Floods

Over the span of a given year, all rivers and streams experience a range of flows that reflect the seasons, recent weather conditions, soil moisture levels, and the runoff characteristics of the watershed. For relatively short periods of time, ranging from hours and days to many weeks, flow can temporarily exceed the capacity of a channel. This causes water to overflow the river banks and inundate low-lying lands adjacent to the channel. Such an occurrence is a flood.

Floods are part of the natural hydrological cycle (the seasonal fluctuation of water levels) and occur along rivers and streams somewhere in Canada every year. In some watersheds, flooding can be caused by the formation and failure of natural dams (for example, ice jams) that locally obstruct flow and then later suddenly release the impounded water.

Deaths and Dollars

In Canada, flooding is a common natural hazard that has caused 260 known disasters since 1900, resulting in the loss of 235 lives and 8.7 billion dollars* in damage. The five most damaging floods were:

- 1996 Saguenay flood ($1.7 billion)
- 1950 Red River flood ($1.1 billion)
- 1954 flooding arising from Hurricane Hazel (81 people killed, $1.1 billion)
- 1997 Red River flood ($817 million)
- 1948 Fraser River flood ($425 million)

*The estimated total cost of the damages from 1900 to 1999, based on 1999 dollars; cost of damages from 2000 onwards, based on year dollars.

Flood Mechanisms

Weather-Related Floods

Most flooding in Canada is caused by hydrometeorological (or weather-related) mechanisms, consisting of runoff from snowmelt, storm rainfall, rainfall on snow and the obstruction of flow in rivers and streams by ice jams (see Table 1 below). Weather-related floods are a direct product of climate. The intensity of such flood mechanisms varies regionally reflecting the different climates across the country, but all four types occur broadly in every region of Canada. The importance of weather-related floods varies considerably throughout the year, again reflecting the connection to climate. For example, snowmelt-runoff floods occur more often during the spring-melt period, but they can also occur during mild periods in the winter. Storm-rainfall runoff flooding can occur in the spring, summer or fall, while ice-jam flooding can occur during freeze-up in the fall or during ice break-up in the spring. Particularly severe flooding may result when several weather-related mechanisms occur at the same time; for example, in the spring, snowmelt can be combined with rain-on-snow runoff and ice jamming.

Table 1. Hydrometeorological Flood Mechanisms

Mechanisms	**Description**
Snowmelt	Snowmelt floods are one of the most common types of flooding in Canada. The magnitude of the flooding reflects, in part, the thickness and density of the snowpack and the rate of melting. Snowmelt floods occur in watersheds of all sizes, often in combination with storm-rainfall runoff and/or ice jams. Notable snowmelt floods in the 20th century occurred along the Fraser River, British Columbia during May–June 1948 and the Red River, Manitoba during May 1997.
Storm-rainfall	Storm-rainfall floods occur directly from rainfall runoff in all regions of Canada. Notable examples from large storm systems include the flooding in southern Ontario caused by Hurricane Hazel, in October 1954, and in the Saguenay area, Quebec in July 1996. More isolated, but particularly severe flooding can be caused by thunderstorms, for example, in Timmins, Ontario during August 1961, in Edmonton, Alberta during July 1978, and in Montréal, Quebec during July 1987.
Rainfall-on-snow	Rainfall-on-snow floods occur in all parts of Canada and result from a combination of snowmelt and storm-rainfall runoff. Such floods can be particularly severe in the fall along the west coast, and during the winter and early spring elsewhere in Canada. Notable examples include flooding along the St. John River, New Brunswick, during March 1936 and April 1973, in Newfoundland during January 1993 and in southwestern British Columbia during October 1984.
Ice-jams	Ice-jam flooding is caused by the temporary obstruction of flow by the build-up of river-ice debris cross the channel. Ice jamming is a significant flood mechanism along rivers in most of Canada. Large rivers that are well known for ice-jam flooding are the Mackenzie, Red (Manitoba), Saint John (New Brunswick) and St. Lawrence (Ontario-Quebec) rivers.

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

Flooding Related to Natural Dams

The formation and failure of a natural dam can also cause flooding, although it is much more localized and occurs far less frequently than weather-related flooding. Floods from natural dams result from the blockage of drainage by landslides, glaciers and moraines, and, at a much smaller-scale, by snow and beaver dams (Figure 1).

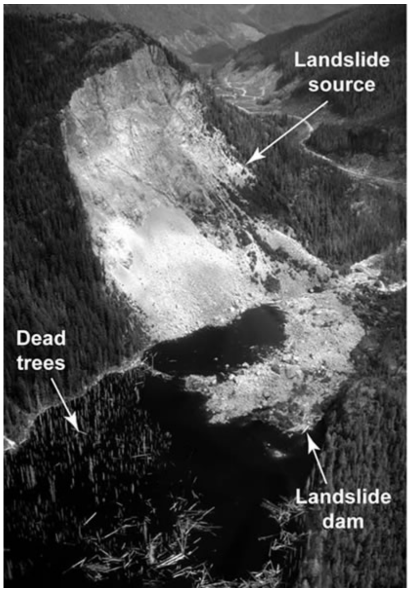

Figure 1. Photograph of a permanent landslide-dammed lake on the Kennedy River, Vancouver Island, British Columbia. Note the dead trees in the lake, killed by lake waters that rose shortly after the landslide debris formed the dam.
Source: Geological Survey of Canada, photograph GSC 2000-111, taken by S.G. Evans.

Flooding occurs upstream from the damming itself as a lake forms behind the dam. Flooding downstream will happen from the sudden release or 'outburst' of the impounded water if the dam is breached and eroded rapidly by the escaping water (Figure 2).

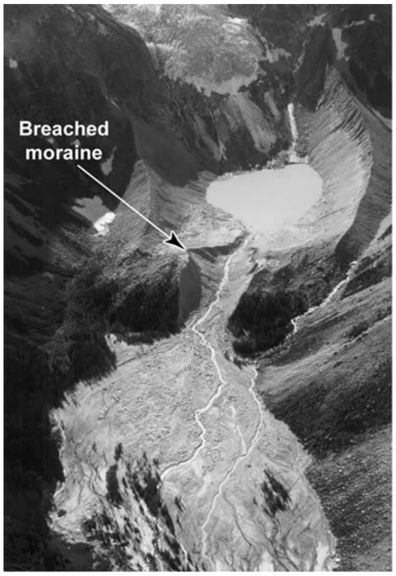

Figure 2. Photograph of a breached moraine dam at Nostetuko Lake, British Columbia
Source: Geological Survey of Canada, photograph GSC 2000-119, taken by S.G. Evans.

An 'outburst flood' can have a peak discharge many times greater than the maximum expected for the stream or river from weather-related floods, and can cause enormous inundation and erosion downstream. Sometimes, however, a natural dam will form a permanent lake (Figure 3).

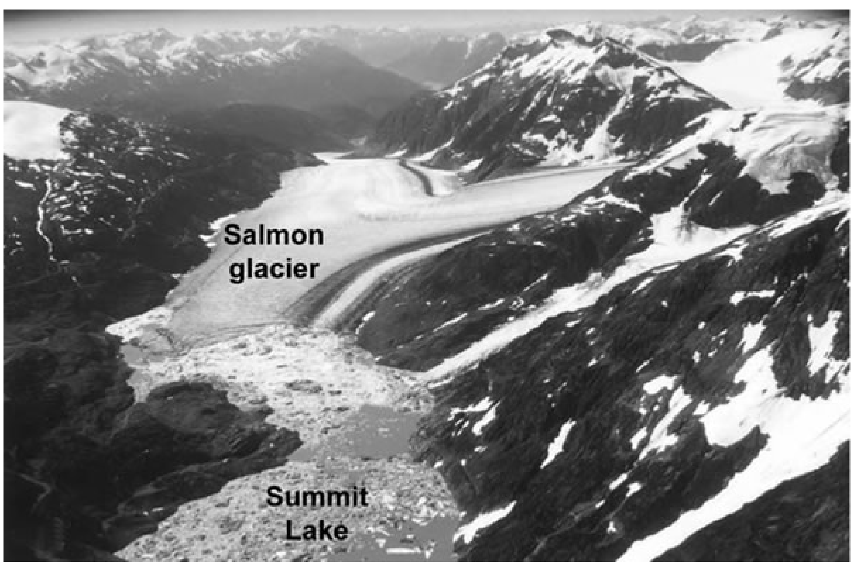

Figure 3. Photograph of a natural dam at Summit Lake, British Columbia, dammed behind the Salmon Glacier

Source: Geological Survey of Canada, photograph GSC 2000-113, taken by S.G. Evans.

Table 2 provides a detailed description of the various formation mechanisms of natural dams.

Table 2. Formation Mechanisms of Natural Dams

Natural Dams	Description
Landslide	Landslide dams form when landslide debris blocks drainage along a valley bottom. The scale of damming depends upon the thickness and lateral extent of the debris on the valley bottom. Large landslides consisting of several hundred million cubic metres of debris can form significant, but often temporary, lakes within major valleys. Flooding related to landslide dams occurs in several parts of Canada, but is most common in the mountains of British Columbia and the Yukon where frequent landslides and narrow, steep-sided valleys create conditions favourable for the obstruction of rivers and streams. In the Great Plains region, landslide dams have temporarily blocked major rivers (for example, the Peace River). In eastern Canada, landslides in glaciomarine sediments have blocked rivers and flood low-lying areas upstream.
Glacier	Most glacier-dammed lakes in Canada are found in high mountain valleys of British Columbia and the Yukon. Glacier dams may fail catastrophically, creating an outburst flood, or 'jökulhlaup' (an Icelandic word describing a sudden glacier flood). Once an outburst flood ceases, the lake can refill if the glacier dam reforms. A reformed glacial lake can drain again at some time in the future. Although most jökulhlaups in Canada occur in remote areas, they can pose a serious threat to infrastructure, forest lands and fish habitat far downstream from the glacier dam.
Moraine	Moraine-dammed lakes can form in basins vacated by retreating glaciers, typically in cirques and steeped-walled valleys. Some of these dams are vulnerable to rapid erosion by waters flowing from the lake, which may lead to a catastrophic outburst flood. Since 1925, there have been at least ten outburst floods from moraine-dammed lakes in the Cordillera. Like jökulhlaups, floods from moraine-dam failures occur in remote areas, but they pose a serious threat to infrastructure, forest lands and fish habitat far downstream from the lake basin.
Snow	Thick accumulations of avalanched or windblown snow can block streams, forming small temporary lakes that may subsequently drain suddenly to produce a flood. Flooding resulting from snow dams is thought to be of only local significance.
Beaver	Beavers are well-known for constructing wood and mud dams across small streams and creeks to create ponds. Abandoned beaver dams can deteriorate over time and then erode rapidly, releasing a flood that is large relative to the size of the stream. Although localized, such floods have eroded road crossings and railway embankments.

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

Flood Damage

Flooding causes loss of life and damages property. Buildings and infrastructure, such as bridges and pipelines, can be structurally damaged or destroyed by fast-flowing water and/or collisions from large floating debris (for example, ice or trees) being carried by the current. In extreme circumstances, buildings and bridges may be washed off their foundations and carried downstream (Figure 4).

Figure 4. Photograph of a house washed off its foundation and located on a river channel after the flood, Saguenay area, July 1996
Source: Geological Survey of Canada, photograph taken by G.R. Brooks.

Riverbank erosion by floodwaters can damage or destroy buildings and infrastructure by undermining them, even when they are situated above the level of flooding (Figure 5).

Figure 5. Photograph of buildings on a terrace undermined by bank erosion, Saguenay area, July 1996
Source: Geological Survey of Canada, photograph GSC 1997-42DD, taken by G.R. Brooks.

Bridge supports may be scoured and undermined where they constrict and accelerate the current. Bridges can also partially dam flow and be overtopped by water, causing the approaches to be washed out (Figure 6).

Figure 6. Photograph of a bridge crossing where the constriction formed by the bridge abutments has caused floodwaters to spill over the bridge, Saguenay area, July 1996

Source: Geological Survey of Canada, photograph GSC 1997-42WW, taken by G.R. Brooks.

Floodwaters can wash out roads, highways and railway lines. Artificial dams may be breached by overtopping flood flows (Figure 7).

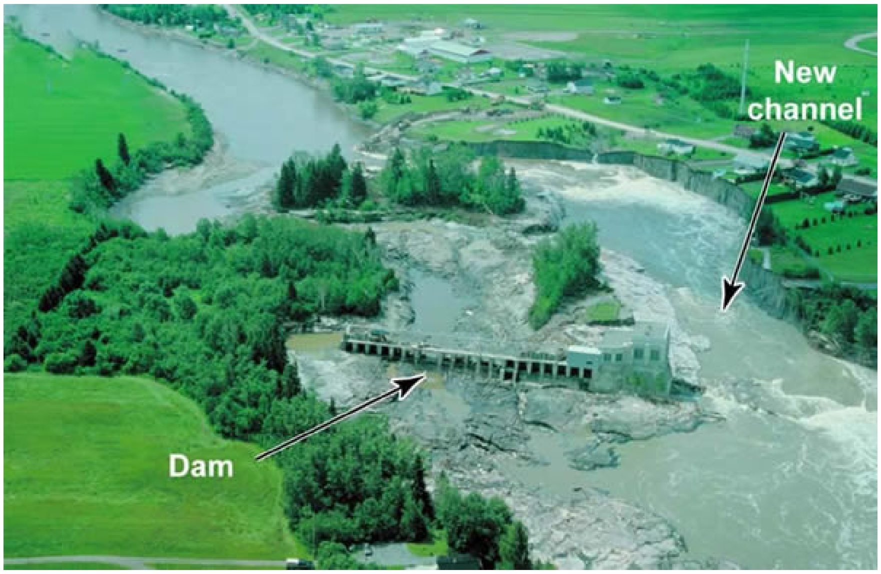

Figure 7. Post-flood view of the intact, but non-functioning Chute-Garneau dam along the Chicoutimi River, Saguenay area, July 1996
Source: Geological Survey of Canada, photograph GSC 1997-42N, taken by G.R. Brooks.

Significant damage from flooding can even happen where floodwaters are flowing relatively slowly or are stagnant. Flooded buildings and their contents will experience water damage, with the potential for damage increasing with greater water depth (Figure 8).

Figure 8. Photograph of buildings partially flooded by Red River floodwaters in St. Norbert, Manitoba, May 1997
Source: Geological Survey of Canada, photograph taken by G.R. Brooks.

Any contaminants in the water (for example, oil, gasoline, raw sewage, chemicals) will enter buildings and coat floors, walls and building contents, compounding the water damage. Electrical short-circuits may start fires in partially flooded buildings. Sewer backups can flood the basements of otherwise dry buildings when the amount of storm rainfall runoff cannot be handled by storm-sewer drainage systems.

Water-damaged buildings require thorough clean-up, decontamination and restoration following a flood. Allergenic and toxigenic fungi can grow within wet drywall, insulation, books, carpets, furniture and air-ventilation systems. These fungi can cause significant health problems to occupants of formerly flooded buildings long after the flood. In some cases, it may be best to write off the structure and rebuild on higher ground or in a less flood-prone area. Flooding of agricultural lands during the spring may delay planting, thereby shortening the growing season and affecting the type of crops that can be grown. Planted crops (for example, winter wheat) can be damaged by persistent flooding, resulting in reduced crop yields. The harvest of forage crops may be delayed by wet ground conditions after summer floods.

Sediment deposited by floodwaters can further damage property. Clay and silt carried in suspension will settle out on the floodplain and low-lying areas, and within flooded buildings, leaving a veneer of mud (Figure 9).

Figure 9. Photograph of sun-cracked mud, several centimetres thick, on a field near Morris, Manitoba, June 1997
Source: Geological Survey of Canada, photograph taken by G.R. Brooks.

During some floods, floodplain areas may also be buried with sand and gravel. The thickness of sediment deposited on floodplains varies considerably, depending on the flood location, energy of flow and amount and calibre of sediment introduced into the river by erosion upstream. In extreme cases, broad sheets of sediment, up to tens of centimetres thick, can be deposited (Figure 10).

Figure 10. Photograph of a broad sheet of sand, up to 1 to 2 metres thick, deposited along the valley bottom of the Ha! Ha! River, Saguenay area, Quebec, July 1996
Source: Geological Survey of Canada, photograph GSC 1997-42CC, taken by G.R. Brooks.

Deposition of silt and clay on floodplains can increase soil fertility, but also can reduce the yields of crops or pastures that are buried.

Canadian Flood Disasters

Canadian flood disasters since 1900 are depicted on the map. Detailed information on some of the disasters can be obtained by searching the Internet for some interesting Web sites. The following are descriptions of the most significant floods that occurred in the twentieth century.

Fraser River, 1948

The last great flood of the Fraser River in the lower mainland of British Columbia occurred in 1948 and resulted in the evacuation of 9000 people.

Saguenay Floods, 1996

The Saguenay floods involved the flooding of many rivers in southern Quebec in July 1996, but the worst flooding occurred in the general area of Chicoutimi–Lake St. Jean. This disaster is notable because of the breaching of a number of small dams. A post-disaster inquiry led to provincial legislation that improved the management and safety of small dams in Quebec.

Red River Flood, 1950

The Red River flood of 1950 was a major Canadian flood disaster that resulted in 107 000 people being evacuated from Winnipeg (one-third of the city) and $1.1 billion in damage (1999 dollars). This disaster led to the construction of the Red River Floodway in the 1960s, which is Canada's best known and most successful engineered flood-control structure. Since it became operational in 1968, Floodway operations have prevented damage costs in Winnipeg that far exceed the cost of its construction.

Red River Flood, 1997

The Red River flood of 1997 was the largest Red River flood since 1852 and the third largest since the great flood of 1826. The greatest impact of the flooding in Manitoba was to small communities and isolated farms and residences located between Winnipeg and the Canada–United States border. Severe flooding in Winnipeg was prevented by the operations of the Red River Floodway, constructed in the 1960s to prevent the recurrence of a disaster similar to that caused by the 1950 flood.

Hurricane Hazel, 1954

The remnants of Hurricane Hazel struck southern Ontario in October 1954, causing a major flood disaster that killed 81 people.

Flood Mitigation

Flood Warnings

In general, the exact time, date and magnitude of weather-related floods cannot be predicted. For some watersheds, discharge levels during the spring can be estimated several days in advance using models that incorporate snowpack levels, stream and lake levels, ground moisture content, temperature, wind, evaporation and weather forecasts. 'Outlooks' of peak spring discharge can be made weeks in advance using similar models with various scenarios of melt rates and rainfall based on climate records. Potential peak flow levels are expressed as probabilities of occurrence (for example, 5% chance of severe flooding). With such estimates, the actual level of peak flow is dependent on uncertain climatic events that are yet to occur, but worst-case scenarios can be identified and possibly planned for well in advance of the actual flooding.

Flood advisories or warnings can be issued in expectation of severe weather conditions (convective storms, mid-latitude and tropical cyclones). The advisories or warnings can be regional or local, but are issued in most instances only hours in advance of the storm. Nevertheless, they can provide sufficient time for the initiation of emergency flood-control measures (for example, the construction of earthen and/or sand bag dykes) and, in extreme cases, the evacuation of people, livestock and property from flood-prone areas.
The forecasting of floods caused by the failure of natural dams is more a problem of estimating the timing of the flood rather than the magnitude. Formulae exist for estimating peak discharge of outburst floods for the different types of natural dams.

How to reduce flood impacts?

The simplest and cheapest way to reduce the damaging effects of flooding is to identify and carefully manage flood-prone lands. Floodplain mapping has been undertaken along river reaches in many Canadian communities that are prone to damaging floods, based on, for example, a discharge with a 100-year recurrence interval. Land use and building construction are carefully regulated on low-lying areas susceptible to flooding. It is, therefore, common in many Canadian towns and cities to see parks, playing fields and natural areas situated on floodplains. These are types of land use compatible with periodic flooding because of the resulting minor consequences.

There are urban areas in many Canadian towns and cities that encroach on flood-prone lands and have experienced flooding problems in the past. Commonly, these areas are now protected by flood-control structures and are generally unaffected by moderate to large floods. Common engineered flood-control measures are shown in Figures 11, 12, 13 and 14.

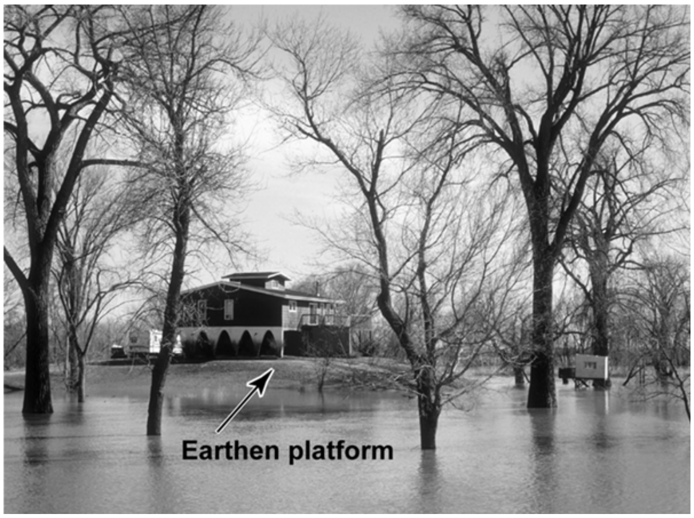

Figure 11. Photograph of a building situated on a earthen platform, surrounded by floodwater near St. Jean Baptiste, Manitoba, 1997
Source: Geological Survey of Canada, photograph taken by G.R. Brooks.

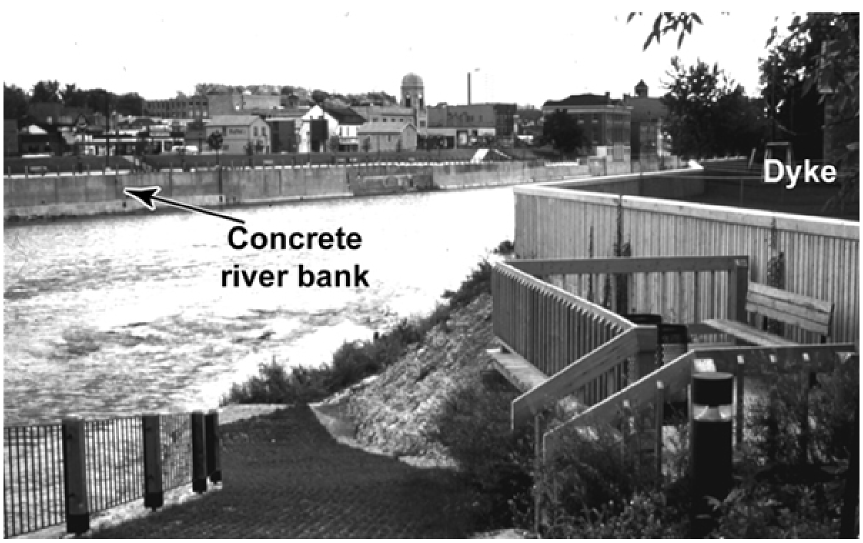

Figure 12. Photograph of a river channel that has been artificially deepened with concrete and the floodplain dyked, to increase the channel discharge capacity along a reach of the Grand River, Cambridge, Ontario
Source: Geological Survey of Canada, photograph taken by G.R. Brooks.

Figure 13. Photograph of a ring-dyke protecting Morris, Manitoba from Red River flooding in May 1997
Source: Geological Survey of Canada, photograph taken by G.R. Brooks.

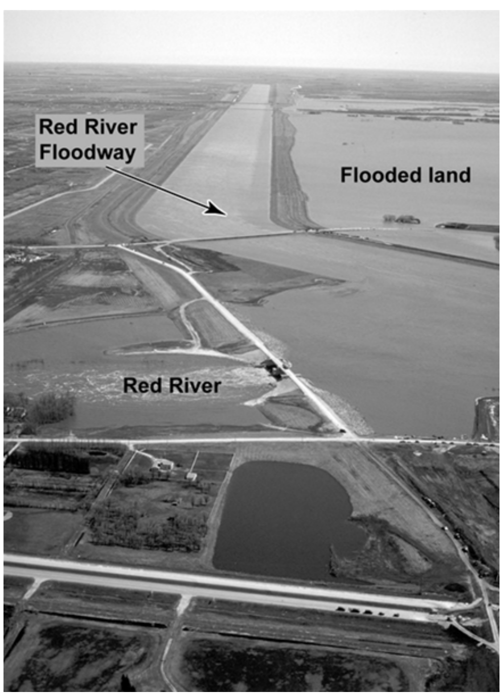

Figure 14. Photograph of an artificial channel (extending towards the horizon) that is carrying flow diverted from the main river channel, Red River Floodway, Winnipeg, Manitoba, 1997 flood
Source: Geological Survey of Canada, photograph GSC 2000-118, taken by G.R. Brooks.

Such structures are effective within their design parameters, as long as they are adequately maintained and there are no changes in the watershed upstream that increase the flow of water through the watershed (thus increasing the peak discharge downstream), or changes downstream that cause water levels to become elevated at the location of the flood control structure. Flood control structures, however, can lead to a sense of complacency about the local flood hazard and often promote further development on the formerly flood-prone lands. There is always the possibility that an extreme flood, in excess of the 'design' discharge (for example, the 100-year flood), will overwhelm the protective structures and inundate the protected land. Such a disaster is virtually inevitable over the long term because it is not economic to construct flood-control structures that can contain the maximum possible discharge a given river can experience.

What can you do to be prepared?

The Public Safety Canada website "Is your family prepared?" (http://www.getprepared.gc.ca/index-eng.aspx) has excellent advice on what to include in both an emergency plan and an emergency kit - these can be put to good use in any natural disaster or emergency.

This text was adapted from Brooks, G.R., Evans, S.G. and Clague, J.J. 2001. Flooding in a Synthesis of Natural Geological Hazards in Canada (G.R. Brooks, editor). Geological Survey of Canada, Bulletin 548, p. 101–143.

Definitions of underlined terms

Convective storm: Storm produced by a cloud which forms in an atmospheric layer made unstable by heating at the base or cooling at the top.

Cyclone: Storm characterized by a giratory wind movement, converging and rising around a zone of low pressure

Glaciomarine sediments: Materials that are deposited on the sea floor by glacial meltwater, by debris flows from the surface of a glacier or by melting icebergs.