A Summary of Flood Issues on the Lower Pembina River, North Dakota

Prepared for:
The International Joint Commission
International Red River Basin Task Force
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Executive Summary

The Pembina River Basin straddles the Manitoba/North Dakota boundary along its entire length from the Turtle Mountain south of Boissevain, Manitoba to its confluence with the Red River near the town of Pembina, North Dakota. Because of the extremely flat topography of the lower portion of the basin from Walhalla, North Dakota to the Red River, flooding is a common occurrence. Once out of the river channel, flood waters flow overland south toward the Tongue River watershed, and north toward the International Boundary and Manitoba.

Since the 1940s, many unilateral actions have been taken to control the extent of overland flooding. Farmers along the river in the Neche area have constructed levees in an effort to contain the river. While it has been somewhat successful, this action has changed the natural flow patterns in the area. In response, Manitoba farmers and municipalities have constructed a road/dike along the International Boundary to restrict the amount of overland flow entering Manitoba. The road/dike in particular, and its impact on flooding south of the Boundary, has been a major point of international disagreement for years.

Since the 1960s, a number of studies have been conducted in search of an engineering solution to the flooding problem in the Lower Pembina River Basin. Most notable among these were studies by the International Joint Commission in 1967 and studies by the United States Army Corps of Engineers in 1976 and 1983. These studies focused on construction of flood control reservoirs upstream of Walhalla, North Dakota, options for diversion floodways from the Neche/Walhalla area to the Red River, and various combinations of reservoirs and floodways. None of the proposed projects has been implemented. Some have proven to be economically unfeasible, and others did not receive the necessary local support.

With the support of the International Joint Commission's International Red River Basin Task Force, a number of initiatives have been implemented that will provide local people and governments with new data and tools to assist them in making informed decisions regarding a solution to the flooding problem in the area.

A Digital Elevation Model (DEM) is being developed to provide accurate topographic data necessary for floodplain definition and management. In conjunction with this, a flood frequency analysis has been conducted to confirm the magnitude of a 100-year flood and the probable maximum flood for the area.

A computerized hydraulic model capable of forecasting overland flows has been prepared and tested for the lower Pembina River. The model has revealed that under natural conditions, overland flows of flood waters from the Pembina River would be a great deal different than they are under existing conditions. This model may also be used in determining the potential impacts of constructing new dikes or reservoirs.

A decision support system is being implemented to provide local people and governments a virtual database for the Red River Valley, including the lower Pembina Basin. A prototype for the Pembina basin is the early stages of development. It will focus on flood forecasting tools, flood preparedness tools, emergency management tools and economic tools to investigate possible modifications to flood control systems.

A number of grass roots organizations are poised to take responsibility for water management and flood control in the Pembina River Basin. Among these is the Pembina River Basin Advisory Board, an organization comprised of representatives of local governments and water management groups from both sides of the border as well as representatives of state and provincial governments. With the assistance being provided by the International Red River Basin Task Force and others, a local solution to the flooding problem and related issues in the Lower Pembina River Basin is nearer than it has been for decades.

1.0 Introduction

1.1 Geography of the Pembina River Basin

The Pembina River rises in Manitoba along the northeastern slope of Turtle Mountain, about 10 miles (16 km) south of the town of Boissevain, Manitoba. Turtle Mountain straddles the U.S. - Canada boundary between Boissevain and Bottineau, North Dakota. From there the river flows in a generally easterly direction crossing the International Boundary near Maida, ND and Windygates, MB and continuing its eastward flow until it empties into the Red River at Pembina, North Dakota, about two miles (3 km) south the International Boundary.

The total area of the watershed is about 3,950 square miles (10,230 square kilometres), divided nearly equally between Manitoba and North Dakota. The length of the Pembina River basin from west to east is about 130 miles (210 km) as the crow flies, although the winding river channel itself is about 310 miles (500 km) long. The river drops from about 2,000 feet (610 m) above sea level (asl) at its source on the Turtle Mountain to about 790 feet (240 m) asl at its confluence with the Red River.

There are two distinct topographical types in the watershed separated by a prominent ridge known as the Pembina Escarpment. Within the study area, the escarpment extends in a line from just west of Morden, Manitoba across the International Boundary continuing southeastward past a point immediately west of the town of Walhalla, North Dakota. Relief along the escarpment in the Walhalla area rises abruptly 500 to 600 feet (152 to 183 m) above the plain below to an altitude of about 1,500 feet (457 m) asl at its crest.

During the most recent Ice Age and until about until 12,000 years ago, the entire watershed was covered by a continental glacier. As the glacier melted and receded to the north, a huge lake of meltwater - glacial Lake Agassiz - formed along the glacier's leading edge, covering the Red River Valley. The Pembina Escarpment formed the western margin of Lake Agassiz. Evidence of beaches created during this period are still recognizable today.

Over several hundred years, rich layers of silts and clays up to 200 feet (61 m) thick accumulated on the lake bed. When the lake finally receded, an extremely flat, smooth plain emerged.

The area west of the escarpment is an undulating glacial moraine upland of potholes, ridges and knolls. Surface soils are relatively shallow and characteristic of glacial till.

The entire Manitoba portion of the Pembina River watershed lies above the Pembina Escarpment. The river leaves the Turtle Mountain, flowing northeastward through an increasingly deep valley until it reaches the eastern end of Pelican Lake. From this point eastward, the river flows through a broad valley — the remnant of a massive glacial meltwater channel formed as the continental glacier receded. In places, the valley is 200 feet (61 m) deep and two miles (3 km) wide.

Several streams and deep coulees entering the valley along this reach of the river have deposited sediments along the valley bottom, creating natural dams behind which several lakes have formed, including Pelican, Rock and Swan lakes, as well as some smaller water bodies. Downstream from Swan Lake, the river turns to the southeast, occupying an ever-deepening channel (as much as 400 feet [122 m) deep and a mile (1.6 km) or more wide) until it crosses the International Boundary about 15 miles (24 km) northwest of Walhalla, North Dakota, near the community of Maida.

Near Walhalla, the river emerges from the uplands and onto the former Lake Agassiz lakebed. Over the next 15 miles (24 km) downstream from the escarpment, the valley gradually disappears. From a point near Leroy, North Dakota to its confluence with the Red River at the city of Pembina - a distance of approximately 20 miles (32 km) - the river is at the same level as the surrounding plain, or slightly higher,

confined by natural levees built up over centuries of flooding, or by man-made levees constructed in an attempt to control flooding.

The only major tributary of the Pembina lying wholly within North Dakota is the Tongue River, which joins the Pembina a few miles upstream of its junction with the Red River. Several streams rise in North Dakota and flow northward to join the Pembina River within Manitoba. Those of significance include - from west to east - Badger Creek, Long River, Snowflake Creek, Mobray Creek and the Little Pembina River. A number of smaller tributaries lie entirely within Manitoba including Crystal, Pilot and Mary Jane creeks. The Little North Pembina River flows from Manitoba southward to join the Pembina a few miles west of Walhalla, North Dakota.

The climate of the basin is characterized by wide variations in temperatures and precipitation. Average monthly temperatures range from 68^0 F in July to 2^0 F in January. However, extremes of 112^0 F and -54^0 F have been recorded.

Average annual precipitation is about 20 inches (500 mm), one-fifth of which falls as snow. Heavy summer rains are not uncommon, although they are generally localized and occasionally result in short-term flooding on smaller tributaries. The heaviest 24-hour rainfall recorded in the basin is 8.76 inches (222 mm) at Boissevain in August, 1957.

1.2 Settlement History

The first European settlers came to the area in 1812, when the Selkirk Settlers from Scotland and Ireland established a colony near present-day Winnipeg. A segment of this group traveled south and established a smaller outpost near Pembina, North Dakota.

However, settlement did not begin in earnest until the early 1870s with the advent of steamboat traffic on the Red River from the south. With the completion of railroads on both sides of the border in the 1880s, the influx of settlers increased dramatically. By the turn of the century, most of the arable land in the valley had been homesteaded and agriculture developed rapidly.

The current population of the basin is about 65,000, with about 40,000 in Manitoba and 25,000 in North Dakota. The major towns in Manitoba include Killarney, Pilot Mound, Swan Lake, La Riviere and Manitou, as well as a number of smaller centres. In North Dakota, Walhalla, Langdon, Cavalier, Pembina and Neche are the most significant communities.

1.3 Land Use

The most valuable resource of the basin is its fertile soil, particularly within the Red River Valley portion of the watershed. Because of the combination of the soils and a favourable climate, agricultural land in this area is considered among the best on the continent. As a result, the economy of the basin is dominated by agriculture and associated product processing and service industries.

Land use above the escarpment consists mainly of grain farming and mixed farming interspersed with pasture, forage production, wetlands and wooded valley slopes. The variety of landscape, and in particular the Pembina River valley itself, provides excellent habitat for a wide variety of wildlife such as white-tailed deer, grouse and waterfowl. The lakes along the valley in Manitoba provide water-based recreation and angling opportunities for local residents and visitors alike. A ski resort on the Pembina River at La Riviere is a popular winter destination for down-hill skiing enthusiasts from the surrounding area and Winnipeg. A ski facility has also been recently developed west of Walhalla.

Below the escarpment, land use is almost entirely a continuous-cropping agricultural monoculture. Major crops include wheat and other grains, oilseeds, corn, sugar beets and potatoes. Much of the land in this area owes its productivity to an extensive agricultural drainage network which has claimed land from marshes

and bogs over the course of time. Drainage activities continue today, although generally on a more local scale.

1.4 Water Management

1.4.1 Flood History

Floods are a natural and common occurrence along the entire length of the Pembina River. But of the 310 miles (500 km) of river channel, the most significant and devastating flooding occurs along the 35-mile (57 km) reach between the Pembina Escarpment at Walhalla and the Red River. This area is highly susceptible to flooding because of the extremely flat terrain. All of the significant floods in this reach of the river have occurred in the spring as a result of snowmelt or heavy rain either combined with, or immediately following, snowmelt. Runoff in the lower basin exhibits a characteristic double peak on account of the delayed arrival of upper basin runoff.

According to recent computer modeling conducted for the International Joint Commission, the natural capacity of the Pembina River downstream from Walhalla varies from approximately 4,300 to 5,700 cubic feet per second (cfs) (122 to 161 cubic metres per second [cms]), although diking activities over the years has raised the capacity to as much as 6,400 cfs (181 cms). Because of peak attenuation and the loss to overland flow during floods, recorded peak flows on the main channel at Neche are generally lower than at Walhalla.

Since the river in the vicinity of Neche is at, or slightly above, the elevation of the land around it, flood flows breaking out of the main stem of the Pembina River under natural conditions move away from the river and overland into the Tongue River watershed to the south, or eastward to the Red. Natural levees built up along the river channel over centuries of flooding impede the return of flood water to the channel.

Because of the well defined channel and associated valley, floods above the escarpment are generally limited to the valley floor. Localized flooding may also occur along the tributaries to the Pembina as a result of rapid snowmelt or heavy spring or summer rains.

Historic accounts mention major floods in 1882, 1897, 1904 and 1916. Since 1940, several other significant floods have occurred on the Pembina River downstream of the escarpment including those of 1950, 1974, 1979, 1996 and 1997. Until the Flood of Century (1997 - 14,300 cfs [405 cms]), the 1950 flood was the largest on record at 10,700 cfs (303 cms). Based on statistical analysis of the flood peaks, the 100-year flood is considered to be 18,000 cfs (510 cms).

Table 1: Major floods on the Pembina since 1950

Date	peak flow at Neche
Apr 27, 1997	14,300 cfs*
Apr 20, 1950	10,700
Apr 28, 1974	10,300
Apr 20, 1970	9,600
Apr 20, 1979	9,500
Apr 23, 1995	8,500
Apr 16, 1998	7,620
Apr 18, 1996	7,500
Apr 21, 1969	7,360
Apr 12, 1971	7,350
Apr 27, 1970	7,070

Source: United States Geological Survey
** one cubic foot per second (cfs) is equal to 0.0283 cubic metres per second (cms)*

Flood damages result from direct economic losses such as damage to buildings and infrastructure, flood fighting costs, and so on. In addition, many intangibles may be considered as indirect costs, such the threat to human life, human misery, community disruption and threats to the quality of water supplies.

Agriculture may suffer losses in two ways, through flood damage to buildings, losses of stored grains and other products, and loss or damage to stored agriculture input products; and loss of valuable topsoil through erosion, sedimentation or salinization. In addition, crop seeding may be delayed (or lost altogether), generally resulting in later crop maturity and subsequent lower yields at harvest time. Crop management techniques following a flood may require additional inputs for weed control, or to compensate for fall-applied crop management inputs (fertilizers and herbicides) washed away or lost to the flood waters.

For more than 50 years, local farmers and governments, as well as provincial, state and federal governments on both sides of the border have been trying to solve the problems of flooding from the Pembina River. Efforts have ranged from local, unilateral efforts to some attempts at cooperation in fighting a common problem.

Unilateral flood control efforts on both sides of the Boundary have created tension between landowners on either side. Over time, local drainage and flood control activities undertaken in North Dakota have lead Canadian farmers to believe that American farmers were attempting to divert flood water into Canada. Canadian farmers are of the opinion that diking along the Pembina River in the Neche area has forced flood waters overland to the north, and that this condition would not exist under natural conditions.

In response, Canadian farmers constructed a road/dike along the International Boundary in an attempt to prevent this water from entering Canada. Culverts installed in the road/dike have only slightly more than the capacity required to convey normal agricultural drainage, and cannot handle the substantial overland flows when the Pembina spills over its banks. North Dakotans claim that flooding south of the International Boundary has been further aggravated because of the obstruction.

Discussions relating to the amount of water that will be allowed to pass along the various drainage ways crossing the International Boundary have been underway for more than 20 years. While some agreement has been reached on design flows into Canada from North Dakota at each crossing, the issue of sharing the costs of the necessary works has delayed progress. In addition, decisions on the amount of water that will be allowed to cross the border have been somewhat influenced by the general agreement that a major flood control project on the Pembina River is necessary to fully alleviate the problem.

A number of flood control projects identified by the International Joint Commission, the U.S. Army Corps of Engineers and other international and local groups have all been proven to be economically unfeasible or unacceptable to the local people.

1.4.2 The 1997 flood

In April and May of 1997, record flooding occurred on the Pembina and Red rivers.

The 1997 flood is the largest on record for the Lower Pembina River. The Pembina experienced a double peak, a common, if not normal, occurrence. On April 22, a flow of 12,800 cfs [362 cms]was recorded at Neche as runoff from the lower portion of the basin passed. After dropping to 10,000 cfs [283 cms], the peak rose again three days later, this time to the record 14,300 cfs [405 cms] on April 27, fed by runoff from upstream reaches of the river.

What was unusual (in addition to the size of the flood) was that the peaks on the Pembina and the Red coincided at their confluence. The peak runoff from local streams such as the Pembina is normally over by the time the peak on the Red River reaches the international boundary. The flows on the Red were in the order of ten times that of the Pembina. As a result, for a short distance from where it joins the Red River,

the Pembina reversed its flow until it joined the overland flow from the Red and moved northward west of Interstate 29 and across the international boundary and into Manitoba.

Above Neche, most of the flow was contained within the river channel and associated levees, and by portions of the road network that acted as dikes in the area. Below Neche, the river broke out of its banks and moved south and north. To the south, County Road 55 contained the flow and redirected the flood waters back toward the river further downstream. From there, the flows continued overland until they met with overland flows from the rampaging Red River.

To the north, floodwater moved overland until it met the road/dike at the international boundary. Floodwater accumulated there until it spilled over a small height of land, known locally as Switzer Ridge, and then moved east to meet up with overland flows from the Red.

The eastern portion of the road/dike, just west of the Red River, was overtopped and failed in two locations. The failure, however, was more likely the result of combined overland flooding from the Red River and the Pembina, rather than of the Pembina itself. Following the flood, Canadians repaired the road/dike.

1.4.3 Water Supply

Ironically, one of the main resource management issues in the lower Pembina Valley has been the lack of a reliable, quality water supply for municipal, industrial and agricultural use.

There is a concern that this lack of water has been presenting an impediment to industrial development in the region, particularly on the Manitoba side of the Border. In recent years, several Manitoba towns such as Winkler, Morden and Altona have been growing at an impressive rate, but while doing so, have been placing increasing demands on existing surface water sources and groundwater aquifers as well.

In the past, studies had been conducted in Manitoba examining the feasibility of a variety of water supply options including a dam and reservoir on the Pembina River and diverting water from the Assiniboine River or Lake Manitoba. None of these alternatives has proven to be economically feasible.

Until recently, Altona and Gretna received their water from a treatment plant at Neche, North Dakota, about eight miles south of Altona. When expensive upgrades became necessary in order to meet U.S. Environmental Protection Agency standards, the Manitoba towns chose to seek their own source of water and the Neche plant was closed. Neche now receives its water from Cavalier.

The Pembina Valley Water Cooperative was established in Manitoba to provide water to the towns and villages in Manitoba's "Pembina Triangle". The cooperative, with its 17 member towns and municipalities, has constructed water treatment plants at Letellier and Morris on the Red River, and at Stephenfield Reservoir on the Boyne River west of Carman and the necessary infrastructure to service the communities in the area. Future plans include extending the service east of the Red River in Manitoba.

There is relatively little agricultural irrigation being carried out on the North Dakota side of the Border below the escarpment, primarily due to the lack of an adequate, reliable source of water. On the Manitoba side, some efforts have been undertaken to capture and store spring runoff from smaller, intermittent streams for irrigation use later in the season.

Over the years, many studies of options for flood control on the lower Pembina have been conducted. Most of these proposals have included water supply components as a benefit to the particular project. It may be that with new initiatives being carried out in Manitoba to obtain a secure potable water supply, the benefits that may accrue to a multi-purpose water management project may no longer apply.

2.0 The Border Issue

2.1 The Early Years

The dispute between North Dakota and Manitoba concerning the management of Pembina River flood waters along the International Boundary has festered for more than five decades.

In 1944, a Manitoba provincial official observed that obstructions to the flow of water northward across the International Boundary had been installed at six separate locations within the Manitoba Rural Municipality of Rhineland. A road had been constructed just inside Manitoba running parallel to the Boundary. Although culverts had been placed along this road, the official expressed the opinion that they would not be adequate to convey enough water at periods of high flow.

In April, 1945, the Pembina County Drain Commission informed the North Dakota State Water Commission (SWC) that farmers along the Boundary in Pembina County had suffered considerable damage and crop production losses in 1944 due to overland flooding. They reasoned that the blockage to the movement of the floodwaters into Canada had been the cause of their problems.

The SWC relayed their concerns to Manitoba officials. In response, Canadian farmers expressed their own concerns over a large land drainage project being planned in North Dakota. While they indicated that a mutually acceptable arrangement could likely be made concerning the issue, they asked that a complete survey of the proposed project be undertaken and that an accurate estimate of additional waters to be drained into Manitoba be determined.

In 1952, Pembina County farmers requested that a certain drain - referred to as Drain #11 - be improved in order to handle the increased flows as a result of additional land drainage upstream in North Dakota. This drain crossed a corner of the county on its way to the Border and into Canada. In addition, local farmers reasoned that since, in their eyes at least, natural drainage into Canada was being blocked, an old natural channel north into Canada - the Aux Marais River channel - should be improved to handle the flows.

In an attempt to manage runoff reaching the Border from Drain #11, and from several other channels as well, a tentative agreement was reached between Manitoba and North Dakota in 1956 to construct the Rhineland Drain, also known as the International Boundary Drain. The drain would run parallel to the International Boundary, just inside the Canadian border from a point about one mile (1.6 km) west of Gretna, Manitoba to the Aux Marais River crossing - a distance of about eight miles (13 km). The drain was to be built by Rhineland Municipality and the costs shared among the State Water Commission, the Cavalier County Drainage Board and the Rural Municipality of Rhineland. By spring, 1959, the drain was completed and over the next three years, negotiations continued over the installation of culverts and field inlets into the drain.

In 1964, the SWC was informed that the RM of Rhineland was extending the road/dike about a quarter-mile (400 m) eastward along the Boundary past the outlet of the Rhineland Drain where it turns north into the Aux Marais. There would be only a 36-inch (one metre) culvert into the Aux Marais in place of the previous open outfall location. Manitoba Water Resources indicated that since the project was a road, a culvert only needed to be provided for the design capacity of the drain. The shallow Aux Marais channel had apparently also been diked at the border.

Concerned over the possibility of additional flooding south of the Border, the SWC and the county boards expressed an interest in negotiating a joint project which would extend the Rhineland Drain eastward along the Border to the Red River. While this option was agreeable to Rhineland municipality, they suggested that immediate action was unlikely. The Americans requested that until the Rhineland Drain could be extended, the opening through the Drain at the Border be re-established to its design capacity, and that this would take care of the effects of the blockage along the Aux Marais.

Manitoba officials requested the RM of Rhineland to install a second 36-inch (one metre) culvert through the road over the Drain at the border, or to replace the existing 36-inch (one metre) culvert with a 48-inch (1.2 metre) culvert to increase the capacity to approximately 195 cfs (5.5 cms).

Upon closer scrutiny, extending the Rhineland Drain east to the Red River proved to be unfeasible because of the depth of cuts required through the terrain. Another alternative was sought to redirect water eastward to the Red River using natural channels as much as possible. However, this option also floundered when the North Dakota State Highway Department informed the group that it would have no obligation to construct or maintain a structure to accommodate the drain through Interstate 29 on its way to the Red River. Local interests on the downstream end of the proposed project also expressed strong opposition to the project.

In the meantime, drainage improvements continued upstream in North Dakota, notably along the Walhalla Drain.

In 1966, the SWC reported that the Canadians were extending the road/dike westward along the border in the RM of Rhineland and into the neighbouring Rural Municipality of Stanley. To SWC engineers, it appeared as if the Canadians were building a protective barrier to any runoff from the U.S. all along the Border.

In 1967, a group of farmers in the Rhineland Drain area in North Dakota reported that a *"considerable amount of water"* was being drained into the channel on the Canadian side of the Border that was not part of the original agreement. They also reported that the banks on the U.S. side of the channel were apparently lower than those on the Canadian side, causing overflows and flooding on the U.S. side.

Once again, the SWC recommended that the outlet to the International Boundary Drain be opened as originally designed and that an appropriately-sized bridge be placed over the drain.

In October, 1968, North Dakota reiterated an interest in improving drainage on the U.S. side of the border, expressing the hope that the Aux Marais channel design would provide for 200 cfs (5.7 cms) at the border, rather than the 120 cfs (3.4 cms) capacity at the time. Manitoba objected to the possibility of not being able to manage the amount of floodwater runoff entering Manitoba from North Dakota.

In July, 1969, television station KCND expressed concern to the Governor of North Dakota over the high water and danger to their transmission tower in the vicinity of the Rhineland Drain. In response to KCND's concerns, the Governor explained that the proposed Pembilier Dam on the Pembina River would help solve the problem - in reference to the 1967 International Joint Commission report recommending the construction of two reservoirs along the Pembina River, the Pembilier Dam upstream of Walhalla and the Pembina Dam in Manitoba.

According to a SWC report, the dike along the Canadian side of the border had been raised over the summer of 1969 and the original culverts through the dike had been replaced with one 48-inch (1.2 m) culvert, set one foot (0.3 m) higher than those previously in place.

On December 16, 1969, a meeting was held between Manitoba Water Resources and the Pembina Water Management and Drainage Commission to discuss the opening in the Rhineland Drain. The Canadians expressed a willingness to improve the situation by increasing the capacity of the Aux Marais River. However, agreement on the amount of water to be accepted by Canada and the size of opening still needed to be reached.

It was proposed that the capacity of the Aux Marais river would be increased to 161 cfs (4.6 cms) and the project would be cost-shared with North Dakota contributing $90,000 of the estimated $300,000 cost.

The Canadian action along the border in the 1950s and 1960s was apparently in response to increased overland flows from the south which they believed to be aggravated in large part by the construction of levees along the Pembina River in the Neche area.

Following the 1950 flood, farmers in the Neche area began to build dikes along the river to protect their land from flooding. After each major flood event (1966 and 1969, for example) these dikes were extended and/or raised in preparation for the next. While a flood protection system was developed over the years to protect the town of Neche, it was these agricultural dikes upstream and downstream of the town that caused Canadians the most concern.

They were of the opinion that overland flow was being forced north toward the border in a flow pattern that had not existed prior to the construction of the dikes. This suspicion was upheld later in a 1976 USACE report stating that under natural conditions, flood flows would normally escape the river upstream of Neche, and that the levees had changed the flow conditions in the area.

2.2 The 1970s

The 1970s were a decade of significant floods — 1970, 1971, 1974 and 1979. During this period, the border issue began to intensify. The North Dakotans were of the opinion that the construction activities along the Border were in violation of the 1909 Boundary Waters Treaty which prohibits the stopping of free-flowing water across the border. The question of what could be considered "free-flowing" was raised, considering the source of the overland flow.

In January, 1970, the SWC asked the International Joint Commission (IJC) to review the border problem. The IJC suggested that the problem should be referred to the Souris-Red River Engineering Board. In March, the Governor of North Dakota asked the U.S. Secretary of State to involve the IJC.

On May 4, 1970, the U.S. State Department requested that the Canadians *"secure the removal or reconstruction of the (boundary levee) in order that the normal flow of flood waters across the boundary may be restored",* in compliance with the 1909 Treaty.

The Canadians agreed that improvements were necessary in order to prevent flooding, but the issue of sharing the costs continued to block an agreement.

On April, 1971, the North Dakota State Water Commission placed a moratorium on all drainage in the upper reaches of the Pembina basin in North Dakota.

April flooding in the area made the headlines. There were unsubstantiated reports that Canadian farmers were patrolling their road/dike to prevent sabotage. Once again, the Governor of North Dakota requested the IJC to take action to relieve the problem. The IJC replied that it had no authority to take action to prevent or halt any violation of the Boundary Waters Treaty without a reference from governments.

Following each major flood in the 1970s, diking activities on both sides of the border flourished. In 1979, the USACE conducted an inspection of the dikes at Neche and agricultural dikes both upstream and downstream of the town. The inspection determined that there were 12.5 miles (20 km) of dikes along the river upstream of Neche and another 4 miles (6.5 km) of roadway that served as a dike. There were even more along the downstream reach of the river. The engineers examining the dikes expressed concern over the condition and viability of most of the dikes. It appeared as though most had been constructed in haste without proper construction techniques. Much of the system was made up of "ridge dikes", constructed by either piling soil with a dragline or pushing it into a ridge with a bulldozer.

As the road system in the area was developed and improved over the years, roads became a significant factor in altering natural overland flows.

2.3 The Canada-United States Ad Hoc Water Resources Committee

On October 13,1971, representatives of the governments of Canada, the United States, North Dakota and Manitoba met to consider the flooding problem in the area of Neche, North Dakota and Gretna, Manitoba. A number of recommendations were developed including the cessation of all unilateral actions affecting water flow in the area and the establishment of an ad hoc committee to examine the flooding problem.

The Canada-United States Water Resources Committee (the Ad Hoc Committee) set out to prepare recommendations for a short-range approach to solving the flooding problem. In a December interim report, the Ad Hoc Committee recommended diking the south and west sides of Gretna as well as the KCND TV tower, installing additional culverts on the Aux Marais at the International Boundary and installing culverts at the various border crossings on the Walhalla-South Buffalo Lake watersheds. While these recommendations were quickly accepted, the question of cost-sharing arrangements required more discussion over the months that followed.

Insert MAP ?

There are six drainage ways flowing into Canada between a point southwest of Haskett, Manitoba and the Aux Marais. These have been referred to as outfalls, or crossings and have been numbered for identification. From west to east these are:

Crossing 1 - section 2-1-5W - about 3 miles southwest of the community of Hasket, Manitoba
Crossing 2 - section 6-1-3W - about 1 mile south of the community of Rosengart, Manitoba
Crossing 3 - section 4-1-3W - about 3 miles east of Crossing 2
Crossing 4 - section 5-1-2W - about 1 mile west of the community of Blumenort, Manitoba
Crossing 5 - section 3-1-2W - 2 miles east of Crossing 4, on the eastern edge of Blumenort.
Crossing 6 - Aux Marais - section 4-1-1E - 6.5 miles east of Gretna, about midway between Gretna and the Emerson/Pembina border crossing.

In December, 1973, the Ad Hoc Committee submitted its final report, adding several recommendations to those included in its interim report. The Aux Marais River and the Walhalla-South Branch of the Buffalo Lake System would be improved to accommodate flows equaled or exceeded once in eight years. This flow was referred to as the agricultural flow. With that standard as a guide, the document outlined the flows that would be allowed through all six crossings along the border, including the Aux Marais, and recommended the Rhineland Drain also be improved accordingly. A method of sharing the costs of the improvements and maintenance between Canada and the United States was developed based on the contributing drainage area for each channel lying within each country.

Attached to the report was a Memorandum of Understanding between the parties confirming and accepting the recommendations presented in the report.

The report did not examine the problem of overflows from the Pembina into the Aux Marais and cautioned that the problem could only be addressed by effectively controlling the Pembina River.

2.4 The Canada - United States Flood Control Review Committee

Many residents in Cavalier and Pembina counties, as well as government representatives in the United States, felt that the flow recommendations in the 1973 report for the openings along the border were inadequate, and would not afford proper flood protection. The report was also viewed as incomplete because it did not make specific recommendations as to the size or elevations of the various openings.

The North Dakota State Water Commission asked that the Ad Hoc Committee be reactivated long enough to arrive at a definition of adequate crossing capacity of each opening. In October, 1974, the Canada - United States Flood Control Review Committee was established to make further recommendations to governments. The committee was instructed to assume, when preparing its recommendations regarding flow

design or standard for drainage works, that the Pembilier Dam would be built, and to exclude from their considerations the presence of overflows from the Pembina River.

The Flood Control Review Committee submitted its report in August, 1976. Only Recommendation #1 from the 1973 report was revised - the section describing the amount of flow crossing the border. The amount of flow to be allowed through each of the six crossings along the border was revised, and the numbers and sizes of culverts to be installed recommended. The agricultural drainage standard of a one in eight-year flood was applied.

The question of cost-sharing was not addressed except to indicate that the formula presented in the 1973 report was supported. The remainder of the recommendations in the 1973 report remained unchanged.

Table 2 - Recommended openings in Border crossings
Canada - United States Flood Control Review Committee - 1976

Crossing	Location (Manitoba)	Flow	Openings
#1 (Hyde Park Coulee)	section 2-1-5W	350 cfs	four 60" culverts
#2	section 6-1-3W	410 cfs	six 60" culverts
#3	section 4-1-3W	430 cfs	adequate at present
#4	section 5-1-2W	400 cfs	adequate at present. However, if required for traffic - five 60" culverts
#5	section 3-1-2W	21 cfs	one 36" culvert
#6 (Aux Marais)	section 4-1-1E	260 cfs	four 60" culverts or three 85"X54" arch culverts and spillway*.

* An emergency spillway at the Aux Marais crossing was to be built only after the Pembilier Dam or equivalent flood control works were in place.

2.5 The 1990s

Between 1976 and 1990, several attempts to come at an agreement between Canada and the U.S. produced few results. During this period, controversy surrounding water issues in general eased due to an extended period of low flows and drought conditions.

On November 7, 1990 a meeting of North Dakota officials and Manitoba Water Resources representatives was held to review the progress of the work along the border and on the Aux Marais. A technical committee was set up to further examine the situation.

The technical committee toured the area from Crossing #1 to Crossing #6 in May, 1991. Generally, it seems that the actions recommended by the 1976 report (primarily in regard to the sizing and number of openings across the border) had not been applied. In addition, it was recorded that the road/dike had been built over crossings #'s 2 to 5 to such a height that it would not likely be overtopped even during an extremely high frequency event.

At Crossing #6, Manitoba was in the process of upgrading the Aux Marais channel to handle 260 cfs (7.4 cms) as recommended. The group concluded that if the culverts and emergency spillway were installed as recommended in the 1976 report, this portion of the plan should be satisfied.

Spring of 1996 brought another major flood to the Red River valley. During the flood the road-dike was breached. Efforts by local Manitobans to repair the breach were protested by North Dakota. The provincial government ordered that the repairs cease.

In 1996, a new International Technical Working Group was established and instructed to revisit the 1976 agreement once again. At its first meeting in September, 1996, the Working Group determined that the Aux

Marais system had been completed as recommended in the 1976 report, with the exception of the emergency spillway. They also reached the consensus that waters reaching crossings #'s 1 to 5, since they form part of the Walhalla - South Branch of the Buffalo Lake drainage systems, were not affected by overflow from the Pembina. Accordingly, it was agreed that the recommended openings in these border crossings could be installed, providing the cost-sharing agreement outlined in the 1976 report could be implemented.

However, the major point of contention continued to be the situation at Crossing #6 — the Aux Marais. A major stumbling block to reaching a solution was the failure to implement a flood control project on the Pembina River. Canadian representatives insisted that no further changes be made to the crossing until provisions were made to handle additional flows from the Pembina River.

The Pembilier Dam — a flood control project being proposed upstream of Walhalla —could still not be justified economically nor environmentally. A proposed floodway recommended by the U.S. Army Corps of Engineers from a point near Neche eastward to the Red River was not acceptable to local people or local governments. The Group concluded that the possibility of establishing an overflow channel, smaller than the one recommended by the Corps, from Crossing #6 eastward about 5 miles (8 km) to join a natural channel to the Red, should be examined.

At its second meeting on March 19, 1997, an assessment of this new, smaller diversion was examined. The diversion would consist of a bypass channel that would intercept flows in excess of 260 cfs (7.4 cms) at the Aux Marais Crossing and divert them through the floodway along to the south side of the Border to the Red River, a distance of approximately six miles (10 km). It was unclear whether local landowners and politicians would accept this proposal.

In April and May of 1997, severe flooding was experienced on the Pembina and Red rivers. The eastern portion of the road/dike, just west of the Red River, was overtopped and apparently failed in two locations. However, the failure was most likely a result of overland flooding from the Red River rather than the Pembina. Following the flood, the road/dike was repaired by the Canadians.

The Technical Working Group has not met since its March, 1997 meeting.

Today, continued discussions concerning the management of overland flooding in the area are centered on reaching an agreement on the method of sharing the costs of works necessary to solve the problem.

3.0 History of Flood Studies

3.1 Introduction

As early as 1941, the construction of storage reservoirs on the Tongue and Pembina rivers were being recommended to help solve the problems of water supply and flood control in the lower Pembina River basin in North Dakota. Under a pilot watershed program conducted by the U.S. Soil Conservation Service in the late 1950's and early 1960s, a number of small storage reservoirs and other water management projects were constructed along the Tongue River and its tributaries. However, similar action was not undertaken on the Pembina.

Prior to 1960, several studies had been undertaken unilaterally in each country for the purposes of providing water management in the lower Pembina River basin. These studies revealed that any potential multi-purpose development for flood control, water supply and irrigation could not be justified economically unless both countries participated in the project.

3.2 The International Joint Commission - 1967

In 1948, the Governments of Canada and the United States requested the International Joint Commission (IJC) to investigate and report upon the existing and future uses of the waters of common interest to both countries in the Red and Souris river basins. Being a tributary of the Red River, the Pembina River was included in the study. As a result of those studies, the IJC recommended to the governments that it be authorized to conduct further studies specific to the Pembina River Basin.

On April 3, 1962, the governments of Canada and the United States instructed the International Joint Commission *"to investigate and report on what measures could be taken to develop the water resources of the Pembina River in the Province of Manitoba and the State of North Dakota"* and to *"determine what plan or plans of co-operative development of the water resources of the Pembina River Basin would be practicable, economically feasible, and to the mutual advantage of the two countries, having in mind: (a) domestic water supply and sanitation; (b) control of floods; (c) irrigation; and (d) any other beneficial uses."*

Under the direction of the IJC, an International Pembina River Engineering Board examined a number of options for water management in the lower Pembina River valley and selected three plans of development for consideration by the IJC. Each plan included components for flood control, irrigation and water supply to both sides of the border, and considerations for recreational opportunities.

During its study, the International Pembina River Engineering Board also considered the flood control benefits of increasing channel capacity of the Pembina River downstream of Walhalla through a combination of channel improvement and levee construction between Leroy, North Dakota and the junction with the Tongue River. The study determined that flood protection could be provided more economically by reservoir storage than by channel improvements.

The first plan was a multi-use Pembilier Dam and reservoir situated immediately west of Walhalla, North Dakota. Of the estimated 299,000 acre feet (ac-ft) of reservoir storage, 164,000 ac-ft would be for irrigation and water supply and 115,000 ac-ft would be reserved for flood control.

The second option involved constructing two reservoirs, including a smaller Pembilier Dam at the Walhalla site, and an additional dam about 11 miles (18 km) upstream of the International Boundary near the community of Kaleida, Manitoba, referred to as the Pembina Dam.

The smaller, 110,000 ac-ft Pembilier Reservoir would be used entirely for flood control, while the 246,000 ac-ft of storage in the Pembina Reservoir would be assigned to irrigation and water supply.

The third plan also called for two reservoirs - a 110,000 ac-ft Pembilier Reservoir strictly for flood control, and a larger dam situated about two miles (3 km) downstream of the outlet to Swan Lake in Manitoba. The Swan Lake reservoir would have a storage capacity of 540,000 ac-ft and be assigned for water supply and irrigation.

In December 1964, the International Pembina River Engineering Board submitted its report to the IJC who in turn, made the Board's report available for review at 13 public offices throughout the basin. On June 9 and 10, 1965, the IJC held hearings in Manitou, Manitoba and Walhalla, North Dakota. In all, 62 witnesses were heard. In general, the option calling for the Pembilier Dam/Pembina Dam combination was favoured by those providing testimony at the hearings.

In October, 1967, the International Joint Commission recommended to the governments of Canada and the United States a slightly modified version of the Pembilier Dam/Pembina Dam combination.

In the 1964 plan, the estimated 21,300 acres (8,623 hectares [ha]) to be irrigated were divided equally between the two countries. The IJC recommended modifications to the irrigation water supply infrastructure so that 12,800 acres (5,182 ha) would be irrigated in Canada, and the remaining 8,500 (3,441 ha) acres in the United States. This change was introduced to lower the costs of supplying irrigation water and to improve the net returns from irrigation to project benefits.

Under this plan, 60 percent of the water yield above Walhalla would be allocated to Canada and the remaining 40 percent for use in the United States. The first costs and average annual costs of the project would be divided according to the benefits accrued to each country.

This recommended project had a benefit-cost ratio of 0.9 in Canada and 1.4 in the United States. The Commission recommended that a transfer of approximately $3 million U.S. to Canada to help defray the costs of joint projects undertaken in Canada. The result would be a balanced benefit-cost ratio of 1.2 for each country.

Calculations were based on July, 1963 prices, the currency of the country in which the works were located, a U.S. interest rate of 3 1/8 percent and a Canadian interest rate of 5 percent and a project life of 100 years. All analyses were based solely on primary benefits.

3.3 Manitoba Water Commission - 1973

Because of the marginal benefit/cost ratio of the two reservoir plan recommended by the IJC in 1967, no action was taken to implement the plan. But because of the continued regional interest in developing the water resources of the Pembina River, various groups continued to examine the issue of water management in the area. One of these was the Manitoba Water Commission.

In September, 1972, the Manitoba Minister of Natural Resources asked the Manitoba Water Commission to review existing plans for the development and utilization of the water resources of the Pembina River and to recommend which of the plans would be most advantageous to Manitoba. The Commission was also asked to recommend any additional studies required.

The Commission focused its efforts on further appraisal of the plan recommended in the 1967 IJC report (Pembilier Dam, Pembina Dam and irrigation and water supply infrastructure). Using 1972 prices and interest rates (7.5 percent for Canada and 5.5 percent for the U.S.), the Manitoba Water Commission determined that capital costs and annual costs had increased significantly. First costs had risen to about $56.5 million with average annual costs of approximately $5.2 million, while annual primary benefits only totaled about $4.5 million. When considering flood control, water supply, irrigation and recreation benefits, the benefit/cost ratio for the project had dropped from 1.2 to 0.85.

However, the Commission concluded that, in Manitoba eyes, benefit/cost ratio aside, a two reservoir project was preferable to any single reservoir development. And while the project could not be justified on economic grounds, the Commission recognized that the Province may might feel the project could be justified on social grounds. The Commission also recommended that since water supply may prove to be a large issue in the development of the "Pembina Triangle" area of Manitoba over the course of the following years, a detailed investigation of the water supplies in the area be conducted, with particular reference to the dependability of the Winkler aquifer.

3.4 The U.S. Army Corps of Engineers - 1976

Implementation of the 1967 IJC proposed plan was being delayed because of its marginal economic feasibility and because of a shift in priorities within Canada to other water management projects. In response, the U.S. Army Corps of Engineers (USACE) initiated a study to examine possibilities for providing flood control and water supply by constructing a project within the U.S. portion of the basin alone.

The study examined a number of options, from non-structural measures such as flood plain regulation and flood insurance to structural measures including the construction of the Pembilier Dam and a couple of options for a constructed floodway along the International Boundary to the Red River.

In its report, *"Feasibility Report for Flood Control and Related Purposes"*, released in 1976, the USACE recommended the construction of a larger version of the Pembilier Dam than had been suggested in earlier studies. The multi-purpose flood control, water supply and recreational-use reservoir would be located on the Pembina River two miles (3 km) upstream from Walhalla. The design flood for the project was a 2.8 percent flood (one in 36 years) and would provide protection up to a 40-year and 37-year flood at Walhalla and Neche respectively. The study estimated that flood damages could be reduced by an amount in excess of 70 percent along the Pembina River from the dam site to Pembina, North Dakota. The reservoir would provide an assured source of water for downstream users and a site for recreational development.

Of the total 147,000 acre-feet storage capacity, the reservoir would use 128,000 acre-feet exclusively for flood control. The report also indicated that the project would *"relax social pressures surrounding the existing diking problems along the international border. These dikes were constructed to reduce the flow of Pembina River floodwaters to the Aux Marais basin in Manitoba."*

The total first costs were calculated to be $24.9 million, with an average annual cost of $1.8 million. Costs were calculated using October 1975 prices and an interest rate of 6 1/8 percent. The study calculated the benefit/cost ratio of the project at 1.6 if Canada contributed to the project, and 1.5 if not. Benefits of the project to Canada included some flood reduction in Manitoba and amounted to an estimated 7.5 percent of the total benefits.

During its investigation, the Corps examined the feasibility of using floodways to provide a certain degree of flood protection to the area downstream of Walhalla. This seems to be the first serious consideration for a floodway as a possible solution to flooding problems south of the International Boundary.

An option of a floodway in conjunction with a reduced-size Pembilier Dam was found to be uneconomical. A floodway with a diversion near Neche and a 2,000 cfs (57 cms), 16-mile (26 km) diversion channel along the International Boundary to the Red, in combination with levees along the Pembina River from Walhalla to Neche was also found to be economically unfeasible.

A third option consisted of a small diversion dam three miles downstream of Walhalla which would divert up to 3,500 cfs (99 cms) into a floodway channel flowing north to the International Boundary, then east along the U.S. side of the border to the Red River. The total length of the channel would be 32.6 miles (53 km). With the natural river channel capacity of about 3,000 cfs (85 cms) (as calculated at the time), a total

of 6,300 cfs (178 cms) could be managed safely at a benefit/cost ratio of 1.17. However, the project would provide only limited flood protection to the area -- 11-year along the channel and 9-year at Neche itself.

However, the boundary floodway was not acceptable to the local people for a variety of reasons. There were objections to the loss of productive agricultural land to the channel, the need for easements for holding water at the entrance to the channel and the disruption to access to farm land across the channel. Also, there was a question of a loss of tax revenues to local governments. In addition, the relatively low level of flood protection and the absence of a water supply option worked against the proposal.

In the end, the report chose the Pembilier Dam and reservoir over a floodway as the most acceptable approach to flood control for the area.

3.5 U.S. Army Corps of Engineers - 1983

No action was taken following the 1976 report, although the proposal was supported by both the North Dakota State Legislature and the North Dakota Senate. Following a major flood in 1979, the interest for flood control in the valley grew stronger.

In 1983, the 1976 *"Feasibility Report for Flood Control and Related Purposes"* was re-visited by the U. S. Army Corps of Engineers. Over the intervening period, new information and the changing economic conditions resulted in a re-evaluation of the Pembilier Dam and reservoir project recommended in the 1976 report. The 1983 analysis produced a benefit/cost ratio of only 0.54. This dramatic change came about as a result of several technical and economic factors.

New analysis determined that the drainage area contributing to the project was larger than anticipated in 1976 and the probable maximum flood was revised upward to 118,600 cfs (3,356 cms) from the 80,300 (2,272 cms) used in 1976. It was determined that a much larger spillway would be required on the project, adding about $9 million to the cost.

Interest rates in the U.S. had risen from 6 1/8 percent used in the 1976 plan to 7 5/8 percent, resulting in a higher annual cost. The increase in construction costs also added to the cost of the plan. Capital costs of the project were now estimated at $44 million with an average annual cost of $3.6 million ($24.9 and $1.8 in 1976).

New information also determined that high flows would occur less frequently than anticipated in the 1976 report, and that "zero-damage" point (the point at which flood damages begin) would be 4,000 cfs (113 cms), not 2,200 cfs (62 cms) as calculated in the 1976 plan.

Another factor contributing to the less favourable benefit-cost ratio was a change in the estimated date of the start of the normal agricultural planting season. The 1983 report determined that the planting season would begin two weeks later than the date used in the 1976 report, thereby reducing the amount of calculated agricultural losses caused by late planting due to flooding.

When informed that the Pembilier Dam and reservoir option did not warrant further consideration based on the new information, State and local interests questioned the technical analysis. In view of feedback gathered at two public meetings in June and July of 1982, the plan was subjected to further, more intense analysis.

In the end, the report concluded that the Pembilier Dam and reservoir was not a economically viable option from a Federal perspective. However, the report did allow that it may be possible in the future that changing conditions such as a climatic shift to wetter conditions, increased crop prices and yields and/or lower interests rates might improve the b/c ratio.

Several other options were also examined including a dry dam at the Pembilier site, various combinations of floodways and dams, and three options for a floodway from the Pembina River north to the International Boundary then east to the Red River. In the end, the report selected a 21-mile (34 km) long floodway from point six miles (10 km) west of Neche to the Red as the most feasible plan.

The 1983 selected floodway plan differed from the floodway option described in the 1976 report in that it would be considerably shorter and somewhat smaller. The 1976 plan suggested a 33-mile (53 km) long, 3,500 cfs (99 cms) floodway beginning three miles downstream from Walhalla. This new report suggested the diversion point be located immediately upstream of Neche and that the capacity would be 2,000 cfs (57 cms).

At the design flow of 5,500 cfs (155 cms), the study determined that 3,500 cfs (99 cms) could pass down the existing river channel and 2,000 cfs (57 cms) would be diverted into the floodway. This would afford Neche a relatively low level of flood protection (8-year protection as calculated in 1983) and would reduce anticipated flood damages by 38 percent. However, emergency flood protection efforts could be reduced accordingly as a result of 2,000 cfs (57 cms) less flow in the natural channel.

In the analysis, existing levees were assumed to be ineffective for flood protection because of their generally poor condition as viewed from an engineering perspective. However, the report did conclude that even so, it might be reasonable to expect that the levees, combined with emergency measures, may be able to confine as much as 5,000 cfs (141 cms) within the river channel, providing a total system capacity of 7,000 cfs (198 cms). This would provide protection for a flow of a 17-year frequency.

During a flood, water from farmland to the south of the floodway channel would be carried in a ditch running along the south side of the floodway to the Aux Marais River. At that point it would be directed through a siphon under the floodway into Canada. According to the report, the plan would reduce the frequency and volume of flood flows into the Aux Marais. The plan would produce minimal environmental impacts.

The total cost of the project was estimated at nearly $8 million with an annual cost of approximately $630,000. The benefit/cost ratio was calculated at 1.53.

However, objections to the plan were similar to those expressed in 1976, including the loss of farmland to the channel, the relatively low level of flood protection, inconvenience to farmers with land on either side of the channel and the lack of water supply and recreational opportunities. Some concern was also expressed over the possibility of increasing flood stages on the Red River downstream of the outlet. However, studies concluded that the impact would be negligible, and in most cases none at all.

In May, 1983, the draft report was sent to 204 organizations and individuals and made available for public review and comment. Public meetings were held at Cavalier in June and Walhalla in July. Out of the 31 official responses received on the report, only eight supported the floodway plan and 19 continued to feel that the only acceptable solution to flooding in the area was the construction of the Pembilier Dam.

In general, those favouring the Dam lived in the flood-prone area and opposed the floodway for the reasons listed previously. Those favouring the floodway, in general, lived upstream and had concerns over flooding the Pembina River Valley — considered by many to be the most attractive natural feature in the State.

Again, the process of providing flood protection to the area stalled.

3.6 Pembina Dam - PFRA, 1987

Under a 1980 Canada-Manitoba agreement for economic expansion and drought-proofing, the Prairie Farm Rehabilitation Administration (PFRA) conducted an extensive examination of options for supplying water to the area between the Pembina Escarpment and the Red River in Manitoba - an area referred to as the

Assiniboine South - Hespeler Area. The intent was to provide adequate water for an expanding agricultural irrigation industry and for the many growing towns in the area. As part of the study, a dam on the Pembina River near Kaleida was considered.

As described in PFRA's 1987 report on the project, the reservoir would have a 250,000 ac-ft capacity. The reservoir would provide an assured water supply for the town of Morden and be capable of irrigating 42,700 acres (17,287 ha) east and southeast of that community. However, the relatively high unit cost of the project was a major drawback the project. Since another option for water supply to the area (a dam on the Assiniboine River and associated works) was considered more practical, the Pembina Dam option was not pursued further.

3.7 Lower Red River Valley Water Commission (Manitoba) - 1999

In April, 1999, the engineering consulting firm Acres International was contracted by the Lower Red River Valley Water Commission (Manitoba), to re-examine "Sustainable Water Supply Development and Impacts of such Development on Flooding in the Red River Basin". The International Joint Commission provided half of the funding for the project as part of its International Red River Basin Task Force investigation into flooding on the Red River.

Acres was asked to re-assess the feasibility of three projects discussed in previous reports - the Pembilier Dam and Reservoir (USACE, 1983), Pembina Dam (Prairie Farm Rehabilitation Administration, 1964/1987) combined with the Boundary Floodway (USACE, 1983) and the smaller Pembilier Dam and Floodway (USACE 1983). Included in the assessment was a review of the technical aspects of each alternative as well as a review and update of the capital costs for each. Economic benefits of each project were updated and the flood control benefits of each was also assessed.

The Pembilier Dam and Reservoir located near Walhalla would provide flood control downstream to Pembina and water supply to Manitoba and North Dakota. In 1983, the Corps estimated the benefit/cost ratio at 0.54. However, the 1999 Acres report calculated the b/c ratio to be 0.75 owing in part to the higher benefits in Canada than originally estimated. According to Acres, the total costs of the project in 1998 Canadian dollars are now estimated to $107.5 million

A dam on the Pembina River near Kaleida, Manitoba was considered as a part of the two-dam proposal put forth by the International Joint Commission in 1967. Canada's Prairie farm Rehabilitation Administration (PFRA) also examined the option as a possibility for water supply to the Pembina Triangle region of Manitoba in 1987.

The combination of the Pembina Dam and the Boundary Floodway from Neche to the Red River would cost about $117 million (1998 Canadian) and produce a benefit/cost ratio of 0.74. In 1983, the Corps showed that the floodway alone would have a b/c of 1.16, but it would provide no water supply benefits.

The smaller Pembilier dam and associated floodway (USACE 1983) produced a benefit/cost ratio of 0.52. Acres calculated the b/c at 0.67 in 1999, primarily because the Canadian benefits are larger than the 1983 report used.

4.0 Current Activities

4.1 International Red River Basin Task Force Technical Studies

The transboundary nature of the Pembina River basin and the long-standing dispute concerning the management of flood waters in the area led the International Joint Commission to conclude that studies aimed at gathering the facts and at providing a basis for local discussion of potential solutions would be in everyone's interest. Through the IJC's International Red River Basin Task Force, a number of technical studies related to the lower Pembina River were initiated. These studies were undertaken, either by government organizations or consultants on behalf of the IJC, or by other organizations in collaboration with the IJC. The work has been centered on three main initiatives — Data Acquisition and Interpretation, Model Development and Decision Support.

4.1.1 Data Acquisition and Interpretation

Accurate topographic data forms the basis for floodplain definition and floodplain management. There is a need to improve this data throughout the Red River basin. The lower Pembina basin has served as a test area for preparation of a "seamless best available" Digital Elevation Model (DEM).

A 130,000-acre (52,632 ha) study area was selected which is located primarily in Pembina County, North Dakota, beginning about six miles (10 km) west of Neche, and extending a short distance across the Red River into Minnesota and north to Highway 243 in Manitoba. Three separate technologies were used to collect topographic data with the intent of fusing the data into one DEM. These were DGPS (differential global positioning system), Lidar (LIght Detection And Ranging) and IFSAR (Inferometric Synthetic Aperture Radar). The US Army Topographic Engineering Center managed the project.

In the fall of 1998, a DGPS survey of the centerline of paved and gravel roads and main levees was carried out. The data collected was processed to provide a complete set of elevations of these features to an accuracy of two to four inches (5 to 10 cm). The work was curtailed because of a snowstorm before spot heights on fields could be obtained.

A 50,000-acre (20,234 ha) section of the study area along the Pembina River from Neche to the Red River was flown in October 1998 using Lidar technology. With Lidar technology, a laser mounted in an aircraft whose position and altitude are known fires several hundred thousand bursts a minute toward the land surface and measures the return signals, providing a reading of elevations. The data can be processed to produce a highly accurate 'bare earth' DEM, that is buildings and trees are removed in the processing. The result was a DEM with absolute accuracies in the order six inches (15 cm). Accurate Lidar surveys can be conducted rapidly but the cost is high.

Another more experimental airborne technology known as IFSAR was also used to map the study area in October 1998. The stated aim of the system is to collect data for processing into a DEM at the rate of 40 square miles/minute (100 km^2/minute) with 10 foot (3 m) vertical accuracy. The system has the potential to map large areas at medium accuracy at a reasonable cost.

It was anticipated that, by fusing the DGPS, Lidar, and IFSAR data, a more accurate IFSAR product would be possible. This analysis is still underway.

RadarSat images of the study area were acquired on 12 days during the 1997 flood and four days during the 1996 flood. To assist future floodplain management and calibration of models, four RadarSat images of the lower Pembina basin were produced. These images are coded for input into a GIS and the water features are classified. The satellite can obtain images in any weather, day or night, to a horizontal resolution of about 80 feet (25 m). The additional unprocessed data could be coded and classified as the need arises.

The U.S. Army Corps of Engineers has carried out a flood frequency analysis of the Pembina River to determine whether there were any significant changes in the 100-year flood and the probable maximum flood as a result of the 1997 data. This analysis is needed to perform studies of flood damages and the potential economic benefits of mitigation measures. The Corps found that there were no changes in the updated flood frequencies from previous values.

In collaboration with the Lower Red River Valley Water Commission (in Manitoba), the costs and benefits associated with the proposed Pembilier and Pembina dams in the USA and Canada respectively, as well as those associated with the proposed Boundary Floodway were reviewed and updated. The project was undertaken by Acres International on behalf of the Commission with half of the funding for the undertaking being provided by the International Joint Commission. These flood control projects have been discussed in the IJC and Corps of Engineers reports described in Section 3.0 of this document. The findings from Acres' draft report are also discussed in that section.

4.1.2 Model Development

The hydraulic models that existed for the Red River basin at the time of the 1997 flood were not capable of dealing with complex overland flows typical of major flood events in the Valley. The International Red River Basin Task Force sought a computer model capable of forecasting overland flows during a flood as well as one capable of being used for planning to determine the effects of new dikes or reservoirs.

The Task Force commissioned the development of two one-dimensional models aimed at achieving a water level accuracy of six inches (15 cm). A UNET model was implemented in the upper basin from Lake Traverse to Letellier, Manitoba and a MIKE 11 model was applied to the lower basin from Grand Forks to Selkirk. The lower Pembina River basin is in the overlapping portion of the two models.

The models were used to examine the effects of hypothetical upstream storage on downstream water levels. Among the scenarios tested was the effect of storing 75,000 acre-feet of water at the optimum time in the Pembina basin. This storage was found to have no effect on water levels on the Red River at Emerson under 1997 conditions.

A detailed sub-model of the lower Pembina basin was added to the MIKE 11 model. The configuration of the model allowed the development overland flow corridors which permitted a variety of scenarios to be examined. The model was run for the Lower Pembina River for both 1996 and 1997 from a location about six miles (10 km) west of Neche, North Dakota where County Road 55 crosses the Pembina River at the Paton Bridge to the confluence with the Red River at Pembina. A comprehensive discussion of the results of the modeling is presented in a separate report to the Task Force. Findings can be summarized as follows:

- Under Existing Conditions

Under conditions that existed in 1997, the flow on the Pembina River where in meets County Road 55 was 14,300 cfs (405 cms). The model determined this flow was contained within the channel and associated dikes, and the adjacent road network to a location just east of Neche. At this point, about 55 percent of the total flow broke out of the river and moved both north and south. About 6,400 cfs (181 cms) of flow remained within the river channel.

About 15 percent of the flow (2,100 cfs[60 cms]) moved northeastward from the breakout point to the International Border where it was impeded by the road/dike along the Border and a height of land known locally as Switzer Ridge. Here, it flooded about one square mile in the vicinity of a television transmission tower. (The impact of this unnatural impoundment over a number of floods has been the salinization of the soil in this area.)

A relatively small amount of the flow passed through culverts in the road/dike and into the Aux Marais River. Most of the flow eventually crossed Switzer Ridge and continued along the U.S. side of the Border and on to the Red River.

In total, about 40 percent of the 14,300 cfs (5,700 cfs [161 cms]) broke through the dikes on the south side of the river and moved south and east. This overland flow was confined by County Road 55 and forced to the east and back across the river to the north side where the river crosses County Road 55 downstream, then overland to the Red River. From this point downstream to the Red, about 5,700 cfs (161 cms) remained in the channel.

In effect, the road/dike along the International Border on the north and County Road 55 on the south acted as setback dikes, containing the flow between them with the larger portion being held back by County Road 55.

The peak flow for the 1996 flood at Neche was 8,500 cfs (240 cms). Modeling this flood indicated that the flow was contained within the channel and dikes to the same point east of Neche where the breakouts occurred in 1997. From that point, only about 5 percent escaped to the north and about 25 percent to the south while about 6,000 cfs (170 cms) remained in the channel. Further downstream, the flow within the channel dropped to 5,100 cfs (144 cms).

The modeling has shown that the capacity of the Pembina River channel downstream of Neche, with the existing dikes, is in the range of 5,100 to 6,400 cfs (144 to 181 cms).

- Removal of the Pembina River Dikes

When the system of dikes along the Lower Pembina River is removed, an entirely different overland flow pattern evolves. The river flows along the height of land formed by the river itself. Over the centuries, silt was deposited along the banks as floodwaters broke out of the channel, slowed down and dropped their sediment load. In effect, the river has developed its own natural levees. Once out of the channel, the water flows away from the river, and does not return unless forced to do so by impediments such as roads.

With no man-made levees in place, and under 1997 flows of 14,300 cfs (405 cms), modeling revealed that the flow would have broken out of the channel west of Neche, instead of east, easing the conditions in the town. Existing roads on the north side of the river would act as dikes locally and as a result, no flow from the flooding Pembina River would reach the International Boundary. About 40 percent of the flow (5,700 cfs [161 cms]) would remain in the channel and the remaining amount would spill out on the south side of the river, flowing south and east, eventually meeting up with the river downstream and crossing it on its way overland to the Red. Again, County Road 55 would act as a setback dike on the south side of the river.

- Natural Conditions

Under natural conditions — with no dikes along the river and no roads in place — flood flows would leave the river channel west of Neche. About 30 percent of the flow (4,300 cfs [122 cms]) would find its way north - 15 percent into the South Buffalo Drain in Manitoba via Hyde Park Coulee in North Dakota and another 15 percent further east. However, there would be no flow along the International Boundary east of Neche and no flow into the Aux Marais system.

An additional 30 percent of the flow would escape to the south, past the present location of County Road 55. Only 30 to 40 percent of the total flow (4,300 to 5,700 cfs [122 to 161 cms]) would remain in the channel through Neche. This should be considered the natural capacity of the Lower Pembina River.

The modeling shows that existing roads have a marked effect on overland flows.

- Boundary Floodway

A 2,000 cfs (57 cms) floodway along the International Boundary as proposed by the U.S. Army Corps of Engineers in 1983 would have a minimal impact on flooding under conditions similar to 1997. As indicated in Section 3.0: History of Flood Studies, the channel would only be able to divert a relatively small portion of the total flow during such an event. However, this floodway could provide some benefit in lower flood years such as 1996.

- Set Back Dikes

The feasibility of building a system of dikes set back from the river from a location upstream of Neche eastward to the Red River was examined. The dikes would be set 2,700 feet (823 m) apart, creating a channel between them. Removing trees and shrubs from the channel would increase its hydraulic efficiency, but may not be environmentally acceptable. Allowing the natural vegetation to remain in the channel would decrease its hydraulic efficiency and require that the dikes be constructed two feet higher than those for a "clean" channel.

Installing these dikes presents other challenges. Ideally, the dikes should be tied into a height of land on the upstream end and into an existing diking system on the downstream end. While it may be possible to tie the dikes in to the sloping terrain at the upstream end, there is no logical tie at the downstream end. They would terminate near where the Tongue River joins the Pembina. The land adjacent to the levees near the Red River would still be subject to flooding from the Red or Tongue rivers.

- Bridges at Pembina and Emerson

Modeling also determined that the highway bridge across the Red River at Pembina and the railway bridge at Emerson in themselves have no impact on water levels in the area. However, the channel restrictions created in part by diking systems around the two communities may have a minimal impact on water surface profiles in the area.

For a short distance from where it joins the Red River, flow was reversed in the Pembina River in 1997 until it joined overland flow from the Red and moved northward west of Interstate 29 and through the road/dike at the International Boundary.

The results of the modeling will be very useful in helping to come to a basin approach to water management in the area.

4.1.3 Decision Support

One of the tasks undertaken by the Task Force in partnership with the Global Disaster Information Network is the development of a virtual database for the Red River Basin. This will provide a means of making data and information concerning mitigation measures, emergency response, and flood recovery available to governmental and non-governmental organizations, and the public.

The virtual database is a distributed database searchable over the Internet. Each contributing agency will continue to be responsible for maintaining and updating its own holdings and the related data documentation. Hundreds of relevant data sets held by dozens of agencies have been catalogued. Searches can be carried out for a specific data type or some attribute of the data such as the data holder or location.

These data sets used in concert with a suite of models or model outputs and interactive tools comprise a decision support system. In effect the system would search for data, present or report data, export data to models and execute some models, and import and present results from models. Such a system must be developed in phases so that it can be tested and evaluated.

A prototype focusing on the Pembina basin is in the early stages of development. Specific flood management issues within the Pembina River Basin that the system will focus on include the following four applications.

- Flood forecasting tools, including interpretation of official flood forecasts for both Canada and the US;
- Flood preparedness tools, to select appropriate structural and nonstructural measures for reducing flood risk and flood damages, including hydrologic models to estimate runoff and hydraulic (or hydrodynamic) models to generate water elevation and flood extent maps;

- Optimization tools, including the use of economic models to investigate possible modifications to flood control systems for minimizing economic loss; and
- Emergency management tools, including models to simulate, test and update emergency plans.

4.2 Grass Roots Involvement

Over the decades, a number of local interest groups were formed, then faded away as the degree of concern over flooding issues in the area ebbed and flowed with the flood cycle. Currently, there are a number of grassroots organizations in operation, the most notable being The International Coalition, Red River Basin Board and the newly-formed Pembina River Basin Advisory Board.

4.2.1 The International Coalition (TIC)

Following the 1979 flood, a number of concerned citizens and public officials from both sides of the Border formed a group called the Red River Flood Coalition. Originally, the group was concerned primarily with flooding and flood issues in the valley. However, it soon realized that water management could not be considered in isolation of other resources and people. This coalition evolved into The International Coalition for Land/Water Stewardship in the Red River Basin (TIC), officially chartered in 1983.

As its name implies, TIC has a larger interest in land and water management for the entire Red River Basin, of which the Pembina is part. The organization is dedicated to *"Grassroots solutions for a better tomorrow in the Red River Basin".* Its intention is to be an international model for communication, cooperation and action regarding land and water management in the basin.

Membership in TIC includes cities, towns, counties, municipalities, governments and various interest groups from the headwaters of the Red River to Lake Winnipeg and as far west as the Saskatchewan border. TIC's annual conference has long been one of the best forums for discussion of resource management problems in the basin, regularly attracting upwards of 300 delegates.

Over the years, TIC has supported research on wetlands, water retention, land use, water supply and hazardous waste. Between 1995 and 1997, TIC was heavily involved in the formation of the Red River Basin Board.

4.2.2 Red River Basin Board

The Red River Basin Board (RRBB) was established in July of 1997, following by coincidence, the devastating Flood of Century. The group originated as a spin-off from TIC, but with a more specific agenda. Its mission is *"To develop and cause to be implemented, a comprehensive water management plan for the Red River Basin, and to facilitate and pursue the resolution of interjurisdictional disputes."* RRBB has set a tentative timeline for producing its management plan, intending to formally unveil it at the annual TIC conference in January, 2001.

The Board consists of more than 20 members, comprising representatives of local governments, watershed boards and other water management groups, First Nation representatives and the governments of North Dakota, South Dakota, Minnesota and Manitoba.

The Board has stated it is not its intention to replace government, but to accomplish objectives governments have yet to reach, by acting as a facilitator and working toward achieving consensus. The Board has indicated, that in its opinion, it is well-positioned to become the focus for water management activities in the Basin for years to come and that it can fill the role of a coordinating body for future water management initiatives.

The RRBB has three special task forces, including the Pembina River Watershed Task Force. The purpose of this task force was to ensure that the work being done in the Pembina watershed was compatible with the objectives of the RRBB. The work of this task force has been placed in abeyance pending the outcome of the work of the IJC's Red River Basin Task Force, the Pembina River Basin Advisory Board and others.

4.2.3 Pembina River Basin Advisory Board

Like the RRBB, the Pembina River Basin Advisory Board (PRBAB) was established in 1997. However, the PRBAB has the more narrow focus of attacking flooding problems and associated issues along the Pembina River.

While it began as a group of individuals from the lower end of the watershed concerned about the flooding problem in their area, it soon came to realize that dealing with the problem was beyond their own abilities. They approached counties and municipalities upstream and discussions began. Membership includes representatives from counties, townships and municipalities, state and provincial governments and conservation districts and water management organizations throughout the basin.

The PRBAB is currently working toward the development of a water management plan for the basin. The Board has provided a valuable forum for the public presentation and discussion of new information on water management as it becomes available. As an example, the results of computer modeling of flood flows along the Pembina prepared on behalf of the International Red River Basin Task Force has been shared with the Board at public meetings. Scenarios proposed at those meetings have been incorporated into the model.

5.0 Conclusion

Flooding along the Lower Pembina River is as old as the river itself. In historic times, overland flows found their way according to the lay of the land. However, the intervention of humankind has altered this balance. Not only are the results of this action an issue between North Dakotans and Manitobans, but also between local groups living along the river within North Dakota itself.

Attempts over the years to solve the flooding problem have fallen short. Several studies have centred on the construction of flood control reservoirs upstream of Walhalla and/or floodway channels to shunt the runoff around vulnerable areas. While many still tout the construction of the Pembilier Dam as the solution, others continue to support the floodway concept. But, for a variety of reasons, none of these projects have come to fruition.

Tentative agreements have been reached concerning the amount of water that should be allowed through the road/dike at the International Border, but for the most part, these have not been implemented largely because of an inability to come to an agreement on sharing the costs of such an undertaking.

But in spite of its volatile history, we appear to be closer to solving the problem than ever before. With the support and leadership of the International Joint Commission's International Red River Basin Task Force, activities have been implemented to provide local people with new, valuable information to allow them to make informed decisions. Examples include updated, modern topographical information for the valley, detailed flood modeling data and a decision support system comprising a comprehensive database accessible to all.

The solution to the problem lies in communication, cooperation and compromise among those most affected. Local groups are poised to take control of their own destinies by opening the issue up to the people of the area. For example, the Pembina River Basin Advisory Board, armed with new information and a local commitment, is setting out to develop a comprehensive water management plan for the Pembina River Basin. Their efforts are to be applauded, encouraged and supported by local people, regional governments and senior governments alike.

Appendix A: Sources of Information Reviewed

Joint Investigation for Development of the Water Resources of the Pembina River Basin, Manitoba and North Dakota. Report to the International Joint Commission by the International Pembina River Engineering Board, December 1964. Volume I, Main Report; Volume II, Appendices A to L.

Cooperative Development of the Pembina River Basin. Report of the International Joint Commission, October 1967.

Pembina River Basin: Review of Existing Water Resource Development Proposals. Province of Manitoba, Manitoba Water Commission. July 1973.

Report Concerning Drainage in the Aux Marais and Walhalla-South Buffalo Basins. Canada/United States Ad Hoc Water Resources Committee, December 1973.

International Boundary Drainage. A 32-page compilation of information gathered from the North Dakota State Water Commission files from 1944 to 1974. Prepared by C.P. Nelson, Drainage Engineer, ND SWC. January 1975(?)

Pembina River, North Dakota: Feasibility Report for Flood Control and Related Purposes. United States Army Corps of Engineers, March 1976. Main Report; Appendices under separate cover.

Report on Drainage in the Aux Marais Drainage Basin and the Walhalla-South Branch of Buffalo Lake Drainage Basin. Canada/United States Flood Control Review Committee, August 1976.

Pembina River, North Dakota: Phase I General Design Memorandum and Final Supplement to the Final Environmental Impact Statement for Flood Control. United States Army Corps of Engineers, September 1983.

Assiniboine South - Hespeler Area Study: Canada/Manitoba Interim Subsidiary Agreement on Water Development for Regional Economic Expansion and Drought Proofing. Appendix B: Engineering. Prairie Farm Rehabilitation Administration, Agriculture Canada, February 1987.

Aux Marais and Walhalla/South Branch of Buffalo Lake drainage basins - A Chronicle of events. A point-form chronicle of the major events occurring in the area including the dates of various meetings, reports and other activities from 1971 to 1997. Author unknown.

Status - International Technical Working Group. A 9-page report describing the activities of the group; includes meeting notes and action items. Author Unknown. June 26, 1997.

Studies Review for Pembina River Sustainable Water Supply Development(s) and the Impacts of Such Development(s) on Flooding in the Red River. (Draft Report) Acres International Limited for the Lower Red River Valley Water Commission (Manitoba), July 1999.