RED RIVER FLOODWAY
AND RELATED
FLOOD CONTROL WORKS

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INTRODUCTION

The Red River Floodway is the major project in a 95 Million Dollar Flood Control Program on the Red and Assiniboine Rivers recently completed in Manitoba. The Floodway, in conjunction with the Portage Diversion and the Shellmouth Dam on the Assiniboine, will provide protection to the City of Winnipeg against a flood having a peak flow sixty per cent greater than the tragic flood that occurred on the Red River in 1950.

The two projects on the Assiniboine River will, in addition to reducing flood levels in Winnipeg, provide protection to the Cities of Portage la Prairie and Brandon and an estimated 400,000 acres of land along the Assiniboine River in Manitoba.

This paper describes the detailed engineering investigations, financial studies leading up to the construction of the flood control works, the design procedure and the method of construction required to complete the projects.

DESCRIPTION OF BASIN

Winnipeg is located at the junction of the Red and Assiniboine Rivers approximately sixty miles upstream of Lake Winnipeg into which the Red River discharges. The Red River's course lies in the basin of the prehistoric glacial Lake Agassiz. The River rises near the Town of Whapeton, North Dakota, approximately 250 miles south of Winnipeg and flows northerly on a gentle slope averaging one-half foot per mile.
FIGURE 1  RED RIVER DRAINAGE BASIN

GENERAL OUTLINE OF THE RED RIVER DRAINAGE BASIN

SCALE IN MILES
0 25 50 100 150
0 100 200

SCALE IN KM.
The total drainage area of the Red River at Winnipeg is 111,000 square miles (Figure 1). The Assiniboine River drainage area represents 63,000 square miles of this total, however, the topography and climate of the Assiniboine Basin are such that the maximum flow is much less than that of the Red River with its 48,000 square miles of drainage area.

HISTORICAL FLOODS

In 1950, the tragic flood which occurred on the Red River, formed a lake in the valley south of Winnipeg, 75 miles long and 20 miles wide. The River rose in Winnipeg to an elevation of 30.3 feet (local datum), 12.3 feet above first flood stage. The flood waters inundated 10,500 homes, despite the heroic efforts of thousands of volunteer "dykers". The River remained above flood stage for a period of fifty-one days and "Operation Blackboy", a plan for the total evacuation of the City was ready if the River had risen another 1.3 feet.

The Flood of 1950, as disastrous as it was, was not the highest on record. In 1861 a flood two feet higher than that in 1950 occurred; in 1852 one four feet higher; and in 1826 the water rose six feet higher. In 1956, it appeared that a flood of greater size than 1950 was in the offing, however, due to favourable weather conditions, the water rose only four feet above the initial flood stage. In 1965, the river rose to an elevation of 20.8 feet in the Winnipeg area but the absence of rain during the critical spring run-off period prevented the water from rising to the predicted elevation of 24 feet.

The record breaking blizzard that raged over the Red River Valley on March 4 and 5, 1966 dumped an average of 17 inches of snow on the frozen ground which was saturated due to the above normal precipitation the previous fall. The break-up in the Valley started earlier than usual and the potential run-off indicated a flood elevation of 29.5 feet in 3
Winnipeg. A return to colder weather in the early days of April slowed down the movement of the water into the main stem of the Red River and the elevation of the water only reached 26.3 feet on April 15th, just below the minimum forecasted elevation of 26.5 feet.

In the Spring of 1969, flood flows were experienced on the Red and Assiniboine Rivers, and provided an opportunity to test the Red River Floodway which had been completed in the fall of 1968. The works operated very satisfactorily reducing the flood levels in Winnipeg by five feet, and if the Portage Diversion had been in operation, a further reduction of approximately 1.5 feet would have been possible.

**URBAN DYKING SYSTEM**

Immediately after the 1950 flood, the Greater Winnipeg Dyking Board was established to construct a system of dykes in Winnipeg to provide a degree of protection for the City against flooding. Under the direction of the Board, a system of main line of defense against flooding from the Red, Assiniboine and Seine Rivers was established. In low areas, boulevard type dykes were constructed, pumping stations installed to lift storm and sanitary sewage into the River, and established borrow areas from which material could be obtained to raise the dykes during flood emergency. The profile of the top of the dykes was established approximately four feet below the maximum 1950 water surface profile through the City, which has a flood frequency of once in 18 years. The minimum top width of the dykes is 26 feet to permit the raising of the dykes under emergency conditions an additional four feet. Under the terms of the Provincial Dyking Authority Act, the City of Winnipeg is responsible for the maintenance of the dykes, under the supervision of a Dyking Commissioner appointed by the Province. Since 1950, the primary line of defense has been extended or raised in line with the land.
development in the City. There are at present 68 miles of the primary line of defense varying in maximum elevation between 26.5 and 32.0 feet with 30 pumping stations. In the Spring of 1966, forty-two miles of the primary dykes were raised to an elevation of 31.5 feet, involving the handling of 600,000 cubic yards of material during a three week period in the latter part of March. (Figure 2)

INVESTIGATIONS

Following the 1950 flood, the Red River Basin Investigation, (R.R.B.I.), Water Resources Division, Engineering and Water Resources Branch, Department of Resources and Development of the Government of Canada was formed to investigate measures to reduce the flood hazard in Winnipeg. The investigation included a comprehensive study of the hydrology of past floods, analysis of flood run-off and feasible methods for flood protection. Preliminary design and cost estimates were prepared for channel improvements, diversions, dykes and storage reservoirs.

The report was submitted in October 1953 and, included in an appendix, was the report of a similar study carried out by the Prairie Farm Rehabilitation Administration (P.F.R.A.) Department of Agriculture, Government of Canada, on the Assiniboine River. The terms of reference of the R.R.B.I. did not require a recommendation for the implementation of any works.

In December 1956, the Province of Manitoba appointed a Royal Commission on Flood Cost-Benefit. The Commission was instructed to compare the costs with the benefits which would accrue from the implementation of any of the schemes studied by R.R.B.I. or any other methods of flood control. In addition to engineering works, the Commission included in its studies a scheme for Government sponsored
flood insurance. The report of the Commission was presented in December 1958 and in it the following projects were recommended:

1. The construction of a 60,000 c.f.s. capacity floodway around Winnipeg.
2. The construction of a 25,000 c.f.s. capacity diversion from the Assiniboine River to Lake Manitoba, near the City of Portage la Prairie.
3. The construction of a storage reservoir on the Assiniboine River near Russell, Manitoba. (Figure 3)

The Commission estimated the capital cost of these projects would be $72,483,000.00 having a benefit-cost ratio of 2.73. The projects would provide complete protection for the City of Winnipeg with the permanent dyking system up to a flood of 169,000 c.f.s. measured below the confluence of the Red and Assiniboine Rivers with a frequency of occurrence once in 161 years.

DESCRIPTION OF PROJECTS

The three projects recommended have now been completed; the Red River Floodway in 1968, the dam on the Assiniboine River in 1968 and the Portage Diversion in December 1969.

Portage Diversion

The Portage Diversion, which the Commission recommended be built on a location running northerly from the Assiniboine to Lake Manitoba on a route lying east of the City of Portage la Prairie, was relocated. Further investigations on this proposal indicated that a more desirable route was one lying approximately 2½ miles west of the City of Portage la Prairie. This location would provide flood protection for the City
FIGURE 3  MAJOR FLOOD CONTROL WORKS  RED AND ASSINIBOINE RIVERS
as well as an additional section of the River below the City. The revised location also provides secondary benefits for irrigation, municipal water supply and wildlife. The route of the Diversion lies to the west of a block of potential irrigable land which could be served; water can also be diverted as required to stabilize water levels in the marsh around the southern end of Lake Manitoba.

The first contract was let on the Portage Diversion in the fall of 1965. The Diversion involved the excavation of approximately ten million cubic yards of excavation, the construction of a diversion dam, inlet and outlet structures and two gradient control structures in the channel. There are four road crossings and five railroad crossings along the 18.5 mile Diversion.

**Shellmouth Dam**

The third project, which the Commission recommended, a dam on the Assiniboine River near Russell, Manitoba, was relocated to a point on the River near Shellmouth, Manitoba. Investigations carried out by the P.R.F.A. subsequent to the Commission's report, recommended that the dam be relocated to Shellmouth to avoid the flooding out of a railway line in the proposed reservoir. The Shellmouth Dam provides a reservoir with a maximum storage of 340,000 acre-feet, of which 150,000 acre-feet can be used for flood control operation. The reservoir reduces flooding downstream, particularly in the vicinity of the City of Brandon as well as providing a dependable flow of 400 c.f.s. in the River downstream of the Dam.

The first contract on the Shellmouth Dam was let in 1964, and the dam was completed in the fall of 1968.
The Red River Floodway, the major project in the three-pronged flood control program is in the simplest terms, an earth channel 30 miles long to carry the flood flows of the Red River around The City of Winnipeg from a point upstream of the City and return them to the River at a point downstream near Lockport. (Figure 4)

In March 1959, the Manitoba Government announced its intention to proceed with the Floodway as soon as the necessary detailed investigations and designs could be completed. Early in the spring of 1959, detailed surveys began to determine the final location, as well as investigations to relocate the inlet from a point near the South Perimeter Highway to a point upstream of the Town of St. Norbert, a distance of five miles. The Commission had suggested this revision, due to the increasing development between the Perimeter Highway and St. Norbert, as it felt that the increased benefits would justify the additional costs. The results of these investigations proved that such a relocation was justified and the present location of the Floodway was approved in 1960.

Detailed hydraulic investigations based on the various mentioned reports and on data collected in the intervening period, were made to determine the conditions which would exist on the Red River and Assiniboine River under natural conditions and with the recommended flood control works in operation. This information was developed to determine the water surface profile through the City as well as at the inlet and outlet of the Floodway for the final design.

The Royal Commission had recommended the 60-768 design of the Red River Basin Investigation as the desirable floodway capacity. This design would have a capacity of 60,000 c.f.s. in the Floodway when the water level at the inlet was 768.0 (G.S.C. datum 1928 adj.) but under
design flood conditions would carry approximately 67,000 c.f.s. The water surface profile under design conditions was calculated through the City assuming an initial storage of 150,000 acre-feet in the Shellmouth Reservoir; 25,000 c.f.s. diverted through Portage Diversion; an average Assiniboine contribution occurring 90% of the time; and 67,000 c.f.s. in the Floodway. The resulting freeboard on the Winnipeg dykes was over two feet which was in excess of that considered necessary. Therefore, the Floodway design capacity was reduced to 60,000 c.f.s. resulting in a freeboard of one foot on the existing dykes within The City of Winnipeg.

The Manning formula was used in the design of the Floodway Channel and the various parameters in the formula were selected on the basis of available information. The prime consideration was that the water level in the River above the inlet control structure would not exceed that which would obtain under natural conditions. This constraint was necessary as the previous investigations did not reveal that an economically viable scheme could be recommended to provide protection along the River above the Floodway and therefore no increase in the natural flood levels could be tolerated without subjecting the Province to flood claims. The roughness coefficient (n) that was selected was 0.028. The maximum permissible velocity was selected as five feet per second.

The selection of side slopes was based on extensive analysis of existing natural and artificial channels in the Red River Valley, and detailed investigations of the soils along the Floodway route. Dr. A. Casagrande acted as Soils Consultant on the Floodway and recommended that 6:1 side slopes be used except in the granular material of the Birds Hill area where 2.5:1 slopes could be used. This latter slope was changed to 3:1 in the final design due to practical
considerations. In the vicinity of railway and road structures, due to economic and safety reasons, the side slopes were flattened to 9:1. Transition sections were incorporated in the channel at points of change in cross-sections and above and below structures where the side slopes were flattened.

In the selection of the most economical cross-section for the channel which would satisfy the design criteria, the estimated excavation cost was an important consideration as the estimated volume of 100 million cubic yards of excavation represents almost half the total cost of the project. The R.R.B.I. and the Royal Commission used an excavation price of 30 cents per cubic yard for earth and one dollar for glacial till, these prices were used in estimates for the final design with the cost of the bridges being estimated by the constructing authority.

In the final contracts however, the unit price for excavation included the removal and disposal of all materials either clay or glacial till as encountered by the contractor. The minimum price was 18.9 cents per cubic yard, the maximum 41 cents, with the overall average being 28.8 cents per cubic yard.

A computer program system was used to calculate accurately the backwater curves and earth work calculations, on ten designs selected from about fifty preliminary designs in which approximate calculations were used. The variations in the cost of ten designs was only about two per cent. The final selection of the cross-section was to use a shallower channel rather than a deeper channel which would have encountered additional till excavation and increased maintenance costs.

The channel is divided into three reaches, the reach from the inlet to Birds Hill (a glacial esker crossing the route), has a channel
with a base width of 540 feet, with 6:1 slopes, the section through
Birds Hill a base width of 420 feet, side slopes of 3:1 and the reach
north of Birds Hill to the outlet, a base width of 380 feet and 6:1
slopes. The designed depth of flow is 27 feet in the channel with the
maximum depth of cut being 65 feet. A small channel with a capacity
of 100 c.f.s. was incorporated in the cross-section to confine the
normal flows from the waterways intercepted by the Floodway to the
centre of the channel. The excavated material was deposited along
the sides of the channel with 150 berm between the top of channel and
toe of embankment slope. The maximum allowable height of the
embankment was 19 feet and the side slopes were 6:1 with the top width
varying as required to dispose of excavated material. (Figure 5)

The Floodway inlet section consists of a broad crested 700 foot
wide earthen weir with a crest elevation of 750 at the River and a
transitional section widening to the normal floodway cross-section.
The summer and spring flows below 30,000 c.f.s. will pass down the
Red River without entering the Floodway.

The Floodway inlet control works and outlet control structures
are the two major hydraulic structures on the Floodway. The design
and supervision for construction of these works was carried out by

At the Inlet without control works in the River, the flood
flows would split between the River and the Floodway resulting in a
drawdown of approximately eight feet extending upstream in the River.
This drawdown would dictate a larger channel, however, with control
works in the River, the natural water levels can be maintained
upstream and the water entering the Floodway regulated.

In addition to the regulatory role the structure also had to
TYPICAL CROSS SECTION
NORTH OF BIRDS HILL

FIGURE 5 RED RIVER FLOODWAY CROSS-SECTION

TYPICAL CROSS SECTION
SOUTH OF BIRDS HILL
include facilities for the passage of small pleasure boats up and down the River during normal summer navigation season and the widest clear spans economically feasible to permit the passage of ice and floating debris. Consideration was given to various types of conventional gates, the final selection was in effect a reversed submersible tainter gate hinged on the upstream side, and operated by servomotors housed in the piers. Hydraulic model testing was carried out on the proposed gates and the structure layout. The final design selected was two gates 112.5 feet long and 34.9 feet high. The weir crest was set at 728 and energy dissipation was obtained by a "flip bucket" arrangement. The structure is founded on bedrock approximately 100 feet below the deck level of the public roadway over the structure. The centre pier contains the operating machinery and the control room.

At the design discharge the water surface profile on the Floodway at the outlet was 14 feet above the River level. A control structure was therefore required to dissipate the energy and ensure that scouring did not occur on the river banks. The final design, as a result of model tests, consisted of a rollaway with a length of 162 feet at an elevation of 730 feet with a stilling basin having a length of 120 feet and floor elevation of 707.5 feet. This structure was also founded on bedrock which occurs at approximately elevation 706 in the area. Two 42" diameter conduits are provided through the rollaway to handle the low flow discharge from the Floodway channel.

In order to prevent the flood flows in the valley entering the City from the south-west a dyke extending westerly for approximately 20 miles, varying in height between two to twenty feet was required. During full design flow in the Floodway the water surface will be above
prairie level for a distance of approximately six miles downstream of
the inlet and a special compacted dyke section was incorporated in the
disposal embankment on the west side of the Floodway.

The Floodway intercepts numerous natural and artificial waterways.
Due to the difference in elevation between the bottom of these channels
and the Floodway bottom, drop structures were required. In order to
reduce the number of structures, a collecting drain was constructed
on the Eastern limit of the Floodway right-of-way with entrances into
the main channel at selected locations. There are six local inlet
structures along the Floodway.

At the point where the Seine River crosses the Floodway, a
siphon was constructed under the Floodway to carry 100 c.f.s. of the
Seine River flow. The balance flows into the Floodway through a drop
structure.

Bridges over the Floodway were designed by the various
transportation authorities. The Water Control and Conservation Branch
provided the hydraulic requirements at each location, approved the
plans and were responsible for contract administration. There are
seven railway crossings and six highway crossings.

The Floodway crosses the two branches of the City of Winnipeg water
supply aqueduct. Similar arrangements were made for the lowering of the
aqueduct as were made with the bridges. There are six hydro transmission
lines crossing the Floodway, one oil pipe line and one gas pipe line.
Communication lines across the Floodway have been incorporated in the
various bridge crossings where possible.

In planning the construction of the Floodway, detailed
investigations were carried out as to the possibility of employing
hydraulic dredging. It was considered, however, that dredging was not
feasible due to the difficulty of handling the clays, and the volume of water which would be available from the Red River. The consideration of dredging appeared favourable in the earlier stages due to the expected difficulties of operating conventional equipment at the depths of the Floodway. In the Fall of 1961, a full scale test pit was constructed to determine slope stability as well as the ability of equipment to work in the highly saturated clays above the glacial tills. In addition, a smaller test pit was constructed to determine the best method for the removal of the cemented glacial till (hard-pan) in the area north of Birds Hill.

The excavation contracts on the Floodway were on the average one and one-half miles long and represented on the average two million cubic yards of excavation. The bridges were constructed in the dry by excavating approximately one-third the estimated depth at the bridge site, completing the bridge and then requiring the earth contractor to remove the remaining earth to the design channel cross-section.

In 1962 the total cost of the Floodway was estimated at $63,212,000.00 and the final total cost was $61,276,000.00. The Floodway was constructed under a Federal-Provincial agreement under which the Federal Government contributed $35,065,000.00.