Interim Report
of the International Red River Basin Task Force
to the International Joint Commission

Red River Flooding
Short-Term Measures

December, 1997
Ottawa / Washington

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I Preface

The Red River flood of 1997 was the worst on record in many locations; it caused widespread damage throughout the Red River valley. The flood's full effect on people may never be known, but the economic and social damages were extensive, and recovery will take time. The governments of Canada and the United States have agreed that steps must be taken to reduce the impact of future flooding. Accordingly, in June 1997, they asked the International Joint Commission (IJC) to analyze the causes and effects of the Red River flood of 1997 and to recommend ways to reduce the impact of future floods. They asked the IJC to provide an Interim Report by December 31, 1997, and a final report by December 31, 1998. In September 1997, the IJC announced the appointment of the International Red River Basin Task Force to examine a range of alternatives to prevent or reduce future flood damage.

In the short period available to write the Interim Report, the Task Force reviewed extensively the material readily available and consulted as much as possible with the people involved in the 1997 flood. In order to gain an understanding of the issues surrounding the preparation, response, recovery and mitigation efforts in the basin, the IJC and the Task Force sought the views of individuals, groups and officials. In late September and early October, the Task Force and commissioners toured some of the hard-hit areas of the basin and held briefing and fact-finding sessions with civic and community leaders in Moorhead, Minnesota; Grand Forks, North Dakota; and Morris, Manitoba. In Devils Lake, North Dakota, commissioners and Task Force members met with the newly created Red River Basin Board. Task Force members and IJC commissioners also met with Manitoba Premier Gary Filmon and Ministers Franklin Pitura and James McCrae, and North Dakota Governor Ed Schafer and Senator Kent Conrad. In addition, the Task Force commissioned detailed interviews with families affected by the flood and with civic officials and local emergency management coordinators. Workshops were sponsored in Winnipeg on the social impact of the flood and in Minneapolis on flood forecasting and modeling. In addition, Task Force members held meetings and discussions with the public in a range of forums.

Given the December 1997 deadline, the Interim Report must of necessity be more descriptive than analytical. It is not based on in-depth research, a full range of public consultations or comprehensive studies of flood management issues in the basin. Nevertheless, the Task Force has gathered sufficient information and held discussions with enough of the people who were involved to allow it to make a number of observations.

While the chances of a flood of the magnitude of 1997 occurring next year are small, this is no time for complacency. The Task Force is convinced that flooding comparable to that experienced in 1997 could occur again in any year. The Task Force has made 40 recommendations on short-term measures that governments should consider to prepare for the possibility of a flood in 1998 or 1999.

Short-term recommendations are only the first step. Attached to this report is a draft Plan of Study that outlines the issues that need further study over the coming year and the methods the Task Force intends to use to undertake this work. While the consultations held to date helped the Task Force identify the issues, the IJC and the Task Force recognize the value of engaging in more extensive, in-depth consultations, which will begin this winter. These consultations will be used to refine the draft Plan of Study, to give as many people as possible an opportunity to share experiences and views with the Task Force, and to ensure that relevant issues are being addressed and suggestions for remedial action considered.

The IJC has a long history of involvement in transboundary water issues in the Red River valley. In 1929, the IJC reported to the governments of Canada and the United States on ways the Roseau River basin could best be developed through a coordinated international effort. Since 1948, the IJC has had investigative responsibilities regarding requirements, further uses, apportionment and planning for waters in the midwestern portion of the international boundary area, including the Red River. The International Souris–Red Rivers Engineering Board, established in May 1948, continues to report to the IJC semiannually on water development and management activities in the basin. Among other activities, the board has reported on flood events, water supplies and storage possibilities on the Pembina River, Red River dikes, the Garrison Diversion project and Devils Lake water levels.

In 1967, the IJC reported on measures to develop the water resources of the Pembina River basin in Manitoba and North Dakota. The report contained recommendations for cooperative development of the water resources of the basin, including joint projects to maximize flood control, irrigation, recreation and fishery benefits. In a 1968 report, the IJC recommended the adoption of water quality objectives at the international boundary. The governments accepted the IJC's recommendations to ensure maintenance of water quality in the Red River, and the International Red River Pollution Board was created to maintain surveillance of water quality at the international boundary. The board reports annually to the IJC on water quality and the health of the transboundary ecosystem.

In 1975, the IJC produced a coordinated plan for managing water in the Roseau River basin.

The June 1997 reference from the governments of Canada and the United States asked the IJC to consider, examine and report on

0. the history, extent and effects of flooding in the Red River basin, with particular emphasis on the 1997 flood;
1. the relationship of the 1997 flood to past and anticipated future Red River floods;
2. the effects on flood conditions of flood control and other structures, changing land use and land management practices and any other pertinent factors;
3. the current state of flood forecasting practices, capabilities and technologies, including the sharing of data among agencies;
4. the policies, programs and mechanisms for emergency preparedness and response, risk reduction, floodplain management and flood damage control;
5. the potential effects of weather variability on flood frequency, peak and/or duration;
6. the water quality issues associated with flood events; and
7. other matters that the IJC deems relevant to the purpose of this study.

Based on these considerations, the IJC was to examine and make recommendations on

0. remedial, restorative, protective or management measures that would help to mitigate the effects of flooding;
1. other innovative measures for flood reduction, damage reduction and future relief options, such as building design and construction, ring dikes, levee setbacks, insurance, regulation of floodplain use, watershed management, basin storage, ecological restoration and land acquisition;
2. scientific and technical investigations, and applied research or demonstration projects relating to enhanced flood protection and mitigation;
3. a relevant information base, including monitoring and alerting networks, and its integration with respect to the Red River basin;
4. the objectives, parameters, organization and structure of bilateral cooperation and measures for its improvement;
5. a plan or plans of cooperative flood management, flood forecasting, emergency response and flood mitigation; and
6. any other matters that the IJC deems appropriate and relevant.

In September 1997, when the IJC announced the appointment of the International Red River Basin Task Force members, it directed the Task Force to examine a range of alternatives to prevent or reduce future flood damage. The Task Force was asked to note the work of other organizations in both countries and to access the full breadth of available programs and information.

International Red River Basin Task Force

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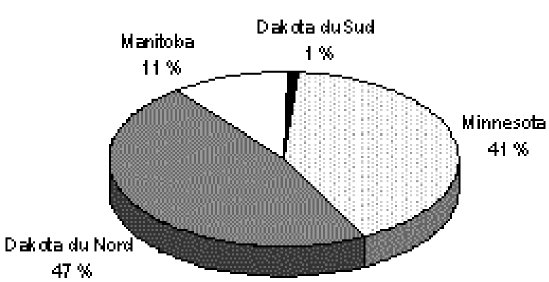
In keeping with the traditions of the IJC, members of the International Red River Basin Task Force serve in their personal and professional capacities, rather than as representatives of their countries, agencies, organizations or other affiliations.

Note: Throughout this report, U.S. spelling has been used, except for proper names in Canada. Dollars are stated in the currency of the country under discussion, unless otherwise noted. In the United States, the river is called the Red River of the North; in Canada, the Red River. This report uses the short name. In Canada, the term "dike" is commonly used for riverside flood control works; in the United States the term is "levee." In this report, the terms are used interchangeably.

II The Red River Basin

Situated in the geographic center of North America, the Red River originates in Minnesota and flows north. It forms the boundary between North Dakota and Minnesota and enters Canada at Emerson, Manitoba. It continues northward to Lake Winnipeg.



The Red River basin covers 45,000 square miles (116,500 square kilometers),—exclusive of the Assiniboine River and its tributary, the Souris—of which nearly 40,000 square miles (103,600 square kilometers) are in the United States. The remaining 5,000 square miles (13,000 square kilometers) are in Canada.

The basin is remarkably flat. The elevation at Wahpeton, North Dakota, is 943 feet (287 meters) above sea level. At Lake Winnipeg, the elevation is 714 feet (218 meters). The difference is only 233 feet (71 meters) over a distance of about 545 river miles (872 kilometers). The slope of the river averages less than one-half foot per mile (0.15 meters per 1.6 kilometers), varying from about 1.3 feet per mile (0.4 meters per 1.6 kilometers) near Wahpeton, North Dakota and Breckenridge, Minnesota, to 0.2 feet per mile (0.06 meters per 1.6 kilometers) near the Manitoba border. The basin is about 60 miles (100 kilometers) across at its widest. When the conditions are right and the river floods, nothing holds it back. During major floods, the entire valley becomes the floodplain. In 1997, the Red River spread to a width of about 25 miles (40 kilometers) in Manitoba.

The flatness of the terrain also means few natural large water storage sites are available. Small dams have been constructed, but the opportunities for major flood control reservoirs do not exist.

Another feature of the floodplain is the natural levees found along some reaches of tributary streams and along the main stem. These levees, which are sometimes as high as 5 feet (1.5 meters), are the result of river overflow and sediment deposition during past floods. When these levees, which stand well above the elevation of adjacent lands, are overtopped or bypassed, land for several miles on each side may be flooded.

The Red River basin has a subhumid to humid continental climate with moderately warm summers, cold winters, and rapid changes in daily weather patterns. Extreme temperature variations are the norm. On average the Red River basin mean monthly temperatures range from 5 degrees to 68 degrees Fahrenheit (-15 degrees to +20 degrees Celsius).

About three-fourths of the basin's approximately 20 inches (50 centimeters) of annual precipitation occurs during April through September, with almost two-thirds falling during May, June and July. November through February are the driest months. Precipitation during that period averages only about one-half inch (1.3 centimeters) per month. Normally, the dry winter months with low snowfall do not create conditions for flooding. Most major floods occur following heavy precipitation the previous fall, hard and deep frost prior to snowfall, substantial snowfall, sudden thaws, and heavy rainfall or wet snow conditions during the spring breakup. The low absorptive capacity of the basin's clay soils is a contributing factor. Ice jams can occur occasionally, particularly on tributaries, causing backwater flooding and exacerbating main stem flood conditions.

While flood characteristics north and south of the border are similar in some instances and in some years, Manitoba floods do not simply replicate what has occurred south of the border. For example, in 1989, the southern reaches of the Red River valley experienced near record-breaking flooding while the remainder of the basin had few problems.

The basin floods regularly. Early records show several major floods in the 1800s, the most notable being those of 1826, 1852 and 1861. This century, major floods occurred in 1950, 1966, 1979, 1996 and 1997.

The Red River basin has 25 subbasins, which have different topography, soils and drainage that result in different responses during flood conditions. One common characteristic is overland flow during times of heavy runoff. Water overflows small streams and spreads overland, returning to those streams or other watercourses downstream. Existing monitoring and forecasting systems do not track these flows well, leading to unanticipated flooding.

At the margins of the Red River drainage basin, elevations range from 1,200 to 1,600 feet (360 to 480 meters) above sea level. The boundaries are often indistinct, particularly in low-lying swamps and marshes along the eastern side. In times of severe flood, Lake Traverse in the Red River basin and Big Stone Lake in the Mississippi River basin may become connected. Along the western side of the basin, wide belts exist where water collects in potholes, kettles and sloughs. Water stands until it evaporates or percolates downward into the soil, never flowing directly into the river.

About 60 percent of North Dakota's 640,000 people live in the Red River basin, compared with 2 percent of Minnesota’s 4.6 million, and about 70 percent of Manitoba’s 1.1 million. In Manitoba, almost 90 percent of the residents of the Red River/Assiniboine basin live in urban centers, while more than half of the U.S. Red River basin population is rural. Metropolitan Winnipeg contains 650,000 people, and another 50,000 live along the Red River north and south of the city. North Dakota and Minnesota have two large urban centers in the basin: Fargo-Moorhead, with a population of about 100,000, and Grand Forks-East Grand Forks, with a population of about 60,000. Most of this population is susceptible to flooding.

The Red River valley is a highly productive agricultural area serving local, regional and international food needs. The region features market gardens, mixed farming, livestock production, and grain and sugar beet farming. Despite migration of the rural population to urban centers, the ethos in the basin remains predominantly rural and agricultural.

III Flood History

The earliest recorded flood in the basin was in 1826, although anecdotal evidence refers to larger floods in the late 1700s. Settlements grew along the banks of the Red, Assiniboine and other tributaries despite the risks of building and living on the floodplain. During the period of rapid growth between 1862 and 1948 there were few major floods of the Red or Assiniboine rivers—leading many people to believe flooding had diminished. The flood of 1897 at Grand Forks did not discourage further settlement and growth on the floodplain. The only serious flooding in Winnipeg occurred in 1916, when the attention of most inhabitants was diverted by the war in Europe.

Some communities south of Winnipeg were flooded regularly, but this flooding was regarded as local rather than systemic, often caused as much by the flooding of tributary rivers as the main stem. The valley inhabitants appreciated the risks of flooding, but they appear to have regarded high water as a part of life in the region. Communities such as Morris, Emerson, Grand Forks and Fargo simply evacuated low-lying lands and rebuilt after each inundation. As early as 1920, a few voices warned that the dry period since 1870 would not continue and called for structural flood protection in the Red and Assiniboine basins. Nevertheless, most water management plans of the 1930s and 1940s were for water supply rather than flood protection. In the United States, because of the activities of the U.S. Army Corps of Engineers, some planning for total water management was done; nonetheless, water supply measures dominated before 1948.

The 1826 flood remains the largest on record. The floods of 1852 and 1861 were exceeded by the 1997 event. Table 1 compares recent floods.

Table 1: Red River Floods
(cubic meters per second*)

Location	1950		1979		1997	
Red River at Fargo	April 7	217	April 19	487	April 17	793
Red River at Grand Forks	May 12	1,530	April 23	2,290	April 18	3,850
Red River at Emerson	May 13	2,670	May 1	2,620	May 2	3,740
Red River at Winnipeg	May 19	3,058	May 10	3,030**	May 4	4,587**

* One cubic meter per second equals 35.3 cubic feet per second.
** Computed natural flow as would have occurred without the use of existing flood control works.

Institutional Response to the Floods

The 1950 flood forced major changes in thinking about recovery and protection on both sides of the border. Damage to the larger cities in the United States was deceptive. Fargo experienced the evacuation of a few hundred families and half a million dollars of damage. Damage to property in Grand Forks and East Grand Forks was estimated at almost $1 million and the total cost at $7.5 million. Smaller communities, often on tributary rivers, also incurred losses. Only about one-third of the total damage, estimated at $30 million, occurred on the main stem of the Red River, and most of the damage was to infrastructure, especially roads and bridges.

In the United States, disaster relief came from a patchwork of federal, state, local and private policies. Short-term flood relief and long-term assistance for flooded inhabitants were the primary responsibilities of the Red Cross, which had federal statutory responsibility for these tasks. President Harry Truman sent $400,000 from the President's Emergency Disaster Fund, but it could be used only for the repair of infrastructure. Eventually, Congress approved a national disaster relief policy that allowed the President to disperse more money to those regions he declared "emergency disaster areas." The Bureau of Public Roads provided emergency funds for road reconstruction, and the Reconstruction Finance Corporation provided low-interest loans both to individuals and to communities. Individuals received little or no public aid apart from loans.

In Manitoba, the total population south of Winnipeg was evacuated during the1950 flood. The inundation came within a few inches of forcing the complete evacuation of Winnipeg. Cooperation on disaster management between Canada and Manitoba began on a major scale with this flood. Financial arrangements historically have been varied and subject to dispute. During the 1950 flood, Canada deployed the Canadian Army, but expected the province to pay for this assistance. The federal and provincial governments disagreed over the extent of federal financial support. Disagreement also arose during later floods, including the flood of 1997.

The principles of rehabilitation of 1950 served as the model for post-flood recovery in Manitoba. Rehabilitation was a combined effort of the federal government, the provincial government and private charity. Assistance and restoration, rather than compensation, were the objectives. The public sector would undertake rehabilitation of buildings; charities and later a combination of public and private assistance would restore personal property. Private charities helped farmers with livestock replacement and rehabilitation of flood-damaged land. They were responsible for evacuees during the flood and when they first returned to their homes.

Following the 1966 flood, Manitoba used the Red River Valley Board to deal with damage under federal-provincial agreements, processing 1,400 applications for flood disaster assistance. From 1966 onward, government took primary responsibility for the assistance, with private charity playing a supplementary role. In 1970, the federal government put in place the Disaster Financial Assistance Arrangements (DFAA), which provided a new formula for federal assistance to the province. The DFAA, administered under provincial guidelines by a Manitoba board, helped people who had incurred damage in the 1979 flood. The Manitoba board offered 75 percent compensation to a maximum of $10,000.

In the 1960s, both Canada and Manitoba concentrated on replacing *ad hoc* flood-fighting measures with formal structures. In 1957, a federal Emergency Measures Organization was created, and in 1965, it was assigned the task of coordinating federal involvement in peacetime disasters. Since the 1970s, the role of the federal government in disasters has been to provide support and assistance to the provinces and territories. That support involves physical assistance in flood fighting and flood rehabilitation, as well as federal-provincial disaster cost- sharing through Emergency Preparedness Canada (EPC).

The Manitoba Emergency Measures Organization (EMO) first mobilized flood-fighting activities in the 1966 flood. It coordinated the activities of provincial, federal and municipal agencies, as well as private organizations such as the Red Cross and the Mennonite Disaster Relief Committee. The 1966 flood represented the second greatest emergency operation in Winnipeg's history, behind that of the 1950 flood. It required thousands of workers, and the Canadian Army contributed 17,850 person-days.

In the United States, Congress established the National Flood Insurance Program in 1968 to provide subsidized flood insurance for buildings and contents located in an identified flood zone. Insurance is required on property secured by a federally guaranteed loan and located in an area marked as a 100-year floodplain on Flood Insurance Rate Maps produced by the Federal Emergency Management Agency (FEMA). This insurance is available only in communities that join the program and enact floodplain management regulations. Existing structures are charged subsidized rates, and new construction is charged actuarial rates based on the 100-year flood elevations. Other federal flood-related programs provide different forms of assistance, such as income tax deductions and employment assistance. FEMA offers funding for the repair of public buildings and infrastructure on a cost-shared basis: usually the federal government pays 75 percent and the local government pays 25 percent (the 25 percent is split between the state and city or county governments). Low-interest loans are available for damage not covered by insurance through the Farmers Home Administration and the Small Business Administration. FEMA makes cash grants of up to $13,100 to people who do not qualify for a loan, and its Disaster Housing Assistance Program assists people whose homes are temporarily uninhabitable. The U.S. approach favors insurance and supplementary public and private programs. In contrast, Canadian practice favors direct public grants to people who need flood assistance, supplemented by private charity.

The U.S. portion of the basin has no overall permanent flood-fighting organization. Departments (Divisions) of Emergency Management in the states have developed Disaster Services Plans; flood containment is one component of them. Activities associated with flood fighting include early convening of agencies following flood-outlook reports; review of flood-containment plans; and communication. The Corps of Engineers remains the principal federal agency responsible for flood fighting in the U.S. portion of the basin. It provides technical assistance to local units of government, the construction and implementation of emergency measures, and overall coordination.

Floodplain Zoning

The traditional solution to flooding problems has been to construct dams, dikes or levees, and modify channels in an attempt to divert floodwater away from residences and commercial establishments. Unfortunately, structural measures are expensive to build and maintain and do not provide complete protection from flooding. They also may promote a false sense of security among floodplain residents and attract additional investment to flood-prone areas, which increases the potential for loss of life and property.

Zoning is an important element of contemporary floodplain management. Urban areas that are at risk from a flood (often the 100-year event) are identified, public awareness of flood risk is increased, and regulations covering new development are adopted. Flood hazard maps for urban areas such as Winnipeg and Grand Forks are valuable, but the flood risk in the rural portions of the valley calls for different measures.

In the United States, both Minnesota and North Dakota had floodplain zoning regulations in place prior to the 1997 flood that exceeded National Flood Insurance Program (NFIP) minimum standards. Regulations require that the floodway be kept open so that floodwater can proceed downstream and not be obstructed or diverted onto other properties. New construction projects or projects to substantially improve existing structures in the floodplain must include protection from the 100-year flood. Also, development of hazardous waste facilities is prohibited.

To qualify for federally subsidized flood insurance, communities and counties are required to adopt and enforce NFIP floodplain management regulations that meet the minimum FEMA requirements. The FEMA regulations address existing and new development in delineated floodway and floodway fringe areas. Permits are required for all development in designated floodplain areas.

Both Minnesota and North Dakota actively assist communities and counties in floodplain management and damage mitigation. The

Minnesota Department of Natural Resources is the state agency that provides the assistance. The North Dakota State Water Commission provides the assistance in North Dakota. Both states recognize that structural solutions to flooding are not the only answer. Both promote and help fund flood damage reduction programs that consist of structural as well as non-structural components. Both provide technical floodplain management assistance to counties and communities. With FEMA assistance, both states periodically audit counties and communities to ensure that they are complying with the terms of their floodplain management ordinances. If a community does not enforce its ordinances it can be suspended from the NFIP. Individuals in a suspended community are not eligible for federally backed loans or disaster assistance for flood damage.

Both states and FEMA are purchasing structures that were damaged during the spring 1997 flood. Structures that were not substantially damaged, but are at risk are also being considered for purchase. The transaction is administered by the local governments, and the land is deeded to them for open-space purposes in perpetuity. Most of the larger counties and communities have full-time floodplain zoning staff.

Prior to the 1997 flood, both states and FEMA publicized the availability of flood insurance. However, only a small percentage of the flood-prone properties in the Red River valley were covered by flood insurance at the time of the 1997 flood.

Manitoba established the Red River Designated Flood Area, which includes all towns, cities and rural residences in the floodplain, in 1979. A permit is required to construct or reconstruct within the Designated Flood Area. The permit issued under the program specifies that the main floor of a home with a basement must be 3 feet (1 meter) above the 1979 flood level. Elevation surveys are provided at no cost.

To be fully effective, zoning programs require inspection and enforcement. In Manitoba, only 63 percent of the new homes constructed in the Designated Flood Area comply with the criteria. However, the main floors of 95 percent of these homes are above (but less than 3 feet [1 meter] above) the 1979 flood level. Individuals are encouraged to comply with the terms of the permit, but the regulation has never been rigidly enforced. While the *Water Resources Administration Act* provides authority to remove noncompliant structures, it is not surprising that this remedy has never been seriously considered.

Institutional Arrangements in Place for 1997

Federal emergency support to Manitoba is coordinated by the Federal Emergency Preparedness Coordinating Committee (FEPCC), which is chaired by EPC. It consists of three permanent staff members in Manitoba and expands to as many as 16 through assignments during a crisis. Twenty-five federal departments involving at least 100 individuals are coordinated by FEPCC, which deals with the Manitoba EMO on their behalf.

During the 1997 flood, the Manitoba Water Resources Branch was in charge. Advice was provided by a provincial task force composed of representatives from Water Resources, Manitoba Highways and Transportation, the City of Winnipeg, the Canadian Armed Forces Engineering Division, Acres International, Manitoba Hydro, and the University of Manitoba. Reliance was placed upon structural protection, including the Red River Floodway, the Portage Diversion, the Shellmouth Reservoir, and the ring dikes south of Winnipeg. The provincial task force assessed the existing flood situation and recommended flood-fighting measures to the Manitoba EMO, the City of Winnipeg and the rural municipalities. The task force was responsible, for example, for recommending the construction of the West Dike Extension and for generating worst-case scenarios in the event of its failure.

Table 2: Canadian Federal Disaster Assistance Arrangement

Provincial Eligible Expenditure	Federal Share
First $1 per capita	0%
Next $2 per capita	50%
Next $2 per capita	75%
Remainder	90%

Note: Applied to a flood of, for example, $100 million in eligible costs, the formula applied to the Manitoba population of 1.1 million would be a federal share of 88%.

The federal Disaster Financial Assistance Arrangements (DFAA) of 1970 govern federal-provincial funding. Federal guidelines are supplemented by provincial ones. In Manitoba, provincial guidelines, established by the Manitoba EMO, provided up to $30,000 compensation (raised to $100,000 after the 1997 flood) for eligible expenses incurred by small businesses, nonprofit organizations and individuals, subject to a 20 percent deduction from approved costs. An additional arrangement, the Canada–Manitoba Agreement on Red River Flood Disaster Assistance, was established May 1, 1997. Under this agreement, the federal government gave the province $25 million for flood preparations as an advance payment under the DFAA. The agreement also dealt with measures outside the DFAA, including joint planning for diking and enhanced flood-proofing, agricultural compensation and reconstruction, business restoration programming, and improved water planning and technical cooperation. The Department of Western Economic Diversification was made responsible for coordinating federal activities; the Clerk of the Executive Council for provincial activities.

Disaster assistance in the United States is managed through the operating programs of governments at all levels. Local Divisions of Emergency Management prepare and maintain the local emergency operating plans. Water Resource Districts, Watershed Districts and Conservation Districts provide local assistance with levees, emergency coordination, information distribution, and coordination with FEMA recovery personnel. States maintain Divisions of Emergency Management, which provide statewide systems for disaster preparation, response, recovery and mitigation. State health agencies provide information and exercise regulatory powers for disease control, food and lodging, food safety, maternal and child health, municipal facilities, waste management and water quality.

State Transportation Departments maintain and repair damaged roadways and provide technical assistance to communities during emergencies. National Guard units can be deployed quickly and effectively in the wake of disaster declarations by governors and the federal government. Several state agencies, such as the North Dakota State Water Commission and the Minnesota Department of Natural Resources (Division of Waters), provide flood control design and construction, distribute flood advice, and also offer emergency information and coordination services.

Federal disaster assistance is made available when the governor certifies to the President that the disaster is beyond the capability of the state and local governments. When the President declares a disaster, FEMA coordinates the federal response. FEMA provides a comprehensive, risk-based, all-hazards emergency management program of preparedness, response, recovery and mitigation. FEMA generally assigns the Corps of Engineers the job of coordinating projects to increase water supplies and provide temporary housing, technical assistance and coordination locally. The Corps constructs levees on an emergency basis. The National Weather Service provides forecasting and other information. The Small Business Administration offers disaster loans to home-owners, renters and businesses to cover uninsured losses. The U.S. Department of Agriculture provides emergency food assistance to those forced from their homes, logistical and transportation support to FEMA, low-cost loans to replace farm buildings, and federal crop insurance. The U.S. Department of Transportation administers the Emergency Relief Program, which reimburses states for emergency work and damage to federal-aid highways.

IV The Flood of 1997

Heavy precipitation occurred in major segments of the basin in the fall of 1996. As much as 6 or more inches (about 15 centimeters) of rain fell in late October and November—in many areas, that amounted to 4 inches (10 centimeters) above average. Soil moisture in the fall of 1996 was high. The winter of 1996–1997 was unusually severe. Record or near-record snowfall throughout the basin created conditions conducive to major flooding. The heaviest snowfalls occurred along the main stem of the Red River. In Fargo, for example, 117 inches (297 centimeters) of snow fell, compared to a long-term average of 39 inches (99 centimeters); the city's previous record was 89 inches (226 centimeters). Grand Forks experienced a record accumulation of 97.9 inches (248.6 centimeters). In many areas, snowfall reached levels two to three times the average.

There was also heavy early spring precipitation. Crookston, Minnesota, received 3.6 inches (9.2 centimeters) of water equivalent on April 5–6. The previous two day April record was 2.4 inches (6.1 centimeters). Average precipitation across the basin for the month of April is less than 2 inches (5 centimeters).

There was yet another precursor of severe flooding in 1997: temperatures that created less than ideal melt conditions. During one week, for example, temperatures were approximately 10 degrees Fahrenheit (5.5 degrees Celsius) above average. During the following week, temperatures dipped as much as 20 degrees Fahrenheit (11 degrees Celsius) below average.

The Red River began to flood on March 30. It crested twice at Wahpeton-Breckenridge, first on April 6 and then on April 15, at a stage of 19.2 feet (5.8 meters). Flood stage is 10 feet (3 meters). To compound this, parts of Breckenridge were inundated by overland flooding.

On April 8, most of the residents of Ada, Minnesota, evacuated as overland flooding from the Marsh and Wild Rice rivers inundated that city. On April 18, a maximum peak stage of 39.6 feet (11.9 meters) occurred at Fargo-Moorhead. A peak stage of

54.4 feet (16.3 meters) occurred at Grand Forks on April 22. On April 25, the stage at Drayton reached 45.6 feet (13.7 meters), 1.9 feet (0.57 meters) higher than the record set in 1979.

Table 3: Peak Flow and Recurrence Intervals *

Monitoring Station	Rates of Flow		Recurrence Interval
	Date	CFS**	Years
Twin Valley (Wild Rice River)	April 15	9,300	100–200
Wahpeton-Breckenridge	April 15	12,800	100–200
Fargo-Moorhead	April 17	28,000	50–100
Grand Forks-East Grand Forks	April 18	136,900	200–500
Drayton	April 25	123,000	200–500
Emerson	April 27—28	132,000	115
Ste. Agathe	May 2	135,000	125
Winnipeg (downstream of Assiniboine)	May 4	162,000***	110
Lockport (downstream of floodway)	May 4	150,000	

* Recurrence interval represents the average interval in which a flood of a given size is equaled or exceeded. Given the difficulty of accurately determining recurrence intervals, particularly for sites that have short periods of record, ranges are used within which the recurrence intervals for the 1997 floods are likely to fall. Source: U.S. Geological Survey and Manitoba Natural Resources.

** Cubic feet per second. 1 cfs = 0.03 cubic meters per second.

*** Unregulated discharge that would occur in the absence of the flood control works on the Red (Floodway) and Assiniboine Rivers (Portage Diversion, Shellmouth Reservoir).

In addition to the main stem of the Red River, many tributary rivers and streams had 100-year or greater recurrence intervals during the 1997 flood. The Bois de Sioux was in the 200- to 500-year range. For the Wild Rice River at Twin Valley, Minnesota, the recurrence interval was between 100 and 200 years. On the Red Lake River, it was between 50 and 100 years.

In the United States, flood stages at 29 of the 34 forecast points located in the Red River basin exceeded previous floods of record. One location tied the previous record flood, and five other locations were within one foot of the previous flood of record.

The 1997 flood contained about the same volume of water as did the 1950 flood. But the 1997 peak was much sharper and of shorter duration. This could have been the result of the rapid melt of the early April snowstorm, but changes in land use may also have played a role. This subject will be pursued in the more detailed studies to be implemented in 1998.

Flood outlooks were issued by Manitoba's River Forecast Centre in February and April. The outlooks proved accurate in spite of the many variables facing the forecasters. Crest elevations from Emerson to Morris were within the range predicted on April 9, just after the major blizzard, and crests at Ste. Agathe and St. Adolphe were equal to the top of the range predicted. Floodwaters crested at the Red River Floodway inlet south of Winnipeg at 1.5 to 1.7 feet (0.45 to 0.51 meters) higher than the forecast range.

Earlier flood forecasts were not altered greatly following the blizzard in early April because snow melt during the two weeks before the blizzard had reduced the winter snow cover enough to compensate for the new snowfall. However, Manitoba forecast elevations were revised upwards as crests in the U.S. portion of the basin came in higher than predicted. In addition, it was necessary to account for crests arriving from Manitoba tributaries. The low amounts of precipitation after the first week of April reduced the flood potential.

The 1997 flood forecasting was greatly hampered in both Canada and the United States by the extent of overland flooding, which accounted for a major part of water flows and flood damage. The lack of information on overland flooding made the difficult task of forecasting even more complex. A major shortcoming was the inability of existing hydraulic models to deal with the massive volumes of overland flow. Binational cooperation in forecasting and modeling was excellent. It is apparent, however, that forecasting and model results can be improved if more work is done to establish a common and more extensive database.

Knowledge of the spatial distribution and amount of snow cover during the winter is important for forecasting spring and summer water supply conditions. Since 1989, weekly maps of snow/water equivalent for the Canadian prairies have been produced using passive microwave data obtained from the U.S. Defense Meteorological Program series of satellites. Thus far, these maps are valid only for open areas, such as the Red River valley. The 1998 Task Force Plan of Study will address this issue.

Forecasts are based in part on gage readings on the tributaries and the main stem of the Red River. The number of gaging stations operating within the basin is not constant, a consequence of changing needs and budgets. Approximately 140 are currently in place. Experts advocate improvements, including adding gages and flood-proofing U.S. gages. The Minnesota Flood Forecast/Warning System project will include the installation of 44 new or upgraded precipitation and stream flow gages. This will greatly enhance the ability of the National Weather Service to develop timely and accurate forecasts. This subject will also fall within the ambit of the 1998 study plan.

During the 1997 flood, a new instrument known as an acoustic Doppler current profiler was used to obtain river discharge measurements under extreme conditions. These measurements are valuable for model verification, and future use of this promising technology is warranted. During this flood, RadarSat imagery also supplemented gage data. Incorporation of remotely sensed data into forecast models could lead to major improvements. To some extent, this technology could replace or supplement gaging station data.

Ice jams can result in flooding. During 1997, efforts were made on several parts of the river—primarily through the use of helicopters to "dust" the river near bridges with sand—to accelerate the melting and breakup of ice in the face of advancing floodwaters. The effects of these initiatives are largely unknown. In 1996, ice jams on the river in the Selkirk and Breezy Point areas north of Winnipeg caused flooding and damage. During the first two weeks of April 1997, local volunteers using 12 specially equipped snowmobiles bored 45,000 holes in the ice in that reach of the river. The objective was to weaken the ice, reducing the potential for ice jams. No ice blockages occurred in this stretch of the river during breakup. In Lake Manitoba, at the outlet of the Portage Diversion of the Assiniboine River, holes were also drilled in the ice, but not enough, it appears, to weaken it. An ice jam backed water up the diversion channel.

Overland flooding is almost always a factor in even smaller floods in the Red River valley. Rarely, has overland flooding been so pronounced as in the flood of 1997. Communities particularly damaged by the added impact of overland flooding were Ada, Wahpeton-Breckenridge, Fargo and Grand Forks-East Grand Forks and on the Canadian side, Ste. Agathe and Grande Pointe. It is generally accepted that overland flooding contributed to uncertainty in estimating crests. A major portion of the 1998 Plan of Study will be directed at overland flooding.

Emergency Flood Preparation

Municipalities in Manitoba are responsible for acquiring and filling their own sandbags. With the first flood forecast in February, the Manitoba Water Resources Branch began informing municipalities of the likelihood of a flood in the Red River valley, and encouraged them to purchase bags. Recognizing that the demand for sandbags would be high in some areas, Manitoba Natural Resources purchased a sandbag-filling machine and made it available to the municipalities. It was set up and used at Ste. Adolphe and Ile des Chênes.

In late winter, municipalities responded slowly to advice from the Manitoba Water Resources Branch to prepare for a major flood. This changed after the blizzard of April 5 and 6. The new snow created many logistical problems. Transportation of bags and sand and general access to diking sites was difficult because of blocked roads. In many cases, snow had to be removed before sandbags could be put in place.

In January, preparations were being made to move livestock and grain from flood-prone areas in the Red River valley. A database was developed that included numbers and types of livestock, producers' names and phone numbers, and the elevation and degree of properties' flood protection. Flood awareness meetings were held with producers and local government officials. In April, movement of livestock out of the valley began in earnest. Offers of help and livestock accommodation came from across the country. For a variety of reasons, logistical and personal, not everyone chose to move their livestock out of the flood zone. Overall, however, livestock losses were small.

Among the achievements of the 1997 flood was the extension of the West Dike south of Winnipeg. The La Salle River flows through the southern fringe of metropolitan Winnipeg from the west, joining the Red River at St. Norbert—within the area protected by the Red River Floodway and West Dike. The West Dike extends from the floodway inlet 20 miles (32 kilometers) to the south and west to prevent floodwater from entering the city through the La Salle River.

Concerns arose that the historically high flood levels could go around the West Dike, enter the La Salle River system and move into the city through the back door. On April 23, the provincial task force recommended that the West Dike be raised and extended. Between April 24 and April 30, the West Dike was raised where necessary, and a 21-mile (34-kilometer) extension was constructed. The height of the dike varied from 5 to 8 feet (1.5 to 2.5 meters). A task that would normally take two or three months to complete was accomplished in just six days. At the peak of construction, more than 400 pieces of heavy equipment and 450 civilian personnel worked on the dike. Military equipment and skilled military personnel contributed greatly to the effort.

As it turned out, only 7 or 8 miles (about 12 kilometers) of the dike extension was required to hold back the water. Much of the overland flow was intercepted by the road grid and impounded before it reached the dike. More important, wind conditions were favorable during the high-water period. Had a strong, sustained south wind blown up, the West Dike would have been tested by the resulting wind tide. This subject warrants further study in 1998.

From the outset, the City of Winnipeg decided to plan for the worst-case scenario. The April 19 flood forecast predicted flood levels within the city near 24.5 feet (7.4 meters) above datum at James Avenue—6.5 feet (2 meters) above flood stage. City engineers then decided to raise the primary diking system to the 26.5-foot (8-meter) elevation to provide 2 feet (0.6 meters) of freeboard. At 20 locations, the primary dikes were upgraded using trucked-in clay. These raised sections varied from a few feet high and long, to 5 to 10 feet (1.5 to 3 meters) high along several city blocks. Secondary dikes provided a lesser degree of protection to 800 properties situated between the primary dikes and the river. Raising dikes to the required elevation involved the placement of an estimated 3.9 million sandbags and the participation of local residents, supervised by city workers. In total, 6.6 million sandbags were produced—4.3 million filled by the city's sandbagging machines and 2.3 million filled by hand by volunteers and the military.

Dike upgrading within Winnipeg was largely successful. Of the 800 properties protected by emergency diking, 29 were damaged by the floodwaters.

Also in Winnipeg, the entire sewer system was made ready. Stormwater retention basins would function as rainwater runoff collection basins if the need arose. All land drainage and combined sewer and wastewater outflows penetrating the primary dikes were sealed. Temporary pumps drew outflows over the dikes into the rivers. In case St. Norbert flooded, plans were developed to isolate water and sewer mains from the rest of the city system to prevent contamination.

Precautions were taken in the United States as well. Based on a late February outlook that projected flood levels approaching or exceeding record levels on the main stem and tributaries of the Red River, the Corps of Engineers began planning protective measures in 34 communities in the basin and meeting with communities to coordinate the planning process. At that time, the Corps requested "advanced measures" to initiate flood response activities far in advance of the snowmelt. Construction contracts were awarded and material and supplies positioned for the most efficient response to the anticipated flooding. Corps-operated reservoirs—Orwell Lake, Lake Traverse, and Lake Ashtabula—were drawn down to the lowest levels permitted by their operating plans.

Emergency construction of levees and other protection measures were undertaken in 37 communities, and they succeeded in all but Breckenridge, Ada, East Grand Forks and Grand Forks. In Breckenridge and Ada, the levees were overtopped, and unexpected overland flooding occurred at various locations. In the Grand Forks and East Grand Forks area, levees were initially constructed to a level of 49 feet (15 meters) plus freeboard and were in the process of being raised to meet the updated forecast when sandbag levees breached, causing flooding in the towns. In Fargo, approximately 40 homes were affected by floodwaters from sandbag breaches and unexpected overland flooding.

Approximately $9.5 million was expended on emergency levee construction. The majority of the construction was for new levees or the raising of existing levees with clay material. Plywood flood walls were also constructed, recycled concrete was used to construct levees in the water, extensive use of poly-on-clay levees was undertaken—sometimes after the water was on the levees, necessitating the use of divers for installation.

The Corps of Engineers spent $14.8 million on flood-response activities, preventing an estimated $233 million in damages. Approximately 5 million sandbags were provided to local communities to support flood-fighting activities. Several of the breaches that did occur were in areas where sandbag levees were constructed with insufficient cross sections. A total of 750 rolls of poly and 221 pumps were provided to communities to support their flood fighting and supplement the material and equipment they were already using. Communities were responsible for filling and placing sandbags and operating pumps for interior drainage.

Considerable mitigation work has been accomplished in the basin to repair, rehabilitate and construct new levees, install river outlet controls on storm gates and remove damaged homes or other structures in the floodway. Much of this work will continue through 1998.

Existing Flood Protection Works

In the United States, there are a number of structural works in place for flood protection. In 1948, the Lake Traverse Dam in South Dakota and Minnesota was constructed on the Bois de Sioux River south of Wahpeton. The Baldhill Dam in North Dakota upstream from Valley City was built in 1951. Orwell Dam on Minnesota's Ottertail River near Fergus Falls was constructed in 1953. All three provide floodwater storage. They are complemented by scores of smaller floodwater retention structures throughout the basin.

The Red River and its tributaries have limited natural storage, and dams are small. These dams, including "dry" ones, where the reservoir is usually empty, can reduce local damage during smaller spring floods and after heavy summer rainfalls, but have little impact on reducing floods along the Red River main stem.

Most of the smaller retention structures on the North Dakota side were constructed under the direction of the Natural Resources Conservation Service. Most are multipurpose. Several small dam sites are being examined by the Red River Joint Board (North Dakota) and the Lower Red Watershed Board for flood control, low-flow augmentation and wildlife benefits. In Minnesota, the focus of small dam construction is on structures with somewhat larger storage capacities.

The Lower Sheyenne River Flood Control Project in North Dakota, which was built by the Corps of Engineers, kept the town of West Fargo from flooding in 1997 by diverting water around the city. In addition, the built-up channel contained overland flows, preventing them from spreading. With near-record flows occurring on the Sheyenne River at Cooperstown, North Dakota, and along Baldhill Creek at Dazey, the Corps held water in Lake Ashtabula at the Baldhill Dam. This allowed for a slower release through Valley City, Lisbon, and eventually into the already swollen Red River. The dam was held to near capacity with a controlled release as local runoff diminished. Homme Dam, on the south branch of the Park River, was held to near capacity to reduce peak flows.

The 6-mile (10-kilometer) English Coulee earthen dam cuts in half the 115-square-mile (298-square-kilometer) English Coulee watershed near the city of Grand Forks. It dams runoff from the upper basin. A 36-inch (91-centimeter) pipe underneath the dam is used to draw down the 240-acre (96-hectare) storage pond. The structure protected much of the western side of Grand Forks from severe flooding.

Levees provide good protection to the north of Grand Forks-East Grand Forks, where flooding is usually the most extensive and prolonged. Twelve towns have earthen levees completely or largely encircling the built-up areas. Individual landowners have built an extensive levee system along a short stretch of the Red River north of Grand Forks-East Grand Forks. Many farmsteads have levees as well.

The levee system at Fargo-Moorhead held throughout the flood, despite record water levels. Built through the coordinated efforts of local, state and federal agencies, the levees prevented flooding.

In the period from 1962 to 1972, three major federal-provincial cost-shared works were constructed to protect Winnipeg: the Red River Floodway, the Portage Diversion and the Shellmouth Reservoir. Extensive ring diking was also undertaken to protect communities south of Winnipeg.

In Winnipeg, the Red River Floodway performed well. The Floodway operated from April 21 to June 3. The peak flow through the floodway channel of 65,000 cubic feet per second (1,950 cubic meters per second) occurred on May 4, surpassing the previous peak flow of 52,000 cubic feet per second (1,560 cubic meters per second) on May 9, 1979.

The Shellmouth Reservoir on the Assiniboine River maintains a balance between water supply and flood protection. Seasonal operation strategies are developed based largely on runoff forecasts and experience, with the understanding that extreme conditions may develop rapidly. Over the winter of 1996–1997 the reservoir was drawn down to an all-time low in anticipation of high runoff in 1997. About 70 percent of the runoff above the reservoir—approximately 254,000 acre feet (313,182,000 cubic meters)—was stored. The peak flow on the Assiniboine River was reduced from 10,600 cubic feet per second (318 cubic meters per second) to 1,650 cubic feet per second (50 cubic meters per second).

The Portage Diversion project is another component of a system designed to protect Winnipeg. The Diversion intercepts flows coming down the Assiniboine from the west and shunts them 18 miles north into Lake Manitoba. On April 29, the diversion gates were raised and until May 5, as the peak on the Red reached and passed Winnipeg, flows downstream on the Assiniboine were maintained at nearly zero. Operating the Portage Diversion eliminated the need to divert even larger flows into the Red River Floodway.

After the 1966 flood, and especially after the 1979 flood, joint federal-provincial programs encouraged rural inhabitants to raise their outbuildings and homes, and to build individual dikes around their properties. In 1979, a special federal-provincial flood relocation program added the purchase of residences to other strategies. The level of protection was upgraded to provide protection to the level of the flood of record or the 1979 flood level. It became evident in March that ring dikes at Emerson, Rosenort, Dominion City, Letellier, St. Jean Baptiste, Brunkild, Morris, St. Adolphe and Roseau Reserve would not be adequate for the 1997 flood. Shortly after the early April blizzard, work began to bring the dikes up to a safer elevation. None of the towns protected by ring dikes were flooded.

The town of Ste. Agathe was not protected by a ring dike and was flooded unexpectedly by overland flows from the west, not directly from the river on the east side of town. Ste. Agathe sits upon land that has, in past floods, been flood-free. Flood protection was provided on the river side of the community, but additional protection of the town was not considered necessary.

Emergency Measures

With few exceptions, emergency measures served the purposes for which they were intended and ultimately contributed to flood damage reduction. The 1996 flood prepared those involved for the 1997 event.

Preparation for an emergency action must be taken before the crisis. Conditions within a flood zone tend to be chaotic. Communication is difficult and command structures can break down because of logistical or communications failure. Complaints during the emergency cannot normally be addressed. To respond effectively requires planning, preparation and training. During the 1997 flood, the participation of the Canadian military and the Minnesota and North Dakota National Guards were important. Declaring an emergency prior to the point of crisis is vital to the preparation and deployment of resources and personnel. However, taking emergency measures unnecessarily—when the expected crisis does not occur—leads to post-event criticisms, particularly with regard to the cost implications, and damages the credibility of emergency organizations. Striking the right balance can be difficult.

Effective communication of risk and the need to evacuate are important as well. If those at risk are not advised early enough and in ways that prompt cooperative action, emergency measures will not work. Evacuation problems occurred in 1997. In Minnesota and North Dakota, some residents seemed unwilling to evacuate because their homes were not in the areas that had previously been flooded. They felt secure because of the sandbags added to the new and existing levees. Some residents have insisted that officials did not tell them the forecast levels early enough. South of Winnipeg, until late in April, many residents defended their properties with diking or with pumps. People operating their own pumps were reluctant to abandon their properties, even when ordered to evacuate. Some residents refused to leave, whatever the circumstances. It was never clear to what extent the authorities were prepared to use force to accomplish evacuations, or what the implications of forced evacuations would be. Many evacuees argue that once they had been ordered from their properties, the authorities became morally if not legally responsible for whatever damage occurred.

Communication issues were behind many of the evacuation problems and other difficulties in the field. Flood emergency procedures must have the support and cooperation of the local governments and local communities. The rural municipalities differ from cities where full-time professionals and experienced departments deal with flood matters. Local governments tend to be staffed by part-time officials who may be less experienced in dealing with the inner workings of the flood emergency system. Communication between emergency preparedness staffs and elected officials was also an issue. In the United States, many elected officials were unaware of local/state/federal responsibilities and authorities. In turn, decisions were made that could have been contrary to emergency preparedness practices. In some cases, communication problems may have reflected policy problems. From the outset, for example, City of Winnipeg officials understood that the central government would reimburse them for the money that they committed to flood defense; in fact, no such compensation provisions were in place at the beginning of the crisis. Rural municipalities, required by law not to run deficits, were reluctant to commit financial resources in advance of funding arrangements.

New Information Technologies

The 1997 flood was distinguished by the introduction of several new technologies. This was the first major Red River flood in which cellular phones had been employed in emergency flood fighting to any great extent, and most flood fighters regarded them as essential. This was also the first flood that received heavy attention from the Internet. Many public and non-public agencies had their own Web sites, presenting up-to-date and comprehensive information and statistics. Many local residents, as well as people around the world, considered the Internet their best source of information.

The Role of the Military

The work of the Canadian Forces in the 1997 flood was successful. The military's "Operation Assistance" was the largest Canadian military operation since the Korean War and probably the largest civil operation ever mounted. The military was asked to help late in the flood cycle, but it was able to respond quickly because it prepared in advance of any formal warning from the civil authorities. However, the forces felt they might have been able to contribute more effectively had they been involved in planning at an earlier stage. Ultimately, a joint force operation of 8,500 personnel, 2,850 vehicles, 131 watercraft and 34 aircraft was drawn from across the country. The military was prepared to evacuate 100,000 or more metropolitan Winnipeg residents if required.

Military assistance in Canada was invaluable, but not without some problems. The chief difficulty lay in communication problems between the civilian and military authorities. These were most marked in the relationship between the troops and the local law enforcement agencies, the RCMP and the Winnipeg Police Service. The public attitude toward military aid was misjudged; it was much more favorable than anticipated, and the presence of the soldiers gave many affected residents a sense of security.

The National Guards of North Dakota and Minnesota were involved at an early stage. Planning for the flood began in January. This early planning led to the successful evacuation of thousands of people. Over 25,000 people were rescued by various land and water vehicles and helicopters in Minnesota and North Dakota. The National Guard provided potable water, security and traffic control, dike watch, fire protection and other emergency necessities. The Minnesota and North Dakota National Guards deployed over 5,300 troops, 14 aircraft and hundreds of vehicles and other pieces of equipment.

The Role of Charities

Manitoba, North Dakota and Minnesota have a strong tradition of volunteer activity in flood disasters. That tradition meant that thousands of volunteers helped in flood fighting and relief work in all sorts of ways, from building sandbag dikes to baby-sitting the children. Volunteer labor was invaluable: in addition to the work that it accomplished, it provided enormous psychological support to the endangered people.

In Manitoba, private agencies raised more than $30 million. The Red Cross, the Salvation Army, the Mennonite Disaster Relief Committee and many other charitable organizations offered help. All major religious denominations funneled money into local communities through their churches. These donations were used to provide assistance and to supplement public support given through the Manitoba Flood Assistance Fund. Private agencies were part of a Flood Management Committee that coordinated the rehabilitation effort. This committee, chaired by Manitoba EMO, involved government departments and private agencies, and met weekly.

Private entities also provided many millions of dollars to the U.S. portion of the basin. Final figures are still being calculated, but the contributions were considerable. These funds were augmented by donations from individuals and non-charitable corporations, some of them anonymous. An example is the largesse of Joan Kroc, McDonald's Inc. heiress, who donated $2,000 to each head of household directly affected by the flood in Greater Grand Forks.

Agencies that are part of the National Voluntary Organization Active in Disaster (NVOAD) and their local Minnesota and North Dakota chapters were active in response, recovery and fund-raising efforts in the United States.

Socio-economic Impacts

At least 103,000 people (75,000 in the United States and 28,000 in Canada) evacuated their homes in both urban and rural areas. Many homes were so badly damaged they had to be abandoned. The impact of the flood upon residents, both in monetary and non-monetary terms, was enormous.

Many of the evacuees' expenses were covered by government and private charities at the time, and other expenses were reimbursed later. Numerous people were moved into the homes of families, friends and volunteers. Lost income for individuals and small businesses was not compensated. Evacuees had to move furniture and appliances either to upper stories or away from their homes to protect them from floodwater.

There were psychological costs, too. These include the days of uncertainty before evacuation, the confusion over where to go when evacuated, the disruption of daily routine and the strain on families removed from their home environments. The effects of these disruptions will be felt in some families for many years. There is some evidence that evacuees who were sent to communities with counseling and recreational programs may have done better than those who were without such programs.

Trauma treatment for people who were flooded was slow to move into full operation. Some counseling was carried out in evacuation centers, but most trauma support did not occur until residents returned to their homes, in some cases several months after the emergency had ended. Individuals and health care and social work professionals have expressed concern about the slow response and early termination of support to people traumatized by the flood.

When the Task Force held a workshop in Winnipeg on the social dimensions of the flood, a number of themes emerged. The perception of some people during the flood was that communication with individuals in the flooded areas was good, and that a reliable chain of command and infrastructure such as effective dikes were in place. Others seemed to feel flood managers were reactive rather than proactive. Many did not feel that they had been kept fully informed.

Workshop participants considered that the prevailing flood-fighting approaches focused on "top-down" decision-making; they said that more effort is needed to achieve "bottom-up" decision-making as well. The participants suggested that the success of future mitigation strategies will depend on putting some control in communities' hands. They argued that involving communities in flood management will increase their capability to understand and to act in future flood-fighting efforts.

There was extensive discussion of the traumas that individuals experience during floods and disasters (distress, disruption, loss of property and possessions, altered social relationships, personal vulnerability and loss of control). Participants agreed that physical losses are visible, but that social impacts often are not.

The Recovery Process

The rehabilitation of damaged properties, particularly the development of a policy on individual claims and their processing, has been the subject of public controversy. Initially, the Government of Manitoba required that claimants pay a deductible amount, and it imposed a maximum claim amount. These requirements have now been partly removed. This has affected charitable organizations, whose role is to supplement provincial payments. Many people experienced delays in receiving their assistance from private charities because they had not yet been paid by Manitoba EMO. As of November 26, 5,022 claims had been dealt with, with average payments of $9,000. The total payout was $45.4 million; the federal government pays approximately 90 percent of this amount. In addition, the joint Canada/Manitoba Jobs and Economic Recovery Initiative (JERI), which provided grants, advances and loans for small businesses, farms and nonprofit organizations directly affected by the flood, had approved more than 2,000 registrants and dispensed approximately $9.5 million in assistance.

In October 1997, phase II of JERI was announced. It provides for up to $100,000 in assistance and $100,000 in interest-free loans to businesses, farms and nonprofit organizations to help restore their operations to pre-flood levels. To December 12, 1997, the Canada-Manitoba Business Recovery Office had received 489 applications for claims totaling over $8.3 million.

In the U.S., the recovery process has worked reasonably well. The primary criticisms deal with the cumbersome and lengthy application process. People have also complained that in some instances those who did not purchase flood insurance have been "treated better" than those who did.

Environmental Impacts

Water Quality

Major environmental impacts caused by the 1997 flood have not yet been identified for the Red River itself or in Lake Winnipeg or its recreational beaches. The flood's effect on the environment may have been minimal for two reasons. Many sources of pollution were safeguarded before the flood arrived, and the tremendous volume of relatively clean snow meltwater diluted contaminants.

Several agencies assessed water quality during the flood at a number of sites throughout the basin. One of the most important sites was near Selkirk, Manitoba. Since this location is only a few miles upstream from Lake Winnipeg, water quality there reflects an integration of basin-wide effects.

Sediment loads in the Red River at Selkirk during the flood rose quickly as river flow increased, reaching a near-record maximum of 138,516 tons (125,634 metric tons) a day. During the flood, sediment loads remained above 55,115 tons (49,989 metric tons) a day from April 22 to approximately May 20, then gradually decreased.

Upstream from Winnipeg, fecal coliform densities exceeded only briefly the water quality objective adopted by the IJC for the protection of recreation, and then declined to normal levels.

Densities downstream from Winnipeg, although substantially higher than those observed at the international boundary, did not differ markedly from normal for this reach of the river. Densities of the fecal streptococci group appeared higher than normal at Emerson near the international boundary in samples collected by Environment Canada. This is common during floods, since some bacteria measured in this test are native to soils and plants. These findings were similar to those reported by the United States Geological Survey. Fecal streptococci levels were higher in 1997 at Fargo and Pembina than in recent years. The elevated levels of fecal coliform and fecal streptococci may have been from agricultural sources.

Tests were also conducted for a variety of materials such as dissolved salts, nitrogen, phosphorus, metals and other trace elements, and pesticides. Concentrations of these compounds generally did not exceed normal levels or levels that presented an unacceptable risk to human or aquatic ecosystem health. Several compounds were detected during the flood that had not previously been recorded. Pentachlorophenol, a wood preservative, was likely leached from inundated railway ties or bridge structures, while several persistent organochlorines such as the pesticides dieldrin, g-chlordane, and endrin were likely mobilized from previously undisturbed soils. A number of pesticides currently in use were detected, including 2,4-D, trifluralin, triallate, dicamba and atrazine. Concentrations of atrazine in the U.S. portion of the Red River were higher than previously observed in spring runoff. The IJC alert levels established at the international boundary are exceeded if any pesticide is detected; they are therefore commonly exceeded.

The 1997 flood contaminated many dugouts used by farmers for agricultural production (in particular, hog and poultry water supplies) and others used for general purposes, such as mixing water for farm chemicals and household needs. According to producers, such poor water quality had never been experienced before.

Hazardous Material

Within Manitoba, more than 550 containers that held or may have held hazardous materials before being swept into the floodwaters were retrieved from the Red River. These included propane cylinders and home heating fuel tanks. A total of 40 containers with some contents were also collected between Wahpeton, North Dakota, and the international border. The contents of these containers were wide-ranging: petroleum products, fire-fighting foam, tar, alcohol, solvents, corrosive liquids, polyester resin, flammable liquid, paint, pesticides, compressed gases such as propane, and home heating fuel.

Home heating fuel tanks were a source of hazardous materials in Grand Forks, where approximately 1,000 of the flooded homes used heating oil. During the flood, many of these tanks broke free from their connections and spilled fuel oil. After the flood, heating-oil-contaminated water was removed by vacuum trucks from 726 flooded homes and businesses in Grand Forks and separated. The water was discharged into the Grand Forks sanitary sewer system while the oil was recycled.

Estimates of the number of residential fuel oil tanks that spilled in Manitoba are not available. However, 56 home heating tanks were retrieved from the Red River within Manitoba. Other petroleum products were also lost. For example, approximately 15,000 gallons (68,100 liters) of gasoline spilled from service stations in Breckenridge, Minnesota. Several petroleum components were detected in water samples collected in the U.S. portions of the basin.

Cleanup after the flood revealed a plethora of household hazardous wastes, such as paint, pesticides, oil, solvents, aerosols, water putty, detergents, tar and batteries, in flooded basements. In the United States alone, excluding Grand Forks, 86 barrels of household waste were removed from flooded areas.

Sewage and Related Facilities

Raw sewage bypassed the sewage treatment facilities of many towns, including the City of Winnipeg, directly entering the floodwater. Up to 40 municipal wastewater treatment facilities in Minnesota were either bypassed or inoperable for periods during the flood. Municipal sewage lagoons were flooded at Emerson, St. Jean, Morris and Otterburne in Manitoba, and Pembina in North Dakota. As the floodwater receded, the systems were put back into operation. Numerous private septic systems and septic fields in the Red River basin were also flooded.

Commercial Facilities

Two agricultural chemical storage facilities were flooded in the Grand Forks area. In one commercial facility, 13,480 gallons (61,200 liters) of sunflower oil was contaminated with high concentrations of insecticides. The oil was shipped for disposal to Kansas City. The 293,000 gallons (1,330,220 liters) of water below the oil was also contaminated and was pumped through an activated carbon filter system and then discharged into either the English Coulee River or the Red River. Studies showed that the discharged water was not toxic to fish. A fertilizer company building near Grand Forks was also flooded, saturating stored fertilizer. An estimated 4,000 tons (3,600 metric tons) of urea and 1,000 tons (900 metric tons) of phosphate were lost to the floodwaters. At the same location, a large basement filled with various farm chemicals was also flooded. An estimated 147,000 gallons (667,400 liters) of contaminated water from this facility was collected and pumped through activated carbon for treatment before discharge.

Livestock

About 8,000 head of cattle, hogs, poultry and sheep died in floodwater. Most of the animal deaths occurred in Minnesota, likely as a result of the lack of advance notice for farmers and commercial operators. Most carcasses were contained in the area of origin, but a number of dead animals were retrieved from floodwater. Approximately 12 livestock storage facilities, numerous concrete storage pits, livestock pens, holding areas and barns were subjected to floodwater in the rural municipality of Morris, Manitoba, alone.

Groundwater

Although bacteria densities during the flood were not unusually high for the Red River, levels were sufficient to contaminate groundwater in areas south of the City of Winnipeg. Floodwater entered the aquifer through both active and improperly sealed abandoned wells. Some wells were covered with up to 8 feet (2.4 meters) of standing water for extended periods, while in one case, an abandoned well allowed floodwater to flow into the aquifer for about four days at such a rate that a vortex formed over the well. Subsequent to the flood, 250 wells in the Grande Pointe, St. Adolphe and St. Germain areas south of Winnipeg were rehabilitated by pumping followed by chlorination. Thirty-six abandoned wells in the region were permanently sealed, and a further 17 wells were equipped with proper sanitary seals.

Red River and Upper Mississippi Basin Hydraulic Connection

The divide between the two basins at the southern end of the Red River basin between Lake Traverse and Big Stone Lake is a gradual one. Interbasin transfer of water between the Red and Mississippi river basins through Lake Traverse and Big Stone Lake is a concern due to the potential for the exchange of non-native biota. The issue is complex and requires longer-term study.

Human Health

Water treatment facilities in the valley continued to provide good quality drinking water throughout the flood. The drinking water treatment facility at Grand Forks was disabled for about three weeks because of flooding. Drinking water treatment facilities within the Manitoba portion of the basin were able to operate throughout the flood with the exception of the system at Ste. Agathe. This system was shut down for about one month when floodwaters entered part of the storage reservoir through an overflow drain.

Many flooded homes experienced mold problems, especially when basements were not completely dried prior to re-entry. Molds create health problems for some people. In a number of cases, even partially damaged and rebuilt homes had to be declared unsafe for occupation.

The International Dimension

Many transboundary rivers become the subject of contention as uses on one side of the border have unwelcome effects on the other. The Red River basin, however, is remarkable for the spirit of cooperation that prevails on both sides of the border that crosses it. This can be seen in the way in which federal, state and provincial governments share information and assist each other in responding to the common cause of fighting flood emergencies.

Cooperation can also be seen at the local level where communities that share the basin recognize a common interest in the good management of the basin and its waters. For example, the Red River Water Resources Council, consisting of government officials from Manitoba, North Dakota and Minnesota, meets a number of times annually to share information. Some local and state governments have come together to create the Red River Basin Board. Its 21-member Board of Directors intends to develop a comprehensive, basin-wide water management plan that spans local, state, provincial and national boundaries. It also intends to serve as a forum for the discussion of inter-jurisdictional issues.

In October 1997, the IJC responded to the governments' request to report on measures that might best help them to meet the environmental challenges of the twenty-first century. The IJC proposed a system of international watershed boards for the Red and Souris rivers. The new boards would focus on the overall environmental integrity of each watershed—water, land and air—and monitor and report on all relevant concerns, including questions of habitat, biodiversity, exotic species and pollution from all sources. Their mandate would cover issues of water quantity, as well as water quality. The boards would be binational and have primarily local membership.

There are other notable examples of international cooperation. The Souris River Board of Control has a mandate to ensure the waters are equitably apportioned among Saskatchewan, North Dakota and Manitoba. The Flow Forecasting Liaison Committee established by the Board shares information and maintains communication among the partners. The committee has made forecasting on the Souris more reliable.

Binational cooperation in flood forecasting, modeling and data collection has been excellent. Manitoba relies heavily on the hydrometric information generated in the U.S. portion of the basin. Airborne gamma snow surveys in Manitoba are conducted under contract with the U.S. National Weather Service. However, the flood of 1997 points to areas where improvements can be made in both modeling and forecasting, and the Task Force has sponsored work to strengthen the technologies employed. The consensus is that there need not be common models, that each side should be able to maintain its own model to suit institutional and user needs. But a common database is required if differing models are to provide compatible and complementary results. In addition, cooperation could be enhanced if Canadian liaison officers were present in the U.S. flood emergency centers to immediately relay information to Manitoba. An enhanced database is proposed as part of the Task Force Plan of Study.

A comparative study of activities in both countries is a relatively untapped source of "best practices." For example, much could be learned from Minnesota's approach to the problem of abandoned wells. Before a property can be transferred or sold, wells must be identified, and if abandoned, properly sealed. Neither Manitoba nor North Dakota has similar regulations.

The criteria for the regulatory description of a floodplain vary. In Manitoba, the floodplain is identified using the flood of record—now the 1997 flood plus 2 feet (0.6 meters). In the United States, as required by the National Flood Insurance program, the regulatory floodplain is identified by the 100-year flood. However, a community or state can adopt a higher standard. The effects of having differing criteria and the value of common criteria have been identified as an issue and will be explored in Task Force studies in the coming year.

During the 1997 flood, environmental agencies operating throughout the basin were in constant contact, sharing information on contamination and other hazards. Before the flood, Manitoba, North Dakota, Minnesota, and Canadian and U.S. federal agencies examined proposals to speed the melting of ice near bridges, and during the flood, they shared information on dead livestock in the floodwaters, hazardous materials and floating containers, petroleum products, sewage treatment and drinking water treatment facilities and flooded agricultural chemical storage areas, and they provided regular progress reports on recovery efforts. Principal contacts were members of the IJC's International Red River Pollution Board. The list of environmental agency contacts identified in the Board's contingency plan was used at the operations center of the Manitoba EMO to obtain information during the flood response.

Formal international coordination is advisable and has been established in the past through the "Agreement between the Government of the United States and the Government of Canada on Cooperation in Comprehensive Civil Emergency Planning and Management." This agreement, signed April 28, 1986, has now lapsed but forms the basis of an informal cooperation protocol.

Under this agreement, an international consultative group was given the authority to coordinate international response to civil emergency situations by planning cooperatively and sharing resources such as emergency personnel and equipment. It would be advantageous if equipment, personnel and supplies could readily cross the border during emergencies.

To facilitate decision-making, information from both sides of the border should be collected and stored in easily accessible locations. All parties would benefit by a much more methodical and organized exchange of information, best practices and research results.

V Current Recovery and Risk Management Measures

During the summer of 1997, Manitoba Environment conducted remedial activities to restore the original quality of the contaminated groundwater in the Grande Pointe area. Contaminated water was pumped to the surface through existing wells until tests indicated "fresh" water was being pumped. Next, the wells and associated equipment were disinfected by injecting a chlorine solution into them.

Water quality was closely monitored over time. Where necessary, treatment was repeated. Where the well structure itself was deemed to be the problem, the well was replaced. The final stage of the rehabilitation program was to implement a well improvement program and to seal abandoned wells in a proper manner.

Dugouts are the major source of water for most farms in the Manitoba portion of the Red River valley west of the Red River. Many of these were contaminated by floodwater in 1997. Following the flood, many farm dugouts were treated with an aluminum sulfate solution to restore the water quality of the dugouts. In most cases, water quality was improved to a level that would have taken years to achieve under natural conditions.

Mitigation Measures

Several communities in the basin have undertaken mitigation measures to protect against future floods.

In response to the flood of 1997, the governor of Minnesota established a Recovery and Redevelopment Planning Council to address the implications of the flood and the redevelopment of the affected region. The primary charges of the council were to attract private investment; encourage economic development; identify and prioritize infrastructure and housing needs; facilitate technical assistance to local governments and businesses; and leverage federal, state and private resources. The council provided a structure that enabled one-stop shopping for state and federal recovery dollars and programs. The outgrowth of the governor's council that reviews community applications is the Minnesota Recovers Disaster Task Force (MRDTF).

To date, the MRDTF, which is comprised of federal and state agencies, has reviewed and approved flood recovery proposals from over 90 communities. Applications included requests for mental health services, acquisition of flood damaged homes and businesses, housing financing assistance, small business loans, planning and engineering assistance, infrastructure repair, and flood protection measures, such as levees. Minnesota’s commitments to fund flood recovery have exceeded $125 million and total local, state, federal and private expenditures will likely exceed $830 million before the recovery effort is complete.

Communities, with the assistance of regional flood coordinators and development commissions, completed and submitted a single, universally accepted flood recovery application to the MRDTF. The MRDTF reviewed the various elements of the application, and funding responsibilities were assigned to participating state, federal and private agencies and funding sources. Community proposals for levees, storm water closures, flap gates, flood walls and other flood damage reduction measures were forwarded to a technical advisory team of the Corps of Engineers. The Corps team reviewed the technical merits of each proposal and provided recommendations for funding.

Minnesota has an existing flood-reduction program that provides up to 50 percent funding for projects to reduce future flood damage. Over $18 million has been appropriated in 1997 for the flood program.

In Minnesota, Ada is reinforcing, raising and extending emergency levees to protect against overland flooding. Some 16 houses will be purchased. The city plans to make repairs to the sanitary and storm sewer systems. In Breckenridge, several miles of levee are being built to protect against overland flooding. The city expects to buy approximately 100 houses by spring and another 40 next summer. Other plans include a 6-foot (1.8-meter) concrete flood wall to protect downtown sanitary and storm sewer systems. Dilworth will heighten and extend low-level levees to protect against overland flooding. In East Grand Forks, an 850-foot (255-meter)-long wall will be built by next spring to protect the central business district. The base will be a 4-foot (1.2-meter) concrete wall upon which metal tubing can be attached to form a 12-foot (3.6-meter)-high wall. About 450 houses and 40 businesses will be removed by next spring. All city levees will be reinforced. The present levee system in Hendrum is being modified to create a ring around the city. Perley will create a ring levee. Moorhead is reconstructing and improving its permanent levees. Flood-control gates will be installed at strategic locations. About 60 families have been protected by ring dikes. Additional home buyouts are anticipated here and elsewhere in the valley. The cities of St. Vincent, Hallock, Kennedy, Dumont, Roseau, Shelly and Mahnomen are repairing and improving existing levees.

In North Dakota, Mapleton is considering home buyouts and a permanent levee system. Most of the temporary levee that protected Harwood during the flood of 1997 has been upgraded and made permanent. Wahpeton has begun a three-phase flood-protection program, involving constructing a levee, improvements to the city sewer system, and a 2-mile (3.2-kilometre) levee which will be constructed in 1998. When the system is completed, the city will be protected to a river level of 22 feet (6.6 meters). The Red River crested at 19.2 feet (5.8 meters) in April 1997. In Grand Forks, the existing dike system has been repaired and studies are under way to to help the city decide whether to build a larger dike system or a combination dike-diversion. A decision is expected in the spring of 1998. In Fargo, flood mitigation efforts have centered on buying and demolishing homes in five different areas along the river in order to construct berms. By spring, Rose Coulee will be deepened and widened and a section will be lined with concrete. Roadway raising, fortified temporary dikes and new dikes will be located in southwest Fargo to prevent overland flooding. Three storm sewer lift stations will be installed. All these initiatives are to be completed by April. Home buyouts are under way, with more than 80 expected by spring.

In Manitoba, where possible, dikes have been sculpted and seeded and left in place. The upgrading done to the existing West Dike has been made permanent, and there are plans to make the extension permanent in the near future. Much of the temporary West Dike extension has been dismantled and will likely be relocated to serve as an elevated road bed. Within Winnipeg, upgraded primary and secondary dikes at 50 locations were modified to become permanent structures. Many secondary dikes have become permanent structures.

In July 1997, the Canadian and Manitoba governments announced a flood-proofing program to prevent future flood damage in Manitoba. The project is patterned after similar 1996 and 1997 programs. It provides communities with technical and financial assistance to build or enhance their ring dikes, or to relocate. Private property owners who meet the flood-proofing standards will have the 20 percent deductible for their disaster assistance claim waived. Funding is available for up to 75 percent of costs subject to varying upper limits depending on the type of work being done. All works must meet the new flood-proofing standard—the 1997 flood level plus 2 feet (0.6 meters) for dikes, and the 1997 flood level plus 3 feet (1 meter) for buildings.

Governments are proposing $30 million to build new ring dikes around 17 communities in the Red River valley that previously did not have them, including Ste. Agathe, St. Pierre, Aubigny and others. Engineering consultants have completed feasibility studies on the projects with a view to some construction next spring.

VI Forecasting and Modeling

Overall, the hydrologic and hydraulic modeling techniques used during the 1997 flood worked well, but there is room for cost-effective improvements.

Hydrologic Modeling

The National Weather Service (NWS) is the official source of river forecasts in the United States. It relies on other agencies to provide much of the information needed to produce forecasts. For example, the United States Geological Survey is responsible for maintaining river gages and developing rating curves. The Corps of Engineers maintains information on levee elevations and has access to other valuable hydraulic and structural information. Improved coordination of all agencies feeding information into the forecast model in the United States is desirable.

In the United States, the flood of 1997 tested the limits of flood-forecasting technology used by the NWS. Several key problems that require further attention were encountered during the course of this event. Ice jams caused floods at some locations. Also, ice remained in drainage ditches and other channels, forcing runoff into temporary storage and delaying the arrival of runoff to the main stem of the Red River. Refinements to the forecasting system are needed to avoid these problems. Rating curves used to predict flood levels had to be extended beyond anything ever before observed. This resulted in inaccuracies at some locations.

Critical data were lost when gages were damaged or inundated by the high water. In general, equipment should be installed in future gage installations so as to avoid the loss of data at the height of a flood. Many of the gages used to forecast peaks in the Red River basin were never designed for the purpose; many did not perform during the 1997 flood. The Task Force will consider over the coming year whether a formal basin-wide flood monitoring network should be designed, constructed and maintained.

Snowmelt Outlook Flood Potential forecasts were not well understood by some users. Two forecasts are provided—one assumes no further precipitation; the other factors in normal precipitation for the period. Many users interpreted these values to be the actual crest forecasts. Users advocate simpler crest forecasts that include average precipitation.

Manitoba Natural Resources prepares forecasts using an index type of model to predict the runoff volume and peak discharge at Emerson. Once runoff is well under way, Manitoba depends on the U.S. NWS predictions for the Red River at Pembina. About 80 percent of the total runoff on the Red River in Manitoba comes from the United States portion of the basin.

Weather and stream flow data are provided by Environment Canada, with supplemental measurements by Manitoba Natural Resources. In 1997, all of the Environment Canada gages were flood-proofed before the flood, so very little data loss was experienced.

Using data on soil moisture, precipitation, snow pack and other variables, the runoff volume and timing of each of the tributaries is calculated to produce predictions of stage and discharge along the Red River. While this technique has worked well, it requires judgment that is based on the experience of the forecaster. It should be noted that in Manitoba this demanding work is done by only one person, with many years of experience.

In the immediate future, steps can be taken to improve the forecasting model. A number of the following improvements can be put in place immediately, and others could be completed by the spring of 1998.

1. Document the 1997 flood, taking particular note of inundation mapping, overland flows and high-water marks.
2. Extend to the 500-year flood the rating curves used for predictions, and improve frequency curves based on new information.

3. Employ a more definitive flood forecast model for the areas of Grand Forks-East Grand Forks, Fargo, Wahpeton and perhaps Emerson if the need arises.
4. Permanently raise existing gages above maximum flood levels to prevent losing them during critical times.
5. Extend gamma snow surveys this winter, primarily in Canada, by increasing the frequency of flights.
6. Provide users with more detailed forecast information that includes the level of uncertainty, worst-case scenarios and possible ranges.

Over the long term, the U.S. NWS is committed to providing more complete information and forecasts to allow water managers and emergency agencies to deal with a major flood. They are working toward establishing the Advanced Hydrologic Prediction System (AHPS). This system can extend lead times and provide information that expresses the relative uncertainty of hydrologic values such as discharge, volume and stage.

Weather radar is an important element in the prediction of flood stages and flows. New radar is scheduled for Winnipeg in the future. The public interest would be served if a higher priority was accorded this particular installation.

Hydraulic Modeling

Overall, the hydraulic models used on either side of the border during the flood performed as expected, given their limitations. The models were generally unable to deal with the overland flow. At Ste. Agathe, floodwaters moved up the valley many miles west of the main stem of the river, built up and eventually broke through roads and railways. In Grande Pointe, the water crossed overland and became trapped behind a railway embankment, forcing water levels higher than predicted.

When floodwater flows across country, it meets an entirely different set of conditions than if it had run through a defined river channel. Topography, road and railway networks, wind and many other factors affect it. To predict these movements before the fact requires a dynamic hydraulic routing model that can deal with the many variables in routing flood flows of the magnitude of the 1997 flood.

A dynamic model has the capability to predict what floodwater will do given any number of possibilities. If such a model had been used in 1997, forecasters could have predicted the potential for a problem at Ste. Agathe, and the community could have been protected. The effect of infrastructure features in holding water away from the West Dike Extension could have been predicted and the dike constructed somewhat differently. The Grande Pointe, Grand Forks and East Grand Forks situations could have been modeled, and preparations would have reflected the expected levels.

In spite of hurdles, the development of a dynamic model is essential. While it is not absolutely necessary for the same hydraulic model to be used throughout the entire basin, it is imperative that both the U.S. and Canadian models input similar data. To provide consistent results, both must work with equally detailed basic information. A zone of convergence spanning the international border would be necessary to allow the two models to merge.

A dynamic model could be used to track water quality problems resulting from contaminants entering the system through spills, flooding of communities and so on, which would enable timely preventive action to be taken downstream. This model could also be used to determine the effects of new structural measures, such as dikes, roads and bridges, on adjacent areas. The effects of roads on overland flooding are major. It is essential that those effects be predicted and mitigated.

Over the coming year the Task Force will be exploring the uses that can be made of models to improve forecasting. In addition, it is recognized that the models also have great potential to help decision-makers in land-use planning and other floodplain management activities.

VII Plan of Study

Many of the issues that have been raised in the interim report or brought to the attention of the Task Force require further study. These subjects are described in the proposed plan of study. The plan of study addresses the scope, strategy, schedule, and budget of the proposed improvements. The plan is a work in progress, requiring further consultation and input before it is finalized.

The Task Force has defined specific objectives for its investigations as:

- develop and recommend a range of alternatives to prevent or reduce future flood damages; and
- improve tools for planning and decision-making.

Each objective includes the development of recommendations, which will form part of the final report.

The plan of study places great emphasis on the development of a database, models and studies that will assist future floodplain management. The intent is to draw topographic, land-use, hydrologic, hydraulic, environmental, and economic information into a common accessible database that can provide support for all floodplain management activities and decisions.

The Task Force will seek public input into the proposed plan of study early in 1998. Public meetings will be held in the basin in February. Following that, the plan of study will be revised to reflect further public concerns and advice.

VIII Conclusions and Recommendations

This interim report presents 40 recommendations that should be initiated within the short term. The recommendations are based on consultations with people in the Red River valley, public officials and experts and a review of available material. The limited time, consultations and investigations available to the Task Force result in recommendations that highlight only what could be helpful in reducing the adverse effects of flooding in the short term. To provide longer term and more specific recommendations, the Task Force will consult further with the public and carry out more detailed studies in 1998 as presented in the draft plan of study.

General Issues

Future Floods

There are many lessons to be learned from the experience of the flood of 1997. However, having survived the "Flood of the Century," there is a risk that people may become complacent about the possibility of another major flood in the near future. This is no time for complacency.

1. Recommendation : Alert the public in the Red River basin to the reality that while the 1997 flood had a return interval ranging from 100 to 500 years, depending on the location, there is a statistical probability of a similar flood each year. Flood preparedness must be part of the culture of the Red River valley. Put simply, the flood of 1997 or an even larger one could happen any year.

Flood Policy Review

Improvements and clarifications are warranted in a number of flood policies as a result of experience gained during 1997. Moreover, senior officials responsible for policy advice can gain efficiencies by working together in advance of an emergency.

2. Recommendation : A meeting of senior federal-provincial and federal-state officials in each country should be convened to undertake policy level discussions and an examination of the 1997 flood. Special attention would be placed on extending the positive aspects of flood preparation and management during 1997 to future events throughout the Red River valley.

3. Recommendation : Increased liaison on a regular basis among the emergency management organizations throughout the basin should be a priority in order to establish better appreciation for the manner in which each operates during an emergency.

4. Recommendation : During a flood, Canadian liaison officers should be present in U.S. flood emergency centers to immediately relay information to Manitoba.

Flood Forecasting

Flood forecasting models require constant updating and enhancement. This is a complex science that demands analysis of large amounts of data, sophisticated equipment and analytical tools. The process also requires expert judgment based on knowledge and experience flood forecasters accumulate over years. Manitoba Natural Resources has just one experienced forecaster.

5. Recommendation : Update and enhance existing forecast models based on 1997 data and experience, focusing specifically on improvements that can be incorporated in basin-wide forecasts prior to the 1998 season. In particular, rating curve extensions should be undertaken as soon as possible.

6. Recommendation : Monitor the potential effects of El Niño on 1998 weather.

7. Recommendation : All flood forecasting agencies should ensure that they have sufficient, experienced flood forecasting staff at all times.

Flood Forecasts for the Public

Effective communication of both technical and non-technical information is a challenge, especially during disasters such as the 1997 flood. In some cases, local officials and individuals did not place credence in early flood forecasts; others did not understand the significance of the forecasts. For clear communications, the public should be made aware of the source of flood forecasting information and the variables inherent in it.

8. Recommendation : Simplify and clarify communication between flood forecasters and those with local flood emergency responsibility, throughout the basin. The dissemination of forecast information to the public through the media should be simple and the variables inherent in those forecasts easily understood.

Floodplain Management

Since 1979, any new home built on the floodplain in Manitoba has had to comply with the Red River Designated Flood Area legislation, which stipulates that the main floor of the home must be 3 feet (1 meter) above the flood of record. While legislation provides the authority to have a non-compliant home removed, this option is too extreme to have been used. Only 63 percent of the new homes in the Designated Flood Area comply with the regulation.

Prior to the spring 1997 flood, North Dakota and Minnesota and FEMA publicized the availability of flood insurance, and many new policies were taken out. Historically, less than 25 percent of flood-prone structures have had flood insurance.

9. Recommendation : The Province of Manitoba, and affected municipalities, should review all Designated Flood Area legislation and zoning provisions with the intent of widening the options for enforcement. A comprehensive program of early inspection and enforcement should be developed and implemented immediately. Once this program is implemented, non-compliant new structures should not be eligible for disaster assistance.

10. Recommendation : In the United States, more stringent adherence to existing policies is a necessary, immediate and effective first step for better floodplain management. Emphasis should be placed on increasing participation in the flood insurance program.

11. Recommendation : Update profiles, maps and flood frequency curves for the Red River basin.

Structural Measures

Floods are inevitable. It has been demonstrated by the events of 1997 that communities can be protected against extreme events by reservoirs, floodways, community dikes, levees and other protective structures. Individual residences and businesses can also be flood-proofed. However, new works raise the potential for negative impacts elsewhere in the basin.

12. Recommendation : Plans to implement new flood mitigation and flood-proofing measures for individuals and communities—if sound in economic, environmental, engineering and social terms—should continue as rapidly as possible. All such measures, whether by government or individuals, should be coordinated and examined to determine possible damage to others within the basin.

Emergency Management

Coordination

The 1986 Canada–U.S. Agreement on Cooperation in Comprehensive Civil Emergency Planning and Management negotiated by FEMA and EPC has expired, although the cooperation continues on an informal basis. While communication and cooperation among governments, agencies and organizations on both sides of the border is excellent, a formal agreement between the two countries could facilitate further cooperation, for example, the sharing of resources during times of crisis. The expiry of the 1985 agreement offers an opportunity for a full review and for particular adaptations for special problem areas such as the Red River basin.

Communication within the flood forecasting sector is critical to producing accurate flood forecasts. An international flood forecasting committee has been operating successfully in the Souris River basin for several years.

Communication may be difficult within organizations. A number of U.S. federal agencies' regional operations are based on state boundaries. Federal Regions Five and Eight are divided by the Red River. That presents problems with communications, consistency and overall coordination.

13. Recommendation : Pursue an agreement between the United States and Canada to enable comprehensive civil emergency planning and management that takes into account current trade agreements between the two countries, and in particular, allows for the cross-border transfer of supplies, equipment, contracting services and labor in the event of an emergency. The agreement should look into the possibility of developing regionally specific arrangements, including state–provincial protocols.

14. Recommendation : North Dakota and Minnesota should review emergency measure agreements in the light of the experience of the 1997 flood.

15. Recommendation : A basin-wide flood forecasting committee patterned on the Souris River Flood Forecasting Liaison Committee should be established for the Red River basin.

16. Recommendation : In the U.S., where regional operations of federal agencies are divided by the Red River, a lead region should be appointed for emergency operations when a flood is forecast.

Flood Emergency Plans

Emergency plans in all communities in the basin are fundamental to effective flood preparation, response and recovery. These plans should be reviewed annually and adjusted in light of past experience and the lessons learned from other communities. Where innovations have proven effective, they should form part of the revised plan.

17. Recommendation : All flood emergency plans within the basin should be reviewed in the light of the lessons learned during the 1997 flood to prepare more effectively for the next event.

18. Recommendation : Each jurisdiction with responsibilities for evacuation within the basin should establish an evacuation protocol within its emergency operation plan. Particular attention should be given to the clarity and public dissemination of the protocols to help prevent confusion at the time of evacuation. Evacuation plans affect different parts of the population in different ways, and plans should take into consideration the specific requirements of vulnerable groups, such as nursing home residents.

Emergency Communications

19. Recommendation : Establish sufficient information centers prior to and during a flood event, through 1-800 hot lines or other well-publicized toll-free telephone numbers, to provide critical information to residents of the flooded area before, during and after the event. Enhance the opportunities for Internet access, particularly for small communities and rural areas.

Human Impacts

The enormous impact of a flood such as that of 1997 on the lives of people in the basin is not always fully understood. Steps should be taken to ensure support is available to affected families and individuals. Among those groups affected by the trauma of flood fighting and evacuation are the children of the valley. Young people need to understand the nature of floods, contingency measures and the actions that are being taken to ensure their safety and well-being.

20. Recommendation : Trauma teams, emergency-response teams and personal decision-management teams should be maintained until the current demand for services subsides.

21. Recommendation : In future times of crisis, such support teams should be established early and begin work as soon as possible.

22. Recommendation : Information about flooding and the measures in place in case of flooding in the Red River valley should be introduced into the school curriculum throughout the basin, and in particular, in the communities most at risk.

Canadian Forces

The Canadian Armed Forces are an important source of emergency support during a flood, as demonstrated by their participation in the 1997 flood.

23. Recommendation : Earlier notice should be given to the Canadian Forces of their potential involvement in flood fighting in order to allow them additional preparation time.

24. Recommendation : Canadian military and civil authorities should reach a common understanding of the types of assistance available, particularly in terms of aid to local law-enforcement authorities.

Technical Improvements

Modeling

Hydrologic and hydraulic models play a key role in flood preparedness, response and mitigation. They are also important for land-use planning and design decisions. During the 1997 flood it became evident that improvements to existing hydrologic and hydraulic models are required in order to help protect basin residents from future extreme events and to improve floodplain management. In particular, the ability to deal with overland flow must be enhanced. Such improvements involve data acquisition, modeling and research. In order to meet these objectives, certain initial steps are critical.

A solid information base underpins good forecasts and models. A key recommendation of the Task Force workshop on hydrologic and hydraulic modeling was the need for implementation of a common Canada–United States Red River database. Information on high-water marks, the extent of inundation, identification of overland flows, estimated amounts of flow and other critical elements is available in a number of different forms and through different agencies. An effort is required to gather this information and to identify and store additional needed information.

25. Recommendation : Develop hydraulic models for the Red River and its major tributaries, capable of being expanded for use in forecasting and analyzing overland flooding, as well as for floodplain management.

26. Recommendation : Document the 1997 overland flow areas within the basin, high-water marks and head losses, wind effects, timing and extent of road or dike breaches and blow-outs, and data networks used during the flood. In addition, document the shape, elevation and alignment of roads, dikes, levees and drains, including the size of bridge and roadway openings.

27. Recommendation : Develop a consolidated database containing hydrometric, climatic, topographical and other technical data within the basin needed to improve forecasting and modeling capability.

The Hydrometric Gaging System

To forecast flood flow and understand flood routing, it is necessary to have adequate and accurate hydrometric information. An important part of this information is provided by gages located on the Red River and major tributaries. Some problems were experienced in 1997 when gages became inoperable after being overtopped, or the network was unable to provide sufficient information.

28. Recommendation : A high priority should be given to raising existing gages above the 1997 high-water level or replacing them.

29. Recommendation : Add to the current gaging system in the basin and, where needed, automate reporting to increase information for flood forecasters.

Airborne Gamma Surveys

Airborne gamma surveys are used to determine soil moisture levels, snow cover and water content along certain flight paths during the winter and spring. These surveys provide critical information which flood forecasters use to formulate their runoff predictions. At present, the U.S. National Weather Service flies these surveys in Canada under contract with Manitoba. The density of the survey network and the frequency of the survey flights in Manitoba are considerably less than those in the United States.

30. Recommendation : Depending on the flood outlook, the frequency of airborne gamma snow survey flights over the Manitoba portion of the Red River valley should be increased. Increasing the density of the network by adding more flight paths should also be considered.

Doppler Radar

Identifying and tracking storm systems, especially during the spring runoff, is a critical element in predicting floods. Environment Canada is currently upgrading the weather radar system in Canada by installing a number of Doppler radar sites. Winnipeg has been identified as a future site.

31. Recommendation : In view of the critical need for accurate flood forecasting in the Red River valley, Environment Canada should identify Winnipeg as the highest priority location for the new radar installation.

Ice Management

Many methods of dealing with ice jams have been tried over the years. In 1997, sand was spread on sections of river ice adjacent to bridges in the United States to reduce ice jams. North of Winnipeg, volunteers drilled 45,000 holes in the Red River ice in 1997 to weaken it prior to breakup. No ice jams occurred at that point. Holes drilled in Lake Manitoba ice at the mouth of the Portage Diversion appear not to have prevented an ice jam in that area.

32. Recommendation : Innovative methods of reducing ice jams should be reviewed and expert advice sought on how ice jams may be diminished. This subject should be explored at a workshop on ice control held in the winter of 1998 and attended by international experts and basin officials. The adverse and beneficial effects of ice management on flooding and the environment need to be carefully considered.

Flood Information Archives

Considerable technical data and records of individuals and agencies involved in flood response and recovery phases are in danger of being lost or remaining inaccessible to people and agencies who could benefit from the information.

33. Recommendation : Information available to individuals, government and non-government organizations and others who contributed to the flood-fighting effort in 1997 should be gathered and made available at a central basin-wide archive or archives in each country.

Environmental Concerns

Hazardous Products

A variety of hazardous products found their way into the floodwaters during the flood of 1997. Excellent cooperation from such industrial groups as bulk petroleum and farm chemical associations played a key role in removing much of the material from the floodplain or protecting it on-site before the flood. Communications regarding hazardous materials such as heating and farm fuels, agricultural chemicals and other products were not as effective with individual farm owners and residents.

34. Recommendation : Liaison among governments and industry associations throughout the basin should be encouraged and strengthened. Communications should be extended to other businesses, individual home-owners and farmers.

35. Recommendation : The development of a broad public awareness program within the Red River floodplain should be started to encourage home-owners and farm operators to collect and properly dispose of all waste products that present a contamination hazard. There should also be an immediate and concerted effort to remove or secure hazardous materials stored in the floodplain.

36. Recommendation : An inventory of all major potential sources of contamination should be developed and maintained, to include location, elevation, type of material, and amount. This inventory should extend to the agriculture industry and include intensive livestock operations.

37. Recommendation : A review of legislation on the management of hazardous materials should be conducted throughout the basin.

Groundwater Contamination

Groundwater was contaminated when floodwater entered aquifers through active and abandoned wells.

38. Recommendation : Conduct an inventory of all abandoned and active groundwater wells throughout the basin and institute an aggressive program of properly sealing abandoned wells and flood-proofing active wells against floodwater contamination from the surface.

Levee/Dike Design

New levees and dikes, particularly when they are set well back from the river, provide opportunities for environmentally beneficial uses of the floodplain.

39. Recommendation : The natural and beneficial functions of the floodplain must be considered in the design of new levees.

Interbasin Hydraulic Connection

Interbasin transfer of water between the Red River and Mississippi River basins at Lake Traverse–Big Stone Lake is a concern due to the potential for the exchange of non-native biota. This issue is complex and requires longer-term examination.

40. Recommendation : Reasonable measures should be implemented, consistent with current operating plans, to prevent (if possible), the movement of water between the Red River and Mississippi River basins at Lake Traverse–Big Stone Lake.

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The flood of 1997 in the Red River valley was a major event in the lives of the people of the valley and a major challenge for the governments that serve them. The governments of Canada and the United States recognized the severity of the event and tasked the IJC to undertake an analysis of its causes and effects, and to recommend means to reduce the impact of future floods. The request was urgent: the IJC was to provide an interim report by the end of 1997 and a final report by the end of 1998.

The Task Force recognizes that the Interim Report, given the short time available to consult with people in the valley and to investigate the issues, is only a partial response. Much more work is needed to respond to the issues that the governments have raised. Nevertheless, the Task Force appreciates the governments' need to enter the coming flood season having reflected on what can be learned from the 1997 experience. The Task Force believes that the preliminary observations and recommendations it is putting forward in this report provide the starting point governments seek.

The flood of 1997 produced some remarkable achievements by the people facing inundation, and the volunteers and government staff who responded to the emergency. Events of this nature test our preparations and offer some lessons on how to do better the next time. For the most part, those people who know how to do better are in the basin. The Task Force believes there is a need to link and pool expertise within the basin so that people and organizations can profit from the experience of others. Another Task Force theme is the need to provide a more integrated approach to dealing with a common threat. History and institutional structures vary across the basin, and there is no single model of how to organize, what tools to develop or what actions to take. But the differences are not great enough to preclude the need to learn from each other or to initiate actions that lead to more effective trans-jurisdictional responses.

The Task Force could not achieve a full understanding of the issues in the few months since it was created. Those issues are complex and relate to flood preparation, response, recovery and mitigation. This report is primarily directed at immediate measures to be taken; the major consultative and investigative work will be undertaken in 1998.

The final report will provide a more in-depth, longer-term response to flooding in the Red River Basin. However, the themes and recommendations that have emerged from this report will provide the direction as the work continues. The Task Force will not attempt to provide a comprehensive basin-wide water management plan. Recognizing the binational and jurisdictionally complex nature of the basin, the Task Force seeks to provide direction on how the people and organizations there can learn from each other, work together on common problems and avoid conflict.

Appendix: Draft Plan of Study

Introduction

The purpose of this draft plan of study is to briefly describe studies that will be undertaken by the International Red River Basin Task Force to support preparation of its final report on problems related to flooding of the Red River in Minnesota, North Dakota, and Manitoba. The Interim Report of the International Red River Basin Task Force: Red River Flooding—Short Term Measures provides considerable detail about the Red River, its physical characteristics, historical flood problems, and the devastating flood of 1997.

The plan of study is a work in progress. After further consideration, it will describe precisely the research that will be undertaken and will include level of detail, procedures, coordination requirements, cost, schedule, and so on. Its elaboration also requires substantial input and coordination with various public officials, agencies, and other groups in Canada and the United States. It especially requires consultation with the public at large and with many individuals who are vitally interested in flooding in the Red River basin. Following public consultations in February 1998, a more detailed version of the plan of study will be completed and intensive studies will begin. However, the Task Force fully recognizes that this is an exploratory effort and that new data, emerging technology, early results of studies, coordination during the research period, changing needs and priorities, and a host of other causes will dictate that the plan of study be continually reviewed and revised.

Objectives

The basic objectives of the Task Force and the plan of study are contained in the June 1997 reference to the IJC from the governments of Canada and the United States, and the subsequent instructions from the IJC to the Task Force. That is, the work of the Task Force will be directed at examining and making recommendations that will provide improved flood preparedness, response, recovery, and mitigation. Included are measures or activities that will facilitate international cooperation and an integrated, basin-wide approach to flood management. Implicit in the Task Force's approach is consideration of policies and procedures, structural and non-structural measures, environmental problems and opportunities, economic growth, and social well-being.

It is important to understand what the draft plan of study will and will not attempt to accomplish. The draft plan is directed at a single aspect of water management—flooding (specifically the flood of 1997)—and what might be recommended to prevent or reduce damages during future floods. The investigations identified in the plan are not intended to result in a comprehensive basin-wide management plan; nor are they directed at identifying, designing or recommending site-specific projects. The intention is to contribute to the effort by federal, state, provincial and local agencies for more effective floodplain management.

The principal thrust of the investigation will be to provide insights and advice for decision-makers on what should be accomplished to significantly reduce or prevent such devastation as occurred during the 1997 flood. The investigations will provide useful data and tools for those who plan, design, and implement flood-reduction policies, programs and projects. These data and tools will also provide those with operational responsibilities a much greater ability to forecast flood events and to efficiently safeguard lives and property.

The investigations will also address the need for and benefits of more collaborative and integrated problem-solving mechanisms in the Red River basin. Because of these studies and the resulting data and tools, it is expected that coordination and cooperation throughout the entire basin will be enhanced. The Task Force will strive to encourage and facilitate establishment of processes and organizational structures that will ensure the work of resolving the difficult flooding problems in the basin continues long after the Task Force has finished its assignment.

In summary, the Task Force has defined specific objectives for its investigations as:

- develop and recommend a range of alternatives to prevent or reduce future flood damages
- improve tools for planning and decision-making
- facilitate integrated flood emergency management in the basin

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Study Area

The 45,000-square-mile Red River basin slopes northward from the U.S. Great Plains to Lake Winnipeg. The basin, illustrated in Figure 1 , includes portions of South Dakota, North Dakota, Minnesota, and Manitoba.

The primary focus for the plan of study will be the Red River and its major tributaries. Of particular importance are those areas of the basin flooded in 1997. Excluded from the study area are the Assiniboine River, a tributary that joins the Red River in Winnipeg and the Devils Lake basin, a closed sub-basin of the Red River basin.

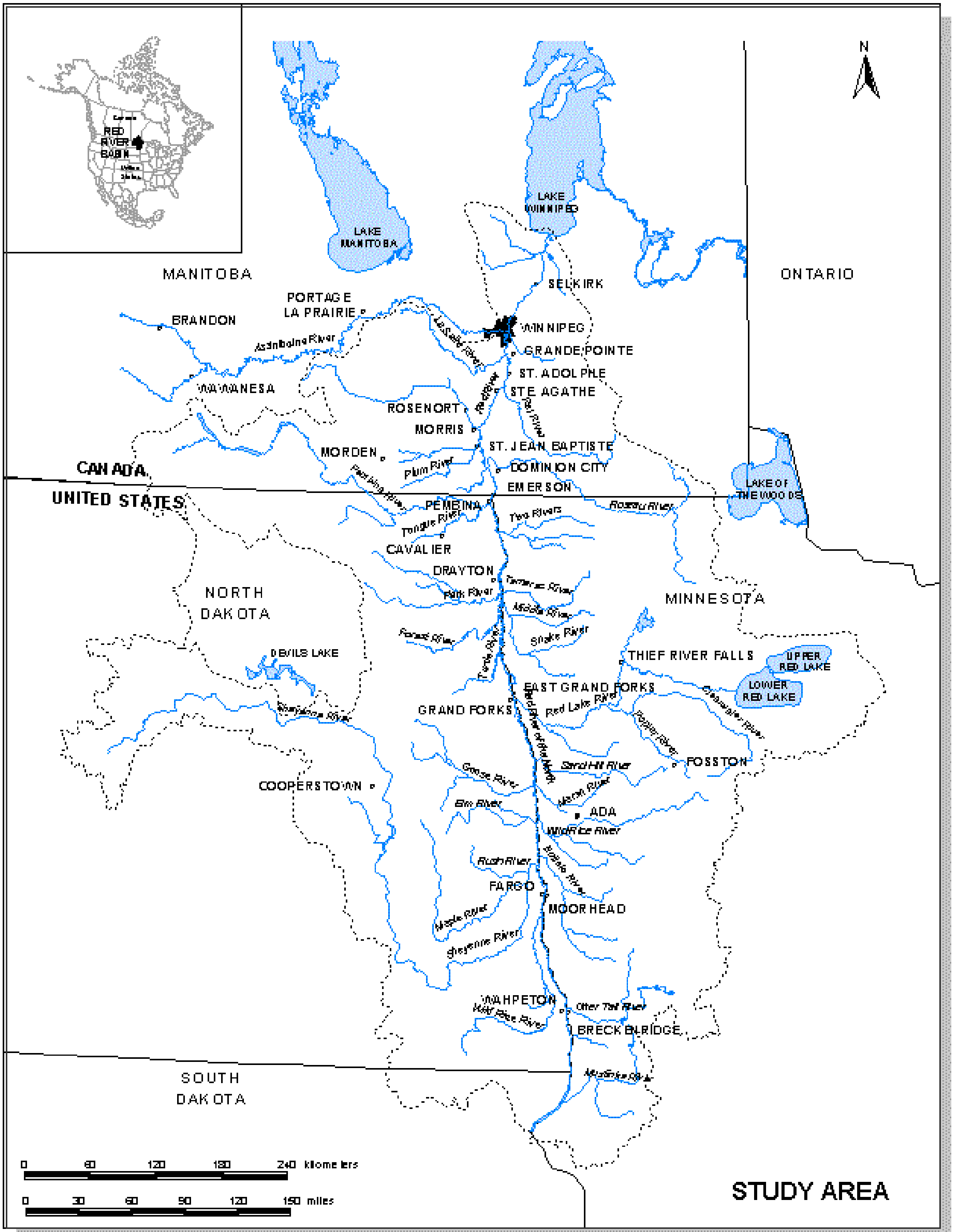


Figure 1: Red River Basin Study Area

Organization

The International Red River Basin Task Force will manage the research. It will define required studies, coordinate the funding and scheduling, provide oversight of subgroups, synthesize the findings, and prepare the recommendations for the final report to the IJC. The Task Force will establish three subgroups—Database, Tools, and Strategies—to conduct or direct much of the data collection, model development, program evaluation, and prepare preliminary recommendations. The study management structure is shown in Figure 2 .

Figure 2: Study Organization Flowchart

Each subgroup will include subject matter experts from the United States and Canada. The teams will develop procedures for accomplishing their assigned work within the budget and time constraints of the study. Each will submit to the Task Force for approval a proposed budget, schedule, and description of deliverables. The work will be accomplished directly by subgroup members or through contracts and work agreements with consultants, institutions, and agencies. The Task Force will synthesize and coordinate the work of the three subgroups.

Design

The concept for implementing the plan of study is shown in Figure 3 . A coordinated database is fundamental to success, as it supports the development of both models and flood damage reduction strategies. Each of these is a key element in the decision-support system.

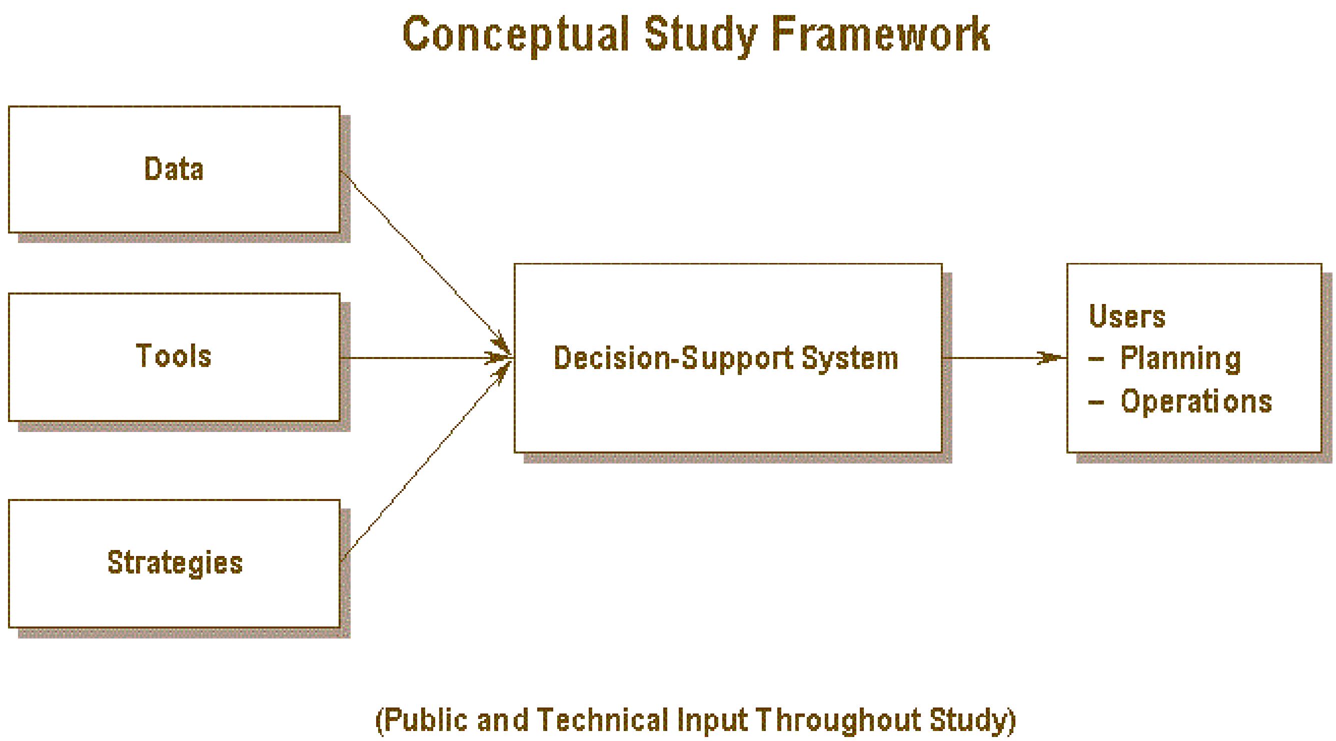


Figure 3: Conceptual Study Framework

The Task Force's final report will draw together the findings of the subgroups and recommend actions relating to policy, operations, and research issues. The IJC will use the final report as the basis for hearings in the basin prior to the submission of its report to governments.

Database

Data about the Red River basin exist in many forms and are not always widely available. The database subgroup will take the lead in assembling data from paper records, from other electronic databases, and from their own investigations. They will evaluate existing forecasting data networks in both countries and seek means of improving the data used in support of forecasting operations. The intent is to ensure that all data (topographic, land use, hydrologic, hydraulic, environmental, and economic) are accessible to all users in order to provide support for all floodplain management activities.

Database Structure

The database will consist of point and spatial data, both current and historical. The data must be organized to meet study needs and be coded in space and in time. The anticipated end result is a distributed digital database with various agencies assuming the responsibility for continuing, maintaining and updating it, since the Task Force cannot maintain a long-term database. This structure requires that 'meta data' (data regarding data) be made widely available.

Data Transfer

Data must be converted to established formats to facilitate transfer among users. The ready availability of Internet service makes data transfer by that method the most feasible for study purposes. Large files can be transferred by providing electronic, possibly Internet, access. A subset of data transfer is the transmission of data from the field sites to forecast centers in real time and the transfer of forecast information to emergency workers.

Geographic Information Systems

Geographic Information Systems (GIS) provide a means of carrying out spatial analysis of data. Image products used include terrestrial and aerial photographs, passive and active microwave satellite images, visible and infrared images. Once geo-coded, these images will be combined with point data and analyzed using standard software packages.

Tools

Improved management of the floodplain calls for more coordinated and integrated decision-making, using in part models and other decision-support tools. Hydrologic, hydraulic, economic, and environmental models will be needed to support improved decision making in the basin. It is anticipated that model development will form a major part of this study.

Hydrologic Models

Hydrologic models combine precipitation and other inputs to forecast runoff in a river system. This component will describe the present state of flood forecasting in the basin and recommend measures for improvement. The subgroup on tools will review the adequacy of data networks that support the current forecasts, examine modeling options. and examine the state of science of current remote-sensing products and their incorporation into forecast models. The long-term hydro-meteorological databases will be examined and standard tests carried out to verify the data. Current knowledge of climate variability will be applied to the Red River basin to determine potential effects on flooding.

Hydraulic Models

Hydraulic models take the runoff provided by hydrologic models and simulate water surface elevations and velocities in a river system. Models of the Red River basin have potential as an effective aid in real-time flood-fighting efforts, especially if coupled to decision-support systems incorporating geographic information. Hydraulic models are also necessary to evaluate the cumulative effects of works such as levees, bridge and culvert changes, and road construction. Models will be designed so that trained staff using generally available computer hardware can operate them.

Many structural and non-structural measures were put into effect prior to the 1997 flood and a number of temporary levees were constructed during the flood. Some temporary works could provide cost-effective flood damage reduction if they were made permanent. Hydraulic models can be used to evaluate specific structural options.

Economic Models

The subgroup will review and recommend economic evaluation tools that help decision-makers compare the flood-related economic factors of alternative means of reducing flood damages.

Potential areas of investigation are:

- economic assessment of structural and non-structural measures
- incentives/disincentives facing individual activity in the floodplain
- efficiencies involved with data collection, modeling, and other research and operational aspects

Environmental Models

Environmental models such as spill response models and habitat evaluation models will play a role in evaluating the environmental consequences of flooding. Such models can assist in identifying environmentally hazardous or sensitive features of the basin. They can also contribute to resolving water management issues in the basin.

Decision-Support System

Decision-support systems require integration of products from data collection and modeling into an environment with relatively simple and transparent (but flexible) user interfaces. The spatial database and hydrologic and hydraulic tools are the foundation of the system. Eventually, forecast centers should have a decision-support system with direct connections to monitoring stations, other services that provide data in real time and all emergency management centers. Such systems can support emergency operations or can be used for planning purposes.

Flood Damage Reduction Strategies

Flood strategies will cover components of the emergency planning cycle such as preparedness, response, recovery, and flood damage reduction. The strategies will also address specific technical, environmental and social topics.

Preparedness

Past flooding in the Red River basin has led to floodplain mapping and zoning and to the development of a number of structural measures, notably the Red River Floodway around Winnipeg, levee construction in urban centers, and moving and raising of rural dwellings. Flood emergency plans have been developed and modified based on new information. This component will examine the level of preparedness needed for a flood of the magnitude of the one in 1997.

Flood-related programs and policies in the floodplain differ throughout the basin. Reviews of those management programs can help identify successful approaches and possible interjurisdictional issues. The Red River floodplain encompasses the economic heartland of Manitoba and North Dakota, including major population centers, industrial developments, and food production and processing sites. Portions of the floodplain in Minnesota and South Dakota are also important within the context of the basin. Floodplain management policies and programs in the basin are fundamental to safeguarding public and private investment, to reducing the cost of damaging floods, and to making decisions on new investments, including mitigation measures, in the floodplain. This component will review the policies and programs of the two countries, three states, one province and many local governments.

Emergency Response

This study component addresses possible improvement in emergency response based on lessons learned in the 1997 event. There is a need to define procedures by which flood emergencies are managed in each of the jurisdictions and to describe the local, state, provincial and federal roles. There is currently a fairly high level of U.S.–Canada cooperation on flood emergencies, but the scope for further collaboration will be pursued. In particular, opportunities will be examined to make more use of the Canada–United States Agreement on Cooperation in Comprehensive Civil Emergency Planning and Management.

Recovery

Thousands of people were evacuated during the 1997 flood and many businesses were shut down for significant periods of time. Many agricultural producers were directly affected. Recovery was assisted by existing and new government programs and by charitable organizations. This study component will examine the effectiveness of recovery programs available to specific sectors of the basin’s economy.

Damage Reduction

This study component will investigate possible actions to eliminate or reduce long-term risk to human life and property due to flooding. It will review the need for changes to existing structural and non-structural measures. Also, it could examine required design changes to various types of temporary works and determine the benefits of making these permanent.

Watershed Land Use

The Red River basin has been profoundly altered by human activity. Roads, drains, small dams, and farm dugouts have been constructed and wetlands drained. Vegetation cover has been altered by agricultural development. The cumulative effect of all these land use changes is uncertain, but there are local and possibly regional effects on timing, magnitude, and volume of peak flows. Work on this component will lead to increased understanding of the impacts of land use on runoff in the Red River basin.

Ice Management

Ice jams are a factor in flooding on some tributaries of the Red River and at a few locations on the main stem. A number of means have been proposed to mitigate the effects of ice-jam flooding and some concerns have been expressed concerning the downstream consequences of such measures. This study component will describe the hydro-meteorological conditions that have or could lead to ice-jam flooding and determine feasible ice management practices.

Environmental and Habitat Considerations

Flooding can have long-term positive or negative consequences to the natural and built environment, resulting in effects to human and ecosystem health. Data will be assembled and studies may be conducted to examine more fully environment impacts of the 1997 flood, including impacts on Lake Winnipeg. Areas of potential assessment include:

- the impact of contaminants on the ecosystem,
- environmentally hazardous or sensitive features of the basin,
- critical aquatic life and wildlife habitat vulnerable to damage from flooding,
- options to protect better the basin from contaminants during future floods,
- options to protect critical habitat, and
- conversion of marginal agricultural lands.

During implementation of flood damage reduction measures in the basin, jurisdictions will be encouraged to explore fully opportunities to restore or enhance the existing environment.

Health and Social Concerns

Severe flooding can lead to social disruption and human health consequences ranging from accident or injury during flood fighting, to chronic exposure to molds in improperly decontaminated houses, and to stress-related ailments. Human health can also be affected by some environmental changes brought on by the flood, for example contamination of groundwater wells.

Other Issues

In early phases of this study several international issues were identified. Resolving these issues would enhance the opportunity to reach consensus on water management plans. This study component will address issues brought to the Task Force's attention and seek a means for resolution. Many complex water management issues may be difficult to resolve; at a minimum, the Task Force may be able to provide an information base and models that would assist in addressing a specific problem. Areas of concern identified thus far include:

- Pembina River flooding
- cross-drainage between the Red River basin and the Mississippi River basin at Lake Traverse–Big Stone Lake
- water retention opportunities
- water quality effects of flooding on Lake Winnipeg

Public Involvement

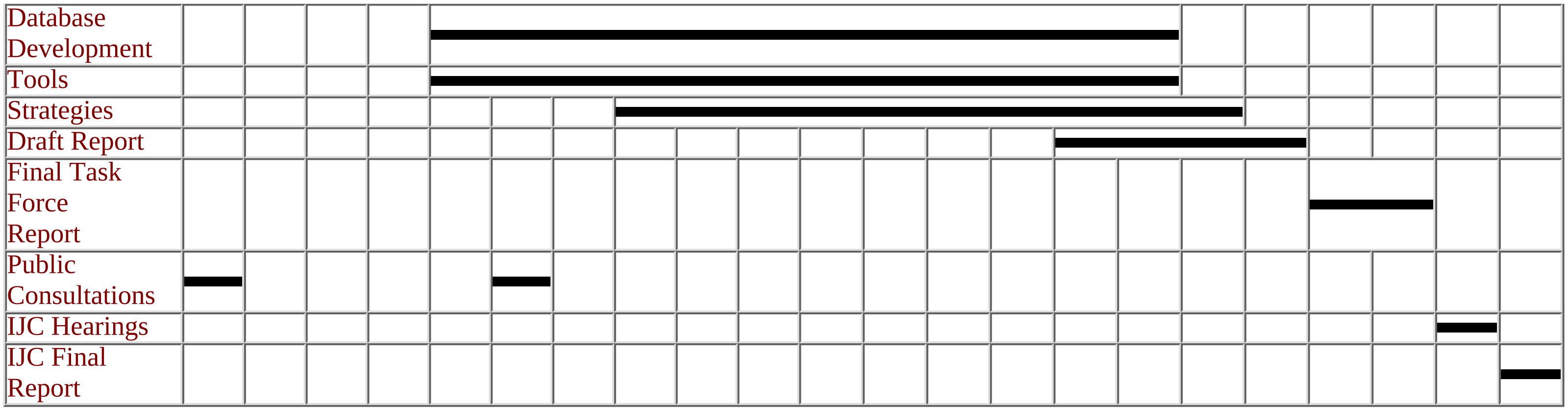
Public participation is an important part of the process. The IJC and the Task Force will conduct a series of public meetings throughout the basin in February 1998, following the distribution of the Interim Report. The findings from these meetings will be incorporated into the study plan. Efforts will be made to keep people in the basin informed throughout the study using the Internet, news releases, and other means of contact. A detailed public involvement plan will be included in the final plan of study.

Study Schedule and Funding

The Task Force will plan its work so that a final report to the IJC is made in April, 1999. The funding provided to conduct the work is US$5 million. The proposed schedule and funding are shown in Figure 4 .

Study Schedule

	1997				1998												1999					
	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Interim Report / Plan of Study																						



Funding
(Expressed in US$)

Canada	
September 1997	400,000
April 1998	2,400,000
Total	**2,800,000**
United States	
September 1997	100,000
January 1998	1,000,000
October 1998	1,400,000
Total	**2,500,000**
Study Total	**5,300,000**

Note: conversion rate to C$ is $1.40

Figure 4: Study Schedule and Funding

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