Canadian National Report

Prepared for the IDNDR Mid-Term Review and the 1994 World Conference on Natural Disaster Reduction Yokohama, Japan, 23-27 May 1994

Prepared by the Canadian National Committee for the International Decade for Natural Disaster Reduction

Royal Society of Canada
Canadian Academy of Engineering

PREFACE

The Canadian National Committee for the International Decade for Natural Disaster Reduction was established in 1993 by the Government of Canada, under the auspices of the Royal Society of Canada and the Canadian Academy of Engineering. It was preceded in the early part of the Decade by the Joint Committee of the Royal Society of Canada and the Canadian Academy of Engineering, which prepared a report entitled *Toward a Canadian Program for the International Decade for Natural Disaster Reduction*, published in 1990. This report recommended the establishment of the Canadian National Committee (see Appendix A for a list of Committee members and Appendix B for Terms of Reference).

Canada has taken an active role in the initial sponsorship of the Decade and the United Nations World Conference on Natural Disaster Reduction in Yokohama, Japan, May 1994. The preliminary edition of this report is specially prepared for this conference.

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This report represents the views of the contributors, but not necessarily those of the Government of Canada.

(Ce rapport est aussi disponible en français.)

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I. INTRODUCTION AND OVERVIEW: CANADA'S PARTICIPATION IN THE IDNDR

THE IMPACT OF NATURAL DISASTERS

During the last 20 years, the costs of natural disasters around the world have escalated significantly. The lives of millions of people have been disrupted. The number of catastrophes, as defined by the reinsurance industry, has nearly quadrupled; and the World Bank has made a similar estimate for the increase in post-disaster reconstruction costs. The losses to smaller nations from natural disasters often exceed their GNP, seriously affecting their development and widening the gulf between the rich and the poor. Over the past five years the proportion of aid funds diverted to natural disaster recovery has increased from 2% to nearly 7%.

Natural disasters have often been considered inevitable. History and mythology are filled with tales of the dread humans have for catastrophes. The fatalistic "they are inevitable" response to these fears is an ancient one, but today we know that by taking prudent reasoned actions, we can often prevent disasters and mitigate their impacts.

Humanity is becoming more vulnerable to natural disasters. Increases in urban population are increasing the size of the targets that disasters can strike. The increasing scarcity of usable land is leading to increased settlement in vulnerable areas, such as coastal zones and floodplains. As well, the increasing complexity of modern life makes humans more dependent on the infrastructure required to support it. The result is more severe disruptions when that infrastructure is affected by natural causes.

We are steadily becoming more vulnerable and the nature of the vulnerability differs from place to place. In India and Bangladesh, threatened by cyclones in the Bay of Bengal, there is the tragic threat to human life and the destruction of a fragile economy. In Tokyo or San Francisco, Seattle or Vancouver -- cities threatened by major earthquakes -- there is not only a threat to life but also a different kind of danger from the economic shock wave that could follow as insurance companies sell investments to pay claims reaching tens of billions of dollars, and governments attempt to borrow even greater sums to pay for public and uninsured losses.

This growing threat can seriously undermine the economies of developing communities, and further add to the need for disaster relief and funds for recovery. But developed countries themselves are also vulnerable as events following recent earthquakes in California, hurricanes in Florida and floods in Mississippi have dramatically demonstrated. There are strong indications this trend is increasing.

To meet this urgent threat, the United Nations (UN) General Assembly on December 22, 1989 passed a Resolution which declared the 1990s to be the International Decade for Natural Disaster Reduction (IDNDR). Canada co-sponsored this Resolution and also the more recent resolution to hold the UN World Conference on Natural Disaster Reduction in Yokohama, May 1994.

THE UN RESOLUTION ON THE IDNDR

The 1989 Resolution outlined an International Framework of Action for the Decade. It states that:

"The objective of the Decade is to reduce through concerted international action, especially in developing countries, the loss of life, property damage, and social and economic disruption caused by natural disasters, such as earthquakes, windstorms, tsunamis, floods, landslides, volcanic eruptions, wildfires, grasshopper and locust infestations, drought and desertification and other calamities of natural origins."

The targets set by the UN General Assembly for the Decade are that by the year 2000, all countries, as part of their plan to achieve sustainable development, should have in place:

- comprehensive national assessments of risks from natural hazards, with these assessments taken into account in development plans
- mitigation plans at the national and/or local levels, involving long term prevention and preparedness and community awareness
- ready access to global, regional, national, and local warning systems and broad dissemination of warnings.

NATURAL HAZARDS IN CANADA

Canada is vulnerable to a range of major natural hazards, some of which are potentially as severe as anywhere in the world. Examples are the Queen Charlotte and Grand Banks earthquakes, the Edmonton and Barrie tornadoes, intense winter storms off the Atlantic, the St. Jean Vianney and Frank slides, and severe forest fires in Manitoba and even volcanoes in the Cordillera. In addition the cumulative effect of the much more frequent but minor occurrences of natural hazards may cause greater suffering.

Canada is characterized by very marked differences between summer and winter conditions. Over most of the country, except for the southern coastal region of British Columbia, the winters are long and relatively cold, with periods of severe weather, whereas the summers are quite warm and characterized by stormy periods. In the interior of the country, which has a strongly continental climate, the summers can be very hot and the winters very cold. These differences result in marked seasonal differences in the range of potential hazards. Severe flooding can be widespread as a result of spring snow melt and sudden thaws, excessive rainfall, and seiches induced by storms on the Great Lakes.

Wildfires occur during the warmer months and tornadoes, thunderstorms and hail pose a hazard all year round, but especially in the summer. In the summer and early autumn, tropical storms and hurricanes can affect large parts of Eastern Canada.

The geological hazards include earthquakes, landslides, liquefaction of marine clays and other soft sediments and volcanoes. Although the last are largely dormant, the active volcanoes in the states of Washington and Oregon are close to the Canadian border. These geological events are largely independent of seasonal influences although they can often occur together. Landslides can be triggered by flooding, and the damming of a river by a landslide can produce a flood. An earthquake may trigger a landslide or liquefaction of soft sediments.

THE COSTS OF NATURAL DISASTERS IN CANADA

Over the last 10 years, the property and casualty insurance industry in Canada has paid more than $1 billion to 400,000 owners of homes, businesses and vehicles to repair damage and compensate losses caused by major natural hazards. On average, insurers pay more than $100 million each year to settle the claims arising from those natural events, such as major thunderstorms, hailstorms, windstorms and flooding, which generate hundreds of claims in a matter of hours. In addition, thousands of other claims for losses resulting from more localized natural hazards are settled every year. The total economic costs of these events, including the cost of damage to public and other uninsured property, is often more than double the insurance cost.

While the cumulative cost of damage and suffering from the natural hazards mentioned above is significant, it pales in comparison to the potential losses that Canada would face in the event of a severe earthquake in a major urban centre. The risk of an earthquake of this sort is greatest in the lower mainland of British Columbia and in Quebec's St. Lawrence Valley, where major earthquakes have been recorded over the past century. A recent study estimated that the economic loss from a major earthquake in the Vancouver, British Columbia area could range from $14 to $32 billion. Preparing for a potential loss of this magnitude is an activity that must be shared by the government and the insurance industry.

CANADA'S PARTICIPATION IN THE DECADE

There are several reasons for Canada's participation in the Decade:

- participation in the Decade will assist in improving Canada's own assessment of the risks of the prevailing natural hazards and the associated vulnerabilities. This will be useful for a variety of users from insurance companies, to emergency and city planners and home builders. It will allow Canada to share in the development of new techniques for the assessment of risks and experience with new data gathering techniques.

- Canada has a humanitarian tradition of providing assistance and relief and has stood in the forefront of aid donors. Participation in the Decade is consistent with that tradition. Without compromising these critical relief efforts, it is important to stress the importance of preventive measures in the long-term solution -- a primary focus of the decade.

- Canada can contribute its engineering and scientific expertise and equipment to set up training programs for disaster mitigation and warning systems. These skills are a byproduct of living in a country with extensive geographic and climatic variety and modern educational and research resources. Further, Canadian technology such as satellites and remote sensing techniques developed in Canada are world ranking; they have potential application to monitor forest fires and floods, assess damage and provide emergency communications networks. Geophysical monitoring equipment developed in Canada has important application to the detection of seismic events and volcanic eruptions. Geographic Information Systems have a wide variety of applications in hazard management.

A CANADIAN PROGRAM FOR THE IDNDR

The following identifies several key, national and international activities for Canada's involvement in the Decade:

National

1. Assessment of Natural Hazard Vulnerability and Risk

Assessment of natural hazards, the vulnerabilities of the communities and infrastructure to the hazards, and the resulting risk, are central to the effectiveness of a variety of disaster mitigation activities. Principal users are those concerned with emergency management agencies, insurance, building regulation, urban planning, forestry, agriculture, and planners for flood protection and other hazards.

2. *Implementation of Mitigation Measures*

- flood damage reduction
- earthquake preparedness and loss prevention
- Canadian Disaster Investigation Panel
- provincial and federal disaster management programs;
- review of zoning and land use in the light of risks by provinces.

3. *Warnings*

International

1. Natural disaster reduction through improvements in Structural Quality.

2. Engineering and scientific programs:

   - GSHAP
   - landslides
   - large river floods.

3. Technical cooperation;

Publicity and Publications

- conferences
- workshops
- newsletters

Participation in the IDNDR

This above program is a beginning. The efforts of the Canadian National Committee on behalf of the IDNDR are open-ended and cross-disciplinary and invite the participation of many sectors. Canadian National Committee members are active in promoting the goals of the Decade and in carrying out a Canadian program of action. The Committee also endorses those activities of related groups which are consistent with the Decade's objectives, as well as acting as a catalyst to stimulate other groups and individuals into action in support of the Decade's goals.

Relations with the Geneva Secretariat

To ensure the effectiveness of the results of the Decade, it is important to support the Secretariat in Geneva. The Canadian National Committee will consider the most effective way for Canada to assist.

CHAPTER SUMMARIES

Chapter II: Risk Assessment

Risk assessment generally involves both an evaluation of hazards: their frequency, severity and location; and an evaluation of the vulnerability of life and property to hazard-related losses. Although the former components have been studied by surveys and research programs, detailed vulnerability assessments have generally not been carried out in Canada, and little research has been undertaken in this area.

Chapter II examines the frequency, severity and location of the large number of natural hazards to which Canada is exposed. These hazards are grouped into four main categories: meteorological, hydrological, geological and biological. In the absence of vulnerability assessments, loss estimates are derived from historical experience. The chapter also addresses the gaps in Canada's knowledge of vulnerability to natural hazard losses.

Chapter III: Mitigation Activities

Chapter III discusses the roles of the various agencies of government and the responsibilities of the other members of the emergency preparedness community in responding to natural disasters. Members of the community include provincial and municipal governments, the insurance industry, universities and research centres, and the private sector.

Mitigation measures are discussed through a hazard-by-hazard approach and several of Canada's successful programs are highlighted. These include the National Flood Damage Reduction Program, Project Tornado, and the National Building Code of Canada. An examination of the issues facing the emergency preparedness community, including the need for greater public awareness, is provided.

Chapter IV: Warning

Integrated warning systems are essential to warn the public of imminent disasters. To ensure that warnings are effective, all levels of government and the private sector must work closely together to develop strategies for warning systems. This would include strategies for monitoring and detection, interpretation and dissemination, warning, management and response to all natural and technological hazards. The four categories of natural disasters (meteorological, hydrological, geological and biological) are discussed in this chapter.

Chapter IV deals with the roles and responsibilities of the various jurisdictions involved in issuing warnings of hazards and ensuring the safety and well-being of all Canadians.

Also discussed are education and public awareness, communication and technological advancement issues.

Chapter V: International Cooperation

Canada contributes to international efforts and provides assistance internationally in many areas of disaster management, including training, monitoring and hazard assessment.

The Canadian government's official assistance to developing countries is provided by the Canadian International Development Agency (CIDA), which focusses primarily on multilateral efforts when responding to disasters. There is also a large body of non-governmental organizations, universities and private sector groups involved in a wide variety of disaster-related activities internationally. Chapter V discusses the role and responsibilities of these different groups, and presents case studies of Canada's efforts in Bangladesh and Somalia.

Chapter VI: Evolution of a Canadian Program for the IDNDR

Canada has been active in the sponsorship of the Decade in the United Nations. However, a plan of action for the country is still being developed by the Canadian National Committee.

Chapter VI identifies, from national and international perspectives, several essential areas and new initiatives that will be carried out by the Canadian National Committee to reach the Decade targets.

II. RISK ASSESSMENT

INTRODUCTION

Canada is vulnerable to a range of major natural hazards, some of which are potentially as severe as anywhere in the world. The cumulative effect of the much more frequent but minor occurrences of natural hazards may cause even greater suffering, however. As a northern country, Canada is characterized by very marked differences between summer and winter conditions. Over most of the country, except for the southern coastal region of British Columbia, the winters are long and relatively cold, with periods of severe weather, whereas the summers are quite warm, and characterized by stormy periods. In the interior of the country, which has a strongly continental climate, the summers can be very hot and the winters are very cold. These differences result in marked seasonal differences in the suite of potential hazards. Throughout the winters, most precipitation falls as snow, which accumulates until the spring thaw, leading to almost annual instances of flooding. Because of the cold and snow, wildfire is largely a summer phenomenon. Summers are the season for hurricanes and tornadoes, thunderstorms and hail events, and, of course, wildfire. Geological hazards, except for some categories of slope failures, are largely independent of seasonal influences, however.

In the following discussion, the occurrence of natural hazards in Canada is organized genetically, in four categories: meteorological, hydrological, geological and biological. Although presented in this fashion, it should be recognized that these four groups are not mutually exclusive. Thus severe meteorological events, such as rainstorms or thunderstorms, can and often do lead to the development of flood events. Similarly, a major landslide, while it will often have a direct effect on people or economic activity (farming, logging, transportation, etc.), may also dam a river. Failure of this dam may, in turn, cause a flood, which may be more far reaching in its effects than the original landslide, particularly in the sparsely populated, mountainous terrain typical of much of the Canadian Cordillera. Similarly, an earthquake may trigger other ground failure events such as landslides or the liquefaction of soft sediments. If coincidental with a tsunami, for example, the cumulative effects may be considerable more severe than the effects of either hazard alone.

Risk assessment generally involves both an evaluation of hazards: their frequency, severity and location; and an evaluation of the vulnerability of life and property to hazard-related losses. While Canada has various surveys and research programs which allow for a regular assessment of Canadian natural hazards, detailed vulnerability

assessments have generally not been carried out, and little research has been undertaken in this area.
What follows is an assessment of the frequency, severity and location of the large number of natural hazards to which Canada is exposed. In the absence of vulnerability assessments, loss estimates are derived from historical experience. The report discusses only natural hazards of a catastrophic nature. Chronic conditions, such as the problems related to permafrost and ground ice, swelling clays, slow changes in water levels in lakes, sea level changes and climatic change are not considered. Throughout the report, and unless otherwise noted, "insured losses" refers to losses reported to and paid by property and casualty insurance companies to Canadian policyholders.

METEOROLOGICAL HAZARDS

In Canada about one half of the major disasters with 20 or more fatalities, natural or otherwise, have been weather related. Although the nation's population has been increasing steadily, the number of people killed in major disasters has been dropping gradually. In the last three centuries, Canada has experienced 63 major, weather-related disasters resulting in about 14,600 deaths. Slightly over one half of these weather-related disasters were of a maritime nature, occurring within the 200 nautical mile economic zone of Canada, and resulting in the bulk of the fatalities (11,560 deaths). These do not include a number of major disasters that have occurred just beyond the Canadian economic zone. The most noteworthy of these was the sinking of the Titanic (1912) after hitting an iceberg just south of the Grand Banks and resulting in the loss of 1513 lives.

One of the most costly major natural disasters which could be expected in Canada would be a Caribbean hurricane moving up the east coast and landfalling in the Maritime provinces. The estimated damage for such an extreme event is about $2,000 million. Another very severe potential natural disaster would be a major wind storm in southern Ontario, such as might result from a hurricane or tornado. The $300-$400 million Edmonton tornado type event is an illustration of the next third most costly type of meteorological disaster likely. While it is the extreme disasters that get the headlines, in Canada much more common meteorological hazard events take a toll of human life and cause more damage. Extremes in cold and heat, lightning and flooding are examples of the hazards that kill an average of 150 Canadians annually. In addition, each year, 500 Canadians die and 37,000 are injured in road accidents where weather is the major or a contributing factor, such as reduced visibility in fog and blowing snow, as well as icy roads. Also, a number of deaths occur due to accidents on water, during recreational activities, and these are influenced by weather conditions, such as gusty winds induced by thunderstorms. Cold water is a silent killer with 77 (or 12%) of the 639 drowning fatalities in 1991 due to hypothermia. Most of these hazards, though frequent, involve only one or two fatalities each and thus do not get counted in normal (major) natural disaster statistics.

While the number of fatalities associated with individual weather-related disasters has been decreasing steadily, the actual number of major disasters has been equally steady in its increase through the years. The number of maritime disasters per half century appears to have stabilized at 7 to 10, with the number of fatalities per disaster dropping significantly. This trend in the maritime community has been offset by the opposite trend in other sectors of the transportation industry, particularly the aviation sector. Inland, the general sparseness of the Canadian population distribution, along with the concentration of most people in a small number of urban centres, and the implementation disaster prevention measures, such as strict building codes, has mitigated the impact of weather-related natural disasters.

Severe Summer Weather Hazards

Severe summer weather can strike suddenly and unexpectedly with disastrous consequences for human activity. Traditionally severe summer weather has been defined as consisting of tornadoes, strong winds, hail, lightning and heavy rain. On average, Canada experiences over 400 severe weather events each summer.

Tornadoes: Canada rates second in the world for tornado occurrence, after the United States, and followed by Russia. There have been about 10 damaging tornadoes in the period from 1979 through 1991. The greatest number of tornadoes occur in extreme southwestern Ontario, with an average annual incidence peaking at three tornadoes per 26,000 km^2. The second highest number of such events occur in the extreme southern Canadian Prairies with an average annual incidence of two to three tornadoes per 26,000 km^2. Tornadoes can occur, however, anywhere from the foothills of Alberta to the Maritime provinces. Indeed, the two worst events in Canada occurred in Regina, Saskatchewan (June 30, 1912 -- 28 deaths and $4 million damage [1912 dollars]), and in Edmonton, Alberta (July 31, 1987 -- 27 deaths and $350 million in damage, of which $250 million was insured), while the ninth worst occurred in Buctouche, New Brunswick (August 6, 1879 -- five deaths).

The severity of tornadoes is classified by the Fujita scale (F), which ranges from F0 to F5. F1 implies an emergency, F3 a disaster, and F5 (and some F4s) a catastrophe. Using this scale, estimates of recurrence of tornadoes of a certain severity can be made.

In the case of severe tornadoes (F3 or stronger), the return period is five years for southwestern Ontario. This means a disastrous tornado can be expected in the populated area of Ontario once in five years. The damage caused by a tornado is not necessarily related to its severity. The tornado's path is obviously a critical factor. For example, the Edmonton tornado, classified F4 at its most intense phase, caused the most fatalities and damage by passing through a trailer-home park when it was at its weaker, F1-F2 phase.

The shortest return period of an F2 or stronger tornado (1.3 years) is for a location somewhere in southern Ontario. With the risk of tornado damage typically in the range of 0.3% and 0.1% per year per unit area, the return period of damage in a small city sized area about 200 km^2 is between 15 and 17 years for southwestern Ontario. With the implementation of new technologies and an extensive volunteer severe weather watch program, the ability to observe tornadoes and to distinguish between tornadoes from other severe weather phenomena has improved significantly. In recent years, between 80 and 100 tornadoes have been observed annually in Canada.

Strong Wind Events: These include microbursts, macrobursts, derechos and surfacing of the rear inflow jet behind mesoscale convective systems. The most hazardous form of low level wind shear to aviation is the microburst, an intense downdraft from convective clouds which induces a divergent outburst of winds hazardous to aviation on or near the ground, with a horizontal wind velocity difference of 15 m/s or more over a distance of 4 km or less. The smaller spatial scale of a microburst converts into tighter wind shear gradients that are experienced in the penetrating aircraft as more rapid changes in wind vector, perhaps well in excess of the inertial capabilities of the plane.

An aircraft on approach through a microburst would first encounter an increase in air speed, resulting in a decrease in the rate of descent. Then, shortly after, the aircraft would enter the downdraft, and then enter the increased tailwind portion of the outflow, resulting in a serious drop in air speed and a marked increase in the rate of descent. This is the danger area because the aircraft is low and slow. Recovery depends on the location of the starting point of the encounter relative to the runway, the pilot's reaction and the aircraft configuration and performance, including the amount of reserve thrust available.

From 1975 to 1985, a significant number of airline accidents caused by microbursts occurred in the United States, resulting in the loss of more than 500 lives. Canadian airports are not instrumented for detecting, tracking or forecasting the small scale and transitory phenomena that are microbursts. However, the results of wind damage area surveys jointly conducted by Transport Canada Aviation and Environment Canada Forecast Centres since 1990 have shown that microbursts do occur in Canada. A total of 12 cases in Quebec and 10 cases in Ontario were jointly investigated in the summers of 1991, 1992 and 1993. A study by the Economic Analysis Unit of Transport Canada, to determine the requirements for low-level wind shear operational systems at major Canadian airports, concluded that Toronto - Lester B. Pearson International Airport would definitely require a system. The situation is uncertain for the remaining Canadian airports. Consequently a Canadian microburst climate study is being undertaken.

Microbursts also pose hazards to small sail boats, that may be capsized by sudden-shifting, strong winds, and to persons fighting forest fires, who may be suddenly engulfed in a fire storm fanned up in an unexpected direction by a microburst.

Lightning: While there have been many lightning strikes which kill one or two people at a time, there has been only one documented major disaster caused by lightning. Thirty crewmen died in an explosion when a freighter, *The John B. King*, loaded with explosives was struck by lightning in the St. Lawrence River in 1930. Lightning is a major cause of forest fires, however, causing approximately 42% of wildfires in Canada.

Hailstorms: While there has not been a single recorded death attributed to hail in Canada, hailstorms probably cause the greatest economic losses of any natural hazard in Canada in terms of property and crop damage. A storm in Calgary on Labour Day, September 7, 1991, caused the largest hailstorm and rain loss ever, in the order of $450 million in damage, with insured losses of $350 million. A significant portion of the damage caused by the 1987 Edmonton tornado was due to hail. Another Calgary hailstorm, July 28, 1981, caused in excess of $150 million in damage during its 15-minute lifetime, of which about $125 was insured. Other severe hail events have included storms in Winnipeg, May 25, 1978, when hail accompanied by heavy winds caused about $20 million in damage, $6 million of which was insured; in Montreal, on May 26, 1986, where a severe hailstorm struck the area causing $90 million in damage, of which $75 million was insured (Montreal also had a costly hailstorm on the same day of the following year, resulting in an insured loss of $125 million); and in Alberta in 1988 when two serious hailstorms hit Edmonton (June 7) and Calgary (August 16). The Edmonton storm resulted in an insured loss of $48 million, while total losses from the Calgary storm were $30 million, of which $22 million was insured.

On top of these losses are the millions of dollars farmers pay out each year for crop insurance. Hail typically occurs in heavy but localized showers associated with mature thunderstorms. The main cause of hail is atmospheric instability, which often produces up-drafts strong enough to carry the weight of hailstones as they grow. The favoured hail area is the continental interior, namely central Alberta's "hailstorm alley," to the lee of the Rockies and the southernmost part of Saskatchewan, east of Cypress Hills. These areas experience four to six major hail events each year. May to July is the period of maximum hail occurrence, and nearly three quarters of all hailstorms occur between 1200 and 1800 hours.

Thunderstorms and Rainstorms: June and July seem to produce some of the most damaging rainstorms and thunderstorms in Canada, with the thunderstorms often accompanied by severe hailstorms. Because flood insurance is not generally sold, Canadians may not be fully aware of the extent to which Canada is subject to damage from such storms. Nonetheless, even with the limited extent to which the industry becomes involved in compensation for damages, there have been several costly storms in recent years. Examples of severe thunderstorm and rainstorm events, with loss estimates, include storms on June 24, 1983, which hit Regina and Edmonton, causing about $25 million in damage, $5 million of which was insured; and another event in Regina on July 8-9, 1983, the cost of which was about $60 million, of which about $50 million was insured. (The significant amount of insured losses, relative to total losses reflects the extent of wind damage and sewer backup which occurred.) There was a severe rainstorm in Montreal on July 14, 1987, the cost of which has been estimated at about $100 million, of which about $20 million was insured; and an event at Slave Lake, Alberta which suffered severe flooding because of heavy rain on July 6, 1988, at an estimated cost of about $31 million, of which about $22 million was insured. Again, the high amount of insured loss must be attributable to accompanying winds and sewer backup. Finally, Kent, Essex and Leamington counties in Ontario suffered a severe rainstorm in 1989 which caused about $15 million in damages, with an insured loss of $13 million.

Tropical Cyclones: Tropical cyclones, including their transition to extra-tropical storms, have a significant impact on Canada. Hurricane Hazel, in 1954, is probably the best known tropical event in Canada, causing 79 fatalities and damages of $54 million in losses (in 1954 dollars, equivalent to $350 million today). Hurricane Edna caused great damage and some loss of life in 1954. In June 1959, an unnamed hurricane "It" was responsible for the loss of 33 fishermen off Nova Scotia and considerable damage. Lesser hurricanes have also had significant impact on Canada, either in their tropical cyclone form or even in their diminished, extra-tropical form. "Daisy" caused extensive damage to Nova Scotia in 1962. "Beth" in 1971 caused an estimated $3.5 million of flooding damage in Nova Scotia. High surf from "Gabrielle" was responsible for one death in Nova Scotia in 1989, and two deaths in 1991 from "Bob." In fact, the "Halloween Storm" in 1991 involved, as its source, two hurricanes: "Grace" and an unnamed storm over the North Atlantic between October 25 and November 3.

Given that three to four tropical cyclones now affect Canadian territory on average each year, and given the uncertainties of the impact of global warming on the natural cycle (related to African Sahel/El Niño) of intense hurricanes, the potential for disaster may well increase with time.

An extreme form of extra-tropical cyclones pounds both the Atlantic and Pacific coasts of Canada each winter. The rapid and sustained lowering of central pressure in this system, known as explosive deepening, results in greatly intensified winds, near or exceeding hurricane force, and often increased precipitation. Such storms are most prevalent during the winter over Atlantic Canada where the frequency of occurrence is about one per week. An example of such a winter storm would be the severe winter storm of 1964 that hit the Maritime provinces of Canada resulting in 23 deaths. Over a typical winter, about 17 such storms develop and affect the British Columbia coastal area. For example, on October 11-12, 1984, the unexpected development of a severe storm off the west coast of British Columbia caused the deaths of five fishermen. That storm developed explosively and unexpectedly from the remnants of Typhoon "Ogden".

Severe Winter Weather Hazards

Winter storms typically produce heavy precipitation, bitterly cold conditions, strong winds and blowing snow in all regions of Canada. These storms exhibit a wide variety of features but they all affect society in many ways when they occur. The aviation, transportation and fishing industries are just a few of the affected sectors of society. Intense systems pound the Atlantic Coast, severe blizzards lash the Prairies and Arctic, strong storms strike the British Columbia coast, spring storms dump heavy snow over Alberta, mesoscale vortices often occur in the North and lake-effect storms produce heavy snowfall in many regions including the Great Lakes basin. An example is the 1969, 60-hour snowstorm that dumped 70 cm of snow on Montreal resulting in 15 deaths. Avalanches, known to have disastrous effects, include the Granduc Mountain Avalanche near Stewart, British Columbia (1965 - 26 deaths), the Britannia Mine Avalanche near Howe Sound, British Columbia (1915 - 57 deaths) and the 1918 Avalanche in Rogers Pass, British Columbia (62 railway workmen died). Winter severe weather is implicated in aviation disasters by way of aircraft icing and severely reduced visibility. Such disasters include the Air Ontario crash at Dryden, Ontario (1989 - 24 deaths) and the Pacific Western Airlines Boeing 737 crash at Cranbrook, British Columbia (1978 - 42 deaths).

Canada's climate exposes it to winter storms across the country. While these occur annually, they seldom cause significant economic loss, but there are exceptions. One such exception occurred in southern Ontario on January 26, 1978, when heavy snow, high winds and extreme cold caused $40 million in damage. Less than 10% of this loss was insured. A freeze in British Columbia on January 30, 1989 caused pipes to burst. The loss from this event was only $2.5 million, but, unlike the previous example, most of this loss was insured. Ontario suffered a similar storm on January 25, 1990 and, while economic loss figures are not available, the insured loss was about $3 million.

Blizzards: The blizzard is one of the most dangerous types of severe winter weather encountered in the Prairies. Each year a few people and many domestic animals perish from direct exposure to blizzard conditions. In Canada a blizzard is defined as a storm with the following characteristics: wind speed greater than 40 km/hr; wind-chill greater than 1600 W/m^2; visibility less than 1 km in snow or blowing snow; and duration of greater than four hours. Typically, blizzards are caused by a low pressure system or storm which produces fresh snow and strong northerly winds combined with cold temperatures behind the system. The maximum average number of blizzards on the Canadian Prairies occurs over southwestern Saskatchewan, with 1.6 episodes per year at Swift Current.

The most frequent blizzard-producing storm is the Alberta Low or Alberta Clipper. These usually develop east of the Rockies, over Alberta or western Saskatchewan, as a result of a vigorous short-wave trough in a westerly to northwesterly flow aloft. These lows move quite rapidly (about 65 km/hr) in an southeasterly direction towards southern Manitoba or North Dakota. The Alberta Low storms affect all of the Prairies, but they have their greatest impact on Saskatchewan. The blizzard conditions associated with these systems usually last less than 12 hours. The most severe Alberta Low storm occurred on March 14, 1941. This storm lasted only 7 hours, but it produced winds in excess of 100 km/hr and caused at least 76 deaths in northern U.S. states and southern Canadian Prairie provinces.

Classic examples of a less common blizzard, caused by systems known as Colorado Lows, are those of 1966 and 1975, each of which paralyzed southern Manitoba for several days. Another type of Prairie blizzard, as common as the Colorado Low type and accounting for 18% of the total, is the "pressure gradient storm." A classic example of this type of storm occurred on February 5-9, 1978, producing negligible snowfall amounts but the fierce winds brought all activity to a standstill over southern Saskatchewan for nearly four days.

Remoteness and the general lack of shelter is typical of the Canadian Arctic. Average wind speeds across a significant portion of the Arctic are generally higher than experienced over southern Canada. Because of the persistence of strong winds, the blizzard is one of the main meteorological events of the Arctic winter. Most sites north of the tree-line can expect to see three "one-day" arctic blizzards per year with about one "two-day" blizzards per year. The longest blizzard observed in the Arctic was 110 hours, or more than four days, at Baker Lake. The combination of cold temperatures and strong northwesterly winds give wind-chills that are significantly higher than elsewhere in Canada. For example, at Baker Lake, on average, almost 80% of the days in January and February have at least one report of a wind-chill greater than 2200 W/m^2 and about 50% of the time the wind-chill is greater than 2500 W/m^2.

Lake-effect Storms: These storms are a frequent occurrence in many parts of Canada that are near large bodies of water. Lake-effect snow is produced by the passage of cold air over a relatively warm body of water. Most lake-effect snow storms occur during the late autumn and early winter months when the water to air temperature difference is at its maximum. The most intense lake-effect storms, referred to as "enlarged lake storms," commonly produce extreme snowfall rates often in excess of 10 cm/hr.

Freezing Rain or Drizzle: Aircraft icing, whether it occurs while the aircraft is still on the ground or in flight, represents a serious hazard to aviation safety. The Canadian Aviation Safety Board has identified 78 accidents between 1978 and 1989 in which icing was a contributing factor. These accidents included 298 fatalities. The 1985 Gander, Newfoundland Air Arrow disaster, in which 256 U.S. servicemen were killed, may have been caused by freezing drizzle. A study has shown that the meteorological conditions were very similar to those in which freezing drizzle is common. Freezing drizzle was reported in the surface weather observations for three hours prior to the crash and pilot reports received at the time of the crash reported icing conditions in the clouds above the airfield. Freezing drizzle and freezing rain are both severe problems. Often they produce the most severe form of aircraft icing, especially in the Newfoundland area, where freezing precipitation is reported on 25% of the days at Gander and St. John's during the winter months. Aircraft icing conditions involving freezing precipitation are not accounted for in the standard FAA or Transport Canada guidelines indicating safe flying conditions. Private operators of helicopters indicate that they often fly in freezing precipitation because they cannot avoid it.

Ice Storms (Glaze): An ice storm, while it may be aesthetically pleasing, is potentially one of the most destructive forms of winter storm. Freezing precipitation is a major hazard which affects all parts of Canada. Ice storms have crippled communities from Vancouver to St. John's, by disrupting services, damaging property, and causing accidents that are sometimes fatal. Ice storms often result in power blackouts, disrupted telephone service, broken tree limbs and downed utility lines, streets that are impassable to vehicles and pedestrians, and roofs rendered unsafe by heavy ice loading.

The most disruptive ice storms occur when significant amounts of liquid precipitation fall from an above-freezing layer of air aloft through a sufficiently deep layer of sub-zero air near the surface. The precipitation freezes as it falls down through the sub-zero surface layer. Raindrops that freeze completely prior to coming in contact with the ground are referred to as ice pellets. Ice pellets generally do not cling to wires or exposed surfaces unless accompanied by rain or wet snow. If the surface layer is not deep enough or cold enough to freeze the drops completely, these raindrops freeze almost immediately upon contact with a surface, such as pavement, car windshields and utility wires, spreading out into a smooth veneer of clear ice, often referred to as glaze ice. If accompanied by snow, an opaque and milky rime, with embedded air bubbles, is the result. It is often this combination that results in sufficient build-up to cause structural failure or lines to snap.

Communication and power lines, antennas, and support structures which are exposed to the elements are thus readily damaged by ice accretion. These can usually support a heavy ice load, but often fail because of the combined effect of ice and wind. The transverse loading on wires may be increased substantially when the wind is blowing at right angles to the lines. Where a surface is exposed at right angles to the wind, the ice accretion rate can exceed the precipitation rate. Very small droplets are easily deflected by the air stream and thus tend to miss the obstructing object, whereas larger droplets are not easily deflected and tend to collide with the object. Wet snow sticks to objects and may change to ice. Since snow is not very adhesive, it is easily removed from utility wires by strong winds, it may, however, be compacted against other structures and thereby cause damage.

No Canadian location is completely exempt from freezing precipitation. Even Victoria, British Columbia, gets an average of a couple of hours of freezing precipitation per year. This figure increases gradually to the east. The exception to this is that some parts of the interior of British Columbia tend to experience a fairly high incidence of freezing precipitation. The Canadian Prairies can expect 20 to 35 hr/yr of freezing rain, while southern Ontario can expect between 30 and 50 hr/yr, as can many parts of Nova Scotia, New Brunswick and much of the Arctic. The Ottawa Valley and much of southern

Quebec routinely receive 50 to 70 hr/yr of freezing precipitation. The freezing precipitation champion, however, is Newfoundland, with St. John's getting about 150 hr annually. Typically, freezing precipitation occurs in November or December on the west coast of Canada, November through February in the Prairies, December through March in Ontario, Quebec and the Maritimes. Newfoundland can expect it from December through April, while in the Arctic it is a summer event. Areas near large bodies of water tend to receive more icing than inland locations. Also, the frequency of occurrence tends to increase with elevation. Finally, ice storms are most often night-time events.

One of the worst ice storms ever struck St. John's, Newfoundland, on the evening of April 11, 1984. Overhead electrical wires snapped from the weight of 15 cm jackets of ice forming on them, leaving 200,000 people in the Avalon Peninsula without heat and light for days. In March 1958, St. John's was hit with 43 hours of continuous freezing rain. In January 1968, southern Ontario experienced three days of on-and-off freezing rain and wet snow resulting in significant damage. Typical effects were widespread power outages, closed schools, cancelled food deliveries, disrupted mail and fire services, the collapse of buildings and antennas, isolation of hospitals, dangerous and blocked highways and railways, shattered trees and absenteeism. Some areas of Montreal were left without electricity for a week after an ice storm on February 25, 1961, abetted by winds gusting to 120 km/hr, caused heavily loaded utility wires to snap. The Prairies generally have a couple of major ice storms per year. Storm cleanup costs exceeded $2 million after an ice storm on March 6, 1983 closed the international airport for two days and toppled several large television towers. One of the most memorable ice storms struck eastern Ontario and southwestern Quebec on Christmas Eve in 1986. After 14 hours of freezing rain, one Ottawa home in four was left without electricity, and on Christmas Day, many residents cooked their turkeys on propane barbecues or had dinner with more fortunate friends or relatives.

HYDROLOGICAL HAZARDS

Hydrological hazards are commonly related to and often directly caused by meterological events. Hydrological hazards range from too much water (flooding) to too little (drought), and include both fresh water and salt water phenomena.

Floods

Flood events meet all the appropriate criteria for hazards of natural origin. They develop suddenly, sometimes with little advance notice; they can result in extensive loss of life and damage and they may affect a large area. However, these effects can be greatly reduced through proper planning and the development of a better predictive and monitoring capability. In Canada, the most outstanding flood from the perspective of death and damage was that asssociated with hurricane Hazel in 1954 which resulted in

79 deaths. Floods are both big business and the cause of huge economic losses in Canada. Major dams, often built at least in part to mitigate flood losses, cost hundreds of millions of dollars each. About $600 million dollars per year is spent in the Toronto area on new construction to deal with water drainage. Extrapolating that to the rest of Canada yields a staggering $3,000-$5,000 million per year on construction of new drainage works across the country. In 1993, flooding was widespread in North America covering much of the Mississippi River and Red River valleys. In the city of Winnipeg, flood damage and cleanup costs were estimated at $50 million, while the insurance industry indicated that claims for damages due to storm sewer backup totalled an additional $160 million. The costs associated with flooding fall into three general categories. First there is the cost of building flood control infrastructure. Secondly, there are the losses associated with damages directly resulting from floods. Thirdly, costs are associated with routing the water after it has inundated an area and in restoring the area to its normal condition. The hydrometeorlogical factors that control floods include snow melt, ice jams, and summer rainstorm runoff.

Snow Melt Floods: Approximately 36% of the mean annual precipitation in Canada occurs as snow, most of which accumulates over many months. Snow melt flood potential depends on the magnitude of the snow accumulation and the rate at which the snow melts to water and flows into a drainage system. The deepest accumulations of snow in Canada form near major sources of moisture, such as the western Cordillera, where snowfall is fed by moist Pacific air; the Maritime Provinces, that are affected by winter snowstorms that track along the eastern seaboard; and the margins of the Great Lakes, that experience lake-effect snowstorms. Once deposited, the redistribution of snow by wind and avalanching can further modify snow accumulation patterns. The highest flood frequencies tend to occur in alpine areas where a number of events in one winter season can be produced by melting occurring at different elevations at different time-bands. Quite severe and prolonged floods result from snow melt events affecting a large elevation range. Although rapid rates of snow melt events may characterize the Prairies, generally low accumulations ensure that snow melt floods have a low recurrence interval. Snow melt floods are also low-frequency events at the large basin scale, where significant lake storage acts to dampen the runoff peaks.

Ice Jam Floods: Due to water transport velocities in rivers, ice may jam and cause a rapid rise in upstream water levels, resulting in flooding, shore erosion and damage to structures by ice. Conversely, water levels downstream of the ice jam may drop quickly, creating a situation where sudden rupture of the jam could cause a downstream surge of high water laden with ice. This situation is particularly serious during spring breakup, when water and ice conditions are near their maximums. Ice jams can also occur during freeze-up. Characteristic sites include those where ice passage is obstructed, such as sharp bends, constrictions, islands or bridge piers and where the river slope rapidly decreases and the channel widens, particularly in the presence of an intact downstream ice cover. Rivers entering other rivers, lakes or oceans that maintain ice cover for longer periods are prime areas for this sort of flooding. Generally, in Canada, south to north flowing rivers are more susceptible to ice-jam flooding than are north to south flowing rivers. Snow dams or snow jams can form in favourable localities, primarily in tundra areas where dense, windblown snow can block stream channels and gullies. These can result in flood events when the dams or jams fail. Similarly, snow avalanches can block streams, also leading to flood events when the dams fail.

Rain Storm Runoff: The volume of water falling from the atmosphere during heavy rain storms can be truly staggering. The largest storm analyzed dumped nearly 80 mm over 300,000 km^2 of Alberta in June 1973, during a single day. This represents a volume of 25 km^3 of water falling from a single synoptic scale event in a 24-hour period, which would be enough to raise the level of Lake Winnipeg by 1 m. A thunderstorm may cause flooding in small streams and urban catchments. A mesoscale system with thunderstorms or a hurricane may cause difficulty on medium-sized rivers, such as those found in Nova Scotia or southwestern Ontario. Large area, intense, frontal cyclones are needed to produce flooding in Canada's larger rivers. Augmentation of the runoff by melting snow is usually a contributing factor on these larger rivers. The Prairie Provinces and Alberta in particular have the highest risk of flooding as a hazard, from both thunderstorms and synoptic scale events.

Urban Flash Flooding: Many Canadian cities and towns experience flooding problems during spring and summer because (1) they are located along streams or lakes for historical reasons, water supply purposes, or aesthetic reasons, and (2) the effects of urbanization greatly increase local runoff due to compaction of soil, impervious streets, and so on. Most cities have reasonable protection against flash flooding from intense local rain by way of storm sewer systems. However, these systems seldom provide complete protection for events exceeding a five-year return period, due to the enormous cost of larger storm sewers. On July 14, 1987, when 103 mm of rain fell in one hour in Montreal, the resulting flash flood caused the submerged Decarie Expressway to temporarily turn into a 1.3 m deep river. About 2,100 non-automobile insurance claims, totalling around $17 million, were paid out for this event. In 1993, the City of Winnipeg experienced its wettest summer in 120 years. Three major downpours on July 24-25 (100 mm of rain in about three hours on eastern portions of the city, followed by 50-100 mm in about six hours over the entire portion of the city), August 8 (50-100 mm in about three hours, with heavier amounts in western portions) and August 14 (50-100 mm in a few hours) exceeded the design moisture input of the city's sewer system at many locations. This was complicated by the fact that the level of the Red River was 3.3 m above its normal level.

Storm Surges: Canadian waters that may be affected by storm surges include the east and west coasts, the Beaufort Sea, the Gulf of St. Lawrence and the St. Lawrence estuary, Hudson Bay, and the Great Lakes. The storm surge problem is an air-sea interaction problem, i.e., the atmosphere forces the water body, which responds by oscillations of the water level with various frequencies and amplitudes. In Canada, storm surges most of the time are due to extra-tropical weather systems. The storm that passed through the

Newfoundland area on January 10, 1982 caused considerable property damage along the eastern part of the southern coast of Newfoundland. The water level at Argentia, on the western shore of the Avalon peninsula rose about 2 m above normal, a height that was exceeded only once this century, on November 18, 1929 (which was attributed to the tsunami that was triggered by the Grand Banks earthquake). On October 25, 1983 a storm surge (levels 0.76-1.5 m above the normal high water mark) struck the eastern shores of Cape Breton Island, causing $2.75 million in damage to fishing vessels and properties. Between 1905 and 1940, six storm surge events resulted in 567 casualties (people drowning near the coast and the sinking of ships battered by high waves) in the Great Lakes.

Sea, Lake and River Ice

In southern Canadian waters, sea, lake and river ice are winter phenomena which generally begin to form in December, reach a maximum extent and thickness in late February, and then melt, beginning in some areas as early as March and in other areas as late as July or August. Generally speaking, in latitudes south of the Arctic Circle, sea ice melts completely every year to result in a significant period of time where water-related operations are not affected by this phenomenon. In the Canadian Arctic, however, the presence of sea ice is the norm where summer melt is variable and short-lived. "Open water" routes usually first appear along coastlines in June and July, expanding to include the southern Beaufort Sea and Baffin Bay, but only portions of waterways connecting the Eastern Arctic with the West in August, and refreeze in October and November, when most offshore operations cease. Most of the sea ice in the Canadian Arctic Archipelago persists year-round, subjecting it to recurrent melt-freeze cycles, which create a very dense and strong ice type commonly referred to as "old or multi-year ice," and is generally avoided by ships.

In terms of hazards to shipping and offshore operations, the degree to which sea ice affects related activity depends upon the amount, thickness, strength and movement of the ice as well as the capability of the offshore vehicle or structure, its crew and the information available. For instance, heavily ridged, rafted, hummocked sea ice, or even thin sea ice under pressure, is generally avoided by even the heaviest and most powerful ice breakers. Under the influence of persistent onshore winds, sea ice may pile up into rows along coastal shallows sometimes as high as 15 m above sea level or be pushed inland, shearing off trees and damaging structures in its path. Any amount of sea ice is generally a hazard to non-ice strengthened or low-powered vessels. The strength of sea ice generally increases as its temperature decreases. At the same time, most materials become more brittle with decreasing temperature. This indicates that vessel or structure impacts with ice at low temperatures are more likely to result in greater damage than at warm temperatures.

Because technology still does not have the capability of reliable ice-type discrimination in order to detect changes in ice conditions, disasters like the sinking of the *Titanic* will occur, especially under conditions of poor visibility and high sea states where the performance of radar and other remote sensors lessens.

Icebergs and Ice Islands: Icebergs and ice island fragments are calved from glaciers and ice shelves respectively. Ninety percent of icebergs found in Canadian waters originate from glaciers in Greenland, and, although they are found in the waterways of the Arctic Archipelago, and north of the Arctic Islands in the Arctic Ocean and Beaufort Sea, most icebergs in Canadian waters are located in Baffin Bay and southward along the Labrador Current and connecting waterways. Of the 20,000-40,000 icebergs located in the source region Baffin Bay, approximately 350 reach as far south as 48°N in the Newfoundland Grand Banks area each year. Statistically. the number of icebergs crossing the 48th parallel varies from zero to near 2000 per year. At the latitude of the transatlantic shipping route connecting the Strait of Belle Isle, icebergs are always present with maximum numbers in May and minimums in September. Generally, the number of icebergs increases northwards due to less dispersion and a colder environment, which preserves their existence. Iceberg sizes average approximately 500,000 tonnes, but may be as large as 20 million tonnes. They move mainly in response to water currents which, in the Labrador Current, typically amounts to 15-18 km/day southward. In some areas, and under certain conditions, icebergs may attain short-term speeds of up to 5 km/hr. Small air bubbles within glacial ice tends to deter the propagation of cracks which gives the ice very high crushing strengths.

Specifically, the occurrence of sea ice and icebergs affects the safety and economies of Canadians involved in fishing, shipping, and offshore exploration. The cost of maintaining shipping lanes and the threat to shipping from icebergs is not usually a serious concern of the Canadian property and casualty insurance industry. Traditionally, most marine insurance has been provided by the international market. Sea ice present in the vicinity of an oil spill may actually contain the oil spill in some situations, but it generally makes retrieval impossible and predicting oil spill movement and dispersion extremely complex.

The situations described have been those where ice conditions affect human activity. It is also possible that human activity may inadvertently change local and regional ice conditions, however, which may then become potentially hazardous in cases where the changes may involve the transport of pollutants and other hazardous materials deposited on or entrapped within the ice, or where construction of causeways, for example, may hold back ice from normal drift patterns causing upstream and downstream changes in ice climatology which, in turn, may affect other ecologies and activities.

Tsunamis

Unlike wind-generated waves, tsunamis are true gravity waves, with exceptionally long length and period, which strike most often along the Pacific Ocean's "rim of fire." A severe earthquake can trigger a tsunami when the seabed suddenly ruptures, causing the column of water above it to oscillate violently in seeking its own level. Giant submarine avalanches can occur when a nearby earthquake weakens a sizable segment of unstable sea-slope material resulting, in vertical oscillations disturbing a large enough column of water to cause a tsunami. The third cause of tsunamis is explosive submarine volcanic eruptions.

Although tsunamis do not occur frequently in Canada, significant tsunami events have occurred this century, on both the Atlantic and Pacific coasts of Canada. On the Atlantic coast, the Grand Banks earthquake of November 18, 1929 produced a tsunami with a maximum amplitude in excess of 10 m, which claimed 27 lives on the Burin Peninsula of Newfoundland. The tsunami generated by the Alaskan earthquake of March 28, 1964, caused considerable damage to property along the British Columbia coast, where it had a maximum amplitude in excess of 5 m. Most tsunamis affecting the Pacific coast of Canada are generated by earthquakes occurring in other regions of the Pacific; several locally generated destructive tsunamis have been documented, however.

In the last few years there has been compelling evidence that very large earthquakes occur along the Cascadia Subduction Zone at intervals of several centuries. Geophysical reasoning has suggested that a "megathrust earthquake" might occur, as a sudden stress release event within the subduction process, every few hundred years or so, with a significant (5 to 10 m) sea-bottom displacement roughly along the 200 m isobath off the seismically active British Columbia coast. The last major event occurred about 300 years ago, prior to the written history of the region. The recent thrust earthquake near Cape Mendocino (April 1992), and the resultant tsunami, have served to focus attention on this area. Geodetic studies by the Geological Survey of Canada and the U.S. Geological Survey reveal that the Cascadia Zone is locked and strain is building.

Tsunamis have been much less frequent in the Atlantic, with only four events on record on the Atlantic coast of Canada. The most spectacular and damaging tsunami on Canada's east coast was that which followed the "Grand Banks" earthquake of November 18, 1929. The tsunami wave pattern was strongly directional; no wave was observed at all at Sable Island.

Marine Severe Weather and Sea Waves

The Atlantic and Pacific coasts of Canada often experience intense weather storms that can adversely affect coastal and offshore activities. The movement and evolution of the Atlantic storms is quite different from the movement and evolution of Pacific storms. However, both the Atlantic and Pacific coasts of Canada are often severely affected by extreme wind and waves that are associated with these storms. The configuration of the coastline and the coastal topography can be important factors in creating hazardous sea-state conditions in selected regions of Canada's east and west coasts. Tall mountain ranges along the Juan de Fuca Strait, off Vancouver Island, often create a wind channelling effect and hazardous sea-state conditions. Cold air outbreaks in the Scotian

Shelf region of the Canadian Atlantic, accompanied by strong winds, can often create hazardous sea-state conditions in the Canadian Atlantic. Offshore regions of long fetches and sustained strong wind conditions can cause extreme sea-states. The Grand Banks region experiences frequent passage of storms providing strong winds and long over-water fetches. On the west coast, storms approaching the British Columbia coast can generate high sea-states off Vancouver Island, due to long fetches extending from the north central Pacific to the Canadian west coast.

There is no doubt that, on a global scale, ocean waves represent the most severe natural marine hazard known to man. There are countless episodes where ocean waves have been responsible for catastrophic loss of life and property. On February 14-15, 1982, a single large wave broke a porthole window on the semi-submersible drilling vessel *Ocean Ranger*, triggering a chain of events that led to the sinking of the rig with a loss of 84 lives; the same storm was also responsible for the sinking of the *Mechanik Tarasov* with the loss of 33 lives. Recently, the so-called "Storm of the Century," on March 15, 1993, off the east coast of North America, is estimated to have produced maximum waves in the order of 30 m, which resulted in the sinking of the *Gold Bond Conveyer* south of Halifax, Nova Scotia with 33 lives lost. The effect of the hazard of ocean waves is not restricted to the open ocean. Coastal structures have often been battered by waves associated with these large storms, often magnified by high storm surges. The "Halloween Storm" on the east coast of North America on October 31, 1991, caused thousands of millions of dollars of coastal damage from Nova Scotia to Florida and the Bahamas. One result of this storm was the measurement of the highest waves ever recorded by an instrument anywhere in the world, 30.7 m, on the Scotian slope. Apart from these extreme values, the 100-year return period for maximum waves, used for design criteria for facilities like oil rigs, suggests waves in the low 20 m range off of Nova Scotia and in the mid-20-m range off the Avalon Peninsula of Newfoundland and to the west of Vancouver Island. Large lakes, such as Lake Superior, have also felt the hazards of such waves, such as the sinking of the *Edmund Fitzgerald* in November 1975 with the loss of 29 lives.

One aspect of the impact of wave hazards is that related to shipping, ship routing and ship design. Ideally, sea-state information is of immense value to help determine the shortest as well as the least hazardous ship route in respect of a specified journey. A wave hazard related to ship routing is the problem of ship motion and ship response to a variety of sea-state conditions and the problem of ship design, based on the analysis of ship motion and ship response, which requires a detailed knowledge of sea-state in terms of a two-dimensional (frequency and direction) spectrum at a given location. Directional buoys could provide the required detailed sea-state spectrum at a given location, but few such buoys are deployed at present, hence the sea-state information based on the available buoy data is inadequate for the problem of ship design.

Another aspect of the wave hazard relates to offshore structures and associated offshore and near-shore activities. Offshore hydrocarbon exploration activities have increased significantly in the Canadian east coast, while on the west coast offshore marine transportation has increased. A knowledge of wave force on submerged structures can provide a guideline for building safe structures which can withstand extreme sea-states as well as steep waves generated as a result of interaction with near-shore currents.

Freezing spray represents a serious hazard to marine activities, especially for Atlantic Canada during the winter months. A late January 1993 snowstorm resulted in the sinking of the 40 m scallop dragger *Cape Aspy* and the loss of 5 of the 16 crew members, with the sinking thought to be due to ice buildup from several hours of freezing spray. The ship left Lunenburg with westerly winds gusting above 55 km/hr and an air temperature of around -10 °C and ultimately sank in northwesterly winds gusting, at times, up to 75 km/hr and air temperatures dropping to -20 °C, accompanied by heavy snow squalls.

Drought

In parts of Canada, the word drought is seldom heard, which is not surprising considering that in most locations west and east of the Canadian Prairies, (which include Alberta, Saskatchewan and Manitoba), the average annual precipitation is greater than 600 mm and maritime coastal regions receive well in excess of 1000 mm. However, in the semi-arid to subhumid region in the lee of the western cordillera, distant from the moderating influence of ocean air, lies the Palliser Triangle, which extends from southern Alberta through Saskatchewan and into the southwest corner of Manitoba. Here, drought is a persistent and pervasive problem. The Prairies have highly variable weather. Drought and its impacts tend to develop over the course of weeks, months and years and move from region to region sometimes growing in area and severity and sometimes diminishing. On the Canadian Prairies, drought is seldom ever non-existent. Drought is pervasive because of the constraints and disruptions that the lack of water place on the environment, economy and social activity. Drought does occur in other regions of Canada but nowhere so frequent or with such severity over such large areas. This section of the report will focus mainly on the Prairie region where planning for and mitigating against drought is a way of life.

The seasonality of the weather -- the cool temperate climate and annual precipitation that generally averages between 290 mm to 470 mm -- results in some limitations. Winter and early spring snowfall are relied on heavily to provide the spring runoff that replenishes the water reserves. May through July rains are required to provide most of the moisture that in the good years is sufficient to produce an exceptional quality high protein wheat and a wide range of field crops. The timing of the weather is critical. An August rain may be too late for a crop that has not received adequate moisture, but may have benefits for pasture, fall seeded crops, or the next year's crop.

Drought is a meteorological term. The seasonality of climate changes the impacts that the short drought sequences have. For example, a short duration drought in the winter or early spring may cause a hydrological drought that reduces surface and shallow ground water supplies. But if a short duration drought occurs in the fall and spring, it can reduce the yield of cool season grasses, causing a pasture drought and reducing the yield of the first (sometimes the single annual) cut of hay for winter feed supplies. Furthermore, a short duration drought in the late spring and summer can result in a crop drought. Lack of fall moisture may result in insufficient carry-over of grass on pastures, leading to reduced stocking rate potential and even a severe lack of grass in prolonged situations. Thus, drought can be a double-edged sword to livestock producers because of the need for both grass and water.

The risk of drought in terms of its impacts on society are many, but the full impact of drought depends on the timing of the dry period, its persistence and its association in time with other environmental, economic and social circumstances. As a developed country with good education, communication, transportation, enhanced water delivery and income support systems, the impact of drought is not of the severity experienced by the lesser developed or drier parts of the world. However, Western Canada, and particularly the brown soil zones of the Canadian Prairies remain particularly vulnerable to drought.

Frequency

Many reports that define the drought periods of this century do not fully agree and that is due to the variations in time, severity and impact. However, there are two decades in this century that will be remembered in stories and history books for the ravage they caused. The 1930s and the 1980s were extended periods of severe and widespread drought, with associated, pervasive impacts brought by years of back-to-back droughts.

The worst agricultural droughts occurred in 1961, 1988, 1936-1937 and 1984-1985. Other years in this century when cereal crop droughts occurred in parts of the Prairies included 1910, 1914, 1917, 1918, 1919, 1920, 1924, 1929, 1931, 1933, 1934, 1938, 1941, 1943, 1945, 1947, 1949, 1950, 1957, 1958, 1960, 1964, 1967, 1968, 1969, 1974, 1977, 1979, 1980, 1983, 1989 and 1990. 1948 was a normal year, by some accounts, but in parts of the southern Peace River and northern agricultural fringes of Alberta and Saskatchewan cereal drought was severe. This is similar in some aspects to 1992 when heavy summer rains resulted in good yields in most of the Prairies, but forage yields were low in northern Alberta and Saskatchewan due to dry conditions. In Ontario, heat and drought stress took their toll on crops in years such as 1936, 1963, 1973, 1978, 1983 and 1988.

Surface water droughts have occurred over different basins in different years. These droughts are characterized by low streamflows, low lake levels and low dugout levels. Low shallow groundwater levels may also occur in phase with the surface water drought. A review of the recorded flows on the Prairies since 1950 shows the most widespread and severe droughts, with streamflows less than 10% of the median, were in 1961, 1977 and 1988. Some widespread and severe surface water droughts also occurred in 1958, 1959, 1963, 1964, 1968, 1973, 1980, 1981, 1984, 1987, 1989, 1991, 1992 and 1993. In fact, there were only five years in the 43 years analyzed, in which there was no recorded streamflow less than 10% of the median.

Environmental, Social and Economic Impacts

Droughts of short duration may have very severe impacts at farm and local levels but these impacts are generally masked by the overall performance in the rest of the region. Large scale and multi-year droughts give rise to a multitude of problems. An obvious impact of drought is the sparse shrivelled stands and dismal harvests that occur. For example, in 1910, wheat production in the Prairie provinces declined by 25%. In 1937, the average yield per seeded acre was only 6.4 bushels per acre (430.4 kg/ha). Annual wheat production had declined more or less steadily each year to only 37% of that produced in 1932.

In 1979, total production of principal field crops in Western Canada declined 15% due mainly to losses in Manitoba and Saskatchewan. In 1980, production remained at similar levels and was again concentrated in Manitoba and Saskatchewan. In 1983, production declined in Western Canada by 7.5% due to the onset of drought, which occurred during the growing season. In 1984, production declined another 9.6%. In 1985, production increased from 1984 levels but remained 12% below 1982 levels despite the 6.5% increase in seeded area. In 1988, production in Western Canada declined by 24% from 1987 levels. The greatest impact occurred in Saskatchewan where wheat production declined from 15.2 million tonnes in 1987 to 6.9 million tonnes in 1988. These trends are provided in greater detail in **Table 1.**

Dollar values of the drought impacts are very difficult to determine. Inventories of grain can be significantly reduced. The impact would be felt in the current year and for one or two years following. During the 1970s, there was a steady rise in grain prices. With the more widespread and severe droughts of the 1980s there came a steady decline in grain prices. When droughts coincide with periods of economic stress from depressed returns for agricultural production, as was the case in both the 1930s and 1980s, the impact on producers is severe and may lead to bankruptcy. In the 1930s, drought was the principal cause of a migration in excess of a quarter of a million people from the Prairies. Crop farm bankruptcies increased slightly in 1988 but the full impact is difficult to determine due to offsetting support payments. Today, drought remains a factor contributing to the decline of rural populations and the fabric of rural life.

In 1936, the value of inventories in the Prairie provinces (farmer-owned crops and livestock) dropped $35.7 million and total net farm income declined by 14.7%. In 1937 the value of inventories declined by another $22 million and net farm income increased 60% from 1936. However, the net farm income in Saskatchewan was $-44.5 million.

TABLE 1
Production of Principal Field Crops and Farm Income
(000s)

Year	Manitoba				Saskatchewan				Alberta			
	Seeded Area (ha)	Production (tonnes)	Value of Inventory Change	Total Net Income	Seeded Area (ha)	Production (tonnes)	Value of Inventory Change	Total Net Income	Seeded Area (ha)	Production (tonnes)	Value of Inventory Change	Total Net Income
1930	2,540	3,126	13,488	21,337	9,031	8,920	26,529	32,484	4,189	5,719	30,997	50,203
1931	2,191	1,519	-7,940	-7,907	8,795	5,068	-10,867	-36,220	4,575	5,709	4,333	8,425
1932	2,156	2,224	5,570	4,875	8,943	8,110	11,324	-5,638	4,781	6,592	5,276	11,108
1933	2,137	1,730	-4,906	-530	8,519	5,084	-8,860	-18,678	4,684	4,202	-7,809	2,223
1934	2,115	1,834	-2,187	11,265	7,891	4,416	-9,987	-6,180	4,648	4,671	-1,504	30,656
1935	2,132	1,659	-437	7,093	8,064	6,567	8,464	22,972	4,738	4,355	-9,258	25,494
1936	2,271	1,470	-2,617	15,741	8,674	4,436	-19,291	14,240	4,541	2,959	-13,761	17,647
1937	2,367	2,721	15,077	55,429	8,151	1,465	-44,252	-40,515	4,772	3,762	6,371	60,476
1938	2,529	2,758	-565	30,415	7,933	5,678	19,056	24,794	4,920	6,300	12,383	78,371
1939	2,496	2,872	930	30,463	8,240	9,945	30,272	92,164	5,026	6,360	12,973	61,909
1940	2,553	2,992	8,847	38,225	8,717	9,424	29,652	89,275	5,117	7,290	31,789	84,107
1941	2,291	3,011	3,743	50,361	7,741	5,945	-21,809	62,308	4,566	4,362	-19,642	62,526
1942	2,315	4,202	29,063	94,203	8,725	14,802	184,260	289,663	4,858	9,162	102,917	202,230
1943	2,228	3,397	-5,396	93,959	8,724	9,040	-66,397	149,500	4,581	5,530	-38,151	104,584
1944	2,397	3,380	-20,763	97,761	9,059	11,256	-73,770	327,373	4,712	5,597	-56,129	190,828
1945	2,368	2,981	-25,173	68,271	8,926	7,819	-105,668	170,020	4,900	4,308	-69,604	125,217

Year	Manitoba				Saskatchewan				Alberta			
	Seeded Area (ha)	Production (tonnes)	Value of Inventory Change	Total Net Income	Seeded Area (ha)	Production (tonnes)	Value of Inventory Change	Total Net Income	Seeded Area (ha)	Production (tonnes)	Value of Inventory Change	Total Net Income
1946	2,395	3,334	-1,138	102,463	8,816	8,319	-4,543	250,707	4,782	6,089	15,792	190,928
1947	2,565	2,607	1,954	110,782	9,168	7,247	-35,159	243,153	4,906	5,313	-2,401	213,481
1948	2,526	3,506	10,454	172,604	9,120	7,959	-3,331	368,271	4,785	5,852	-6,674	289,328
1949	2,582	3,105	-20,524	133,668	8,815	7,234	-23,995	354,974	5,156	4,502	-52,113	238,651
1950	2,439	3,692	15,330	114,795	9,182	10,322	64,063	262,907	5,249	5,684	7,462	189,032
1951	2,720	3,694	9,336	176,915	9,272	13,026	140,640	529,659	5,156	8,663	129,175	385,574
1952	2,720	4,249	23,473	158,165	9,599	17,031	169,827	605,468	5,194	9,470	55,998	351,030
1953	2,686	3,622	1,985	109,055	9,504	14,620	12,471	478,404	5,196	8,843	31,912	295,036
1954	2,588	2,448	-12,480	66,272	9,201	7,372	-84,192	135,353	4,750	5,699	5,864	174,589
1955	2,540	2,944	17,775	84,216	9,393	13,583	151,353	323,864	5,063	7,606	52,956	192,038
1956	2,664	4,037	31,675	124,245	9,286	14,642	91,981	399,655	4,836	8,487	44,044	236,391
1957	2,579	2,918	-12,446	68,138	9,079	9,274	-76,282	176,474	4,633	5,927	-40,350	153,945
1958	2,484	3,544	15,548	124,223	9,018	8,993	-76,866	238,540	4,676	6,363	-6,432	237,802
1959	2,442	3,339	-3,774	97,309	8,873	9,510	-43,512	227,281	4,872	7,029	-1,868	208,658
1960	2,449	3,398	8,396	102,858	9,225	12,405	67,758	328,488	4,778	6,613	-21,190	189,248
1961	2,317	1,632	-57,037	44,828	8,486	4,768	-209,135	88,238	4,722	5,703	-40,214	190,309
1962	2,543	4,295	52,514	158,737	9,136	12,672	95,448	457,887	4,842	7,091	21,174	270,292
1963	2,556	3,271	-3,936	106,558	9,352	17,385	231,320	546,837	5,055	8,814	103,270	282,088
1964	2,736	4,161	28,985	155,750	9,395	11,393	-108,880	334,349	5,150	7,839	7,895	227,652

Year	Manitoba				Saskatchewan				Alberta			
	Seeded Area (ha)	Production (tonnes)	Value of Inventory Change	Total Net Income	Seeded Area (ha)	Production (tonnes)	Value of Inventory Change	Total Net Income	Seeded Area (ha)	Production (tonnes)	Value of Inventory Change	Total Net Income
1965	2,830	4,312	10,180	164,129	9,589	14,403	23,807	469,653	5,232	8,728	28,771	286,540
1966	2,847	4,123	-27,109	137,483	10,129	18,638	105,883	555,957	5,509	10,716	35,850	352,366
1967	2,847	4,449	15,964	152,256	9,984	11,746	-128,209	333,247	5,585	8,584	-42,141	261,382
1968	2,905	5,033	50,517	162,812	9,957	13,517	103,779	453,565	5,632	10,183	61,972	335,154
1969	2,708	4,134	8,913	117,814	9,515	17,000	244,071	417,287	5,481	10,103	44,745	250,780
1970	2,344	3,284	-15,185	88,774	7,045	12,234	19,325	240,999	4,644	8,858	32,147	219,057
1971	2,930	5,739	39,063	154,847	9,975	18,358	55,807	458,892	5,502	9,879	-1,749	216,736
1972	2,788	4,967	-31,967	164,278	9,154	14,863	-220,768	381,537	5,269	10,565	17,530	309,652
1973	3,028	5,296	95,401	365,331	9,696	16,063	159,944	888,202	5,459	10,166	202,476	618,427
1974	2,873	3,845	-48,590	311,485	9,289	13,169	-26,135	1,134,745	5,180	8,888	-8,698	662,523
1975	2,962	4,577	8,614	390,771	9,439	15,869	68,992	1,468,502	5,584	11,077	98,786	730,223
1976	3,041	5,533	40,487	275,275	9,497	19,999	269,188	1,208,482	5,649	12,573	97,009	519,363
1977	3,040	6,395	129,874	280,837	9,652	19,066	47,342	766,619	5,534	11,053	-75,028	292,815
1978	3,168	6,309	49,227	341,352	10,117	19,357	55,461	846,365	6,030	11,952	101,002	568,101
1979	3,086	4,703	-52,704	232,528	10,183	14,542	-215,967	764,188	6,070	11,432	63,486	651,240
1980	3,036	4,332	-234,413	39,514	9,883	15,598	-314,424	614,117	6,241	14,130	150,883	646,438
1981	3,374	6,862	225,302	409,684	10,662	19,676	465,360	1,506,459	6,595	15,573	117,413	689,784
1982	3,452	7,647	77,978	288,785	10,781	22,448	129,674	1,058,786	6,739	15,205	-53,520	400,247
1983	3,565	6,257	-162,865	52,353	10,975	19,811	-185,271	517,577	6,784	14,252	-192,934	219,450

Year	Manitoba				Saskatchewan				Alberta			
	Seeded Area (ha)	Production (tonnes)	Value of Inventory Change	Total Net Income	Seeded Area (ha)	Production (tonnes)	Value of Inventory Change	Total Net Income	Seeded Area (ha)	Production (tonnes)	Value of Inventory Change	Total Net Income
1984	3,752	7,291	13,603	312,519	11,409	16,260	-741,135	262,169	6,848	12,006	-320,220	101,978
1985	3,814	9,607	283,131	561,428	11,696	19,102	238,560	786,654	6,893	11,986	-25,458	252,647
1986	3,641	7,935	-36,758	378,299	12,007	25,165	710,498	1,362,127	7,102	17,625	498,709	867,332
1987	3,575	7,327	-75,325	379,572	11,457	21,715	-179,757	720,496	6,991	15,451	-29,213	573,366
1988	3,628	4,594	-219,759	149,754	11,208	11,219	-835,331	170,600	6,890	14,833	42,983	927,155
1989	3,794	6,850	146,177	471,013	12,023	18,721	405,730	1,204,808	7,052	15,266	67,761	806,490
1990	3,679	9,182	326,404	472,428	11,791	24,260	794,387	1,182,830	6,821	15,803	219,781	540,007
1991	3,580	7,642	-14,353	143,231	11,764	24,094	108,718	524,707	6,790	16,174	159,779	408,048
1992	3,622	9,191	115,688	406,846	11,669	21,551	-133,725	443,337	6,748	13,660	-169,450	714,719

* Crops include Wheat, Barley, Rye, Flax, Rapeseed-Canola, Oats.

SOURCE: Statistics Canada

In 1961, the losses in net farm income were 56% in Manitoba, 73% in Saskatchewan and nil in Alberta compared to 1960. The value of farm inventories dropped $298.4 million and total net farm income dropped by 48% from $620.6 million, in 1960 to $323.4 million.

In 1979, losses in net farm income were 32% in Manitoba and 10% in Saskatchewan compared to 1978, followed by an additional 88% decline in Manitoba and 27% decline in Saskatchewan in 1980, the second year of the drought. The 1980 drought was estimated to have cost the agricultural sector about $1.5 billion.

In 1984, losses in net farm income were 49% in Saskatchewan and 54% in Alberta compared to 1983. The 1984-1985 drought was estimated to have caused a total loss of gross domestic product, due to lost agricultural production, of $1.1 billion. Associated with this loss was a reduced labour employment component of 2,200 person years. The next largest sector impacted was financial, insurance and real estate with losses of $60 million. The service sector was next with losses of $45 million.

In 1988, a significant number of farmers were unable to produce the 8 bushels per acre (538 kg/ha) required to cover harvesting costs. In many cases, the crop was ploughed under or left unharvested. Losses in net farm incomes were 76% in Saskatchewan, 60% in Manitoba, and 11% in Ontario compared to 1987. Drought was estimated to have caused a direct production loss of $1.8 billion, or 0.4% of the gross domestic product. On-farm closing stocks of the seven major grains on July 31, 1989, were 50% less than in 1988.

Drought can also have a significant impact on the environment. Dry soil, reduced stubble cover and open fields (particularly during spring planting) leave the soil subject to erosion by wind and water. The incidence of soil erosion is thus increased during drought.

Dust storm frequency increased in 1988, in all seasons. Dust storms even occurred in the winter due to lack of snow cover. Fifteen dust storms, which reduced visibility to less than 1 km were reported at Kindersley, Saskatchewan, in 1988. This number approaches the greatest annual total number of days with dust storms recorded at one station, which was 19 at Regina in 1981.

Grasshopper survival and propagation also increase during drought periods. Grasshoppers thrive in hot, dry weather while crops suffering from the moisture and heat stress become more injury prone from grasshopper feeding. The drought of the mid-1980s coincided with a major grasshopper outbreak. In 1985, Saskatchewan had record grasshopper numbers, a mean of 9-10 per square metre over the entire agricultural area of the province. An estimated 2.8 to 3.6 million ha of crop land were sprayed in Saskatchewan to control grasshoppers that year. Despite the massive control effort, grasshoppers were estimated to have caused more than $200 million in crop losses and reduced yields.

On-farm surface water supplies can reach critically low levels. Livestock water supplies on pastures tend to be the most vulnerable. Economically feasible pumping distance (generally less than 3 km), surface water storage projects are often filled using provincial dugout pump rental services, sometimes augmented with PFRA (Prairie Farm Rehabilitation Administration) pumps. But during some of the worst periods of drought in the 1980s, pumping distances of up to 14 km (approximately) were accomplished. Small agricultural service centres supplied with water through community dugouts can run short of water due to lack of recharge and increased demands from town residents and farmers hauling water. Many towns and cities experience water shortages on the Prairies during severe drought periods. Many of the large centres supplied by relatively stable water supplies are generally considered to be drought proofed. However, the increased demands on water supply systems, particularly at peak periods during the day, may cause shortages, and thus necessitate conservation measures such as voluntary or imposed rationing.

Drought also causes desiccation of standing waters on the Prairies. The evaporation of standing water bodies increases rapidly due to increased air temperatures and as water volumes decline the water temperatures increase more rapidly. The net results are: increased salination, reduced oxygen content, decreased carrying capacity of fish and some aquatic invertebrates, increased light penetration, which along with increased nutrient concentrations increases plant and algae growth. The limited runoff volumes may result in little or no flushing of salts in the spring causing the water supply to begin the summer season with a poor quality. The number of surface water bodies declined drastically through the 1980s culminating with the 1988 drought. Some water bodies continued to decline after 1988 and many have not yet recovered.

The long-term average number of ponds observed on the May pond count for the Waterfowl breeding population survey in southern Saskatchewan is 1996. Pond counts fluctuated throughout the 1980s but generally declined to 611 in 1981 and 861 in 1989. The extensive drought in the 1980s is primarily blamed for a decline in duck populations to near all-time lows.

Droughts may have a direct effect on the capacity to produce hydro-electric power. Alberta and Saskatchewan rely largely on thermal power generation, whereas in Manitoba, 98% of the power production is hydro-electric. Drought-reduced sales and increased operating costs in Manitoba in the years 1987 to 1989, yielding a net loss of $90-100 million.

Extended drought may significantly increase the incidence of well failure due to the demand for water and the natural decline in groundwater levels. Deep aquifers are often less affected and the recharge/discharge occurrences may be out of phase with the meteorological drought due to the lag time and complex nature of the aquifer. The demand for potable deep groundwater supplies becomes very high and may lead to aquifer dewatering.

One half of Canada's land is forested and drought has very serious implications for forested regions. Heat stress, lack of moisture, disease, insect damage and fires are drought-related forest hazards. However, it should be recognized that fires occur naturally and the vegetation and wildlife adapt to this phenomenon. The forested areas burned in Canada are a consequence of weather and fire control. The vulnerability of and dependence on forestry is greatest in the Province of British Columbia. In 1980, 4.8 million ha, an area six times greater than that logged by the forest industry, were burned in Canada. Droughts in the forested regions are relatively rare. Extremes in areas burned, such as in 1980, depend to some extent on prolonged and severe drought.

GEOLOGICAL HAZARDS

In addition to the geological hazards listed in the IDNDR Report Guide (earthquakes, landslides and volcanoes), two other hazards are described in this section -- snow avalanches and meteorite impact. A discussion of the hazard posed by snow avalanches has been included because this phenomenon is a significant problem on an annual basis in the mountainous region of western Canada. Meteorite impact has been included as an example of a hazard of very low magnitude but potentially very high impact. Canada, with the broad expanse of very old but relatively well-exposed rocks of the Canadian Shield, is an excellent area for the study of this hazard.

Earthquakes

Potentially, the most devastating natural hazard to which Canada is exposed is earthquake. Both the St. Lawrence Valley and the lower mainland of British Columbia are exposed to the hazards of severe earthquakes.

The landmass of Canada and the adjacent offshore area experience earthquakes produced by two main global tectonic regimes: first, active transcurrent faulting and subduction along the Pacific / Juan de Fuca / North America plate interaction zone in the west and, secondly, compressive intraplate stresses acting on crustal scale, Palaeozoic and younger rift structures that surround or break the North American craton.

The most intense region of seismicity lies just west of Vancouver Island, with over 100 earthquakes with Richter magnitude 5 or greater in the past 70 years. *(The Richter scale of earthquake magnitudes (M) is a measure of the energy released by an earthquake. The scale is logarithmic, such that an increase of 1 in magnitude is associated with a 10-fold increase in energy release. Richter magnitudes are determined from seismographic observations and are independent of the location of the observer. In theory, there is no upper limit to the magnitude of an earthquake, but the strength of rocks produces an* *actual upper limit of slightly less than M9.)*

Most of this earthquake activity is occurring on fracture zones that mark the boundaries of the Explorer and Juan de Fuca plates. The tectonics of the southwest margin is dominated by the Cascadia subduction zone, where the Juan de Fuca plate subducts beneath the North American plate. During historical times no earthquakes have occurred on the subduction interface, but the tectonic setting suggests that large subduction earthquakes are possible. Earthquakes within the North American plate, such as the magnitude 7.3 event on Vancouver Island in 1946, have caused the most damage during this century. The Queen Charlotte transform fault, which forms the boundary between the Pacific and North American plates, was the site of the largest Canadian earthquake in recorded history, magnitude 8.1, in 1949. Lower levels of seismicity extend across the Cordillera, with the largest historical and recent events occurring in the Richardson and Mackenzie Mountains in Yukon and Northwest Territories.

Canada east of the Cordillera is substantially aseismic, but contains several zones of significant seismicity. Almost all of the significant earthquakes in the continental part of southeastern Canada can be spatially, and probably causally, associated with the Palaeozoic rift system along the St. Lawrence Valley. This region has seen magnitude 6 or greater earthquakes in 1925, 1935 and 1988. Along the eastern margin of the continent the earthquakes are concentrated near the ocean-continent transition and appear to be due to reactivation of Mesozoic faults formed during the opening of the Atlantic. This "passive" continental margin has seen magnitude 7 earthquakes: in 1929 on the southern Grand Banks, where the associated tsunami killed 27 people on the south coast of Newfoundland; and in 1933 in Baffin Bay. Earthquakes as large as magnitude 6 occur in the Arctic Islands, by reactivation of geological structures in the current compressive stress regime, and in the "unbroken" portion of the craton in southeastern Canada, but at much lower rates than along the rift features.

The dense populations of the regions of the St.Lawrence Valley and the lower mainland of British Columbia are exposed to the risk of loss of life, injury and the loss of personal and commercial property that would result from a severe earthquake.

A recent study by the Munich Reinsurance Company of Canada examined the economic and insurance consequences of an earthquake of magnitude 6.5, at 123 °W, 49°N, and 10 km depth, below the Strait of Georgia, in southwestern British Columbia. The estimated Modified Mercalli intensity (MM) of this hypothetical earthquake ranges from a high of MM=X in the municipalities of Richmond and Delta to MM=VII-VIII in the city of Vancouver and all other suburbs. *The Mercalli scale of earthquake intensity is an arbitrary descriptive scale of the strength of an earthquake in terms of its observed effects. The Modified Mercalli scale, used in North America, runs from MM=I (not felt except under very favourable circumstances) to MM=XII (total damage). MM intensity depends not only on the earthquake magnitude, but also on the distance from the earthquake epicentre and on local geological conditions.*

The Munich Reinsurance study estimated economic losses of $14-32 thousand million, and insured losses of $6.7-12 thousand million. The number of "off-site" injuries has not been estimated; the study predicts the following "on-site" losses, however: 6,240 minor injuries, 832 serious injuries and 207 fatalities. Neither the Canadian economy, nor the insurance industry, can absorb losses of these magnitudes without severe dislocation.

To date, there has been no similar study to examine the likely loss that a severe earthquake would cause in the Montreal region. A number of factors, such as the relative size of the economy and generally older stock of buildings, suggests that losses similar to those estimated for British Columbia would be likely from an even less severe earthquake.

Landslides

In Canada, a wide variety of landslide types occur in many geological environments. Serious landsliding problems are concentrated in: sensitive Champlain Sea sediments of the St. Lawrence Lowlands, overconsolidated Cretaceous clay shales of the Prairie provinces, ice-rich, fine grained sediments of the permafrost regions; and in a variety of materials in the complex geological environment of the Cordillera.

Landslides occur relatively frequently in Canada. Since 1855, for example, 30 major rock avalanches have occurred in the Cordillera, three of which affected strategic transportation corridors, and seven large-scale debris avalanches have occurred in Quaternary volcanic materials in the Garibaldi Volcanic Belt of southwestern British Columbia. In addition, 24 major landslides have occurred in sensitive Champlain Sea sediments since 1840, the most recent being the 1993 Lemieux Landslide, South Nation River, Ontario.

Of 16 known major landslides in the period 1840-1984, with volumes in excess of 5×10^6 m^3, 12 are located in the Cordillera and its margins, while four are in the St. Lawrence Lowlands. With respect to materials, seven occurred in Quaternary sediments and five in Quaternary volcanic deposits. Of the seven in Quaternary sediments, five were in Champlain Sea sediments.

In nine major landslide disasters since 1840, five landslides in Pleistocene surficial deposits caused as many as 153 deaths, while those involving failures of rock slopes caused 209 fatalities. Canada's worst landslide disaster, the 1903 Frank Slide in Alberta, resulted in the deaths of approximately 76 persons. In addition to loss of life, landslides in Canada cause millions of dollars of damage to the economic infrastructure each year. Millions of dollars are also spent on the implementation of mitigation measures. Of increasing importance is the value of land lost to sterilization due to landslide hazard.

Volcanic Eruptions

British Columbia and Yukon encompass a geologically dynamic region, in which some 100 volcanoes and volcanic fields have formed in the past two million years. These volcanoes are arranged in five broad belts and eruptions within each belt have occurred in the last 10,000 years. In terms of eruptive styles, these have ranged from "Hawaiian" type eruptions, consisting largely of lava flows and localized tephra (ash) distribution to eruptions on a scale similar to that at Mount St. Helens on May 18, 1980. While no eruptions have occurred in Canada in the period of recorded history, the tectonic forces that produced these volcanoes and volcanic fields are still active today. It must therefore be assumed that a potential for a volcanic eruption in Canada still exists.

A second factor is the potential impact on Canada of eruptions elsewhere in North America. Within 24 hours of the May 1980 eruption of Mt. St. Helens, enough tephra fell in southern British Columbia, Alberta and Saskatchewan to cause concern among residents and the aviation community. During the 1989-1990 explosive eruptions of Mount Redoubt, Alaska, tephra drifted into Canada on at least two occasions. Following the three explosive eruptions of Mount Spurr, Alaska, in 1992, ash drifted over Canada, disrupting air traffic and falling to the ground over central Yukon on one occasion.

Two prehistoric eruptions of Mount St. Helens left readily observable ash layers in southern British Columbia and the eruption of Mount Mazama (Crater Lake, California) left a blanket of ash several centimetres thick over much of southern British Columbia and most of Alberta. The eruption of Mount Churchill, just a few kilometres west of the Alaska-Yukon border, 1200 years ago, devastated 300,000 km^2 of Yukon. It is quite likely that Canada has been dusted by other tephras that have not been preserved in the geological record. When eruptions like these occur again, they will have significant effects on aviation and residents in Canada and, in the case of a very large eruption, a major economic impact can be expected.

Snow Avalanches

Snow avalanches are the greatest single mountain hazard threatening safety to people and security of facilities. There appears to be a dramatic increase in human activity in avalanche terrain with a much increased risk to people and rescuers. There are more than 1,600 avalanche paths which threaten public transportation routes in British Columbia. Since 1980, there have been 523 avalanche incidents with people at risk, resulting in 89 fatalities.

The principal problems with respect to avalanches in Canada occur in the mountainous regions of British Columbia, Alberta, and Yukon, all in the western part of the country; more than 80% of Canada's avalanche problems are found in British Columbia. In particular, a high proportion of roads and highways in British Columbia are subject to avalanches and <u>all</u> major railways are threatened. About 60-70 sections of major roads in British Columbia, with about 1500 avalanche paths, need monitoring for avalanche forecasting and control. These facts guarantee that the transportation industry is strongly influenced by snow avalanches in Canada. It is estimated that several hundred thousand large avalanches powerful enough to destroy small buildings occur every winter in Western Canada. However, due to the low population density in hazardous areas, only a small percentage of these threaten building sites and transportation routes. In addition to these large avalanches, several million small avalanches with the potential for hazard to persons on foot or skis occur each year in western Canada.

The diversity of snow climates in the mountain ranges influences snow stability and the frequency of avalanching. Generally, the frequency of natural avalanching is lower in continental snow climates, as found in the Rocky Mountains, but instability persists longer, to produce a potentially higher hazard to people on skis or foot. Maritime snow climates, in the Coast Ranges, result in more frequent avalanches, but the hazard is less persistent. These varying snow climates in Canada prevent general, country-wide avalanche forecasts.

In Canada, the character of avalanche accidents has changed since the early 1970's. Formerly, major disasters occurred when mining and construction camps, and private residences were destroyed by avalanches. Better planning and control measures have largely eliminated these disasters, however. Between 1968 and 1989 avalanches resulted in an average of seven fatalities per year, of which 87% were skiers, mountaineers, snowmobilers or other back country travellers. These rates are similar to those in European alpine countries, Japan and the United States. In Canada, the response has been to institute extensive operational avalanche education programs for targeted education to those potentially affected.

Meteorite Impacts

The hazard presented by the collision of interplanetary bodies with the Earth is a combination of frequency and consequences of occurrence. The former can be estimated fairly well. The latter, however, is poorly understood, particularly when dealing with complex systems. In major impact events on Earth, the impact energy and its effects are partitioned into not only the geosphere and/or hydrosphere but also into the atmosphere and, thus, ultimately affect the biosphere. Impact represents the extreme case of a very infrequent but truly catastrophic event. As the consequences can be so dire, the statistical risk of individual death compares to that of other natural disasters like hurricanes and earthquakes.

More than 140 terrestrial impact structures are known, and about five new structures are discovered each year. In Canada, 27 impact structures are known, ranging from approximately 200 km (Sudbury) to approximately 3 km (New Quebec) in diameter. From an analysis of their ages and preservation state, the terrestrial cratering rate is estimated to be $5.6 \pm 2.8 \times 10^{-15}/km^2/a$ for craters with diameters of 20 km or greater.

This rate is comparable to that estimated from the direct observation of Earth-orbit-crossing bodies. Collisions with smaller bodies are more frequent. For example, events such as the Tunguska explosion, which devastated 2000 km^2 of Siberian forest in 1908, occur with an estimated frequency of once every few hundred years. The energy released in this event is estimated to be 10^{17} - 10^{18} J (10-100 megatons TNT equivalent). If such an event were to occur over a populated centre the effects would be devastating. Fortunately most of the world, and Canada, is sparsely populated.

Attention has been drawn recently to the potential for larger impact events to produce biological crises through the connection of the Cretaceous-Tertiary (K/T) impact, which resulted in the 180 km diameter Chicxulub structure, Mexico, to a temporally equivalent mass-extinction event. While the potential killing mechanisms of this event are only now under study, it appears that atmospheric effects (dust loading, aerosols and acid rain) played a dominant role. The importance of this aspect of cratering mechanics was unappreciated and has been largely ignored until recently.

Impact events on the scale of that at the K/T boundary occur on time-scales of approximately 100 million years. Smaller impact events may not produce mass extinctions, but will affect the terrestrial atmosphere and biosphere to varying degrees. Modelling of the K/T event suggest that 10^{16} g of dust are sufficient to reduce photosynthesis to 10^{-3} of normal for at least a year. Such events occur on time scales of 2-4 every million years. While unlikely to affect seriously the biosphere, their equivalence to nuclear winter suggest they would have disastrous global results for human civilization.

BIOLOGICAL HAZARDS

The only hazard of a biological nature considered in the report is wildfire, also known as forest fire, or wildland fire.

Wildfire

Wildland fire is an environmentally and ecologically important part of the Canadian landscape. An average of 250 wildfires exceeding 200 ha in size occur each year. Above this threshold, wildland fires have the potential to become disasters. Although these represent only 3% of the total number of wildfires, they account for 93% of the 2.5 x 10^6 ha burned annually in Canada -- 70% more area than is harvested. An average of $433 million is spent annually on fire management in Canada -- a significant 18% of the total cost of forest management.

Canadian forests have evolved in a context of high-intensity, stand-replacing fires at 15- to 150-year intervals. Most forests trace their origins to historical wildfires; many require fire to maintain their species composition. Although more common in the central boreal forest, large fires occur in all regions of the country. The forest fire season in Canada lasts from April through October, with peak fire activity in June, July, and August.

Despite strong fire prevention programs, the average annual number of fires has increased from 6,000 in the 1950s to 10,000 in the 1980s. This is attributed to an increasing population and expanding forest use. Compounding the problem, lightning starts 42% of all fires in Canada, but because these fires are often in remote locations, they account for 86% of the total area burned.

Notwithstanding major advances in suppression technology and management efficiency, the long-term trend of annual total area burned has increased from 800,000 ha in the 1950's to 2.5 x 10^6 ha in the 1980's. Many possible reasons have been cited for this increase: a fire management policy that consciously allows remote fires to burn naturally; improved reporting of remote fires; increased fire occurrence; extreme fire weather; early effects of global climate change; shrinking budgets with fewer resources for extreme fire situations; and a statistical clustering anomaly. Determining the actual cause(s) of the recent upward trend in area burned will be critical to fire management effectiveness over the long term.

RESEARCH ISSUES

While several areas for further research in the domain of hazard assessment can be identified, the gaps in Canada's knowledge of vulnerability to natural hazard losses deserve primary attention. The Canadian program for IDNDR supports the efforts by some sectors, such as the property and casualty insurance industry, to evaluate hazard-related losses.

Risk and Vulnerability Assessment: A common calculation of the distribution of risk as it affects property, and its insurers, is know as the "probable maximum loss," or PML. Using the example of earthquakes, the calculation of PML requires information on (1) the spatial distribution of various kinds of structures exposed to ground shaking, landslides, liquefaction, and surface faulting associated with the earthquake; (2) the spatial distribution of these geological hazards; and (3) the susceptibility of each building type to loss from these hazards. The calculation methodology has been used for more than 20 years, and remains the most useful index of the distribution of probable loss.

What has changed in recent years is the technology which supports PML estimation. An increasing number of insurance companies are subscribing to software packages to conduct such analyses on their portfolios. The technique can also be applied to single risks (single buildings for example) although it has not yet been employed in any regular fashion in the underwriting (i.e. rate-setting) process.

PML estimation in Canada could be improved to include hazards other than earthquake. Some estimation procedures could also be improved, in particular, in their treatment of fire losses related to earthquakes. Insurance companies are working to improve the quality of the data they are able to feed into their PML estimation programs to increase the precision of their loss estimates. Similarly, technological improvements are required before PML estimation will get "into the field" and become a regular part of the underwriting process on a site by site basis.

Risk Posed by Remote Events: Canada is also vulnerable to very major natural disasters occurring in other parts of the world. An example is the risk of a large earthquake in the Tokyo region, Japan. Over the past 350 years, major earthquakes have occurred approximately every 70 years. The last one, in 1923, resulted in a firestorm and a tsunami, with an estimated death toll of 140,000. Today, Tokyo and the surrounding municipalities constitute the most densely concentrated financial and industrial complex in the world, with 12 of the world's 13 largest banks headquartered there, business worth $450 million, annual profits of about $100,000 million, and a population approaching 30 million. In the event of an earthquake, the disruption of the financial markets and the cash requirements of reconstruction would devastate the whole world economy.

RISK ASSESSMENT IN THE PRIVATE SECTOR

Prediction of storm surges on the Great Lakes has been the topic of continuing work by consultants as part of the development of the industrial infrastructure. Skills in the consulting sector include storm surge prediction, hazard zoning, land use planning and the development of long term protective measures for shoreline protection.

Skill related to river flooding is the strongest area for the Canadian consulting sector's IDNDR participation. These skills have developed through very extensive work within Canada and internationally in water resources planning, irrigation, flood control and hydroelectric power projects. Several of Canada's largest consulting engineering companies have some of their strongest expertise within this realm. They have particular skills in flood forecasting, inundation mapping, monitoring and warning systems, and the design of protective measures and diversion works.

Although the toll from earthquakes within Canada has been low relative to many countries in the world, certain areas of western and eastern Canada have serious seismic hazards. As a result, capabilities have developed in the universities, government agencies and, increasing over the past few years, in the consulting sector, for hazard mapping and earthquake-resistant design.

As a result of ongoing cooperation with the Ocean Sciences Centre and concerns on the west coast of British Columbia, some fairly unique capability has been developed by consultants in tsunami prediction. Although the number of Canadian specialists in this field is limited, it is an area in which Canada could make a useful contribution to hazard identification in certain parts of the world, particularly around the Pacific rim.

As an outgrowth of avalanche research at the University of Calgary and many years of railway and highway operation and maintenance, some highly specialized expertise in avalanche hazard forecasting and reduction exists in Canada. Although the market for these skills is relatively limited, in certain situations it may offer the potential for useful contributions by Canadian consultants.

In the past, most expertise in Canada in the field of wild fires has existed within federal and provincial government agencies, as well as some of the major forestry companies. Normally these agencies would not market this expertise, although they would provide assistance in the event of natural disasters. To make such capability more available internationally, it may be of value to seek mechanisms to allow the consulting sector to develop expertise in this area.

As a result of Canada's problems with certain forms of insect plagues, such as gypsy moth, grasshoppers, spruce budworm and pine beetles, the consulting sector has some specialized capability. This capability could play a significant role in parts of the world where these species occur.

Specialized consulting expertise has been developed on desertification as a result of problems in the Prairies, which have resulted in the loss of agricultural land due to soil salinity and related phenomena. Several companies are now working internationally in this area, particularly in the Sahara Desert region. With the current concerns about climatic change, this area represents a significant opportunity for Canadian participation in IDNDR.

In addition to the provision of specialist engineering and scientific skills in the areas mentioned above, the Canadian consulting industry is active in the development and installation of computer modelling and monitoring systems, in particular through the use of geographic information systems, for hazard zoning and disaster assessment and analysis. These systems provide an interface between the communications, remote sensing, field investigations and planning groups, and consequently are playing an increasingly important role in natural hazard assessment and reduction.

III. MITIGATION ACTIVITIES

A. STATUS OF MITIGATION STRATEGIES AND MEASURES

FEDERAL GOVERNMENT PERSPECTIVE

The principles underlying emergency preparedness in Canada, the roles of the various orders of government, and the responsibilities of the other members of the emergency preparedness community, are key to understanding and assessing the state of emergency preparedness in this country. At the federal level, the emergency preparedness function is decentralized. Each department and agency is required by the *Emergency Preparedness Act* to identify the potential emergencies that could arise within its area of responsibility, develop plans to deal with them, and to exercise the plans. Emergency Preparedness Canada (EPC) promotes and co-ordinates planning by departments. A number of departments have additional responsibility to lead the emergency planning for a sector, such as transportation or energy, which may require the close support of other departments. These sectoral plans are called "national emergency arrangements." In general, for reasons of efficiency, the approach to emergency preparedness within the federal government is to start with the subject matter knowledge residing in key departments -- Environment for example -- and add to that knowledge the expertise needed to assess the risks and make emergency plans.

Another basic principle of emergency preparedness in Canada -- as in virtually all Western nations -- is the all-hazards approach. There are more than 60 potential causes of emergencies in Canada. Therefore, to devise specific emergency response plans geared to specific emergencies is an unrealistic goal. But, while the causes of emergencies and disasters are diverse, the response capabilities needed to cope with them are similar. So, as a matter of efficiency, emergency planning is built on the common response capabilities that will be required, to the extent that this is practical. There are some exceptions, such as marine spills response and nuclear accidents, which require specific plans.

The mitigation activities at the federal level, in effect, are driven by the Canadian emergency response system, which is based on the following premises:

- Responsibility for initial action in an emergency rests with the individual; individuals should know what to do to protect their lives and property.

- If the individual cannot cope, the municipal services respond. Mayors are responsible for ensuring that emergency plans exist and are exercised within their municipalities. Most emergencies occur within, and are dealt with effectively by, a municipality.

- If the municipality cannot manage to respond effectively to an emergency, the province or territory is expected to come to its aid. Provincial or territorial governments are responsible for co-ordinating the interface with the municipalities.

- If a province or territory needs help, the federal government's aid is formally requested, usually - but not necessarily - through Emergency Preparedness Canada; the federal government only intervenes when asked or when the emergency clearly lies within federal jurisdiction (e.g. floods or fires on federal lands, air crashes at federal airports).

The federal government does have in place an assessment of major national vulnerabilities and has developed plans on how to cope. Some examples, with the federal government agency responsible, in parentheses are:

a. *Energy (Natural Resources Canada)*
National arrangements for responding to energy shortages, mainly through the National Energy Board and the Energy Supplies Allocation Board in conjunction with provincial and industry advisory bodies have been in place since 1989.

b. *Environmental Emergencies (Environment Canada)*
Coordination of emergency response to environmental emergencies is the responsibility of Regional Environmental Emergency Teams in each province. Work has begun on developing terms of reference for a National Environmental Emergency Team to better coordinate interdepartmental policy, roles and mutually supporting operations at the headquarters level.

c. *Food (Agriculture & Agri-Food Canada)*
Consultations continue among federal government departments and with provincial agriculture departments in Alberta, Quebec and New Brunswick concerning the definition of respective responsibilities within a Food and Agriculture Emergency Response System.

d. *Health and Welfare Services (Health Canada)*
Government-industry arrangements concerning an assured supply of emergency pharmaceuticals are in place through letters of agreement with suppliers.

e. *Housing and Accommodation (Canada Mortgage & Housing Corporation)*

Regional plans for emergency housing and accommodation have been endorsed by provincial agencies in Newfoundland, Nova Scotia and Manitoba. Procedures to support previously agreed plans are being developed in Alberta and cooperative planning has been initiated in Saskatchewan.

f. *Human Resources (Human Resources & Labour Canada)*
Plans and arrangements concerning services to be provided, procedures to be followed and use of local resources have been concluded in all provinces and territories -- and in several municipalities. Expansion of national-level plans to encompass all types of emergencies is under way.

g. *Industrial Production (Industry Canada)*
A conceptual approach to emergency intervention and regulation by government in the industrial goods and services sector has been set out under an Industrial Crisis Action Network and an interdepartmental Industrial Coordination Committee established to coordinate the further elaboration of national arrangements. Studies have been undertaken on the nature of an industrial priority and allocation system and on potential trade control mechanisms.

h. *Telecommunications (Industry Canada)*
Thirteen Regional Emergency Telecommunications Committees have been established (one in each province/territory and one additional for the Atlantic Region) are in place to serve as fora for federal-provincial-territorial cooperation and coordination in preparation for, and in response to, emergencies.

i. *Construction (Public Works/Government Services)*
A list of participating organizations, roles and draft operating procedures for provincial components of a National Emergency Construction Agency have been produced in cooperation-operation with New Brunswick, Prince Edward Island, Manitoba, Newfoundland, Alberta, Yukon and the Northwest Territories. Planning continues with Quebec, Nova Scotia, Ontario and British Columbia.

Emergency Preparedness Canada manages the federal program and reviews it annually by:

- surveying the state of emergency preparedness and reporting to Parliament and others, as appropriate
- proposing government-wide priorities for emergency preparedness and providing guidance
- proposing changes to the program based on changing circumstances.

The Emergency Preparedness Advisory Committee is the main forum for interdepartmental consultation and management of the federal government's emergency preparedness program. This Committee balances the program priorities to ensure an effective response to common emergencies and to develop a framework for dealing with less common ones.

A federal department has been designated to take the lead in developing national emergency arrangements in each of 12 sectors including transportation, telecommunications, health and welfare services and industrial production. These arrangements vary according to the specific nature of the exceptional emergency powers required and the best means of coordinating their application in close cooperation with provincial, territorial and local governments.

Preparedness and Planning

a. Business Resumption Planning is required of each federal department and agency, comprising the assessment of risks and the introduction of measures to reduce the potential for disruption.

b. The federal government, working in concert with the provincial and territorial governments undertakes an extensive program of public awareness and training to assist in the identification of risks and encourage mitigation activities.

c. The single most important mitigation technique is good planning to respond to disasters. The following examples indicate the range of such planning in Canada.

    1) *British Columbia Earthquake Response Plan*
    This plan was developed to respond to the needs of the people of the province should an earthquake occur. Most provincial ministries and agencies have been involved in the plan's development.

    2) *National Earthquake Support Plan*
    The federal government is developing a national plan, in consultation with the provinces and territories, to support the provincial response to such an occurrence. Emergency planners in many federal government departments are involved.

    3) *Catastrophic Earthquake: Alberta Support Plan*
    This plan to assist British Columbia in the event of a catastrophic earthquake is dedicated to providing coordinated non-governmental and intergovernmental support.

d. *The Joint Alberta-Canada Critical Plant Pest Response Plan* responds to critical plant pest incidents in Alberta, taking into account the shared jurisdictions involved.

e. *The Joint Alberta-Canada Foreign Animal Disease Eradication Support Plan* provides a model of intergovernmental cooperative planning to provide Agriculture authorities with the massive logistic support required in the event of a major disease outbreak.

f. The Transport of Dangerous Goods Directorate develops standards and regulations compiled to control the movement of dangerous materials. An emergency response unit, known as CANUTEC (Canadian Transportation Emergency Centre) operates on a 24-hours-a-day, 7-days-a-week basis. Staff of this unit are able to offer advice related to dangerous goods accidents across the country.

PROVINCIAL AND MUNICIPAL PERSPECTIVES

Provincial and Territorial Governments

Provincial and territorial governments are responsible for public safety programs including the preparation for, response to, and recovery from emergencies and disasters. This responsibility is discharged by a number of departments through a wide variety of regulations, plans and programs coordinated through provincial and territorial emergency measures organizations. The objectives are to prevent loss of life and protect public health and safety; minimize damage; minimize disruption to Canadian communities; and inform the public of the potential risks from natural hazards. When a serious emergency or disaster occurs that is beyond the capability of the local authority, the provincial and territorial governments coordinate response and recovery programs.

The Provincial-Territorial Senior Officials Committee of the Canadian Council of Ministers Responsible for Emergency Preparedness supports the work of the Canadian Council of Ministers and exchanges information and ideas on emergency preparedness planning, operations and other associated subjects; provides advice to Deputy Ministers and the Minister's Council on the needs and matters concerning civil emergency measures programs; and provides a forum for coordinating the views and positions of the provinces and territories on emergency preparedness management issues.

Municipal Governments

Municipal governments are responsible for hazard assessment, development and maintenance of municipal emergency plans, and for the direction and control of municipal emergency response unless assumed by the emergency measures organizations of the provinces or territories.

Canadian municipalities demonstrate a very high level of emergency preparedness, and are eager to enhance their readiness for all potential incidents. Indian Bands and Metis

Settlements have recently gained access to emergency preparedness programs in some provinces.

Volunteer Groups

Municipal and provincial governments depend on volunteer groups to assist in responding to and recovering from disasters and the assistance of volunteer groups is integrated into municipal emergency plans. Emergency volunteer groups are well-trained people with expertise in many different fields who help in saving lives and minimizing injuries, and assist victims in recovering from the effects of disasters. The key to the effective use of volunteers is that they are well organized and well trained. Training for various volunteer groups is provided by some provinces. Some of the volunteer groups, for example, Ham radio operators, run their own training courses for emergency response and exercise their skills by participating in the provincially run courses.

Some volunteer groups provide critical social functions in response to emergencies and assist in providing the basic necessities of life, such as emergency medical services, food, shelter and clothing, and emotional support to victims in need. Examples of these groups include St. John Ambulance, the Canadian Red Cross Society, the Salvation Army, and Mennonite Disaster Services.

Other volunteer groups provide emergency response functions. Examples of these functions are organizations that conduct search and rescue by air and ground, emergency medical response and rescue teams, search and rescue dog associations, and mine and industrial rescue teams.

PROPERTY AND CASUALTY INSURANCE INDUSTRY PERSPECTIVE

Insurance, as a financial hedge against loss, is closely concerned with the problems presented by natural disasters. In many insurance markets, natural hazards are covered to a greater or lesser extent by property insurance and various other branches of insurance. This entails making a close study of such hazards in order that the premium requirements on the one hand and the loss potential on the other may be correctly estimated. To that end, insurers can draw upon extensive loss data and analyses from all parts of the world.

Insurance has an appreciable influence on the behaviour of the public and of industry in the matter of preparedness. By making the right use of the tools of insurance techniques, especially deductibles, the insured can be motivated to take preventive measures. After a disaster, the insurance industry gives swift financial help and has, for the most part, an efficient loss settlement organization at its disposal for this purpose.

In Canada, the Property and Casualty insurance and reinsurance industry is concerned with the increased frequency of tornadoes and heavy rainstorms causing flash flooding or major sewer backups, as well as major hailstorms in Alberta, Ontario and Quebec. Moreover, Quebec has recently been hit by two earthquakes of noticeable magnitude. As a result, the insurance industry has begun to assess the potential of reoccurrences and the best means to cover them. Current action plans include :

- A joint committee of government and industry in Quebec has been formed to analyze the problem of how to manage major catastrophes; the areas to be considered involve examining the current protection offered, the present and future needs and how to coordinate reactions in case a disaster occurs.

- The Reinsurance Research Council of Canada is compiling a survey to assess the Canadian insurance industry exposure to damage from earthquake and ensuing fire.

- The insurance Bureau of Canada is involved through the research, compilation and publication of cost data from major catastrophes in Canada.

- The Insurance Advisory Organization of Canada (IAO) has publicly announced its intention to hold a seminar on earthquakes and related insurance in the near future.

Currently, the availability and capacity of insurance and reinsurance in Canada appears to be sufficient. Property coverage is available for events such as tornadoes, windstorms, hailstorms and earthquakes. Recently, coverage to deal with the impacts of major rainfalls has been established. Comprehensive crop insurance coverage is also offered, in part by state-run monopolies and private companies. Only flood, tsunamis and, in British Columbia, landslide coverage, are not offered at large.

There is substantial use of engineering risk evaluation reports in the assessment (and reduction) of risk on major properties. These are provided by a variety of sources: specialized services organization of insurers (IAO), individual brokers or independent consulting engineers. There may be a need to develop a closer association between the insurance and reinsurance industry with researchers concerned with risk assessment on one hand and technical standards writing and materials testing on the other.

With regard to premiums, rates used in Canada for earthquakes, for example, vary widely by seismic zone and type of construction. These rates are established by IAO or major reinsurers (such as Munich Re of Canada). They provide some incentives and have an impact on the quality of construction for larger risk projects. Recent experiences following an earthquake in Canada have increasingly suggested that major diasters will become more expensive.

Overall, there is growing interest within the insurance and reinsurance industry for approaches that best deal with natural disasters. Currently, many studies are being undertaken to assess the damage and frequency potential of disasters and the related insurance needs.

MITIGATION STRATEGIES

METEOROLOGICAL AND MARINE HAZARDS

Background

As already explained in chapter II, various kinds of natural disasters in Canada have their origins in atmospheric forces. In the planning and implementation of measures to cope with such disasters, meteorology is involved over the whole spectrum from disaster prevention through mitigation to the emergency organization and operational activities that correspond to disaster preparedness. In all these measures at some stage or other, whether in the preparatory work or the actual implementation or in operational conditions, many branches of Environment Canada are involved. In fact meteorological disaster prevention is directed principally towards the formulation and application of long-term permanent measures which will serve either to avert the impact of potentially dangerous phenomena or to withstand them as far as possible and mitigate their harmful consequences. The Canadian meteorologist is given information regarding these two broad categories of measures aimed at the prevention and mitigation of disasters and appreciates that varied requirements for climatological data and advice are to be expected and that each type of problem needs to be dealt with in a specific manner. The two categories in question are structural measures and non-structural measures. The former are protective in nature and include engineering works and building codes. Non-structural measures are designed to steer development away from hazardous zones and include physical planning, land-use legislation and other measures such as taxation, insurance, mortgage policies and public information, education and training. Their objective is partly to establish economic and social goals for given locations in light of the various risks associated with the phenomena that can cause disasters and partly to bring risk factors to bear on the planning process in general. In ideal conditions land-use planning is based on a composite vulnerability analysis which provides risk values for given locations and for various types of development in hazardous areas.

Structural measures against damage caused by meteorological phenomena are advisable both in coastal areas, wherever a risk of storm surge exists, and in the flood plains through which the rivers flow.

The Atmospheric Environment Service (AES) of Environment Canada monitors weather conditions and broadcasts warnings over Weatheradio (radio stations in major Canadian cities that transmit weather information continuously over VHF-FM radio). They also relay warnings to provincial and territorial emergency measures organizations which contact local authorities to advise them to respond to the hazard.

Storm damage of a similar scale has occurred repeatedly in Canada during the last few years: a hailstorm in Calgary in 1981 ($100 million covered by insurance); a storm in Regina in 1983 ($50 million insured); a gale in 1984 and several tornadoes in 1985 in Barrie, southern Ontario ($65 million and $117 million, respectively, insured); a hailstorm in Montreal in 1986 ($80 million insured); and another storm in Montreal on July 14, 1987 (total damage exceeding $100 million).

In wind engineering, Canada has one of the leading research and consulting laboratories in the world at the University of Western Ontario, in addition to a number of private consulting companies. The traditional work of these groups is in the area of the design of facilities to withstand extreme windloading, but has also developed into the area of hazard zoning and land use planning. Many results of these efforts are now in the National Building Code of Canada -- a model in its field. This expertise is now being applied to major new property developments in the western world, which otherwise would be subjected to high risk. It should also continue to be made available worldwide, particularly to assist in the development of building codes for low cost housing in high density population areas.

Reducing Tornado Disasters

The disastrous storm that struck Edmonton, Alberta (530,000 inhabitants) on the afternoon of July 31, 1987, killed 27 people, injured more than 250, and left almost 400 families homeless. The property damage amounted to hundreds of millions of Canadian dollars, about 300 million of which was covered by insurance, mostly fire and motor home damage.

Nightly newscasts showing devastation caused by natural disasters such as tornadoes ripping through small communities, focus public attention on the need for both personal and municipal emergency disaster plans. However, for some, the lessons learned are all too quickly forgotten. This has not been the case for Environment Canada's Atmospheric Environment Service.

The above-mentioned windstorms which occurred in very different parts of Canada, demonstrated to staff at Environment Canada's regional office in Ontario, the need for public education on severe-weather safety procedures. The impact of these local natural disasters also emphasized the important role municipalities have to play both in preparing their community for emergencies, so that people will know how to protect themselves, and in responding to the disaster. To address these needs, Environment Canada developed an educational interactive one day workshop called "Project Tornado." This project is targeted at local and provincial officials and emergency responders. One objective of the project to raise the awareness of key public officials about how Environment Canada's Atmospheric Environment Service (Canada's Weather Service) predicts the development and movement of severe thunderstorms, and to educate these officials about the methodology used to ensure that the general population is alerted to the potential threat of severe weather.

The second objective of "Project Tornado" focusses on what official plans emergency responders should have in place both prior to and after a severe weather event.

The inaugural workshop, took place in March 1988 and since then the workshop has been duplicated at least twice a year at other locations in Canada. The workshop material consists of a 15-minute video plus a series of detailed workbooks. The workshop consists of three segments. The first segment describes the atmospheric conditions necessary for the triggering of severe thunderstorm development. It also provides details about the distribution of severe thunderstorms in Canada, emphasizing those regions that are most prone to experiencing them. The second segment of the workshop describes Environment Canada's severe weather Watch and Warning program and how vital information about hazardous weather is delivered to the electronic media, key officials and the general public. The last segment concentrates on the emergency plans that should be in place at a given location prior to any natural disaster occurring. In addition the activation and management phases of these plans are discussed.

Each "Project Tornado" is custom designed to match the location where the workshop occurs. A simulated occurrence of a tornadic event is incorporated into the workbooks, and participants have to deal with this form of natural disaster as if it were occurring within their jurisdiction on a "real time" basis.

Further information and sample workshop materials are available through the Canadian National Committee for IDNDR.

Using Climate Information for Safety, Design and Structural Integrity of Buildings

Climate information is used for the safe design of structures and commercial and industrial operations such as off shore oil and gas exploration. Environment Canada is engaged in the development and provision of this climate information. In some cases, the information is developed for incorporation into building and engineering design codes; in others, the information is published as scientific information for applications for which codes and standards do not exist, so as to be available to the appropriate authorities to ensure safe and effective design and operations.

Building Codes: Environment Canada provides climatic design information for use in building and engineering design codes to ensure the structural integrity of buildings and other structures with respect to extreme loads and forces due to weather.

For the design of buildings, 30-year return period values of ground snow loads and wind pressure are provided for about 640 Canadian locations in the 1990 Supplement to the National Building Code of Canada (NBCC). Environment Canada also provides recommendations for locations not listed in the NBCC Supplement. Most provinces and municipalities adopt the provisions of the NBCC, which is a model code. The NBCC uses the 30-year return period values of ground snow load and wind pressure, along with appropriate values of the load (or safety) factor and sound engineering practices, with the intent of ensuring that the risk of structural failure due to extreme snow or wind loads is equal and minimized for all parts of Canada.

Snow loads for the 1990 NBCC were updated in 1987 using the lastest observations of snow on the ground from about 1,600 Canadian locations. Wind pressures are currently being updated for the 1995 NBCC based on an analysis of hourly wind speed of about 200 wind observing sites.

Wind pressures in the NBCC do not include the extremes due to tornadoes, which are infrequent at any single location, but can provide wind pressure loads far in excess of those prescribed by the design wind pressures. The most severe tornadoes normally occurring in Canada, F4 on the well-known Fujita scale, can cause disasters with significant loss of life and property damage, as borne witness by the Barrie and Edmonton tornadoes in the 1980s. Since tornadoes are so infrequent at any single location, and the associated conditions so extreme, most codes do not explicitly require structures be designed to withstand tornadoes. Recent tornado disasters, however, have highlighted the vulnerability of certain structures to tornadoes and the increased risk of loss of life and serious injuries. Recent changes in the NBCC and various Canadian Standards Association (CSA) standards will require considerably more robust requirements for normal home floors and roofs, and for other structures such as mobile homes. Work currently underway in Environment Canada will determine the tornado-prone regions of Canada in which the more robust anchoring procedures will be required.

Other Engineering Standards: Environment Canada provides climatic design information, often in a form related to or consistent with the NBCC. Design wind and ice amounts are provided for use in standards for antenna towers and overhead systems (overhead telecommunications and electrical transmission lines). Both of these standards are currently being updated with 30 and 50-year return period values of wind and ice amounts, respectively. Similar information will be provided to the new CSA highway and bridge standard.

Hydrological Disaster Mitigation: Major hydroelectric and multi-purpose dams provide both protection from floods and a threat of flooding should they fail. The design, construction and safety review of these structures are determined by information on the quantity of water, from rainfall and snowmelt, that can be expected in the drainage basin controlled by the dam. Through coordination with engineering associations and the provision of archived data, publications, consultations, reviews and partnership studies, AES ensures that high quality meteorological information is used to make the important safety decisions concerning major hydrological structures across the country.

Green Plan Initiatives – Impact on Canadian Emergency Preparedness

A continuing Canadian government initiative of considerable significance in the emergencies field is the *Green Plan* presented by Environment Canada in 1990. Three of the many components of the Plan announced to date: Marine Pollution Emergencies; Land, Fresh Water and Air Pollution Emergencies; and Natural Hazards Prediction and Warning, bear importantly on enhancing the national capability for responding quickly and effectively to these specific classes of environmental disaster.

Canadians are familiar with threats to the environment and to public health when there is an oil spill, a chemical spill, a fire in a building containing hazardous material, or a severe weather event such as flooding or a tornado.

The *Green Plan* responds to both types of emergencies: those created by human activity and those created by Nature. The Plan states that, "The Government of Canada plans to upgrade its ability to provide more timely and effective warnings of natural hazards such as blizzards, tornadoes, and marine storms." These hazards are themselves often linked to pollution emergencies. The *Green Plan* provides the following actions :

- improved techniques for understanding and detecting natural hazards
- better communications
- enhanced public education about the impacts of severe weather.

The Marine Spills Prevention and Response part of the *Green Plan* has brought needed equipment and trained personnel to many areas of Canada vulnerable to oil and chemical spills. The Coast Guard has increased marine navigational support and aerial surveillance activity on the east and west coasts and the St. Lawrence River. As well, inspections of foreign vessels visiting Canada have risen to 38%, from 16% in 1991 and 8% in 1990, to ensure compliance with Canadian law. (The international minimum standard is 25%.)

National and regional contingency plans in the event of an oil spill are being developed. All Coast Guard icebreakers now carry spill response equipment. In the Arctic, pollution countermeasures equipment has been stationed at Iqaluit. Training of volunteers has also been increased under the *Green Plan.* Discussions are under way with Inuit groups on community involvement in responding to a spill. In Placentia Bay, Newfoundland, 760 fishermen have been trained to use the spill response equipment placed there.

Land-based spills have not been ignored. Research and training in prevention and response techniques have been increased. The Major Industrial Accidents Council of Canada (MIACC) is developing guidelines for spill prevention, emergency preparedness, public education, and contingency planning standards and guidelines. In the area of spill response, Environment Canada's Environmental Technology Centre in Ottawa purchased two truck chassis and converted them into specialized spill-response vehicles. As well, the Centre's prototype mobile analytical laboratory has been upgraded to allow analysis of a wider range of toxic compounds. This analytical equipment was used at the Oakville, Manitoba, chemical train derailment to verify that homes, businesses and feedlots were safe before evacuees were permitted to return to the town.

HYDROLOGICAL HAZARDS

The National Flood Damage Reduction Program

Flooding is the number one natural disaster in terms of property damage in the country. Countless citizens have experienced the impact of flooding, whether it be cleaning up their basements or surviving a major disaster such as hurricane Hazel. Those living along the Saint John River in New Brunswick, by the St. Lawrence or on the shores of the Mackenzie in the North know the hazards of ice jam flooding. Many with homes and cottages along the shores of major lakes, such as the Great Lakes, or along Canada's coasts can tell stories of flooding, property damage and death. During springmelt, heavy runoff called "freshet" floods many areas. And anywhere, anytime, a sudden intense rainfall can cause a flash flood.

Flooding is both feared as a natural disaster and valued as an integral part of the ecosystem. It is by inhabiting the floodplain that people become vulnerable to property damage, social and economic disruption, and loss of life. The best long-term and sustainable solution is prevention, which can be achieved by discouraging development in flood-prone areas. This is the guiding principle of Canada's Flood Damage Reduction (FDR) Program, established in 1975. The key objectives of the Program are to prevent flood-related loss of life, to reduce future flood damages and decrease federal (and provincial) disaster assistance payments.

The prime reason for the Flood Damage Reduction Program (FDRP) was the escalation in flood disaster payments by the federal government in the early 1970s. Traditionally, structural works (dams and dikes) were widely used for flood control, most of which were publicly financed. Structural works often create a false sense of security and even new development could be encouraged in their "protected" areas, resulting in further flood damages and extra disaster payments. From 1970 to 1988, about $250 million (approximately $465 million in 1992 dollars), or about 75% of all natural disaster assistance, has been paid by the federal and provincial/territorial governments to victims of major flood events which qualified for cost sharing under the federal Disaster Financial Assistance arrangements. This figure represents only a fraction of the true costs borne by individuals, businesses and industry, and provincial and municipal treasuries.

The National Flood Damage Reduction Program, therefore, promotes non-structural means of flood control, i.e. through mapping and designation, as opposed to construction of dams and dikes.

Provincial governments agreed that the first step was to stop encouraging or assisting flood-prone development within the floodplain. This would mean joint federal-provincial cooperation in identifying areas prone to flooding, mapping those with the highest development and therefore damage potential, and making this information available to the public. The governments would then designate them as flood-risk areas and stop supporting flood-prone development there. The flood-risk area designation process and public information program are crucial to the success of the program.

Established in 1975, the FDRP operates under a series of federal-provincial-territorial cost-sharing agreements. All the provinces (except Prince Edward Island, which does not experience riverine flooding) and the Northwest Territories participate in the Program. At present, there is no agreement with the Yukon Territory. Program responsibility in each of the provinces/territories is delegated to four Steering Committee members by Ministerial appointment: two federal (Environment Canada), and two provincial-territorial.

For each designated area, the two levels of government agree to the following policies:

1) They will not build, approve or finance flood-prone development in the designated flood-risk area.

2) They will not provide flood disaster assistance for any development built after an area becomes designated (except for floodproofed development in the flood fringe).

3) The provinces will encourage local authorities to zone on the basis of flood risk.

Although the Flood Damage Reduction Program represented a new approach to reducing flood damage for many governments, the provinces of British Columbia, Alberta, and Ontario had had similar programs for some time. Their experience provided significant impetus to the national program, which took the important step of building public support through the dissemination of high-quality information maps and through the involvement of the local community.

Federal-Provincial-Territorial Agreements. The FDRP is funded from Grants and Contributions allocations provided through the terms and conditions of cost-shared federal-provincial/territorial agreements signed pursuant to the *Canada Water Act*. Federal-provincial/territorial agreements on FDRP take various forms. Normally, a General Agreement outlining the policies of the program is supplemented by a separate agreement on mapping, with further sub-agreements, in some cases, on flood forecasting, structural controls, and other related studies. The agreements with Quebec, Ontario, Alberta, and British Columbia, combine the policy provisions (otherwise in a General Agreement) and the mapping/study provisions into a single agreement.

Since 1970, federal financial participation in disaster assistance arrangements has been determined by a "dollar-per-capita" formula. The first dollar per capita of damages is a provincial-territorial responsibility. Damages beyond that threshold level are eligible for federal assistance with the federal proportion rising with the damage, as illustrated in the table below.

The "Dollar-Per-Capita" Formula for Federal Cost Sharing

Provincial Expenditures Per Capita Eligible for Sharing	Federal Share (%)
First dollar	0
Second and third dollars	50
Fourth and fifth dollars	75
and for the excess	90

The total financial commitment for flood-risk mapping under the FDRP from 1975 to the present is $52 million ($26 million federal share) in current dollars. The total number of designations of flood-risk areas reached over 250 by the end of 1992 covering more than 600 communities with more than 7 million inhabitants, and involving approximately about 200,000 ha of flood plains.

Expenditures on flood forecasting under the program sub-agreements have been about $3 million. These activities complement the mapping program by helping provinces in establishing a flood forecasting system with joint technology development and transfer.

Although structural controls are not promoted under the program, some structural works have been supported, particularly in the Montreal and Quebec City areas of Quebec, the Red River Valley communities within Manitoba, and some communities in New Brunswick. For the structural works, the federal and provincial governments usually each share 45% of the total costs, with the remainder being financed by the beneficiary municipality. Expenditures for structural controls have totalled about $40 million under the Program.

The FDRP mapping objectives have largely been met in most of provinces and is currently undergoing a program transition from an active mapping phase to a "maintenance" phase. Under the "maintenance" phase, the FDRP policies and public information programs are kept in place and the maps are updated periodically.

Canada's National Flood Damage Program has been successful, under joint efforts of federal, provincial and local governments, and will continue to be successful, through ongoing maintenance phase activities, in reducing flood damages by non-structural means such as flood forecasting and warning, acquisition of flood-prone lands, floodproofing, and studies, research or surveys related to flood problems.

Several Canadian consulting companies are now actively working on major flood protection projects, either for that purpose alone, or as a part of large multipurpose energy and irrigation projects. Several of these projects are funded by provincial agencies within Canada and by the federal government through the Canadian International Development Agency. *(For details on "flood forecasting and warning," please refer to Chapter IV on Warning.)*

Evaluation of the FDR Program. After 15 years, a comprehensive review of the Program was initiated. An early element of this review took the form of a workshop of federal officials involved in the Program. The principal conclusions of this workshop are that :

- The FDRP has been singularly effective in redirecting damage-prone development away from flood-risk areas, and is a model of federal-provincial cooperation in developing public support and initiating a long-term policy of discouraging such development.

- The policies of the FDRP need to be maintained in perpetuity.

- This policy maintenance should be accomplished through long-term, federal-provincial commitment through FDRP continuance agreements.

Over most of Canada, flood-risk maps have been used effectively to serve their intended purposes of information and as a tool in preventing flood-prone development and redevelopment. In addition, there are many examples of other uses: planning redevelopment, emergency preparedness planning, ecosystem analysis, identification and protection of source areas for ground water supplies, etc.

Tsunamis

Recent tsunamis in Nicaragua, Indonesia, and Japan have heightened public awareness of earthquakes and the tsunamis which they can produce. In Canada, tsunamis are mostly a problem on the Pacific coast although they have occurred in the eastern parts also. At present a tsunami warning service exists, for the coast of British Columbia, under the responsibility of the Department of Fisheries and Oceans as part of an international system coordinated by UNESCO. However, this system will not respond to local tsunamis on the British Columbia coast from local submarine landslides. In these instances, public education provides the best means of reducing the loss of life.

Drought

There are a variety of mitigation strategies for dealing with drought. Producers, municipalities, industry and governments coordinate their efforts to focus on the appropriate mix of long and short-term strategies that best suit the industries, regions, individuals and the characteristics of the land base. Drought mitigation demands flexibility. For example, the management of one field may be quite different from another due to soil texture, topography and microclimate. Water resource options also vary. The diversity of farm operations and the diversity of regions require diverse approaches to drought mitigation.

Table 2 lists some mitigation strategies employed on the Prairies. Some strategies are short-term responsive strategies and others are long-term preparational strategies. Some strategies are single-party endeavors and others include support from one or more levels of government or other players. Many of the measures listed have been researched, tried and tested with support from governments, universities and producer groups. The Government of Canada has been involved in drought mitigation programming since the Prairie Farm Rehabilitation Act of 1935 was put in place to provide support for the rehabilitation of the drought and soil drifting areas of Manitoba, Saskatchewan and Alberta and to promote within these areas, systems of farm practice, tree culture and water supply that will afford greater economic security.

PFRA's (Prairie Farm Rehabilitation Administration) mission today is to work with Prairie people to build a viable agricultural industry and to support a sound rural economy, healthy environment and a high quality of life upon which agriculture depends. PFRA provides technical and financial asssistance for rural water supply development and multi-use reservoir projects and has been supportive in a wide range of community water infrastructure programs and projects for rural service centres. Irrigation based research and economic development have long been supported. PFRA promotes soil conservation, provides awareness, plans and delivers services and programs in Western Canada in partnership with the provinces. Community pasture and breeding services are provided for pasture patrons on reclaimed lands that were badly eroded and abandoned during the drought of the 1930s. The Shelterbelt Centre does research on tree species

TABLE 2	MITIGATION STRATEGIES
FARM LEVEL STRATEGIES	
Seed drought tolerant plant varieties	
Diversification (ie. mix of crops and livestock)	
Soil testing for moisture and fertilizer requirements	
Flexible cropping	
Early seeding to maximize moisture	
Minimum or zero tillage (use grass strips to trap snow)	
Plant and maintain tree shelterbelts	
Seed into moisture, but not exceed maximum recommended depth	
Efficient herbicide use to reduce weed competition	
Bale straw for forage	
Plant greenfeed crops (ie. oats and barley)	
Cull open cows	
Graze stubble	
Pasture cereals	
Purchase hay	
Maintain 50% carry-over on pasture	
Maintain a one year supply of feed in storage	
Feed straw, grain and supplements	
Test for nitrate levels in field crops before grazing	
Truck cattle to areas with forage and water	
Small scale irrigation	
Drought proof water supplies (i.e. deep wells)	
Design and locate dugouts to maximize potential recharge	
Dugout pumping (provincial and PFRA pumps and pipe for rent)	
Install dugout covers (under research)	
REGIONAL LEVEL STRATEGIES-government funding and technical services are provided	
Multi-use reservoirs (municipal and large scale irrigation)	
Regional multi-user pipelines	
Tank loading facilities for water haulers	

and annually provides some 7.5 million seedlings to farmers. On behalf of the Government of Canada, PFRA has delivered ad hoc financial assistance during some of the severe droughts of the 1980s.

There are a number of other government supported programs designed to provide a line of defence against drought. Crop insurance is the main vehicle providing protection against yield losses from a number of natural hazards including drought. This is a tripartite program with costs shared between producers, and provincial and federal governments.

Community pastures are owned and operated by provincial governments. Research and development of drought tolerance in crops is carried out at Agriculture Canada research stations and universities. Tax deferral for drought-induced sales of breeding livestock is offered during severe droughts to help producers maintain ready cash to replenish their herds when better weather returns.

Traditional safety-net programs become stressed during multi-year droughts and ad hoc injections of cash have been required to help satisfy the financial needs of the farming industry.

GEOLOGICAL HAZARDS

Building Codes and Natural Disasters

Building failure is a primary cause of natural disaster due to earthquakes, severe winds storms and other hazards. Such building failures can affect homes, hospitals, schools, public buildings, offices, hotels and industrial buildings, as well as communication facilities, bridges and utilities. Many of these structures are critical to reducing the impact of a disaster and assisting in recovery. Disaster follows directly from the death, damage and dislocation caused by these failures.

Reductions of the vulnerability of structures to these natural hazards is a primary objective of building codes and other design standards for other types of structures such as communication and transmission towers, bridges and utilities. While codes and standards primarily affect only new construction, they have the effect of raising standards generally and awareness of the need for maintenance of existing structures. The latter is a special need in reducing vulnerability, and one that is more difficult to address, but it is now being assessed more carefully.

The essential components of building codes and design standards include the following:

- a definition of the natural hazards which the structure and its foundations should be designed and built to withstand

- the specification of the risk levels, magnitudes of the loads and effects from the hazard

- the structural resistances and analysis procedures that shall be provided

- the qualifications required by the persons undertaking the design and approval of the completed structure and services

- the requirements for inspection of the structure.

In Canada, the key document controlling the hazard resistance of structures is the National Building Code of Canada (NBCC). This is a model building code issued by the National Research Council of Canada and prepared by a special division of the Institute for Research in Construction which acts as the secretariat. This body also issues the National Fire Code for buildings.

By itself this document has no direct authority to control the standards of construction, which is a provincial jurisdiction. Consequently, each province has provided legislation establishing provincial building codes. These provincial building codes almost exclusively follow the NBCC, thus providing an unusually high degree of uniformity of building standards across Canada, particularly with respect to the technical content.

The administration of the provincial building codes is delegated, for the most part, to the municipalities. They normally have building departments, which issue building permits, provide inspection, approve plans and ensure conformity with the codes.

Development of the technical content of the codes -- more specifically the NBCC -- is under the NRC Associate Committee for the NBCC. The structural requirements of the code are reviewed and approved by the Standing Committee on Structural Design. This Committee comprises technical experts drawn broadly from across Canada. They provide the expertise in concrete, steel, wood, masonry, glass and other materials, as well as experts familiar with the load effects due to earthquakes, wind, snow and other structural actions. The Standing Committee on Structural Design is, in turn, supported by special advisory committees such as the Canadian National Committee for Earthquake Engineering. The actions of wind and snow are supported by ad hoc committees. The detailed design treatment of the structural resistances and material performance is provided by separate standards for the various construction materials issued by several standard-writing bodies. Cross representation of the various committees ensures uniformity and consistency in approach and treatment.

Other standards supporting the NBCC are in many cases prepared by the industry-based Canadian Standards Association (CSA) or the government-based Canadian Government Standards Board (CGSB).

The technical development of the risks and the magnitudes of the effects of natural hazards earthquake, severe wind storm and other natural hazards is highly relevant to the problem of disaster reduction.

In Canada, there is generally a high level of expertise in these areas. The supplements to the NBCC contain detailed risk maps for seismicity, wind speed, snow temperature and other geophysical hazards.

The initial seismic risk maps in Canada were the first statistically based documents. Current maps are prepared by Natural Resources Canada. The areas of greatest risk are the West Coast (the major cities affected are Vancouver and Victoria); the St. Lawrence region (including Montreal, Quebec and Ottawa); the east coast region and the Arctic. Technical expertise in earthquake engineering exists within many consulting companies and University engineering departments across Canada. Shaking tables for investigating the response of structures are available at University of British Columbia and McMaster Universities.

Wind risk maps and tables have been prepared by the Atmospheric Environment Service of Environment Canada, which present hourly average wind velocity pressures in open country at 10 m height above ground. These are given for return periods of 10, 30 and 100 years. While such data reflect the influence primarily of large-scale storm systems, they do not adequately reflect the risk of tornado, violent downbursts, and thunderstorms. Wind storm risk needs to be further evaluated and represents a potential area of research.

Canada is well equipped with wind tunnel facilities for evaluating the dynamic response of turbulent wind on buildings and other structures and these wind tunnels are situated in government, university and private sector laboratories. The Canadian wind loading code has been adopted widely in other countries and is the basis of much of the International Standards Organization wind-loading requirements.

Other loads such as snow and ice, also referred to in codes and standards, can cause extensive dislocation in severe blizzards.

Earthquakes

Canada has had seismic loading provisions in the National Building Code since the first edition in 1941, initially as an appendix based on concepts presented in an early United States code, and later based on increasingly improved national seismic zoning maps in 1953, 1970 and 1985. These zoning maps are based on seismic hazard assessments undertaken by the Geological Survey of Canada (GSC), and agreed to within the Canadian National Committee on Earthquake Engineering, which advises the Canadian Commission on Fire and Building Codes. Although the Code and its associated seismic zonation is developed as a national model, jurisdiction rests with the provinces and is often delegated to the larger cities. The philosophy of the earthquake provisions of the

Code is to design and construct buildings to prevent loss of life due to building collapse, although significant economic losses may occur as a result of earthquake shaking.

The National Building Code officially applies to common buildings, but not to other structures and facilities such as bridges and dams. Construction of many of these other kinds of structures does, however, make use of the seismic zoning maps that appear in the Code. In essence, these zoning maps provide a national reference framework on seismic hazards for a wide variety of purposes. Critical facilities, those that would produce significantly greater damage in the surrounding area should they fail due to earthquake loading, are treated separately. Nuclear power stations, liquefied natural gas storage and offshore petroleum production facilities are all covered by special seismic qualification guidelines developed by the Canadian Standards Association.

The GSC is responsible for earthquake monitoring and rapid earthquake information services. As part of this role, the GSC provides timely information on the locations and magnitudes of the larger events to federal and provincial emergency preparedness agencies, public utility companies, police forces, etc., so that these agencies can respond rapidly to potential damage. General earthquake preparedness and planning in Canada is coordinated by Emergency Preparedness Canada in cooperation with the provincial emergency measures organizations. These efforts have recently produced a federal, national plan to deal with a catastrophic earthquake in southwestern British Columbia. In Canada, the GSC is cooperating with other federal and provincial agencies and interested individuals in a research effort to improve the assessment of seismic hazard at low levels of probability, and to understand the influence of neotectonism on earthquake occurrence. The GSC routinely assists provincial and municipal agencies with local earthquake education services, preparedness and planning.

Within Canada considerable attention has been paid to the earthquake-resistant design of normal residential and multi-storey buildings, critical industrial facilities, power plants and dams. As a matter of routine design of major international projects in some of the most seismically active areas of the world, such as Nepal, Iran or Papua New Guinea, Canadian consultants carry out state-of-the-art hazard assessments, design, and training of local engineers.

The geotechnical engineering consulting community in Canada has developed one of the strongest international reputations covering an extremely wide range of geological conditions and soil types as a result of its participation in the design of major Canadian and international development projects in the fields of transportation, marine structures, mining and energy projects. Several organizations have made detailed investigations of major landslides and have developed specialized instrumentation for monitoring movements and pressures which have considerable worldwide application. In addition, the analysis of slope stability, both in the short and long term, and the design of protective measures for slope protection are major areas of Canadian expertise.

Landslides

Canada has developed substantial world-class expertise in landslide hazard mitigation strategies. The techniques in use include slope stabilisation, defensive works, land use zoning, and warning systems (*see Chapter IV*).

B.C. Hydro has successfully stabilized several large-scale mountainslope movements in the vicinity of its hydroelectric generation facilities in the southern Cordillera. These engineering achievements have made B.C. Hydro world leaders in this area of landslide hazard mitigation. At the Downie Slide, Dutchman's Ridge, and Wahleach sites, tens of millions of dollars have been spent on large-scale mitigation measures such as drainage adits, the implementation of which have led to the reduction of slope movements at the sites. Canadian engineers have also developed considerable expertise in the design and construction of defensive structures to protect communities and transportation routes against debris flows. For example, at Lion's Bay, British Columbia, debris check dams were built at a cost of several millions of dollars to protect homes and the community.

In Eastern Canada, attempts have been made to reduce the consequences of landslides in marine clays of the former Champlain Sea, through mapping of landslide occurrences, geotechnical investigations at vulnerable sites, and landuse zoning. For example, studies by the South Nation River Conservation Authority, at the former village of Lemieux, beside the South Nation River, Ontario, in the 1980's, led to the removal of the village just three years before a major slide on June 20, 1993.

Canada has also taken a lead in developing research tools, such as kinematic models of landslide behaviour, to permit the prediction of landslide behaviour on a site-specific basis. Such models are key to landslide mitigation strategies, since they predict such variables as travel distance, volume, and velocity, which are important parameters in engineering design and land-use decisions. Recent advances in this field include the development of predictive models for small- scale rockfalls and larger scale catastrophic rock avalanche behaviour.

Volcanic Eruptions

The GSC has the expertise and ability to monitor volcanoes and forecast or predict eruptions, but considerable effort would be needed to marshall these resources. Since the likelihood of an eruption in Canada is low, few resources of money and time are devoted to the study of active volcanoes. The GSC is the only source of such expertise within any level of government in Canada, however, and is therefore regarded as a source of information on volcanic hazards, whether or not they occur in Canada. A particular, current concern is the effect of airborne clouds of volcanic ash from distant volcanoes on aircraft operations in Canadian airspace. The GSC presently works with other government agencies, especially those with regulatory and land management responsibilities, to coordinate issuance of warnings of volcanic events. At present the main focus of this group is on the potential effects for aviation safety and on communities located downwind from the volcanoes of the Aleutian arc, Alaska.

Snow Avalanches

Avalanche control in Canada consists of both active and passive measures, including (1) closure of roads, railways and ski runs during hazardous times, (2) avalanche release by artillery and hand charges, (3) control structures to slow, stop or deflect avalanches, and (4) zoning measures based on avoidance by placing structures, facilities and communication lines outside hazardous zones. A strong avalanche education program is also maintained in Western Canada for avalanche safety personnel and skiers.

Forecasting avalanches for traffic and roads, railways and ski runs, and the release of avalanches by explosives are the most important operational avalanche safety measures in Canada. In Western Canada, 42 public roads, 25 forest and mining roads and all major railways are exposed to snow avalanches. In addition, 47 ski operators have avalanche hazards requiring control measures or continuous evaluation of avalanche hazards.

Industries and governments spend about $10 million per year on avalanche safety. In addition, closures of major transportation networks represents a large cost to Canada and a potentially serious situation from an emergency preparedness perspective. Lengthy closures resulting from imprecise control methods and uncertainty in forecasting avalanches exert extreme pressure on agencies charged with avalanche safety, which has resulted in a new emphasis on research into avalanche forecasting methods, now under way at the University of British Columbia.

The equipment and methods for explosive control in Canada comprise hand placed charges, the most popular method, and artillery. It is believed that the forecasting and explosive control system operated by the Canadian Park Service at Rogers Pass, British Columbia, is the largest of its kind in the world on a major transportation route, covering 134 avalanche paths over 44 km of highway. The British Columbia Ministry of Transportation and Highways operates nine major avalanche-control crews on problem highways. The effectiveness of avalanche-control on transportation systems is demonstrated by the near elimination of deaths on transportation corridors.

Due to the low population density in mountainous Western Canada, the emphasis on structural control of avalanches is virtually all in the runout zone. This contrasts with European alpine countries, where structural control can be aimed at preventing avalanches in the starting zone because villages are often threatened. Similarly, reforestation is seldom used in Canada in snow avalanche terrain: a further difference from European conditions.

In Canada, the emphasis is usually on placement of barriers or deflectors to slow, stop or deflect avalanches and so reduce their destructive effects in the runout zone. During 1980-1989, land-use restrictions and protective works construction was carried out on 28 avalanche paths in Canada at an estimated cost of $225 million; feasibility studies were carried out on an additional 70 paths. For buildings and major highways, structural control measures are usually regarded as a secondary means of protection, with avoidance by location the preferred choice. In the case of railways and electric transmission lines, however, the locations can be less flexible, so that snow sheds and earth splitting wedges are preferred for these two options respectively.

Low population density in the largely wilderness areas of Western Canada has resulted in avalanche zoning and land-use planning having a different character from that in Europe. Nevertheless, location of facilities and transportation routes remains an important element of avalanche control. Ideally, land-use planning in snow avalanche terrain involves specification of expected return periods and impact pressures at a given location, should structures or defences be contemplated. In general, the expected impact pressure and return period decrease and increase respectively as distance downslope into the runout zone increases.

In Canada, the planning constraints commonly faced are (1) lack of return period information, except at the extreme boundaries of the avalanche path; and (2) runout position known only for the extreme boundary of the path, or if unknown, quantifiable only if maximum runout positions are known for 30 or more paths for the mountain range in question. Methods of land-use planning based on these constraints are now being developed which focus on prediction of extreme runout for a mountain range. This empirical method is now replacing runout predictions based upon selection of friction coefficients in avalanche dynamics models.

Meteorite Impacts

No systems or procedures are presently in place in Canada specifically for mitigating the effects of a meteorite strike. Routine minor impacts of small meteorites have a minimal effect on most occasions. A truly major impact, such as that associated with the K-T event, are unmitigable, given the levels of energy involved. Mitigation of a moderate size impact may be possible, provided sufficient warning could be given. Forecasting such an event would be the responsibility of the astronomical and global physics science communities, issuance of a formal warning and evacuation plan would fall to the government emergency measures organization.

BIOLOGICAL HAZARDS

Wildfires

In Canada, wildland fire suppression is the responsibility of provincial agencies. Because large fires have the potential to devastate communities, local forest industries, and high-value recreation sites, these areas receive the most vigorous protection. Furthermore, because large fires generate the energy equivalent of a small nuclear explosion every 30 minutes, they are essentially unstoppable. Therefore, the focus of fire control is aggressive initial attack to prevent a fire from becoming large. Provincial agencies know how to suppress forest fires and do so effectively; more than 90% of all fires are controlled at less than 10 ha in size.

Every provincial agency is organized to attack most fires within minutes of detection and to rapidly expand to a temporary large-fire suppression structure. In Canada, there is a heavy reliance on aircraft, portable equipment, high technology, and sophisticated management systems to optimize the use of limited resources to protect a very large land base of more than 900,000 km^2. When the demand for resources exceeds the capabilities of an individual province, the Canadian Interagency Forest Fire Centre facilitates the transfer of resources across the country.

In Canada, we can neither exclude wildland fire, nor can we allow it to run its natural course. This leads to major socio-economic challenges. There are no generally accepted methods for: (1) determining appropriate levels of fire management (2) assessing values at risk, and (3) optimizing the cost effectiveness of a fire management organization.

There are also major ecological and environmental challenges. Methods must be developed to: (1) support the extremely complex decision to observe or suppress a fire (2) allow fire to play a more natural role in Canadian forests, and (3) determine the effects of a changing climate on wildland fire in Canada. Effective fire management in the next century will require significantly increased knowledge in all of these areas.

TRAINING AND AWARENESS PROGRAMS

TRAINING

The federal government, through Emergency Preparedness Canada, has taken the lead in training candidates from provincial and municipal governments in aspects of emergency planning and response at the Canadian Emergency Preparedness College in Arnprior, Ontario. The courses are designed to teach participants about their responsibilities for the development and implementation of plans to meet emergencies. There are 60 emergencies for which the officials are trained. Introductory courses provide participants with a broad base from which they will be able to carry out planning and operations during an emergency or disaster. In the more advanced courses, disaster situations are simulated and students experience conditions where they have to make life-threatening decisions.

The Alberta Public Safety Services Training School (at Edmonton) is also a valuable resource for anyone involved with disaster preparedness and response. Together with the Emergency Preparedness Canada College at Arnprior, the schools are the only specially designated facilities in Canada. Examples of the training courses given by the Alberta School are :

- Emergency Planning for Elected Officials of Municipalities, First Nations, Metis Settlements
- Emergency Preparedness and the School System
- Emergency Site Management, Emergency Public Information Officers, Exercise Design, Casualty Simulation, Disaster Health and Social Services
- Response Training - Basic Rescue, Rescue Leader, Basic Ice Rescue, Dangerous Goods Incident Response/First Responder, Dangerous Goods Second Responder
- Compliance Training - On-Highways Inspectors, Dangerous Goods Carriers and Shippers
- Emerging Issues in Emergency Preparedness
- Prehospital care is a vital part of the emergency response system. Training programs are provided for paramedics and emergency medical technicians.

The Alberta Public Safety Services Training School was developed in support of Alberta legislation that requires each municipality to develop an emergency response plan for disasters.

Periodically, the federal government co-sponsors conferences for professionals in the field of emergency preparedness. Recent examples include the Major Industrial Accident Coordinating Council of Canada "Emergency Response '93" Conference in New Brunswick, the "Emergency Response Symposium 1993" in Newfoundland; and the Sixth Annual Emergency Preparedness Conference held in Vancouver, British Columbia.

Exercise CANATEX 2, the second in the series of Canadian National Exercises, was conducted over a two-week period in May 1994, on the theme of a catastrophic earthquake occurring in British Columbia. Participants included 21 federal departments,

- media and emergency communications studies at Carleton university.

The IDNDR provides a conduit for channelling these skills and resources into practical applications.

B. RESEARCH ISSUES

METEORLOGICAL HAZARDS

Hail Suppression Activities in Alberta

Hailstorms have been seeded to suppress the formation of hail in a number of countries around the world since the 1950s. In Canada, the Government of Alberta funded a hail suppression research project from 1956 to 1986. Assessments of these hail suppression programs have been extremely difficult due to the variability of hailstorms and hail damage. Nonetheless, the Canadian property and casualty insurance industry's losses grew significantly following the cancellation of the Alberta program. For the period 1982 through 1986, homeowners' policies in Alberta generated $347 million in premiums and $258 million in claims. For the period of 1987 through 1991, premiums earned were $419 million compared to claims of $577 million. Of this $577 million, close to 50% was related to wind and hail damage. Efforts are currently under way to resume a hail suppression program in Alberta.

HYDROLOGICAL HAZARDS

Flood Damage Reduction Program

Provincial-territorial emergency measures organizations have been directly involved in the federally sponsored Flood Damage Reduction Program (FDRP) because of the potential to limit the damage resulting from flooding and to reduce the costs to government. While the FDRP has been successful in identifying areas subject to periodic or regular flooding, there is no method to control or restrict activities on flood plains since it is not possible, for legal reasons, to ensure that current and future owners of property located on flood plains are warned of the risk. The lack of a mechanism to ensure this information has been provided potentially leaves governments open to considerable financial liability. Among possible cost-effective ways of addressing this problem, it was suggested that a form of subsidized flood insurance could be developed in consultation with the insurance industry to provide relatively low cost insurance to individuals and owners while reducing the financial exposure of governments to the risk of flood damage.

By initiating the national FDRP, the federal government took on a leadership role in developing a national program which was to prove extremely successful. The need for federal leadership is greater now than at any time since the initiation of the Program. Once the mapping specifications were set and budgets allocated, implementation of the mapping program was a management function. Now, with the initial mapping mostly completed and the concept of non-structural solutions widely accepted, there is a need for leadership in designing a maintenance and/or continuance phase. It is somewhat ironic that in this time of need, there is talk of federal phasing out.

Tsunamis and Storm Surges

In Canada, tsunamis are mostly a problem on the Pacific coast although they have occurred in the eastern parts also. On the other hand, storm surges are mostly a problem in Eastern Canada and in the North, and is less of a problem on the west coast. Real-time warning systems for tsunamis and storm surges for all vulnerable areas must be developed and put into operational practice. At present a tsunami warning service exists for the coast of British Columbia, as part of an international system coordinated by UNESCO. However, this system will *not* respond to local tsunamis on the British Columbia coast from local submarine landslides.

There is no storm surge warning service in place in Canada at this time in the same sense as it exists in many other countries like the United States, Japan, the United Kingdom, and Germany. The Canadian Atmospheric Environment Service will provide storm warning and indeed may give some indication of the storm surge. This service needs to be developed further.

GEOLOGICAL HAZARDS

Earthquakes

The principal issues related to earthquake hazard assessment in Canada are the research challenges associated with developing an adequate understanding of earthquake potential and earthquake effects, so as to provide accurate estimates of seismic hazards. The challenges comprise those associated with delineating earthquake source zones within the rifted North American craton, including developing an understanding of the linkage between structural geology and seismicity in source zone definition, and establishing an adequate understanding of the excitation and propagation of strong ground motion in Eastern Canada. A significant research challenge in the West will be to develop an adequate understanding of the Cascadia subduction zone and the shaking hazard that would be produced by a large subduction earthquake. In both Eastern and Western Canada, long profiles of deep seismic reflection surveys (LITHOPROBE), undertaken jointly with industry, are providing data on the crust and its structural defects which will contribute to an improved understanding of the links between structure and seismicity.

Most subduction zones around the globe have experienced giant earthquakes during historical times, but none has occurred on the Cascadia subduction margin from southern British Columbia to northern California during the 200 years of written history for that region. Good evidence is now available, however, that past large subduction earthquakes have occurred and elastic strain is building up for release in a future event. Evidence for past events has come from buried coastal marshes and deep sea turbidite layers that indicate coastal down-drop and major shaking at irregular intervals averaging about 600 years, the most recent being about 300 years ago. The accumulation of elastic strain has been determined through long-term trends in tide gauge data, repeated levelling and precise positioning surveys. The challenge will be to improve the understanding of past events, to establish as accurately as possible where we are in the earthquake cycle and to estimate the extent and severity of shaking effects should a large earthquake occur. The 1985 seismic zoning maps do not include the shaking effects of a Cascadia subduction earthquake.

Landslides

The Canadian landslide research community faces a number of research challenges in its efforts to improve on the assessment of landslide hazard. Key research areas include:

- *Magnitude and Frequency Estimates*. Work has begun on developing a universal magnitude and frequency relation for landslide occurrence in time. If the development of this relation is successful it will allow a more precise definition of landslide risk.

- *Understanding Spatial Behaviour*. As more landslide mapping is undertaken, the causative links between landslide distribution and geological, hydrogeological and geotechnical factors, are becoming an important area of research. Understanding these linkages is a major research challenge. If this objective is achieved, the spatial distribution of future landslides may be predicted and areas of high landslide risk will therefore be identifiable.

- *Prediction of Post-failure Behaviour*. Once a slope failure has occurred, it is important to know how far and how fast the landslide mass will travel. As noted earlier, substantial progress has been made on the development of predictive dynamic models for rockfalls and rock avalanches. These need to be refined and similar models are needed for other types of landslides.

- *Development of New Field Techniques*. The possibility of using global positioning systems (GPS) for monitoring slope movements should be explored and developed, particularly with respect to remote, but important localities, or inaccessible mountain slope sites.

- *Public Education.* In landslide mitigation it is important that the public be aware of some of the technical background concerning landslide processes and landslide behaviour. More attempts should be made to educate the public on this issue through outreach programs and popular articles.

Volcanic Eruptions

Many Canadian volcanoes (while presently quiescent) have long histories of activity, spanning millions of years. In some areas these eruptions have alternated between quiet effusion of lava and destructive explosive eruptions. Very little is known of the repose time between eruptions, the eruption mechanism and whether or not there is any systematic variation in eruption types. These questions are fundamental to answering questions on appropriate land use close to a volcano. It is vitally important that Canadian expertise is maintained, and even expanded, so that dialogue between Canadian and American scientists continues in the event of a volcanic crisis in either Washington State or Alaska. Mount Baker, in Washington, just 80 km east of Vancouver, is a likely candidate for an eruption in the near future. Even if this eruption were to be small, it would have a significant impact on the population of British Columbia.

Snow Avalanches

Dissemination of Canadian expertise and knowledge to less developed countries affected by snow avalanches is difficult, due to lack of travel funds and the heavy demand put on the limited number of personnel who deal with the technical aspects of avalanche problems in Canada. One positive aspect of international cooperation has been the strong support shown by foreign institutes and scientists when federal support for avalanche research in Canada was withdrawn in 1991. It seems that people in other countries appreciate Canadian avalanche research and safety programs far more than do Canadians.

Meteorite Impacts

Cratering rate estimates result from the analysis of limited sub-populations of craters from areas where there have been national programs of study, e.g., Canada and the former Soviet Union. Rate estimates, however, have high uncertainties ($\pm$ 50%). These uncertainties can be reduced through systematic programs to identify and date impact craters in these and other areas. Similar systematic efforts are required to establish impactor types and their variation with, for example, size through trace element analyses of impact lithologies. Such basic information is required as input to model calculations of the effects of impact. In addition, impact ejecta has to be better characterized. This area of study has been largely ignored, as impact ejecta are seldom preserved on the geologically active surface of the Earth.

The importance of atmospheric coupling and ejecta in degrading the environment over large areas has been made clear by studies of the K/T event. Recently, a number of cases of preserved ejecta in the stratigraphic column have been discovered. Other occurrences need to be identified and studied. Possibilities in Canada include ejecta from Brent crater in nearby Ordovician carbonates and Sudbury related ejecta in the Gunflint Formation. K/T studies have also highlighted the importance of impact-related seismic and tsunami events. At present, many of the potential effects of impact on the geosphere, hydrosphere, etc., are based on model calculations. Studies are required not just of craters but also of their effects, as recorded in the stratigraphic record, to provide constraints and ground truth for these model calculations.

BIOLOGICAL HAZARDS

Wildfires

In forest protection areas the provincial and territorial governments are responsible for preventing and responding to wildfires. Municipalities are responsible for responding to wildfires and structural fires in their areas. There has been a consistent increase in wildfire threats to rural developments and communities. This increase has impacted the abilities of forest services to respond to wildfire priorities within the protection areas.

In Alberta, the Alberta Forest Service initiated a meeting to give other agencies and stakeholders the opportunity to address concerns associated with wildfire in the wildland/urban interface. This led to the formation of a group called Partners in Protection. The members represent all orders of government, and other key stakeholder associations and organizations. Their mandate is "to increase the level of interagency cooperation aimed at reducing the risk of loss of life and property from fire in the wildland/urban interface area."

TRAINING AND AWARENESS

TRAINING

In 1992 an Implementation Planning Group (IPG) was established with representation from the provincial, territorial and federal governments. The group was charged with preparing a plan to implement the Federal/Provincial Strategy for Training and Education in Emergency Preparedness and Response.

The issue was the requirement in Canada to increase emergency preparedness and response training from 10,000 to 30,000 individuals per year. Meeting the full requirement of 30,000 trained would cost an additional $2.55 million per year using traditional classroom delivery.

The recommended solution was to reduce costs by minimizing reliance on traditional classroom delivery and maximizing use of alternative delivery methods, including electronic. The IPG has also made recommendations on the most rational and economic use of existing resources. The IPG identified the need for standards and a process for their adoption and maintenance, and criteria for assigning responsibility for elements of the plan to either the federal or the provincial and territorial governments.

The strategy is based on a rearrangement of the responsibilities for training between the federal government and the provinces and territories. These new arrangements will promote the development of courses that better meet local needs.

EDUCATION AND PUBLIC AWARENESS

- Public information, awareness and education are important aspects of disaster prevention. This is a continuing challenge in all Canadian jurisdictions.

- The increase in the number of non-English and non-French-speaking people in Canada means many are unable to fully understand the awareness and warning packages available only in Canada's two official languages. These packages need to be developed in other languages and possibly adapted to other cultures and for the print impaired and other persons with disabilities. Some effort should be directed to considering the use of universal signs and symbols.

- The federal government, through Emergency Preparedness Canada has translated a booklet on earthquake preparedness distributed by the federal government, provincial government, the City of Vancouver and the private-sector into Spanish, Cantonese, Vietnamese and Urdu in addition to English and French.

- While much has been done by a wide variety of jurisdictions to involve native communities in emergency preparedness, there is also a continuing requirement to develop a higher level of preparedness appropriate to their circumstances and culture.

- There is also a need in Canada to produce a set of maps displaying the level of risk for each major hazard.

- Many agencies, including associations within the property and casualty insurance industry, have printed brochures on preparing for the emergency period of an earthquake or other major disaster. However, surveys indicate that the majority of households do not prepare for major natural disasters whether through the adoption of insurance or other measures. Even after direct experience with a natural disaster, such as an earthquake, most households continue to avoid taking voluntary protective action. More work needs to be done on assessing the risk-avoidance behaviour of Canadians, as it pertains to low-probability events such as natural hazards, and evaluating the various policy tools available for mitigating the social costs that such behaviour entails.

- An education program, designed at appropriate levels for children and adults, should impart basic knowledge about natural disasters in Canada, the risks involved and also about warning services and protective measures. It would be advisable to emphasize local dangers. For example, the inhabitants of coastal areas would benefit from information and advice on the nature of coastal hazards they are exposed to. In this case, the programme would no doubt give the best results if it is repeated year by year with intensified effort and training exercises.

EMERGENCY PREPAREDNESS IN FAR NORTHERN COMMUNITIES – A SPECIAL CASE

The purpose of the International Decade for Natural Disaster Reduction (IDNDR) is to reduce human and economic losses from natural disaster through prevention and preparedness, and nowhere in Canada is this need more evident than in our far northern communities. While actions are being taken to prepare for future natural hazards, very little effort has been directed to actions designed to prevent disasters.

In Northern Ontario, and across much of sub-arctic Canada, many communities face recurring threats from natural hazards, such as forest fires and floods. Across most of the North, forest fires are an annual hazard that arise in the spring and persist through the hot, dry, summer months, until the fall. In recent years, several First Nation communities have had to be evacuated in successive years. In 1991, the community of Webequie was evacuated twice in the same year, when forest fires approached causing dense smoke to threaten the health of the residents. And, who can forget Manitoba's "Summer of Fire" in 1989?

Other communities on the major northern river systems and along the James Bay and Hudson Bay coast lines are threatened virtually every spring by flooding. Huge ice jams that form on the rivers such as the Albany, Attawapiskat, Liard and Mackenzie create the twin dangers of raging flood waters and ice flows that have the potential to destroy an entire community, and occasionally do. In May 1986, the northern community of Winisk was swept away and two died in the welter of rushing water and ice. Similarly, in 1989 the community of Fort Liard was inundated and Aklavik being in the delta of the Mackenzie River is at risk each year.

Emergencies that beset far northern communities impose higher levels of hardship and uncertainty than is the case in the southern parts of Canada. As they have grown rapidly from small trading posts to established settlements, many northern communities are singularly ill-equipped to respond to emergency conditions on their own. Today a coordinated effort with up to four levels of responsibility is required.

Whether the threat comes from fast flowing waters or raging fires, the traditional coping skills of northern residents can no longer protect all belongings and community members. And therein lies another frustration, a growing dependence on external agencies to make decisions that determine their safety and welfare until the crisis passes.

In response to these unacceptable conditions there are a number of hopeful signs of change. Several initiatives are being undertaken in Ontario, and throughout the North, to reduce the human and economic consequences and to lessen some of the frustration that has historically accompanied natural disasters in northern areas.

New management practices are being developed in response to First Nation's concerns about the two-tiered forest fire emergency response system that was in place until recently. To illustrate, in some northern areas forest fires that did not threaten human life or property were allowed to burn unchecked if they did not threaten timber stands of commercial values or areas of human habitation. However, this policy did not take into consideration the effect unchecked forest fires could have on hunting, trapping, fishing, and other traditional economic values held by aboriginal people. Moreover, there was additional frustration about the lack of opportunity for those most affected, the Far North residents, to become involved in forest fire management decisions and operations.

In 1992, a Far North Fire Management Working Group was organized to address this issue, as a partnership arrangement between the provincial government and First Nation communities. The Working Group was tasked to consult with northern residents and make recommendations for an improved forest fire management program. Such a program would reduce the impact on those most affected by a forest fire emergency. Four of the recommendations now being considered are:

1. a distinct forest fire management program in the Far North to be delivered in a partnership arrangement between the provincial government and First Nation communities

2. locally based fire management capabilities to be established in 25 Far North communities

3. training and equipment to be provided to and operated by First Nation fire fighters

4. emergency plans and response arrangements that reflect the authority of First Nation councils regarding community safety and the desirability of reducing the frequency of evacuations.

A second initiative is a resource agreement between Indian and Northern Affairs Canada and the Ontario Ministry of the Solicitor General and Correctional Services. This agreement provides the resources that will enable Emergency Planning Ontario to deliver emergency preparedness and response services to First Nation communities in all parts of the province, including training, planning and emergency response assistance. As a result of this agreement, formal training courses and planning workshops are being conducted in aboriginal communities across Ontario, including the Far North. Now when emergencies arise, Emergency Planning Ontario staff immediately deploy to the community affected to provide advice for the implementation of the local emergency plan and to arrange assistance from provincial and federal government sources.

A third initiative, the Northern Ontario Evacuation Centre Study, will look at the problems of arranging evacuations and satisfactory shelter arrangements for people who have distinctly different social, cultural, and dietary needs. Through the implementation of this initiative it is anticipated that multi-party consultations will lead ultimately to the development of a Northern Ontario Evacuation Strategy. The project has three interconnected areas of examination that are designed to:

1. lessen the need for evacuation by stockpiling resources under a local authority for constructing temporary shelters in the vicinity to threatened communities

2. reduce social, cultural, and dietary hardship by stockpiling supplies for use in designated First Nation communities that will serve as evacuee centres

3. designate other sites where permanent facilities and supplies are in place as a backup or when other less disruptive arrangements are not possible.

However, while much is being done, there is another element of emergency preparedness that may be overlooked in the Far North. Elsewhere in Canada, communities faced with recurring threats have been protected from medium scale episodes of flooding by the construction of barriers such as dams, levees, and other flood-control measures. Few, if any, of these measures have been considered in the North because of their substantial cost, and until recently the relatively small size of their highly mobile populations. In light of a growth rate three to four times that in the southern region of Canada, the ability to cope is declining, requiring that alternative protective measures be considered. With the rapidly expanding infrastructure of many northern communities, detailed assessments of protective measures can now be justified on the basis of saving life and property. The success of these measures will depend on their integration with local emergency plans and capacity building within the population of each community. Only through a concerted effort by all levels of government, and the active involvement of local citizens, will the sustainability and survival of the remote communities throughout Canada's vast northern frontier be assured.

IV. WARNING

Warning Canadians of potentially hazardous events is vital in the quest to reduce loss of life and property damage when disaster strikes. The development of appropriate warning systems requires close collaboration by all levels of government and the private sector.

METEOROLOGICAL HAZARDS

A. Atmospheric Environment Service (AES) - Environment Canada

Canada's national weather service is responsible for ensuring the safety and well-being of all Canadians by providing high quality environmental information and advice, and promoting human behaviour that respects the present and future conditions of the atmosphere.

The Atmospheric Environment Service provides public, aviation, and marine weather forecasts and warnings, as well as forecast services for weather-sensitive economic sectors such as forestry, agriculture, tourism, and recreation. During 1993-94, Environment Canada expects to spend $193 million and 1,884 person-years for its weather warning and forecast production program.

Environment Canada has a direct supporting role in natural disaster response and mitigation, and through AES, provides information and advice on atmospheric conditions during major environmental emergencies. Air-quality models are also used to estimate the concentration and areas affected.

Research is regularly being undertaken in the following areas:

- development of better numerical forecast models
- more innovative use of new technologies
- new systems to produce better weather forecasts and warnings.
- climatic risk analyses and assessment studies
- climate change impacts and return periods for natural extremes.

In addition, AES issues climate-based predictions and provides environmental assessment consultation.

Environment Canada's IDNDR-related objectives help to improve the capacity of Canadians to mitigate effects of natural disasters. These objectives include: devising guidelines and strategies for applying existing knowledge, closing gaps in knowledge, disseminating information, and helping to develop measures related to specific disasters and locations.

Systems for Observing Meteorological Hazards:

In Canada, approximately 467 stations take hourly weather observations while 32 additional stations sample the upper atmosphere twice daily using instrumented balloons. Ten weather satellite centres receive continuous measurements and 15 radars, three with Doppler capability, cover most of the populated area of southern Canada. There are also 31 instrumented weather buoys strategically located in Canadian waters and on ice in the Arctic. Ships operating on the Great Lakes and in the Atlantic, Pacific, and Arctic Oceans provide more than 120,000 observations annually.

Canadian and international data is relayed on a telecommunications network to all Environment Canada forecasting centres. This data gives the forecaster a "snapshot" of the world's weather. Additionally, about 5,000 "severe weather watchers" serve their fellow citizens by quickly reporting severe thunderstorms, tornadoes and hailstorms to Environment Canada regional centres. (A partnership has been formed between AES and the CANWARN network -- a group of Ontario amateur radio operators recruited to report the occurrences of severe thunderstorms to weather centres.) A network of 2,500 climatological observers takes daily readings of maximum and minimum temperatures and precipitation. This network provides much of the essential statistics for the climate archives.

The Weather Warning Program:

Public, marine and aviation weather warnings are produced and issued when necessary as part of the weather services program.

The weather warnings issued by Environment Canada Weather Centres and Service Offices are disseminated primarily by radio and television media, and automated telephone answering devices. Weather Warnings are also broadcast to the public continuously from 73 VHF "Weatheradio" stations, and re-broadcast from 57 repeater stations across Canada. Other organizations, such as the Canadian Coast Guard also send out these warnings.

Fifty Weatheradio transmitters also offer the "Weathercopy" service providing specialized users with alphanumeric bulletins sent digitally via Weatheradio.

Environment Canada has made some agreements with emergency response agencies to share communications infrastructure. More of these partnerships are expected to form in the future.

There are several projects under way within Environment Canada to improve the distribution of weather forecasts and warnings. Cable television companies will be offered the capability to broadcast hazardous weather "crawlers" simultaneously on all channels. Environment Canada is expanding this network to allow more Canadians to be within range of a Weatheradio signal. Expansion is financed in cooperation with municipalities, provinces, and the National Search and Rescue Secretariat. Automatic text-to-voice technology is being developed for loading both Weatheradio and telephone answering devices.

Environment Canada offers education and awareness training to ensure that clients receive and understand weather warning information and are able to react. An example of this activity is that eight regionally focussed marine weather guides have been made available to Canadian marine interests of all types. Environment Canada also continues to cooperate with response agencies, to educate the public about weather warnings and necessary prevention measures.

Public Weather Warning:

Weather warnings can be classified into two types: those relating to summer severe weather (mesoscale); and those due to larger (synoptic scale) systems. The national weather service in Canada uses a target lead time of 1/2-2 hours for summer severe weather warnings and a target lead time of 12 hours for warnings in the synoptic scale.

In addition, less specific "Weather Watch" bulletins are issued for summer severe weather. The target lead time for watches is six hours. Watches alert the public to possible severe weather development later in the day.

Weather "Advisory" messages are issued for other situations where actual or expected weather may cause inconvenience or concern. Weather advisories may also be issued in those situations not sufficiently definite to justify issuing a warning.

Marine Weather Warning:

Marine Warning messages provide an effective warning service of hazardous meteorological and sea state conditions. This service assures safe shipping and boating, as well as protection of the natural environment. Where possible, Marine Warnings provide at least 12 hours advance notice of hazardous weather. Severe convective weather is included with up to two hours lead time.

The Canadian Coast Guard is a major disseminator of AES Marine Warnings. In 1994, the Coast Guard will be starting a NAVTEX Service for marine areas. NAVTEX will provide shipping navigational and meteorological warning information in addition to urgent search and rescue messages. Automatic printout will be provided from a dedicated receiver suitable for all types and sizes of ships. For some vessels, NAVTEX is expected to become part of mandatory equipment specified by chapter IV of the International Convention for the Safety of Life at Sea.

Canada's national weather service will produce specially tailored marine forecasts for NAVTEX service. Also, the Weatheradio program is being expanded to help the marine community to avoid weather-related marine disasters.

As a direct result of the "Cape Aspy" incident of January 1993, Environment Canada is developing a freezing spray forecast program. "Severe freezing spray" terminology is now used in warnings under certain conditions. Educational brochures are also planned to emphasize freezing spray hazards.

The Canadian Meteorological Centre operates the Canadian Spectral Ocean Wave Model in two separate oceanic regions (northwest Atlantic and northeast Pacific). Because the model still significantly underestimates waves associated with intense storms, the input of professional meteorologists is still essential.

Most researchers agree that over the next 100 years, wave climatology may differ appreciably from that of the past 100 years. Most global climate change projections show higher rates of warming in polar regions than in equatorial areas. Decreased pole to equator temperature gradients will tend to reduce storm severity.

Higher sea surface temperature regimes, on the other hand, may contribute increased energy to storms. This effect appears to be indicated by most experiments with Global Circulation Models (GCM). These GCMs can reproduce the larger scale features of climate but they do not allow accurate depiction on regional scales.

While the past decade has seen overall global warming, the Atlantic Ocean off the east coast of Canada, has been cooler than average. This has resulted in record amounts of sea ice, and the two largest wave-producing storms ever. The "Halloween storm" of October 31, 1991, and the "Storm of the Century," March 15, 1993, both produced record breaking extremes. Similar events have also occurred on the west coast of Canada, where the 100-year wave height return period has been exceeded four times since 1990.

It is not clear whether future climates will be more hazardous or less hazardous and by how much. There is also no way to predict whether the risk may be reduced in some regions and increased in others. Much more research is required in this area. The key to reducing the hazards associated with ocean waves is to improve our understanding of their causes. This is especially true for the very large waves that occur over small areas in large extratropical storms. Accurate measurement and modelling is critical for both determination of reliable design criteria and for production of wave forecasts and warnings.

Aviation Weather Warning:

Warnings to the aviation community take the form of SIGMET messages. SIGMET messages are "weather warnings" which notify aircraft in flight of potentially dangerous weather phenomena. A SIGMET is issued when a hazardous phenomena has been reported or is expected to occur within the next four hours. However, a SIGMET concerning volcanic ash should be issued up to 12 hours before its arrival *(see Environmental Emergency Response Program in the section on "Volcanic Eruptions" in this chapter).*

For many of these phenomena current atmospheric measurement technologies are deficient in accurately detecting existence and extent. Recent developments in automated aircraft weather reporting have resulted in significant improvements in the measurement of upper atmospheric winds and temperatures. This will ultimately reduce operational costs to the aviation industry and should be of benefit to meteorological prediction.

Parallel advancements in measurement technologies for aircraft icing and turbulence have not yet been achieved. More work is needed to characterize the conditions under which freezing precipitation occurs, and to develop better forecasting models that can warn operators to avoid these conditions. Also, current meteorological forecasting models do not account for the prediction of super-cooled liquid water content associated with in cloud aircraft icing.

The Canadian Meteorological Centre is designated by the World Meteorological Organization as a Regional Specialized Meteorological Centre specializing in atmospheric transport modelling for nuclear emergency response. The operational response capability is directly applicable to volcanic ash transport as well and has been used in that capacity several times recently providing regional forecast centres with guidance for the issuance of volcanic ash SIGMETS.

Climate Services:

The activities of Environment Canada Climate Services are related to the IDNDR goal of "fostering scientific and engineering endeavours aimed at reducing critical gaps in knowledge." The related IDNDR activities are: identifying hazard zones; vulnerability and risk assessment; and improving awareness of policy makers.

Climate Services undertakes climatic risk analyses and assessment studies to produce information on wind normals and extremes, moisture availability for crop production, rainfall intensity-duration curves, probable maximum precipitation, and the occurrence and impact of severe weather. Users include emergency response organizations, national engineering codes, the insurance and reinsurance industry, etc. Also provided are extreme wind, snow, and ice loading information for national building and engineering codes and standards.

Climate information and air quality data are frequently provided as well. Consultation includes environmental assessment and the review of major projects in Canada. This service reduces vulnerability to natural disasters and environmental changes that may increase the likelihood of natural disasters.

Environment Canada's Climate Services also includes climate extremes monitoring, prediction and reporting. An example of a regionally focussed program is the Winnipeg Climate Centre's Near Real-Time Climate Program for the Prairies. This program provides drought monitoring and supports snow melt and flash flood forecasting.

Finally, Environment Canada Climate Services is involved in climate change impact and sensitivity studies of climatic conditions that impact most significantly on Canadian society and the economy.

Tornadoes:

a. Project Tornado

In the spring of 1988, Environment Canada developed a workshop called Project Tornado. Project Tornado is designed to increase the understanding of severe weather by municipal officials. It ensures that they have plans to react to tornadoes and other severe weather emergencies. Project Tornado was started in cooperation with Emergency Planning Ontario whose aim was to have emergency response plans developed. Project Tornado is an interactive educational workshop targeted at local and provincial officials and emergency responders. The inaugural one day workshop took place in March 1988, and since then the workshop has been held at least twice a year at other locations in Canada.

The workshop describes the atmospheric conditions necessary for the triggering of severe thunderstorms, and Environment Canada's severe weather Watch and Warning program. Participants learn how this information is delivered to the electronic media, to key officials and to the public, and they also have to deal with a simulated tornado in "real time." *(See Chapter III Mitigation, "Reducing Tornado Disasters" for more details about "Project Tornado.")*

b. Emergency Public Warning

Another example of a regional initiative is the warning delivery system that has been developed by Alberta Public Safety Services in the Edmonton area. AES severe weather forecasters are authorized to interrupt programming of 18 Edmonton area broadcast stations to deliver tornado warnings.

c. Doppler Radar

Canada's Doppler radar research centre is located at King City just outside of Toronto, Ontario. This installation has shown considerable success at predicting severe weather phenomena such as funnel clouds, low level wind shear, and snow squalls. Doppler radar has increased the accuracy of warnings in southern Ontario by about 20%.

Building on this success, Environment Canada has installed Doppler radars near Edmonton, Alberta, and in Montreal, Quebec. AES plans to further modernize its radar network by upgrading some radar processing systems and eventually adding more Doppler radars. Meanwhile, research continues to improve Doppler techniques for detecting tornadoes and other types of severe weather.

Windstorms:

a. Sustained Winds

Public and marine wind warnings are issued when strong sustained winds are expected to occur.

b. Strong Wind Gusts due to Thunderstorms and Squall Lines

Public and marine severe thunderstorm warnings are issued when strong wind gusts resulting from convective weather are expected to occur. Squall Line SIGMET messages are issued, for aviation purposes, when wind gusts of 40 knots or more are expected to occur. Low level wind shear SIGMETs are issued for hazardous convective down drafts.

c. Hurricanes and Tropical Storms

Hurricanes and tropical storms result in storm force winds, high waves and flooding, causing damage to property and structures and threaten life.

Environment Canada has two centres which deal with meteorological matters relating to hurricanes and tropical storms. The Pacific Weather Centre functions as the Western Canadian Hurricane Centre and the Maritimes Weather Centre functions as the Eastern Canadian Hurricane Centre. Officials from these centres represent Canada at national and international meetings dealing with this phenomena.

The Hurricane Centres are tasked with giving advance warning of hurricane movements through nation-wide dissemination of Environment Canada hurricane and tropical storm messages. The Hurricane Centres prepare and issue Canadian Hurricane Prognostic Messages to guide Environment Canada and Canadian Forces Weather Services meteorologists in the preparation of appropriate weather warnings and forecasts. They also issue Hurricane Information Statements, which are written in plain language and disseminated through the media to provide general information and guidance to the public.

SIGMET messages for hurricanes and tropical storms for aviation users are issued for affected areas.

d. Storm Surges/Seiches

Storm surges/seiches information is included as part of the outlook in High Water Level Forecasts. A High Water Level Warning is issued when water levels are expected to exceed a critical level. The critical levels are defined regionally for each water body in consultation with the appropriate agencies.

The intensity and frequency of tropical storms might be increased, due to higher sea surface temperature regimes contributing increased energy to those storms as appears to be indicated by most experiments with Global Circulation Models (GCM). These GCMs are capable of reproducing the larger scale features of climate but do not allow accurate depiction on regional scales.

While the late 1980s and early 1990s have seen overall warming on global scales, the north Atlantic Ocean, particularly off the east coast of Canada, has seen cooler than average temperatures. This has resulted in record amounts of sea ice, and the two largest wave-producing storms ever recorded, in 1991 and 1993. *(See "Marine Weather Warning" in this chapter for more details.)* Similar events have been seen also on the west coast of Canada. It is not clear whether future climates will be more or less hazardous. Nor is there is any basis to predict whether the risk may be lessened in some regions and heightened in others. Much more research is required in this area.

The key to reducing the hazards associated with ocean waves is to improve our understanding of their causes. Accurate measurement and modelling of these conditions is critical for both determination of reliable design criteria and production of wave analysis, forecasts and warnings in real time.

B. Emergency Preparedness Canada

All Channel Alert System (ACAS): A consortium of federal departments and private industry is developing a proposal to place warning messages on all cable TV channels. This service would be offered at no cost to the taxpayer by a private broadcast service.

The initial prototype of ACAS would mean weather warnings issued by Environment Canada would be distributed to cable channels.

C. Alberta Public Safety Services

Emergency Public Warning System: In 1992 the Alberta Government completed an Edmonton Region pilot project for an emergency public warning system for major emergencies. It was a partnership between all radio, television and cable companies and all orders of government. It provides virtually instantaneous access to the broadcast outlets for authorized users and has the capability to have in-location warning devices for special facilities such as hospitals, schools, etc. The system is available to 22 local and provincial government authorities and Environment Canada's severe weather team, to provide immediate warning of life-threatening conditions. A study is now under way to determine the benefits of a province-wide expansion of the system.

HYDROLOGICAL HAZARDS

Floods

The federal and provincial governments have several programs in place to provide warning of potential floods. One such program is a national flood damage reduction program that identifies flood risk areas for the purpose of discouraging inappropriate new development in flood plains. The program is coordinated with the affected municipalities who are encouraged to develop zoning bylaws for the designated flood risk areas. This information also assists municipalities in preparing for and responding to flooding in their areas.

Flood Forecasting and Warning:

Over the past 40 years, flood forecasting and warning in Canada has evolved into a network of forecast systems across the country. There are five provincial streamflow forecast centres: the Saint John River Forecast Centre, the Ontario Streamflow Forecast Centre, the Manitoba River Forecast Centre, and Alberta's River Forecast Centre. In addition to these provincial centres, there are a number of other flood forecasting operations such as those of Ontario's Conservation Authorities.

Systematic river forecasting has often been initiated in the aftermath of a particular flood event. In Manitoba, river forecasting was started following the widespread flooding of the Red River in 1950, and in Ontario, a flood forecasting system was developed following the devastating impact of hurricane Hazel in 1954.

Most of the centres provide multiple services and operate on a year-round basis. While spring flood forecasting may be their primary role and usually their busiest time of year, centres provide year-round streamflow forecasts for flood control and water management. Streamflow forecasts outside the flood season are used to regulate reservoirs and streams for hydroelectric power, irrigation, domestic uses, pollution assimilation recreation and other low-flow augmentation purposes. For instance, the Saskatchewan River Forecast Centre monitors and controls international and interprovincial flows to meet requirements under various agreements.

The purpose of flood forecasting is to provide as much advance warning as possible of an impending flood. Over time, the demands for flood forecasts have changed from a simple indication of the likelihood or severity of flooding to an accurate prediction of magnitude and timing of flood passage.

Flood forecasting systems generally have a similar operational set-up to carry out the following activities:

- collecting and managing pertinent data
- developing river forecasting procedures
- forecasting floods
- providing advice for flood control operations (also floodway operations, emergency diking, etc.)
- communicating flood warnings.

Forecasting is becoming increasingly sophisticated, particularly in the areas of data collection and modelling. However, these activities vary in individual forecasting centres depending on the funds available and the need for increased technology.

To forecast river or lake flood levels, two primary types of data are required: hydrologic and meteorologic.

Data collection methods are diverse. Field data collection by instrumentation ranges from manual reading of gauges, to telephone hook-ups between a gauge and the forecast centre, to a satellite link between a gauge and the centre. Most centres have a combination of these systems. More modern systems are introduced as old equipment is replaced or as the network of instrumentation is expanded. As the sophistication of the data collection systems increases, the access to data comes closer to real time. In other words, the data are available to the user within a few minutes or even seconds of having been recorded by the gauge.

Forecast centre computers and teleprinters are often used to access other agencies' information. For instance, the computer systems of the Atmospheric Environment Service of Environment Canada are accessed for meteorological data, weather forecasts, and radar maps.

Flood Event Communications:

As the ultimate purpose of a flood forecasting unit is to provide flood warnings, the dissemination of information is an integral part of the unit's duties. Generally, a forecasting unit is responsible for notifying the emergency measures agencies, senior government officials, and the public through the media. Ordinarily, the responsibility for flood warnings lies with the provinces and the territories.

There are several forms and levels of flood warnings given to the public and emergency agencies to prepare them for flooding. The warning system is usually initiated with a statement or flood alert early in the season. The alert often gives a general indication of the potential threat based on various weather scenarios. The statements are often printed in the local newspapers or broadcast on the radio or television. This notice serves to remind responsible agencies, such as the emergency measures organizations, that the flood season is approaching, allowing them to prepare themselves. At this point, the floodplain residents should plan how they could protect their property and valuables.

During the course of the spring melt the forecasting unit will issue a flood warning when a flood event is foreseen. The warning triggers municipal and regional contingency plans to be put into effect by police, fire, public works, emergency measures, and other departments. These agencies would assist in the evacuation, sheltering, feeding and clothing of the threatened population; sandbagging operations; ice jam management; and the operation of flood control structures. These warnings also give the public from several hours to a couple of days to prepare themselves by moving valuables to higher ground, possibly sealing the home to some extent, and volunteering to aid in the flood fighting.

Some jurisdictions mobilize people to knock on doors to warn residents that the river is topping its banks. At this late stage, people only have time to evacuate.

There are limits to forecasting operations. Often smaller streams are not monitored, or sudden ice jams can occur. This can cause flooding that is not predictable by flood forecasters.

Flood Forecasting in the North:

The development of flood forecasting systems in the North has been restricted by a lack of basic data on floods, and the cost and complexity of forecasting. As well, the limited cost of damages to the few flood-prone communities over the years has been a factor.

In the Yukon, Indian and Northern Affairs Canada performs the following forecasting functions :

- developing and issuing daily flood forecasts for Ross River and Mayo during the freshet using a computer-based temperature index model
- developing estimates of breakup timing and associated water levels for the Yukon River at Dawson
- issuing monthly estimates of both peak flows and April to September volume runoff during the spring months starting March 1.

Moreover, flood forecasts are developed for all major Yukon drainage basins and other selected key locations.

In the Northwest Territories, Environment Canada field staff have extensively advised and assisted local flood watch committees in Hay River, Fort Simpson, and Aklavik for many years. An initial interagency flood forecast system has been developed for Hay River, which uses winter snow accumulation, ice deterioration due to warm weather and solar radiation, observed and forecast flows, and weather forecasts to estimate flood levels. Further cooperative efforts are required by Environment Canada, Indian and Northern Affairs Canada, the Government of the Northwest Territories, and the community of Hay River to complete development of a forecast system for the complex flooding situation at this location.

Atmospheric Environment Service (AES) - Environment Canada:

Environment Canada's Atmospheric Environment Service (AES) issues Heavy Rainfall Warnings as a means of alerting local conservation authorities of the potential for flooding. A heavy rainfall warning is issued as part of the ongoing AES operational meteorology program. Although river floods may occur due to ice jams, there is little expertise in this area and there is no operational facility at the Ice Centre to observe, analyze and predict this phenomenon.

Environment Canada, through its regional representation, participates actively in provincially led flood prediction and/or control committees and provides meteorological support prior to, and during, natural flood disasters. This support includes specific input data, both measured and predicted, including snowfall, rain, temperature (snow melt) and wind (lake set-up and seiche).

Examples of regionally focussed programs are the Winnipeg Climate Centre's Near Real-Time Climate/Climate Extremes Monitoring and Reporting Program which directly supports snow melt and flash flood forecast programs of the provincial agencies in Manitoba, Saskatchewan and Alberta. Other support includes hydro-meteorological studies of the snow pack and input to scientific studies related to the socio-economic impacts of flood and drought under scenarios of a variable and changing climate.

In Quebec, a special threshold water accumulation forecast advisory is provided to "Direction Generale de la Securite Civile" and to the provincial Ministry of the Environment.

In Alberta, the Alberta Environmental Protection, River Forecast Centre monitors weather, snowpack, river and stream flow conditions, and ice jams and provides flood forecasts for disaster prevention and flood damage reduction. They maintain a widespread network of automatic weather data collection stations which are constantly monitoring conditions. In addition regular weather reports from Atmospheric Environment Service (AES) and from the Alberta Forest Service's network of forest fire lookout observers.

Most damaging floods in Alberta are not very sudden. They usually start out as high streamflow situations which worsen as rain continues to fall. When the River Forecast Centre has determined a significant probability of imminent flooding, they provide warnings to a variety of agencies (federal, provincial and municipal governments, private industry and the media) on changes in river levels. Ice jam monitoring is carried out at both freeze up and breakup.

Ice Hazards - Systems for Observing, Forecasting and Warning

Atmospheric Environment Service (AES) - Environment Canada

AES's Ice Service Centre in Ottawa through its Sea Ice Observing Program provides ice information to assure safety in and near floating ice and to enhance working decisions made by marine enterprise. Besides delivering on-site briefings to those operating in ice, the program issues ice bulletins and charts to support ship navigation, arctic enterprises, and offshore platforms.

The regular Sea Ice Observing Program, a mix of visual ice interpretations from ships, aircraft, and shore stations, involves:

- remote sensing with Sideways Looking Airborne Radar (SLAR) and satellite Synthetic Aperture Radar (SAR)
- interpretations of visual and infrared satellite imagery
- a full set of meterological observations and oceanographic data.

In addition to the regular issue of ice forecasts and charts, the Ice Centre provides special "Ice Hazard Warnings" when the following hazards are expected to occur:

- Ice edge - for "non-ice-capable" ships and structures.
- Icebergs - for all marine enterprises.
- Ice Ridging and Pile-up - for marine enterprises.
- "Old Ice" - for all ice capable ships and structures.

The Canadian Coast Guard marine radio broadcast provides ice hazard warnings to all users. Where applicable, hazard warnings are also broadcast to the public continuously from selected "Weatheradio" stations on VHF radio frequencies. Warnings are available through weather offices and, where applicable, on radio and television. In future, ice hazard warnings may become available through satellite TV channels.

An iceberg reconnaissance, and iceberg hazard advisory service has been recently added to the existing Sea Ice Program. Timely iceberg information, predictions, and warnings reduce the risks of encountering hazardous ice conditions along navigation routes and in east coast oil exploration.

This new service is designed to incorporate information and other benefits resulting from partnerships with the International Ice Patrol, the Canadian Coast Guard, the Department of Fisheries and Oceans, and the Canadian Department of National Defence. Potential new partnerships include the Newfoundland Oil and Petroleum Board, and private industry.

The presence of icebergs off Canada's east coast is a potential threat to offshore activity for most of the year. This is primarily due to continually changing weather conditions that make visual iceberg observation ineffective. Therefore the use of remote sensing and the development of related technologies must be relied upon to a great extent.

AES uses a Dash-7 ice reconnaissance aircraft to maintain regular iceberg surveillance. Atlantic Airways also provides iceberg surveillance data as a result of their Fisheries and Oceans Canada surveillance flights. Ship reports and data from the U.S. Coast Guard's International Ice Patrol (February-June ONLY) are also used. As a result, the Ice Centre is receiving adequate information to enable the publishing of regional iceberg analyses.

The AES Ice Service offers education and awareness training to ensure clients receive and understand ice hazard warnings. They must understand preventive measures and know how to react.

The Ice Climatology Services section of the Ice Centre provides risk analyses, ice normals, and ice extremes as required.

Technologically, the Canadian Ice Service is the most advanced in the world. Over the next decade the Ice Centre will further improve client services though model development, enhanced forecast techniques, and customized products. These improvements include:

- implementing digital radio systems for delivery of warnings and issuing forecasts of iceberg distributions in near real-time
- implementing an archive of iceberg data for all applications
- improving the skill of forecasting ice hazards
- developing models able to determine areas of convergence and divergence as well as outputs of ice pressure.

Existing iceberg databases are not suitable for determining distribution statistics because they require considerable knowledge by the user. The existing iceberg climatology must be improved to be more useful in designing and planning. This improvement will prevent unnecessary disasters and will assure safe offshore oil drilling activities.

Potential commercialization of products will require development of new strategies and accounting procedures, and will involve private sector partnerships.

Tsunamis

Environment Canada

The National Oceanic and Atmospheric Administration (NOAA) Tsunami Warning Centres, located in Hawaii, California and Alaska, monitor seismic and volcanic activity and assess tsunamis potential. If there is potential for a tsunami they will contact the Institute of Ocean Sciences of Fisheries and Oceans Canada. The Institute of Ocean Sciences will confer with the provincial emergency measures organization on whether a tsunami advisory or warning should be issued. Environment Canada receives a copy of this warning from the provincial emergency measures organization and the Pacific Weather Centre is consulted regarding sea state and weather conditions. They may also be asked to assist with warning distribution.

Most tsunamis striking the Pacific coast originate at sources sufficiently distant that some warning (two to five hours) of their arrival may be issued with the cooperation of the International Warning System. This warning system would be inadequate in the event of coastally generated tsunamis, where lag times between earthquake and flooding would be in the order of a few minutes. Other kinds of public safety measures would have to be developed for such circumstances. Since nothing can be done to prevent the effects of tsunamis once they occur, preventive measures must be taken in advance, on the basis of estimated risk. The estimation of potential damage requires detailed knowledge of the degree of flooding in specific locations which is still beyond the ability of existing models.

In recent years, tsunami-prone coastal areas have been increasingly developed and populated with little thought to the grievous loss of life and property that will occur when the big waves come. The only hope is to reduce tsunami warning time to a minimum and further educate coastal populations about the realities of these great waves.

Fisheries and Oceans Canada

Canada operates and maintains three tsunami warning stations as its contribution to the Pacific Tsunami Warning System. The water level data from these stations is also available for use by the Alaska Tsunami Warning Centre, for regional warnings in the northeast Pacific.

Province of British Columbia

On the Pacific coast of Canada, the British Columbia Provincial Emergency Program (PEP) is responsible for issuing tsunami watches and warnings. The federal government provides scientific and technical assistance (for both earthquakes and tsunamis) as required, through the Pacific Geoscience Centre and the Institute of Ocean Sciences, both located in Sidney, British Columbia.

PEP has a Tsunami Warning Plan which is exercised several times each year. In addition, representatives of the various levels of government and the public utilities meet several times each year to discuss issues related to communications during a natural disaster. For the past 10 years the Pacific Geoscience Centre has been carrying out a program to monitor crustal deformation on the Vancouver Island portion of the Cascadia Subduction Zone.

Drought

Agriculture and Agri-Food Canada

Monitoring and early warning systems are in place across Canada. Weather information, short-term weather forecasts, streamflow recordings and related research are provided by Environment Canada. Agrometeorological models developed at Agriculture and Agri-Food Canada research stations and universities are used to provide an interpretation of the impact of weather and other environmental factors on disease and pest propagation and crop conditions. Hydrological and hydrogeological investigations and modelling are used to forecast and monitor water supplies. Provincial water resource agencies and agriculture departments routinely prepare and disseminate conditions reports. Remote sensing methods are researched and developed for monitoring snow on the ground and crops in the field. Data and information are distributed by mail, fax and computer interfaces.

Agriculture Agri-Food Canada through the Prairie Farm Rehabilitation Administration (PFRA) coordinates Prairie drought activities. The PFRA coordinates the Prairie Drought Monitoring Network, which consists of provincial departments of agriculture, environment, provincial emergency measures organizations and private agencies. The network receives information from many sources including the agricultural producers in the field and the satellites in the sky) that is used to provide data on the following:

- crop and forage conditions and yield prospects
- pests
- livestock conditions
- pasture conditions
- soil moisture
- surface water and ground water reserves
- on-farms water supplies
- agricultural service centres water supplies
- urban centre water supplies
- irrigation water supplies
- hydroelectric power generation
- wildlife

This information is prepared by responsibility centres and distributed to users, and a great deal of it is summarized in a comprehensive report called the Prairie Provinces Water Supply Conditions report, which is updated and published by the PFRA three times a year.

Drought management plans are developed to outline what government, industries and individuals should do before and during a drought. Steps on how to ensure adequate water supplies and reduce drought impacts are included in the plans.

All three types of drought: meteorological -- below normal precipitation; hydrological -- water supplies below normal; and agriculture -- crops and livestock affected, may occur in Canada. Their occurrence is irregular, and any one or all three types may affect the same or different regions of the country. Severity can range from slight to severe, depending on what areas or regions are affected, and on the duration of the dry periods.

Parameters used to determine a drought year include rainfall, temperature, reduction of water resources and streamflows, general water supply conditions, forest fire danger rating system and areas burned, soil moisture, vegetation and crop conditions and yields.

Monitoring and prediction of drought are based on soil moisture following harvest; winter and spring precipitation as a percentage of normal; growing season precipitation as a percentage of normal; temperature; actual minus potential evaporation; status of crops and their yields. Soil moisture models and yield models are employed, and the effects of the El Nino are studied.

Based on the above parameters the Prairie Drought Monitoring Network develops drought severity indices. Given this warning communities can decide when to activate their drought management plans based on the severity indices and information on local water conditions. Individual farmers receive advice on when and how to conserve water through crop rotation, development of new water courses (irrigation systems, dugouts, additional wells, etc.), and maintenance of cattle herds.

Each of the Prairie provinces has formed provincial drought monitoring committees. Member agencies meet to share information on conditions, program activities and anticipated problems in preparing information for public and senior bureaucrats. In 1988, when severe and widespread drought was imminent, a Federal-Provincial Drought Response Committee was formed to coordinate the information and response at federal and provincial levels. Also in response to the 1988 drought, the Great Lakes Commission formed a Drought Management and Great Lakes Water Levels Task Force, which recommended a regional approach to drought planning for the Great Lakes states and provinces.

GEOLOGICAL HAZARDS

Avalanches

Environment Canada

There are more than 4,500 volunteers involved in avalanche awareness and rescue in British Columbia. Environment Canada issues avalanche forecasts as support to Parks Canada for their avalanche control programs.

Geological Survey of Canada

Avalanche forecasting and warnings are important on the personal level as well as in operations. Avalanche education and current research on warning systems are now of primary importance. Avalanche education in Canada provides information on avalanche safety aimed at reducing fatalities. The Canadian Avalanche Association organizes basic and advanced courses in avalanche safety operations for highway and railway technicians, and ski operators, with an emphasis on: the development of practical knowledge and field skills for analysis of avalanche terrain and snow stability; teaching snow, avalanche and weather data; and rescue techniques. Short courses for skiers and mountain climbers are also available.

The mesoscale is the important one for avalanche forecasting in Canadian avalanche safety operations. Current Canadian research at this scale is focussed on development of a coupled expert system as a forecasting tool. The system treats standard meteorological and precipitation data using parametric and non-parametric discriminant analysis coupled with Bayesian statistics. In addition, rule-based expert knowledge on snow profile interpretation and weather forecasts is coupled to the statistical treatment. It is planned to use the system operationally across Western Canada.

Earthquakes

Geological Survey of Canada

Over the past 100 years there have been several earthquakes of the magnitude of 7 or 8 in Canada. The west coast of Canada and the St. Lawrence Valley are felt to be the most earthquake prone areas. The largest recorded earthquake in Canada, with a magnitude of 8.1, occurred off the Queen Charlotte Islands in 1949. Earthquakes generally occur without any advance warning. Natural Resources Canada has established more than 100 seismograph stations across the country. This network is sufficiently sensitive to locate any Canadian earthquake of a magnitude of 3.5 or greater. National seismic-zoning maps have been produced that are continuously updated. While earthquake prediction is not an exact science, a seismic zoning map is one representation of prediction. When there is a large degree of seismic activity, a region can be alerted to the probability of a potential earthquake and emergency response agencies can be alerted to the fact.

Environment Canada

Environment Canada is participating in the development of its part of the National Earthquake Support Plan (NESP). The plan is led by Emergency Preparedness Canada and involves many federal agencies and departments. Environment Canada's regional office is involved with other federal departments in support to British Columbia's earthquake emergency response plan.

Province of Alberta

Alberta, as the contiguous province to British Columbia, has joined forces with regional federal elements to develop a response plan to a catastrophic earthquake in British Columbia. The plan coordinates the mobilization of public and private sector support from Alberta to assist British Columbia to respond to and recover from a catastrophic earthquake.

Landslides

Environment Canada

After a Heavy Rainfall Warning is issued for a landslide prone area, the public forecasters from the Pacific Weather Centre in Vancouver, British Columbia, or the Mountain Weather Services Office in Kelowna, British Columbia, notify the appropriate local authorities and emergency response agencies.

Geological Survey of Canada

Canada has developed world-class expertise in the technology of landslide instrumentation systems. These include sophisticated multiple piezometer systems which measure water pressures at different levels within landslide masses (for example, West Bay Instruments), slope movement monitoring devices and warning systems (for example, Wahleach), and slope movement monitoring systems based on real-time stability analysis, utilizing time domain reflectometry and fibre optic technology (for example, in the Syncrude open pit, Fort McMurray, Alberta).

Turtle Mountain Study Team

The Turtle Mountain Study Team was established to direct the research aspects of the Turtle Mountain monitoring program in the Crowsnest Pass area of southern Alberta. This team includes representatives from Alberta Environmental Protection, Alberta Public Safety Services, members of the academic community, and the facility manager of the Frank Slide Interpretive Centre in the Municipality of Crowsnest Pass. The program has evolved from a research mode toward a monitoring mode.

The configuration of the monitoring systems in place should allow several weeks' warning in the form of precursory data indicating the possibility of major rock movement. In the event of any significant increase above baseline data rates, the Municipality of Crowsnest Pass and members of the Turtle Mountain Study Team will be notified.

Volcanic Eruptions

Environment Canada

1) <u>Modelling the Atmospheric Transport of Volcanic Ash</u>

The WMO has established the Canadian Meteorological Centre (CMC) as a Regional Specialized Meteorological Centre for atmospheric transport modelling and nuclear emergency response. CMC has also used its forecast capability in response to volcanic ash emergencies.

The main dispersion model is called CANERM (the Canadian Emergency Response Model). Volume 41B of Tellus contains a detailed description of this model in a paper by J. Pudykiewicz entitled, *Simulation of the Chernobyl Dispersion with a 3-D Hemispheric Tracer Model.* The model operates on a polar stereographic grid for both the Northern and Southern Hemispheres. The horizontal resolution is 50 km when the model runs in continental configuration.

The trajectory model uses a simple 3-D Lagrangian technique, to calculate the path of air parcels in the three-dimensional wind field. The CANERM model runs on a supercomputer. The trajectory model can execute quickly on a smaller front-end system.

CMC runs CANERM and the trajectory model routinely to maintain preparedness. This ensures that model output will always be available.

Trajectory guidance was used to track volcanic ash clouds from the recent eruption of Mount Spurr in Alaska. Based on this information Regional Weather Centres issued SIGMETs for international aviation. Comparison of the model results with pilot observations and satellite photographs showed that the model produced useful and timely information.

2) Environmental Emergency Response (EER) Program

The Environment Canada Environmental Emergency Response (EER) program involves the provision of meteorological services and products in response to emergencies that arise out of natural and human-caused hazards. On-site support and advice is provided to the response teams. The EER program has been directly involved with volcanic eruptions and earthquakes.

The Canadian Emergency Response Model, CANERM, and the Trajectory Model provide the capacity to track and predict the atmospheric transport of pollutants anywhere on the globe. They have been adapted to track airborne volcanic ash (see Aviation Weather Warning in this chapter). These models are integrated with the numerical weather prediction system and are run at the Canadian Meteorological Centre.

One other Environment Canada EER program initiative is the development of the Emergency Weather Station system. This transportable system is deployed to acquire site specific meteorological data in support of emergency response operations. This capability applies to emergencies, whether they result from natural or human-caused hazards.

3) <u>SIGMET Messages</u>

Environment Canada issues SIGMET messages advising the aviation community of volcanic ash cloud hazards. The Canadian Meteorological Centre provides direct support to Environment Canada forecast centres, Natural Resources Canada, Transport Canada, and emergency response agencies (such as Emergency Preparedness Canada) in the tracking of airborne volcanic ash using the Canadian Emergency Response Model (CANERM), and the Trajectory Model. Real-time meteorological satellite imagery as well as pilot reports can also be very useful for determining the location of the ash cloud. The CANERM model was initially designed and is being enhanced for use in tracking radioactive clouds anywhere in the world in the event of a nuclear disaster.

Geological Survey of Canada

Canada's proximity to active volcanoes both south and north, large eruptions in the past, coupled with increased sensitivity worldwide to the hazards of airborne ash, brought about the development of an Interagency Volcanic Event Notification Plan. This plan coordinates the alerting of appropriate responding agencies to a volcanic hazard and serves to disseminate information about that hazard. The IVENP is a redundant, multiple path communication network, and uses existing 24-hour a day operational facilities and services. Key to notification are the operational plans of the responding agencies. And critical to the rapid flow of information are direct contacts with sister agencies in adjoining jurisdictions. The direct linkage to Canadian and U.S. air traffic controllers is vital for the safe passage of aircraft. Additionally, rapid availability of plume trajectory information is critical. All these features are incorporated into the Canadian response plans.

The seismic network, in place to monitor tectonic earthquakes, is also of value for warning of volcanic eruptions. Stations have been placed so that they can also function to detect earthquakes associated with volcanic unrest. Many precursor earthquakes to volcanic eruptions are very low magnitude, however, and the density of stations in parts of British Columbia and the Yukon Territories may preclude detection of these events. In the event of a large eruption that would have significant impact on aviation and surrounding populations, the network would detect seismicity related to the eruption.

Meteorite Impacts

Geological Survey of Canada

Warning of an interplanetary collision is actually an astronomical problem, rather than a geological one. It is also an international problem. At present, about 5% of the interplanetary objects with diameters of greater than 1 km and orbits that intersect that of the Earth have been observed. None will affect the Earth in the near future.

At the direction of the U.S. Congress, NASA convened two workshops in 1992 to examine the threat posed by impact and possible responses to that threat. The International Near-Earth-Object Detection Workshop recommended a 20-year international observing program, using six 2-3 m telescopes equipped with CCD-array cameras and appropriate image processing software. It was estimated that 95% of objects greater than 1 km would be discovered within the time period.

Capital cost for constructing the network was estimated to be approximately $75 million with operating costs approximately $10 million per year. The other study, Near-Earth-Object Interception Workshop, discussed the use of "Star War" technology to take appropriate countermeasures to divert any object on a collision course with Earth.

BIOLOGICAL HAZARDS

Wildfire

Warning System:

All Canadian provinces currently utilize the Canadian Fire Behaviour Prediction System, one of the world's most advanced systems for predicting fire behaviour and monitoring fire danger. Many methods were used successfully to transfer the technology to fire management agencies including published articles, presentations at meetings, instructional workshops, training courses, and hypermedia software for computerized self-instruction.

At the tactical scale of individual fires, the computer-based system integrates data on weather, fuels, and topography to predict fire behaviour attributes such as rate of spread, fire intensity, and the onset of crowning. It also describes fire growth over time, in terms of spread distances, fire size, and fire shape. This information is used to guide prescribed burning, aid in initial attack, and support suppression operations on large fires.

At a management level, most provinces employ state-of-the-art management information systems. They automatically access real-time weather observations and short-term forecasts, transform the data into fire-danger indices, and spatially display the information over provincial networks. Many provinces also currently use decision support systems with Geographic Information System (GIS) capabilities to optimize functions such as aerial detection, route planning, initial attack dispatch, and resource allocation.

Research is currently under way to develop an automated national fire severity system to support strategic-level decision making. The system would produce national maps of the daily probability of large fires and exceptionally large numbers of fires -- either of which can overload fire management systems, resulting in significantly increased damages. It is anticipated that the system will incorporate forecasting up to five days in advance to support decision making on a weekly scale.

Animal Disease

Agriculture Agri-Food Canada

Agriculture Agri-Food Canada is responsible under the Animal Disease and Protection Act for the eradication of foreign animal disease outbreaks in Canada. The federal government and the provinces have jointly developed the Foreign Animal Disease Eradication Support Plan. A foreign animal disease emergency is an outbreak of a foreign animal disease requiring immediate action to contain, control and eradicate the disease. Plans and procedures for eradication are the responsibility of the Regional Veterinary Director of Agriculture Agri-Food Canada working with his provincial counterparts.

The Animal Health Divisions at both the federal level (Agriculture Agri-Food Canada) and the provincial level network closely with their American counterparts and departments of agriculture of other countries. When an outbreak occurs, health inspectors monitor the importation of animals and the entry of persons into the country from rural agricultural areas. When an outbreak occurs within the country, steps are immediately taken to contain, control and eradicate the disease. Warnings are given to all stakeholders in the animal industry, including, including, producers, distributors and consumers.

Pest Infestation

Agriculture Agri-Food Canada

Canada has no systems for observing, forecasting and warning for pest infestation. However, Agriculture Agri-Food Canada has a plan to respond to pest infestation as detailed in the Plant Protection Act. The details of such a response are contained in the Plant Pest Emergency Program Manual.

Effective management of a pest infestation requires the involvement of all levels of government and private industry with a mandate to support, or which have an interest in pest management.

Agriculture Agri-Food Canada administers the Plant Protection Act of Canada to prevent the importation, exportation and spread of pests injurious to plants and to provide for their control and eradication and for the certification of plants.

Provinces

Under provincial legislation, the prime responsibility for the management of pests rests with provincial agriculture and forestry departments in collaboration with Agriculture Canada. The populations of several species of insects are monitored such as gypsy moth, mountain pine beetle, eastern spruce budworm, and spruce bark beetle using pheromone traps. This information is used to predict infestation levels in future years and enables provincial governments to advise producers when pest infestations are likely and what control measures will be effective.

Provinces typically warn visitors to refrain from importing elm wood to prevent the spread of dutch elm disease and often restrict the commercial movement of timber from known pine beetle infested areas.

ISSUES

General

The necessity to have integrated warning systems to effectively warn the public and private sectors of Canada of pending disastrous events requires that all levels of government and the private sector work closely together to develop strategies. These strategies include monitoring and detection, interpretation and dissemination, warning, management and response of and to all environmental and natural hazards. Governments at all levels have recognized this responsibility. However, in times of fiscal constraint the "political will" to make available the required resources, both the organizational structure and funding, is somewhat diminished.

Issues involving education and public awareness, communication, and technological advancements pertaining to warnings are dependant on the appropriate resources being available and are discussed in further detail.

Education and Public Awareness

Emergency Preparedness Canada, Environment Canada and provincial emergency measures organizations such as the Alberta Public Safety Services and the British Columbia Provincial Emergency Program are examples of the many government organizations that have the responsibility of warning the public of pending disasters. Such warnings depend upon the public awareness, reception, interpretation and response to the actual warnings.

Government organizations make extensive use of the media, both print and electronic, to warn the public of what to do in an emergency. Telephone directories across the country contain health and safety messages on what to do in case of emergencies (electrical storms, tornadoes, earthquakes, etc.). A large percentage of the public is not aware of these warnings. Emergency measures organizations at the provincial government level deliver educational courses to municipal officials and first responders who have a responsibility for further dissemination of emergency preparedness to the general public. Financial constraints limit a municipality's ability to deliver the appropriate awareness to its residents. The increasing number of different ethnic groupings across Canada require that public officials have the ability to deliver emergency preparedness programs and, in particular, warning messages in a multitude of languages.

Emergency measures organizations such as Alberta Public Safety Services, through its training school, delivers central and extension courses to thousands of people each year but reach only a small percentage of those who could benefit from emergency preparedness training. Additional funding and resources should be identified and made available to deliver these programs to more people.

Within the private sector, the Canadian property and casualty insurance industry, through the Insurance Bureau of Canada, has been particularly pro-active in assembling representatives from concerned government bodies, and other public and private organizations, and engaging in joint public awareness activities related to disaster preparedness. The British Columbia group, headed by the Insurance Bureau of Canada, is called Pre-Emergency Planning (PREP). The group has distributed brochures in several languages outlining residential and commercial emergency preparedness and loss prevention pointers. More such initiatives by the private sector are needed.

Communications/Dissemination of Warnings

Canada does not have a national emergency warning system in place and is only now addressing the need to have such a system in place to effectively warn the public of a pending disaster. Alberta has completed a successful Emergency Public Warning pilot project utilizing a broadcast transmission network comprising all commercial AM and FM Radio, Television and Cable Transmission outlets in the Edmonton and surrounding area. To expand this initiative province-wide and for the federal government to implement an All Channel Alert System across the country requires government funding and resources yet to be identified.

Additional Technological Issues

Atmospheric Environment Services

Environment Canada has identified several issues requiring additional technological advancement, cooperation among agencies, additional funding and organizational resources:

- Additional electronic observing networks in Canada's forest environment.
- An expanded Lightning Network.
- Adequacy of the Doppler radar network in Canada. Major population centres are not covered by this technology which is essential for detection of atmospheric conditions that could lead to tornadoes and other hazardous weather phenomena.
- Lack of microburst detection technologies at Canadian airports. Delay in funding for a minimum system at the third busiest terminal in North America, Toronto Pearson International Airport.
- Lack of developed technologies for the detection of atmospheric conditions with aircraft icing potential and techniques for forecasting its occurrence.
- Adequacy of marine weather data acquisition systems generally and wave measurement technologies specifically. Current measurement systems do not report the highest wave height but rather the "significant wave height" which is the height of the average of the highest third of the waves. Also, these systems typically do not report wave direction nor wave slope.
- Adequacy of public education programs for summer, winter and marine severe weather.
- Inadequacy of climate change prediction models.
- Wind pressures in the National Building Code of Canada do not include the extremes due to tornadoes.
- The presence of icebergs off Canada's east coast is a potential threat to virtually all offshore activity during most of the year. This threat is primarily due to the fact that although technology and computerization has advanced tremendously during the past decade environmental conditions over waters along Canada's east coast are among the most complex in the world. Resultant and continually changing weather conditions make visual iceberg observation ineffective in our waters. We must rely heavily on the use of remote sensing and the development of related technologies. This requires continued interpretive training and development of automated techniques. Also, existing iceberg databases are not generally suitable for the determination of distribution statistics and require specific knowledge by the user. Iceberg climatology, as it exists, must be corrected for use in future plans, designs and key decisions to ensure safe

operations for offshore oil drilling and other offshore facilities.

- To provide emergency response to remote northern sites and the Arctic within the responsibility of Environment Canada and the Atmospheric Environment Service, a requirement exists where Environment Canada may seek the assistance of other government agencies or be called upon by them to establish temporary Emergency Control Centres, probably, but not limited to, remote locations. This would require the provision of expertise and services and possibly staff necessary to operate such centres. There is no real contingency for this built into the Ice Program.

- The use of reconnaissance aircraft may be required for the visual and/or remote sensing monitoring of offshore oil spills in areas beyond the normal operational area of interest which would require additional flying and funding.

- Weather Service Offices are intended to provide centralized service to Canadians at the local level. Weather forecasting, climate, air quality and ice services are not presently centralized under one roof. Continued planning and integrated development will be required to achieve this.

- Potential commercialization of product will require development of new strategies and accounting procedures, and will involve private sector partnerships.

Deficiencies -- Drought Warning

On the Canadian Prairies the cause of drought includes the presence of a quasi-stationary mid-tropospheric high pressure ridge over the region. The causes of the persistence of this ridge are not certain but there are indications that a relationship exists with the Pacific-North America oscillation pattern. Other patterns and relationships exist between precipitation anomalies and circulation patterns such as the often publisized ENSO. These relationships may form the basis for long range (one month to one season) predictions of drought occurrences.

A working group met to discuss this issue at the National Hydrology Research Institute at Saskatoon in April 1993. The group's recommendations strongly endorsed the availability of data to users, research into teleconnections over various Canadian regions and development of long-range prediction techniques and routine long-range forecasting. A connection with a U.S. proposed International Research Institute for Climate Prediction was recommended.

INDUSTRY AND THE PRIVATE SECTOR

Canada has perhaps the most highly developed communications systems in the world, with an exceptional quality of service. Canadian systems planners already assist many nations in upgrading their systems and can contribute to making them more resistant to natural disasters.

Canada has strong capabilities in conventional radio communications, having pioneered "tropo scatter", "meteor burst", and other remote long-distance communications systems. Canada has well established high frequency systems as well as shorter range portable systems to mobile and remote sites. Canadian microwave capabilities, while perhaps less directly relevant to IDNDR, are already exploited internationally to provide the point-to-point heavier route capabilities to act as a spine to extensive systems with local coverage.

Canada has been a leader in the exploitation of space for communications. Space-based communications are, by their nature, uniquely adaptable to disaster situations of many types. The fact that communications of almost arbitrary capability-from low rate telex and voice to full high definition television-can be provided to geographically isolated vehicles or sites without use or control of surrounding territories, makes space communications a prime technology to serve remote areas or to restore services in the event of failure of other systems such as fibre optics systems. Assuming the availability of hardware, it is relatively easy to airlift a transportable space communications terminal to either establish services where none existed or to recouple local distribution networks to national systems.

Furthermore, space communications are readily established in areas and times of potential concern. These communications systems can range from rudimentary unattended stations, transmitting back critical data such as weather, tidal water level, or seismic activity, to elaborate communications systems based on manned observations and assessments of local environments and situations.

Because of its large landmass, coupled with its advantageous position as a technologically advanced nation, Canada has been a leader in technologies of remote sensing of all types for many diverse purposes. Many of these technologies are relevant to the assessment of regional or local susceptibility to natural disasters. For example, the technology which allows the search for oil-bearing strata geologically, also provides data regarding faults and earthquake susceptibility in this or other ground; the airborne radar and optical sensors which map resources can also provide the data for analyses of susceptibility to disaster and post-disaster evaluations, including such risks as flood plains, erosion, mud and rock instabilities, etc.

Canada has exploited air and space remote sensing for a wide range of applications including mapping, resource analysis, land use and evaluations after natural disasters. Canada has developed not only the ability to receive and prepare images from space observations but also has the highly developed "value-added" industrial and university infrastructure to analyze and interpret the images. For example, analyses of space-based remote sensing multi-spectral imagery has provided routine crop and forest inventory data as well as wide-area assessments of insect infestations and disease. These images can provide the basis of land use allocation including classification of the nature and severity of potential natural disasters. These high resolution images can also provide detection of the ignition of forest fires, as well as damage assessments. While the coverage of multi-spectral imagery and the delays in processing suggest it is most useful in before-and-after assessments, the initial detection can be achieved by lower resolution broad coverage imagery, such as is provided by the weather satellites. This general imaging capability will be substantially augmented by the launch of the European Remote Sensing Satellite (ERS-1) and the recently announced Canadian Radarsat Program. These satellites will provide synthetic-aperture, high-resolution radar imagery with all weather capabilities to complement the optical-infrared images from EOSAT and SPOT. It is noteworthy that Canada not only has the ability to receive, distribute, and analyze imagery from these and similar sensors, but also is already a major international supplier of relevant equipment, software, and expertise.

In transportation-related communications, Canada has world status in such areas as Short TakeOff and Landing (STOL) aircraft, bush planes, all-terrain vehicles, water bombers and snowmobiles, all of which have applications in particular disaster situations. Weather monitoring buoys and small, handheld radios are also used internationally, to varying degrees.

V. INTERNATIONAL COOPERATION

GOVERNMENT ACTIVITIES

EMERGENCY PREPAREDNESS CANADA (EPC)

Through NATO, Canada has collaborated on emergency preparedness with Central and Eastern European/former Soviet Union countries. This initiative has given rise to two seminars (November 1992 and May 1993) during which representatives of these countries were briefed on Western approaches to civil emergency preparedness. Canada, in collaboration with the Czech Republic, prepared a third seminar, held in March 1994, on the theme of transportation of dangerous goods and industrial safety.

Emergency Preparedness Canada has printed and distributed *Guidelines for the Design and Construction of Mobile Command Posts and Similar Emergency Vehicles* in English, French, and Spanish as a contribution to the IDNDR.

A conference has been put forward by Canada as an IDNDR initiative for summer 1996. Emergency Preparedness Canada will support the Disaster Preparedness Resource Centre at the University of British Columbia in the preliminary organization of this conference at which Canada and Pacific Rim countries will address earthquake-related topics.

FISHERIES AND OCEANS CANADA

Tsunamis: Canada has been a member of the International Coordination Group for the Tsunami Warning System in the Pacific (IOC/ITSU) since 1965. At the fourteenth session of ITSU, Tokyo, September 1993, Canada volunteered to serve as a member of an ad hoc Working Group on Tsunami Public Education and Awareness. One task assigned to the Working Group is preparation of the textbooks on Earthquakes and Tsunamis, produced by Chile during the intercessional period, for publication (these texts were produced in Spanish, along with draft English versions). Canada will coordinate this activity and provide the revised English version to the Chairman of ITSU by June 1994. In response to a recommendation of the IUGG/IOC Tsunami '93 Symposium, an ad hoc Working Group was also formed to develop standards for surveys of tsunami runup and damage. The Canadian representative is one of the three members of this group.

NATURAL RESOURCES CANADA

A. GEOLOGICAL SURVEY OF CANADA (GSC) -- Geological Hazards

Earthquakes: Canada provides assistance internationally in seismological training, earthquake monitoring and earthquake hazard assessment. Through the Geophysics Division of the GSC and its predecessors, the Dominion Observatory and Earth Physics Branch, technical support has been provided to UNESCO for development of a seismograph network in southeast Asia, and to CIDA for development of a seismograph network in Colombia. Additional training is being arranged for Colombian seismologists.

The GSC has been instrumental in launching the IDNDR Global Seismic Hazard Assessment Program (GSHAP), under the National Lithosphere Program, one of the Decade's international demonstration projects. GSC staff took the lead in developing a program, in defining the technical guidelines for GSHAP's seismic hazard assessment and advising the GSHAP Coordinating Centre. The response of international agencies to funding requests for GSHAP has been disappointing.

Landslides: Canada is a leader in several aspects of landslide research and is involved in a number of international cooperative programs addressing landslides. In 1992 and 1993, under the auspices of the Japan Science and Technology Fund, GSC scientists collaborated with the Disaster Prevention Research Institute of Kyoto University in Japan, on dynamic models of rapid landslide behaviour and predictive models of landslide occurrence. In addition, collaborative work between French research institutions and Canadian researchers was carried out mainly in the field of rock slope movements. This was reflected in a strong Canadian participation in the Pierre Beghin Symposium on Rapid Gravitational Mass Movements held in Grenoble, France, December 1993. Cooperative research was also conducted with the U.S. Geological Survey on a variety of topics, including the effect of global warming on landslide occurrence, landslide dams, and rock avalanches. Finally, Canadians have made very significant contributions to the International Symposia on Landslides, where it was evident that Canadian work leads the world in several aspects of landslide research, notably stability analysis, dynamic analysis of landslide movements, landslide-groundwater relationships (piezometry), and the development of critical case histories of landslides.

Volcanic Eruptions: Because of the proximity of active volcanoes in Alaska and the American Pacific Northwest, Canada must undertake volcanic response planning, monitoring and impact evaluation. As a part of this effort, Canada has made significant advances in educating pilots and aircraft maintenance personnel on the hazardous effects of volcanic ash on aircraft engines and frames. Reporting of ash encounters is now mandatory and enables an assessment over time of the impact of volcanic ash on planes. SIGMETs and NOTAMs ("notices of SIGnificant METeorological events"and NOtices To AirMen") have been standardized for dealing with volcanic ash and the implementation of other specialized types of notification is under review.

Snow Avalanches: Canada contributes to international efforts on avalanche safety through scientific conferences, meetings with avalanche institutes in other countries and biennial International Snow Science workshops. Although the 1991 withdrawal of federal support for avalanche research has made it difficult to disseminate Canadian research results internationally, the Canadian Avalanche Association maintains regular contact with a similar organization in the United States, as well as the International Commission on Alpine Rescue.

Meteorite Impacts: Few meteorite impacts have occurred within any single nation, therefore the development of a global astronomical warning system may represent the best approach to preparing for such events.

Canada has a relatively high number of craters, is very involved in related research, and enjoys an international reputation in the study of impact processes. Significant research has also been undertaken on craters in the former Soviet Union and recently discovered craters in Europe. This information, as well as that obtained from craters elsewhere, must be integrated for a clearer picture of the processes operating during and following large impact events to emerge. Rapid contributions to this understanding can be made through international multi-disciplinary studies of impact craters.

B. CANADIAN FOREST SERVICE

Wildfire: Under sponsorship of the World Bank, Canadian fire management specialists recently participated in a technical assistance visit to Byelarus (in the former Soviet Union) and prepared a report on forest fire protection, including the special problem of irradiated forests. Similar technical assistance visits have recently been made to Greece and Indonesia. The Canadian/U.S. Reciprocal Forest Fighting Arrangement permits the international exchange of suppression resources during fire emergencies.

In research, the Fire Behaviour Prediction System has been implemented in New Zealand and the State of Alaska, and is being evaluated in several other countries. Joint studies are being conducted with U.S. scientists on fire behaviour and smoke management. Canadian scientists are collaborating on a study of stand-replacing fires as part of the International Boreal Forest Research Association. These scientists are also studying the effects of savannah burning on the atmosphere as part of the Southern African Fire-Atmosphere Research Initiative. Finally, they are cooperating with NASA scientists on using satellite imagery to inventory global biomass burning.

CANADIAN INTERNATIONAL DEVELOPMENT AGENCY (CIDA)

The Canadian government's official assistance to developing countries is provided by the Canadian International Development Agency. CIDA focusses primarily on multilateral efforts when responding to disasters. Two main funding channels are available: the International Humanitarian Assistance Program and the Food Aid Centre.

CIDA funds are channelled through international organizations such as United Nations agencies, the Red Cross and Red Crescent Societies, Canadian non-governmental organizations and, occasionally for food aid, through governments of the affected countries. CIDA's response to an emergency is determined on the basis of international burden sharing of the assessed needs. The objective is to ensure that the assistance provided through the various channels is complementary, timely and effective. To improve the coordination of international disaster response, CIDA actively supports the United Nations Department of Humanitarian Affairs (DHA).

Food Aid Centre

When a disaster is of a type that requires food aid, CIDA's activities are coordinated through the Food Aid Centre. The Centre makes core funds available to the World Food Program, usually to enable the local purchase of food to meet needs during the first critical weeks of a disaster while formal appeals are being launched. A recent example of such direct funding to the World Food Program for a specific emergency was the Food Aid Centre supported regional purchase of rice for flood-affected people in Nepal. The World Food Program may also meet short-term food requirements by temporarily diverting food, provided by donors for development programs, to the emergency situation.

Cash pledges to the World Food Program from CIDA's Food Aid Centre help finance the Global Information and Early Warning System, a world-wide crop and food surveillance system managed by the UN's Food and Agricultural Organization and World Food Program. The Global Information and Early Warning System is the principle monitoring mechanism used by the Food Aid Centre in planning disaster responses. Information obtained through the Global Information and Early Warning System is supplemented by information received regularly from the U.S.-based Famine Early Warning System which monitors conditions in the Sahel and southern Africa, as well as reports from non-governmental organizations and Canadian missions in the field.

Food Aid Centre funds may also be channelled through CIDA's bilateral programs to NGOs in support of feeding projects in disaster-affected areas such as occurred in 1992 in response to drought in southern Africa. In addition, a small fund exists within the food-aid budget to directly support NGO responses to food emergencies.

An increasing share of Canadian food aid is provided as an emergency response. This share has grown from 25% of the food-aid budget in the early eighties, to about 60% in 1992/1993. This increase in emergency response was only possible through a reduction in food aid for development purposes, and brings into sharper focus the links between emergencies, post-disaster rehabilitation and development.

A current priority of the Food Aid Program is to strengthen the links between food aid and food security. In an effort to focus on these linkages, the Food Aid Centre recently provided a special contribution to help initiate a World Food Program activity entitled, "Disaster Mitigation and Famine Prevention in Africa". The program will explore ways to use food aid in conjunction with cash inputs from other agencies to prepare for, lessen the impact of, and speed the recovery from food emergencies.

International Humanitarian Assistance Program

CIDA's International Humanitarian Assistance (IHA) Program funds non-food assistance such as immediate medical aid, emergency water and sanitation, temporary shelter and resettlement. The IHA program does not fund in-kind contributions or the transportation costs thereof, or such things as search and rescue teams or unattached experts. IHA believes that cash contributions are the most effective form of assistance, and that local procurement should be used where feasible.

The IHA program currently supports a variety of disaster preparedness programs in developing countries. Funds are channelled through the UN's Department of Humanitarian Affairs, the World Health Organization and the Pan American Health Organization, and the UN Development Program. The type of activities funded include disaster management training, and the development of regional emergency telecommunication systems including related training and testing. IHA also supports community based activities to enhance local disaster preparedness and believes that greater interest and involvement of NGOs in community-based preparedness activities could be particularly worthwhile. The IHA program provided core funding to the Canadian Council for International Cooperation to establish a disaster prevention and preparedness fund aimed at promoting NGO involvement in such activities as part of the IDNDR. IHA also provided support for IDNDR activities and publications organized by the Pan American Health Organization and the World Health Organization in the Caribbean.

Bilateral Programs

Serious, prolonged and/or frequent natural disasters such as drought, insect infestations, or flood can impede normal development assistance efforts. CIDA's bilateral programs in disaster-prone regions incorporate flexibility to facilitate appropriate responses as necessary. In particular, agricultural output and food availability are often affected by disasters. A relatively heavy concentration on food aid assistance may be adopted in regions prone to such disasters.

Infrastructure and human resource development projects increase local capacities to manage disasters by enhancing transportation and communications networks and by increasing the supply of skilled personnel. The positive effects of such development was demonstrated during the recent drought in southern Africa. In this case, emergency responses were facilitated by improvements made to the regional transportation network prior to onset of the drought.

Non-Governmental Organization Division

Non-Governmental Organization (NGO) Division supports the programs and projects of NGOs working in developing countries. Within NGO Division, CIDA's has established the Reconstruction and Rehabilitation (R&R) Fund administered by the NGO umbrella organization the Canadian Council for International Cooperation (CCIC). The R&R Fund supports Canadian NGOs providing such post-emergency assistance. NGO Division also administers the food-aid emergency response fund.

INTERNATIONAL DEVELOPMENT RESEARCH CENTRE (IDRC)

Canada's International Development Research Centre assists scientists in developing countries to identify long-term, practical solutions to pressing development problems. Support is given directly to scientists working in universities, private enterprise, government and non-profit organizations.

Following the United Nations Conference on Environment and Development (UNCED), in 1992, IDRC has reinforced its role in contributing to sustainable development. IDRC does not have a Natural Disaster Reduction Program per se. However the Centre will not turn down a research proposal with a natural disaster reduction component if the main thrust of the project deals directly with the areas of research it has identified as pertaining to sustainable development.

IDRC is presently supporting a few projects in the area of natural disaster reduction or in related areas. In the Dongting Lake Region of China, the Centre supports the establishment of an experimental Geographic Information System site to design a spatially-related information database to assist in the management of this flood-sensitive region. In Costa Rica, a project will facilitate capacity building in remote-sensing imaging radar with applications in disaster assessment. IDRC administers a CIDA (Canadian International Development Agency) project to establish a library and information network for the International Federation of Red Cross and Red Crescent Societies (IFRC); this network will provide quick and easy access to a comprehensive base of information on Red Cross "know how," activities, programs and other humanitarian assistance efforts. The ultimate objective of this project is to strengthen the institutional capacity of the IFRC in its humanitarian assistance efforts and role as a

Secretariat to National Red Cross and Red Crescent Societies.

IDRC has also sponsored the development of a number of community-based water quality monitoring technologies and methods which would give communities in the middle of a natural catastrophe the means to test the suitability of drinking water. The sustainability engendered by such technologies would be particularly useful during or after natural disaster occurrence. IDRC is also sponsoring a growing number of community-based primary health care projects which would ensure that during any natural disaster occurrence, a critical mass of primary health care workers and services would be available and capable of managing basic health care needs.

In Central America, in 1992, IDRC helped create La RED, The Network for Social Studies on Disaster Prevention in Latin America, which is now regrouping 14 institutions in Latin America and Canada through three sub-regional nodes. The project will produce a reference typology of urban communities at risk, a comprehensive survey of degrees of vulnerability and a repertory of guidelines for the transfer to communities of the skills required to apply information relevant to prevention and mitigation initiatives. La RED stresses a balanced multidisciplinary approach, prevention and mitigation as opposed to relief and recovery. Its objectives are to design and provide training courses for local governments, NGO's and community based organizations, to produce a scientific review in Spanish of literature on disaster management for Latin America and to create databanks on specific urban risks microzoning which can be easily accessed by NGO's.

In mid-1993, IDRC approved funding for a Disaster Management Network linking institutions in Canada and Brazil. This project is the research component of a five-year training program funded by CIDA that aims to develop a core of specialists, training curricula and research modules to respond to local, regional and national needs created by "natural" disasters. Initially it will address Brazil's North-East's recurrent problem of drought management, thereby complementing the range of hazards covered by other networks supported by IDRC and other donors in the region.

The Canadian International Development Research Centre is also funding a project on seismic hazard assessment in Latin America and the Caribbean through the Pan American Institute of Geography and History.

MUNICIPAL ACTIVITIES

Many Canadian cities are twinned with cities throughout the world to share Canadian experience and expertise in emergency preparedness. The Canadian Federation of Municipalities could be a channel to further such contacts.

NON-GOVERNMENTAL ORGANIZATIONS (NGOs)

Canada has a large body of NGOs involved in a wide variety of disaster-related activities internationally. To provide an overview of these activities, a national NGO umbrella organization and two of Canada's largest and most active NGOs in international disaster response were consulted. Although a complete roster of Canadian NGOs involved in disaster-related activities is not currently available, a list of NGOs who have received funding in support of a disaster response overseas from the Reconstruction and Rehabilitation Fund (see below), has been included at the end of this chapter.

Canadian Council for International Cooperation

The Canadian Council for International Cooperation (CCIC), is a national coalition of 120 voluntary agencies committed to achieving global development in a peaceful, equitable and healthy environment. The Council is a coordinating body representing its members interests to the government, media and the public.

The Reconstruction and Rehabilitation Fund

The Reconstruction and Rehabilitation Fund (R&R), was established by the Canadian International Development Agency (CIDA), and the Canadian Council for International Cooperation (CCIC) in 1981. The R&R Fund channels federal funds through Canadian NGOs to overseas partner organizations working in crisis situations. The objective of the Fund is to shift the emphasis away from providing relief to enhancing local capacities to prepare for and respond to disasters.

The R&R Fund is allocated by a committee of experts from the NGO community and a CIDA representative. The Committee provides a forum for reflection on NGO experience in crisis situations aimed at improving the quality and long-term impact of projects. Canadian NGO responses to disasters and the reaction of their overseas partners to such actions are regularly reviewed and documented. This approach has highlighted the need for a greater emphasis on institution and network strengthening, human resources development, and improved communications, coordination and planning. Community workshops held in a post-recovery context have proved a valuable forum for supporting improvement in these areas.

There are three channels through which NGOs may access R&R Funds:

1) The Regular Fund

The Reconstruction and Rehabilitation Fund provides co-funding to Canadian NGOs for projects which renew community efforts to achieve sustainable development following a disaster. R&R Funds are also used to provide program support to NGOs in Canada and overseas through R&R research, training and outreach, and to promote education, advocacy, and policy development in Canada on disaster-related issues.

2) Special Funds

In the event of a particularly high NGO response to a disaster, a special fund may be allocated. Special Funds include an evaluation component whereby the results of the program are published and disseminated through NGO networks in Canada and overseas. Since the beginning of the IDNDR, R&R has administered two Special Funds responding to natural disasters. The Bangladesh Cyclone Reconstruction and Rehabilitation Fund was administered in 1991-1992. The Southern Africa Drought Fund was administered in 1992-1993.

3) The Prevention and Preparedness Fund

The Prevention and Preparedness Fund was established in response to the IDNDR. The objective of the Fund is to improve NGO awareness of the goals of the Decade, and to encourage them to support requests from disaster-prone countries for prevention and preparedness activities.

In 1990, in response to discussion at an IDNDR meeting on disaster preparedness in Latin America and the Caribbean, R&R became involved with a number of Caribbean and Canadian groups examining disaster response strategies. The collaborative process was documented in a widely disseminated report produced in 1991 by the R&R Fund, *Collaboration in the Aftermath of Disaster: A Study of NGO Consortia in Canada and the Caribbean.*

The Reconstruction and Rehabilitation Fund is currently compiling a series of information dossiers on disaster affected countries. The dossiers will include a roster of the Canadian NGOs responding to disasters in the respective countries.

The Canadian Red Cross Society

The Canadian Red Cross Society (CanCross), is an active and contributing participant in the work of both the International Committee of the Red Cross (ICRC), and the International Federation of the Red Cross and Red Crescent Societies (the Federation).

The ICRC works to protect and assist victims of armed conflict and civil strife, including military and civilian victims, prisoners of war and civilian detainees. The five main activity areas of the ICRC include protection, medical services, relief assistance, family tracing and dissemination. While mandated to operate mainly in conflict zones, the ICRC is also responsible for promoting and disseminating humanitarian law throughout the world.

The Federation focusses its operations on natural disaster zones and on areas outside conflict zones. Through its 161 member societies, the Federation coordinates relief and development operations and refugee assistance programs.

CanCross forwards funds, goods and/or personnel to both the ICRC and the Federation as contributions to their important work. As an example, more than one million dollars has recently been raised through public and government sources for relief efforts in response to the September 30 earthquake in India. In addition, CanCross is actively involved in funding disaster prevention and preparedness activities in China, Bangladesh, Costa Rica, and southern Africa.

CARE Canada

Responding to natural disasters is an integral part of CARE Canada's programming. CARE's responses are focussed primarily in countries where the agency already has an established operational presence (40 countries in Africa, Asia, and the Americas). CARE regularly responds to large-scale disasters such as flooding in Bangladesh or the recent earthquake in India. In addition, CARE provides assistance during and following the numerous smaller-scale emergencies that occur each year through an emergency fund, accessible to each of CARE's foreign missions in the event of a disaster in their country.

CARE teams work to support local capacities to conduct rapid needs assessments, to carry out emergency operations, and to incorporate longer term considerations into disaster response planning. Efforts are made to work with governments toward improvements in early warning, planning and human resource management.

To enhance CARE's disaster response capacity, CARE International has proposed the establishment of emergency response units (ERUs) in a number of CARE offices (Canada, the United States, the United Kingdom, Australia). The ERUs will coordinate the provision of funding, personnel, food, medical supplies and other materials, and will provide information and technical support to CARE's field offices. The ERUs will contribute to the development of an international roster of disaster/emergency response personnel. Finally, the ERUs will facilitate the flow of information from the field to the media to generate support for CARE's disaster response efforts.

Vulnerability Assessment

Capacities and Vulnerabilities Analysis is a methodological framework that highlights the characteristics that determine whether or not a natural event becomes a disaster. The framework is designed to assist in identifying people's vulnerabilities to disaster as well as their capacities to prepare for, withstand, and recover from the effects of disasters. By considering the variables that render people both susceptible and resistant to natural events, the impact of that event can be effectively predicted, evaluated and responded to. The framework helps in defining post-disaster responses that focus on reducing pre-disaster vulnerabilities and strengthening pre-disaster capacities; an important objective as a return to "normal" following a disaster leaves communities equally susceptible to future events. The use of Capacities and Vulnerabilities Analysis in disaster situations has been widely promoted through the Canadian development NGO community.

UNIVERSITY-BASED CENTRES

University of Manitoba, The Disaster Research Unit

The Disaster Research Unit of the University of Manitoba fosters interdisciplinary research on disaster-related problems in the Third World. The activities of the Unit include monitoring of existing disaster-prone areas, forecasting of potential disaster situations and consequent needs, and management strategies to mitigate the effects of such disasters. The Disaster Research Unit also provides education and training programs for people engaged in disaster response and management and supports institutional development through linkages with universities and institutions in the developing world. Two areas of recent focus for the Unit have been Bangladesh and Somalia.

- *Cyclone Disaster Response in Bangladesh*

Events in the 1991 cyclone disaster and their subsequent review and evaluation shows a number of vulnerabilities along the potential/realized disaster continuum. The type of economic, environmental and political control over the land militates against farmers seeking protection from cyclones away from their farms. The community interaction is characterized by severe competition and insecurity, which makes communal action on preparedness difficult. Thus, application of protection and security measures including cooperation, preparedness, resistance to hazards and access to resources is restricted.

Cultural contexts make women dependant on men for risk reduction. This limits the contribution of women to disaster preparedness. Families headed by women have fewer assets than male headed families. In the economic context, these women have less physical protection and fewer resources for recovery than men, as they have limited access to resources.

During the realized disaster event, vulnerabilities in the psychosocial and sociobiological situational contexts were seen to be increased by inadequate prediction of the response of the population to the storm warning. Information was needed on two aspects. First, what type of security was required from within the community, that allows individuals at risk to give storm warnings priority? Second, what information can be interpreted correctly by people at risk? Panic in the responses could have been averted through the informed and appropriate institution of protective and security measures including preparedness, surveillance and communication.

- *Somali Women and Children in Disaster*

Women and children in disaster are subjected to a high degree of vulnerability particularly in developing countries. In the Somali conflict, women are being displaced from their households by a combination of the civil strife and drought. Concomitantly, there is an almost exponential increase in the number of women-headed households. These developments have so affected the households that there is a loss of access to economic means, impossible responsibility demands, a lack of support services, a severe reduction in protection and security for children, violence in the living environment and maladapted behaviours in both women and children.

High degrees of vulnerability are evident in economic, political, demographic, psychosocial and sociobiological contexts. The conflict has resulted in a demographic shift toward greatly increased numbers of older orphan children, many showing strong war-related trauma due to the violence in their lives. Although they require immediate therapeutic assistance it is not available for economic and political reasons. Young children have a biological need for security. This need is in a backdrop of women experiencing a range of traumatic events and displaying maladapted behaviours. Such behaviours include, feelings of hopelessness in association with increasing frustration, hysterical attacks and other forms of violent behaviour.

The reconstruction and rehabilitation of post-war Somalia will involve economically, politically, nutritionally, psychosocially and sociobiologically deprived refugees and displaced persons. Therefore, it is crucial to mitigate the medium and long-term effects of economic, political, demographic, psychosocial and sociobiological vulnerabilities through institution of appropriate protective and security measures. Application of these measures as soon as possible is important in order to secure the fullest potentiality of Somalia's productive opportunities.

University of British Columbia, the Disaster Preparedness Resource Centre

The mission of the Disaster Preparedness Resources Centre is to provide access to information and to facilitate research that supports counter-disaster planning and mitigation activities. The Centre is international and multi-hazard in scope, with a concentration on disaster planning and preparedness, and earthquake-related risks and their mitigation. A particular strength of the Centre is its electronic links to specialized documentation collections elsewhere in North America and overseas.

The Centre's information facilitator and its director are actively involved with their counterparts around the world in developing standards and a more formal consortium facilitating information exchange among counter-disaster research, documentation and planning centres.

The First International Pan-Pacific Conference on Earthquakes and Earthquake-Related Hazards

As part of Canada's contribution to the IDNDR, the Disaster Preparedness Resource Centre of the University of British Columbia, along with the Province of British Columbia and Emergency Preparedness Canada will host a conference: The First International Pan-Pacific Conference on Earthquakes and Earthquake-Related Hazards. The conference will be held in Vancouver, British Columbia in May 1996, and will bring together scientists, researchers, emergency management personnel, planners and others. Linked by a common risk, earthquakes, countries from around the Pacific will be invited to participate and share their research and experiences. The main focus of the conference will be on the 4 R's: Research, Risk, Readiness and Recovery, and will stress the 4 C's: Cooperation, Communication, Coordination and Community. The conference will provide a unique opportunity to share findings and to develop social and scientific networks for the future.

Université du Quebéc à Rimouski, The International Society for the Prevention and Mitigation of Natural Hazards

The International Society for the Prevention and Mitigation of Natural Hazards was formally established in August 1988 with its headquarters in Canada. The more common name of the Society is the Natural Hazards Society (NHS). The major objectives of the Society are:

- to promote research in all aspects of natural hazards
- to assist in the distribution of preparedness and emergency response plans for countries around the world

- to assist in the formation and implementation of educational programs on hazards and mitigation.

The NHS organizes international meetings in different parts of the world every few years, with special symposia on topical natural hazards studies. The meetings have so far been held in Honolulu, U.S.; Rimouski, Canada; Ensenada, Mexico; Perugia, Italy; and Qingdao, China. In addition, NHS co-sponsors appropriate scientific meetings, summer schools and workshops organized by other bodies. *Natural Hazards: An International Journal of Hazards Research and Prevention* is now the official scientific publication of the Society. The Journal is published at regular intervals by Kluwer Academic Publishers in the Netherlands.

Industry and the Private Sector

Due to Canada's relatively severe environment and large, sparsely populated areas of land, many problems routinely faced within Canada are similar to those occurring during or after a significant disruption or disaster elsewhere. Canadian industry, in reflecting the nature and environment of the nation, has developed strong capabilities in many areas relevant to the IDNDR. Canada's consulting community has been involved in project management and supervision worldwide and offers a variety of organizational skills of importance to disaster planning and management.

Canadian consultants are involved in carrying out hazard assessments, designing structures and facilities, and training of local engineers in some of the most seismically active areas of the world such as Nepal, Iran, and Papua New Guinea. Similarly, several Canadian consulting companies are actively working on major flood protection projects internationally. Several of these projects are funded by provincial agencies within Canada and by the federal government through the Canadian International Development Agency (CIDA).

Canada's varied geography has resulted in the development of particular skills within the civil engineering consulting sector that are relevant to natural disaster reduction. Such specialist capabilities have evolved out of assignments for government and industry, and at times, in cooperation with university research laboratories. Initially, providing services for the development of major transportation, power, industry, and infrastructure projects within Canada, the sector now performs a large percentage of its work overseas. Although consultants have played a minor role in planning for and responding to natural disasters in the past, such private sector participation could be enhanced. The Canadian civil engineering contracting industry has many highly skilled engineers and managers, as well as an large inventory of heavy equipment. Additional mechanisms facilitating the mobilization of these contracting resources in response to natural disasters should be identified.

The geotechnical consulting community in Canada has a strong international reputation. The community has expertise covering a wide range of geological conditions and soils types due to its involvement in domestic and international projects in the areas of transportation, marine structures, and mining and energy. Canadian geotechnical companies have carried out detailed investigations of landslides and have developed specialized movement monitoring instrumentation suitable for worldwide application. Slope stability and protection is also an area of Canadian expertise with international application.

Canada's wind engineering sector, in addition to designing wind-resistant structures, is also involved in hazard zoning and land-use planning. This work facilitates the development of building codes for low cost housing in high density population areas and is applicable worldwide.

Specialized consulting expertise has been developed on desertification as a result of erosion, soil salinity and related problems in the Prairies. Several companies are working internationally in this area, particularly in the Sahara Desert region. This area represents a significant opportunity for Canadian participation in IDNDR.

Canada's problems with a number of insect plagues have led to the development of expertise in this sector which, with greater mobilization of specialized contracting resources, could contribute to addressing insect plagues internationally.

The recreational industry in Canada provides equipment such as sleeping bags, tents, cooking equipment and food suitable for survival in difficult environments. The industry also supplies axes, chain saws and other equipment and supplies associated with recovery operations.

Although not a large exporter of remote sensing equipment, Canada has a strong international position in processing and interpreting the data obtained by it. These activities are important to meeting the challenge of the IDNDR and represent an area in which Canada can make a significant contribution. Canadian universities and high technology companies have made notable progress in developing advanced instrumentation for dealing with resource and environmental problems.

NON-GOVERNMENTAL ORGANIZATIONS

List of NGOs funded through the R&R Fund, CCIC for Disaster Response

Adventist's Development and Relief Association Canada (ADRA)
African-Canadian Council
Association Mondiale des Radiodiffuseurs Communautaires (AMARC)
Anglican Church of Canada/The Primate's World Relief and Development Services
Canadian Baptists Overseas Mission Board (CBOMB)
Canadian Catholic Organization for Development and Peace
Canadian Council of Churches (CCC)
Canadian Feed the Children (CFC)
Canadian Friends Service Committee (CFSC)
Canadian Jesuit Missions
Canadian Lutheran World Relief (CLWR)
Canadian Organization for Development Through Education (CODE)
Canadian Physicians for Aid and Relief (CPAR)
Canadian Red Cross Society
Canadian Saints Outreach
Canadians for Education, Development and Reconstruction International (CEDRI)
CARE Canada
Carrefour de Solidarité Internationale
Carrefour des Cedres
CAW Social Justice Fund
Centre d'etude arabe pour le developpement (CEAD)
Christian Children's Fund
Christian Reformed World Relief Committee of Canada (CRWRC)
Club 2/3
Centre Mission Oblates
Coady International
Comite de Solidarite Tiers-Monde de Trois-Rivieres
CUSO
Developing Countries Farm Radio Network
Emmanuel International
Eritrean Relief Association in Canada (ERAC)
Farmers for Peace
Fondation Leger
Fondation Les Batisseurs de L'espoir en Haiti
Help the Aged
Hope International
Horizons of Friendship
Human Concern International (HCI)

Interchurch Fund for International Development (ICFID)
Inter Pares
International Development and Refugee Foundation (IDRF)
Jesuit Center
Medical Aid for Palestine (MAP)
Match International
Mennonite Central Committee
Operation Eyesight Universal
Organisation canadienne pour la solidarité et le developpement (OCSD)
Oxfam-Canada
Oxfam-Quebec
Plenty Canada
Pueblito Canada
SalvAide
Save a Family Plan
Save the Children - British Columbia
Save the Children - Canada
SOPAR
South Asia Partnership
Steelworkers' Humanity Fund
SUCO
Trans Himalayan Relief Association (TRAS)
Unitarian Service Committee (USC) Canada
World Vision Canada
World Relief Canada
World Concern
YM-YWCA

VI. EVOLUTION OF A CANADIAN PROGRAM FOR THE IDNDR

The targets accepted by the UN General Assembly for the IDNDR are, that by the year 2000, all countries, as part of their plan to achieve sustainable development, should have in place:

- comprehensive national assessments of risks from natural hazards, with these assessments taken into account in development plans
- mitigation plans at national and/or local levels, involving long-term prevention and preparedness and community awareness
- ready access to global, regional, national, and local warning systems and broad dissemination of warnings.

While some progress has been made broadly in the establishment of national committees and setting up special demonstration projects, much is still needed even to reach these minimal targets. Although Canada has been active in the sponsorship of the Decade in the United Nations, the formation of the National Committee and the evolution of a program of action has been more hesitant. There is a need to stimulate some action if Canada is to meet these targets nationally and to make a more significant contribution internationally.

The following identifies, from the national and international perspectives, several essential areas and new initiatives.

NATIONAL

Assessment of Natural Hazards, Vulnerability and Risk

Assessment of the risks from natural hazards is central to the effectiveness of mitigation and preparedness of natural disasters. Principal users are those responsible for emergency management, insurance, building regulation, agriculture, planning and preparedness for protection from floods, storms and other hazards.

Risk assessments requires, on the one hand, the continued updating of knowledge of frequencies, intensities and spatial distributions of the major natural hazards in Canada, and on the other hand the estimation of the vulnerabilities of various sectors and communities to those hazards. (Note: risk = hazard x vulnerability.) Work is needed in both of these areas as well as in the evaluation of the effectiveness of current methodology. Special attention is needed to examine climactic and other trends in these risk data.

A further important need is the development of comprehensive risk management models to assess the actual benefits of present standards and practices and demonstrate the potential benefits of possible improvements. In addition, a series of hazard, vulnerability and risk maps, adapted to the wide variety of users from emergency planners to civic officials, real estate developers, builders, insurers, and home buyers, should be prepared. In developing these maps the principal users should be brought together to define the requirements.

Implementation of Mitigation Measures

Review is required of current mitigation programs on a province by province basis. Examples of where this would be effective are:

- Flood damage reduction: The economic benefits and costs of the Federal-Provincial Flood Damage Reduction Program, introduced in 1975, as well as the risk analyses, should be studied with the objective of demonstrating the strengths and weaknesses of this pioneering program. This should result in improving the zoning of flood plain regions and increasing awareness with key individuals and institutions who need to know, such as civic planners, the insurance industry, builders and home buyers.

- Earthquake preparedness and loss prevention: Although to date major earthquakes in Canada have taken place mainly in unpopulated areas, the potentiality of a major impact on a metropolitan area exists. The emergency preparedness plans and simulations which have been enacted, principally on the West Coast, should be closely monitored and assessed for their effectiveness and application to other regions. Government and the insurance industry should also work together to assess the country's financial capacity to respond to the recovery demands of such an event, and to identify practical preparedness and loss prevention approaches.

- Canadian Disaster Investigation Panel: In the event of a major natural disaster such as an earthquake or tornado, in which there is significant structural damage, much valuable insight into the performance of structures may be lost unless experts can visit the site soon after the vent. For this to happen, it is necessary to identify a panel of experts who have indicated their availability and from which a site visiting team can be selected to develop guidelines to be followed and to obtain the necessary authorization and assistance to visit the site. To undertake this requires a small secretariat and networking facilities.

- Provincial and federal disaster management programs: In addition to a general overview of these programs, a comprehensive overview of drought management should be undertaken in the light of increased international experience.

- Provinces should be asked to review zoning and land use in the light of risks identified above.

Warnings

Warnings of natural disasters from severe weather events, including storms, floods and droughts, and the dissemination of warnings should be reviewed for their effectiveness. The needs of special groups such as children and the handicapped and those in remote regions should be considered.

INTERNATIONAL

The Canadian National Committee (CNC) is taking a proactive role with government departments and international funding agencies to develop a program of major projects on aspects in which Canada has particular expertise.

The CNC is planning to act in a program management capacity by entering into partnerships with learned societies and professional associations for the initiation and implementation of projects.

Such projects may include initial feasibility studies to define and scope larger projects, pilot projects targeted to specific countries to develop methodologies and further develop the applications, and international projects to apply the results more generally. Projects will be initiated on such topics as structural quality and address risks from wind and earthquake effects. The feasibility studies would be carried out by panels of experts. The pilot projects would be conducted in areas where major events had occurred recently and be bilaterally funded with participation by Canadian and local experts and executed by contractors. The international projects would be multi-laterally funded and involve international teams of experts.

The CNC would hold workshops and international conferences to assist in the dissemination of the results of the projects.

Technical Cooperation

Canada is a world leader in providing international financial and other assistance after a disaster occurs. Programs of technical cooperation should be strengthened to more strongly emphasize prevention and disaster loss reduction. It must be recognized that in many developing countries, sustainable development cannot be achieved without vigorous disaster loss reduction measures. Linkages with other National Committees should be established. Opportunities should be sought to widen the usage of Canadian equipment, products and expertise to mitigate disasters (examples include forest fire fighting equipment, general information and warning systems related to disaster management, communications equipment, remote sensing, etc.)

Engineering and Scientific Programs

Canada will provide leadership and participation in a few selected international programs. Examples include:

- *GSHAP, landslides and large river floods.*

- *The reduction of natural disasters through the improvement of structural quality.* An important contributing factor to the structural damage from earthquake and windstorm is poor quality of construction. This lack of quality may originate in the design stage, the materials supply stage or during the construction itself, and can arise at all levels of the construction industry. The evidence is that good quality construction survives and that improved quality is cost effective not only in preventing failures during disasters but also in improving the general serviceability of buildings.

  The subject of the proposed project is to understand the operational, technical, economic and social factors affecting the industry well enough to identify ways to assure quality. This activity would be carried out in liaison with the World Federation of Engineering Organizations..

- *Assistance in development of building codes.* These projects would involve the development and application of appropriate building codes based on the National Building Code of Canada. These would be designed to suit local construction practices, materials and environmental conditions, and would provide a framework for implementation of research results.

Publications

Initiatives should be taken to publicize successful Canadian contributions to disaster loss reduction in national and international newsletters and journals.

IDNDR Secretariat (Geneva)

Canada will consider the best means of providing assistance to the IDNDR Secretariat in Geneva in order to provide input to the program and obtain feedback.

APPENDIX A

Canadian National Committee for the International Decade for Natural Disaster Reduction

Dr. Alan Davenport (*Chair*)
Director
Boundary Layer Wind Tunnel Laboratory
University of Western Ontario

Dr. M. J. Berry
Director General
Mineral & Continental Geoscience
Geological Survey of Canada

James Bruce (ex officio)
Chair
Scientific and Technical Committee, IDNDR

Dr. R.G. Charlwood
Vice-President
Acres International Limited

René DeGrâce
National Director
International Services
The Canadian Red Cross Society

James Dunlop
Director, Protection Branch
Ministry of Forests, British Columbia

I.D. Mark Egener
Managing Director
Alberta Public Safety Services

Jim Ellard
Coordinator
Emergency Planning Ontario

Dr. Mohammed I. El-Sabh
Director
Département d'Océanographie
Université du Québec à Rimouski

Hon. John Fraser, P.C., Q.C.
Ambassador for Environment (EDX)
Department of Foreign Affairs and International Trade

Paul Kovacs
Vice-President of Policy Development
Insurance Bureau of Canada

Dr. Jan Loubser
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Dr. N.R. Morgenstern
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Department of Civil Engineering
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Vice-Admiral L.E. Murray
Deputy Chief of Defence Staff
Department of National Defence

Dr. Léopold Nadeau (ex officio)
Executive Director
Canadian Academy of Engineering

John Phelan
President
Munich Reinsurance Company of Canada

Dr. John Rogge
Director
Disaster Research Unit
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Valerie Warmington
Research Officer
Reconstruction and Rehabilitation Fund
Canadian Council for International Cooperation

Dr. W. Edgar Watt
Professor
Department of Civil Engineering
Queen's University

Danielle Wetherup
Associate Deputy Minister
Environment Canada

APPENDIX B

TERMS OF REFERENCE

CANADIAN NATIONAL COMMITTEE FOR THE INTERNATIONAL DECADE FOR NATURAL DISASTER REDUCTION

The Canadian National Committee for the International Decade for Natural Disaster Reduction (CNC/IDNDR) is established in order to promote activities and initiatives related to the IDNDR, according to the International Framework of Action for the Decade. The goals of such action, as stated by the United Nations are to:

- Improve the capacity of each country to mitigate the effects of natural disasters.
- Apply existing scientific and technological knowledge.
- Foster advances in science and engineering.
- Disseminate new and existing technical information.
- Develop activities for the assessment, prediction, prevention and mitigation of natural disasters through technical assistance and technology transfer, demonstration projects, education and training, and then, evaluate the effectiveness of these activities.

The CNC would be responsible to the Government of Canada and operate under the joint leadership of the Royal Society of Canada and the Canadian Academy of Engineering. To attain the goals and objectives of the Decade, the responsibilities of the CNC would include the following:

1) Provide the leadership, promote the development of, and coordinate a Canadian program for the Decade and identify priorities and initiatives, emphasizing the paramountcy of prevention and preparedness in disaster reduction.

2) Encourage participation from the various sectors of the Canadian community in the IDNDR, and request that they review and report on current activities in disaster reduction (e.g. assessment, prediction, prevention and mitigation) and recommend new initiatives.

3) Consider initiatives within Canada and internationally for improving land use planning, risk management, construction standards, public education, warnings, etc.

4) Endorse ongoing research where appropriate and increase new research (especially interdisciplinary research) where there are gaps in knowledge; mobilize scientific and engineering institutions; further the UN goal 2c (UN Resolution 44/236, Annex 2c);

5) Review and recommend initiatives in the areas such as rehabilitation, procurement and delivery of humanitarian assistance and aid;

6) Encourage partnerships between Canada and other countries.

7) Review and make recommendations concerning opportunities for disaster prevention in relation to aid and development programs (e.g., the Caribbean). Recommendations would be directed to the appropriate governmental and/or non-governmental organizations or bodies for consideration and implementation.

8) Participate in Canada's representation in matters relating to the Decade and provide liaison with the IDNDR Secretariat and other partners in the IDNDR.

9) Make recommendations in order to assure that Canada meets the targets internationally agreed for the decade.

SECRETARIAT OF THE CNC/IDNDR

TERMS OF REFERENCE

A small secretariat will be provided and will be located within the offices of the Royal Society of Canada to support the day-to-day operations of the CNC/IDNDR. Under the supervision of the Chair of the CNC/IDNDR, the Secretariat will:

- support the day-to-day activities of the CNC/IDNDR, including the planning and organization of meetings;
- respond as needed, to individual and Canadian organizations requesting more information on the mandate, objectives and activities of the CNC/IDNDR;
- assist the Chair with regard to his/her liaison role with other international programs;
- collect and organize information on Canada's resources in disaster-related services in order to set up a database of information in Canada's key areas;
- tracking revenues and administration of funds provided by the various sources of funding;
- prepare progress and financial reports as required, to the funding agencies;