. (See Section 4.2: Prediction)
In Canada, the Meteorological Service of Canada issues forecasts and weather watches and warnings. The Geological Survey of Canada provides information on earthquakes and geomagnetic storms. The goal in both cases is to inform the public about present and future hazardous conditions so they can take appropriate action before, during and after disasters to reduce losses.

5. New Technologies: GIS, Remote Sensing

New developments in space and computer technology, such as remote sensing and GIS (geographic information systems), offer new ways to mitigate hazards and improve disaster management. The information they collect about the impacts of previous disasters are compiled into data bases and combined with other information to produce hazard maps that highlight potentially dangerous areas.

One example is seismic hazard maps that delineate earthquake risks in a given area. Another is flood mapping; satellite data can be used to map and monitor flooded areas and is also useful for flood damage assessment, flood hazard zoning and post-flood surveys of rivers and protection works.

Because satellites can provide an overview of large tracts of land, they can help detect and monitor natural events. This improves detection and prediction, which in turn enables communities to prepare adequately before a disaster strikes.

Finally, remote sensing (See Section 4.5: Disaster Financial Assistance) can help assess the damage caused by a disaster, thus providing data for relief operations. This data can also be used to map the post-disaster situation, which can aid reconstruction. If remote sensing information helps communities take precautions based on past experience, it can play an important role in preventing or minimizing future disasters. Continuing improvements in computer and satellite technologies will create new opportunities to detect, monitor and map natural hazards.

In Canada, the Canadian Space Agency (CSA), Canada Centre for Remote Sensing (CCRS) and other stakeholders offer images and archival information to monitor and manage natural hazards such as hurricanes and floods. These images are often supplied commercially, but those used for research purposes are available at a special price.

6. Education

A well-informed public is key to reducing the catastrophic impacts of a disaster. People who know the risks they face, as well as the benefits of risk-avoiding actions, are more likely to make informed choices. It's important, therefore, that they have access to accurate and up to date information on potential hazards and on programs to reduce the impacts of disasters.

Before a disaster, information on hazard-prone areas in a community—usually in the form of hazard and vulnerability maps—help individuals decide whether to put themselves in harm's way or not. Forecasts and other warnings about impending disasters are relayed to residents so they can decide whether to evacuate and/or make their structures more secure. Lists of basic do's and don'ts can also help people reduce their vulnerability even in the face of unavoidable natural disasters.

In Canada, organizations like PSC, Natural Resources Canada and Environment Canada provide information to the general public through the Internet, publications and seminars. PSC provides a record of all Canadian disasters, a Hazard Map of the country and simple self-help brochures on individual preparedness. (See Public Safety Canada: Get Prepared).

As well, since 2002 Canada has been in the process of developing a National Disaster Mitigation Strategy which was then launched in early 2008. Federal, provincial and territorial governments have worked together on this all-hazards approach which focuses on reducing the risks posed by natural hazards. This strategy involves education, leadership, research and cost-sharing mitigation investments. Disaster prevention/mitigation measures in Canada are broad and it is hoped that this program will achieve organization and broadening of mitigation knowledge across the country.

Other organizations that provide disaster information include the Institute for Catastrophic Loss Reduction (ICLR) and the Canadian Space Agency (CSA). CSA provides satellite images and ICLR has publications dealing with almost all major natural hazards facing the country.

Sources and Further Reading

- Miletti, D. (1999) Disasters by Design a reassessment of natural hazards in the United States, Joseph Henry Press: Washington.
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SUMMARY

5.0 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 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 ourselves 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 nature's fault. In fact, these events do not become disasters without human complicity – without humans creating vulnerability, because of where and how they build their homes, businesses and other critical infrastructure.

Natural events like hurricanes, floods, earthquakes or tornadoes are, in fact, hazards that have the potential to harm people and damage property. They 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 it gets much more of it. But an event outside the range of normal experience—such as the 1998 ice storm—can decimate the resources even 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 ice storm of 1998 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. Hail storms 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's 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 building dams and prohibiting people from building home 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 the disaster has occurred. The activities of police, firefighters and medical personnel during and immediately after the 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 unfortunately encourage 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 more immediate and 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 just how large the price tag is. 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 so disrupted their lives.

Public Safety Canada has developed a National 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 maintain 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. This is being achieved through the continuation of the Canadian Disaster Database and the Canadian Risk and Hazards Network. 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 departments and agencies; they are not well co-ordinated and there is little information on what savings 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 through programs (such as that by the Government of Canada promoting a 72 hour survival kit) 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 1 per cent 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 rooted out because they can lead to an increase risk-taking behaviour that increases a community’s vulnerability.

It is also important to adopt mitigation strategies that reduce over-reliance on technological solutions. The technological approach, which 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.

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 disasters that do happen and improve our ability to respond to and recover from them. We can modify risky behaviours and policies that increase our vulnerability to disasters.

Disaster losses are now measured in the billions and rising steadily. The human toll, though less quantifiable, is also large. Even more damaging events are predicted for the future as the climate changes. There is a need for action. Protecting ourselves against disasters demands increased awareness, co-operation and commitment from everyone—governments, corporations, community groups and individuals.