An Assessment of Flood Risk Management in Canada

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Executive Summary

Canada has developed a worldwide reputation for its flood management programs. Despite this recognition, flood damages continue to rise. This paper provides some insight into the current practice of flood management in Canada and offers recommendations to address shortcomings.

Following an introductory chapter, the nature of floods and flood damages are described. The third chapter describes the Flood Damage Reduction Program with a particular focus on floodplain regulation. Efforts to distribute losses through disaster relief and insurance are outlined in the fourth chapter. The fifth chapter describes two recent floods in the Saguenay Valley and the Red River. Comments concerning the implications are provided in the last chapter.

There is no doubt that over the last 50 years Canadian flood managers have made tremendous progress in reducing the flood risks. However, the trend of increasing flood damages suggests that additional efforts are required. The research opportunities outlined provide a basis for future projects that could reduce future losses. The nature of flooding, the impacts from floods, assessment of flood programs and policies, and better understanding human behaviour during and after floods are important areas for future research. At a practical level, past experience suggests that a lack of commitment by some or all levels of governments has been associated with the implementation of programs. Recent floods have demonstrated the follies of this shortcoming. In addition, future programs will have to better involve municipal governments that have been often overlooked in the formulation of past programs. Important areas to consider for policy development pertain to the use of decision support systems, and improving flood response and recovery programs. These programs will also have to rely on collaborations with the private sector, particularly the insurance industry, which has a vested interest in reducing damage levels. Finally, reducing flood risks will require greater personal acceptance of responsibility by those living in floodplains.

Table of Contents

List of Figures

List of Tables

Floods are acts of God; flood losses are the results of acts of humans (White, 1945).

1.0 INTRODUCTION

While people cannot do much about floods, they can influence the nature and extent of flood losses. The latter can be achieved through flood management policies and programs. On the one hand, Canada has been identified as a leader in flood management. In 1975, Canada introduced the Flood Damage Reduction Program (FDRP), which was innovative for its time (Bruce and Mitchell 1995). The fact that many nations requested Environment Canada's assistance in mapping floodplains is evidence of the high regard for that program. Handmer and Parker (1992) identified Emergency Preparedness Canada (EPC) (now known as the Office of Critical Infrastructure Protection and Emergency Preparedness, or OCIPEP in short form) as a model that Britain could follow in enhancing its institutional arrangements for emergency planning and management. Some of these early successes with flood management initiatives and the accolades they had drawn internationally must be assessed in the context of massive flood losses. Between 1975 and 1999, 63 floods resulted in payments of almost $720 million (1999 dollars) through the federal government's Disaster Recovery Financial Assistance Arrangements program (EPC, 2000) (Figure 1.1). Between 1984 and 1998, insurance claims for flooding, which do not include residential losses, were in excess of $750 million (1999 dollars) (Insurance Council of Canada, 1998). Although the amount of damage varies dramatically on an annual basis, governments and the insurance industry are concerned about the recent and high incidence of catastrophic flood losses – particularly in the Saguenay region, Quebec, in 1996 and the Red River basin, Manitoba, in 1997. Despite our past best efforts, are Canadians becoming more vulnerable to flood hazards?

Recently, the collaborative aspects of Canadian flood management programs and their adequacy are questionable or to have failed. Environment Canada is not renewing any of the 10-year General Agreements under the FDRP. Budget reductions and administrative changes during the late 1980s and early 1990s led some Canadian water experts to conclude that the federal government was unable "to understand and deal with pressing water issues" (Bruce and Mitchell, 1995, vi). The unilateral withdrawal of the federal government raises two main concerns regarding the variable capacity and commitment of provincial and local governments (de Loë, 2000). First, provincial governments may abandon the underlying FDRP principles, and even if their commitment remained, smaller provinces could no longer rely on access to federal technical and financial assistance. Some governments have abandoned flood programs as illustrated by British Columbia's disbanded Floodplain Mapping Branch (Day, 1999). Second, if strong provincial commitment was lacking, municipalities may find it difficult to reject development in flood risk areas or may loosen restrictions of developing on the floodplain.

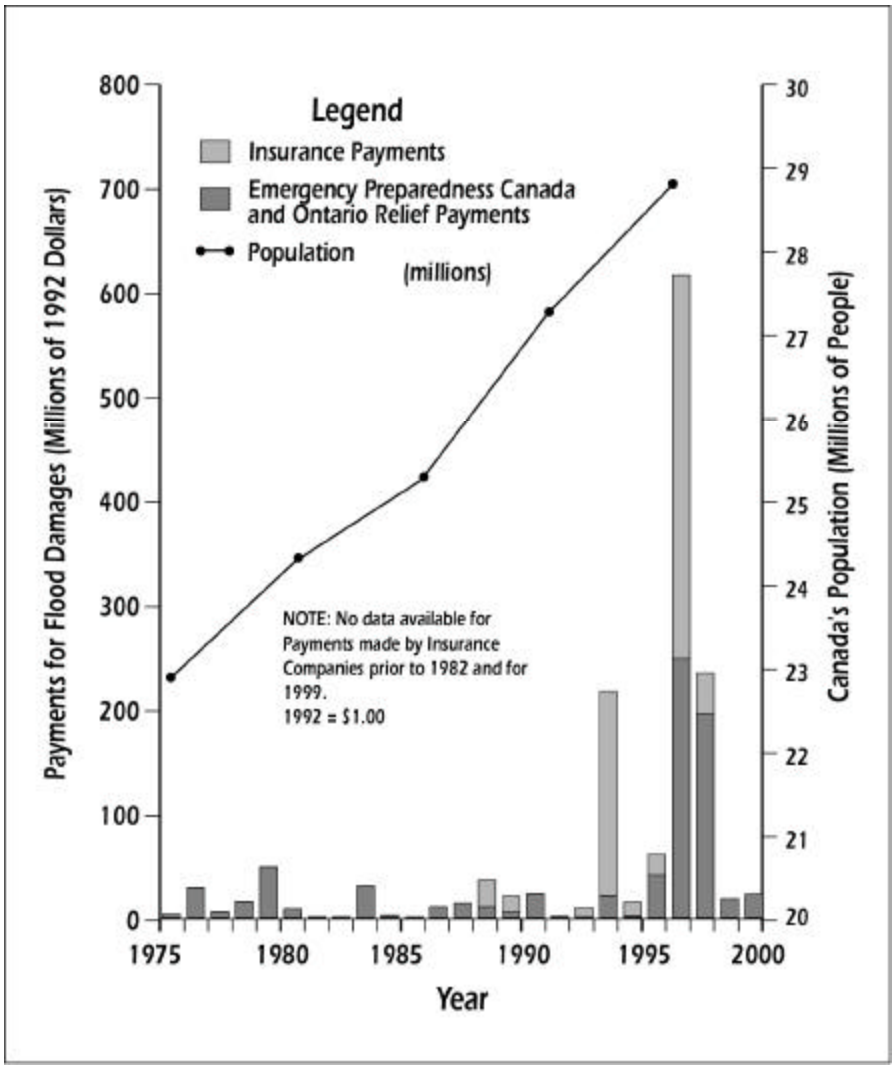


Figure 1.1 Flood Damages in Canada 1975-2000

Traditionally, effective Canadian flood management has required the participation of all levels of government. In general terms, the federal government often provides research and recommendations concerning aspects of flood risk management, such as building standards or acceptable levels of risk (Doern and Conway, 1994). It also provides training for local emergency officials. However, the division of responsibilities under the *Canada Constitution Act* provides little legal motivation to prompt Canada's federal government into leading flood management efforts (Newton, 1997). Thus, it is unlikely that Canada's federal government would assume the same level of leadership that is seen in the United States under its National Flood Insurance Program. Provinces can establish specific regulatory flood levels, set building standards, and advise municipal governments about flood mitigation. Municipal governments must comply with provincial building codes through the passage of local by-laws. If minimum standards are not established by provincial statute, municipal governments have considerable

discretion in implementing programs. Harrison (1996) suggested that this arrangement epitomized 'passing the buck' because all levels of government are involved but no one is truly accountable for decisions made or not made.

At this time, federal and provincial governments are reviewing their flood management programs. The Canadian Council of Environment Ministers (CCME) is surveying provincial and territorial governments concerning the present status and future directions. Therefore, it is timely review the state of flood management in Canada. The objectives of this paper are: (1) to describe the causes of flooding in Canada in order to identify the scope required and the challenges facing flood management programs; (2) based on available literature, describe current practice approaches to flood management with a focus on land use regulation and disaster relief; (3) describe current practice on the basis of the recent experience with flooding in the Red River and Saguenay Valley; and (4) to outline future options for practice and research.

This report is divided into five chapters. Following the Introduction, Chapter Two reviews the causes of flooding in Canada and overviews damaging floods in Canada. The next chapter discusses preventive practices, flood response, disaster relief and insurance initiatives. The fourth chapter comments on the recent experiences of floods in the Saguenay Valley and the Red River basin. The concluding chapter reviews underlying problems with current flood management initiatives and describes how these might be best addressed.

A brief comment on terminology would be appropriate. The terms "flood hazard" and "flood risk" are often used synonymously. It is more appropriate to consider a hazard as the source of risk or, put another way, risk is the combination of hazard and vulnerability. Paraphrasing the earlier quote from White, God provides the flood hazard, humans create the flood risk.

2.0 FLOODS AND FLOOD DAMAGES IN CANADA

The first section of this chapter describes some of the causes of flooding in order to provide insight into why some flood protection and response polices might succeed in one area, but fail in another. Since natural flood mechanisms exist and socio-economic conditions vary throughout the country, a mix of responses is necessary to effectively deal with the flood problem. The second section of this chapter describes the nature of specific damaging floods in Canada. In this manner, the need for effective flood management is demonstrated.

2.1 Causes of Flooding

2.1.1 Hydrometeorological Mechanisms

Flooding in Canada is caused primarily by hydrometeorological mechanisms, acting either individually or in combination (Watt, 1989; Andrews, 1993). The regional variability in the intensity of these mechanisms reflects the diversity of climate across Canada. Nevertheless, Watt (1989) and Andrews (1993) suggested that all mechanisms are generally applicable to all regions of Canada. However, the relative importance of the hydrometeorological flood mechanisms varies considerably throughout the year because of their close link to climate. In particular severe flooding may result when several of these mechanisms occur coincidentally, as can happen in the spring.

Snowmelt runoff floods: The melting of a snowpack that has accumulated during the winter months is a common flood type in Canada (Andrews, 1993). This occurs in watersheds of all sizes, often in combination with storm-rainfall runoff and/or ice jams. The amount of snowmelt runoff is controlled directly by the thickness, ripeness and extent of the snowpack, and by the rate of melting (Watt, 1989). The greater the amount of snow on the ground during a melt period, the more water is potentially available for snowmelt runoff. Ultimately, however, the rate of snowmelt is controlled primarily by radiant energy (Church, 1988). Relatively cool weather causes slow melting of the snowpack and the gradual release of meltwater, while warm weather speeds melting and releases meltwater more rapidly, thereby increasing the possibility of flooding. Severe flooding from snowmelt can happen when there is a rapid shift from cold to warm temperatures in the spring following a winter of high snow accumulation. It can also be triggered during the winter months by a sudden and rapid thaw. Since the climatic factors influencing both the accumulation of snow and the rate of melt are regional, snowmelt flooding commonly occurs over large areas and affects numerous watersheds (Andrews, 1993).

Storm-rainfall floods: Heavy or torrential rainfall associated with convective storms and mid-latitude and tropical cyclones (including hurricanes) can cause flooding, even after a period of drought (Watt, 1989; Andrews, 1993). This type of flood can develop rapidly, particularly when the ground is saturated and the rate of rainfall far exceeds the capacity of the ground to absorb the water, or when a significant portion of the ground surface is covered with impermeable materials, such as concrete or pavement in urban areas (Andrews, 1993). The magnitude of storm-rainfall flooding depends on the intensity and duration of the rainfall, the areal extent of the storm, pre-storm ground moisture conditions, and drainage basin characteristics (*e.g.*, topography,

overburden thickness, vegetative cover, drainage density) (Watt, 1989). Storm-rainfall floods can significantly affect watersheds of up to 100,000 km^2 in size throughout Canada (Church, 1988). A recent example is the July 2000 Vanguard, Saskatchewan storm during which 375 mm of rain fell in eight hours, the largest eight-hour storm ever documented on the Canadian prairies (Hunter *et al.*, 2002).

Rivers with larger watersheds generally are unaffected because the zone of intense rainfall within a storm system commonly is concentrated within a smaller portion of the drainage basin. However, prolonged, heavy rainfall over a large area from a succession of storms may produce storm-rainfall flooding along a river draining a very large watershed. For example, in June 1973, an average of nearly 80 mm of rain fell over an area larger than 300,000 km^2 in Alberta during a single day. This represented a volume of 25 km^3 of water falling from a single synoptic-scale event in a 24-hour period (Hogg, 1994).

Rain-on-snow floods: Rain-on-snow floods are a combination of snowmelt runoff and storm-rainfall floods. They occur when rainfall runoff is augmented by snowmelt, which increases the amount of water flowing into a stream system. The rate of snowmelt during a rainstorm is affected directly by air and rainfall temperatures, amounts of rainfall and wind speeds (Church, 1988). However, the amount of surface runoff released from a snow pack is controlled by snowpack ripeness, since an unripe snowpack will store more rainwater than a ripe snowpack (Watt, 1989). When heavy or sustained rainfall occurring in combination with other meteorological conditions leads to ripening and significant melting of a moderately deep snowpack, rain-on-snow can generate substantial runoff causing very severe flooding (Watt, 1989; Matthai, 1990). The most extreme event recorded along many Canadian rivers commonly is a rain-on-snow event (Church, 1988). Rainfall-on-snow floods occur in all parts of Canada, but can be particularly severe in the fall along the west coast, and during the winter and early spring elsewhere in Canada (Watt, 1989).

Ice jam floods: Ice jam floods result from the temporary obstruction of river flow by the build-up of ice fragments within the channel, and can occur during both the freeze-up and break-up periods. However, ice jams during break-up are more likely to cause flooding (Andrews, 1993). Once formed, an ice jam causes the river to rise immediately upstream and may overtop its banks, depending on the height of the obstruction relative to the sides of the channel. The failure of an ice jam can release a surge of water and ice downstream that causes a sudden rise in water levels and flow velocities downstream (Beltaos, 1995). Ice jams that form during the break-up period commonly coincide with the freshet flow arising from snowmelt runoff and can accentuate the level of flooding. While the peak discharge along rivers in Canada that experience significant ice jamming results from other processes (*e.g.*, snowmelt, storm-rainfall or rain-on-snow runoff), the high water level — the direct cause of flooding — often is a product of ice jamming (Gerard, 1990).

Flooding from ice jams tends to be localized since it is dependent directly on the formation of an ice jam, and the tendency for an ice jam to form at any given location along a river is variable. Ice jam formation along a river is promoted by the presence of local sections of intact ice cover during break-up, and/or local channel characteristics

(*e.g*., channel shoaling, variation in channel width, channel splitting by islands or bars, and sharp bends) (MacKay and Mackay, 1973; Betlaos, 1995). However, ice jams can also form behind bridges and other artificial structures that constrict a channel (Betlaos, 1995). The severity of ice jamming varies from year-to-year, and depends on factors such as the harshness of the winter, the amount of ice decay and melting prior to break-up, and the amount of rise in river level immediately prior to and at the time of break-up. Commonly associated with larger, north-flowing rivers, ice jams have also caused significant flooding on many rivers throughout Canada, including some that flow towards the south (Watt, 1989; Gerard and Davar, 1995).

2.1.2 Natural Dams

Floods can also be caused by the formation and failure of natural dams, although these events are far more localized and less frequent (at the national scale) than hydrometeorological flooding. Floods from natural dams occur due to the blockage of drainage by landslides, glaciers, and moraines (Costa and Schuster, 1988; Clague and Evans, 1994; Clague and Evans, 2000; Brooks *et al.*, 2001). Flooding occurs upstream of the natural dam as a result of ponding, but also downstream if there is a failure of the dam (or in some instances the development of a tunnel under a glacier) that allows the rapid drainage of the impounded water. These 'outburst floods' (also known as jökulhlaups when originating from a glacier dam) produce peak discharges that are proportional to the volume of the impoundment, rather than the area of the contributing watershed, and the resulting flood can be larger by an order of magnitude or more than the maximum expected hydrological flood for the stream (Costa and Schuster, 1988; Clague and Evans, 1994). Such large floods consequently may cause enormous erosion and channel change along the flood paths for many kilometers downstream of a dam (*e.g*. Desloges and Church, 1992), and represent a much greater potential risk than the flooding behind the dam. With some specific glacier dams, outburst floods have happened nearly annually over periods of up to several decades because the dam has reformed repeatedly after successive drainages of the impoundment. For example, Summit Lake impounded by Salmon Glacier, B.C. has released 34 outburst floods between 1961 and 1997 (Mathews and Clague, 1993; Brooks *et al*., 2001).

In Canada, the occurrence of landslide, moraine and glacier dams has been documented in the Cordillera, and for landslide dams, also in the St. Lawrence Lowlands within areas where sensitive glaciomarine sediments ('Leda clay') are prone to landslides (Clague and Evans, 1994; Brooks *et al*., 2001). Natural dams are also likely to occur in the mountains and at the margins of ice fields in the Arctic Archipelago. Although flooding from glacier and moraine dams primarily occurs along remote, uninhabited watersheds, a number of floods from landslide dams have occurred in valley bottoms of the Cordilleran, southeastern Ontario, and southern Quebec within populated areas (Clague and Evans, 1994; Brooks *et al*., 2001).

2.2 Damaging Floods in Canada

Using data available on the EPC disaster database, Brooks *et al*. (2001) identified that the twelve provinces and territories (Nunavut is included within N.W.T.) experienced 168 flood disasters between 1900 and June, 1997 (Figure 2.1a). In eastern Canada, the flood disasters have occurred predominately in the south where the population is

concentrated (Figure 2.2). The distribution of disasters is much more scattered in western Canada, although there is notable clustering in southern Manitoba and in southwestern and northwestern British Columbia (Figure 2.2). About 62% of the disasters have occurred in four provinces: Ontario (37 events), New Brunswick (26 events), Québec (23 events) and Manitoba (18 events; Figure 2.1a). Specific areas that have experienced recurrent flood disasters are the Saint John River basin, New Brunswick, (16 disasters) and the Red River basin, Manitoba (15 disasters, including the Assiniboine River) (Figure 2.2). The relatively few disasters in the Northwest Territories (5 events), and Yukon (3 events), which represent about 40% of the area of Canada, reflect the very sparse population in the north. The number of floods is only one element in understanding flood disasters. Population, land uses and policies would be other factors that contribute to flood disasters.

Figure 2.1 is a graphic illustration of the occurrence of known flood disasters in Canada for the period 1900 to June, 1997, by (a) province, (b) month, and (c) decade (after Brooks *et al*., 2001). The data are from the EPC Canadian disaster database, modified by Brooks *et al*. (2001). Figure 2.2 maps the distribution of known flood disasters in Canada for the period 1900 to June, 1997 (after Brooks *et al*., 2001). The disasters are listed in the EPC Canadian disaster database, modified by Brooks *et al*. (2001).

Flooding in Canada has resulted directly and indirectly in the deaths of at least 198 people and at least $2 billion of damage during the 20th century (Brooks *et al*., 2001). This figure of 198 deaths must be considered a minimum because damaging floods not included in the database have almost certainly claimed additional lives. In terms of loss of life, by far the greatest Canadian flood disaster was the Hurricane Hazel that struck southern Ontario in October 1954, killing 81 people (Andrews, 1993).

Although the brief summaries of the flood disasters in the EPC database are in some cases too vague to specify the flood mechanisms conclusively, the database suggests that over 65 percent of the flood disasters are the result of snowmelt runoff, storm rainfall or rain-on-snow (*i.e.* combinations of snowmelt runoff and storm rainfall are inferred to be rain-on-snow) (Brooks *et al*., 2001). Of secondary importance are floods that result from hurricanes, ice jams, storm-rainfall, snowmelt-runoff, ice-jam combinations and snowmelt-runoff. Hurricanes (or their remnants) are a significant flood mechanism in the Maritime Provinces. Only one flood in the disaster database is the result of a natural dam failure (Kicking Horse Pass, BC, September 7, 1978) (Jackson *et al*., 1989).

Although flood disasters occur in every month of the year, about 40% takes place in April and May, which coincides with the spring melt in southern Canada (Figure 2.1b). This period also coincides with the likelihood of several common flood mechanisms, such as snowmelt runoff, storm rainfall and ice jams, thereby increasing the likelihood of high flows. Many of the flood disasters during the January to March period are the result of rain-on-snow during winter mild spells, while floods during the June to November period are the result of rainstorm-runoff. In the months of August, September and October, 11 of the 20 flood disasters in eastern Canada (Ontario to Newfoundland) were caused by hurricanes or their remnants. The smallest number of flood disasters has occurred in the months of November and December.

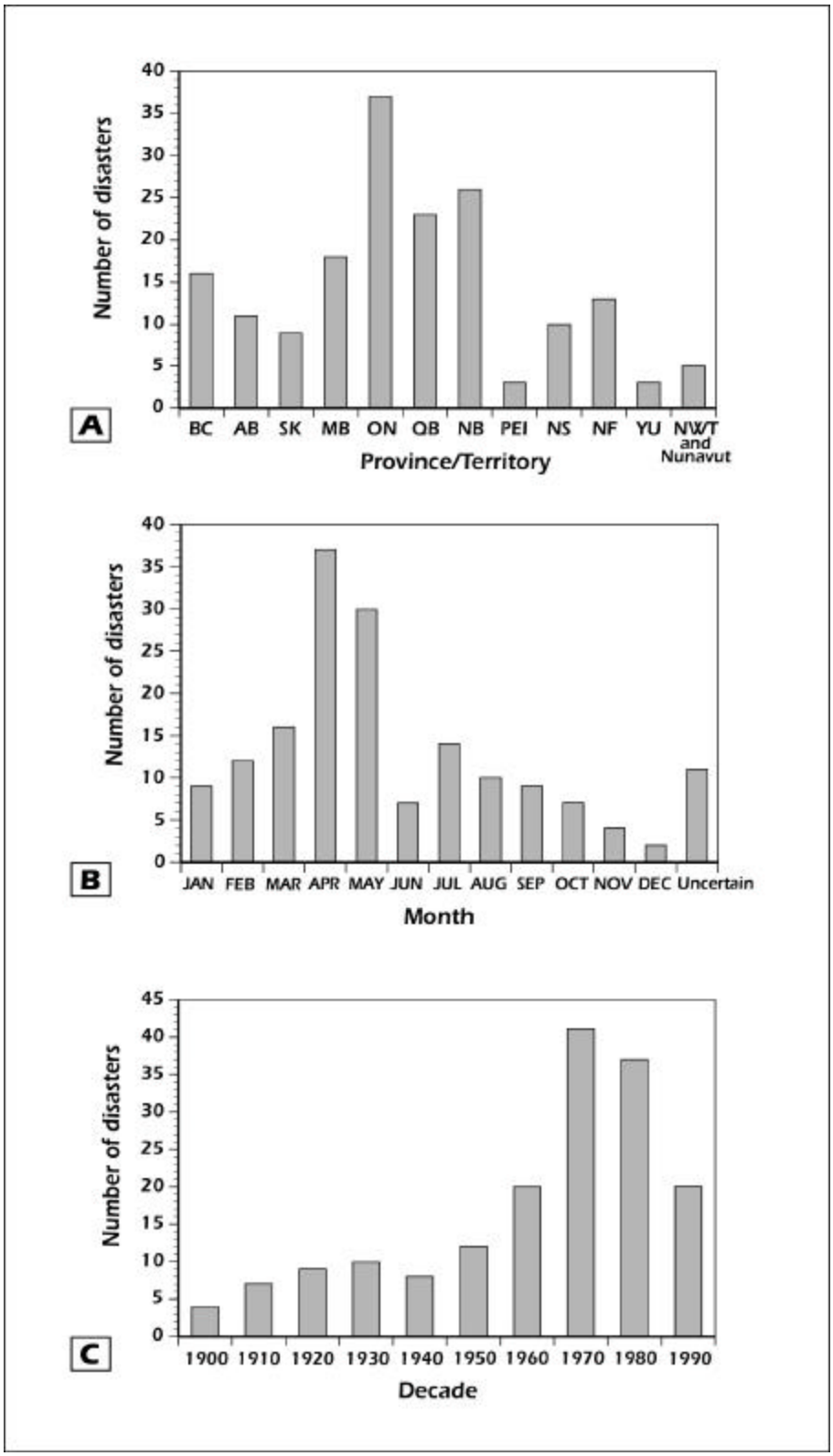


Figure 2.1 The Distribution of Floods in Canada 1900-1997

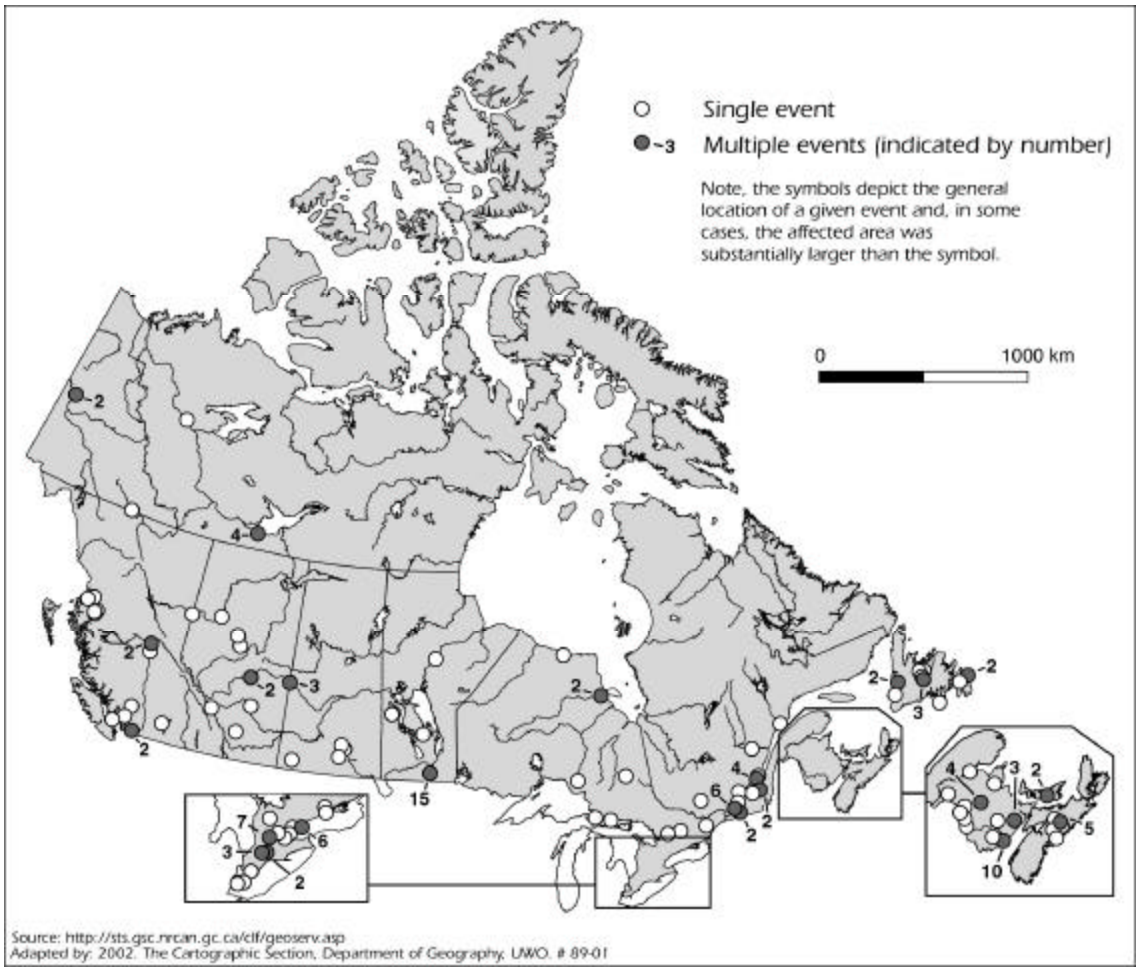


Figure 2.2 The Location of Floods in Canada 1900-1997

The database suggests that the number of flood disasters has increased through the 20th century with about 70 percent occurring after 1959 (Figure 2.1c). This trend likely reflects several factors. Ashmore and Church (2000) indicate that there has been a general increase in the magnitude of flood events in the second half of the 20th century relative to the first half, along many Canadian rivers. This is thought to reflect a shift in climate. Also, over the 20th century there has been an increase in development on flood prone lands as Canada's population has grown along with a general increase in personal wealth. There is also better reporting of flood disasters over the past several decades. Smaller pre-1960 flood disasters probably are under-represented in the database because they were reported mainly in small, local newspapers and the details provided might have been scant resulting in overlooking of these events as disasters. Finally, the availability of senior government disaster assistance in the second half of the century undoubtedly has led to improved record keeping.

2.3 Implications

This information on the nature of floods has relevance to flood risk management and policy. For instance, floodplain mapping under the FDRP was often based exclusively on open water floods. The effects of ice jams and other intervening factors were not always incorporated. Ice jams significantly influence the level of flooding in some areas. For instance, a comprehensive assessment of flood damages in New Brunswick found that 42% of flood events were ice-related. In the Saint John River, ice-related flood events accounted for 69% of all flood damages (Humes and Dublin, 1988; Beltaos, personal communication). Providing flood information that better reflects the physical nature of events would be one way to improve present practice.

An underlying assumption supporting flood modeling and floodplain is stationarity – the climate, weather and runoff processes and patterns of the past will operate in the future. According to the Intergovernmental Panel on Climate Change (IPCC, 1996), precipitation patterns, the timing and magnitude of runoff, the frequency and intensity of storms as well as other elements of the climate will change. Etkin (1999) noted that a shorter winter season could reduce the size of snowpacks. Storm surges along the ocean coastlines could increase the size of storm surges. On the basis of available evidence, Etkin (1999, 41) concluded that "climate models suggest[ed] an increase in flood events, as a result of a trend toward more convective precipitation and greater atmospheric absolute humidity." If this conclusion is correct, there are significant implications for flood management.

While there has been a relatively large effort devoted to the impacts of global climate change on water resource systems, "little has been done to review the adequacy of existing water planning principles and evaluation criteria and related impact procedures in the light of these potential changes" (Frederick *et al*., 1997, 1). According to these authors,

> the absence of a uniform understanding and application of basic assessment and evaluation principles makes it difficult to synthesize the numerous climate change impact analyses and hinders the prospects for developing an integrated assessment to account for the linkages and feedbacks among the climate, socioeconomic factors, ecosystems and atmospheric chemistry (Frederick *et al.*, 1997, 1).

The potential implications for the practice of flood hydrology and flood management are significant.

There appears to be no question that greenhouse gas levels are increasing and global temperatures are rising. However, the extent to which current hydrological records are reflecting shorter term variations as opposed to longer term climate change, and the extent to which human activities are changing the climate are unclear. According to Matalas (1997, 96), "it is also unclear how global warming translates into hydrologic change. Evidence for global warming is not readily apparent in the hydrologic records [for the United States]". This comment suggests that it might be premature to dismiss the idea of hydrologic stationarity. From this perspective, we should continue to base future levels of protection on the basis of past observations.

An alternative approach to stationarity suggests that future climates will be dissimilar to those of the past. From this perspective, one must identify future climate and weather patterns in order to determine levels of risk. To date, global climate models (GCMs) have been unable to precisely and accurately predict precipitation and runoff, and their variability. In addition, there is discordance between large-scale global climate change model output to small-scale flood models. Lins *et al*. (1997) suggested that climate change models not be used in water planning because of the high level of uncertainty associated with long-term GCM forecasts. However, scenarios may be developed using the output from GCM models that can illustrate a range of potential outcomes. Lins *et al*. (1997) maintained that the scaling problem might be overcome by using a nested approach in which GCM output is used to initialize regional climate models. Alternatively, weather patterns that are simulated by GCM models may be used to infer precipitation and temperature distributions that could be incorporated into regional watershed modeling exercises.

A central question in terms of flood management pertains to whether climate change should influence the treatment of climate variability, and the extent of this influence. One could also consider whether another variable should be considered in evaluating, comparing and trading off the economic efficiency, technical performance, social acceptability, and environmental quality of any set of proposed flood management measures. Decisions on this issue will likely have implications for the selection of interest rates, project life and multiple objectives in benefit-cost analysis studies.

One strategy to reduce human and economic losses, and to minimize environmental impacts is to employ best management practices. The implementation of current strategies is considered in the next three chapters.

3.0 REDUCING RISK AND REDISTRIBUTING LOSSES

Preventing flood damages is one important element of flood management. The discussion in this chapter focuses primarily upon activities under the FDRP and highlights the roles of federal, provincial and local governments. Another important aspect involves redistributing losses. At a national level, this was done through the Disaster Financial Assistance Arrangements.

Seven parts form the structure of the chapter. The first part provides background information. Issues associated with the delineation of floodplains are described in the second section. The General Agreements and the implementation of floodplain regulations are explained in sections three and four. The fifth section concerns public information and floodplain management. The sixth section describes the benefits of the FDRP. The final section describes the administrative arrangements for redistributing flood losses.

3.1 Background

Early flood risk management efforts were the responsibility of individuals and local governments. Senior governments became more involved between 1953 and 1970. During that period, the *Canada Water Conservation Assistance Act* guided the federal government's involvement in water management. Senior levels of government could provide up to 37.5 percent each to cover the capital cost of structural adjustments (Quinn, 1985). By the 1970s, some of the shortcomings of existing programs were becoming apparent (Watt, 1995). A number of these shortcomings contributed to the development of the Flood Damage Reduction Program (FDRP) under the provisions of the *Canada Water Act* (1970), which supported joint federal-provincial initiatives (Bruce, 1976). First, major floods in 1973 and 1974 suggested that the protective works, which dominated the type of response under the *Canada Water Conservation Assistance Act*, had not curbed the potential for damage (Bruce, 1976). These floods also led to significant federal disaster financial assistance payments to provinces. Second, structural measures were seen to promote development in floodplains (Watt, 1995). Third, the collective demand for structural adjustments, disaster relief and clean up assistance was straining senior government budgets. Fourth, instead of fully participating in project planning, the federal government simply accepted or rejected proposals submitted by provincial governments. Fifth, there was a belief that the present system was inequitable because it subsidized those residents who occupied flood-prone areas. Sixth, there was a lack of opportunity for public participation or consultation (Booth and Quinn, 1995).

Under the Flood Damage Reduction Program (FDRP) provinces were attracted to sign 10-year General Agreements with the federal government, in part, because Environment Canada had a competent core of professionals and available funds. These General Agreements identified basic approaches to reducing flood damages and the policies agreed by the two governments (Andrews, 1993). The 10-year agreements could be supplemented by subsidiary agreements on mapping to delineate and designate flood risk areas for which the following FDRP policies would apply (Andrews, 1993):

1) federal/provincial governments would not build, approve or finance flood-prone

development in a designated flood risk area;
2) the governments would not provide flood disaster assistance for any development built after an area becomes designated (unless in the flood fringe and adequately flood proofed); and
3) provinces would encourage local authorities to zone on the basis flood risk.

While the emphasis was clearly on non-structural measures such as floodplain mapping, floodplain regulation and flood forecasting, structural adjustments could also be covered in other sub-agreements. Public education was another important element of the FDRP.

3.2 Defining Floodplains

As noted earlier, the primary purpose of the program was to map urban flood prone lands. This was achieved by defining the floodplain as the land inundated by floods of one hundred-year or greater magnitudes. Once these lands were identified, the program encouraged provincial and municipal government to enact floodplain regulations in order to designate, zone and control future development on those lands. The floodplain was divided into two components: a 'floodway' where risks were particularly high and the 'flood fringe' where some development could be contemplated. Studies completed under the program examined the flood history of a basin in order to identify its flood-prone areas, assessed the hydrology in order to define the one-percent or hundred-year floods and floods of other magnitudes, and conducted hydraulic analyses to determine water surface profiles, depths and velocities of high-magnitude floods in the study area. Notes associated with Table 3.1, which reports on some of the characteristics and results of the program, suggest that delineating the floodway was a political, as well as, a technical issue.

When the program was developed, it was believed that there were no significant flooding problems in Prince Edward Island. Recent events, however, have shown that flooding associated with storm surges is possible. Although periodic flooding does occur in Yukon, it never joined the program. No flooding problems were identified in Nunavut either (formerly part of the Northwest Territories). Thus, in these jurisdictions, there was little systematic effort to determine the extent of flooding.

Most provinces applied hydraulic criteria (*i.e.*, depth and velocity of water) to delineate floodways. Others used a statistically defined flood. British Columbia used a physically defined floodway as the channel width plus a minimum of 30 m setback (Table 3.1). Under the FDRP, the federal government agreed to share the cost as long as the minimum requirements were met. Provinces were free to use more stringent requirements. This accounts for the differences in the return flood used for delineating floods in British Columbia, Saskatchewan and most other provinces (Table 3.1).

Another technical aspect that made mapping difficult was a shortage of hydrometric data for small Canadian watersheds. There is uncertainty in the determination of regulatory floodplains (Paine and Watt, 1992). For instance, most of the storm data in Ontario are relevant for large watersheds of 500 km^2 to 1,000 km^2 in size rather than smaller 25 km^2 catchments (Lorant, 1990). In the absence of data for these smaller

areas, the Ontario government has circulated reduction curves defined by the World Meteorological Organization that are applicable to the western United States. Given the recent reductions **Table 3.1: The Implementation of the Flood Damage Reduction Program**

(to June 30, 1995)

Province/ Territory	Communities	Number Mapped	Number Designated	Regulatory Flood	Definition of Floodway
B. C.	143	77	73	1:200	See Note 1
Alberta	67	20	11	1:100	Hydraulic (2)
Sask.	24	22	16	1:500	Hydraulic (2)
Manitoba	26	18	16	1:100	Hydraulic (2)
Ontario	445	318	211	See Note 3	1:100
Quebec	510	211	24	1:100	1:20
N. B. (4)	15	12	12	1:100	1:20
N. S.	6	6	5	1:100	1:20
P. E. I. (4)		0	0		
Nfld. & Labr. (4).	53	19	16	1:100	1:20
Yukon		0	0		
NWT	9	9	9	1:100	Hydraulic (2)
Nunavut	0	0	0	1:100	Hydraulic (2)

Modified from: Watt (1995); Kallio (2001)

Notes:

1. The floodway in British Columbia is defined as the natural channel width plus a minimum 30 m setback.
2. The hydraulic floodway uses criteria of less than 1.0 m/s velocity, less than 1.0 m depth and no more than 0.3 m rise.
3. Ontario's regulatory flood uses the Hurricane Hazel rainfall, the Timmins storm, and the 100-year flood elsewhere.
4. The Atlantic Provinces may also use a historic event or flood from a specified input, provided the water levels are higher than those of a 100-year flood.

in the hydrometric network, it is unlikely that any such curves based on Canadian data will be forthcoming. This information is an important basis for floodplain mapping and warning systems. In order to develop longer-term databases, efforts have been made, for example, in the Red River basin, Manitoba, to utilize tree ring, alluvial and lacustrine sediments, and other proxy data to determine past climate conditions (IJC, 1997; St. George and Nielsen, 2000). It is unclear to what extent these data will effectively support the determination of flood-prone areas at a large scale of mapping. However, they did provide a context for contemporary flooding.

Once a community was designated, provincial regulations or municipal zoning were crucial to the implementation of floodplain land use regulations. These regulations often pertained to the level of fill, or the level of first floor entry, or freeboard requirements for new building construction in flood risk areas. Usually, the freeboard is 0.3 m or 0.6 m; British Columbia uses 0.3 m when the hydrological analysis is based on instantaneous peak flow values, 0.6 m when it is based on daily peaks (Kallio, 2001). Several jurisdictions also developed freeboard and other engineering requirements for dykes. With rare exceptions, development behind a 'certified' dyke did not have to be floodproofed. For example, in Winnipeg new houses that are protected by the Primary Dyking System require backflow preventers while new houses protected by the Secondary Dyking System must be elevated using fill.

The program also funded some additional flood damage reduction studies, particularly related to flood forecasting (New Brunswick, Manitoba and Saskatchewan), and the development of structural measures (New Brunswick, Quebec, Manitoba and British Columbia). While the Flood Damage Reduction Program was always considered as a non-structural approach to flood risk management, in fact, over 50 percent of the expenditures from the *Canada Water Act* Fund used to finance the federal share of this program were for structural measures (Booth and Quinn 1995; Watt, 1995).

3.3 The General Agreements

After the 10-year period, there was no plan to renew the General Agreements (Watt, 1995). However, there were amendments that extended the original agreements. Table 3.2 provides the expiration dates of the General Agreements on Mapping and Policies. Further, in the early 1990s, there was a significant decline in the *Canada Water Act* Fund due to departmental pressure to wind down flood-related agreements. Funding was projected to drop from $5 million to $0.5 million between 1995 and 1998 (Booth and Quinn, 1995). In addition, despite reductions in flood damage under the FDRP, the federal government started recognizing some problems with the program. These included the following: restrictions on floodplain development were difficult to apply with an even hand; some regions were not applying the policies as effectively as others; flood damage compensation from and disaster assistance claims to the federal government continued to grow; and the costs of managing the FDRP were accrued in one department but the benefit of reduced disaster relief were accrued in another (OCIPEP) (Kumar *et al*., 2001). In the mid 1990s these concerns, coupled with a widely recognized need for greater financial stringency in government programs, led to the termination of federal involvement in the Flood Damage Reduction Program.

The late 1990s have witnessed a decrease in flood risk management capacity by all levels of government. At a time when high quality information is needed to meet the challenge of achieving sustainable human settlement and development, the level of information to assist decision making has declined (Bruce and Mitchell, 1995). Between 1995 and 1998, budget allocations for the hydrometric network were reduced by 35 percent (Scott *et al.*, 1999). Federal and provincial programs have also been slashed, resulting in a reduction of governments' professional capability in water management and flood control (Day, 1999). Federal participation in flood management was effectively withdrawn with the end of the FDRP. There was also no plan to renew

the General Agreements with the provinces after their 10-year operating periods or even to continue the maintenance phase of three basic FDRP policies (Watt, 1995; Booth and Quinn, 1995). The federal role in water management is now being reconsidered and the direction of federal involvement in flood risk management is unclear (de Loë, 2000).

3.4 Implementing Floodplain Regulations

By 1999, the FDRP accomplished the mapping and designation of 982 communities (Figure 3.1). The detailed hydrologic and cartographic specifications of the FDRP

Table 3.2 – Expiry Dates of the Flood-Risk Mapping and Policy Agreements [1]

Province or Territory	Expiry Date for "Agreements for Policies"	Expiry Date for "Agreements for Mapping"
Alberta	March 31, 1999	March 31, 1997
British Columbia	March 31, 2003	March 31, 1998
Aboriginal Lands [2]	---	March 31, 1995
Manitoba	March 31, 1999	March 31, 1996
New Brunswick	March 31, 2000	August 31, 1998
Newfoundland	March 31, 2001	March 31, 1996
Northwest Territories	March 31, 1993	March 31, 2000
Nova Scotia	June 22, 2000	June 22, 1995
Ontario	March 31, 1997	March 31, 1992
Québec	March 31, 2002	March 31, 1997
Saskatchewan	March 31, 2000	March 31, 1995

Modified from: Environment Canada (1996); Environment Canada (1999)

Notes:

1 Updated Updated to March 31, 1999; Prince Edward Island and Yukon did not join the program.

2 The Memorandum of Understanding between Environment Canada and Indian and Northern Affairs Canada for the mapping of flood risks on Aboriginal lands expired on March 31, 1995; approximately 40 reserves or communities were mapped with the full cooperation of Band Councils (designation was not part of this arrangement).

mapping program also implemented uniformly high standards across the country and allowed for special needs in each region (de Loë, 2000). Administrative benefits, especially through strengthening and enhancing local land use planning, and considerable environmental benefits through the preservation of wetlands and many plant species, have been noted under the Canada-Ontario FDRP (Millerd *et al*., 1994), and are probably applicable in other provinces as well. Studies have concluded that the FDRP was cost-efficient in Saskatchewan, Quebec, and Ontario (Weiss, 1987; Ouellette *et al.*, 1988; Millerd *et al*., 1994; Brown *et al*., 1997). Several factors, however, complicate evaluation of the FDRP: (1) it is difficult to evaluate the FDRP separately from other provincial water management initiatives; (2) analysis of the FDRP using benefit and cost measurements cannot be precise since they involve estimates of

damages that would have occurred in the absence of the program; and (3) flood damages have not, and will never, be fully eliminated so long as people occupy flood-prone areas (de Loë, 2000).

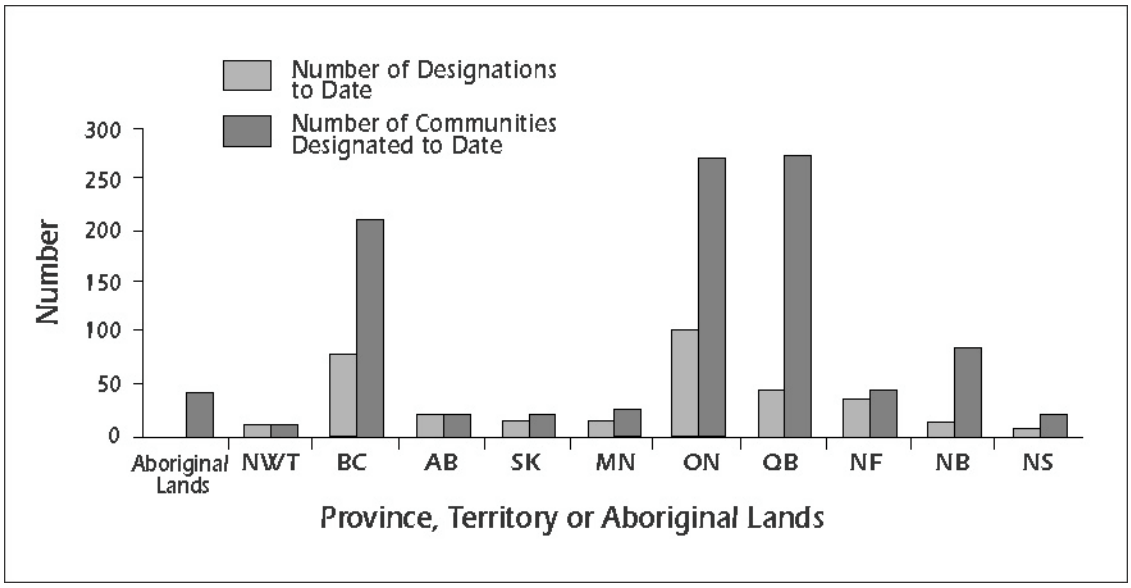


Figure 3.1 Summary of Flood-Risk Mapping and Designations (as of March 1999)

Note: One designation can cover more than one community in a flood-risk area and that number is approximate. The Memorandum of Understanding between Environment Canada and Indian and Northern Affairs Canada for the mapping of flood risks on Aboriginal lands expired on March 31, 1995 and approximately 40 reserves or communities were mapped with the full cooperation of Band Councils (while designation was not part of this arrangement). Adapted from: Environment Canada (1996; 1999).

Several studies have concluded that Ontario's approach to floodplain regulation has been generally effective. Boyd (1997) modeled the storm that generated the 1996 Saguenay Valley flood to the Grand River. Results of this simulation exercise showed that the existing reservoirs on the Grand reduced flows between 4 and 13 percent, dykes reduced flood damages by over $120 million, and land use regulations prevented an additional $5 million in damages. In comparing the flood damages by four major storms that occurred in Michigan (USA) and Ontario during 1986, Brown *et al*. (1997) concluded that although flood magnitudes in Ontario were higher, the success of its floodplain management policies was reflected in much lower damages. When adjusted for differences in the currency exchange, the $500,000,000 (US) versus the $500,000 (Cdn) damage levels differed by four orders-of-magnitude. Although the differential cost of a much more dense network of flood-affected infrastructure in Michigan might be a factor in such estimates, there is little doubt that the combination of structural adjustments, building codes and floodplain regulations has reduced economic losses from what would have occurred without their presence. Since 1975, Ontario has not received payments for flood damages through the Disaster Recovery Financial Assistance Arrangements Program. This point helps reflect the success of Ontario's

flood management program, and the nature of the cost-sharing arrangement under that federal program.

Shrubsole *et al*. (1995; 1996; 1997a) concluded that relative to their stated goals, floodplain regulations by Conservation Authorities (CAs) have achieved an acceptable level of efficiency, equity and performance. No significant impacts on property values have been associated with their implementation (Schaefer, 1990; Shrubsole and Scherer, 1996; Shrubsole *et al.*, 1997b). The existence of CAs and the establishment of a *Provincial Policy Statement* are the cornerstones that have supported this level of success. The CAs use the watershed as the administrative unit, receive funding from provincial and local governments, and generate their own funds. They have the primary responsibility for flood and erosion control on a watershed basis, which reflects a long-standing cooperative approach to renewable resource management (Mitchell and Shrubsole, 1992). The *Flood Plain Planning Policy Statement* committed the province to structural adjustments, floodplain regulation, flood warning, and disaster relief.

Numerous difficulties were also associated in managing floodplains. For example, the initial floodplain protection provisions within the Canada-Quebec FDRP agreement were relaxed in order to allow development to take place in several flood risk areas in Quebec through policy exemptions (Roy *et al.*, 1997). Forget *et al*. (1999) found that designation and mapping failed to prevent inappropriate development on defined floodplain areas in Montreal. They also concluded that dykes, constructed mainly in developed areas, might have promoted a false sense of security and noted a highly variable level of their structural integrity, design and maintenance. In an earlier study, Cardy (1976) commented on the tendency of flood control structures to encourage development and cited the example of extensive development for 30 years in St. John, New Brunswick, behind tidal control dams. Day (1999) maintained that comparatively little mapping was carried out in the lower Fraser River basin of British Columbia. Instead, a dyking program in the basin consumed a very large proportion of all funding under the *Canada Water Act*. This imbalance in resource allocation "overshadowed the otherwise innovative and sustainable thrust" of the FDRP (Booth and Quinn, 1995, 72). According to Day (1999), many of the 2.4 million people occupying the lower Fraser River basin are vulnerable to flooding and some lands have yet to be mapped. In 1979, Manitoba established a Red River Designated Flood Area that saw many communities in the basin implement floodplain regulations without a need for detailed FDRP mapping. Unfortunately, due to a lack of enforcement, by 1997 only 63 percent of new homes in the designated flood areas complied with that regulation (IJC, 1997). This was however addressed following the 1997 Canada-Manitoba Flood Proofing Agreement - now experienced staff carries out compliance checks on flood-proofing measures.

Most of the preceding studies suggest that local governments have not always effectively managed floodplain development. This is partly explained by a lack of political will, competition for development among floodplain communities, and inadequate mechanisms for promoting watershed-based responses. At a practical level, not all existing development and additions or renovations to existing structures can be designed or redesigned feasibly to make them safe (Shrubsole *et al*., 1995; 1996;

1997a). There is also a lack of integration between structural adjustments and floodplain regulations. In the Fraser River basin (British Columbia), Montreal (Quebec) and elsewhere, the adoption of structural adjustments has sometimes promoted intensive development on floodplains and a false sense of security in their ability to prevent future losses.

A mix of structural and non-structural adjustments has long been advocated as a requirement for effective floodplain management (White, 1945; Shrubsole *et al.*, 1995). The explicit and innovative goal of the FDRP was the mapping of flood-prone areas. Implicitly, it was anticipated that once municipalities were made aware of the flood risk through the maps, they would establish floodplain regulations. However, the traditional focus on structural adjustments consumed over one-half of all expenditures made under the *Canada Water Act* and was concentrated on relatively few projects in British Columbia, Manitoba, Ontario and Quebec. In fact, between 1975 and 1987, the dyking work in the lower Fraser River basin was pursued without any commitment to damage reduction policies (Booth and Quinn, 1995). Thus, the FDRP did not ensure that structural adjustments and the mapping program were applied in an integrated manner. More importantly, these problems can be seen as symptoms that reflect a fundamental flaw with existing strategies that implicitly promotes development in flood-prone areas. Therefore, it might be unfair to lay sole responsibility for poor floodplain regulation primarily on the municipal level of government.

3.5 Public Information

Public information was another important aspect of the FDRP. Handmer (1980) assessed the effectiveness of FDRP maps in changing peoples' attitudes to floods. He concluded that although there was an increase in flood awareness, this change could not be attributed solely to the maps. Kreutzwiser *et al*. (1994), Shrubsole and Scherer (1996), and Shrubsole *et al*. (1997b) surveyed the floodplain residents in three Ontario watersheds to assess their perceptions of flood hazards and adjustments to floods. Generally, residents did not perceive a significant risk of future flooding. There was a poor understanding of floodplain regulations, and structural adjustments were viewed as the most effective approach. Thus, although floodplain regulations were supposed to be the most effective mechanism in reducing future flood damages, residents preferred other measures. Current programs to inform and educate the public about floods have resulted in little change in public behavior.

Providing information about the likely risks associated with a particular property during real estate transactions could be a better mechanism for informing residents and promoting a culture of preparedness. Shrubsole and Scherer (1996) obtained the views of home mortgage lenders, real estate agents and land appraisers in portions of the Grand River watershed (Ontario). They concluded that although formal training pertaining to floods and regulations was limited, the real estate sector was aware of the need to disclose this type of information to prospective buyers. At the time of that study, this was pursued in neither an effective nor consistent manner. Real estate agents most often provided this information to potential purchasers late in the purchase process, although prior to an offer to purchase. This timing detracted from effectiveness. In Ontario, CAs had frequently applied a title notice and/or a release as a

condition of development in flood-prone areas. A title notice informs the buyer of the flood risk, while a release suggests that a homeowner is unable to bring legal suit against a CA in the event of flooding. These mechanisms provided homebuyers with information about the flood hazard during the title search. However, since the purchaser's lawyer would normally communicate this information after the offer to purchase had been made, the purchaser might already feel committed to finalize the deal. The mandatory and early disclosure required in the United States could serve as a model for Canada (Platt, 1999).

Another shortcoming with the FDRP concerned the varied and limited mapping of aboriginal lands (Watt, 1995). The implementation of structural adjustments was relatively slow in these areas because planning failed to reflect important socio-political differences between aboriginal and non-native communities. For instance, traditional benefit-cost studies that are frequently used to prioritize mapping projects within provinces were inappropriate for use in aboriginal areas where lands are communally held. In addition, insufficient funds were targeted for flood management on native lands. The Federal Departments of Indian and Northern Affairs, Public Works and Government Services Canada, native communities, and provincial governments through initiatives such as Flood Damage and Erosion Mitigation Plan are now addressing these problems. This has revitalized partnerships among all participants and has increased funding levels from senior governments.

3.6 Benefits of the FDRP

The FDRP had many attributes. For instance, based on a policy delphi involving 50 participants identified four broad areas of benefits of FDRP to the Province of Ontario (de Lo? and Wojanawski (2001). These were land use planning, environmental protection, floodplain management and others. Improvements to local planning included better Official Plans and a more solid basis for decisions concerning hazards. These types of benefits were supported by Millerd *et al*., 1994). Environmental benefits were related to the protection of natural areas, wetlands, wildlife habitats and environmentally sensitive areas. FDRP was also perceived to support an ecosystem approach to planning (de Lo? and Wojanawski, 2001). It was also believed that FDRP contributed to greater public acceptance of floodplain regulations. Since FDRP involved all levels of government in the completion of mapping to implementing floodplain regulations, increased levels of partnership and cooperation were another aspect of benefits derived from the program (de Lo? and Wojanawski, 2001). While this study focused on the perceived experience in Ontario, these types of benefits could also be realized in other parts of the country. However, their breadth and depth would reflect the commitment of provincial and municipal governments to support floodplain regulation, and their capacity to implement them. Since Ontario is unique in establishing conservation authorities to address flooding and erosion issues, it is inappropriate to suggest that these benefits were uniformly distributed across the country.

3.7 Responding to floods and sharing the risks

Since no flood risk management program can provide absolute protection, it is also appropriate to examine the institutional arrangements for responding to and recovering from floods. This section briefly describes these arrangements.

The Office of Critical Infrastructure Protection and Emergency Preparedness (OCIPEP), formerly Emergency Preparedness Canada (EPC), is another important federal flood management agency. As part of the Department of National Defense, it coordinates and encourages emergency preparedness activities within the federal government, and between federal and provincial governments (EPC, 1997a). In the context of flood response, as for all disaster response, it places initial responsibility upon individuals. Based on the extent of the flood and on an individual's capacity to respond, responsibility can move from municipal, to provincial, and finally to federal levels. Each level of government must request the support of the next one. Emergency preparedness and response is clearly a shared activity among individuals, the private sector, and all levels of government. However, an implicit but fundamental principle of the Canadian emergency response approach places ultimate responsibility for public safety with the municipal level of government (Kuban, 1996). During a disaster response, it should be the municipal officials who remain in control, regardless of the level of involvement of other levels of government.

OCIPEP also administers the federal *Disaster Financial Assistance Arrangements* (DFAA) program (EPC, 1999). Under that program, a per-capita cost-sharing formula is used for providing disaster relief for eligible expenses (Table 3.3).

Table 3.3 - Disaster Financial Assistance Cost-sharing Arrangement

Provincial Expenditures Eligible for Cost Sharing (per capita)	Percent of Federal Share
First dollar	0
Second and third dollars	50
Fourth and Fifth dollars	75
Remainder	90

Modified from: EPC (1999)

This arrangement places a significant financial risk on the federal government for catastrophic losses and has prompted OCIPEP to pursue a broader-based strategy that would better define "the roles for cooperative action to reduce loss of life and damage to properties" (Day, 1999, 59).

Provincial and municipal governments provide various forms of disaster relief. In Manitoba, the Manitoba Emergency Measures Organization provided up to $30,000 compensation for eligible expenses, subject to a 20 percent deductible for approved costs (IJC, 1997). The $30,000 limit was raised to $100,000 after the 1997 flood on the Red River. In general, cost-sharing arrangements place a heavier burden on senior governments for extreme losses.

The DFAA generally defines eligible costs as those related to restoring public works to pre-disaster conditions, and replacing and repairing basic or essential personal property (EPC, 1999). The intent is to prevent recipients from financing home or building improvements through taxpayers' contributions. However, this orientation means that the future damage potential is maintained rather than reduced.

Insurance is another way of sharing recovery costs. In Canada, residential insurance policies do not cover water damages attributable to overland flooding. However, depending on the community, residents may be eligible to be covered for losses due to sewer backup through a standard policy or for an extra premium. Sewer damage can be considerable. In 1993, $185 million (1993 dollars) was paid to residents in Winnipeg as a result of damages due to sewer backup following intense rainstorms. Afterwards, many insurance companies ceased to offer this provision to residents of Winnipeg. Private insurers will usually provide coverage for commercial losses due to closures and damages. Following the 1997 Red River flood, insurance companies paid over $200 million for all damages, with only $2 million associated with sewer back-up (Morris-Oswald *et al*., 1998). After that event, the few companies that had provided sewer back-up coverage withdrew this clause for the residents of Winnipeg. In the future, these individuals will bear their own losses. There is a mounting concern from the insurance sector about the rising claims for insured losses (Figure 1.1). The continuing absence of residential flood insurance and selective withdrawal of sewer backup coverage have not led to a recent decline in their flood-damage claims.

For aboriginal communities, it is the federal Department of Indian and Northern Affairs Canada (INAC) that plays the lead role in emergency preparedness and response management. In 1985, INAC entered a flood-risk mapping agreement with Environment Canada. However, risk areas were not designated unless requested by the Indian Band (Andrews, 1993). While OCIPEP will assist aboriginal communities in preparing, implementing and maintaining emergency plans (EPC, 1998), difficulties in implementation have been evident. For instance, Manitoba has assigned local governments the responsibility of creating emergency preparedness and response plans, and maintaining local emergency response groups. However, Manitoba legislation does not recognize the authority of the chief and the council in governing native lands (Haque, 2000). It appears that emergency response on native lands can be overlooked by current institutional arrangements.

3.8 Current Status

As noted earlier, Environment Canada has effectively withdrawn from FDRP. Following the major flood events in the 1990s, the Canadian Council of Environment Ministers initiated a review of flood management programs. That process is currently ongoing and considers all aspects of flood management – warning, response, recovery and mitigation. At the same time, OCIPEP has issued a discussion paper concerning the possibility of establishing a *National Mitigation Strategy*. It is too early to speculate on precise outcome. However, the concluding chapter of this paper will offer suggestions regarding future policy and research directions. In order to provide further insight into flood management, the following chapter describes the Canadian experience with recent flood events in Canada.

4.0 A TALE OF TWO FLOODS: THE RED RIVER AND THE SAGUENAY VALLEY

It is instructive to compare the contexts, events and outcomes arising from two of Canada's most recent and significant floods – those of the Saguenay and the Red River – in order to assess how well Canada responds to major flood disasters.

4.1 The Geography of the Red River Basin

The Red River originates in South Dakota and flows north forming the boundary between North Dakota and Minnesota (Figure 4.1). It enters Canada at Emerson, Manitoba and continues northward to Lake Winnipeg, which is connected to Hudson Bay by the Nelson River (IJC, 1997). The total drainage area of the Red River is 290,000 km^2, including that of the Assiniboine River, which joins the Red at the heart of the City of Winnipeg.

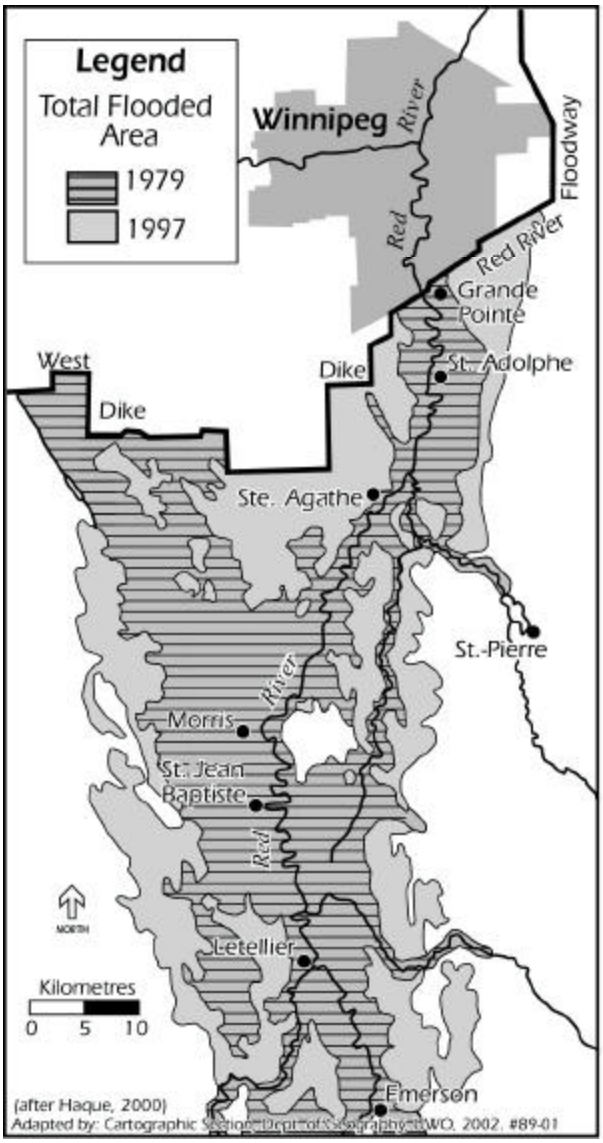


Figure 4.1 The Red River Valley near Winnipeg

Within Manitoba, the Red River is a single-channeled, muddy and meandering stream with a very low gradient (Brooks and Nielsen, 2000). The river occupies a shallow valley, up to 15 m deep and 2.5 km wide at places, and is incised slightly into a flat clay plain which was once the bed of glacial Lake Agassiz. During major floods, river waters overtop the sides of the shallow river valley and spread across the clay plain forming a broad flood zone. Because of its low gradient, high-magnitude floods in the Red River basin rise and fall slowly and may last up to four to six weeks (Morris-Oswald *et al*, 1998). With its flat topography, overland flows in the Red River basin are difficult to monitor and forecast.

The Red River has a long and well-known flood history. The largest historic flood occurred in 1826 and virtually destroyed the Selkirk Colony at the site of present-day Winnipeg. Other major 19th century floods occurred in 1852 and 1861 (Rannie, 1998). Compared to the recorded flow of the Red River in 1997 (4,600 m^3/s at Redwood Bridge, Winnipeg), estimates indicate that the magnitude of the 1826 flood was about 50 percent higher, the 1852 flood was about the same size, and the 1861 flood about 30 percent smaller (IRRBTF, 2000). Major 20th century Red River floods occurred in 1950, 1979, 1996 and 1997. The flood of 1950 was one of Canada's greatest 20th century natural disasters.

4.2 Flood Prevention by Control Structures in the Red River Basin (Canadian Portion)

Existing flood planning strategies in Manitoba involve both structural and non-structural approaches. The present flood-control works consist of the Red River Floodway, the Portage Diversion, the Shellmouth Dam on the Assiniboine River, the primary dyking system within the City of Winnipeg, and community dyking around settlements in the basin (Figure 4.1). Following the 1950 flood, the federal government, in cooperation with the Government of Manitoba, assessed future flood prevention and mitigation options. Based upon recommendations submitted in a 1958 Royal Commission report, the Red River Floodway project (a 50 km-long diversion channel around the City of Winnipeg) was completed in 1968 at a cost of $63.2 million. The federal government contributed $37.0 million and the province spent $26.2 million on the scheme (Topping, 1997). The floodway channel has a design capacity of 1,700 m^3/s. In 1997 it carried about 2,265 m^3/s, which was well above its design capacity (IRRBTF, 2000). It has an emergency (maximum) capacity of 2,600 m^3/s.

A set of rules guiding the operation of the Red River Floodway was developed in 1970 and further modified in 1984. This program of operation has two components: (1) routine (flows less than the design flood), and (2) emergency. The Guidelines state that under routine conditions, the Red River Floodway will be operated to provide maximum protection for the area downstream of the inlet control structures. Meanwhile, the interests upstream of the Floodway should not be adversely affected. Therefore, the water levels upstream of the inlet control structure should be maintained at the elevation that would be reached under natural conditions. An emergency situation is recognized "when the flood stage at James Avenue [in Winnipeg] exceeds 7.77 m, City Datum" (Manitoba Water Commission, 1998b).

Additional control structures have enhanced the protection offered by the floodway. Construction of the Assiniboine Diversion (also called Portage Diversion)– a 29 km diversion channel designed to drain up to 708 m^3/s away from the Assiniboine River and into Lake Manitoba – was completed in 1970 at a cost of $17.5 million. Further, a 21 m high and 1,270 m long dam on the Assiniboine at Shellmouth (near the Saskatchewan border) has created a 56 km long reservoir, with a storage capacity of 863,398 m^3. The protection afforded by the reservoir extends over the entire reach of the Assiniboine River between the Shellmouth Dam and the Red River in Winnipeg. Construction of the dam was completed in 1972 at a cost of $11.5 million (Topping 1997).

Following the flood of 1966, negotiations between the governments of Manitoba and Canada led to sharing the cost of permanent dyking in the Red River basin. Permanent dyking in the province consisted not only of ring dykes around selected towns but also the protection of farmsteads in the basin by either constructing dykes around private properties or by raising the foundations of farm buildings. The eight communities included in the agreement were Emerson, Letellier, Dominion City, St. Jean Baptiste, Morris, Rosenort, Brunkild and St. Adolphe. Following the flood of 1979, the dyking systems were upgraded to provide protection to the then 100-year flood level (Figure 4.1) (Canada-Manitoba, 1991).

4.3 The 1997 Flood Event and Its Damages

During the 1997 Red River flood, an area in excess of 1,945 km^2 was inundated, sometimes extending over 40 km in width (Rahman, 1998). Over 2,500 homes were flooded, and the total damages were in excess of $500 million. Evacuation notices ranged on average from 35 hours in Emerson to 71 hours in St. Adolphe (Rasid *et al*., 2000) and permitted 28,000 residents in 21 communities to be evacuated (Haque, 2000). The IJC (1997) observed that emergency measures in 1997 reduced flood damages but there were some communication and logistical problems that contributed to some difficulties. Many homes were inundated by floodwaters for 1 week or longer. About 8,000 livestock (mostly poultry) within the basin died (Morris-Oswald *et al*., 1998).

4.3.1 Structural Works and their upstream-downstream effects

The flood control works were in full operation during the 1997 flood. The floodway diverted flows around the City of Winnipeg from 21 April to 3 June and was estimated to have prevented about $760 million in direct damages (Morris-Oswald *et al*., 1998; Natural Hazards Centre and Disaster Research Institute, 1999). The west dyke of the floodway inlet control structure, which impedes floodwater from entering Winnipeg from the west, required rapid extension and elevation. Along with the reinforcement of 15 km of the existing dyke, new dykes were constructed for an additional length of 25 km in just five days. Over 8,000 military personnel supplemented provincial and local manpower resources (IJC, 1997). Of the 800 properties protected by emergency dyking in Winnipeg, only 29 were damaged by floodwaters (IJC, 1997, 20). Due to the overall success in flood forecasting and the effectiveness of the flood control works, numerous lives and many vulnerable properties and other economic assets were saved. The IJC (1997) reported on the formidable flood fighting efforts led by the Manitoba Water Resources Branch. Thousands of volunteers filled sandbags, gave care to children, and

provided moral support. Non-government organizations, such as the Red Cross, played an active role during all phases of the flood.

During the post-flood period, many of the rural communities argued that they were flooded because water was diverted through the floodway to save the City of Winnipeg. In response, the provincial government reconstituted the Manitoba Water Commission to review this and other actions taken during the Red River flood. It concluded that the floodway had not been operated in strict conformance with the 1984 published program of operation. This departure from the program of operation was attributed to a number of factors: (1) inadequate freeboard on many sections of the primary dyking system in the city at 7.77 meters; (2) sewer outlets in many places were situated below 7.77 m City Datum and were not gated against backflow; and (3) at 7.77 m at James Avenue, the secondary dykes in certain parts would have been overtopped (Manitoba Water Commission, 1998). Many upstream communities blamed operation of the floodway for above-normal water levels in their vicinity. Residents of Grande Pointe, which is situated immediately upstream of the floodway, in particular, asserted that water levels in their community were much higher than normal due to controlled release from the floodway inlet structure.

Subsequently, the Manitoba Water Commission accepted the findings of a hydraulic investigation carried out by Klohn-Crippen Consultants to determine the effects of flood control works on upstream water levels. That study revealed that the effect of the operation of the floodway indeed raised flood levels above the expected natural levels. Water elevations were 0.61 m above 'natural' at the entrance to the floodway and 0.64 m at Grande Pointe. The operation of the floodway influenced water levels as far south as Ste. Agathe, where the river stage in the main channel were about 0.12 m above 'natural'. (These numbers were considered to be accurate within plus or minus 0.15 m but subsequent modelling by the same consultants using high accuracy Lidar topography calculated a reduced level of 'unnatural' flooding). With these findings, the Water Commission report eventually convinced the Manitoba Minister of Natural Resources to lift the $100,000 limit on flood compensation for about 200 residents of Grande Pointe (Redekop, 1998).

4.3.2 Flood Warning and Response

In 1997, the combination of heavy precipitation in the fall of 1996, exceptional snowpack, a less than ideal temperature pattern, high soil moisture content, untimely runoff, and an April blizzard caused the highest flood recorded in the 20th century (IJC, 1997; Morris-Oswald *et al*., 1998). Although knowledge of these conditions and the long flood history of the river led to an effective flood warning, there were a number of surprises. The IJC (1997) concluded that overland flooding hampered accurate flood forecasting; that it was a major contributor to water flows and flood damage; and that it exacerbated damages on numerous farms. Although flood forecasts for 1997 were very good at taking into account the magnitude of the event (Manitoba Water Commission, 1998a), the town of Ste. Agathe was struck by unpredicted overland flooding. Flood crest estimates at the Red River Floodway were underestimated by 0.5 m to 1.7 m due to the impact of floodway operations (Manitoba Water Commission, 1998a). Although

the volume of water in the 1997 flood was about the same as that in the 1950 flood, the rapid melt made the 1997 flood peaks sharper and of shorter duration than might otherwise would have been expected (IJC, 1997). These surprises reflect the uncertainty and the complexity that are associated with managing human activities in the context of uncertain understanding and predictions of, hydrologic and hydraulic processes.

Weaknesses in the institutional arrangements for flood warning also surfaced during the 1997 flood. One of the constraints of flood forecasting was the shortage of trained hydrologic forecasters in the Manitoba Water Resources Branch. During this catastrophic flood event, only one experienced forecaster managed the forecasting operations single-handedly but with considerable limitations (IJC 1997). Although about 100 hydrometric stations were operating throughout the entire Red River basin during the flood, the IJC (1997) recommended that more and better ones be established. Improved data telemetry was needed and, particularly in the United States, gauges needed to be reinforced so that they could continue to operate during extreme floods. These would also assist in improving prediction of flow patterns associated with overland flows and ice jams.

Jurisdictional issues sometimes hampered timely emergency responses (Tait and Rahman, 1998). During the Red River flood, some rural municipalities were reluctant to spend their own funds on flood fighting before financial arrangements with the province were finalized because provincial statute precluded them from running operating deficits (IJC, 1997). This reluctance was reinforced in those local officials who had underestimated the flood risk and had concluded that funds spent on emergency preparedness would represent a waste of money (Haque, personal communication). Some municipal flood fighting efforts were criticized because they appeared to be ill prepared (Morris-Oswald *et al*., 1998). The capacity of rural municipal response systems was questioned since the part-time officials, who staffed these centers, had relatively less experience with emergency flood systems than their urban counterparts (IJC, 1997).

Some aboriginal communities in the Red River basin suffered specific difficulties. Although EPC (1998) has outlined general roles and responsibilities for flood response in First Nations communities, it was unclear which agencies had a specific role in the development and implementation of emergency plans. Some Band Councils did not have official and approved emergency preparedness plans. This problem reflected, in part, their desire to avoid a perception of "favouritism" that might be associated with those members who were identified in the plan (Epp *et al.*, 1998). At times, the emergency procedures between some bands and the provincial government were unclear. In commenting on the experience of the Roseau River Anishinabe First Nation, Rahman (1998) suggested that the floodplain location of its Emergency Operations Centre and inadequate communications with other relevant parties were problematic. With respect to evacuation procedures, some band members perceived that they were not treated fairly because they were re-located to an arena that offered no privacy while non-aboriginal flood victims were offered better temporary shelters. This

decision evidently was that of the Manitoba Association of Native Fire Fighters which has primary responsibly for aboriginal emergency procedures (Rahman, 1998).

4.3.3 Emergency Evacuation

During the peak of the flood, emergency evacuation procedures had drawn considerable public criticism. The residents of the entire Red River Basin between the U.S. border and Winnipeg were asked to evacuate about one week prior to the flood crest. The mandatory nature of this evacuation was, perhaps, one of the most contentious issues during the 1997 flood in the Red River Basin (*Winnipeg Free Press*, 1997). A post-flood survey in August 1997 among residents of Emerson, Morris, Ste. Agathe and St. Adolphe confirmed this assumption, as nearly 50% of the respondents opposed the evacuation order (Rasid *et al*., 2000). The emergency evacuation order was issued by the Manitoba Emergency Management Organization (MEMO), whose executive authority was mandated by the *Manitoba Emergency Measures Act* (Haque, 2000; Simonovic, 1999). Because of the unambiguous nature of the evacuation order, the MEMO succeeded in preventing loss of life and in minimizing disruption and confusion during the evacuation process.

However, there were several reasons for public resentment against the mandatory mode of the evacuation. First, many residents would have preferred staying home for the purpose of taking some private measures to minimize the impact of flooding. Field evidence of such measures included temporary dykes (made of earth and sandbags), around several homes in Ste. Agathe. At the time of the survey, however, many of these dykes showed signs of damage and failure. In addition, watermarks around buildings indicated that the peak water level submerged most of these dykes. Thus, they were ineffective to prevent flooding of their homes. Secondly, another motivation for the respondents to stay home was the common concern that "property must be safeguarded, as evacuees tend to be worried about the security of what they left behind" (Alexander, 1993). Thirdly, in all surveyed communities, respondents would have preferred significantly longer notification time to evacuate than given by the MEMO. As indicated earlier, average notification time ranged from as little as 35 hours in Emerson to as much as 71 hours in St. Adolphe, whereas respondents' preferences ranged from 58 to 85 hours (Rasid *et al.*, 2000).

In an experimental study using choice modeling, Rasid *et al*. (2000) found that respondents' perception of the risks of flooding also played a crucial role in their preferences for the mode of evacuation. To assess this perceived risk, they were shown a set of choice cards, displaying several variables relating to evacuation policies and other disaster management issues at the same time. Whenever the risk of flooding was stated as extremely high (99 percent), the majority of respondents selected the mandatory evacuation option. With a reduction in the risk to a lower probability, such as 50 percent, mandatory evacuation was much less preferred than a voluntary evacuation. In the case of a mandatory evacuation, respondents would have preferred a slightly longer notification time for evacuation (than that stipulated by the MEMO) and a larger amount of flood relief than that announced by the provincial government (Rasid *et al*., 2000). Respondents were, thus, willing to accept mandatory evacuation with an increasing risk of hazardous flooding. It seems from this type of interpretation that

resentment against mandatory evacuation might have been partly related to the uncertainty and inadequacy of information on the level of risk of flooding. In particular, the changing hydrometeorlogical conditions of the flood period prompted periodic updating of the flood crest by the Water Resources Branch, Manitoba Conservation. This made it more difficult for residents to assess their personal level of risk. Another confounding factor relates to the denial of risk by some people. In some instances, people ignored flood warnings despite a provincial outlook released in February that indicated the "flood levels from Emerson to Selkirk could surpass all previous floods this century."

The social impacts associated with the evacuation and recovery is one area requiring further research and government action. Comments on these aspects will be made in the final chapter.

4.3.4 Flood Recovery Efforts

Claims for disaster financial assistance in the Red River valley were received from 5,100 individuals and 61 municipalities. As noted earlier, since the operation of the floodway increased flooding in Grande Pointe, flood victims of that community were permitted to submit claims for flood compensation in excess of the $100,000 limit (Haque, 2000). In other areas, the 20 percent deductible for disaster assistance was waived and grants of up to 75 percent of costs could be received. Although the FDRP was to limit disaster assistance to those structures built prior to designation, all landowners were compensated (Morris-Oswald *et al.,* 1998). These payments reflect two factors. First, at the time compensation was being paid, the 1997 flood was estimated to be in the order of 1:160 rather than the actual 1:100. Second, there was intense political pressure to compensate people quickly.

The payments to those who had structures that did not comply with regulations undermined the credibility of the FDRP and floodplain regulations. In other words, the decision to provide disaster relief funds to all landowners had major implications for floodplain management. First, it penalized indirectly those landowners and municipalities, which had implemented floodplain regulations at a cost to them. Second, it continued the tradition of subsidizing floodplain development. Third, this policy implicitly promoted development on the floodplain. Although regulations were poorly implemented, damages within Designated Flood Areas were still lower than those experienced outside.

First Nation residents who applied for disaster relief encountered problems because it is the band that owns the buildings and the residents who occupy them (Rahman, 1998; Haque and Epp, 1998). Disaster relief programs are oriented towards private landowners. There was also confusion among federal, provincial and local authorities over how these important socio-political differences could be best overcome.

After the flood, the Manitoba legislature established a new standard for floodplain development. It is now the 1997 flood level plus a freeboard of 0.6 m for dykes and 1.0 m for buildings (IJC, 1997). Primary responsibility for implementation of the new

development standard rests with municipal governments who may use their discretion in applying minimum building elevations into building by-laws (Morris-Oswald *et al*., 1998). While new provincial legislation has been introduced to preclude disaster relief for development that fails to comply with the new standard, past experience suggests that this intent will not be followed (Morris-Oswald *et al*., 1998). The new legislation also identifies public information as a component of the flood management program.

In Manitoba, a $130 million flood infrastructure enhancement program, funded by federal and provincial governments, was developed to improve flood protection in the basin (Caligiuri and Topping, 1999). Funding assistance was provided to homeowners and businesses for dyking or raising foundations. During the first-year of the program, over 2,700 applications were received and about 50 percent of these completed their projects. However, not all homes were able to meet the new floodproofing standards and there appears to be few fundable options available to them (Natural Hazards Centre and Disaster Research Institute, 1999). By the program's completion in 2003, other communities will be protected through structural measures, some groundwater wells sealed, GIS and topographic data upgraded, the flood forecasting network improved, and geophysical research on the historical pattern of flooding undertaken (Caligiuri and Topping, 1999). In addition, the non-governmental sector assisted in recovery efforts. The Red Cross provided $10,000 grants each for residents whose homes were unsalvageable and the Mennonite Disaster Services provided technical advice on rebuilding (Natural Hazards Centre and Disaster Research Institute, 1999; Slmcleod *et al*., 1999).

Ideally, disaster assistance should encourage a reduction in future flood losses. The Disaster Financial Assistance Arrangements program did not encourage the removal of structures and it supported a very limited range of reduction measures. Land acquisition is an alternative that is often not pursued by any program. Given that the 100-year floodplain is up to 40-km wide and comprises Manitoba's most productive farmland, land acquisition is not a viable alternative. The degree of NGO community support in reducing or increasing future losses is unclear. While flood responses by several NGOs were prompt, their ability to reduce vulnerability over the long term is uncertain.

4.4 The Saguenay Valley Flood

Significant urban and agricultural development in the Saguenay-Lac-St-Jean region, Quebec, is concentrated within the Saguenay Valley along the lower courses of major tributaries of the Saguenay River (Figure 4.2). During the 20th century, the hydroelectric potential of many rivers was harnessed. By 1996, over 25 public and private agencies had constructed over 2,000 dams and other control structures (Grescoe, 1997). Since there had been no significant flood losses prior to 1996, only a very modest level of flood protection was afforded to some communities primarily through dyking projects.

On July 19 and 20, 1996, a torrential rainfall inundated south-central Quebec and caused devastating floods in many waterways in the Saguenay-Lac-St-Jean, Mauricie, Québec, North Shore and Gaspésie and Iles de la Madeleine regions. According to Environment Canada, 150 to 280 mm of rain fell over a 72-hour period in an area of

several thousand square kilometers (Figure 4.2). The largest accumulations occurred directly to the south of the Jonquière-Chicoutimi-La Baie area in the Saguenay Valley, with more than 200 mm. Most of this rainfall was recorded in a 36-hour period between July 19 and July 20. This rainfall caused extensive damage to waterways in these regions, not to mention roads, bridges, railways, water retention structures, houses, farms, and public and commercial buildings (Commission scientifique et technique sur la gestion des barrages, 1997; Lapointe *et al*., 1998; Brooks and Lawrence, 1999; 2000). An estimated 16,000 people had to be evacuated and flooding damaged approximately 1,350 homes. The Saguenay-Lac-St-Jean Region was by far the hardest hit, and became the scene of an unprecedented lake and waterway bed and shoreline stabilization effort (Ministère de l'Environnement du Québec, 2000). In addition to the rainfall event, flood levels along some rivers were significantly increased by the failure of water retention structures. By far the worst example of this occurred at the Lake Ha! Ha! Reservoir where rising lake waters overtopped and breached an earthen saddle dyke causing the rapid drainage of the reservoir (Canadian Dam Association, 1997; Lapointe *et al*., 1998; Brooks and Lawrence, 1999).

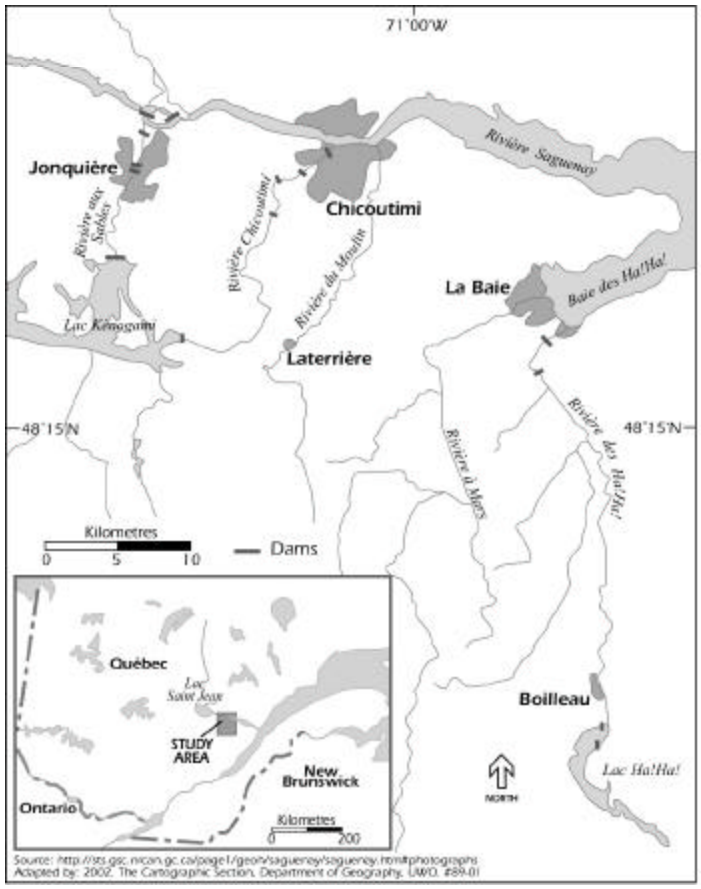


Figure 4.2 The Saguenay Valley Region

4.4.1 Floods on July 19 and 20, and Damage in the Saguenay Region

The torrential rainfalls and ensuing floods caused the most extensive damage to rivers. In the Saguenay River basin, the following waterways were severely affected: the St-Jean, Petit Saguenay, Ha! Ha!, à Mars, du Moulin, Belle, Chicoutimi and aux Sables Rivers (Figure 4.2). According to the Ministère de l'Environnement du Québec (2000), flood impacts included the following:

- Hydraulic: changes in the slope of the waterways, over-deepened and reshaped beds, widened runoff areas, changes in the sedimentary system and heightened flood risks.
- Environmental: aquatic and shoreline plants uprooted, loose soil washed away, habitats destroyed, aquatic wildlife carried away, and enormous quantities of sediment deposited in certain locations.
- Human: a host of social problems, fear and anxiety in disaster victims, psychological distress, the displacement and separation of many families, and the loss of enjoyment of property destroyed or damaged.
- Economic: decreased property values and property taxes, severe damage to hydroelectric facilities, drainage of water storage reservoirs, decreased production by business and industry and individual losses amounting to approximately $700 million.
- Legal: many disputes over property lines following the displacement of river beds, legal action for damages and interest against the Government of Quebec and the private companies involved in managing water retention structures.

Jurisdictional challenges also surfaced during the Saguenay flood. During that event, fragmented dam ownership, as well as the unsystematic design and operation of reservoirs, posed very significant obstacles (Commission scientifique et technique sur la gestion des barrages, 1997). An integrated approval and operating system for water control structures was lacking. These weaknesses were compounded when upstream dams had much larger flow capacities than downstream structures. In addition, design elevations of control structure were different than those of downstream and nearby dykes. Flood damages were exacerbated when water released from the Ha! Ha! Reservoir overtopped downstream dykes. During the flood, six major water control structures failed and several others were damaged (Commission scientifique et technique sur la gestion des barrages, 1997). These failures made effective flood warning and response even more difficult. In its review on the management of dams in Quebec, the Commission scientifique et technique sur la gestion des barrages (1997) noted that records about maintenance were often poorly kept or non-existent. Where there was information about dam safety, it was difficult for communities and other interested participants to obtain it.

4.4.2 Disaster Area Reconstruction

In July 1996, a special $200 million relief fund was established by the Government of Quebec (Order 933-66) and the first relief order allowed an advance payment of $2,500 per household for persons forced to evacuate their permanent residence (Order 932-96).

In addition, a special Relief Fund Program to compensate disaster victims was announced by the provincial government and a Coordinating Committee responsible for overseeing the reconstruction of disaster areas was formed. In all, the Quebec Government passed more than 50 orders on a variety of issues including financial aid for individuals, municipal emergency measures, approval of plans and specifications for dams and dykes, business recovery and reconstruction work. Most of the orders involved government financial aid and by March 31, 2001, the Quebec Government had provided over $400 million to these initiatives (Secrétariat du Comité ministériel de la coordination pour la reconstruction et la relance économique, 2000).

4.4.3 Waterway Restoration

After the flood, it became apparent that immediate action on some rivers was required in order to avoid even greater flooding problems in the coming spring season. Accordingly, in October 1996 the Government of Quebec instructed the Department of Transportation and the Department of the Environment to undertake urgent shoreline and bed stabilization work, especially on the Saint-Jean, à Mars, and Ha! Ha! Rivers (Order 1254-96). The Department of the Environment, in cooperation with the Interdepartmental Coordination Secretariat and the Reconstruction Office, was also required to design a shoreline and riverbed stabilization program. The ensuing program was approved in May 1997 (Order 639-97). The first of its kind, this collaborative program was one of the key actions taken by the Government of Quebec following the Saguenay flood.

In addition to this shoreline and bed stabilization program, Bill 152 was passed. It focused on the reconstruction and redevelopment of areas affected by the storms of July 1996 in the Saguenay-Lac-Saint-Jean region. Despite the need for this work, a host of problems quickly emerged, particularly in relation to rights of way on privately-owned land, ownership of new and former beds and any related fishing rights, as well as, land losses and gains. Moreover, these considerations were subject to various legal interpretations, depending on whether the waterway formed part of the public or private water system. In order to avoid delaying the stabilization work until after these issues had been resolved, the National Assembly passed and gave ascent to Bill 152 in June 1997.

Bill 152 empowered the Minister of Transportation, on behalf of the Government, to purchase by mutual agreement or expropriation the property required to reconstruct and redevelop the areas affected. A 1:100 year flood was the benchmark used to determine the property required for reconstruction purposes. The Department of the Environment ordered surveys and prepared the necessary acquisition plans: 210 plans in all – 80 on the à Mars River, 77 on the Ha! Ha! River and 53 on the Saint-Jean River. In the process, the Department of Transportation acquired ownership of the relevant riverbeds, as well as, a strip of shoreline to the 1:100 year flood mark covering a distance of about 35 km in length.

4.4.4 The Shoreline and Riverbed Stabilization Program

The stabilization program, implemented not only in the Saguenay area but in all regions affected by flooding, targeted three main objectives (Ministère de l'Environnement du Québec, 2000):

1) Restore the shoreline and beds of lakes and waterways to:
   - safeguard people and property;
   - stabilize shoreline;
   - restore ecological potential to shores and beds; and
   - foster the flow of water, sediment and ice.

2) Ensure that a dynamic homeostasis gradually emerged to allow the affected waterways to respond normally to various natural occurrences in light of new hydrological, geomorphologic and ecological conditions.

3) Enlist the help of certain state economic enterprises and municipalities in performing the work.

This program included various types of work involving lake and waterway beds, shorelines and surrounding properties, particularly:

- dredging, digging, filling and backfilling;
- stabilization by riprap, revegetation or other means;
- construction, reconstruction, raising or demolition of a dam, dike or sill located at the outlet of a lake or in a waterway;
- development of habitats for aquatic or shoreline wildlife;
- full or partial diversion of a waterway; and
- removal of debris, rubble or any other impediment to the flow of water or proper operation of structures.

Under this program, work was carried out on some 60 waterways throughout the various administrative regions affected. In all, more than $38 million was invested in stabilization work, including some $33.3 million (88 percent of expenses) in the Saguenay area, which was the most severely affected. Tables 4.2 and 4.3 list the actions taken in the Saguenay area and in the affected regions as a whole, respectively. They specify the number of work sites, overall length of the area of work (in meters) and the total cost of work for each waterway.

Table 4.2: Stabilization Program Overview:
Types of Post-Flood Protection Measures in the Saguenay Area

Location	Number, length and cost by type of project						Total
	Riprap stabilization	Plan stabilization	Earthworks and levelling of flood plain	Clean-up	Sill construction, reconstruction, consolidation	Other	
Rivière aux Sables	38 projects 1,325 m **$782,720**	12 projects 1,695 m **$265,415**				1 project 320 m **$367,040**	21 actions 3,340 m **$1,415,175**
Rivière Chicoutimi	26 actions 2,181 m **$902 036**	38 projects 2,244 m **$512,677**		2 actions 4,400 m **$114,708**		3 actions 134 m **$139,007**	39 actions 959 m **$1,668,428**
Rivière à Mars	9 actions 3,200 m **$1,341,664**	13 actions 21,620 m **$770,715**	5 actions 19,250 m **$1,305,280**		38 actions **$451 143**	38 actions 1,496 m **$422,455**	43 actions 45,566 m **$4,291,257**
Rivière Ha! Ha!	38 actions 8,575 m	6 actions 8,280 m	11 actions 20,480 m		14 actions	2 actions 375 m	40 actions. 37,710 m
	$8,604,312					**$131,866**	**$8,736,178**
Rivière Saint-Jean	16 actions 4,580 m	17 actions 6,485 m			1 actions	38 actions 38,250 m	41 actions. 18,315 m
	$2,998,669				**$35,000**	**$310,459**	**$3,344,128**
Ruisseaux À La Baie	38 actions 10,297 m **$8 211 521**						38 actions 10,297 m **$8,211,521**
Other waterways Saguenay area	112 actions 13,527 m	69 actions 9,949 m		45 actions 95,143 m		5 actions 1,529 m	231 actions 120,148 m
	$5 727 243						**$5,727,243**
Saguenay area Total	186 actions 43,685 m	125 actions 50,273 m	16 actions 39,730 m	47 actions 99,543 m	23 actions	26 actions 11,104 m	423 actions 244,335 m **33,393,930**

Modified from: Ministère de l'Environnement du Québec (2000)

Tables 4.2 and 4.3 show that riprap stabilization accounted for the most widespread activity, performed at 288 of the 386 sites (75 percent of the total). Riprap work also accounted for almost 62 percent of the total cost of projects totalling about $26 million. Other types of projects were less frequently used and less costly. However, earthworks and the levelling of floodplains are noteworthy. They accounted for approximately 12 percent of overall costs, with expenditures of some $5 million. In addition, although clean-up accounted for only 2 percent of expenditures, it covered some 108,915 linear meters, representing almost one half of the action taken. In terms of work and costs, the Saguenay area clearly incurred the heaviest damage and the highest costs, accounting for 88 percent of expenses. Half of these expenses related to the à Mars, Ha! Ha! and Saint-Jean Rivers.

Table 4.3: Stabilization Program Overview Summary of Projects in All Regions

Waterway, sector or region	Number, length and cost by type of project						Total
	Riprap stabilization	Plant stabilization	Earthworks and levelling of flood plain	Clean-up	Sill construction, reconstruction, consolidation	Other	
Waterways Region 04 Mauricie	13 actions 2,067 m **$984,302**	12 actions 2,047 m					25 actions 4,114 m **$984,302**
Waterways Region 03 Québec	10 actions 1 522 m **$776,437**			1 action 12 000 m **$49,671**	3 actions **$190,901**		14 actions 13,522 m **$1,017,009**
Waterways Region 09 Côte-Nord	13 actions 702 m **$369 571**	2 actions 85 m				2 actions 230 m **$30,000**	17 actions 1,017 m **$399,571**
Waterways Region 11 Gaspésie Iles-de-la-Madeleine	3 actions 665 m	2 actions 245 m **$369,571**				1 action 130 m	6 actions 1,040 m **$369,571**
Lac-Saint-Jean Area Total	51 actions 6,452 m **$1,561,827**	24 actions 2,134 m **$215,493**		12 actions 815 m **$113,172**		38 actions 870 m **$133,543**	95 actions 10,271 m **$2,024,035**
Saguenay Area Total	186 actions 43,685 m	125 actions 50,273 m	16 actions 39,730 m	47 actions 99,543 m	23 actions	26 actions 11,104 m	423 actions 244,335 m **$33,393,930**
Total All regions	276 actions 55,093 m	65 actions 54,784 m	16 actions 39,730 m	60 actions 112,358 m	26 actions	37 actions 12,334 m	580 actions 274,299 m **$38,188,418**

Modified from: Ministère de l'Environnement du Québec (2000)

4.4.5 Development and Redevelopment

Despite the urgent need for stabilization work at various sites prior to spring 1997 flooding, it was vital to establish redevelopment objectives from the outset, followed by redevelopment plans. The redevelopment objectives focused special attention on work designed to accomplish the following (Environment Canada, 1997):

- Safeguard people, buildings and infrastructures against the risk of flooding, high water and ice, as well as, landslides and shoreline erosion;
- Allow the free flow of water and ice;
- Restore the ecological functions of shorelines and beds; and
- Comply with future opportunities for land development.

The redevelopment plans also had to comply with the following principles:

- Ensure that the geometry and slope of the waterway beds reflect a morpho-sedimentological balance in the short term, a prerequisite for restoration;
- Adapt the new profiles to existing structures (bridges, railways, water inlets, urban or industrial areas);
- Foster natural shoreline stabilization except where safety, currents, ice flow or economic property losses dictate more extensive action;
- Promote the revegetation of slopes and exposed surfaces to minimize the impact of runoff; and
- Promote the creation or restoration of wildlife habitats by ensuring the circulation and migration of attractive sports species.

All of these principles also had to contribute to the spirit of the policy on shoreline, coastal and floodplain protection, especially in relation to protecting shorelines and aquatic ecosystems. In addition, the various redevelopment scenarios had to take account of Regional County Municipality (RCM) development plans and urban plans.

Finally, another significant factor involved in the waterway restoration and land development work was to develop 24 new flood-risk maps and update 26 others under the Canada-Quebec convention on mapping, floodplain protection and sustainable water resource development (hereinafter the Convention). The last eight maps, of the Rivière Saint-Jean, are currently in preparation.

4.4.6 Monitoring Program

The floods that followed the storm of July 1996 caused severe damage that required stabilization work along shorelines and to waterway beds, as well as, reconstruction on an unprecedented scale in Quebec. In addition to all of these large-scale activities, various steps were taken beginning in the winter of 1996-97, to start monitoring the waterways in anticipation of spring 1997 flooding and, over the longer term, to ensure the lasting safety of the public, buildings and infrastructures (Ministère de l'Environnement du Québec, 2000).

Accordingly, a permanent telemetric and rainfall / water flow interpretation system was developed in the winter of 1996-97. Under the direction of the Department of Civil Security, the purpose of this system is to minimize the risk of further damage and also to reassure the public and adequately prepare municipalities and organizations for spring flooding. Another element of this undertaking by the Department of Civil Security was to develop a public communications strategy and consolidate emergency preparedness plans in the municipalities. These systems are now firmly in place.

As a follow-up to the stabilization program that ended on 31 March 1999, regular inspections of the work completed will continue over a three-year period. These inspections aim to verify the effectiveness of the action taken, monitor the behaviour of the works and take appropriate corrective action as required.

Finally, on 11 June 2000, the Government of Quebec announced a series of measures concerning development of the infrastructures required to ensure public safety in the Lake Kénogami watershed, along the shores of Lake Kénogami, aux Sables and Chicoutimi Rivers. These measures included building an upstream reservoir on Pikauba River, reinforcing and modernizing existing works around Lake Kénogami and installing a sill on the upstream section of the aux Sables River. At an estimated cost of $170 million, these combined works will keep Lake Kénogami at a maximum level of 166.67 m (high water security level) and maintain a level of 163.9 m in summer. The work is scheduled for completion in 2005 (Gouvernement du Québec, 2000).

4.5 Summary

A clear strength of Canada's flood management efforts is its ability to detect and respond to floods in populated centres. In both the Red River and Saguenay Valley floods, flood warnings and responses were rapid. No one lost their life as a direct result of the events. Thousands of volunteers assisted in responding to the event. There is a more mixed assessment on mitigation and response. Structural adjustments significantly reduced losses in the Red River. This illustrates the importance of structural adjustments in flood management. However, the operation of the floodway was controversial. In the Saguenay Valley, reservoirs have been closely linked to economic development and there was no systematic effort to manage them for flood management. Dykes afforded protection from relatively low flood waters, and promoted a false sense of security among some residents. Building upon the strengths and addressing the weaknesses in current efforts is addressed in the following chapter.

5.0 IMPLICATIONS FOR PRACTICE AND RESEARCH

Flood protection infrastructure along rivers is often believed to create a false sense of security about flood risks that can lead to complacency about disaster preparedness and to greater development on the flood protected area (Tobin, 1995; de Loë, 2000). It is noteworthy that the primary and visible response in the wake of recent floods has been on structural adjustments. Mileti (1999) suggests that mitigative measures such as these do not prevent flood damages, but merely postpone them, since the design capacity of the structures can be exceeded by extreme, albeit low frequency, flood events. However, in the meantime, contravening this is the success of minimizing the damages from small to medium-sized flood events, which does suggest that the mitigative measures are in fact working. If the postponement amounts to many years and is accompanied by a significant increase in floodplain development, then the accrued losses can be enormous. It is during these extreme flood events that the need to integrate structural and non-structural adjustments becomes apparent.

The occurrence of extreme floods that exceed the design discharge of flood protection infrastructure and floodplain zoning will cause major flood disasters, as occurred recently in the Saguenay Valley, Quebec, in 1996, and the Red River basin, Manitoba, in 1997. The 1997 Red River flood is particularly noteworthy because the presence of a well-developed flood protection system (Red River Floodway, Portage Division, Shellmouth Dam, and dykes; see Mudry *et al*., 1981) successfully averted large-scale evacuations and flood damage within Winnipeg. However, the Floodway was operated in excess of the design capacity and contributed to increased flood levels for some upstream residents. When the dykes are overtopped and breached, there will be severe flooding in Winnipeg. Development onto flood vulnerable lands is taking place in some urban centers such as Montreal and the lower Fraser River basin.

In Mileti's (1999) view, this type of development that relies upon structural adjustments may be further postponing flood damage that will continue to accrue from the continued expansion of urban centres. In the case of Winnipeg, the probability of this occurring will be significantly reduced if the IJC's (2000) recommendations are followed. It is arguable that the Mileti paradigm in this case is unduly pessimistic since it emphasizes potential future losses rather than focusing on real and undoubtedly substantial loss reductions from the upgraded flood protection infrastructure. However, there are elements of the institutional arrangements for flood management in Canada that appear to support a cycle of escalating flood losses and 'passing the buck'. Extending the ideas of White (1945) and Galloway (1995) who commented on the U.S. experience, the cycle begins with significant flood damages being inflicted on a community that is located on a flood-prone area. Past flood events have prompted the construction of structural works and the establishment of a flood warning system and information campaigns. If floodplain regulations exist, they have likely been implemented poorly. The news media report on the flood, its damages and the emergency response efforts, to the nation. Relief programs, largely funded by senior governments and NGOs, immediately respond to this event. The public places much of the blame for the flood on inadequate government effort. In response, bigger and more structures are built with most of the funding coming from senior governments. Commercial properties and residences are refurbished, in part through the DFAA, to pre-flood conditions. Flood

warning systems and information programs are improved. Since senior governments provide neither consistent nor strong signals on the need to truly integrate structural and non-structural adjustments and lack of enforcement for floodplain regulations, intensive development continues on flood-prone areas. When these developments are flooded, primary blame is often placed upon municipalities. However, it is the previous steps that implicitly support this cycle of escalating economic losses.

It is a basic reality that occasionally and unavoidably, society will experience major flood disasters from rare, extreme events. It is also a reality that the need for effective flood management is growing as reflected in the increasing trend in flood losses. The approaches of the past seem to be inadequate to deal with current and future economic, social, and environmental conditions. Thus, flood management must be seen in the context of day-to-day decisions rather than a response to a disaster.

5.1 Practical Considerations: The Crossroads

It is within this context that Canadian flood management is at a crossroads and now faces difficult choices about whether to address the fundamental challenges confronting it, or to accept a trend of increasing flood damages. The dilemma concerning which road to choose reflects, in large part, the choice of framing flood problems as being primarily technical or institutional in nature. The road well traveled essentially extends a 50-year tradition in flood risk management that appears to make communities more vulnerable to rare, extreme floods. A relatively narrow set of alternatives is actually employed to solve flood problems. In the end, the construction of more, larger and better structures encourages more floodplain development and increases the loss potential. The road less traveled suggests that decisions made by people and governments in the course of their day-to-day lives and in response to disasters exacerbate the vulnerability of communities. It is the choices and decisions made by people and their institutional arrangements that contribute to people's vulnerability (Comfort *et al*., 1999). A difference in the outcomes associated between the two roads lies in what proportion of funds will be spent on disaster relief versus reduction of long-term vulnerability.

On the one hand, some recent decisions by senior government suggest that the road of the future will lead to increased levels of disaster relief payments. Environment Canada is not renewing any of the 10-year General Agreements under the FDRP. Some provincial governments are retreating from the issue as illustrated by the closure of British Columbia's Floodplain Mapping Branch (Day, 1999). In addition, the hydrometric network continues to be in a state of "crisis" (Bruce and Mitchell, 1995, vi). These types of decisions are grounded in a desire to address fiscal problems. While this is an urgent issue, it must not be solved at the cost of other important issues. It appears that its decision to withdraw from FDRP was rationalized by defining Environment Canada's core mandate as environmental quality to the exclusion of water, especially flooding. This separation of environmental quality and quantity appears to be inconsistent with the principles of integrated water management and sustainable development. However, it reflects the perceived realities of Environment Canada's responsibilities during a period of austerity. Reducing the vulnerability of communities to flooding and other natural hazards has therefore become a very low priority for

federal and provincial governments. While there may be questions regarding the appropriateness of Environment Canada's participation in flood management, there is no question that the federal government should participate in these activities. Provincial and local governments also have pivotal roles to play.

The rapid and unilateral withdrawal of provisions from homeowner insurance policies for damages due to sewer back-up is based upon the financial concerns of the insurance industry. On the surface, the remedial actions by governments following major flood events are somewhat reassuring. However, these actions and the trend of increasing damages underscore the current management crisis. While there is some comfort in knowing that an awareness of the problem exists, there has been neither a systematic assessment of the past strategies, nor a rigorous assessment of proposed alternatives. The future forecast suggests that individual agencies working from restricted mandates will continue to do their best in a difficult and constantly changing context. Individually and collectively, these initiatives largely address the urgent issue of funding without confronting the long-standing and underlying problems that underpin Canadian flood management strategies. If the current void in leadership is not filled, a provider of disaster assistance could become a more frequent role of all levels of government in future flood management activities. It was this set of circumstances that prompted the development of the FDRP in 1975. Canadians face pivotal decisions as to whether and how to pursue future strategies. The difficult management challenge is to define management principles that reduce our vulnerability in a cost-efficient and transparent manner.

On the other hand, other actions by government and the insurance sector offer a road that might lead to decreased levels of vulnerability. In 1998, EPC, now OCIPEP, released *A National Mitigation Policy* discussion paper that provides insight into future directions for flood and other hazard policies (EPC, 1998a). The intent is to build safer, more resilient and secure communities. Through a series of workshops that included a broad range of stakeholders, a consensus was achieved on the need for a *National Mitigation Policy*. Mechanisms that will guide future activities are designed to:

- create a Natural Disaster Protection Fund that might consist of an initial $30 million (10 percent of the average disaster recovery costs for the last five years) provided by central governments;
- provide mitigation and risk reduction in disaster recovery spending;
- encourage the private sector to initiate and fund mitigation;
- direct public donations to mitigation;
- establish a national mitigation secretariat to coordinate mitigation activities across Canada, facilitating ongoing dialogue among relevant groups;
- incorporate mitigation as a basic responsibility and priority for each department within government; and
- form a national mitigation partnership.

These steps reflect some progress. It has received the agreement in principle from the Insurance Bureau of Canada (1999) in its *National Mitigation Strategy*. Most significantly, the document embraces a multi-hazard rather than single hazard approach.

However, even this attribute is likely inadequate to promote the required changes to the existing set of flood management practices. Data and decision support systems, funding, partnerships, principles and leadership key issues that are associated with this strategy are discussed below.

5.1.1 Data and Decision Support Systems for Sustainable Flood Management

The initiatives noted above assume that flood-prone areas will be identified, and floods accurately forecast. Future flood and indeed all hazard policies should be grounded in hazard identification and assessment. These require reliable and accessible data. In the context of flooding, these foundations are achieved through data collection and analysis on parameters such as precipitation patterns, water flows on historical and real-time levels, risks, warnings, preparedness levels, remedial measures, and lessons from previous floods (Handmer and Parker, 1992). At a time when the need for information is more crucial than ever, recent decisions have dismantled important elements of the hydrometric network. Between 1990 and 1998, federal and provincial budget reductions resulted in the termination of 724 hydrometric stations. While some stations provided limited value or were deemed redundant, "clearly 21 percent of the former national network did not fall into these categories" (Scott *et al*., 1999, 51). Funding of the hydrometric network and relevant monitoring for other hazards is not mentioned in the EPC (1998a) discussion paper. If traditional sources are unable to renew their commitments, perhaps funds generated from water supply and wastewater treatment agencies, and/or land development charges might be used to finance the hydrometric network.

Many data users in Canada expressed a need for: (1) major improvements in the ways they could get data and in the means for disseminating them to the public; (2) more efficient data exchange between agencies involved in floodplain management; and (3) greater database integration within the river basin. The fragmented and incomplete information available is a major obstacle to better flood planning and preparedness.

The need for access to diverse data sources becomes apparent when the development of hydrologic and hydraulic planning and forecasting models is attempted. In many cases in Canada, the multi-jurisdictional and/or international setting of a watershed makes the implementation of central databases impractical. In response to this reality, increased use of existing communications and computing technology could create distributed virtual databases. These allow information to be made available electronically in an integrated form. However, each of the underlying databases continues to be maintained and operated by the relevant agencies. The ultimate goal is a distributed database for providing public access to data on floodplain management and flood disaster reduction activities, including the development of computer models. The integration of computer models with the virtual database has great potential for creating a powerful means to analyze flood-related problems in the basin. The final report of the Task Force on a Canadian Information System for the Environment supports this philosophy (Environment Canada, 2001).

Based on the experience in the Red River basin, there is support for the virtual database concept among the agencies with appropriate data sets for flood management. Initial

development has been completed and did demonstrate the maturity of the technology to support a development of virtual database for a complex domain such as floodplain management (Simonovic, and Huang, 1999; Simonovic, 1999a). However, issues remain concerning public access to the data. Foremost is the security of the internal network. No agency is willing to risk the integrity of the original data sets by giving the public unlimited online access. Other issues arise from the conservative "data culture" in Canada. In particular, the previous cost-recovery policies of some agencies, especially in federal departments, made public dissemination of data too costly to be practical.

Restricting public access to common good databases is poor public policy. Federal and provincial governments should maintain a high level of involvement in further database development using available computer networking technology. All key data providers in Canada should make freely available the data sets necessary for floodplain management and emergency response. Data providers should remain responsible for maintaining and replicating the data sets.

With adequate data, there are opportunities to form better decisions through the application of data, information and knowledge. Decision support systems (DSS) are one such 'technology' that were identified in the IJC's final report on the Red River flood as one way of facilitating integrated flood emergency management. Decision support systems are ideal for achieving these ends because they can:

(1) assess flood management strategies based on present conditions; and
(2) forecast future conditions in order to:
- identify alternative levels of vulnerability based on future population in the basin and other factors;
- measure losses in future floods based on alternative decisions made today, such as different land use and building code decisions; and
- identify the impacts on and changes in other aspects of sustainability like environmental quality, economic vitality and social equity (Simonovic, 1999b).

Flood management is a broad spectrum of activities aimed at reducing potential harmful impact of floods on the people, environment and economy of the region. Flood management process can be divided into three major stages: (1) planning; (2) flood emergency management; and (3) post flood recovery (Simonovic, 1999). During the *planning* stage, different alternative measures (structural and non-structural) are analyzed and compared for possible implementation in order to reduce flood damages in the region. *Flood emergency management* includes regular real-time appraisal of the flood situation and daily operation of flood control works. *Post flood recovery* involves numerous hard decisions regarding return to the 'normal life' (evaluation of damages, rehabilitation of damaged properties and provision of flood assistance to flood victims). Based on the IJC public hearings in the Red River basin and user needs assessment workshops, conducted in July 1998, there is a real need to integrate and make more readily accessible the distributed databases that currently exist and those to be developed in the future.

The most basic information for flood planning and preparedness concerns hydrologic and hydraulic data that require reliable and appropriate hydrometric and meteorological networks within the basin. Budget cuts in Canada have devastated the data collection networks. The hydrometric and meteorological networks will need to be upgraded in order to satisfy data needs for flood forecasting and water management in general. Additional satellite data, airborne data, and weather radar data may also improve flood management and preparedness. Thus, further reductions in the number of gauging stations are not acceptable and indeed more gauging stations are likely required.

Analysis of future flood control measures, operation of existing flood control structures, and evaluation of different hydrologic scenarios depends on the adequate topographical representation of the basin. Quite often inadequate topographical information is available. Digital elevation models (DEM) for implementation in flood-related activities are rarely available because of the costs of high-resolution elevation data acquisition. Airborne laser (Lidar) mapping today can be a fast, reliable and cost-effective method of obtaining three-dimensional data for the creation of a DEM. These data can be accurate to within the range of 1 m to ±15 cm depending on the terrain and ground control employed. In the future, digital elevation models for flood prone river basins should be completed by collaborative initiatives of the relevant agencies.

5.1.2 Addressing Flood Response and Recovery Issues

To date, only one Canadian study has been completed on the social impacts of flooding in Canada (Morris-Oswald and Simonovic, 1997). It focused on the problems encountered by individuals and communities in coping with the 1997 flood and provided a series of recommendations on how to plan more effectively to reduce human hardship in subsequent floods. It paid particular attention to the need to improve response and recovery efforts. Specific elements requiring improvement are noted below.

1. Development of a Public Information System using state of the art information technology.

This technology can be used to ensure that information is brought together from many sources, both government and non-government, and quickly updated as necessary. The information required for the system includes all relevant data needed in flood prediction and to facilitate the preparation process (*e.g.*, water levels, individual property levels, calculations for sandbag requirements, resource locations and stockpile numbers, government departments' mandates and policies, emergency protocols). It also should be capable of storing information on services for victims and maintaining a registry of victim profiles that is easily accessible by service-providers and government. The information system must be available at a local level, and used by individual households when necessary. In order to be effective, knowledgeable staff committed to meeting local community needs must support it. The lack of consistent accurate information (which residents could access and use in decision making) contributed to enormous stress in preparation for the 1997 flood and considerable resentment towards government.

2. Development of a Comprehensive Flood Management Plan involving all levels of government and local communities

Such a plan requires a commitment from all levels of government to apply lessons learned from previous flood experiences in order to prepare an integrated and comprehensive response to future floods. This includes clarification of a provincial-federal cost-sharing formula for flood damage. This plan also requires identification of various federal, provincial and municipal roles and responsibilities in flood fighting and recovery. The circumstances under which the Canadian Military may be brought in, their ensuing role and authority should be clear. Also at the local level, residents need to have prior training in the essential practical aspects of flood preparation, possibly with some local residents having specialized training so they may take on leadership roles when necessary. To accomplish this, technical expertise must be brought to the community. Failure on the part of all levels of government to establish a comprehensive flood plan which addressed the needs of at-risk communities contributed in large part to a general feeling among many victims that the government has been incompetent in predicting and handling the 1997 flood, and insensitive to victims' hardships.

3. Improved Systems of Warning about risk of flooding and evacuation.

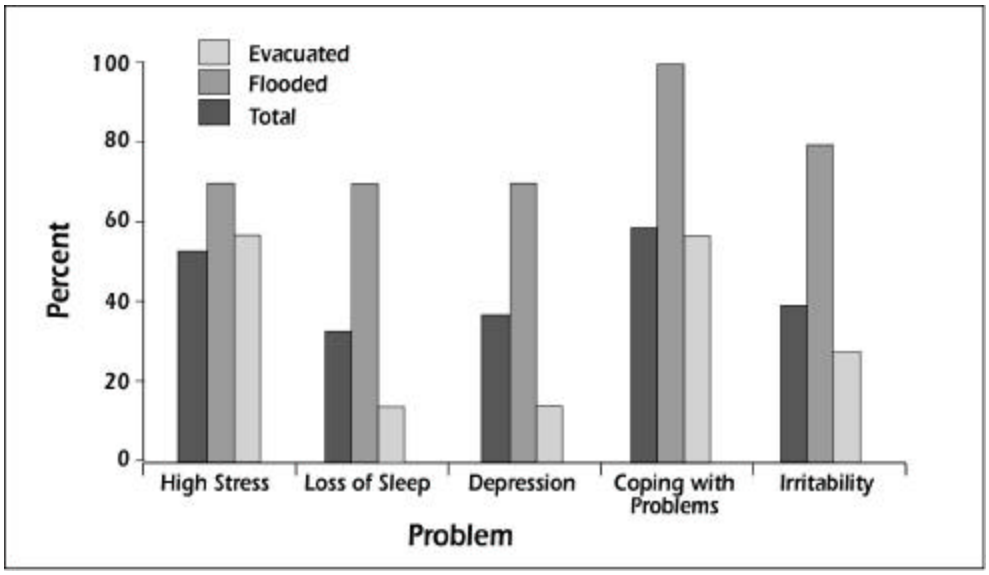
Once an efficient information system is available to accurately assess risk at a local level, there must be an established and consistently applied process for warning families about their individual level of risk. It must also be constantly updated. There should be a mechanism in place for alerting people at regular intervals of their risk in advance of the flood. This mechanism (whether public meetings, hand-delivered alerts or mailed alerts) must not fail in the crisis. This is particularly true once the need for evacuation is identified. It also must be clear whether evacuation is mandatory and what exceptions, if any, might be made. Warning of the potential need to evacuate should be given as far in advance as possible to give adequate time to prepare and prevent losses of irreplaceable items. Lack of warning both about the enormity of the flood and the need to evacuate clearly contributed to hardship to families impacted by the 1997 flood.

4. Identification of Local Communities' Resource Requirements and Development of Mobilization Plans to Get Resources.

Each community needs to complete a self-assessment. This might best include what each property owners' needs are if water levels rise to record limits. This will allow for an approximation of resources that would be needed in the community when another flood is imminent. Local government can then develop a plan to access necessary resources such as sand, bags, labor and other incidentals such as pumps, boats and generators. Communities can also create a plan on how they would mobilize their own local expertise, manpower and other resources to help in flood preparation. This would help address the greatest criticism of many 1997 victims – that local government was unable to predict local needs and supply necessary resources. By developing a mobilization plan that also prioritizes resource allocation based on an objective process, it will also reduce criticisms that resource distribution was neither equitable nor rational.

5. Reorganization of Emergency Measures Organization Claims Process.

The EMO claims process used following the Red River Flood faltered largely because of a lack of foresight and planning. A typical example was use of an outdated form letter which led many victims to believe that what was called their "maximum award" on one form was, in fact just that, when it was not. Victim interviews revealed that the anxiety resulting from that ill-written letter was enormous and was seen as symbolic of the compensation process. Figure 4.2 reveals the continued stress and stress related symptoms among flooded victims during the recovery phase (*i.e.*, after the flood). There is need for a mechanism to ensure that the EMO claims process comes *into* the community and is responsive to victims' needs. EMO should also work more closely with government departments such as Health, Environment Canada or Manitoba Industry, Trade and Mines. They could then expedite the provision of services to families or the condemning of homes. There should be an efficient means of conducting case reviews involving various departments when appropriate.



5.1 Psychological Stresses associated with the 1997 Red River Flood

A more efficient paperwork flow is also necessary. One option that would reduce paperwork, and make case inquiries more straightforward, would be a traditional case management approach. To do this, training of EMO personnel would need to be changed and improved. This approach would increase the accountability of employees, hopefully improve the quality and sensitivity of the service, and the overall efficiency of the compensation program. All of these problems were frequently raised in victim interviews. Better planning by EMO Claims Department would also call for a review and clarification of policies and guidelines for compensation. This preparation, in advance of the next flood, should prevent the frequent and confusing policy changes recently experienced, reduce inconsistencies, and ensure speedier compensation. It should also make it easier to provide information to victims on what items are and are not compensated for in the program.

In response to public concerns and to the specific problem of translating Provincial water level forecasts at specified points to more general application, a decision support system was developed under the Canada-Manitoba Partnership Agreement and has been implemented on a Manitoba Department of Conservation web-site. The system combines accurate Lidar topography with spring forecast water surface elevations from a hydrodynamic model to produce personalized forecasts. A user can enter his or her tax roll number to obtain a water level forecast and degree of protection needed for a specific property. A built in calculator determines the number of sandbags needed to provide that protection (Bowering *et al.*, 2002). Further developments, including information on road access, are planned.

Table 5.1 points out the responsibility for each of the recommendations identified in the report.

Table 5.1: Application of Recommendations

Applicability of Recommendation										
	Flood Sequence			**Authority**				**Community Type**		
Recommendations	**Pre-**	**During Post**	**Fed**	**Prov**	**Mun**	**City**	**Diked**	**Un-Diked**	**Diked**	**Farm**
1. Public Information System	**X**		**X**		**X* X***	**X**	**X**		**X** X**	
2. Flood Management Plan	**X**	**X**		**X**	**X***	**X***	**X**	**X**	**X****	**X****
3. Warning System	**X**	**X**			**X X***	**X**	**X**	**X****	**X****	
4. Resources Mobilization Plan	**X**	**X**			**X**	**X***	**X**	**X**	**X** X**	
5. Claims Department Reorganization	**X**		**X**		**X* X**			**X**	**X X**	

X - indicates recommendation addresses problems relevant to that category
X* - indicates leadership role required
X** - indicates urgency

There is no doubt that the flood of 1997 resulted in hardship to many families and communities in the Red River Valley; however, like any crisis situation, the flood has afforded an opportunity – an opportunity to learn from past errors and evoke necessary

changes. Post-flood reports have focused on changes which must be instituted in flood plain management in the Red River Valley; they clearly require mobilization of various authorities and communities, and an atmosphere of intense cooperation among all stakeholders. Essential to both of these is "vision" and long-range planning.

5.1.3 Funding Issues

The first three mechanisms noted in the previously mentioned *National Mitigation Policy* (EPC, 1998a) focus on funding issues. There is no question that investment to renew some parts of the existing infrastructure and to consider new ones are overdue. However, the proposed $30 million appears inadequate. The IBC (1999) suggested that senior governments should invest $100 million to $150 million a year in hazard mitigation projects. Cost sharing with municipal governments will be a cornerstone of any initiative. This pattern extends a 50-year tradition of cost sharing that has dominated past practice. The IBC (1999) also supported EPC's (1998a) suggestion on the need for spending on mitigative measures during flood recovery. It recommended that the existing Disaster Recovery Financial Assistance Arrangements program be augmented by an amount equal to 15 percent of the post-disaster clean-up cost that would finance preventive measures. This approach addresses the need for reconstruction activities to reduce the potential for future damages. Encouraging donations to fund required project works and obtaining funds from the private sector would spread the significant costs among more participants.

However, the predominant focus of these expenditures appears to be on 'projects'. This view runs counter to the reality that floods and other hazards must be managed on an ongoing basis rather than as sporadic emergencies. No reference is made to developing the required institutional capacity in local governments or restoring the capacity in provincial and federal governments (or special purpose bodies such as conservation authorities) to implement non-structural adjustments, such as warning systems, land acquisition programs and floodplain regulations. Without these operational investments and the required political commitment, floodplain regulations will continue to be conveniently ignored and the invasion of floodplains by increased investment will continue. Required investments in non-structural adjustments and monitoring are not mentioned by the EPC (1998a) or the IBC (1999). As Canada's urban areas extend into areas not mapped by FDRP, all levels of government and the insurance sector will better realize the need for additional hydrometric stations.

5.1.4 Partnerships, Principles and Leadership

The remaining three mechanisms from the EPC (1998a) discussion paper promote mechanisms for cooperation, communication and partnership. The EPC (1998a) and IBC (1999) imply that those who occupy floodplains must become more responsible for their actions, and less dependent on current relief and rehabilitation initiatives. Canadian municipalities have been generally excluded as an effective partner in previous flood management programs. Their meaningful participation is crucial because it is at the local level, where mitigative measures are implemented. The FDRP

left it up to provincial governments to encourage the adoption of floodplain zoning by municipalities and no significant efforts were made to build local capacity.

Community involvement and community-based approaches in disaster reduction is generally acknowledged to be a required ingredient for success (Mileti, 1999). To date, a 'top-down approach' has dominated Canada's flood management efforts. Effective community participation has and will continue to be difficult to achieve because of at least four reasons. First, the personnel in government and non-government organizations and other disaster professionals must subject their work "to a 'democratized' peer community, including both other professions and disciplines and the broader community" (Dovers, 1998, 10). Since this threatens the *status quo*, it will not be easily achieved. For instance, while a greater sharing of responsibilities was advocated by the Commission scientifique et technique sur la gestion des barrages (1997), water operators in the Saguenay basin generally preferred existing administrative arrangements because they were familiar with them, and perceived them to serve their specific needs adequately. The second obstacle is the dilemma faced by emergency organizations to balance rising demands and escalating problems with static or reduced public resources (Dovers, 1998). Indeed, the current emphasis on partnership is often a response to diminished funding. As long as the partnership does not reflect an end in itself, substantive outcomes in the form of reduced vulnerability levels should be expected. Third, effective community involvement is hard to achieve because it requires discussion, debate and dialogue between communities and professionals to develop a shared understanding (Twigg, 1999-2000). Finally, a clear delineation of the current and normative roles of the individual community, province, federal government, NGO, and private sector must be made.

Partnerships among federal, provincial and municipal governments, landowners and the insurance industry are an important element in future mitigation programs. However, given the difficulties in meeting the needs of aboriginal communities, it would be appropriate for a National Mitigation Policy or Strategy to specify this vulnerable group as requiring a dedicated effort. Future mitigation programs must be more sensitive to the socioeconomic characteristics of Canada's native populations.

The goal of future partnerships should be to break the cycle of dependence. In its place, a culture of flood preparedness that the Insurance Bureau of Canada (1999) believes is a central part of human settlement management would be nurtured. Newton (1997) maintained that developing this culture required a shift in basic human values and social-environment interactions. Traditional information and education programs based on pamphlets, open houses, audio-visual productions, and school programs can be of some assistance. However, laws, incentives and resources that promote effective change must support these efforts. For instance, provincial governments could require real estate agents to disclose timely and effective risk information to purchasers during real estate transactions. Some specific alternatives that deserve a full discussion include: reducing property taxes for structures built to specific standards; providing discounts on insurance rates for commercial establishments that undertake specific mitigative measures; linking cost-share arrangements for structural adjustments and warning systems to a community's mitigative efforts; and providing low interest loans

to homeowners to complete mitigative works. These have some of the key incentives and resources responsible for successful mitigation programs in the United States (Krimm, 1998).

The following principles have guided mitigation efforts in the United States and should be considered as a basis for Canadian mitigation and flood management programs:

- Risk reduction measures ensure long-term success for the community as a whole, rather than short-term benefits for special interests.
- Risk reduction measures for one hazard must be compatible with risk reduction measures for other natural hazards.
- Risk reduction measures must be evaluated to achieve the best mix for a given location.
- Risk reduction measures for natural hazards must be compatible with risk reduction measures for technological hazards and vice versa.
- All mitigation is local.
- Disaster costs and impacts of natural hazards can be reduced by emphasizing pro-active mitigation before emergency response – both pre-disaster (preventive) and post-disaster (corrective) mitigation is needed.
- Hazard identification and risk assessment are the cornerstones of mitigation.
- Partnerships between all levels of government, the private sector and people are the most effective means of implementing measures to reduce the impacts of natural hazards.
- Those who knowingly choose to assume greater risk must accept responsibility for that choice.
- Risk reduction measures for natural hazards must be compatible with the protection of natural and cultural resources (Krimm, 1998, 61-62).

To improve Canadian flood management policy and practice, leadership is needed. At present, the EPC (1998a) has identified objectives, principles and mechanisms, but has yet to assign specific responsibility for making it happen. That is the crucial next stage – an outline of how all levels of government and private interests can pursue the policy. Without leadership and a visible commitment to effective flood and risk management, the most sophisticated and well-intentioned institutional innovations to reduce vulnerability will fail.

5.2 Research Issues

Many aspects of the flood management problem are unknown to us at present. In order to make progress in practice, research is required. The following are some suggestions for research in the areas of: the nature of flooding, flood impacts, assessment of flood management programs and policies, and better understanding of human behaviour. Many of these reflect the ideas contained in a report of an Independent Expert Panel on Flood Mitigation (Kumar *et al*., 2001).

5.2.1 The Nature of Flooding

Flood frequency analysis based on the historic record of annual peak floods is a fundamental tool in determining the design discharge for floodplain zoning, flood

protection infrastructure, and structures that span rivers. A basic assumption in frequency analysis is that climatic trends or cycles do not affect flood flows, but there is clear evidence that this is not the case (Gosnold *et al*., 2000), and that even modest changes in climate can result in large changes in flood magnitude (Knox, 1993). A research challenge is to determine how aspects of climate change can be incorporated into flood frequency analysis for planning purposes.

Furthermore, the basic assumptions of homogeneity and independence of any time series of flood peaks can easily be called into question, particularly when evaluating the relatively short Canadian climate and hydrometric records (Booy and Morgan 1985; Klemes 1987; Watt, 1989). The public is understandably confused when, after every major flood event, major changes are made to the flood frequency distribution. Other approaches to determining regulatory floods must be considered in addition to simply improving conventional flood frequency analysis.

Mathematical models play a key role in flood forecasting and in improving our understanding of hydrologic processes. In its simplest sense a model could consist of a rainfall-runoff relation and a routing equation. There are two trends, however, that require the application of significant research effort. First, the increasing availability of remotely sensed data such as precipitation, snow water equivalent or evapotranspiration requires modifying models to accept spatial as well as point data. Improvements to the algorithms for transforming data to useful information as well as improvements to forecast models are required.

Second, physically based models allow a more rigorous examination of discrete hydrological processes such as precipitation, interception, infiltration, interflow, and baseflow (Soulis *et al.*, 2000). Overland flow and channel routing may be incorporated directly in the model or calculated in a hydraulic model. Research into physically based distributed hydrologic models that could be used for forecasting (perhaps in simplified form) and for planning and design is needed. Such models could be used to examine anthropogenic impacts on a watershed. Issues such as the effects of conversion of a land surface to agricultural purposes, drainage development or wetland destruction on runoff volumes and peaks generate considerable public debate. Producing findings that are publicly acceptable requires considerable effort using very detailed models. In addition, these models could ultimately be coupled with atmospheric models to examine issues such as climate change impacts on water resources. Global circulation models could provide the boundary conditions for regional scale models (Pietroniro *et al*., 2001*).*

The geomorphic record can reveal evidence of the occurrence and magnitude of past extreme floods. A research challenge is to develop paleoflood records for a sample of rivers in different climatic regimes of Canada that extend significantly beyond measured and historic floods records. This will begin to address the issue of how the frequency of high magnitude flood events responds to climate change. Innovative, multidisciplinary research approaches will have to be utilized in order to obtain these reconstructions in some geomorphic settings.

Infrequent, large flood events can cross the erosive thresholds along alluvial rivers and result in catastrophic erosion along valley bottoms. Such erosion represents a major risk from flooding that can occur in addition to inundation damage from floodwaters, and can result in significant losses of property and infrastructure, even when these are situated above the flood level. Erosive thresholds are most likely to be crossed during severe floods along rivers where the channel planform is close to the meandering-braid transition. A better understanding of the erosive threshold would allow river reaches that are susceptible to large-scale erosion, during extreme floods, to be recognized, and assessments to be made of the vulnerability of valley bottom development and infrastructure to large-scale erosion.

5.2.2 Flood Impacts

Increasing our knowledge of flood impacts is a second research area. This includes assessments of the direct and indirect social, economic and environmental impacts of flooding. This would provide a greater understanding of the benefits and costs of reducing flood risks. Added research into the impacts of floods could also serve as a tool for educating people about this hazard and assisting in developing future flood programs and policies.

The study of the ecological impacts of flood control structures is of particular importance. Control structures such as dams, reservoirs, channel adjustments and water diversions can drastically alter the river ecosystem in addition to the hydrological cycle due to their grand scale and/or alterations to the landscape. Hunt (1999) noted several impacts of dam and levee construction that severely altered riverine environments or disrupted aquatic ecology and organisms along the river system. Research of new structural designs, operational procedures, and management approaches is needed to protect not only lives and property but also the natural environment.

There is also a need for better data and understanding of flood damages, risks and vulnerability. Risk assessments or analyses of flood events could prove to be useful for collecting various information regarding flood impacts and associated data. A database or information repository should be available through the World Wide Web that would be useful for anyone seeking access to this information. This database could contain technical, socio-economic and environmental information for past flood events, including types of flood mitigation measures taken (their advantages and disadvantages, and costs versus benefits). The database would be beneficial in summarizing and disseminating the knowledge of flood impacts. It would also provide data that could be used for assessing flood impacts in comparison to various flood mitigative options.

5.2.3 Assessments of Programs and Policies

Assessments or post-audits of past flood damage reduction programs and policies are an important area of research. These studies could provide valuable information for future program or policy formulation. One tool that could be used to accomplish this is benefit-cost analysis (BCA). The BCA could be made quite compelling since the amount of costs averted and the benefits accrued could be clearly identified. At present, however, there are difficulties in identifying and quantifying all the benefits and costs in order to perform a comprehensive analysis. Nevertheless, this tool does provide a

method of quantifying impacts and outcomes of measures taken to reduce and control flood risks and for those costs and benefits which cannot be quantified, at least some qualitative information can be provided. Post audits could also include studying effective versus ineffective aspects of flood damage reduction programs and practices, which could offer important insights as to why these programs worked or did not work. Also, existing mechanisms to direct individuals towards flood damage reduction (*e.g.*, flood insurance, mandatory disclosure of flood risk through mortgages and deeds, and flood risk development by-laws) should be reviewed. Learning from these experiences would be helpful and the information could be adapted to areas of similar characteristics in order to determine the best approach to deal with existing flood risks. These studies could also help uncover the extent to which Canadians are becoming more vulnerable to the flood hazard.

5.2.4 Understanding Human Behaviour: Risk-Taking and First Responders' Decisions

How individuals and communities in flood risk areas perceive a flood threat and what risks they are willing to take is not clearly understood. An initial effort has been documented in modeling human behaviour during flood evacuation (Ahmad and Simonovic, 2000) based on the experience in the Red River Basin. However, in general there has also been very little research done with respect to patterns in first responder's (*i.e.*, individual) behaviour in flood hazard risk mitigation and response. These are areas that require attention since the responsibilities of dealing with floods are being directed away from higher-level governments towards the community and individual level. Since greater importance is being placed upon the local and individual level, more in-depth research is necessary to understand and model household and other pertinent unit level (*e.g.*, community) risk-taking behaviour and mitigation measures for floods. This type of research could also assist in determining what individuals and communities are willing to undertake in order to mitigate flood risk and damages (*e.g.*, their willingness to participate in and the feasibility of a flood insurance scheme) and enable more effective approaches in regards to information delivery to end-users.

5.3 Summary

There is no doubt that over the last 50 years Canadian flood managers have made tremendous progress in reducing the flood risks. However, the trend of increasing flood damages suggests that additional efforts are required. The research opportunities outlined provide a basis for future projects that could reduce future losses. At a practical level, past experience suggests that a lack of commitment by some or all levels of governments has been associated with the implementation of programs. It is anticipated that recent floods have demonstrated the follies of this shortcoming. In addition, future programs will have to better involve municipal governments that have been often overlooked in the formulation of past programs. These programs will also rely on collaborations with the private sector, particularly the insurance industry, which has a vested interest in reducing damage levels. Finally, reducing flood risks will require some personal acceptance of responsibility by those living in floodplains. In this manner, Canadians can play a more proactive role in reducing the loss of life and damages.

6.0 REFERENCES

Ahmad, S. and S.P. Simonovic. (2000). "Analysis of Flood Management Policies Using System Dynamics." *Proceedings of the 2000 American Institute of Hydrology International Conference, "Atmospheric, Surface and Subsurface Hydrology and Interactions.*" North Carolina, November. pp.15.

Alexander, D. (1993). *Natural Disasters*. London: UCL Press.

Andrews, J. (ed). (1993). *Flooding: Canada Water Year Book*. Ottawa: Ministry of Supply and Services.

Ashmore, P. and M. Church. (2000). *The Impact of Climate Change on Rivers and River Processes in Canada*. Ottawa: Geological Survey of Canada Bulletin 555.

Beltaos, S. (1995). "Ice Jam Processes." *River Ice Jams.* S. Beltaos (ed.). Highlands Ranch, Colorado: Water Resources Publications, LLC.

Booth, L. and F. Quinn. (1995). "Twenty-Five Years of the Canada Water Act." *Canadian Water Resources Journal.* 20(2): 65-85.

Booy, C. and D. R. Morgan. (1985). "The Effect of Clustering of Flood Peaks on a Flood Risk Analysis for the Red River." *Canadian Journal of Civil Engineering*. 12: 150-165.

Bowering, R., N. Diehl, L. Donnelly, U. Holweger, and R. Lewis. (2002). "Integrating Digital Hydraulic and Terrain Elevation Models into a GIS Decision Support System for Basin Planning and Flood Management Decisions in the Red River Basin". *Proceedings, Canadian Water Resources Association National Conference.* Winnipeg: Canadian Water Resources Association.

Boyd, D. (1997). "Saguenay Storm applied to the Grand River Watershed." Available at: http://www.cwra.org/hydrology/arts/dwight.html.

Boyd, D., A. Smith and B. Veale. (1999). "Flood Management in the Grand River Watershed: A Watershed Conservation Perspective." *Environments.* 27(1): 23-47.

Brooks, G.R. and D.E. Lawrence. (1998). *Geomorphic Effects and Impacts of Severe Flooding: Photographic Examples from the Saguenay Area, Quebec.* Ottawa: Natural Resources Canada.

Brooks, G.R. and D.E. Lawrence. (1999). "The Drainage of the Lake Ha! Ha! Reservoir and Downstream Geomorphic Impacts along Ha! Ha! River, Saguenay Area, Quebec, Canada." *Geomorphology*. 28: 141-168.

Brooks G.R. and D.E. Lawrence. (2000). "Geomorphic effects of flooding along reaches of selected rivers in the Saguenay region, Quebec, July 1996." *Géographie physique et Quaternaire*. 54(3): 281-299.

Brooks G.R. and E. Nielsen. (2000). "Red River, Red River Valley, Manitoba." *The Canadian Geographer*. 44(3): 304-309.

Brooks, G.R., S.G. Evans and J.J. Clague. (2001). "Flooding". *A Synthesis of Natural Geological Hazards in Canada*. G.R. Brooks (ed.). Ottawa: Geological Survey of Canada Bulletin 548. 101-143.

Brown, D.W., S.M.A. Moin and M.L. Nicolson. (1997). "A Comparison of Flooding in Michigan and Ontario: 'Hard' Data to support 'Soft' Water Management Approaches." *Canadian Water Resources Journal*. 22(2): 125-139.

Bruce, J.P. (1976). "National Flood Damage Reduction Program." *Canadian Water Resources Journal.* 1(1): 5-14.

Bruce, J.P. and B. Mitchell. (1995). *Broadening Perspectives on Water Issues*. Ottawa: Royal Society of Canada, Incidental Report No. IR95-1.

Bruce, J.P., I. Burton and I.D.M. Egener. (1999). *Disaster Mitigation and Preparedness in a Changing Climate.* Toronto: Institute for Catastrophic Loss Reduction.

Bumsted, J. M. (1997). *Floods of the Centuries: A History of Flood Disasters in the Red River Valley 1776-1997*. Winnipeg: Great Plains Publications.

Caligiuri, E. and S. Topping. (1999). "Overview and Status of the Canada-Manitoba Partnership Agreement on the Red River Valley Flood Protection." *Proceedings of the Red River Flooding "Decreasing Our Risks" Conference*. Winnipeg: Canadian Water Resources Association.

C anada-Manitoba. (1991). "Manitoba Flood Protection Projects Agreement." *1990-1991 Annual Report, Projects Agreement Wind-up Report*. Winnipeg: Manitoba Natural Resources, Regina: Environment Canada.

Cardy, W.F.G. (1976). "Flood Management in New Brunswick." *Canadian Water Resources Journal.* 1(1): 40-46.

Church, M. (1988). "Floods in Cold Climates." *Flood Geomorphology*. V.R. Baker, R.C. Kochel and P.C. Patton (eds.). New York: J. Wiley and Sons. pp. 205-229.

Clague, J.J. and S.G. Evans. (1994). *Formation and Failure of Natural Dams in the Canadian Cordillera,* Ottawa: Geological Survey of Canada Bulletin 464.

Clague, J.J.and S.G. Evans. (2000). "A Review of Catastrophic Drainage of Moraine-dammed Lakes in British Columbia." *Quaternary Science Review*. 19: 1763-1783.

Comfort, L, B. Wisner, S. Cutter, R. Pulwarty, K. Hewitt, A. Oliver-Smith, J. Wiener, M. Fordham, W. Peacock and F. Krimgold. (1999). “Reframing Disaster Policy: The Global Evolution of Vulnerable Communities”. *Environmental Hazards*. 1(1): 39-44.

Commission scientifique et technique sur la gestion des barrages. (1997). *Report/ The Scientific and Technical Committee on the Management of Dams in Quebec*. Quebec: Canadian Dam Safety Association.

Communiqué de presse (Gouvernement du Québec), Chicoutimi le (11 juin 2000): Bassin versant du lac Kénogami : 170,2 millions de dollars pour compléter la mise en œuvre des recommandations du rapport Nicolet.

Costa, J.E., and R.L. Schuster. (1988). “The Formation and Failure of Natural Dams.” *Geological Society of the America Bulletin.* 100: 1054-1068.

Day, J.C. (1999). “Adjusting to Floods in the Lower Fraser Basin, British Columbia: Toward an Integrated Approach?.” *Environments.* 27(1): 49-66.

DeGagne, M., G.G. Douglas, H.R. Hudson and S.P. Simonovic. (1996). "A Decision Support System for the Analysis and Use of Stage-Discharge Rating Curves.” *Journal of Hydrology*. 184(3-4): 225-241.

de Loë, R. (2000). “Floodplain management in Canada: overview and prospects.” *The Canadian Geographer*. 44: 355-368.

de Lo?, R. and D. Wojanawski. (2001). “Associated benefits and costs of the Canadian Flood Damage Reduction Program.” *Applied Geography*. 21:1-21.

Desloges, J. R. and M. Church. (1992). “Geomorphic Implications of Glacier Outburst Flooding: Noeick River Valley, British Columbia.” *Canadian Journal of Earth Science.* 29: 551-564.

Doern, G.B. and T. Conway. (1994). *The Greening of Canada: Federal Institutions and Decisions*. Toronto: University of Toronto Press.

Doughty-Davies (or Davis?), J.H. (1976). “Floodplain Management in British Columbia.” *Canadian Water Resources Journa*l. 1(1): 67-74.

Dovers, S. (1998). “Community involvement in environmental management: Thoughts for emergency management.” *Australian Journal of Emergency Management*. 6-11.

Emergency Preparedness Canada. (1997a). *Emergency Preparedness Canada*. Ottawa: Emergency Preparedness Canada.

Emergency Preparedness Canada. (1997b). "When Nature runs Wild." *Emergency Preparedness Digest*. 24(1): 8.

Emergency Preparedness Canada. (1998a). *A National Mitigation Policy*. Ottawa: Emergency Preparedness Canada.

Emergency Preparedness Canada. (1998). *The First Nation Experience*. Ottawa: Emergency Preparedness Canada

Emergency Preparedness Canada. (1999). *Federal Disaster Assistance Arrangements (DFAA)*. Ottawa: Emergency Preparedness Canada.

Emergency Preparedness Canada. (2000). *Federal Payments under DFAA for Floods occurring Since 1970*. Data provided by Emergency Preparedness Canada Database, 08 March 2000

Environment Canada. (1996). *The Canada Water Act Annual Report 1995-1996*. Minister of Supply and Services Canada 2000. Cat. N° En36-426/1999.

Environnement Canada (1997). *Pluies diluviennes du 18 au 21 juillet 1996, au Québec : Analyse et interprétation des données météorologiques et climatologiques.* Région du Québec: Division des services scientifiques.

Environment Canada. (1998a). "Response to *Broadening Perspectives on Water*." Available at: http://www.cwra.org/news/arts/fwsumrec.html.

Environment Canada. (1998b). *Canada and Freshwater: Experiences and Practices*. Sustainable Development in Canada Monograph Series Number 6. Ottawa: Minister of Public Works and Government Services Canada.

Environment Canada. (1999). *The Canada Water Act Annual Report 1998-1999*. Minister of Public Works and Government Services Canada 2000. Cat. N° En36-426/1999.

Environment Canada. (2001). *Sharing Environmental Decisions.* Final Report of the Task Force on a Canadian Information System for the Environment. Ottawa: Supply and Services Canada.

Epp, D., C.E. Haque and B. Peters. (eds.) (1998). *Emergency Preparedness and First Nation Communities in Manitoba.* Ottawa: Emergency Preparedness Canada.

Etkin, D. (1999). "Climate Change and Extreme Events: Canada". *Canada Country Study: Climate Impacts and Adaptations, Volume VIII: National Cross-Cutting Issues Volume.* N. Mayer and W. Avis (eds.). Canada: Adaptation and Impacts Research Group, Environment Canada.

Forget, S., B. Robert and J. Rouselle. (1999). *The Effectiveness of Flood Damage Reduction Measures in the Montreal Region.* Toronto: Environmental Adaptation Research Group, Environment Canada and the Institute for Environmental Studies, University of Toronto.

Frederick, K.D., D.C. Major and E.Z. Stakhiv. 1997. "Introduction." *Climate Change and Water Resources Planning Criteria*. K.D. Frederick, D.C. Major and E.Z. Stakhiv (eds.). London: Kluwer Academic Publishers. 1-5.

Galloway, G. Jr. (1995). "New Directions in Flood Plain Management." *Journal of the American Water Resources Association.* 31(3): 351-357.

Gardner, J. and B. Mitchell. (1980). "Floodplain Regulation in Ontario: An Analysis of Existing and Proposed Policy in the Grand and Credit River Watersheds." *Journal of Environmental Management*. 11(1): 119-131.

Gerard, R. (1990). "Hydrology of Floating Ice." *Northern Hydrology: Canadian Perspectives*. T.D. Prowse and C.S.L. Ommanney (eds). Saskatoon: National Hydrology Research Institute Science Report No. 1, Environment. 103-134.

Gerard, R. and K.S. Davar. (1995) "Introduction." *River Ice Jams.* S. Beltaos (ed.). Highlands Ranch, Colorado: Water Resources Publications, LLC. 1-28.

Giles, W. (1976) "Floodplain Policies in Ontario" *Canadian Water Resources Journal.* 1(1): 15-20.

Gosnold, W.D., J.A. LeFever, P.E. Todhunter and L.F. Osbourne Jr. (2000). "Rethinking Flood Prediction: Does the Traditional Approach Need to Change?" *Geotimes*. 45: 20-23.

Grescoe, T. (1997). "After the Deluge." *Canadian Geographic*. 117(2): 29-40.

Handmer, J.W. (1980). "Flood Hazard Maps as Public Information: An Assessment within the Context of the Canadian Flood Damage Reduction Program." *Canadian Water Resources Journal.* 5(4): 113-122.

Handmer, J.W. and D.J. Parker. (1992). "Hazard Management in Britain: Another Disastrous Decade?" *Area*. 24(2): 113-122.

Haque, C.E. (2000). "Risk Assessment, Emergency Preparedness and Response to Hazards: The Case of the 1997 Red River Flood, Canada." *Natural Hazards.* 21: 223-243.

Haque, C.E. and D. Epp. (1998). "Sioux Valley First Nation." *Emergency Preparedness and First Nation Communities in Manitoba.* D. Epp, C.E. Haque and B. Peters (eds.). Ottawa: Emergency Preparedness Canada.

Haque, C.E. (1999). Personal communication. “GIS and new technology in Flood Mitigation.” Mimeo.

Harrison, K. (1996). *Passing the Buck: Federalism and Canadian Environmental Policy.* Vancouver: UBC Press.

Hogg, B. (1994). “Heavy Rainfall and Floods.” *Proceedings of a workshop on Improving Responses to Atmospheric Extremes: The role of insurance and compensation*. J. Mcculloch and Etkin, D. (eds.). October 3-4, 1994. Toronto: Environmental Adaptation Research Group, Environment Canada. Available at: http://www.msc-smc.ec.gc.ca/airg/doc/hogg.html.

Hunt, C. (1999). “A Twenty-First Century Approach to Managing Floods.” *Environments.* 27(1): 97-114.

Hunter, Fraser G., David B. Donald, Brian N. Johnson, Wayne D. Hyde, John M. Hanesiak, Markus O. B. Kellerhals, Ron F. Hopkinson and Bart W. Oegema. (2002). "The Vanguard Torrential Storm (Meteorology and Hydrology)." *Canadian Water Resources Journal* . 27(2): 213-227.

Insurance Bureau of Canada. (1999). *A National Mitigation Strategy*. Toronto: Insurance Bureau of Canada.

Insurance Council of Canada. (1998). “Fact Book.” Toronto: Insurance Council of Canada.

International Joint Commission. (1997). *Red River Flooding Short-Term Measures.* Ottawa/Washington: International Joint Commission. Available at: www.ijc.org/boards/rrb/taskforce.html.

International Panel on Climate Change. (1996). *Climate Change 1995: The Science of Climate Change: Contribution of the Working Group I to the Second Assessment Report of the International Panel on Climate Change*. Cambridge: Cambridge University Press.

International Red River Basin Task Force (2000). “The Next Flood: Getting Prepared”, *Final Report*. Ottawa/Washington: International Joint Commission. Available at: www.ijc.org

Jackson, L. E., O. Hungr, J.S. Gardner and C. MacKay. (1989). “Cathedral Mountain Debris Flows, Canada.” *Bulletin of the Institute of the Association of Engineering. Geologists.* 40: 35-54.

Kallio, R. 2001. Personal communication

Klemes, V. (1987). "Hydrological and Engineering Relevance of Flood Frequency Analysis." *Hydrologic Frequency Modelling*. V.P. Singh (ed.). Kluwer Academic Publishers.

Knox, J. C. (1993). "Large Increases in Flood Magnitude in Response to Modest Changes in Climate." *Nature*. 361: 430-432.

Kovacs, P. (1999). "The Rising Cost of Natural Disasters." *Proceedings from the First Annual Catastrophic Loss Reduction Symposium*. November, 15, 1999. Toronto: Institute for Catastrophic Loss Reduction.

Kreutzwiser, R., I. Woodley and D. Shrubsole. (1994). "Perceptions of Flood Hazard and Development Regulations in Glen Williams, Ontario." *Canadian Water Resources Journal.* 19: 115-124.

Krimm, R.W. (1998). "Making mitigation a reality." *Australian Journal of Emergency Management.* 13(1): 60-64.

Kuban, R. (1996). "The Role of Government in Emergency Preparedness." *Canadian Public Administration*. 39(2): 239-244.

Kumar, A., I. Burton and D. Etkin (eds.). (2001). "Managing Flood Hazard and Risk: Report of an Independent Expert Panel". *Report prepared for Emergency Preparedness Canada and Environment Canada*. March 15, 2001.

Lapointe, M. F., Y. Secretan, S. N. Driscoll, N. Bergeron, and M. Leclerc. (1998). "Response of the Ha! Ha! River to the flood of July 1996 in the Saguenay Region of Quebec: large-scale avulsion in a glaciated valley." *Water Resources Research*. 34(9): 2383-2392.

Lins, H.F., D.M. Wolock and G.J. McCabe. 1997. "Scale and Modeling Issues in Water Resources Planning." *Climate Change and Water Resources Planning Criteria*. K.D. Frederick, D.C. Major and E.Z. Stakhiv (eds.). London: Kluwer Academic Publishers. 63-88.

Lorant, I. (1990). "Are Ontario Floodplain Regulatory Storms too Severe?". *Proceedings of the Floodplain Management Conference*. March 12-14. Toronto: Ontario Ministry of Natural Resources and the Association of Conservation Authorities of Ontario.

MacKay, D.K. and J.R. Mackay. (1973). "Location of Spring Ice Jamming on the Mackenzie River, N.W.T." *Hydrologic Aspects of Northern Pipeline Development*. Ottawa: Environmental-Social Committee, Northern Pipelines, Task Force on Northern Oil Development, Report 73-3. 233-257.

Manitoba Natural Resources. (1998). "Red River Valley Flood". Winnipeg: Poster prepared by Manitoba Remote Sensing Centre, Land Information Division.

Manitoba Water Commission. (1998a). *An Independent Review of the 1997 Red River Flood - Flood Forecasting.* Winnipeg: A report to the Hon. J. Glen Cummings, Minister of Natural Resources.

Manitoba Water Commission. (1998b). *An Independent Review of Actions Taken During the 1997 Red River Flood.* Winnipeg: A report to the Hon. J. Glen Cummings, Minister of Natural Resources.

Matalas, N.C. (1997). "Stochastic Hydrology in the Context of Climate Change." *Climate Change and Water Resources Planning Criteria*. K.D. Frederick, D.C. Major and E.Z. Stakhiv (eds.). London: Kluwer Academic Publishers. 89-101.

Mathews, W.H. and J.J. Clague. (1993). "The Record of Jökulhlaups from Summit Lake, Northwestern British Columbia." *Canadian Journal of Earth Sciences.* 30: 499-508.

Matthai, H.F. (1990). "Floods." *Surface Water Hydrology*. *The Geology of North America, Volume O-1*. M.G. Wolman and H.C. Riggs (eds). Boulder: Geological Society of America, Boulder. pp. 97-120.

Mileti, D.S. (1999). *Disasters by Design: A Reassessment of Natural Hazards in the United States*. Washington, D.C.: Joseph Henry Press.

Millerd, F., C. Dufournaud and K.Schaefer. (1994). "Canada-Ontario Flood Damage Reduction Program Case Studies." *Canadian Water Resources Journal.* 19(1): 17-26.

Ministère de l'Environnement du Québec (2000), *Bilan des interventions à la suite des pluies diluviennes des 19 et 20 juillet 1996*, ISBN 2-551-20441-0, Envirodoq : ENV2000-0514. 27.

Mitchell, B. and D. Shrubsole. (1992). *Ontario Conservation Authorities: Myth and Reality.* Waterloo: Department of Geography Publication Series No. 35.

Morris-Oswald, T. and S.P. Simonovic (1997). *Assessment Of The Social Impact Of Flooding For Use In Flood Management In The Red River Basin.* Winnipeg: Report prepared for the IJC red River Basin Task Force.

Morris-Oswald, T., S.P. Simonovic and J. Sinclair. (1998). *Case Study: Efforts in Flood Damage Reduction in the Red River Basin-Practical Considerations*. Toronto: Environmental Adaptation Research Group, Environment Canada and Institute for Environmental Studies, University of Toronto.

Mudry, N., P.J. Reynolds, and H.B. Rosenberg. (1981). Post-project evaluation of the Red and Assiniboine River flood control projects in the Province of Manitoba, Canada. *Methods of Post-Project Evaluation: Achievements and Remedial Measures*. Grenoble, France: International Commission on Irrigation and Drainage: Special Session R. 9. 147-178.

Natural Hazards Centre and the Disaster Research Institute. (1999). *An Assessment of Recovery Assistance Provided after the 1997 Floods in the Red River Basin: Impacts on Basin-wide Resilience*. Toronto: Environment Canada, Adaptations and Impacts Research Group.

Newton, J. (1997). "Federal Legislation for Disaster Mitigation: A Comparative Assessment between Canada and the United States." *Natural Hazards.* 16: 219-241.

NOAA. (1994). *The Great Flood of 1993*. Silver Spring: Natural Disaster Survey Report, National Oceanic and Atmospheric Administration.

Ontario Flood Plain Review Committee. (1984). *Report*. Toronto: Queens' Printer.

Ouellette, P., D. Leblanc, N. El-Jabi and J. Rouselle. (1988). "Cost benefit Analysis of Flood-plain Zoning." *Journal of Water Resources Planning and Management.*. 114(3): 326-334.

Paine, J.D. and W.E. Watt. (1992). "Uncertainty in Floodplain Delineation: Recognition, Evaluation and Reduction." *Resolving Conflicts and Uncertainty in Water Management*. D. Shrubsole (ed.). Cambridge: Canadian Water Resources Association. 17.1-17.16.

Pietroniro, A., E.D. Soulis, K. Snelgrove and N. Kouwen. (2001). "A Framework for Coupling Atmospheric and Hydrological Models." *Soil-Vegetation-Atmosphere Transfer Schemes and Large Scale Hydrological Models.* A. J. Dolman, A. J. Hall, M. L. Kavvas, T. Oki, and J. W. Pomeroy (eds.). IAHS Publication No 270.

Platt, R.H. (1999). "From Changing Control to Flood Insurance: Changing Approaches to Floods in the United States." *Environments.* 27(1): 67-78.

Quinn, F. (1985). "The Evolution of Federal Water Policy." *Canadian Water Resources Journal*. 10(4): 21-33.

Rahman, M.M. (1998). "Roseau River Anishinabe First Nations." *Emergency Preparedness and First Nation Communities in Manitoba.* D. Epp, C.E. Haque and B. Peters (eds.). Ottawa: Emergency Preparedness Canada.

Rannie, W. F. (1998). "A Survey of Hydroclimate, Flooding, and Runoff in the Red River Basin prior to 1870." Geological Survey of Canada Open File 3705.

Rasid, H., Haider, W. and Hunt, L. (2000). "Post-Flood Assessment of Emergency Evacuation Policies in the Red River Basin, Southern Manitoba." *The Canadian Geographer* . 44(4): 369-386.

Roy, E., J. Rousselle and J. Lacroix. (1998). *Flood Damage Reduction Program in Québec: Case Study of the Chaudière River*. Ottawa: Emergency Preparedness Canada.

Saunders, J.O. (1988). *Interjurisdictional Issues in Canadian Water Management.* Calgary: The Canadian Institute of Resources Law, Faculty of Law, The University of Calgary.

Schaefer, K.A. (1990). "The Effect of Floodplain designation/regulations on Residential Property Values: A Case Study in North York, Ontario." *Canadian Water Resources Journal.* 15(4): 319-332.

Scott, D., T.R. Yuzyk and C. Whitney. (1999). "The Evolution of Canada's Hydrometric Network: A Century of Development." *Partnerships in Water Resource Management*. Cambridge: Canadian Water Resources Association. 42-54.

Secrétariat du Comité ministériel de la coordination pour la reconstruction et la relance économique. (2000). "Les pluies diluviennes des 19 et 20 juillet 1996 : Mauricie, Saguenay/Lac/saint-Jean, Charlevoix, Côte Nord. " Bilan de la reconstruction – document synthèse, ISBN 2-550-36820-7, 383 pages and appendices.

Shrubsole, D. and J. Scherer. (1996). "Floodplain Regulations and the Perceptions of the Real Estate Sector: The Cases of Brantford and Cambridge, Ontario, Canada." *Geoforum*. 27: 509-525.

Shrubsole, D., V.J. Hammond and M. Green. (1995). "Floodplain Regulation in London, Ontario, Canada: Assessing the Implementation of Section 28 of the *Conservation Authorities Act*." *Environmental Management*. 19: 703-717.

Shrubsole, D., V.J. Hammond and M. Green. (1996). "Floodplain Regulation in London, Ontario: Status and Prospects." *Canadian Water Resources Journal.* 21(4): 367-386.

Shrubsole, D., V.J. Hammond, R. Kreutzwiser and I.Woodley. (1997a). "Assessing Floodplain Regulation in Glen Williams, Ontario, Canada." *Journal of Environmental Management.* (50): 301-320.

Shrubsole, D., M. Green and J. Scherer. (1997b). "The Actual and Perceived Effects of Floodplain Land-Use Regulations on Residential Property Values in London, Ontario." *The Canadian Geographer*. 41(2): 166-178.

Simonovic, S.P. (1999). “Social Criteria for Evaluation of Flood Control Measures – Winnipeg Case Study.” Urban Water (special issue ‘Non-Structural Measures in Urban Flood Control’) B. Braga (ed.). 1(2):167-175.

Simonovic, S.P. and P. Huang. (1999). “Prototype Virtual Database Development for Management of Floods in the Red River Basin.” Proceedings of the Canadian Water Resources Association Conference – Red River Flooding – “Decreasing our Risk”, IX-1- IX-12.

Simonovic, S.P. (1999a). “Prototype Virtual Database Development for Management of Floods in the Red River Basin.” *Canadian Civil Engineer*. 16(6):12-15.

Simonovic, S.P., (1999b). “Decision Support System for Flood Management in the Red River Basin.” *Canadian Water Resources Journal.* 24(3): 203-223.

Slmleod Consulting and Brian Wilkes & Associates with M. Gibbs, P. Hawkins-Bowman and R.W. Newbury. (1999). *Review of Red River Basin Floodplain Management Policies and Programs.* Ottawa: International Joint Commission.

Soulis, E. D., K. R. Snelgrove, N. Kouwen, F. Seglenicks, and D.L. Verseghy. (2000). "Towards Closing the Vertical Water Balance in Canadian Atmospheric Models: Coupling the Land Surface Scheme CLASS with the Distributed Hydrological Model WATFLOOD." *ATMOSPHERE-OCEAN*. 38(1): 251-269.

St. George, S. and E. Nielsen. (2000). “Signatures of high magnitude 19th-century floods in *Quercus macrocarpa* tree rings along the Red River, Manitoba.” *Geology*. 28(10): 899-902.

Tait, R.W. and M.M. Rahman. (1997). *The Role and Reactions of Municipalities of the Red River Valley During the Flood of 1997*. Windsor: International Joint Commission.

Tobin, G.A. (1995). “The Love Affair with Levees: A Stormy Relationship.” *Water Resources Bulletin.* 31: 359-367.

Topping, Steven D. (1997). "Red River Valley Flood Control Works and Related Infrastructure in the Province of Manitoba." *Red River '97, the Flood of the Century, Causes, Impact, Management.* Winnipeg: Canadian Water Resources Association.

Wallace, L. (1997). “”Responsibility for Natural Hazards.” *Coping with Natural Hazards in Canada: Scientific, Government and Insurance Industry Perspectives*. S.E. Brun, D. Etkin, D. Gesink Law, L. Wallace and R.White (eds.). Report prepared by Environmental Adaptation Research Group, Environment Canada and the Institute for Environmental Studies, University of Toronto. Toronto: Round Table on Environmental Risk. Available at: http://www.utoronto.ca/env/nh/title.htm.

Watt, W.E. (ed.) (1989). *Hydrology of Floods in Canada: a Guide to Planning and Design*. Ottawa: Associate Committee on Hydrology, National Research Council, Ottawa.

Watt, W.E. (1995). "The National Flood Damage Reduction Program: 1976-1995." *Canadian Water Resources Journal.* 20(4): 237-247.

Weiss, G. (1987) "Benefits of Flood Hazard Mapping: The Case of Pilot Butte Creek in Regina, Saskatchewan" Report WPM-WNR-1888-01. Regina: Environment Canada.

White, G.F. (1945). *Human Adjustments to Floods*. Chicago: University of Chicago Press, Department of Geography.