LOWER PEMBINA RIVER FLOODING

A REPORT TO THE INTERNATIONAL RED RIVER BOARD

R. HALLIDAY
R. BOWERING
R. GJESTVANG

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EXECUTIVE SUMMARY

There is a long history of transboundary flooding issues on the lower Pembina River between North Dakota and Manitoba. The IJC in its report *Living with the Red* acknowledged the long-standing unresolved problem and recommended federal, state and local governments work cooperatively to achieve a solution.

There have been a number of changes in the situation since the IJC report was prepared. These include removal of dikes along the Pembina River deemed illegal, enhancement to South Buffalo Coulee drainage, and further modelling of the lower basin. However, the various entities have not yet been able to reach a solution to this long-standing problem.

In July 2003, the Pembina River Basin Advisory Board (PRBAB) requested the assistance of the International Red River Board (IRRB) to help resolve the issue. As a first step in responding, the IRRB requires a situation analysis report including recommendations for strategies for moving towards a resolution. As a means of preparing the situation analysis a three-person study team was established. The Study Team comprised Rick Bowering, appointed by Manitoba, Randy Gjestvang, appointed by North Dakota and Robert Halliday, whose services were contracted by the IRRB Secretariat.

The key to making progress on resolving the lower Pembina problem is to determine solutions that are deemed to be fair and equitable and that are locally acceptable. At the same time these solutions must be affordable. Part of the study teams activity has been to examine issues that may or may not be important to the basic problem exemplified by the road-dike. Many past studies, however, simply developed an improved statement of the problem rather than solutions. There has also been a perception in the past that the solution lay in major multi-purpose dams on the Pembina River. This perhaps diverted attention from other possibilities.

Based on this investigation, there are three potential components to any solution to lower Pembina flooding. The first is to flood-proof urban centers and rural buildings to a specified flood protection level, most likely the 100-year flood. To a considerable extent, this is the current situation. In effect, this flood-proofing transforms the problem to one of farmland and rural infrastructure protection.

The second component would be set-back levees along the Pembina River from County Road 55 west of Neche to the confluence with the Tongue River. Based on current information such levees could be designed to protect farmland against summer floods due to Pembina River overflows and to provide some protection against spring floods. Detailed hydraulic modeling would be required to determine levee alignment and a feasible level of protection. The city of Pembina will also need assurances that its flooding problems are not made worse by the levees as will landowners that farm near the city of Pembina.

The third component would be adjustments to the openings in the road-dike and County Road 55 and to drainage systems to accommodate natural flows. The underlying philosophy may be to accept some break-out flows from the Pembina River, but to modify drainage systems by increasing culvert and channel capacities to allow water to drain as quickly as feasible.

In the conduct of its work the Pembina Study team drew the following eight conclusions.

1. The Pembina Study Team concludes that the feasibility of a binational multipurpose water project in the Pembina basin that would include flood control storage is sufficiently in doubt that this should not form part of consideration of solutions to the lower Pembina problem. Other more immediate measures aimed at reducing flood damages in the lower Pembina basin need to be examined.

2. The Study Team supports a U. S. federal project that will provide Neche with one-hundred year flood protection provided that it is locally acceptable and meets engineering, economic and environmental tests.

3. The Pembina Study Team concludes that, because of breakouts on both sides of the Red River, any flow constriction caused by bridges, railways and roads in the Emerson area does not have a major effect on water levels at Pembina. During very high flows such as in 1997 water breaks out of the main channel and continues flowing north on either side of these channel restrictions. Any increased water elevation would have been incorporated into the design elevation for the city of Pembina ring dike but raising the road-dike in the Red River overflow area has the effect of further constraining Red River break out flows thereby potentially affecting the flood protection level at the city. Further modeling is required to determine the individual and combined effects of roads, railways, bridges and dikes.

4. The Pembina Study Team concludes that the effect of upstream urban flood mitigation works, at Grand Forks for example, on water levels downstream at Pembina is negligible.

5. The Study Team concludes that the city of Pembina currently has 100-year flood protection, provided that the levee is maintained. The precise flood protection level, which should include allowance for freeboard, should be verified first by determining an agreed-on 100-year flood and then performing hydraulic analysis. The Study Team notes that the city of St. Vincent may require further enhancement of it flood protection to meet federal standards.

6. The Study Team concludes that the degree of rural flood-proofing in the lower Pembina basin (North Dakota) needs improvement. Once the appropriate flood protection level is determined, this should be pursued.

7. A review of crop insurance claim history may clarify the summer flood situation, but the Pembina Study Team draws the preliminary conclusion that agricultural impacts of Pembina River flooding are more often the result of protracted spring runoff than of summer rain storms. Summer flow peaks appear to be controllable to a considerable extent by set-back levees. Such levees, while they would constrain summer break-out flows, would not prevent damages from very heavy rains that fall directly on the land and that are unable to run off quickly.

8. The Pembina Study Team concludes that natural agricultural flows, break-out flows from the Pembina River, and the effects of present infrastructure can all be examined through use of a detailed hydrodynamic model. Further, the effects of mitigation measures such as set-back levees and modifications to bridge and culvert openings can be determined through use of such models.

In order to move ahead on resolving this long-standing problem, the Pembina Study Team makes the following recommendations:

1. *That the Pembina River Basin Advisory Board members appointed to liaise with the IJC's International Red River Board review this report and develop a position on its findings.*

2. *That the IRRB facilitate a process to determine next steps in resolving this problem. Part of that process will be to work with the PRBAB and other interested parties to determine what could be considered an acceptable level of agricultural flooding as that will drive the design of any mitigation measures.*

3. *That government agencies having responsibilities in this geographic area continue to fund programs and studies identified in this report that will help lead to a solution. One small but essential task would be to verify the current location and dimensions of all the crossings of the road-dike.*

4. *That the IRRB lend its support to a USACE planning study, perhaps under the U. S.* Flood Control Act*, that will define the details of a solution. Such a study would include:*

    - *determination of natural flows and drainage patterns in the lower Pembina basin*
    - *designing flood protection measures at Neche (underway under Section 205)*
    - *confirming flood protection levels at Pembina and St. Vincent and identifying a plan to correct deficiencies, if any*
    - *identifying the nature and extent of agricultural damages*
    - *expanding the accurate digital elevation model*

- *developing a detailed hydrodynamic model for the lower basin*
- *identifying desirable changes to east-side Red River overflows such as modifications to openings in the railway embankments*
- *designing set-back levees for the lower Pembina River*
- *designing engineered overflows of the road-dike and changes to land drainage to accommodate agreed-on flood flows*

5. *That relevant agencies be prepared to participate in such a study and to contribute to the funding of solutions.*

6. *That lower basin residents who have experienced flooding problems for a lifetime continue to work together with responsible agencies to determine equitable solutions.*

Considering that urban communities in the study area have, or soon could have 100-year flood protection, the resolution of this long-standing problem requires two other elements: rural flood-proofing to the extent practicable including adjustments to the openings in the road-dike and other relevant roads in the study area, set-back levees along the Pembina River. The adjustments to openings could include changes to Crossing 6, engineered overflows to accommodate overbank flows of the Red River, changes to openings in some North Dakota roads, and improvements to drainage downstream of the openings. Detailed study would be needed to determine the precise design.

While there is some acceptance of a resolution of the problem along these lines, concern has been expressed that all three components should proceed together. That is, persons in the city of Pembina area do not wish to see the set-back levees proceed ahead on adjustments to the road-dike. There is also a continuing interest in upstream storage in the longer term.

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INTRODUCTION

There is a long history of transboundary flooding issues on the lower Pembina River between North Dakota and Manitoba. Appendix 3 in this report summarizes the problem, including a discussion of the road/dike along the International boundary. The International Joint Commission (IJC) in its report *Living with the Red* (IJC, 2000) acknowledged the long-standing unresolved problem and recommended federal, state and local governments work cooperatively to achieve a solution. There have been a number of changes in the situation since the IJC report was prepared. These include removal of dikes along the Pembina River deemed illegal, enhancement to South Buffalo Coulee drainage, and further modelling of the lower basin. However, the various entities have not yet been able to reach a solution to this long-standing problem.

In July 2003, the Pembina River Basin Advisory Board (PRBAB) requested the assistance of the International Red River Board (IRRB) to help resolve the issue. As a first step in helping to respond, the IRRB requires a situation analysis report including recommendations for strategies for moving towards a resolution. As a means of preparing the situation analysis a three-person study team was established. The Study Team comprised Rick Bowering, appointed by Manitoba, Randy Gjestvang, appointed by North Dakota and Robert Halliday, whose services were contracted by the IRRB Secretariat. The study team met twice with representatives of the PRBAB and others. For the most part its work was conducted by email and telephone. The Study Team's terms of reference and work plan is appended to this report as Appendices 1 and 2, respectively.

This report includes background material related to the history of the problem in Appendix 3 and describes major studies of multipurpose water projects and their current status. It describes the current issues related to lower Pembina River flooding, gives their status and, in some cases, a conclusion of the Study Team. The report describes mitigation measures related to lower Pembina flooding and concludes with a statement of further work requirements needed to achieve a fair and equitable solution to this long-standing problem.

For the most part the report uses imperial units and American spelling. Both American and Canadian dollars are used. At the time of writing, one Canadian dollar was equivalent to about US $0.78.

Background

This section contains a brief description of the Pembina River basin and of flooding in the basin. It is adapted from material originally prepared by Beaverbrook Communications for the IJC as part of the IJC study of Red River flooding (IJC, 2000). Because of the significant role of computer models in understanding floods and resolving flood-related issues in the lower Pembina River, the section also contains a short discussion of hydraulic models. As indicated in the Introduction, Appendix 3 contains a historical overview of the dispute.

Basin Description

Plate 1 at the end of this report depicts the water features, political boundaries, and principle communities of the Pembina River basin. The Pembina River rises in Manitoba on the northeastern slope of Turtle Mountain, about 10 miles south of the town of Boissevain, Manitoba. Turtle Mountain straddles the U.S. - Canada boundary between Boissevain, MB and Bottineau, ND. From there the River flows in a generally easterly direction until it joins the Red River at Pembina, ND, about two miles south of the International Boundary.

The total area of the watershed is about 3950 square miles, divided nearly equally between Manitoba and North Dakota. The length of the Pembina River basin from west to east is about 130 miles as the crow flies, although the winding river channel itself is about 310 miles long. The River drops from about 2000 feet above sea level at its source on Turtle Mountain to about 790 feet at its confluence with the Red River.

The watershed has two distinct topographical regions that are separated by a prominent ridge known as the Pembina Escarpment. (The Pembina Escarpment formed the western margin of glacial Lake Agassiz.) The Escarpment extends in a line from just west of Morden, MB across the International Boundary continuing southeastward past a point immediately west of the town of Walhalla, ND. To the west of Walhalla the Escarpment rises abruptly 500 to 600 feet above the plain to an altitude of about 1500 feet.

The entire Manitoba portion of the Pembina River watershed lies upstream of the Pembina Escarpment. The River leaves the Turtle Mountains, 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 deep and two miles 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 deep and a mile or more wide) until it crosses the International Boundary about 15 miles northwest of Walhalla, ND, near the community of Maida, ND.

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 River a few miles west of Walhalla, ND. The Little South Pembina River also joins the Pembina River in the same vicinity; Mount Carmel Dam is on this branch.

Near Walhalla, the River emerges from the Pembina Escarpment and onto the former Lake Agassiz lakebed. Over the next 15 miles downstream from the Escarpment, the valley gradually disappears until near Leroy, ND the River is at the same level as the surrounding plain, or slightly higher, confined by natural levees built up over centuries of flooding. The streams adjacent to the lower Pembina River basin such as the South Buffalo and Aux Marais begin near the northern fringes of the basin and flow northward ultimately becoming Red River tributaries in Manitoba. The study area for this report shown in Plate 2 includes the portion of the basin that is entirely within Pembina County in North Dakota and adjacent areas in the Plum River/Aux Marais basin north of the Pembina basin, including portions of Manitoba in the Rural Municipalities (RM) of Stanley, Rhineland and Montcalm.

Flooding

Floods are a natural and common occurrence along the entire length of the Pembina River. But of the 310 miles of River channel, the most significant and devastating flooding occurs along the 35-mile reach between the toe of the Pembina Escarpment near Walhalla, ND and the Red River. This area is highly susceptible to flooding because of the flat terrain. 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. Double peaks occur on account of the different timing of upper basin and lower basin runoff. Summer floods, smaller than the spring floods, may occur in July and August on account of heavy rains.

The natural capacity of the Pembina River at Walhalla is about 4,000 cfs. Channel capacity near Neche, about 20 miles downstream of Walhalla, is slightly less at about 3500 cfs. Because of the loss to overland flow during floods and attenuation of the flood wave, recorded peak flows on the main channel at Neche are lower than at Walhalla.

Since the river bed in the vicinity of Neche is at, or slightly below, the elevation of the land around it, flood flows breaking out of the main stem of the Pembina River move naturally overland into the Tongue River watershed to the south, or into the Aux Marais basin on the north, and into Manitoba. With the current infrastructure in place, much of the breakout flow is forced to flow to the east. Natural levees built up along the river channel over centuries of flooding also impede the movement of floodwater back into the channel.

Year	**Peak Flows in cfs at**	
	Walhalla	**Neche**
1997		14,300
1950	13,800	10,700
1974	13,300	10,300
1970	7,810	9,600
1979	8,610	9,500
1995		8,500
1998		7,620
1996		7,500
1969	8100	7,360
1971	9320	7,350
1970	7810	7,070

Table 1 - Pembina Floods after 1950
(adapted from IRRBTF, 2000)

Because of the well-defined channel and associated valley, Pembina River 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 and 1916, while the flood in 1904 is documented in the instrumental record. In the latter half of the 20th century, several other significant floods have occurred on the Pembina River downstream of the escarpment. These are displayed in Figure 1.

Statistical analysis performed by the U. S. Geological Survey for the Pembina River at Walhalla define the 5-year flood as being 2910 cfs, the 10 year as 9,590, the 25-year flood as 15,800, and the 50-year flood as 21,600. The 100-year and 500-year floods are calculated as 28,400 and 48,800 cfs respectively. (SWC, 2000) That is, the 4000 cfs channel capacity is less that the 10-year event.

Flood frequency analysis was performed by the USACE in 1999 using instantaneous peaks at the break-out point upstream of Neche. On that basis the 5-year flood was 3980 cfs, the 10-year, 6240, and the 100-year, 17,800.

Figure 1 depicts the mean and median hydrographs for the Pembina River at Neche based on the entire period of USGS record to 2002. (The mean is the arithmetic average of all the values for each day while the median is the flow on any given day that would occur 50 percent of the time.) The illustration obtained from a Canadian website is in metric units, that is m^3/s. The break-out flow of some 100 to 115 m^3/s is beyond the range of the chart. There are indications of the characteristic double spring peak, the result of runoff from the lower basin then the upper.

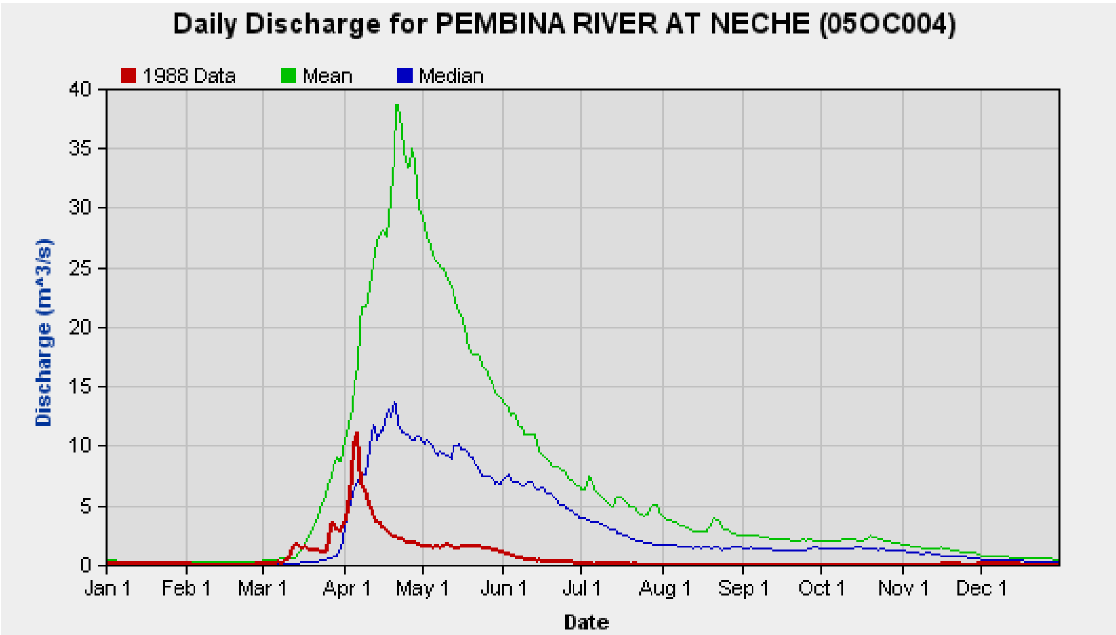

Figure 1. Pembina River at Neche, Average and Median Flows. (courtesy Water Survey of Canada)

In 1950, the Manitoba Drainage Maintenance Board estimated that more than 36,000 acres of agricultural land was flooded in this area by the Pembina River. In North Dakota in 1950, an estimated 96,500 acres was flooded between Walhalla and the mouth of Pembina, including the area flooded by the Tongue River. By comparison, 36,100 acres were flooded in 1997.

Flood damages result from direct economic losses such as damage to buildings and infrastructure, in addition to many intangibles such the threat to human life, human misery, community disruption and threats to the quality of water supplies. Agriculture suffers in several ways; through damage to buildings, losses of stored grains and other products, and loss or damage to stored agriculture input products; and also through the loss of valuable topsoil through erosion, sedimentation or salinization. In addition, crop seeding may be delayed (or lost altogether), resulting in lower yields at harvest. 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 floodwaters.

The 1997 flood was 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 was recorded at Neche as runoff from the lower portion of the basin passed. After dropping to 10,000 cfs, three days later the peak rose again, this time to the record 14,300 cfs 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 second peak on the Pembina and that of the Red at the confluence of the two rivers coincided almost exactly. (The peaks are typically within a week or so of each other.) 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 flow was reversed until it joined overland flow from the Red and moved northward west of Interstate 29 and across the International Boundary and into Manitoba.

Above Leroy (midway between Wahalla and 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. Some water did break out to the north a few miles upstream of Neche in the area near Hyde Park Cemetery. A small amount of this water trickled through the crossing just east of Crossing 4. Additional breakout flows to the north occurred just upstream of Neche. The road/dike was slightly overtopped near Gretna. North Dakota Highway 18 was cut near the border to allow this flow to continue east. However, below Neche, the river broke out of its banks and moved south and north, before being forced east. On the south flows were contained by County Road 55 and redirected back towards the river further downstream. From there, the flows backed into the Tongue River area, or continued overland until they met with overland flows from the Red River.

To the north, flood water moved overland until it met the International Boundary and the road/dike in Manitoba adjacent to the boundary. There flood water accumulated until spilling 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. However, the failure was more likely the result of combined overland flooding from the Red River and the Pembina River, rather than the Pembina itself. Following the flood, Canadians repaired the road/dike.

Figure 2 shows the road-dike area in 1997. Neche and Pembina, ND can be seen directly below the words Gretna and Lynne. The international boundary is marked in red and green. Pembina County Road 55 is parallel to the boundary nearly due west of the city of Pembina.

Communities of interest in the study area in the Pembina River basin are Walhalla, Leroy, Neche and Pembina. Communities in the Tongue River basin include Concrete, Akra, Backoo, Bathgate, Hamilton, and the county seat, Cavalier.

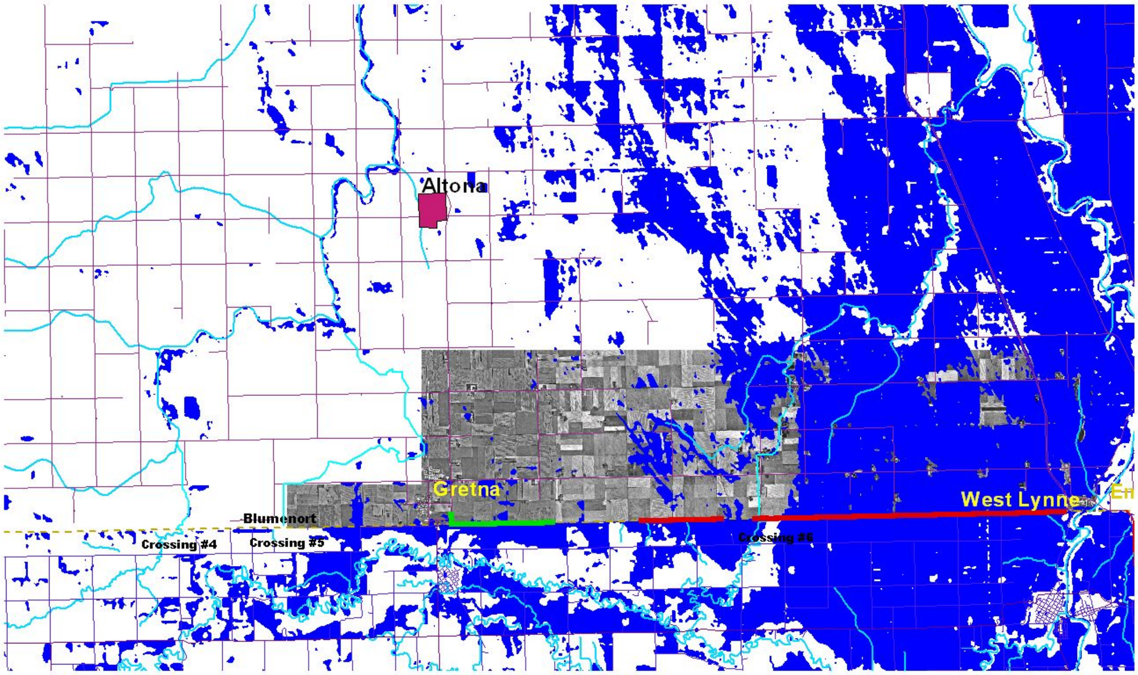

Figure 2. Lower Pembina River in 1997 (courtesy Manitoba Water Stewardship)

Numerical models

It will be evident to readers of this report that the study team places considerable reliance on the use of computer models (or numerical models - as opposed to physical models) in moving forward on obtaining solutions to the lower Pembina River flooding problem. The models of interest are hydraulic models that are used to determine the characteristics, such as depth and velocity, of water flowing over the land.

Hydraulic models may be used to represent open channel flow and depend on the solution of the Saint-Venant equations of continuity and momentum. Solution of these equations can be simplified if it is assumed that flow is steady, that is, there is no flood wave and that flow is one-dimensional. The model that for many years represented the "gold standard" of steady flow models is the USACE's HEC-2. This model was widely used in American and Canadian flood damage reduction studies, particularly in urban areas, in the Red River basin to calculate water surface profiles for selected floods.

Under certain conditions the assumption of steady flow is clearly incorrect and more rigorous solutions of the equations of open channel flow are needed. There are needs for models that are able, for example, to simulate:

- passage of a flood wave through complex topography and structures
- flow over road and railway embankments
- flow and storage changes related to new structural measures or modifications to existing structures
- dividing flow among overland flow corridors
- flow reversals and
- changes in water levels caused by sustained wind

Models that can perform these tasks are known as hydrodynamic or unsteady flow models. Most commonly, one-dimensional models are used but for some applications such as analyzing wind effects, two-dimensional models are used. Several one-dimensional hydrodynamic models exist. In general their differences lie in the computational algorithm used to solve the Saint-Venant equations. Also of interest in comparing models are the way in which they handle situations such as road overflows and break-throughs, flow through culverts, flows through submerged bridges, or strong winds. Of particular interest for this study are the Danish Hydraulics Institute's Mike-11, and the USACE's HEC-RAS Unsteady.

HEC-RAS (River Analysis System) is the first of the USACE's Hydrologic Engineering Center's Next Generation Software programs. This Windows based water surface profiles program will replace HEC-2, UNET and HEC-6 programs. HEC-RAS can operate in both the steady state and hydrodynamic mode and has been widely used in the Red River basin in steady state applications. (The UNET (Unsteady NETworks) model is a one dimensional unsteady flow model that was used to model the Red River main stem in the United States during the IJC studies. HEC-6 may be used to simulate scour and erosion in channels and reservoirs.)

During the IJC studies, a Mike 11 model of the lower Pembina River was developed by Water Management Consultants (WMC, 2000) and used to help the IJC frame its recommendations concerning the Pembina River. The model was subsequently turned over to the government of Manitoba, as it is a licensed user of Mike-11. (The IJC also funded development of a Mike-11 model of the Canadian portion of the Red River mainstem.) One of the key requirements of a model used in determining flow paths over the landscape is accurate topography for use in a digital elevation model. The IJC funded the topographic surveys of the lower Pembina basin using technologies known as Lidar and IFSAR (Bourget, 2004). The Lidar topography has proved very useful but unfortunately does not cover the entire area of interest.

Since the IJC study, the Red River Basin Commission has contracted with Water Management Consultants who developed the original Mike-11 models for the IJC to develop a Mike 11 model of the entire Red River mainstem from Lake Traverse to St. Jean Baptist, Manitoba and HEC-RAS Unsteady from Fargo to St. Jean. With previous modeling, this would mean that Mike 11 and HEC-RAS Unsteady models are available from Lake Traverse to Breezy Point, near Lake Winnipeg. As well, the North Dakota State Water Commission has been developing a HEC-RAS Unsteady model of the lower portion of the Pembina River. Also, the Minnesota Department of Transportation contracted with Water Management Consultants to further analyze the Red River overbank flows in the vicinity of Minnesota Highway 171 using Mike-11.

PEMBINA RIVER FLOOD CONTROL PROJECTS

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 water management project could not be justified economically unless both countries participated in the project. Initial bilateral investigations took place under the auspices of the IJC's International Souris-Red Rivers Engineering Board and, in 1962, the IJC issued a directive pursuant to a 1948 Reference establishing an International Pembina River Engineering Board to conduct technical investigations and studies pertaining to a cooperative development of the Pembina River basin.

In October, 1967, after considering recommendations made to it by the Board (IPREB, 1964), the International Joint Commission (IJC) recommended to the governments of Canada and the United States the construction of a combination of two reservoirs to provide flood control, irrigation and water supply to both the Manitoba and North Dakota portions of the Lower Pembina Basin (IJC, 1967). The Pembilier damsite is located in the United States immediately upstream of Walhalla and would provide 110,000 acre-feet of flood storage. The Pembina damsite is upstream of Windygates, MB and the proposed reservoir would be used entirely for irrigation and water supply. At that level of study, the cooperative project met economic tests, based primarily on irrigation benefits.

The IJC studies also examined various combinations for increasing storage in the upper Pembina basin in Canada. Concepts included dams at the outlet of Rock Lake or Swan Lake or low-head dams on both.

Since implementation of the 1967 IJC proposal was being delayed, the U.S. Army Corps of Engineers 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.

In its 1976 report, the Corps recommended the construction of a larger version of the Pembilier dam than had been suggested in earlier studies. 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.”*

During its investigation, the Corps also examined the feasibility of constructing a floodway to provide a certain degree of flood protection to the area downstream of Walhalla. One option, a 3,500 cfs diversion from three miles east of Walhalla, north to the International Boundary then east to the Red was considered to be marginally economically feasible. However, it was not acceptable to the local people for a variety of reasons and in the end, the report chose the Pembilier dam and reservoir as the most acceptable approach to flood control for the area.

Other actions in the 1970s included the Canada-U.S. Water Resources Committee, which reported in 1973 and the subsequent 1976 review by the Flood Control Review Committee. The work of these two groups is described in Appendix 3 and pertained specifically to issues concerning the road-dike.

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

In 1983, the Corps revisited its 1976 findings. The drainage area contributing to the project and the probable maximum flood were larger than calculated in 1976. Costs were higher and benefits lower. The study also examined a number of other flood control options and finally selected a 21-mile long floodway from point six miles west of Neche to the Red River as the most feasible plan. It had a positive benefit/cost ratio. This new proposal suggested the diversion point be located immediately upstream of Neche and that the capacity would be 2,000 cfs. However, local 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 being provided, inconvenience to farmers with land on either side of the channel and the lack of water supply and recreational opportunities. Out of the 31 official responses received on the report, only eight supported the floodway plan and 19 supported the construction of the Pembilier dam as the only acceptable solution to flooding in the area.

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. As part of the study, the feasibility of a dam on the Pembina River near Kaleida - the same site identified by the IJC - was considered. However, the relatively high cost of the project was a major drawback and the Pembina dam option was not pursued further by PFRA.

In the early 1990s Manitoba constructed the Pelican Lake Enhancement Project to improve recreational opportunities on Pelican Lake. A weir on the Pembina Rivers allows water to be diverted through a canal into Pelican Lake and an outlet canal and structure allows water to be moved from the Lake to the Pembina River to lessen the fluctuations in the lake’s levels. The inlet canal follows the route of the original channel dug in 1919 and the outlet canal follows the natural channel. Rock Lake, downstream of the Pelican Lake outlet, has a stop-log equipped, rock-crib weir on its outlet to maintain water levels for recreation.

The effects of the Pelican Lake diversion on Rock Lake and downstream were modeled (Blais, 1995) using historic flows from 1969 to 1988 and found to be insignificant. The largest average calculated difference in water levels at Windygates on the Pembina River in any year was a decrease of 0.044 m, less than 0.2 ft. The effect of the project under current operating rules on the lower Pembina would be negligible. Operating the project to provide any flood control benefit would compromise its lake stabilization purpose. Even so, the flood control benefit of the project in the lower Pembina would be minor.

Another evaluation of reservoir construction on the Pembina pertaining to water supply and flood protection in both countries was conducted in 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”.

Acres considered four options: a no project base case plus three projects discussed in previous reports - the Pembilier dam and Reservoir (USACE, 1983 Plan 1), Pembina dam (PFRA, 1964/1987) combined with the Boundary Floodway (USACE, 1983 Plan 5), and the smaller Pembilier dam and Floodway (USACE 1983 Plan 8). The study reviewed technical aspects of the projects such as hydrology, flood protection potential, water supply potential, and capital costs. It also examined environmental matters related to the projects and the benefits and costs of the various options. The benefit-cost ratios for the three options were found to be 0.77, 0.65 and 0.74, respectively. (Acres 2001)

The benefits examined related to municipal water supply, irrigation benefits in each country, and flood damage reduction. Benefits related to water-based recreation were not defined. Since the completion of the Acres study significant efforts have been taken to flood proof Red River valley communities and rural dwellings in Manitoba. The flood damage reduction benefits of Pembina dams for the Red River valley in Canada would therefore be reduced. These benefits comprised 5 to 10 percent of project benefits.

At about the same time the North Dakota State Water Commission examined alternatives for additional storage in the Pembina basin. These included depression storage, Pembina dam, Pembilier dam, and Rock and Swan Lakes. The degree to which each alternative could control Pembina flooding was determined. The review concluded that a single purpose project for flood storage does not appear feasible, but left the door open for a multipurpose project based on municipal supply, irrigation, recreation, and other needs. It was not optimistic of such a project meeting benefit-cost tests, however (SWC, 2000).

The Pembina Study Team concludes that the feasibility of a binational multipurpose water project in the Pembina basin that would include flood control storage is sufficiently in doubt that this should not form part of consideration of solutions to the lower Pembina problem. Other more immediate measures aimed at reducing flood damages in the lower Pembina basin need to be examined.

STATUS OF ISSUES

In consultation with the Pembina River Basin Advisory Board, the Study Team reviewed current issues related to Pembina River flooding. In particular this review was aimed at updating information contained in the IJC studies conducted from 1997 to 2000.

The Road-Dike

As indicated in Appendix 3 the road-dike and the origin of flood waters along the international boundary is the crux of the dispute between the United States and Canada over lower Pembina flooding. The road-dike was constructed over many decades along much of the international boundary from west of Wahalla to the Red River, some 32 miles. In 1971 a federal-state-province Water Resources Committee was struck to examine the issue. The Committee made a report in 1973 recommending that the South Buffalo and Aux Marais crossings 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.

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 reviewed the Water Resources Committee recommendations and submitted its report in August 1976. Only the first recommendation from the 1973 report was revised - the section describing the amount of flow crossing the border. An agricultural drainage standard of a one in eight-year summer flood was applied to the stream crossings of the international boundary.

Six drains exist along the boundary from a point six miles west of Walhalla to the Red River. These have also been referred to as outfalls, or crossings. From west to east these are identified in Table 2. All flow north to Manitoba.

Crossing	Location (MB)	Location (ND)	Description
1	Section 2-1-5W	S28-T164N-R57W	about 3 miles southwest of

			the community of Hasket, Manitoba
2	Section 6-1-3W	S26-T164N-R56W	about 1 mile south of the community of Rosengart, Manitoba
3	Section 4-1-3W	S30- T164N-R55W	about 3 miles east of Crossing 2
4	Section 5-1-2W	S30-T164N-R54W	about 1 mile west of the community of Blumenort, Manitoba
5	section 3-1-2W	S28-T164N-R54W	2 miles east of Crossing 4, on the eastern edge of Blumenort.
6 (Aux Marais)	Section 4-1-1E	S30-T164N-R52W	6.5 miles east of Gretna, about midway between Gretna and the Emerson/Pembina border crossing.

Table 2. Location and Description of Crossings

Under a recent cost-sharing agreement between Manitoba and North Dakota, Crossing 3 has been enlarged to three 60-inch culverts from one 67-in. x 42 in. pipe arch plus a 30-in. culvert. Crossing 2 will be enlarged in 2004 from two 40-in. and one 70-in. culverts to four 60-in. culverts.

The Study Team was informed that one culvert in the road-dike has been crushed. This is likely a reference to a small culvert that was west of Crossing 2. As part of the upgrade to Crossing 2 this channel has been redirected to the Crossing 2 opening, and the old culvert closed.

The current capacities of the various crossings are shown in Table 3. Once the work on Crossing 2 is complete, these culverts will pass the 1:8-year natural flow originating in the United States but not overflows from the Pembina River.

Crossing	Location (Manitoba)	Design Flow	Openings
1	section 2-1-5W	350 cfs	Open channel

2 (South Buffalo)	section 6-1-3W	410 cfs	Four 60 in. culverts. Note 1
3 (South Buffalo)	section 4-1-3W	430 cfs	Three 60 in. culverts
4	section 5-1-2W	400 cfs	Note 2
5	section 3-1-2W	21 cfs	One 36 in. culvert
6(Aux Marais)	section 4-1-1E	270 - 280 cfs	One 36 in. and two 48 in. culverts, one 58 in. x 36 in. pipe arch. Note 3

Notes:

1. Scheduled for 2004, see details in text. Currently 2 - 65x40 in. pipe arch and 1 - 30 in. culvert
2. Crossing 4 is actually two crossings that are about 1500 feet apart. There are two culverts in the west channel (18 in. and 24 in.) and one 30-in. culvert on the east channel. The road crossings are low so high flows in both channels would pass over the road.
3. The 36 in. culvert is in poor condition. The top is bent down at the downstream end and the bottom is rusted through, also at the downstream end.

Table 3. Location, Design Flow and Dimensions of Road-Dike Crossings.

Irrespective of the apparent clarity of Table 3, there appears to be some ambiguity of the dimensions and status of the culverts in the road-dike as well as concerning those in a township road in North Dakota one-half mile south of and parallel to the international boundary.

It should be noted that Crossing 6, the most easterly of the numbered crossings, is to the west of Switzer Ridge. Aerial photos obtained in 1997 show that water pooled at this crossing and flowed over the Ridge into the Red River overbank flow area. This may have happened in 1996 as well. Local people also indicate that Red River overbank flows in 1997 may have crossed the Pembina River from the south and found their way to Crossing 6. Flows over Switzer Ridge and the role of Crossing 6 in conveying Red River water require further investigation.

One other concern may be the need to determine exactly what might be the transboundary flow paths prior to development of the road-dike. Pre-cultivation maps, based on surveys in the 1870s in the Canadian portion of the road dike area are available. A cursory examination of scanned copies of the original maps shows stream segments including the Buffalo and Aux Marais. Notes written on the original tracings indicate that the field notebooks provide more details on these dry watercourses and gullies (i.e. how deep the channel was and depth of any standing water). There are similar maps from the same era for the United States portion of the study area. Photocopies are understood to exist in the State Water Commission in Bismarck. A detailed review of the Canadian and American maps could be useful if there is a need to determine pre-cultivation flow paths although the level of detail may be insufficient

As indicated in Appendix 3, construction of a road along the boundary was underway in 1944. The study team learned from discussion with Sam Schellenberg of the PRBAB that there is evidence that there likely was not much of an obstruction to flow in the very early 1940s. It is clear from photos in McClelland (1996) that there was no semblance of a road-dike in 1939-40 in the area a few miles west of Emerson. An examination of aerial photographs from that era may be instructive in verifying flow paths and the status of the road-dike in those days.

One other concern is the need to document the current elevation of the road-dike. During the IJC studies of 1997 Red River flood, Lidar and IFSAR coverage of the lower Pembina River basin in the United States was obtained. The Lidar coverage followed the main stem of the river and did not include the boundary area while the IFSAR coverage was not accurate enough to be of value. Since the IJC study, however, Manitoba has obtained Lidar topography for the entire 1997 flooded area in the province. This coverage, obtained in 2002, includes most of the road dike from Blumenort (near Crossing 5) to the Red River and is shown in red and green in Figure 2. The information is available on the Manitoba Water Stewardship website. There is some local discussion concerning changes that may have been made to the road-dike since 1997. Work was carried out in the vicinity of crossings 2 and 3 and at the two breaches near Emerson following the 1997 flood. Nonetheless, the Lidar data, where it exists, is believed to document the current elevations along the boundary.

Combinations of Red River and Pembina River Flows

One of the technical challenges in the most easterly part of the lower Pembina River basin is to separate the effects of the Pembina River from those of the Red River. Figure 2 shows a plot of Red River flood peaks against those on the Pembina River at Neche. Typically the peak on the Pembina River is about 10 percent of that on the Red although it can be seen that high flows on the Red do not necessarily mean high flows on the Pembina and *vice versa*. Note that, although the 1997 flood was approximately a 100-year event on the Red, the 100-year flood on the Pembina is about 18,400 cfs, much higher than the 1997 peak of 14,300 cfs. As stated earlier, the channel capacity of the Pembina River is 3500 to 4000 cfs, depending on location.

Another factor related to the combined flows is the timing of the peak flows. The peak flows on the Pembina River typically occur within a week of peak flows on the Red. In a year such as 1997 when both peaks are significant, the combined effect must be determined.

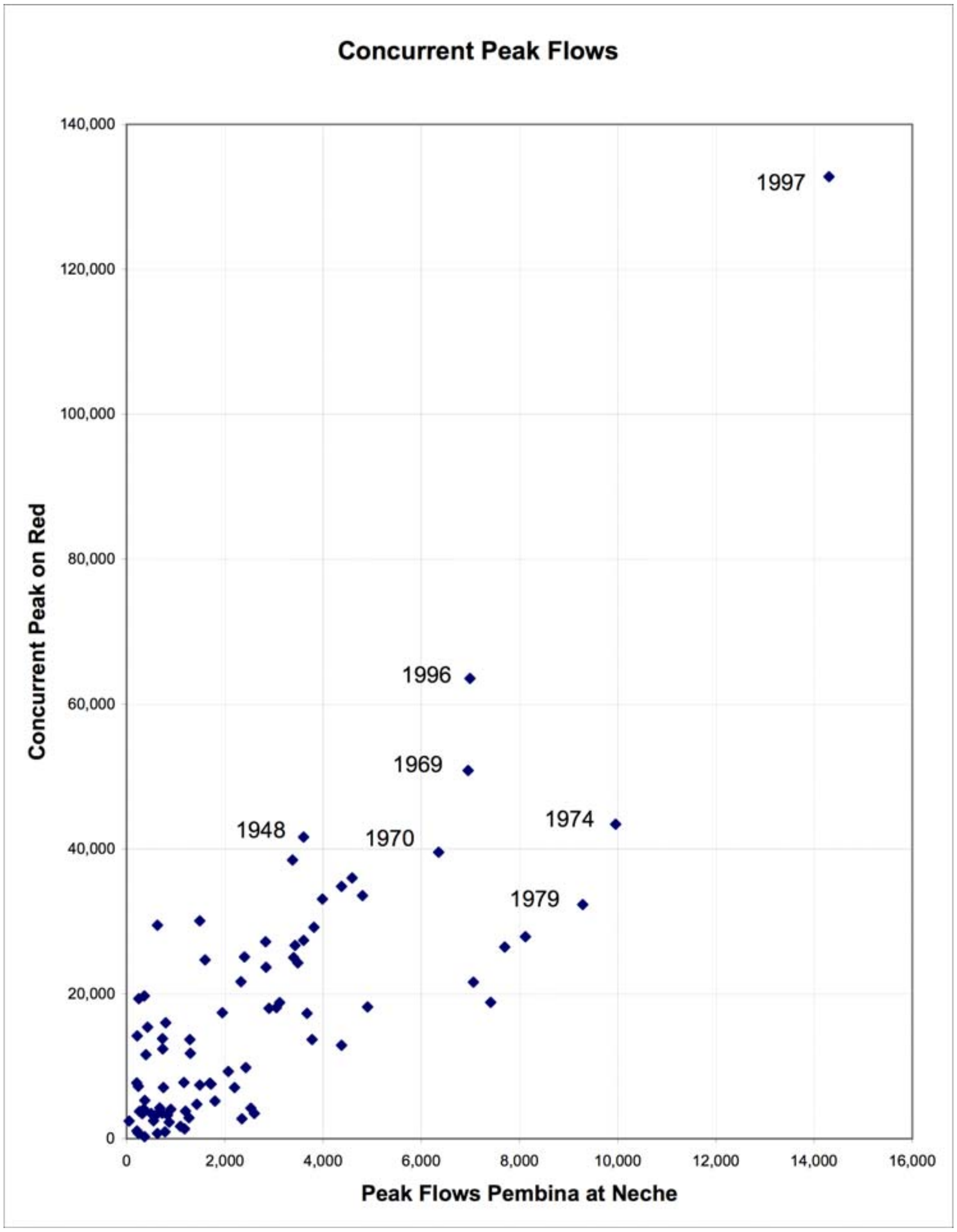

Figure 3. Red River Flood Peaks against Pembina River Flood Peaks in cfs. *(courtesy Manitoba Water Stewardship)*

A rudimentary examination of the situation during the IJC study demonstrated that Red River water levels governed lower Pembina flooding for some considerable distance away from the Red. The work was based on consideration of the 1997 Red River flood and a two-year flood on the Pembina River and a two-year Red River flood and the 1997 Pembina flood. At the city of Pembina the effect of reducing the Pembina River flow led to a water level reduction of a tenth of a foot. On the other hand reducing the Red River flood while maintaining the Pembina River flow led to a water level reduction of 17 feet. (WMC, 2000)

More modeling work can be done to further define this effect. It is evident that the proposed set-back levees would extend well into the area where Red River effects are dominant.

Lower Pembina Dikes

On account of a lawsuit, the dikes along the lower Pembina River were found by District Court, with an appeal to the ND Supreme Court in 2000, not to have the required State permit. All dikes from the city of Pembina to Leroy were removed during the period between 2000 and 2003. The only dikes remaining in the lower basin now are the ones at the city of Pembina, at Neche and a small private dike located upstream of Neche. The base case for future modelling of the basin should be the without dikes scenario.

Neche Dike

Neche is located on the right (south) bank of the Pembina River some 34 river miles upstream of the confluence with the Red River. The community is currently protected by a non-federal levee and a cutoff channel that bypasses the River loop closest to the city. The Corps of Engineers is proposing a protection project consisting of an earthen levee, interior drainage works and modifications to the bypass channel. A key requirement will be to examine the hydrology of the Pembina River to determine the current hundred-year flood. Plans and specifications are expected to be completed in fiscal year 2005.

This project is being developed as a small flood control project under Section 205 of the 1948 Federal *Flood Control Act* as part of the Continuing Authorities Program (CAP). Such projects have a federal funding limit of $7 million. Projects must have sound engineering, be economically justified and be environmentally acceptable.

The CAP is a group of legislative authorities under which Congress has given the Corps of Engineers the authority to plan, design, and construct certain types of water resource and ecosystem restoration projects without additional and specific congressional authorization. The purpose of CAP is to implement projects of limited scope and complexity. Each authority has specific implementation guidelines, total program and per-project funding limits, and cost sharing requirements.

The Study Team supports a U. S. federal project that will provide Neche with one-hundred year flood protection provided that it is locally acceptable and meets engineering, economic and environmental tests.

Emerson-West Lynne Choke Point

Emerson, MB and Noyes, MN on the east bank of the Red River are protected to the 1:100 level by a common dike. West Lynne on the west bank of the Red River is also diked to approximately the 1:100 level. Following the 1997 Red River flood, it was noted that there was a considerable change in slope in the water surface profile of the Red River in the vicinity of the international boundary. This indicates that there is a flow constriction or "choke point" in this area. The question that arises then is, is this steepening of the water surface profile at Emerson, MB a natural or man-made phenomenon?

This situation was modeled in part during the IJC studies (WMC, 2000). Additional detail was added to the Mike11 Red River model to examine the effects of road and rail bridges and dikes in the area. The 1997 flood was then modeled with and without the Pembina traffic bridge and without the Emerson traffic and rail bridges in place. The difference in water levels in the reach from Pembina to Emerson with and without bridges was less than a tenth of a foot.

Similarly the model was run with and without the Emerson-West Lynn and Pembina dikes for 1997 flows. Removal of the Emerson-West Lynn dike reduced water levels upstream by about a tenth of a foot. When the West Lynne dike was made permanent after the 1997 flood the alignment was modeled to ensure that there was no increase in upstream water level. Removal of the Pembina dike within the computer model reduced upstream water levels by 0.4 ft.

Of the manmade features in the vicinity of the international boundary, those that constrain breakout flows on either side of the Red River are most likely to cause increased water levels at Pembina, ND. On the east side of the River, breakout flows first cross Minnesota Highways 171 and 75 as weir flow then flow through railway bridges on the Burlington Northern and Soo lines. These railway crossings appear to have been designed to accommodate local flows, not overbank flows from the Red River. USACE and FEMA (2003) indicate a 0.75 increase in water levels due to constrictions on the east side of the River and indicate more study is needed. This could be done using a hydrodynamic model that incorporates improved typography.

On the west side of the Red River overbank flows encounter the road-dike. In 1997 the dike was breached in two places between Switzer Ridge and the River. The effect of closing off these breaches was modeled (WMC, 2000) and found to lead to a one-foot increase in water level west of Pembina.

The Pembina Study Team concludes that, because of breakouts on both sides of the Red River, any flow constriction caused by bridges, railways and roads in the Emerson area does not have a major effect on water levels at Pembina. During *very high flows such as in 1997 water breaks out of the main channel and continues flowing north on either side of these channel restrictions. Any increased water elevation would have been incorporated into the design elevation for the city of Pembina ring dike but raising the road-dike in the Red River overflow area has the effect of further constraining Red River break out flows thereby potentially affecting the flood protection level at the city. Further modeling is required to determine the individual and combined effects of roads, railways, bridges and dikes.*

City of Pembina Ring Dike

The Pembina Flood Control Project protects the city of Pembina, north of the Pembina River. The project comprises a ring dike consisting of an earthen levee and concrete floodwall designed to achieve a flood protection level that exceeds the 100-year flood, provided the project is adequately maintained and floodplain encroachments are limited. The elevation of the upstream end of the floodwall is 797.8 and that of the downstream end is 796.8. That is equivalent to a project flood of 151,000 cfs with a freeboard of two feet, greater than the 133,000 cfs peak during 1997. Emergency measures were undertaken in 1997 to reduce the risk of dike failure.

The federally designed and constructed project has been transferred to the community for operation and maintenance. On the basis of recommendations arising from an inspection by the Corps, the city of Pembina will be performing some maintenance to both the floodwall and the earthen levee later in 2004.

The hydrology and hydraulics of the Red River have been updated, to account for the recent flood events (USACE and FEMA, 2003). The results of this work determined that the 100-year flood flow at Emerson, MB was 117,000 cfs and the 500-year flood was 176,000 cfs. The elevations at Pembina for the 100- and 500-year floods are about 794 and 796 feet, respectively. Workshops were held to discuss the results of this study but final agreed flood levels have not been promulgated. Following the 1997 flood the province of Manitoba also examined flood frequency calculations. The province determined that the 100-year flood at Emerson was 132,000 cfs.

Although there are some uncertainties related to the precise flood protection level of the federal project at Pembina, the Corps advises that, under current conditions and provided maintenance is performed as required, the flood protection level under current conditions is between 1:100 and 1:500.

South Pembina on the opposite side of the River has an earthen levee that was not removed following the 1997 flood. The levee, which was overtopped in 1997, provides some protection, now primarily for recreation facilities and heritage sites.

The Study Team concludes that the city of Pembina currently has 100-year flood protection, provided that the levee is maintained. The precise flood protection level, which should include allowance for freeboard, should be verified first by determining an agreed-on 100-year flood and then performing hydraulic analysis.

St. Vincent Dike

The earthen levee at St. Vincent, MN was originally constructed as an emergency levee and then upgraded to a permanent structure. It successfully withstood the 1997 flood. This is a non-federal project. It is understood that the levee was re-aligned following the 1997 flood, which would help reduce the channel constriction between it and the Pembina dike. The levee has been inspected under the Corps non-federal levees program and concerns about potential erosion at two points were identified. It is not evident that these concerns have been completely addressed, but it appears feasible in any event that the St. Vincent levee could be upgraded to meet federal standards. The community is interested in pursuing this as, under US floodplain management policy, areas behind a dike that meets federal standards can be removed from the 100-year floodplain shown on FEMA flood insurance rate maps. This leads to reduced flood insurance rates.

Rural Residence Flood-proofing in Lower Basin

Following the 1997 flood there was considerable effort devoted to moving, raising or diking rural residences to flood-proof them against a flood similar to that of 1997, roughly a 100-year flood. North Dakota initiated a rural ring-diking program and Manitoba offered flood protection to individual homes and businesses under a federal-provincial program. In the lower Pembina basin (North Dakota) it is not clear how many dwellings and other buildings were flood-proofed. There has not been a request for funding under the State program although some individuals may have flood-proofed their structures without drawing on the program. A major rainstorm in the lower Pembina basin at the end of March 2004 led to basement flooding of several hundred residences in Pembina County. Houses were affected by storm runoff rather than break-out flows from the Pembina River. Nonetheless, this indicates there is potential for a rural flood-proofing program in North Dakota. In Manitoba, a significant number of rural structures in the study area are already flood-proofed.

Removal of the lower Pembina River dikes and the potential construction of new set-back levees will change the flood protection levels in the part of the lower basin not affected by Red River flows. This has consequences for rural flood-proofing in North Dakota. New flood protection levels should be determined based on current Pembina River hydrology and the alignment and height of set-back levees.

It should be noted that increased flows in the Aux Marais system in Manitoba arising from increased capacity at Crossing 6 or construction of engineered overflows in the road-dike will lead to a need to re-examine flood-proofing in that basin.

The Study Team concludes that the degree of rural flood-proofing in the lower Pembina basin (North Dakota) needs improvement. Once the appropriate flood protection level is determined, this should be pursued.

Effects of Upstream Mitigation Works

One question raised by local people related to the effects of upstream mitigation works on water levels in the lower Pembina area. During the IJC studies, the Corps of Engineers UNET model was adapted to analyze the effect of the then proposed Grand Forks levee and the new East Grand Forks levee on downstream flood stages. The base case was chosen as the 1997 flood where the levees were overtopped and where off-stream storage would have the greatest effect on downstream water levels.

The Grand Forks and East Grand Forks storage areas were filled with water during the 1997 flood calibration modeling. The maximum volume of water stored within these areas at the peak of the flood was 15,000 acre-feet. This quantity is insignificant compared to the large volume of water in the Red River during the 1997 flood. The results on downstream water levels should that storage not be available, that is with no dike failure, are shown in Table 4.

Location	**River Mile**	**Stage Increase above 1997 Flood (feet)**
Letellier, Manitoba	141.17	0.00
Pembina River, North Dakota	158.00	0.02
USGS gaging station at Drayton,	206.70	0.04
Minnesota Highway 1 at Oslo, MN.	271.20	0.04

Table 4 – Modeled Stage Increases with no Levee Overtopping (IJC, 1999)

The Pembina Study Team concludes that the effect of upstream urban flood mitigation works, at Grand Forks for example, on water levels downstream at Pembina is negligible.

Minnesota Highway 171

During the 1997 flood all east-west crossings of the Red River from Fargo to Winnipeg were blocked for some of the time. This meant that Minnesota residents who worked in Pembina were unable to get to work by car. A few took considerable risk in crossing the River by boat. There are a number of reasons to consider flood-proofing additional river crossings, including emergency response and flood fighting.

In 2000 the Minnesota Department of Transportation contracted with Water Management Consultants to examine the effects of raising the Highway 171 approaches on upstream water levels and to determine a means of mitigating the anticipated water level increases. A concept involving installation of a number of large culverts in the raised roadway was developed. No construction work has been undertaken, although a project is still under consideration. It is understood that raising the Highway 171 crossing in such a manner that upstream water levels are increased would be unacceptable.

Summer Floods

Summer flooding can also be a problem in the lower Pembina basin. While, in the study area, the Red River is confined to its main channel during all recorded summer floods, the low channel capacity of the Pembina River means that it can easily leave its channel during summer floods. As stated earlier, the perched nature of the Pembina channel means that waters leaving the channel cannot return. Runoff arising directly on lands north of the Pembina River is unable to flow to the river on account of natural levees. Instead it flows north to Canada through the crossings of the road-dike.

In some high water years such as 1997, 1950 and 1974, River flows can exceed the channel capacity until well into May thus delaying spring planting. There are also some instances, such as in August 1995, when heavy rains raise water levels to the extent that the River leaves its channel. (The agricultural levees along the Pembina River were in place at that time, containing the flows in most areas thus decreasing damages.) Figure 3 shows the maximum daily flows on the Pembina River for the period of record. A number of summer peaks that approximate the channel capacity (3500 to 4000 cfs) are evident. It should be noted that nearly all of the summer maximums (including August 1995) took place in the 1990s with 1995 being the most significant. The channel capacity in metric units is about 100 to 115 m^3/s.

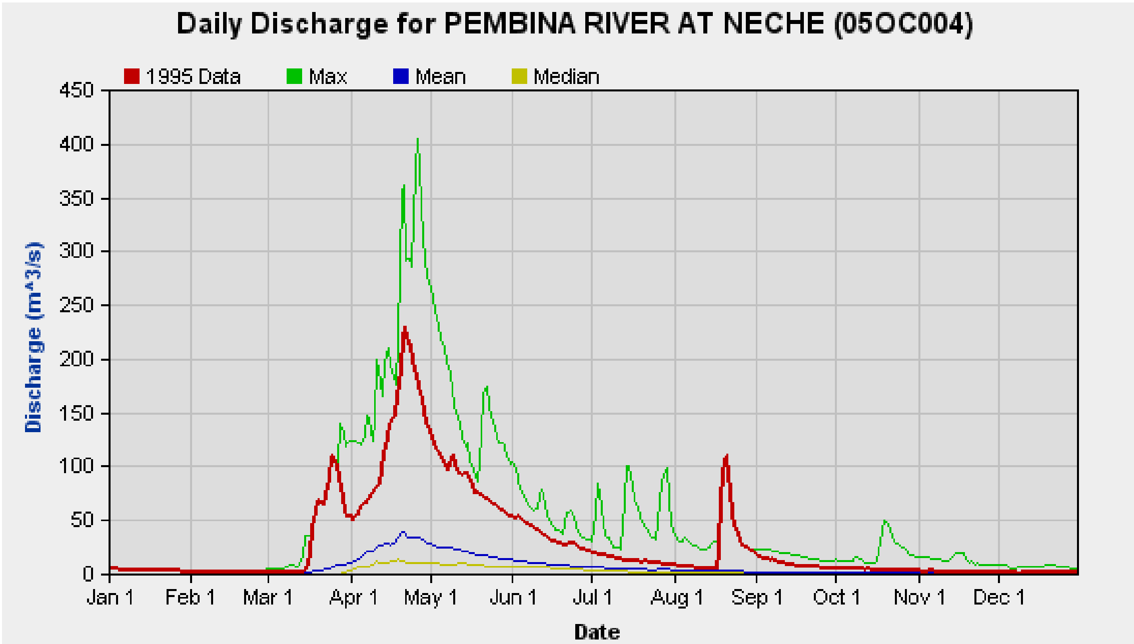

Figure 4. Pembina River at Neche, Maximum Discharges (courtesy Water Survey of Canada)

Based on existing information, it appears that most summer floods downstream of Neche are approximately equal to the channel capacity. It seems likely therefore that summer agricultural losses on account of overbank flooding could be alleviated to a considerable degree by set-back levees along the River that would be not much higher than the existing natural levees. There could still be a problem in the low bowl shaped area located a few miles west of Pembina. Runoff ponds in this area and cannot get back into the Pembina River until the water level goes down. The water from the Pembina River will also back into the Tongue River area. Some of those low-lying areas could also flood. Break-out flows upstream of Neche leading to Crossings 4 and 5 may provide some relief to downstream interests.

The local area is also susceptible to summer flood damage due to heavy rains. The local runoff cannot flow from the area fast enough to prevent crop damage, especially in the low area located a few miles west of Pembina. This problem is further compounded if the water level in the Pembina River is high. Damage estimates related to summer flooding in the study area may be incomplete. At least this was a finding of a flood damage study in the Wild Rice and Maple basins (Shultz and Kjelland, 2002)

A review of crop insurance claim history may clarify the summer flood situation, but the Study Team draws the preliminary conclusion that agricultural impacts of Pembina River flooding are more often the result of protracted spring runoff than *of summer rain storms. Summer flow peaks appear to be controllable to a considerable extent by set-back levees. Such levees, while they would constrain summer break-out flows, would not prevent damages from very heavy rains that fall directly on the land and that are unable to run off quickly.*

MITIGATION MEASURES

If the cities of Pembina, St. Vincent and Neche and rural buildings are protected against flooding, the remaining problem in the lower Pembina basin is that protecting farmland and roads. The farmland in this region will be flooded more frequently than one year in ten during spring events and potential damages due to soil losses and crop losses are considerable. One possible solution is the building of set-back levees along the lower river. These proposed levees, however, are not tied to high ground at the downstream ends. This raises the question of what happens to the flows confined by the levees once they reach the downstream ends. While such flows are unlikely to affect the city of Pembina, the effects on agricultural interests in that area must be carefully considered.

One means of accomplishing this is through the examination of various mitigation scenarios using a hydrodynamic model. During the IJC studies, a one-dimensional Mike-11 model of the lower Pembina River was developed by Water Management Consultants (WMC, 2000) and used to examine a number of scenarios. Since that time, the North Dakota State Water Commission has developed an HEC-RAS unsteady flow model of the lower Pembina River. The HEC-RAS model is much more detailed than the Mike-11 model used in the IJC studies as it uses over 200 stream cross-sections.

The consensus of modeling experts is that both models will produce similar results if the same input data is used. It is a little more difficult to achieve model stability with HEC-RAS. Any model used to examine the lower Pembina should have a downstream boundary on the Red River, say at Letelier, MB. While two-dimensional models such as FLO-2D or TELEMAC-2D may be used in the same reach, further work with one-dimensional models concerning the interaction of Red and Pembina waters should be completed before considering development of a two-dimensional model.

The model results will depend on the previously mentioned amount of detail as exemplified by the number of cross-sections and, as well on the accuracy of the topography used in the model. This is usually referred to as the digital elevation model or DEM. During the IJC studies, highly accurate Lidar topography was obtained along the Pembina River covering some 50,000 acres from Neche to the Red River. This work did not cover the road-dike along the international boundary. Subsequently Manitoba did obtain Lidar coverage for the part of the central Red River basin that was flooded in 1997, including a portion of the road-dike. (Experimental IFSAR coverage was obtained of the entire area, but this is not sufficiently accurate to be of any use in hydrodynamic modeling.)

In addition, accurate elevations using global positioning systems (GPS) on linear features such as roads and dikes was obtained during the IJC study and subsequently. This now includes roads, culverts and dwellings in the flood plain.

Bourget (2004) discusses DEMs for the American portion of the Red River basin in some detail.

There is a need to consider all the existing high resolution topographic information as well as other data and to prepare a seamless DEM for the entire study area. Model runs can then be made to support various mitigation scenarios.

It must be kept in mind that, as it concerns the Pembina River, the mitigative action must be directed at reducing the agricultural effects of relatively frequent Pembina River floods while taking into account the effects of mitigation measures in both countries. Hence the need for detailed modeling.

Set-back Levees

As the name implies, set-back levees are constructed some distance from the river bank and allow the river to occupy part of its natural floodplain. The proposed set-back levees along the Pembina River would be further from the river than the natural streamside levees built up by sediment deposits over many years. Set-back levees along the Pembina River would begin where County Road 55 crosses the Pembina River west of Neche and terminate near the city of Pembina upstream of the confluence of the Tongue River. Plate 3 depicts the general alignment. The exact design of the levees would depend on a number of factors including the desired flood protection level and the ultimate use of the riparian land inside the levees. Generally speaking the flowpath would be some 2700 ft. wide (WMC, 2000). Depending on the height of the levees, they could prevent breakout flows to the south and north during summer storms

The State Water Commission is currently working on a design for set-back levees. The SWC has concluded that flows at Hyde Park Cemetery and Auger Coulee would be controlled by the levees or controlled releases and that Rosebud Coulee and Bathgate did not have a problem. The levees would not help areas such as the lower Tongue River that are influenced by back-up from the Red River. Detailed hydraulic modeling and public consultation would be required to complete the final levee design. One consideration in that work would be to determine the effects, if any, on the city of Pembina and surrounding area. The height of the levees would determine the extent to which drainage systems north and south of the levees should be modified.

Coulee Storage

Although development of major storage projects on the Pembina River appears not to meet benefit-cost tests and, in any event, would require a long time frame for development, opportunities may exist to develop storage on coulees in the escarpment areas on both the Pembina and Tongue Rivers. There are currently ten dams constructed within the Tongue River watershed whose main purpose is flood control. Most were constructed in the 1950s and 1960s by the Soil Conservation Service (now the Natural Resource Conservation Service). The dams have effectively reduced the peak flood flows from the watershed. Opportunities for similar structures in the Pembina watershed could be investigated.

Outlet Options for Boundary Floodway

In 1983, the USACE identified a 21-mile long floodway from point six miles west of Neche to the Red River as a feasible flood control option. It had a positive benefit/cost ratio. This concept suggested the diversion point be located immediately upstream of Neche and that the capacity be 2,000 cfs. The effects of this floodway on downstream water levels were modeled during the IJC studies (WMC, 2000).

One concept identified in discussion with the Study Team was to consider terminating a boundary floodway by directing the outlet northward into Canada so that it joins the Red River north of Emerson. Outlet options for a boundary floodway could be investigated.

FURTHER WORK REQUIREMENTS

In the short time available to conduct this study time did not permit data collection that would allow a detailed examination of all the issues. The principle intent was to provide a status report, clarify any factual information to the extent possible and give an indication of the way forward. The following items need further attention before a long-term solution can be achieved.

Urban and Rural Flood-proofing

As indicated earlier in this report, the USACE is currently examining flood protection at Neche under the authority of Section 205 of the *Flood Control Act* of 1948. This work could lead to updated hydrology for the Pembina River and will allow verification of flood protection levels for communities such as Pembina and St. Vincent, and for rural residences. Protection levels at Pembina and St. Vincent should be based on joint probabilities of Red River and Pembina flows. Red River flows dominate that calculation and it is anticipated that the present 100-year flood protection level for the federal ring dike at Pembina is satisfactory. The St. Vincent levee may need further improvement before it can be deemed to meet federal standards.

The Manitoba program for rural flood-proofing has expired but North Dakota's has not. The Pembina County Water Resources District could still apply for cost sharing from the ND State Water Commission on a rural residence ring dike program. When the new hydrology for the Pembina River is completed and effects of set-back levees determined North Dakota may wish to promote the use of the program to affected landowners.

These items could be carried out under existing authorities but may require some additional funding and would likely take two years, possibly more if the Neche federal project goes ahead.

Agricultural Damage Data

A close examination of agricultural and infrastructure damage data would demonstrate the extent of the summer flooding problem. It appears that summer flooding from Pembina River overflows was relatively infrequent until the 1990s, and could be significantly reduced with the construction of set-back levees. A review of agricultural damage data may confirm this.

A common problem in the Red River basin, however, is that summer flood damages are not recorded very thoroughly unless there is a very significant event. Such damages could relate to rural structures, crop losses, land erosion , or damage to roads and culverts. A review of existing data sources could lead to specific recommendations related to the type of damage data that should be routinely acquired when summer floods occur. This work would likely cost US

$10,000 and take a few months. The cost may be reduced if local entities have already summarized the information

Pre-cultivation Flow Paths

Assuming that aerial photographs of the road dike area are unobtainable or that existing photography is not sufficiently indicative, it would be possible to closely review the 19^{th} Century maps sheets, either for Manitoba or for both Manitoba and North Dakota. This would cost in the order of Cdn $5000-10,000 and would take two months.

Topography

Detailed topography of the lower Pembina basin is required for hydraulic modeling of the basin. While Lidar topography exists for the Manitoba portion of the study area and some of the North Dakota portion, there is an area between the Pembina River and the international boundary where accurate topography is needed. This could be surveyed at a cost of US $30,000. This work should be carried out in the spring before leaf-on and realistically could not be done until 2005. Further work would have to be done to merge the new data with existing data sets to produce one DEM for the study area. It would be important to provide some overlap with previous Lidar data along the Pembina River and with Manitoba data.

Modeling

While both North Dakota and Manitoba have the capability of modeling the lower Pembina, other priorities make it difficult to accomplish this work. One possible approach would be for North Dakota to request that the USACE carry out a study of the lower basin under the *Flood Control Act* authority. This is a small projects' authority that requires 50-50 cost-sharing following execution of an agreement. It may be possible that the local share could be made up of in-kind resources from North Dakota and Manitoba.

A Corps of Engineers study could also be conducted through Section 22. This also requires a 50-50 cost sharing. (This Section of the Act is more directed towards a study rather than pursuit of a specific project.) Another option would be through the reconnaissance study process. Initial scoping of the watershed and its water problems would be done in the reconnaissance phase. This could be followed by a feasibility phase, and eventually to construction of a project. The project would be studied as a multipurpose project; flood damage reduction and environmental enhancement. The project would have to be determined to be feasible to be constructed. A 50-50 cost sharing is required for the reconnaissance and feasibility phase of the study.

Modeling under such a study would be directed to confirming the natural overflows to Canada (including break-out flows), the effects of County Road 55, optimizing the alignment of the set-back levees, and determining the effect of those levees on the city of Pembina. It is recognized that similar work was carried out for the IJC (WMC, 2000), but the proposed work would use much more detailed topography and additional river cross-sections.

The cost of such a study would be US $50,000 and the time required would be one year. The work underway by the SWC would contribute to this effort and may reduce the cost.

Road-dike Crossings

There is a need to unequivocally document the dimensions and hydraulic characteristics of the six numbered crossings of the road-dike and those other roads such as the township road one-half mile south of the international boundary and in County Road 55. A detailed survey, including elevations, of these features is required for modeling potential mitigation measures. Such a survey would cost about $30,000 and could be completed in two months.

Manitoba Channel Capacities

If further modeling indicates that natural flows crossing the international boundaries are greater than the existing crossings allow, consideration could be given to increasing the capacity of these crossings. This may require additional channelization in Manitoba downstream of the crossings otherwise Manitoba agricultural and infrastructure damages will increase. Once the need for increasing the capacity of the crossings, if any, have been determined downstream channelization needs must be determined. This determination could cost Cdn $20,000 and take one year. Part of the work will involve meeting environmental requirements of the Canadian *Fisheries Act*.

Conclusions and Recommendations

The key to making progress on resolving the lower Pembina problem is to determine solutions that are deemed to be fair and equitable and that are locally acceptable. At the same time these solutions must be affordable. Part of the study teams activity has been to examine issues that may or may not be important to the basic problem exemplified by the road-dike. Many past studies, however, simply developed an improved statement of the problem rather than solutions. There has also been a perception in the past that the solution lay in major multi-purpose dams on the Pembina River. This perhaps diverted attention from other possibilities.

1. The Pembina Study Team concludes that the feasibility of a binational multipurpose water project in the Pembina basin that would include flood control storage is sufficiently in doubt that this should not form part of consideration of solutions to the lower Pembina problem. Other more immediate measures aimed at reducing flood damages in the lower Pembina basin need to be examined.

A consequence of this conclusion is that the long-standing concept that openings in the road-dike and openings in roads in Pembina County should be sized to accommodate agricultural flows in the order of the 1:8 flood may have to be revisited. This would depend on the possible role of set-back dikes in resolving the problem.

Based on our investigation, there are three potential components to any solution to lower Pembina flooding. The first is to flood-proof urban centers and rural buildings to a specified flood protection level, most likely the 100-year flood. To a considerable extent, this is the current situation. In effect, this flood-proofing transforms the problem to one of farmland and road protection.

2. The Study Team supports a U. S. federal project that will provide Neche with one-hundred year flood protection provided that it is locally acceptable and meets engineering, economic and environmental tests.

3. The Study Team concludes that, because of breakouts on both sides of the Red River, any flow constriction caused by bridges, railways and roads in the Emerson area does not have a major effect on water levels at Pembina. During very high flows such as in 1997 water breaks out of the main channel and continues flowing north on either side of these channel restrictions. Any increased water elevation would have been incorporated into the design elevation for the city of Pembina ring dike but raising the road-dike in the Red River overflow area has the effect of further constraining Red River break out flows thereby potentially affecting the flood protection level at the city. Further modeling is required to determine the individual and combined effects of roads, railways, bridges and dikes.

4. The Pembina Study Team concludes that the effect of upstream urban flood mitigation works, at Grand Forks for example, on water levels downstream at Pembina is negligible.

5. The Study Team concludes that the city of Pembina currently has 100-year flood protection, provided that the levee is properly maintained. The precise flood protection level, which should include an allowance for freeboard, should be verified first by determining an agreed-on 100-year flood and then performing hydraulic analysis. The Study Team notes that the city of St. Vincent may require further enhancement of it flood protection to meet federal standards.

6. The Study Team concludes that the degree of rural flood-proofing in the lower Pembina basin (North Dakota) needs improvement. Once the appropriate flood protection level is determined, this should be pursued.

The second component would be set-back levees along the Pembina River from County Road 55 west of Neche to the confluence with the Tongue River. Based on current information such levees could be designed to protect farmland against summer floods due to Pembina River overflows and to provide some protection against spring floods. Detailed hydraulic modeling would be required to determine levee alignment and a feasible level of protection. The city of Pembina will also need assurances that its flooding problems are not made worse by the levees.

7. A review of crop insurance claim history may clarify the summer flood situation, but the Pembina Study Team draws the preliminary conclusion that agricultural impacts of Pembina River flooding are more often the result of protracted spring runoff than of summer rain storms. Summer flow peaks appear to be controllable to a considerable extent by set-back levees.

The third component would be adjustments to the openings in the road-dike and County Road 55 and to drainage systems to accommodate natural flows. The underlying philosophy may be to accept some break-out flows from the Pembina River, but to modify drainage systems by increasing culvert and channel capacities to allow water to drain as quickly as feasible.

8. The Pembina Study Team concludes that natural agricultural flows, break-out flows from the Pembina River, and the effects of present infrastructure can all be examined through use of a detailed hydrodynamic model. Further, the effects of mitigation measures such as set-back levees and modifications to bridge and culvert openings can be determined through use of such models.

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In order to move ahead on resolving this long-standing problem, the Pembina Study Team makes the following recommendations:

1. *That the Pembina River Basin Advisory Board members appointed to liaise with the IJC's International Red River Board review this report and develop a position on its findings.*

2. *That the IRRB facilitate a process to determine next steps in resolving this problem. Part of that process will be to work with the PRBAB and other interested parties to determine what could be considered an acceptable level of agricultural flooding as that will drive the design of any mitigation measures.*

3. *That government agencies having responsibilities in this geographic area continue to fund programs and studies identified in this report that will help lead to a solution. One small but essential task would be to verify the current location and dimensions of all the crossings of the road-dike.*

4. *That the IRRB lend its support to a planning study, perhaps under the U. S.* Flood Control Act *(USACE planning assistance to states), that will define the details of a solution. Such a study would include:*

    - *determination of natural flows and drainage patterns in the lower Pembina basin*
    - *designing flood protection measures at Neche (underway under Section 205)*
    - *confirming flood protection levels at Pembina and St. Vincent and identifying a plan to correct deficiencies, if any*
    - *identifying the nature and extent of agricultural damages*
    - *expanding the accurate digital elevation model*
    - *developing a detailed hydrodynamic model for the lower basin*
    - *identifying desirable changes to east-side Red River overflows such as modifications to openings in the railway embankments*
    - *designing set-back levees for the lower Pembina River*
    - *designing engineered overflows of the road-dike and changes to land drainage to accommodate agreed-on flood flows*

5. *That relevant agencies be prepared to participate in such a study and to contribute to the funding of solutions.*

6. *That lower basin residents who have experienced flooding problems for a lifetime continue to work together with responsible agencies to determine equitable solutions.*

Considering that urban communities in the study area have, or soon could have 100-year flood protection, the resolution of this long-standing problem requires two additional elements: rural flood-proofing to the extent practicable including adjustments to the openings in the road-dike and other relevant roads in the study area and set-back levees along the Pembina River. The adjustments could include changes to Crossing 6, engineered overflows to accommodate overbank flows of the Red River, changes to openings in some North Dakota roads, and improvements to drainage downstream of the openings. Detailed study would be needed to determine the precise design.

While there is some acceptance of a resolution of the problem along these lines, concern has been expressed that all three components should proceed together. That is, persons in the city of Pembina area do not wish to see the set-back levees proceed ahead on adjustments to the road-dike. The city would also like to see additional consideration of upstream coulee storage in the longer term.

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APPENDIX 1 - TERMS OF REFERENCE

International Red River Board – Lower Pembina Flooding Study Team

Background

There is a long history of transboundary flooding issues on the lower Pembina River between North Dakota and Manitoba. The IJC in its report *Living with the Red* acknowledged the long-standing unresolved flood issue and recommended federal, state and local governments work cooperatively to achieve a solution.

There have been a number of changes in the situation since the IJC report was prepared. These include removal of dikes deemed illegal, enhancement to South Buffalo Coulee drainage, and further modelling of the lower basin. However, the various entities have not yet been able to reach a solution to this long-standing problem.

In July 2003, the Pembina River Basin Advisory Board requested the assistance of the International Red River Board (IRRB) to help resolve the issue. As a first step in helping to respond, the (IRRB) requires a situation analysis report including recommendations for strategies for moving towards a resolution.

Project Team

The IRRB has struck a three-person team to prepare a situation report. The team is composed of two members appointed by the United States and Canadian sections of the Board plus an independent team leader. Membership is as follows:

> Chair:
> R. A. (Bob) Halliday,
> R. Halliday & Associates Ltd.
>
> Manitoba Member:
> Rick Bowering,
> Manitoba Department of Water Stewardship
>
> North Dakota Member:
> Randy Gjestvang,
> North Dakota State Water Commission

Duties

1. Review the current status of flood mitigation in the lower Pembina River basin. In particular, identify changes that have occurred since the IJC report.

2. Examine the current status of modeling of the lower Pembina, data availability and data needs.

3. Prepare a factual situational analysis report of the current transboundary flooding problems of the lower Pembina River basin including current actions being taken to resolve the issues.

4. Make recommendations for both short and long-term strategies for moving towards resolution of the flooding issues. Recommendations should identify any studies/investigations and mechanisms of cooperation to carry out the recommendations.

5. Provide approximate estimates of time and resources for undertaking the work identified in the recommendations.

6. Consult with the Pembina River Basin Advisory Board, and any other organization or agency that may be identified, about its views of the flooding problems and ways to resolve the issues.

Meetings

1. Although it is anticipated that much of the work of the team will be accomplished using electronic means such as telephone and email, at least two meetings will be required.

2. Meetings will be held in the study area.

3. Meeting expenses for the team leader will be borne by the IRRB. Those of team members will be borne by their respective agencies.

Reporting

1. The team will report to the International Red River Board.

2. The team will submit a progress report to the IRRB by February 06, 2004. [This date is likely very optimistic.]

3. The team will submit a final report by March 15, 2004.

APPENDIX 2 - STUDY PLAN

This work plan is based on the concept that the study team will examine in particular the changes that have taken place in the lower Pembina basin since the IJC report, consider the views of the PRBAB and others, and determine a way forward to resolving the long-standing issue. The way forward will be as prescriptive as possible and will contain a schedule and costs.

It is assumed that Bob Halliday will prepare much of the first draft of the report for review by other team members. This plan reviews the issues that will be examined and defines some action items.

Study Area

The study area encompasses the Pembina River drainage downstream of the Pembina escarpment. That is, roughly downstream of Walhalla, ND and encompassing the northern half of Pembina County and the adjacent lands in Manitoba in the RMs of Rhineland and Montcalm.

The effect of this study area determination is that upstream storage will not be part of the team's work, even though there is a continuing local interest in Pembina River dams for flood control and water supply. It is understood that the projects still do not meet benefit-cost tests and are likely environmental non-starters.

Action Item: Review the "Acres Report" and verify this assumption.

Red River

There are several issues of concern that require separating Red River flooding from that of the Pembina. Some of these may require additional modeling; others simply checking existing information.

Action Item: Review existing information to identify effect of Red River versus Pembina River flooding.

Action Item: Verify current flood protection level for city of Pembina and for rural residential areas in the study area between County Road 55 and the border. Is the Pembina city ring dike certified as a flood-proofing dike?

Action Item: Speak to Red River modelers such as David Sellars, Eugene Kozera and Scott Jutila to seek there views on the extent to which the Emerson "choke-point" is natural or man-made.

Action Item: Review IJC Task Force report to identify the effect of the Grand Forks dike on downstream water levels.

Action Item: Determine the status of any changes to MN Hwy 171 that would lead to improved access during a major flood.

Pembina River

One concept that may be helpful in identifying solutions to lower Pembina River is to consider the problem as a land protection issue. This may lead to different magnitudes of floods of concern for spring flooding and summer flooding. Also, at some point, the magnitude of a flood would be so great that damages are considered uncontrollable.

Action Item: Review present channel capacities of the lower Pembina and relate this to flood frequency.

Action Item: Produce digital maps of the alignment of dikes taken down on account of the court case and of the proposed set back levees.

Action Item: Is there any flood damage data, particularly summer floods, for the study area that could be useful for our task?

Border Road/Dike

The border road/dike is the most visible manifestation of the Pembina issue and current information is required.

Action Item: Prepare a listing of all border stream/culvert crossings in the study area, including culvert dimensions and elevations. Describe the changes Manitoba has made and will make in 2004 to these crossings.

Action Item: Determine whether the Manitoba lidar collect includes the boundary road/dike and whether GPS data was obtained for the road/dike.

Action Item: Review pre-cultivation land use information obtained by IJC to see whether stream alignments are included.

Modeling

Although some residents of the lower Pembina River area have some skepticism related to the use of hydrodynamic models, modeling of possible solutions appears to be an essential requirement. Defining the modeling work that we wish to accomplish in the short term (before March 31) and in the long term is key.

Action Item: Ask the principal modelers (Tim and Eugene) for their views on the current HEC-RAS model's capability and the required improvements to input data needed to provide confidence. This new data could, for example, include additional cross sections in key areas and lidar data between the IJC collect and the border.

Action Item: Model the natural Pembina runoff (w/o dikes, roads) to determine the quantity/percentage of flow crossing the border under various conditions, say the 10, 25, 50 and 100-year floods. Carry out the same modeling with the set-back levees in place.

Mitigation Measures beyond Set-back Levees

Assuming that large dams are not feasible, there are two items that could be examined.

Action Item: Based on existing information, identify any coulee storage opportunities on the Pembina River or the Tongue River.

Action Item: Assuming a no-border situation, is there a possible alignment of the border floodway that may lead to improved performance or capacity, and that might benefit both countries?

Action Item: Provide a basis for estimating the cost of channel improvements in Manitoba if more Pembina water is directed across the border.

Are We There Yet?

If our task provides any benefit to the PRBAB, I think we will have identified the issues of concern to the lower basin and dealt with all of them in a way that is persuasive. We will also have helped them determine whether they have a Red River problem or a Pembina River problem, particularly the city of Pembina, and whether they have a spring problem or a summer problem, or both.

We will have a determination of the "natural" amount of water crossing the boundary or have at least identified the requirements for making that determination. We will know the mitigating effects of the set back levees and their consequences to downstream residents. We will have identified any other options that may be pursued.

We should be prepared to task responsible agencies and the IJC's IRRB with next steps.

Appendix 3 - A Brief History of the Dispute to 1997

(Based on material originally drafted by Beaverbrook Communications for the International Red River Basin Task Force.)

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 Canada 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 west of Gretna, Manitoba to the Aux Marais River crossing - a distance of about eight miles. 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 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" 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 that 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-in. culvert through the road over the Drain at the boundary, or to replace the existing 36-in. culvert with a 48-in culvert to increase the capacity to approximately 195 cfs.

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 being sought to redirect water eastward to the Red River using natural channels as much as possible. However, this option also foundered 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 though the Canadians were building a protective barrier to any runoff from the U.S. all along the international boundary.

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 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 at the border, rather than the 120 cfs 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 - a reference to the 1967 International Joint Commission report recommending the construction of two dams (the Pembilier dam upstream of Walhalla and the Pembina dam in Manitoba) along the Pembina River.

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-in. culvert, set one foot 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 and the project would be cost-shared with North Dakota contributing $90,000 of the estimated $300,000 cost.

During 1970 and 1971, 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. In January 1970, the SWC asked the International Joint Commission 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 the finalization of an agreement.

In 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 and wrote the Premier of Manitoba asking that the Province of Manitoba do the same.

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.

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 then 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.

Six drains flowing into Canada between Neche and the Red River. These have been referred to as outfalls, or crossings. 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.

The 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. These are displayed in Table A1. The Committee also provided equivalent culvert capacity as pipe arches. The agricultural drainage standard of a one in eight-year flood was applied. (A one in eight flood is approximately the channel capacity of the Pembina River.)

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 A1 - Recommended Openings in Border Crossings

Crossing	Location (Manitoba)	Flow	Openings
#1	section 2-1-5W	350 cfs	four 60-in. culverts
#2	section 6-1-3W	410 cfs	six 60-in. culverts
#3	section 4-1-3W	430 cfs	six 60-in. culverts
#4	section 5-1-2W	400 cfs	six 60-in. culverts
#5	section 3-1-2W	21 cfs	one 36-in. culvert
#6(Aux Marais)	section 4-1-1E	260 cfs	four 60- in. 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.

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 low probability event.

At Crossing #6, Manitoba was in the process of upgrading the Aux Marais channel to handle 260 cfs 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.

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 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 #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. 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 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 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 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. 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 at two locations. Following the flood, the road/dike was repaired by Canadians. The road dike was also raised at its western extremity by the RM of Stanley following the 1997 flood. The RM of Rhineland subsequently raised an adjoining section.

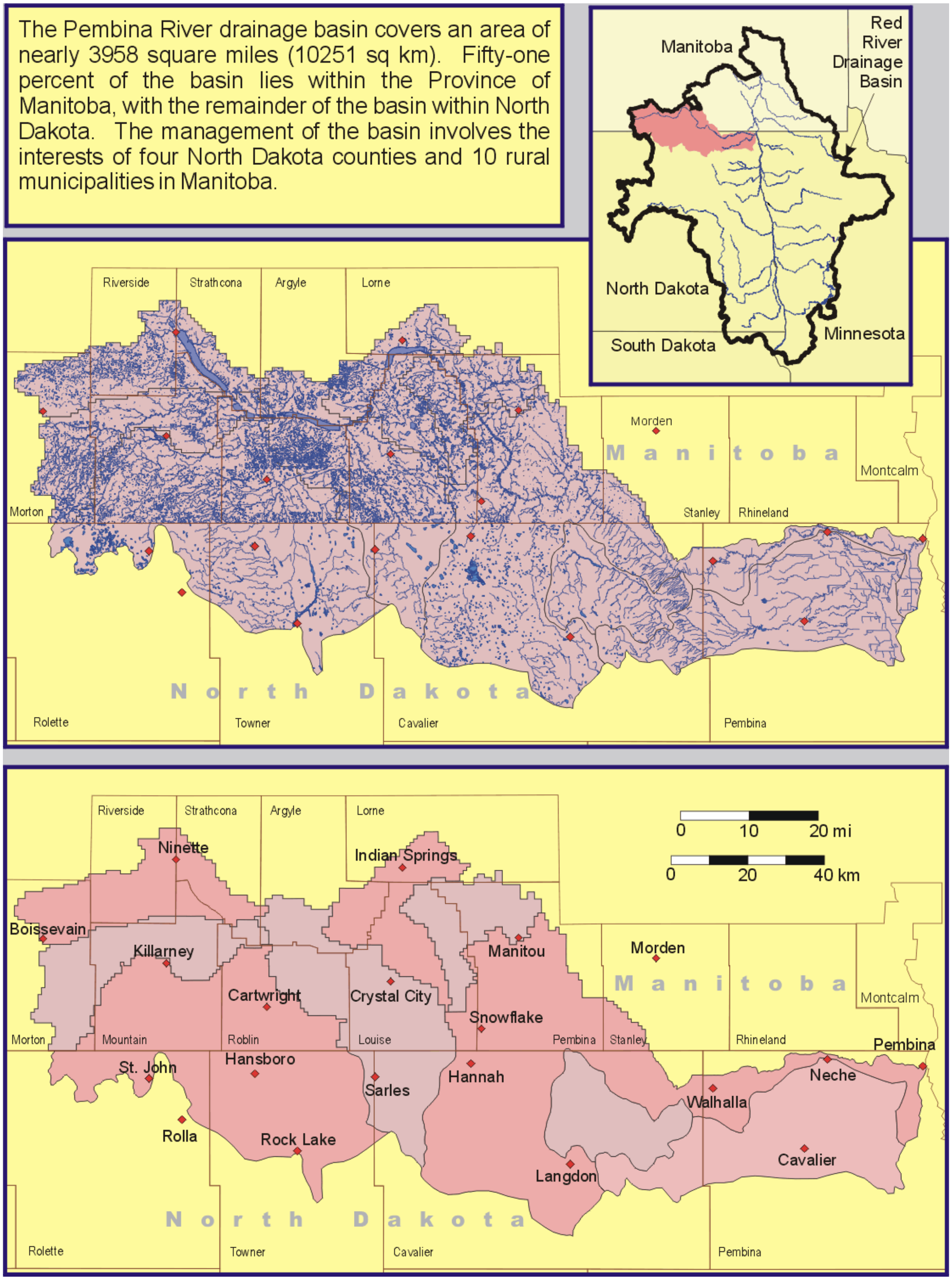

Plate 1. Pembina River Basin Maps (courtesy Pembina River Basin Advisory Board)

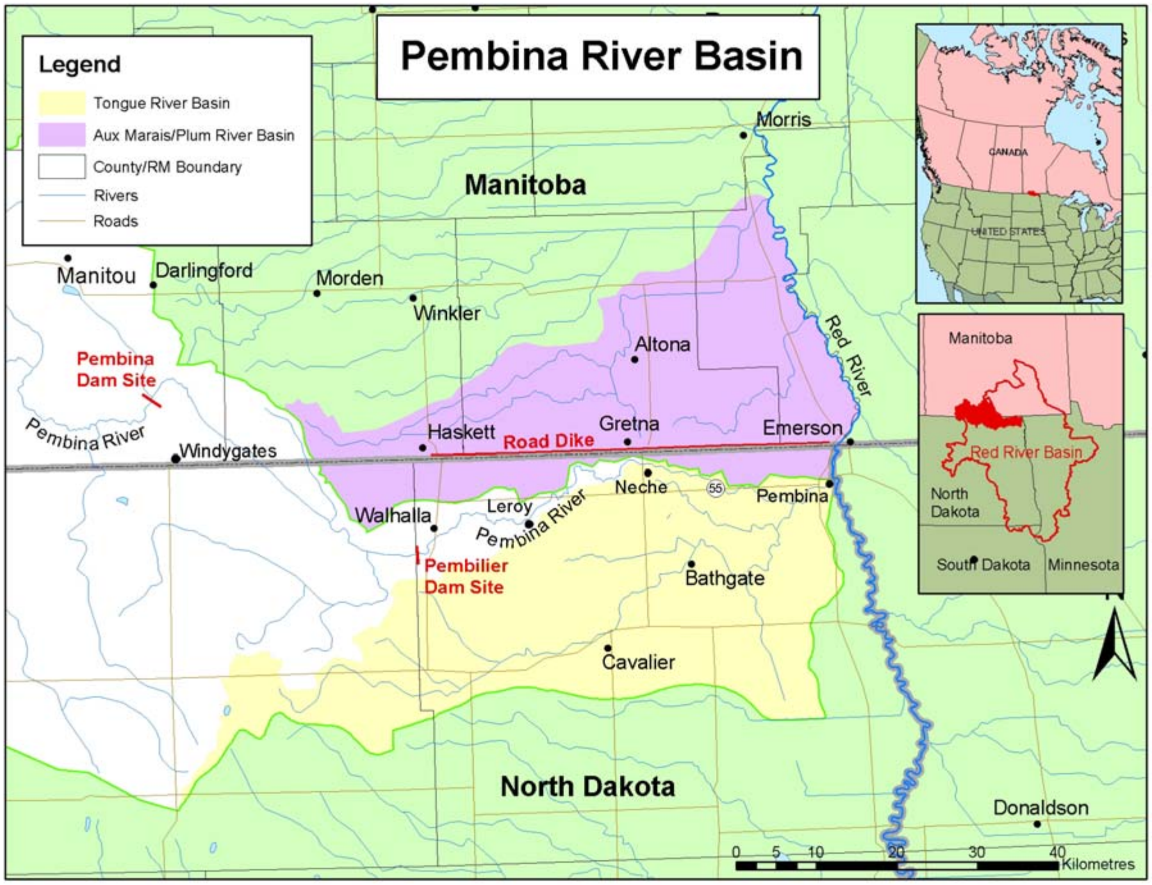

Plate 2. Study Area (courtesy Environment Canada)

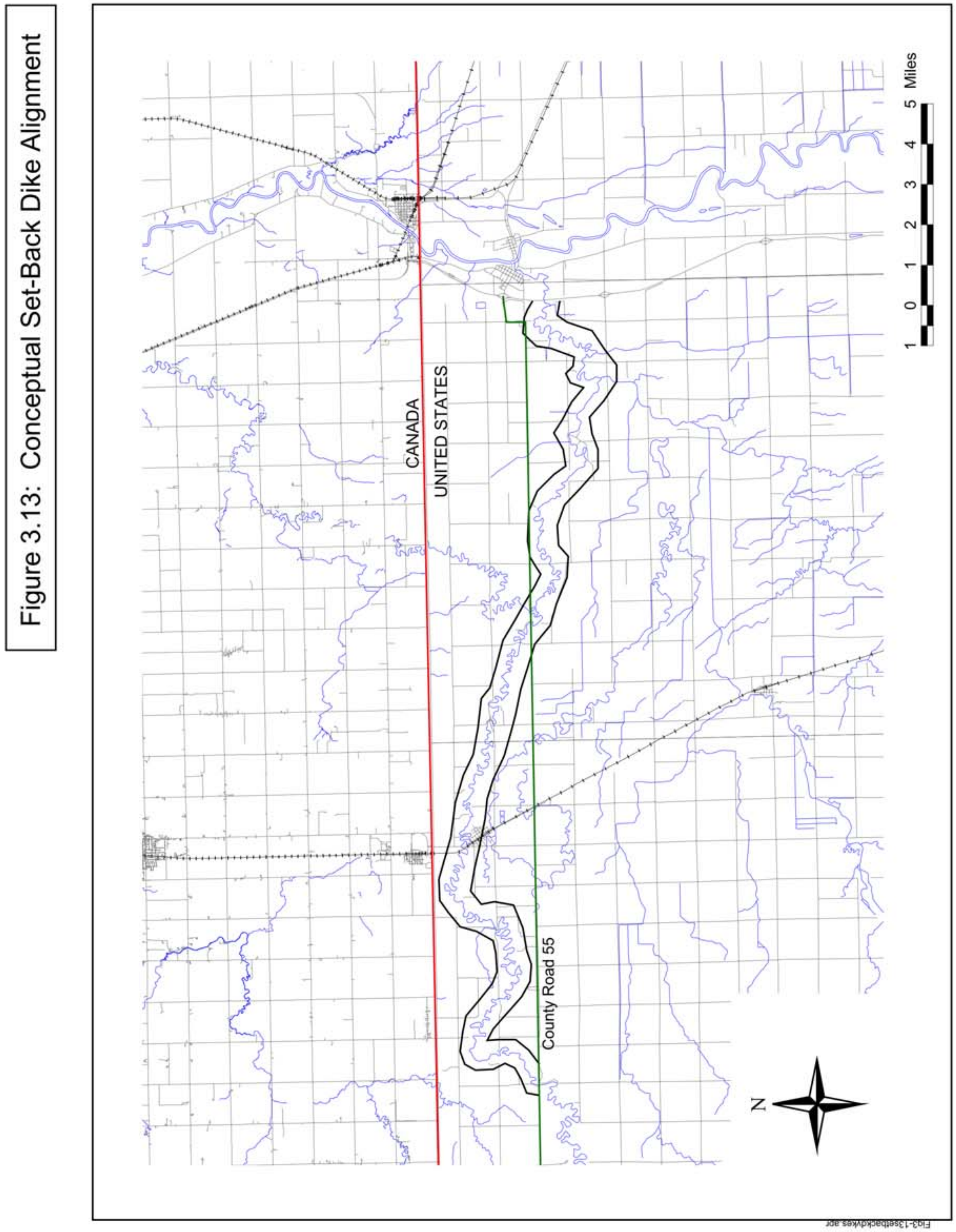

Plate 3. Typical Set-back Levees (courtesy Water Management Consultants)