Transboundary Implications of the Garrison Diversion Unit

INTERNATIONAL JOINT COMMISSION

Transboundary Implications of the Garrison Diversion Unit

INTERNATIONAL JOINT COMMISSION

CANADA AND UNITED STATES

1977

INTERNATIONAL JOINT COMMISSION
CANADA AND UNITED STATES

COMMISSIONERS

MAXWELL COHEN, *Chairman*

BERNARD BEAUPRE

KEITH A. HENRY

HENRY P. SMITH III, *Chairman*

CHARLES R. ROSS

VICTOR L. SMITH

SECRETARIES

DAVID G. CHANCE
Ottawa

WILLIAM A. BULLARD
Washington

FOREWORD

The International Joint Commission wishes to acknowledge with gratitude the valuable contribution of the members of the International Garrison Diversion Study Board and of the members of the five Committees which assisted the Board in its endeavours. Without their individual zeal and collective effort, completion of the Commission's inquiry in such a short time would not have been possible.

The Commission appreciates the large amount of data provided by the United States Bureau of Reclamation. While it was suggested during the inquiry that all data had not been made available, the Commission and its Board are satisfied with and commend the Bureau of Reclamation for its cooperation. The Commission also wishes to acknowledge the support and cooperation of the seventeen federal, state and provincial agencies that actively participated in the investigation.

TABLE OF CONTENTS

TABLE OF CONTENTS (cont'd)

TABLE OF CONTENTS (cont'd)

SUMMARY

This report of the International Joint Commission is in response to a Reference from the Governments of Canada and the United States. It briefly describes the Garrison Diversion Unit, the area in Canada affected by it, the adverse effects on Canadian waters and their uses, and measures to avoid or relieve these adverse effects. The report describes the technical investigation carried out for the Commission by its International Garrison Diversion Study Board during 1976 and summarizes the testimony given at the public hearings conducted by the Commission. Finally, the report outlines the substance of the Commission's deliberations based on the investigation and hearings and presents its conclusions and recommendations.

Construction of the Garrison Diversion Unit was authorized by the United States Congress in 1965. The purpose of the Project was to irrigate some 250,000 acres to provide municipal and industrial water supply to 14 communities, and to furnish recreational, fish and wildlife opportunities in North Dakota using water diverted from the Missouri River. Since many of the features of the Garrison Diversion Unit (GDU) are in the Hudson Bay Drainage Basin, most of the drainage and wastewaters from the irrigated areas would flow into trans-boundary streams and could have an adverse impact on Canada.

Article IV of the Boundary Waters Treaty of 1909 reads in part as follows:

> "It is further agreed that the waters herein defined as boundary waters and waters flowing across the boundary shall not be polluted on either side to the injury of health or property on the other."

Manitoba officially expressed its alarm that leaching of the irrigated soils of GDU would degrade the water quality

of the Souris, Assiniboine and Red Rivers as well as Lakes Manitoba and Winnipeg, and that the return flows would increase the amount and frequency of flooding. There was also concern that the water conveyance systems of the Garrison Diversion Unit would provide a direct connection between the Missouri River and the Hudson Bay Drainage Basin thereby enabling the possible introduction of foreign fish, fish eggs, fish parasites, fish diseases and other biota into Manitoba waters. This could have an irreversible adverse impact on existing aquatic systems and on commercial and recreational fishing in Manitoba.

The Canadian concerns, crystallized in an aide-mémoire, prompted discussion between the Governments of Canada and the United States in 1970. Five years later the two Governments referred the matter of the transboundary implications of the Garrison Diversion Unit to the International Joint Commission. The Commission was requested to report on the existing conditions of water quality, water quantity, biological resources, and present and anticipated water uses; the impact of GDU as envisaged at the time of the Reference on them; to make recommendations as to such measures as might be taken to assist Governments in ensuring that the provisions of Article IV of the Boundary Waters Treaty of 1909 are honoured, and to estimate the costs of such measures. All this was to be completed within the severe time constraint of one year.

The Commission immediately established the International Garrison Diversion Study Board to undertake the technical investigation. The limited time frame precluded field studies to obtain new data. Therefore, existing data were used to assess the impact of GDU on Canadian waters. The Board during their intensive year-long investigation adhered to a rigorous schedule so as to

concurrently determine existing conditions in Manitoba and estimate the quantity, quality and impact of return flows resulting from the Garrison Diversion Unit. It also examined proposals to minimize the adverse effects of GDU and to mitigate the remaining impacts.

The eight public hearings conducted by the International Joint Commission were an integral part of the inquiry into the transboundary implications of the Garrison Diversion Unit. Three initial hearings were held in November 1975 to obtain opinions on the possible effects of GDU and guidance in planning the investigation. Two months after the Board's report was distributed, five public hearings were held, in March 1977, to receive comments on the report and further views of concerned individuals, citizen groups, elected representatives and governmental officials. At each public hearing all those interested were given the opportunity to express their views orally or present documentary evidence. In addition to these formal public hearings, the Board, pursuant to a Commission Directive, held open meetings to answer questions on its investigation.

The Commission in its deliberations considered testimony given at the public hearings, the Board's report and written submissions. On the basis of this evidence the Commission has concluded that the construction and operation of the Garrison Diversion Unit as envisaged would cause injury to health and property in Canada as a result of adverse impacts on the water quality and biological resources in Manitoba. Modifications to GDU as envisaged such as the elimination of direct connections between the Missouri River and the Hudson Bay Drainage Basin, replacement of highly-saline soils with a similar acreage of soils less saline, lining the Velva Canal, and wetland habitat restoration, would reduce, but not eliminate, all

of the adverse impacts in Canada. Most of the remaining impacts, other than those from possible biota transfers, can be mitigated to a significant extent.

The Commission has concluded that it would be prudent to verify the predicted quantity and quality of return flows from GDU. Research to determine the ultimate fate of nitrogen in the Souris River is essential before there is development of irrigation in that area.

The International Joint Commission recommends that the portion of the Garrison Diversion Unit which affects waters flowing into Canada not be built at this time. However, the Commission has outlined in its recommendations the conditions under which it believes that that portion of GDU might later proceed.

CHAPTER I
INTRODUCTION

The Garrison Diversion Unit (GDU) as authorized by the United States Congress in 1965 would divert water from the Missouri River into the Hudson Bay Drainage Basin in North Dakota. Construction was initiated in 1967. A portion of the diverted water would enter the Souris and Red Rivers as return flow from irrigated lands, seepage, operational wastes, and as effluent from municipal and industrial systems. These return flows, mixed with water of the Souris and Red Rivers, would then enter Manitoba.

Nature of the Problem

The Governments of Canada and Manitoba expressed concern that return flows from GDU would have adverse transboundary effects. They were perturbed that the addition of GDU waters might increase the amount and frequency of flooding that occasionally occurs on the Souris, Assiniboine and Red Rivers. The Project could also adversely affect water quality in these streams, and in Lake Winnipeg and Lake Manitoba. For example, return flows might contain higher concentrations of total dissolved solids, nutrients, and other chemical constituents.

The GDU might also affect fish and wildlife resources in Manitoba by transferring foreign biota from the Missouri River into the Hudson Bay Drainage Basin through water conveyance systems. Fish, fish diseases, and fish parasites could have an adverse impact on commercial and recreational fisheries on Lake Winnipeg and Lake Manitoba. There could also be a possibility of the introduction of other biota which could interfere with the existing aquatic systems or cause diseases in animals or humans using the water.

The Government of Canada, on the basis of preliminary studies conducted separately by the United States and Canada, concluded that the Garrison Diversion Unit, as envisaged, would cause injury to health and property in Canada in contravention of Article IV of the Boundary Waters Treaty of 1909.

Scope of the Inquiry

On October 22, 1975, the Governments of Canada and the United States requested the International Joint Commission to examine into and to report upon the transboundary implications of the proposed completion and operation of the Garrison Diversion Unit in the State of North Dakota. The Commission was asked to make recommendations as to measures which might be taken to assist the Governments in ensuring that the provisions of Article IV of the Boundary Waters Treaty are honoured.

Specifically it was requested to report on the present water quality in the Canadian portions of the Souris and Red Rivers, their tributaries, and downstream waters; present and anticipated uses of these waters; and the effects of present water quality on these uses. The Commission was asked to determine the impacts of the completion and operation of the GDU on the quality and quantity of these waters, their present and anticipated uses, and the impact on commercial and recreational fisheries in Manitoba.

Should the Commission make recommendations concerning measures to avoid or relieve adverse effects in Canada, it was requested to estimate the costs of such measures. The text of the Reference is in Appendix A.

The Commission was requested to transmit its report no later than October 31, 1976. With this severe time constraint of one year, it was clear to the Commission

and its International Garrison Diversion Study Board at the outset of the inquiry that there was not enough time for extensive field studies to obtain new data. The assessment of the effects of the return flows from the Project on Canadian waters would have to be made essentially with existing data. The Board submitted its findings to the Commission in December 1976. The Commission published and distributed the Board's report in January 1977.

Chronology of Events

During the 1960's and the early 1970's the Commission's International Souris-Red Rivers Engineering Board informed the Commission of progress in the planning and construction of the Garrison Diversion Unit. Congressional authorization for construction of the GDU was enacted in 1965. After an expression of alarm by Manitoba regarding the potential transboundary effects of the Project, these concerns were crystallized in a Canadian aide-mémoire to the Government of the United States in April 1970. Subsequently, on the basis of reports prepared by the United States Bureau of Reclamation, Canada submitted a diplomatic note in October 1971 reiterating its concerns as to the possible impacts of the Project on quantity and quality of water in the Souris and Red Rivers and the possible introduction of foreign fish species, parasites and fish diseases.

In October 1973 Canada, in a diplomatic note, requested urgently "that the Government of the United States establish a moratorium on all further construction of the Garrison Diversion Unit until such time as the United States and Canadian Governments could reach an understanding that Canadian rights and interests have been fully protected in accordance with the provisions of the Boundary Waters Treaty." In its reply of February 1974, the Government of the United

States stated that it recognized its obligation under Article IV of the Boundary Waters Treaty and no construction affecting Canada would be undertaken until it was clear that this obligation would be met.

During 1974 officials of both countries discussed Canadian concerns over potential degradation of water quality and the associated effects on health and property in Canada. In January 1975, officials of both countries agreed to recommend to their own Governments an appropriate mechanism to undertake a joint examination of the Project to ensure that the provisions of Article IV of the Boundary Waters Treaty are honoured. On October 22, 1975 the Governments of Canada and the United States referred to the International Joint Commission the matter of the transboundary implications of the Garrison Diversion Unit.

The next day the Commission formally established the International Garrison Diversion Study Board and, within a week, issued its Directive to the Board. The Commission held initial public hearings at Minot, Winnipeg, and Grand Forks in November 1975 to receive testimony relating to the potential transboundary effects of the Project. At a public briefing on January 12, 1976 the United States Bureau of Reclamation described the status and plans for construction of the GDU, and stated that the works under construction would not cause a violation of the Boundary Waters Treaty.

The Commission approved the Board's plan of study on January 15, 1976. Throughout the investigation there was constant liaison between the Commission and the Board.

In January 1977 when the Board's report and its five appendices were available in quantity, they were immediately distributed to all known interested individuals,

organizations, and governmental agencies. In addition, copies of the report were made available at public libraries and a number of distribution points in the region. Two months later, in March 1977, the Commission conducted public hearings to receive comment on the Board's report and the views of all those concerned with the transboundary implications of GDU. These hearings were held at Minot and Grand Forks, North Dakota, and at Souris, Winnipeg and Portage la Prairie, Manitoba.

The Commission, during its deliberations, considered the report of the International Garrison Diversion Study Board, the testimony received at public hearings, and other submissions to the Commission.

CHAPTER II
THE STUDY AREA

The area of primary interest to this inquiry is the Garrison Diversion Unit and the area in Manitoba which would be affected by it. It includes components of the Project in the United States; the Souris, Assiniboine and Red Rivers; and Lakes Manitoba and Winnipeg. It is shown on Figure 5, a foldout map, at the end of this report.

The Garrison Diversion Unit

The Garrison Diversion Unit (GDU) is a multi-purpose water resource project designed to divert Missouri River water into central and eastern North Dakota. The diverted water would be used to irrigate 250,000 acres, to provide a municipal and industrial water supply to 14 communities, and to furnish recreational and fish and wildlife opportunities throughout the area. A schematic representation of the components of the Project is presented on Figure 1. It is not to scale, but illustrates the relative position of the components of the Project in the United States.

The Missouri River, the source of water for the GDU, is one of the principal rivers in the Mississippi Drainage Basin, which is one of the important drainage basins in North America. Most of the Garrison Diversion Unit is located in the Hudson Bay Drainage Basin, specifically the Nelson River System, which is another important drainage system on the North American continent. The latter extends from the Rocky Mountains in the west almost to Lake Superior in the east, and from the Mississippi River Basin to about 400 miles or 640 kilometres north of the International Boundary. It drains about 414,000 mi^2 (1,080,000 km^2) in the Provinces of Alberta, Saskatchewan, Manitoba and western

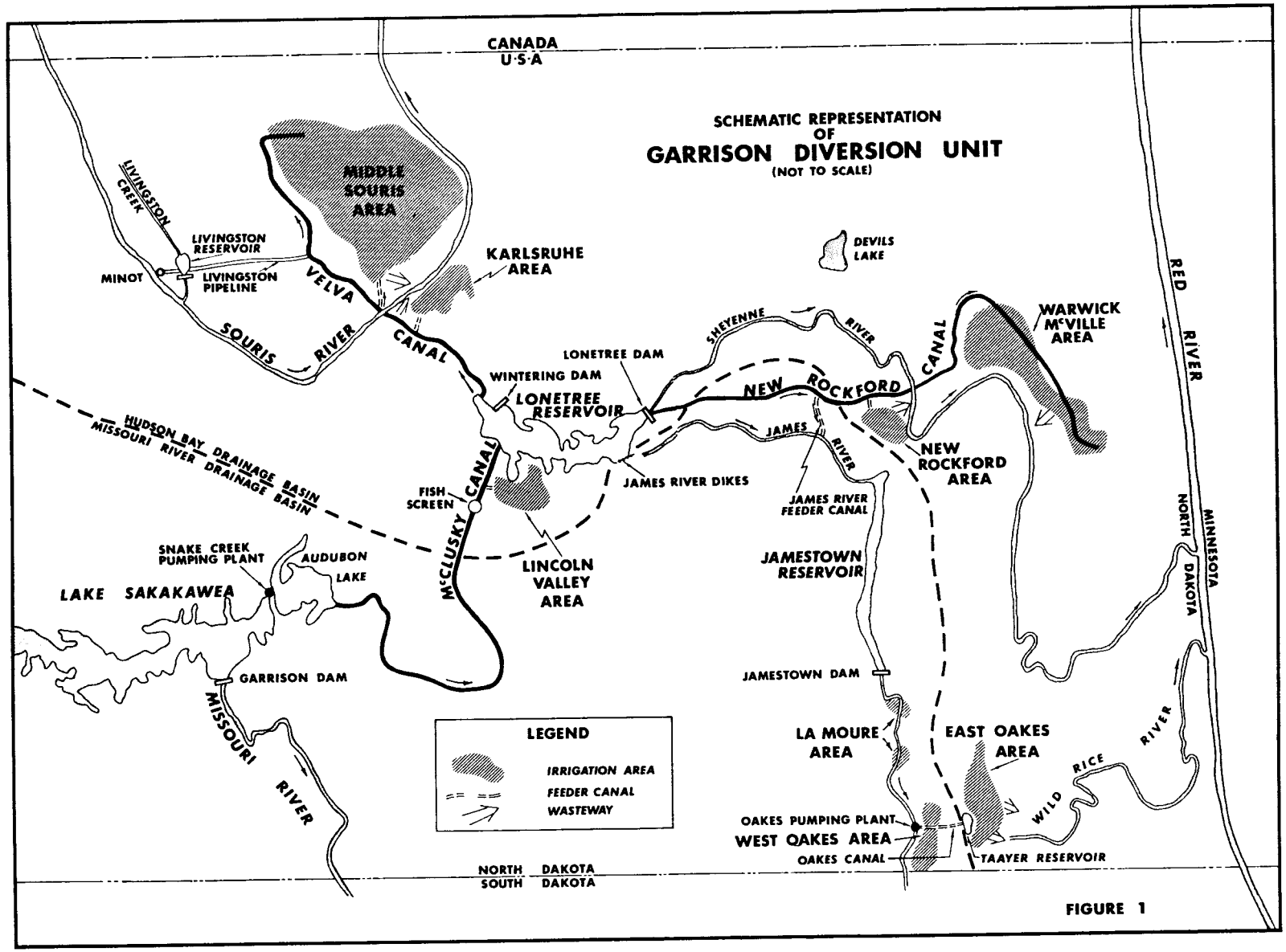

CANADA
U·S·A
SCHEMATIC REPRESENTATION
OF
GARRISON DIVERSION UNIT
(NOT TO SCALE)
MIDDLE SOURIS AREA
LIVINGSTON CREEK
LIVINGSTON RESERVOIR
MINOT
LIVINGSTON PIPELINE
VELVA
SOURIS RIVER
CANAL
KARLSRUHE AREA
DEVILS LAKE
SHEYENNE RIVER
WARWICK McVILLE AREA
RED RIVER
LONETREE DAM
WINTERING DAM
LONETREE RESERVOIR
NEW ROCKFORD CANAL
HUDSON BAY DRAINAGE BASIN
MISSOURI RIVER DRAINAGE BASIN
JAMES RIVER
NEW ROCKFORD AREA
JAMES RIVER DIKES
FISH SCREEN
McCLUSKY CANAL
JAMES RIVER FEEDER CANAL
NORTH DAKOTA
MINNESOTA
SNAKE CREEK PUMPING PLANT
AUDUBON LAKE
LAKE SAKAKAWEA
LINCOLN VALLEY AREA
JAMESTOWN RESERVOIR
GARRISON DAM
JAMESTOWN DAM
MISSOURI RIVER
LA MOURE AREA
EAST OAKES AREA
WILD RICE RIVER
OAKES PUMPING PLANT
WEST OAKES AREA
OAKES CANAL
TAAYER RESERVOIR
LEGEND
IRRIGATION AREA
FEEDER CANAL
WASTEWAY
NORTH DAKOTA
SOUTH DAKOTA

FIGURE 1

Ontario into Hudson Bay. Within the Basin are the watersheds of Lake of the Woods, the Red and Souris Rivers, Lake Manitoba, and Lake Winnipeg. Its principal watercourses are the Saskatchewan and Winnipeg Rivers.

The GDU was authorized by the United States Congress in 1965. The Snake Creek Pumping Plant, the McClusky Canal and Lonetree Reservoir, which are the Project's principal supply works, have been under construction since 1968 by the Bureau of Reclamation, an agency of the United States Department of the Interior.

The Project, as envisaged, would lift Missouri River water from Lake Sakakawea, formed by Garrison Dam, via the Snake Creek Pumping Plant into Lake Audubon, an impoundment adjacent to Lake Sakakawea. Waters from Lake Audubon would flow by gravity through the 73.6-mile (118.5-km) McClusky Canal across the continental divide into Lonetree Reservoir.

The Lonetree Reservoir, with a storage capacity of 424,000 acre-feet or 523,000 cubic decametres (dam^3), would be formed by Lonetree Dam on the upper Sheyenne River and by Wintering Dam on the headwaters of the Wintering River, both in the Hudson Bay Drainage Basin; and by the James River Dikes on the continental divide and also at the headwaters of the James River in the Missouri River Drainage Basin. The Reservoir is so situated that water released from it can be conveyed by gravity into the Souris, Red and James River Basins as well as the Devils Lake Basin.

The irrigable lands in the GDU consist of the Middle Souris Area of 103,800 acres and the Karlsruhe Area of 12,200 acres; the Lincoln Valley Area of 6500 acres; the New Rockford Area of 20,900 acres; the Warwick-McVille Area of 47,200 acres; the LaMoure Area of 13,400 acres; and the Oakes Area of 46,000 acres.

The Velva Canal would convey water northward from Lonetree Reservoir to irrigate the Karlsruhe and Middle Souris Areas. Similarly, the New Rockford Canal would provide irrigation water for the New Rockford Area and deliver water into the James River Feeder Canal for use in the Oakes and LaMoure Areas. The Warwick Canal, an extension of the New Rockford Canal, would serve the Warwick-McVille Area and provide water for the restoration of the Devils Lake Chain.

The GDU provides for the development of nine new or expanded water-oriented recreation areas dispersed over the Project area. A modification to the authorized plan for fish and wildlife development has been conceived by the United States Fish and Wildlife Service. It would eliminate most of the 36 development areas provided by the original Project plans, and would focus on the acquisition and restoration of drained wetlands together with adjoining upland habitat. This would involve the acquisition of 146,530 acres including about 53,000 acres of marsh which would be operated by federal or state agencies as game management areas open to public hunting. The Project reservoirs would provide new fishing opportunities as well as rest areas for migratory waterfowl.

Other important features of the GDU as envisaged include the lining of all canals and open laterals with compacted earth or buried membrane linings in those reaches where soil conditions are particularly conducive to seepage; the design of the distribution system for sprinkler application; and the provision by the farmer of pumps, buried pipelines instead of the traditional open ditches, and a sprinkler system to irrigate his land.

A system of drainage pipes, installed approximately eight feet (two and a half metres) below the surface, would control groundwater levels within the irrigated areas.

They would discharge into natural waterways or into open drains leading to natural waterways. This drainage water, in combination with canal seepage, operational spills, and precipitation passing through the soil profile would comprise the major portion of the return flows from GDU to the principal river systems. In addition, effluent from municipal and industrial sources and discharge from wildlife impoundments would add to return flows. The composition of return flows is illustrated in Figure 2 in Chapter V.

Construction activities to date have been limited to the principal supply works previously described. The Snake Creek Pumping Plant has been completed. The McClusky Canal, which will convey water from Audubon Lake to the Lonetree Reservoir is 90 percent complete, and Wintering Dam, a component of the Lonetree Reservoir complex, is 70 percent complete. Construction on Lonetree Dam and the James River Dikes, and on those components downstream, has not yet begun.

The Areas Affected by the Garrison Diversion Unit

The drainage system of the study area in Canada that will receive GDU waters consists of the Souris, Assiniboine and Red Rivers and Lakes Manitoba and Winnipeg.

The Souris River rises in southeastern Saskatchewan and flows southeasterly for 220 miles (350 km) before crossing the International Boundary into North Dakota. The River then loops 360 miles (580 km) through North Dakota and enters Manitoba just north of Westhope, North Dakota. From there it flows 150 miles (240 km) in a northeasterly direction to its confluence with the Assiniboine River near Wawanesa, Manitoba.

The Assiniboine River rises in eastern Saskatchewan and flows southeasterly through Manitoba to its confluence with the Red River at Winnipeg. In the spring,

when flows exceed 10,000 cubic feet per second (cfs) or 285 cubic metres per second (m^3/s), water is diverted from the Assiniboine River immediately upstream of Portage la Prairie through the Portage Diversion to the southern end of Lake Manitoba. This channel, which is 18 miles (29 km) long, was completed in 1970 and has a capacity of 25,000 cfs (710 m^3/s).

The Red River rises near the North Dakota-South Dakota boundary and meanders northward for 550 miles (900 km) into Lake Winnipeg. It forms the boundary between North Dakota and Minnesota.

Lake Manitoba, located north of Portage la Prairie, has a surface area of 1800 square miles (4660 km^2). It has a north basin and a south basin which differ in characteristics. Its major tributary is the Waterhen River which drains Lake Winnipegosis. Lake Manitoba drains into Lake Winnipeg by the Fairford River which has been regulated since 1934.

Lake Winnipeg, the largest of Manitoba's lakes, has a surface area of 9430 square miles (24,400 km^2) which is roughly the same size as Lake Erie. It has three distinct sections; the south basin, the narrows and the north basin. The principal tributaries to the Lake are the Red, Winnipeg, and Saskatchewan Rivers. Lake Winnipeg itself drains into the Nelson River and thence into Hudson Bay.

Climate

The climate of the study area is characterized as continental, having wide seasonal variations in temperature and precipitation. Average annual precipitation is about 14 inches or 36 centimetres (cm) in the western portion of the Souris Basin near the Boundary and increases to 24 inches (61 cm) in the eastern tributaries of the Red River Basin. Precipitation also varies annually, having

been as low as 8 inches (20 cm) during years of drought and as high as 30 inches (76 cm) in wet years. Surface topography, evapotranspiration losses, and other hydrologic factors limit average annual runoff from the Souris and Red River Basins to about 5 percent of annual precipitation. Most of this runoff occurs during the two months of the spring freshet.

Demography

Approximately 800,000 people live in the study area in Canada and 500,000 in the United States. The principal urban centres in the study area in Canada are Winnipeg, with a population of 540,000; Portage la Prairie, with 13,000; and Selkirk, with 9000. In the United States they are Fargo-Moorhead, with a population of 120,000; Grand Forks-East Grand Forks, with 47,000; and Minot, with 32,000. Rural areas in both countries have experienced population losses to larger towns and cities. This trend is expected to continue. Overall population growth and per capita incomes have been, and are expected to continue to be, lower than the respective national averages.

Agriculture is the dominant industry in the area of concern. In the United States portion 20.5 million acres are cropland and 3.3 million acres are pasture and range. Currently, less than 0.3 percent of this acreage is irrigated. Non-agricultural income sources in North Dakota include processing industries related to food, petroleum, coal, sand, gravel, and timber.

In Manitoba there are 8.7 million acres of farmland, located in the Souris, Assiniboine and Red River Basins. Almost all of Manitoba's production and processing of corn, field peas, buckwheat, sunflowers, sugar beets, potatoes, and canning crops are in the area. About 45 percent

of the cattle, 70 percent of the hogs, and 80 percent of the poultry marketed in Manitoba are from this area. Nearly 11,000,000 pounds or 5 million kilograms (kg) of high quality fish such as whitefish, walleye and sauger were harvested commercially from Lakes Manitoba and Winnipeg during the 1974-75 fishing season. The Lakes and the rivers of the study area are also important for sport fishing and other water-based recreation.

CHAPTER III
EXISTING CONDITIONS IN THE STUDY AREA IN CANADA

In order to assess the potential impacts of the Garrison Diversion Unit on the Souris, Assiniboine, and Red Rivers in Canada and Lakes Manitoba and Winnipeg, it is first necessary to determine their existing conditions of water quantity, water quality, biological resources, and present and anticipated water uses.

Present Water Quantities

SOURIS RIVER flows are affected by wet and dry periods which extend over several years. For instance, since the large spring flood of 1969, above-normal flows have been experienced almost every year. The maximum recorded flow of 12,400 cubic feet per second (cfs) or 351 cubic metres per second (m^3/s) occurred in April 1976. During the drought of the 1930's prolonged periods of low flows were experienced. In addition to these annual fluctuations in flow, the Souris River also experiences seasonal fluctuations. In general high flows occur in the spring and low flows occur in winter. Since 1936 there have been 23 years during which the River ceased to flow for at least one day. The mean monthly flow for the Souris at Wawanesa during the spring freshet is 1300 cfs (37 m^3/s), and in the winter it is less than 100 cfs (3 m^3/s).

Flooding frequently occurs on the Souris between Westhope, North Dakota, and Souris, Manitoba. In this reach 300 acres are flooded when the flow is 500 cfs (13 m^3/s), and 800 acres when the flow is 1000 cfs (28 m^3/s). Most of this flooding occurs just north of the International Boundary. In this reach, a flow of at least 1000 cfs (28 m^3/s) has a

probability of occurring once every two years. Thus, 800 acres are frequently inundated. Similarly, a flow of 7000 cfs (200 m^3/s) has a probability of occurring once in about 15 years, flooding a total of 16,900 acres between the International Boundary and Souris, Manitoba. Flows higher than 7000 cfs (200 m^3/s) would cause little increase in flooded area because the sideslopes of the valley are steep.

ASSINIBOINE RIVER flows are larger than those of the Souris. They also undergo seasonal fluctuations. The average monthly flows range from a low of 300 cfs (8 m^3/s) to a high of 6000 cfs (170 m^3/s) upstream of the Portage Diversion. The minimum recorded flow at Portage la Prairie was 25 cfs (0.7 m^3/s) in 1963; the maximum recorded flow above the Diversion was 51,700 cfs (1460 m^3/s) in 1976.

Flows in excess of 20,000 cfs (565 m^3/s) cause flooding between its confluence with the Souris River and Portage la Prairie. Such flows have a probability of occurring once every five years. Below Portage la Prairie local flooding begins to occur at 10,000 cfs (285 m^3/s), but major flooding occurs at about 20,000 cfs (565 m^3/s). If the Portage Diversion is working at its maximum capacity, then flows of 10,000 cfs (285 m^3/s) in the reach below the Diversion have a probability of occurring once every twenty years, and flows of 20,000 cfs (565 m^3/s) would have a probability of occurring once every 100 years.

RED RIVER flows range from a low mean monthly flow of about 800 cfs (23 m^3/s) to a high of 13,900 cfs (395 m^3/s). The lowest flow recorded at Emerson, Manitoba, near the International Boundary was 1 cfs (0.03 m^3/s) in 1937.

Flooding commences at Emerson when flows reach 30,000 cfs (850 m^3/s). Such a flow has a probability of occurring once every four years. Just upstream of Winnipeg, flooding occurs when the flow exceeds 65,000 cfs (1840 m^3/s).

Winnipeg itself is protected from flooding by the Red River Floodway which has a capacity of 60,000 cfs (1700 m^3/s).

LAKE MANITOBA consists of the north and south basins. The south basin receives most of its inflows from precipitation directly on the Lake surface, although the Portage Diversion may contribute up to 20 percent of the total inflow to the Lake.

LAKE WINNIPEG receives most of its waters from the Winnipeg and Saskatchewan Rivers. The Souris, Assiniboine and Red Rivers contribute only 6 percent of the total inflow to Lake Winnipeg.

Present Water Quality

A number of parameters are used to assess the present state of water quality in the Canadian portion of the study area. The importance of these parameters as they affect water use, and the proposed objectives for water quality of the Souris and Red Rivers in Manitoba, are set out in Chapter V.

SOURIS RIVER flow fluctuations are accompanied by a wide variation in water quality. Concentrations of total dissolved solids (TDS) are high in winter when the groundwater contribution to flows is high compared to surface contributions, and are at their lowest in the spring as a result of dilution by runoff from snowmelt. For example, TDS values ranged from a winter median of 1126 grams per cubic metre (g/m^3) or milligrams per litre (mg/ℓ) to a spring median of 395 g/m^3 in the period 1960 to 1974.

Nitrate and phosphorous concentrations did not show any consistent seasonal variations over the period 1969-74 for which records were available. Median values for nitrates as nitrogen ranged from 0.11 to 0.48 g/m^3. Median values for total phosphorus ranged from 0.23 to 0.39 g/m^3.

Dissolved oxygen concentrations have ranged between 0.1 and 13.8 g/m^3. They are generally lowest during ice cover and low flow periods. As to coliform bacteria, the most probable number ranged from 23 to 547 per 100 millilitres (mℓ). Highest values occur in the fall when sewage effluent is released to the River from urban centres. Most of the trace elements such as boron, selenium, lead, and other heavy metals, are at levels near the detection limit. Pesticides, herbicides and industrial chemicals are rare.

The historic monthly medians for selected parameters for the Souris River at the International Boundary are set out in Table 1 in Chapter VI.

ASSINIBOINE RIVER total dissolved solids concentrations are less than for the Souris because of its higher flows, but follow the same seasonal trends. Median concentrations range from 447 to 622 g/m^3. Nitrate and phosphorous values follow a seasonal trend on the Assiniboine; median nitrate values range from a high of 0.54 g/m^3 in the spring to a low of 0.16 g/m^3 in the summer. Similarly, median phosphorous concentrations range from a high of 0.33 g/m^3 during spring runoff to a low of 0.005 g/m^3 under ice cover. Median dissolved oxygen concentrations range from 12 g/m^3 during spring runoff to 5 g/m^3 under ice cover. Coliform levels are quite low. Trace elements occur at levels near the detection limit. Pesticides, herbicides and industrial chemicals have been occasionally detected.

RED RIVER values at Emerson for TDS vary from 224 to 553 g/m^3. High suspended sediments values, ranging up to 500 g/m^3, reflect runoff from agricultural lands throughout the Red River Basin. Median nitrate values range from 0.10 g/m^3 in the fall to 0.81 g/m^3 in the spring. Median phosphorous concentrations range from 0.16 to 0.21 g/m^3. Median nitrate values in summer, fall and winter increase

between Emerson and Selkirk, probably due to the release of effluent from the City of Winnipeg. There is a reduction of nitrate concentrations between Emerson and Selkirk in the spring. Phosphorous concentrations increase from Emerson to Selkirk due largely to effluent releases from Winnipeg, although other urban centres and drainage from agricultural lands do contribute to nutrient loadings. Median dissolved oxygen values range from 7 to 11 g/m^3. Coliform values are generally low. Trace elements occur at concentrations near the detection limit. Some pesticides, herbicides, and industrial chemicals have been detected. The historic monthly medians for selected parameters for the Red River at the International Boundary are set out in Table 2 in Chapter VI.

LAKE MANITOBA water quality is difficult to describe using available data because of the inconsistencies as to location and timing of water samples. Therefore, it was necessary to estimate average annual concentrations by computing water budgets and calculating loading rates. Suspended solids, total nitrogen, and total phosphorus are common parameters which indicate the water quality of lakes. In the south basin, estimated average annual suspended solids concentrations in the period 1969-74 varied from 6 to 114 g/m^3; total nitrogen varied from 0.9 to 1.6 g/m^3; and total phosphorus from 0.04 to 0.14 g/m^3. In the north basin, estimated average annual concentrations of suspended solids varied from 6 to 12 g/m^3, total nitrogen from 0.97 to 1.21 g/m^3, and total phosphorus from 0.02 to 0.03 g/m^3.

The available data indicate that the Portage Diversion increases concentrations of bicarbonates, total nitrogen, phosphorus and suspended solids in the south basin of Lake Manitoba while constituents such as sodium and chloride are diluted.

LAKE WINNIPEG water quality is also difficult to describe for the same reasons as Lake Manitoba. Estimated average annual suspended solids concentrations in the south basin in the period 1969-74 varied from 12 to 71 g/m^3. Total nitrogen varied from 0.7 to 1.2 g/m^3 in the south basin as compared to 0.6 to 0.8 g/m^3 in the north basin. Total phosphorus in the south basin varied from 0.07 to 0.16 g/m^3 as compared to 0.04 to 0.05 g/m^3 in the north basin. The higher average concentration of nitrogen and phosphorus in the south basin in part reflects the comparatively high nutrient concentrations in the Red River.

Maximum concentrations of nitrogen and phosphorus, the dominant nutrients, occurred in summer when the greatest algal biomass was observed; lowest concentrations were observed under ice conditions when algal production was at a minimum.

Although Lake Winnipeg receives an abundant supply of nutrients, the turbid water in the south basin reduces light penetration, thereby limiting the growth of algae. The north basin and the narrows section are not as turbid and the increased light penetration enables algae to use a higher proportion of available nutrients.

Present State of the Biological Resources

The primary concerns related to the biological resources of Manitoba are waterfowl and fish. Their occurrence in the study area is discussed in the following paragraphs.

WATERFOWL move freely to Manitoba from North Dakota. Banding returns indicate that waterfowl present in North Dakota one year may occupy habitat in Manitoba in another year. Furthermore, even within the same year, large numbers of birds shuffle northward across the Boundary.

Therefore, it is necessary to consider waterfowl populations in North Dakota as well as in Manitoba because they are interdependent breeding areas.

Habitat is the key to waterfowl production. In the areas in North Dakota which would be affected by the Garrison Diversion Unit, marshes, potholes and waterways are extensively used by waterfowl. Approximately 115,000 ducks are produced annually in these areas. In North Dakota, approximately 28,000 ducks are produced annually in three wildlife refuges on the Souris River and its tributaries. In addition, the Souris River shoreline in North Dakota produces 1700 ducks annually. The Red, Sheyenne, and Wild Rice Rivers in North Dakota produce about 12,700 ducks annually.

The Manitoba portion of the Souris River annually produces about 2600 ducks in marshes formed by oxbows in the River valley. The section of the Assiniboine River downstream of the confluence with the Souris annually produces about 3800 ducks. On the Red River, the annual production is about 2600 ducks. The estimated annual production for Lake Manitoba is 115,000 ducks. The Lake has 271,500 acres of major marshes. In addition the world's largest duck hatchery is adjacent to the Delta Marsh. Lake Manitoba supports and stages large populations of waterfowl. Lake Winnipeg, which has 100,000 acres of major marshes produces 58,000 ducks annually.

FISH are a valuable biological resource in the Canadian portion of the study area. The Souris and Assiniboine Rivers are not fished commercially, but they do support a good sports fishery for northern pike, walleye and sauger. The lower 20 miles or 30 kilometres (km) of the Red River is the most heavily fished waterway for sport in Manitoba.

In Lake Manitoba the annual commercial fish catches have varied from 2 to 7 million pounds or 0.9 to 3.2 million kilograms (kg) during the past 15 years. The most valuable commercial species, walleye, sauger and northern pike, make up about half of the total catch. Most fish are taken in the north end of the Lake in winter. The gross income of commercial fishermen on the Lake in 1975 was $412,000 (Can.). In addition, approximately 75,000 pounds (34,000 kg) of fish are taken annually for subsistence use by Indians and Metis.

Lake Winnipeg supports Manitoba's largest commercial fishery. It operates during both open water and winter seasons. The major commercial species, lake whitefish, walleye and sauger, comprise about two-thirds of the total catch. Northern pike are also taken in large quantities but are of lower commercial value. The gross income of commercial fishermen on the Lake in 1975 was $2,614,000 (Can.). Lake Winnipeg also furnishes an important sport fishery for walleye and northern pike, particularly along the west shore of the Lake where roads provide ready access. In 1975, Indians and Metis living in communities adjacent to Lake Winnipeg harvested approximately 175,000 pounds (80,000 kg) of fish for subsistence use.

There are at least 20 species of fish which occur in the Missouri River Drainage Basin which have not been found in that portion of the study area which is located in the Hudson Bay Drainage Basin. These include such trash fish as the pallid and shovelnose sturgeons, paddlefish, shortnose gar, gizzard shad, rainbow smelt, river carpsucker, smallmouth buffalo, and Utah chub. The absence of these undesirable species in Manitoba waters is important because they have a high reproductive potential,

could successfully compete for food and space required by existing species, could reduce and replace indigenous forage fish such as lake herring, could alter the balance between existing predators and their prey, could carry parasites, could destroy some of the present species such as lake sturgeon, could be a nuisance to anglers and foul the nets of commercial fishermen, and could consequently destroy the fishing industry in Manitoba.

One of these species, the rainbow smelt, has been in the headwaters of the Rainy River system in Ontario and Minnesota since 1970. For unknown reasons, these fish have apparently not moved downstream. These smelt may or may not reach Lake Winnipeg through the Rainy River.

The black bullhead has recently been found in the Delta Marsh area of Lake Manitoba as a result of the operation of the Portage Diversion which conveys flood waters from the Assiniboine River to Lake Manitoba. This illustrates the potential movement of foreign species of fish.

OTHER biological aspects include the occurrence of whitetail deer along the Souris River in Manitoba. This region is an important wintering area for whitetail deer. The Delta Marsh area at the south end of Lake Manitoba produces large numbers of muskrats and other furbearers. Blackfly outbreaks which are a nuisance to humans and animals, occur along some reaches of the Souris River during years of high flow.

Present and Anticipated Water Use

Water in the study area has often been in short supply and of poor quality. These water supply problems have compelled municipalities to seek alternative sources, or to install costly storage and treatment facilities.

A moderate increase in population is expected by the year 2000. The trend for people to move into urban

areas is expected to continue. In Manitoba, about 27,000 people live in six communities served by the surface waters which would receive return flows from the Garrison Diversion Unit. That number is expected to increase to about 36,000 by the year 2000.

Almost 3.5 million gallons daily (mgd) or 16,000 cubic metres daily (m^3/d) were withdrawn in 1975 for municipal purposes in Manitoba of which 1.6 mgd (7300 m^3/d) were withdrawn from the Red River, 1.7 mgd (7700 m^3/d) from the Assiniboine and 14,000 gallons per day (65 m^3/d) from the Souris. These withdrawals are expected to increase by the year 2000 to 2.0 mgd (9100 m^3/d) from the Red, 2.5 mgd (11,400 m^3/d) from the Assiniboine and 130,000 gallons per day (600 m^3/d) from the Souris.

Rural domestic water requirements in Manitoba include household uses on farms, Indian reservations, and rural settlements that are supplied from surface waters that could be affected by return flows from GDU. Though small, these withdrawals are vital to the individual users because groundwater supplies are often brackish. In 1975, about 650 gallons per day (3 m^3/d) were withdrawn from the Red, 36,000 gallons per day (165 m^3/d) from the Assiniboine, 7700 gallons per day (35 m^3/d) from Lake Winnipeg, and 34,000 gallons per day (155 m^3/d) from Lake Manitoba for a total of 78,350 gallons per day (355 m^3/d). This is expected to increase to about 238,850 gallons per day (1100 m^3/d) by the year 2000. Although water quantity is not normally a limiting factor for rural domestic use along the Red and Assiniboine Rivers, periods of zero flow in the Souris River limit its use for rural domestic purposes. In many instances some form of treatment is necessary.

Most of the Manitoba industries in the study area rely on municipal water supplies. The major exceptions are two thermal generating plants and sugar beet

processors. They presently withdraw 66.6 mgd (300,000 m^3/d) from the Red River. Some treatment is usually provided for these withdrawals, to control scaling and corrosion for boiler water used by the generating plants, and to reduce hardness, total solids, colour, and chlorine for food processing. By the year 2000, industrial water use in the study area in Manitoba is expected to increase to about 158 mgd (720,000 m^3/d) because of new vegetable and potato processing plants, a nuclear generating station, a glass plant, a winery, a distillery, a sugar beet processor, and a fertilizer plant.

Agricultural uses of water consist of irrigation and livestock watering. Withdrawals in the study area in Manitoba for irrigation totalled 1800 acre-feet or 2200 cubic decametres (dam^3) in 1975. In the Portage la Prairie area, the centre of vegetable production in Manitoba, vegetables, sunflowers and rapeseed were grown on 1000 acres of irrigated land. About 400 acres are irrigated by water withdrawn from the Red River and 100 acres from the Souris. By the year 2000, it is expected that 30,000 acres will be irrigated by waters from the Assiniboine, 25,000 acres from the Red, and 6000 acres by waters from the Souris.

The 34,000 head of livestock in the study area in Manitoba consumed 680 acre-feet (850 dam^3) of water in 1975.

The provision of services and supplies to cottages, guiding and outfitting hunters and fishermen, trapping and other such activities produce income for Canadians along the waterways, and many of these activities are expected to expand. Earnings from guiding and outfitting in 1975 totalled about $1.5 million (Can.). This is expected to increase to $8 million by the year 2000. Subsistence hunting, fishing, and trapping are also important.

The strip of land within a half-mile (0.8 km) on either side of the Red, Assiniboine and Souris Rivers, and within a half-mile (0.8 km) of Lakes Winnipeg and Manitoba encompasses most of the region's water-based recreational opportunities. These opportunities, although limited in number, are experiencing intensive use.

CHAPTER IV
THE BOARD'S INVESTIGATION

The International Joint Commission established the International Garrison Diversion Study Board on October 23, 1975. A week later, at the first meeting of the Board, the Commission issued its Directive which is in Appendix B.

The Board consisted of six Canadian and six United States members drawn from ten federal, provincial and state agencies. They were appointed by the Commission in their personal and professional capacities, as is usual in the Commission's Boards, and not as representatives of their particular jurisdictions and agencies. Their individual backgrounds included engineering, agriculture, biological sciences, economics, and public administration. A list of the Board members is included in Appendix C.

The size, complexity, and time constraints of the study made it necessary for the Board to create five technical committees, namely the Water Quality, Water Quantity, Biology, Uses, and Engineering Committees. The membership of the Committees, which was approved by the Commission, consisted of 53 experts drawn from 16 federal, provincial and state agencies and two universities. In the selection of the Committee members care was taken to involve all the disciplines that could provide a meaningful contribution to the study. The membership of each Committee is listed in Appendix D. The participating agencies and the two universities are identified in Appendix E.

Coordination between the Board and the Committees and between the Committees themselves was maintained during the investigation by a regular exchange of minutes and correspondence, by assigning two Board members to each

Committee to ensure constant liaison, coordination meetings, and individual contact between study participants. In addition, a Synthesis and Reports Committee, consisting of the two Board chairmen and the co-chairmen of each of the five technical committees reviewed the committee reports and assisted in the preparation of the Board's report to the Commission.

On January 16, 1976 the Board submitted its detailed Plan of Study to the Commission and suggested composition of the Technical Committees. After a thorough discussion, the Commission approved both the Plan of Study and the membership of the Committees.

The Board chairmen made monthly reports on the progress of the study and there was also constant liaison between Commission staff and the Board.

During the course of the intensive year-long investigation, the Board members met for 98 days. This included 28 full Board meetings, 8 Board-Committee coordination meetings, inspection of the study area, briefing the Commission on two occasions, attending public hearings, and 8 meetings of the Board chairmen. Several of the Board members were absent from their offices on Board business for about 170 days each. Board members devoted between 70 and 85 percent of their time to the study during the year. Exclusive of travel time, the five Technical Committees met for a total of 200 days. Only the intensive hard work of the members of the Board and its Committees made it possible for the extensive investigation to be completed in such a short time. The cost of the investigation including salaries, overhead, travel and support of the Board and Committee members was more than $1,500,000, shared by both countries.

As directed by the Commission, the Board, during the course of its investigation, held meetings open to the public, approximately every two months. Prior notice of these meetings was given to the news media. At the meetings the Board answered pertinent questions on the progress of the study and adequacy of available data.

The Commission in its Directive requested the Board to have its report completed by August 15, 1976 so that the Commission's report could be completed by October 31, 1976. The acquisition, evaluation and interpretation of existing data precluded meeting that time constraint. The Board's report was delivered to the printer on December 14, 1976 and was ready for distribution to the public in less than four weeks.

The results of the Board's study are given in detail in its report to the Commission, dated December 1976, and the five appendices attached thereto. As can be expected, there were a few differences of opinion among the participants. The differences were not along national lines. They were fully discussed in the Commission's presence. The five principal aspects of the investigation are given in Appendix A, Water Quality; Appendix B, Water Quantity; Appendix C, Biology; Appendix D, Water Uses; and Appendix E, Engineering. Much of the wording in the Commission's own report has been freely extracted from the Board's report and supporting appendices.

The rigorous schedule of the investigation was planned so as to determine concurrently existing conditions and present and anticipated uses in the study area, estimate the quantity of return flows resulting from the Garrison Diversion Unit, and their impact on Manitoba, and examine measures that would modify, alter or adjust the Project so as to minimize its impacts. This Chapter briefly describes the methods employed by the Board. Details are in the appropriate appendices.

Method of Determining Existing Conditions

The present water quality of the Souris, Assiniboine, and Red Rivers and Lakes Manitoba and Winnipeg was determined by taking an inventory of all records available from federal, state and provincial agencies. These data covered the period 1960-1975. Data for metals, nutrients, and biocides were available only for the period after 1969. After examination of the sampling and analytical procedures and after numerous data comparisons, pertinent records from both countries were entered into a master file contained on NAQUADAT, the Canadian national computer data storage and retrieval system. Summary tables for the present water quality of the rivers were then produced from NAQUADAT to show water quality variability on a monthly basis. It should be noted that the available water quality data did not include a period of drought. Since the water quality of the study area is strongly influenced by the rate of flow, streamflow records were correlated with water quality data.

Water quality for Lakes Manitoba and Winnipeg was difficult to describe due to a scarcity of data and the variation in location and timing of water samples. Water budgets and calculated loadings to both Lakes Winnipeg and Manitoba were used to estimate their water quality.

Data available from both countries for the period 1936 to 1974 were used to prepare surface water summaries for the Souris, Assiniboine, and Red Rivers. Missing flow data for locations on the Souris and Assiniboine Rivers were generated. Modifications to flow records were made to reflect the effects of changes such as the Portage Diversion. Flood frequency and flow duration characteristics were developed for the Souris, Assiniboine and Red Rivers. The relationship between streamflow and

flooded area was derived for the Souris River between the International Boundary and the Town of Souris.

An inventory was made of the waterfowl, wildlife, fish, aquatic invertebrates, and plants in the Canadian portion of the study area. Diseases of wildlife, domestic animals, fish, plants, and humans were also considered. Species lists from pertinent watersheds were prepared for indigenous biota and detailed life histories were then developed for those species which might be affected by GDU.

An inventory was made of existing municipal, industrial, agricultural, rural domestic, recreational, and fish and wildlife water uses. The short time period available for the study precluded detailed field investigations, and therefore it was necessary to rely on information obtained from federal and provincial departments, academic institutions, and private studies. The Board predicted water use in the Canadian portion of the study area for the years 1985 and 2000. The effects that present water quantity and quality have on existing uses were also identified. The suspended solids concentrations, which include sediment, in the watercourses of the study area were determined. The archaeological sites were inventoried.

Method of Determining the Possible Impacts of the Project

Return flows would accrue from irrigation, canal seepage, operational waste, municipal use, industrial use, and fish and wildlife areas. The "Detailed Return Flow Salinity and Nutrient Simulation Model" was developed by the United States Bureau of Reclamation to predict the quantity and quality of return flows from the irrigated areas. The Board assessed the reliability of this mathematical model through consultations with its designers,

literature review and discussions with researchers and irrigation experts in the United States and Canada. A sensitivity analysis was performed to determine the significance of the variables. The Board concluded that the model represents the "state of the art" in predicting the quality and quantity of irrigation return flows from GDU.

The Board assumed that BEST MANAGEMENT PRACTICE would be followed in the application of irrigation water, fertilizer and agricultural chemicals on lands to be developed under the Garrison Diversion Unit. The object of best management practice is to obtain optimum economic benefits over the long term. Irrigation water, fertilizer and agricultural chemicals are not only costly but require application at the right time and in the right amount to obtain the desired crop response. Irrigation would commence when the field storage capacity of water in the soil profile is at 50 to 60 percent depletion, and would terminate at 80 percent storage capacity. The remaining 20 percent of field storage capacity would allow the retention of most rainfalls even if they occur shortly after the application of irrigation water. Precise measurements of fertilizer application requirements can be readily made by a standard soil fertility test. These measurements, if effectively used to control application, will minimize nitrogen leaching due to deep percolation. The technology for fertilizer management to obtain the optimum economic benefits has been developed and is generally being practiced.

Concentrations of salts in the return flows are expected to reach their peak 25 to 30 years after development of irrigable lands is initiated; thereafter, it is expected that the salt concentration will slowly

decline until an equilibrium is reached about 30 to 35 years later. In this report, "peak impact period" is used to refer to the former, and "equilibrium period" to the latter.

Based on the sensitivity analyses and judgment, adjustments were made to the results of the 1975 model run by the United States Bureau of Reclamation to derive an estimate of the most probable concentrations of total dissolved solids (TDS) during the peak impact and equilibrium periods. This is called the "best estimate". Further adjustments were applied to the best estimate to derive the high and low concentrations of TDS that would be associated with minimum and maximum return flows developed during the peak impact and equilibrium periods. Based on the adjusted TDS concentrations, the concentrations of calcium, magnesium, sodium, sulphates, bicarbonates and chlorides were adjusted in proportion to values predicted by the 1976 model run.

With regard to nitrate concentrations, fertilizer management schedules and crop distributions were developed and used in simulation runs of the model. Based on these simulation runs and on information from similar projects, adjustments were made to the concentration of nitrogen in the return flows from the irrigated areas which were derived in the 1976 model run by the United States Bureau of Reclamation. All nitrogen accruing to the Project drains has been predicted to be in the nitrate form.

It was recognized that there was a lack of basic information on the complex nitrogen cycle in the receiving streams. After closely examining the original procedures for predicting nitrogen concentrations in the receiving streams, a thorough review of literature on the subject, and consultations with experts, the Board was convinced that

the original assumptions were not valid and accordingly revised their predictions. Even then, the Board was not satisfied and subsequently recommended further research in this field so that more reliable predictions could be made on nitrate concentrations in receiving waters.

Phosphorous concentrations were not derived using the model. They were estimated based on an extensive literature review.

The mathematical model provided the basis for predicting the volume of return flows resulting from irrigation in GDU. After detailed review, the results obtained by the United States Bureau of Reclamation from the model in 1976 were accepted as a base value for use in estimating irrigation return flows. Adjustments were made to these results to compensate for variations in climate and crop pattern during the life of the Project and to improve estimates of evapotranspiration, deep percolation due to irrigation, and snowmelt infiltration.

Using this information the combinations which would result in extreme values were used to determine the highest and the lowest return flows that could be expected to occur. The Board also estimated the return flows which could most reasonably be expected to occur. These are also called "best estimates".

The quality and quantity of return flows from canal seepage, operational wastes, municipal and industrial effluents, and drainage from fish and wildlife developments were not derived using the model. Values established for the quality and quantity of these return flows by the United States Bureau of Reclamation were evaluated and modified by the Board.

The best estimates of the impact of GDU return flows on receiving streams, such as the Souris River, were calculated by mixing the best estimate return flows and their constituent concentrations with the historic median constituent concentrations and flows for the receiving stream. The low estimates of the impact of GDU return flows were calculated by mixing the low return flows and the associated constituent concentrations with the high historic monthly flows and the low historic constituent concentrations for the streams. Similarly, high estimate values were calculated by mixing high estimate GDU return flows and the associated constituent concentrations with low historic monthly flows and high historic constituent concentrations.

The Board assessed the impacts of changes in the quantity and quality of watercourses in Manitoba on indigenous biota and water uses. It considered the introduction of foreign biota, the additional costs of municipal and industrial water treatment, the effect on agricultural, rural domestic and recreational uses, the effects of the Garrison Diversion Unit on fish, waterfowl, wildlife and archaeology.

Measures to Minimize Adverse Effects of GDU

The Board investigated a number of measures which might be taken to avoid or relieve adverse effects on uses in Canada and estimated their costs. Due to time constraints, it was necessary to select alternatives which could be readily evaluated in terms of cost and engineering feasibility. The Board examined a number of alternative concepts, recognizing that further investigation may produce better and more economical measures.

The Board examined proposals to replace some of the irrigated lands with lands that are less saline; lining distribution canals to reduce seepage; eliminating direct

discharge of operational wastewaters to receiving streams; using sand filters for all municipal and industrial water supplies; eliminating or relocating the 400 cubic feet per second (cfs) or 11.3 cubic metres per second (m^3/s) outlet in the Lonetree Dam; excluding supplementary water supplies to fish and wildlife impoundments in the Hudson Bay watershed; modifying the fish screen in the McClusky Canal; and providing sufficient wetland-upland complexes to offset identified duck losses. The impacts on Canada of the Garrison Diversion Unit as modified were then determined. Where possible, mitigating measures were identified.

After summarizing its findings, the Board made a number of recommendations including field testing, verification of the predictions derived from the mathematical model, and research on the ultimate fate of nitrogen in the receiving streams.

CHAPTER V
IMPACTS ON CANADA OF THE GARRISON DIVERSION UNIT AS ENVISAGED

The Commission was requested to examine into and report upon the impacts of the completion and operation of the Garrison Diversion Unit as envisaged on the quality and quantity of the Canadian portions of the Souris and Red Rivers, their tributaries and downstream waters; the impact on the present and anticipated uses of these waters; and the impact on commercial and recreational fisheries in Manitoba through the introduction of foreign species of fish, fish eggs, fish diseases, and fish parasites. The impacts due to the Garrison Diversion Unit (GDU) as envisaged are described in this Chapter.

The quantity of return flows would vary with time due to the progressive development of the irrigable areas. The quantity of salts leached from the soil profile would rapidly increase during the initial stages of development and then gradually decrease to a lower but relatively constant amount. It is expected that the concentrations of salts in the return flows will reach their peak 25 to 30 years after development of irrigable lands is initiated. This is called the peak impact period. The concentrations of salts in the return flows will slowly decline until equilibrium is reached 30 to 35 years later. This is called the equilibrium period. The period of greatest concern is the peak impact period, when concentrations are significantly greater than under equilibrium conditions. It is the predictions for this period that are used in this report to assess the impact of the Garrison Diversion Unit.

Best estimates are the most probable concentration of constituents in the flows that are most reasonably expected to occur. They are generally used in this report to assess the quantity and quality of the water in the receiving streams.

Water Quality Parameters

The two Governments requested that the Commission's examination of water quality include a number of specific chemical constituents. The Board found that the concentration of almost all chemical constituents would be increased by GDU return flows, some significantly and others to a lesser degree. The water quality parameters that would be significantly increased are total dissolved solids, nitrates, sulphates, sodium, hardness and phosphorus. It is these parameters to which the Commission has given its principal attention.

A high concentration of almost any chemical constituent of water can by itself, or in combination with others, interfere with established water uses. If concentrations are excessive, they could cause health problems. Municipal and industrial uses can usually be protected by additional treatment. However, water for agricultural purposes cannot be economically treated.

TOTAL DISSOLVED SOLIDS (TDS) in this report refers to the sum of the concentrations of sodium, calcium, magnesium, potassium, sulphates and chlorides and half the concentration of bicarbonates. These constituents occur in natural waters. TDS concentrations in excess of 500 grams per cubic metre (g/m^3) cause taste problems in drinking water; concentrations between 500 and 1000 g/m^3 can cause foaming in boilers and interference with clearness, colour or taste of finished industrial products.

Excessive TDS concentrations can accelerate corrosion. The yields and quality of crops that have a moderate salt tolerance are reduced if irrigated with waters having high TDS concentrations. They include vegetables, grains and alfalfa. Additional water, if applied on soils that can be readily drained, will leach the salts through the soil profile. Water with a TDS concentration of 1000 g/m^3 contains approximately one and a half tons of salts per acre-foot or 1100 kilograms per cubic decametre (kg/dam^3). The proposed TDS objective for the Souris and Red Rivers in Manitoba is a desirable concentration of 500 g/m^3 and an acceptable concentration of 1000 g/m^3 for flows less than 140 cubic feet per second (cfs) or 4 cubic metres per second (m^3/s). At higher flows the desirable and acceptable concentrations are lower.

NITRATES occur in percolating groundwaters as a result of excessive application of fertilizer. High concentrations of nitrates in drinking waters are a health hazard. Concentrations of nitrates expressed as nitrogen above 10 g/m^3 can cause infant methemoglobinemia, a disease characterized by certain specific blood changes and cyanosis. Excess nitrates cause irritation of the mucous linings of the gastrointestinal tract and bladder, with symptoms of diarrhoea and diuresis. It is widely recommended that water containing more than 10 g/m^3 of nitrate nitrogen should not be used for infants. The proposed objective for nitrogen-nitrate plus nitrite for the Souris River in Manitoba is a desirable concentration of 0.2 g/m^3 and an acceptable concentration of 0.7 g/m^3. The corresponding concentrations for the Red River are 0.3 and 2.0 g/m^3.

SULPHATES in drinking waters may have a laxative effect on new users. Drinking water standards for sulphates are commonly set in the 200 to 250 g/m^3 range on the basis

of these laxative effects rather than on any taste or other physiological effects. Sulphates in irrigation waters may be harmful to both crops and soils. Sulphate concentrations in excess of 500 g/m^3 appear to be generally hazardous for irrigation purposes. The proposed objective for sulphates in the Souris in Manitoba is a desirable concentration of between 110 and 230 g/m^3 depending on the flow rate, and an acceptable concentration of 140 to 500 g/m^3. The higher concentrations for each range relate to low flows. The corresponding concentrations for the Red River are 100 to 130 g/m^3 and 110 to 150 g/m^3. The higher concentrations for the Red River relate to high flows.

SODIUM in drinking water may be harmful to persons suffering from cardiac, renal, and circulatory diseases, or other persons on salt-restricted diets. Concentrations of 200 g/m^3 in drinking waters may be injurious. High concentrations of sodium in irrigation water are not only toxic to plants but deleterious to soil conditions. Sodium soil colloids swell, closing the pores of the soil which reduces soil permeability to water and air and increases the alkalinity of the soil to dangerous levels. The deterioration of soil quality is a steady, cumulative process. The proposed objective for sodium in the Souris River in Manitoba is a desirable concentration of 50 to 150 g/m^3 depending on flow and an acceptable concentration of 50 to 300 g/m^3. The corresponding concentrations for the Red River in Manitoba are 15 to 60 g/m^3 and 30 to 125 g/m^3. The high concentrations for both rivers relate to low flows.

HARDNESS is a term generally applied to describe the soap neutralizing power of water. It is attributable mainly to calcium and magnesium ions. Hardness

in excess of 100 g/m^3 results in a waste of soap and the scaling of utensils and industrial boilers. The hardness of good quality waters is usually less than 270 g/m^3. Hard waters have had no demonstrable harmful effects on health. Excess hardness is undesirable for use in food processing and other industries. A common method of removing hardness is the ion exchange process which increases the sodium concentration in the treated water. The proposed objective for hardness for the Souris River in Manitoba is a desirable concentration of 180 to 400 g/m^3 and an acceptable concentration of 200 to 500 g/m^3. The corresponding concentrations for the Red River are 200 to 325 g/m^3 and 225 to 350 g/m^3. The high concentrations in these ranges relate to low flows.

PHOSPHORUS in the form of phosphates, is of concern primarily as it relates to the stimulation of algal growth and the acceleration of the eutrophication of receiving waters. The proposed objective for phosphorus, expressed as total phosphate, for the Souris River in Manitoba is a desirable concentration of 0.3 g/m^3 and an acceptable concentration of 0.5 g/m^3. The corresponding concentrations for the Red River are 0.2 g/m^3 and 0.5 g/m^3.

Impact on Water Quantity

SOURIS RIVER flows would be increased by the addition of return flows from the Garrison Diversion Unit. The best estimate of total annual return flow to the Souris River from GDU is that 82,000 acre-feet or 100,000 cubic decametres (dam^3) would be added when the full 116,200 acres in the Souris Area are being irrigated. This is an annual average increase of 48 percent in flows crossing the International Boundary at Westhope, North Dakota, over historic flows. The possible low-high range would be from 47,900 acre-feet (69,000 dam^3) to 126,000 acre-feet (155,000 dam^3). The

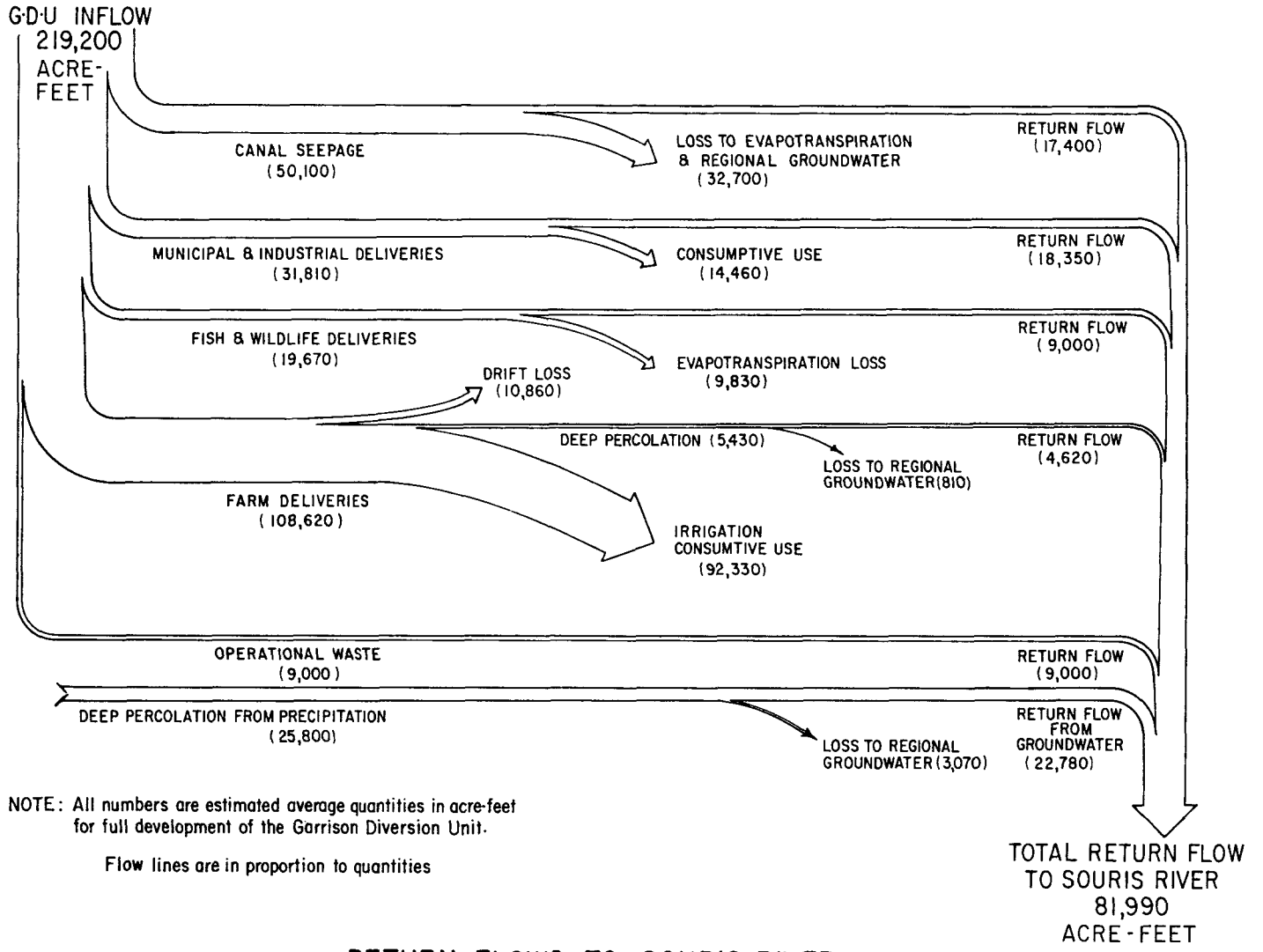
sources of the return flows to the Souris River from GDU as envisaged are illustrated on Figure 2.

The addition of return flows to the Souris would increase water surface levels during a 1 in 2 year flood by only 0.5 foot or 0.15 metre (m). During a 1 in 50 year flood it is even less significant, 0.1 foot (0.03 m). Under the worst conditions, a maximum of only 660 acres in a narrow strip along the Souris River between the Boundary and Souris, Manitoba would be flooded in addition to historical amounts. About 95 acres would be flooded for more than 30 days. The average annual additional flooding due to GDU return flows would be 200 acres on the perimeter of the area that would be flooded without GDU.

The GDU return flows would supplement low flows on the Souris River to the extent that minimum annual daily low flows would be in the range of 40 to 150 cfs (1.1 to 4.2 m^3/s). There would be little likelihood that zero flow would occur in the River as now frequently occurs during the late summer and early fall.

ASSINIBOINE RIVER flows would be only slightly affected by GDU return flows. An average of 110 cfs (3.1 m^3/s) of the GDU return flow would be added to the 2000 cfs (56 m^3/s) average flow of the River above the Portage Diversion, and an average of only 110 cfs (3.1 m^3/s) to the average flow of 1510 cfs (43 m^3/s) below the Diversion. Return flows from GDU will have no measurable effect on flooding in the Assiniboine.

The RED RIVER crosses the International Boundary at Emerson, Manitoba about 100 miles or 160 kilometres (km) north of Grand Forks, North Dakota. GDU return flows will accrue to the Red River through the Wild Rice and Sheyenne Rivers. The best estimate of the total return flow to the Red River from GDU is 32,800 acre-feet (40,500 dam^3) per year with a possible range from 11,700 to



NOTE: All numbers are estimated average quantities in acre-feet for full development of the Garrison Diversion Unit.

Flow lines are in proportion to quantities

RETURN FLOWS TO SOURIS RIVER FROM G·D·U AS ENVISAGED

FIGURE 2

63,900 acre-feet (14,400 to 78,800 dam^3). Even when monthly variations in the GDU return flows are taken into account with the extreme variations in present River flows, it becomes apparent that the GDU return flows will have little effect on the flow in the Red River in Canada. With respect to flooding, the addition of GDU return flows will have no measurable effect on the Red River.

LAKE MANITOBA and LAKE WINNIPEG water levels would not be measurably affected by the relatively small additions of return flows from the Garrison Diversion Unit.

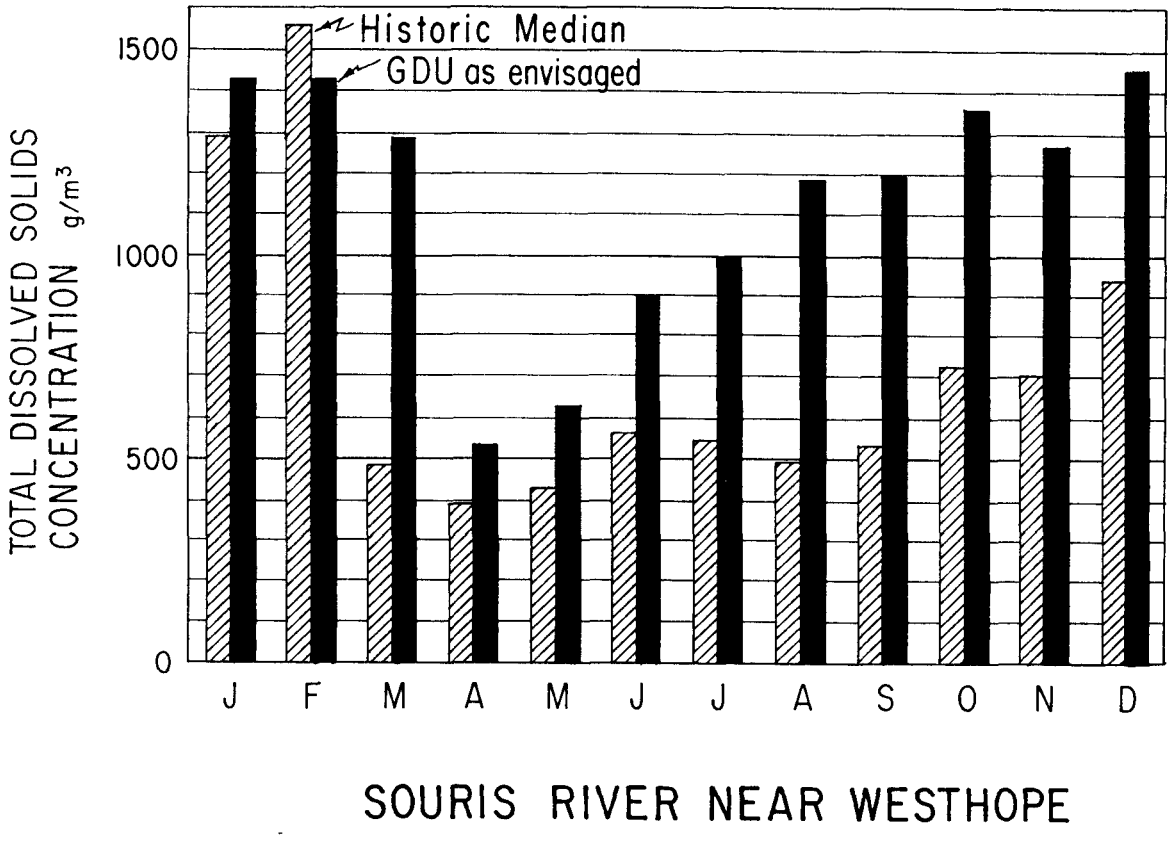
Impact on Water Quality

SOURIS RIVER water quality in Manitoba would undergo a marked change as a result of GDU return flows. Concentrations of total dissolved solids (TDS), hardness, sulphates and sodium are of significance to water users in Canada and in some cases substantial increases above present levels in the Souris River can be expected.

The best estimate TDS concentration for the Souris River at Westhope during the peak impact period ranges from 533 g/m^3 in April to 1450 g/m^3 in December. Changes from historic median concentrations would vary from a 10 percent decrease in February to a 170 percent increase in March. This is illustrated on Figure 3.

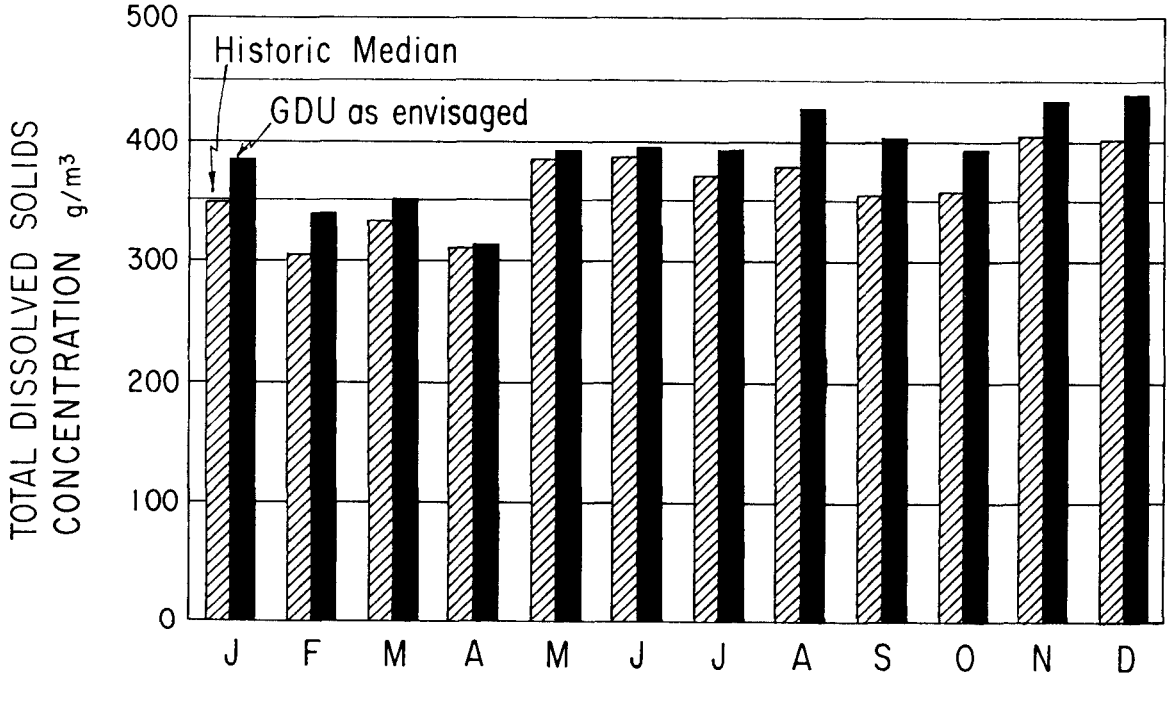
The variations in the concentrations of the constituents of TDS show a similar seasonal trend. After equilibrium is reached, the best estimate TDS concentrations would range from 517 to 1212 g/m^3 during the year.

The best estimate hardness has monthly values ranging from 277 to 767 g/m^3 during the peak impact period. Changes from historic median concentrations would vary



SOURIS RIVER NEAR WESTHOPE

NOTE: Values for GDU as envisaged are Best Estimates for the Peak Impact period



RED RIVER AT EMERSON

FIGURE 3

from a 1 percent decrease to a 160 percent increase. After equilibrium is reached, the best estimate hardness values would range from 263 to 610 g/m^3.

During the peak impact period the best estimate of sulphates (SO_4) would range from 224 to 764 g/m^3 during the year. Changes from historic median concentrations would vary from a 60 percent to a 300 percent increase. After equilibrium is reached, the best estimate of SO_4 would range from 207 to 582 g/m^3.

The best estimate of sodium (Na) has monthly values ranging from 77 to 159 g/m^3 during the peak impact period. Changes from historic median concentrations would vary from a decrease of 40 percent to an increase of 15 percent. After equilibrium is reached, the best estimate Na values would range from 83 to 180 g/m^3.

The effect of GDU on the concentration of nitrogen (N) in the receiving waters is difficult to predict because of the complex biological and chemical reactions and interactions of nitrogen. In addition, the period of record is limited to only 1969-74 for nitrate (NO_3) and 1974-76 for organic nitrogen. Thus, the estimates of future nitrogen concentrations and nitrogen forms in receiving waters as developed by the Board are speculative.

During the peak impact and equilibrium periods the best estimate nitrate levels would be about the same. The nitrate concentrations during the fall and winter would increase from historic levels of less than 0.6 g/m^3 to levels of 6 to 9 g/m^3. Summer concentrations are now 0.2 to 0.3 g/m^3 and the introduction of GDU return flows would increase them to 1 to 3 g/m^3. The Board's high estimates, which were based on extreme conditions, were as high as 20 g/m^3.

As with nitrogen, it is difficult to make accurate predictions of phosphorous (P) concentrations in receiving waters. The best estimate P concentrations for both the peak impact and equilibrium periods are higher than historic summer and fall median concentrations. The greatest change is expected to be in November when concentrations are predicted to increase from 0.36 to 1.29 g/m^3. During winter months, P concentrations will likely be reduced as a result of the dilution effects of GDU.

Best estimate bicarbonate (HCO_3) values indicate ranges from 269 to 580 g/m^3 during the year. Chloride (Cl) values are reduced during winter months by from 35 to 60 g/m^3 and are essentially unchanged for the remainder of the year. Potassium concentrations are decreased during the winter months by from 10 to 20 g/m^3, and are unchanged during the remainder of the year.

It is expected that the dissolved oxygen (DO) concentrations will not drop below 3.0 g/m^3. This is an improvement over historic concentrations. It is predicted that GDU return flows will not cause significant changes in the historic levels of temperature, coliform bacteria, trace elements, insecticides and herbicides.

The impact of GDU as envisaged on the water quality of the Souris River is summarized in Table 1 in Chapter VI.

ASSINIBOINE RIVER water quality would undergo a similar change to that on the Souris River, with the exception of nitrogen. The best estimates of TDS for the Assiniboine at Portage la Prairie has monthly values ranging from 370 to 783 g/m^3. This is an increase of from 5 to 35 percent over historic medians. The best estimates of hardness range from 239 to 506 g/m^3, an increase of up to 30 percent over historic medians. The best estimate for sulphate values range from 134 to 301 g/m^3, an increase of from 10 to

80 percent over historic medians. Projected sodium concentrations would exceed historic medians by from 5 to 40 percent.

The median nitrate values at Portage la Prairie are expected to increase from an average winter level of 0.5 g/m^3 to about 1.8 g/m^3 and from an average summer level of 0.1 g/m^3 to about 0.2 g/m^3 with the addition of GDU return flows. Organic nitrogen is projected to increase from May to September with the highest increase occurring in August. During August the organic nitrogen level is projected to increase from 1.0 to 2.0 g/m^3.

Projected phosphorous concentrations are expected to be higher than historic median concentrations for all months during both the peak impact and equilibrium periods. The incremental increase during both periods will range from 0.01 to 0.25 g/m^3. The best estimate concentrations range up to 0.35 g/m^3.

It is expected that historic concentrations of bicarbonates, chlorides, potassium, suspended solids, trace elements, insecticides, herbicides, coliform bacteria and dissolved oxygen as well as temperature would not change significantly as a result of the addition of GDU return flows.

RED RIVER water quality changes will be similar to those for the Assiniboine River. At Emerson best estimate TDS values range from 312 to 437 g/m^3 during the year. This represents an increase of 1 to 15 percent over the historic median monthly concentrations. This is illustrated in Figure 3.

The best estimate for hardness has monthly values ranging from 208 to 324 g/m^3, a change from historic median concentrations ranging from a decrease of 5 percent to an increase of 20 percent. Projected sulphate values

range from 56 to 115 g/m^3, an increase from 2 to 30 percent over historic median concentrations. The best estimate sodium values range from 24 to 39 g/m^3, an increase of up to 10 percent over historic median concentrations.

Best estimate nitrate levels are expected to increase during the winter at Emerson from 0.25 to about 0.5 g/m^3. During spring and summer, nitrate values are expected to remain unchanged at levels of 0.3 g/m^3. A small increment of nitrate from return flows is expected to be incorporated into algae which will result in a small increase in organic nitrogen in summer. Little change in phosphorous concentrations at Emerson is expected.

Concentrations of bicarbonates, chlorides, potassium, suspended solids, trace elements, insecticides, herbicides, coliform bacteria, and dissolved oxygen as well as temperature are not expected to change significantly at Emerson as a result of the addition of the GDU return flows.

The impact of the Garrison Diversion Unit as envisaged on the water quality of the Red River is summarized in Table 2 in Chapter VI.

LAKE MANITOBA water will undergo a small change in quality as a result of return flows from the Garrison Diversion Unit. In the south basin the predicted maximum increases above historic average annual concentrations would be 1 percent for calcium, 3 percent for magnesium, 2 percent for sodium, 2 percent for potassium, less than 1 percent for chlorides, less than 3 percent for sulphates, less than 2 percent for bicarbonates, less than 5 percent for total nitrogen, and less than 5 percent for phosphorus.

LAKE WINNIPEG water quality would undergo a somewhat greater change. In the south basin, the predicted maximum increases above historic average annual concentrations would be 8 percent for calcium, 17 percent for

magnesium , 19 percent for sodium, 8 percent for potassium, 4 percent for chlorides, 40 percent for sulphates, 6 percent for bicarbonates, 8 percent for total nitrogen, and 22 percent for phosphorus. After the addition of GDU return flows and without improved treatment of municipal wastes by Winnipeg, the concentration of calcium would be 19 g/m^3, magnesium 6 g/m^3, sodium 7 g/m^3, potassium 1.5 g/m^3, chlorides 5 g/m^3, sulphates 21 g/m^3, bicarbonates 67 g/m^3, total nitrogen 0.8 g/m^3, and phosphorus would be 0.09 g/m^3. These additions are not considered significant at this time.

Impact on Biological Resources

Concern that GDU would allow the inter-basin transfer of undesirable fish species, fish diseases and parasites from the Missouri River to the Hudson Bay Drainage Basin were expressed by individual environmental organizations and agencies on both sides of the Boundary before the Commission's study began. The Board's report has given strength to that concern. The Board's report also identified reduced duck populations in North Dakota resulting from the Garrison Diversion Project as envisaged, and the attendant adverse effect on Manitoba duck populations.

There is a possibility of a natural or accidental introduction of foreign biota into Canadian waters. So far as is known, only one foreign fish species, rainbow smelt, has been introduced into the Hudson Bay watershed by accidental means. Although other foreign species are known to exist in Lake Sakakawea and in the James and Minnesota Rivers, accidental introduction to the Hudson Bay watershed is not yet known to have occurred. However, GDU would provide a direct connection between the Missouri River and the Hudson Bay Drainage Basin through the McClusky Canal.

Twenty species of fish that could be introduced into the Hudson Bay Drainage Basin, as a result of GDU, have been identified. Nine are undesirable species because they have a high reproductive potential. They could successfully compete for food and space, replace indigenous forage fish, alter the balance between existing predators and their prey, carry parasites, destroy some of the valuable present species and interfere with fishing. Eight of the undesirable species occur in the Missouri River system in or above Lake Sakakawea and could be transferred by the McClusky Canal. Six of the nine species occur in the lower James River and increased flows and oxygen levels resulting from GDU would enable them to move upstream, be transferred to the Wild Rice River, and thence to the Red River into Canada.

Rainbow smelt have been identified as one of the more serious problem species. They have been in the headwaters of the Rainy River system, part of the Hudson Bay Drainage Basin, for at least seven years but, for some unknown reason, apparently have not moved downstream. In other areas where they have been introduced they have dispersed rapidly. The Board reported that smelt may or may not reach Lake Winnipeg via the Rainy River. It may be prudent for the Governments to take steps to ensure that rainbow smelt do not move further downstream. However, GDU would provide a direct route for the transfer of smelt.

The impact of introductions of foreign fish would probably become apparent within 10 years of completion of the inter-basin connection, and full impact of the introductions is likely to occur within 25 to 50 years. Once introduced into the Hudson Bay Drainage Basin, it is expected that their impact would be irreversible. None of the problem species likely to be introduced as a result of

the Project are expected to have a beneficial impact on commercial species of fish and commercial fisheries in Manitoba.

The Board reported that the introduction of foreign species of fish into Lake Winnipeg would result in major reductions of the more highly-valued species. Whitefish, walleye and sauger populations could decrease 50 percent to 75 percent with the potential for proportionate reductions in annual harvests. It is also expected that lake herring, an important forage fish, could be reduced after equilibrium by 50 percent or ultimately eliminated. In Lake Manitoba the Board estimated that the introduction of foreign fish species would eventually result in a 30 percent reduction in whitefish populations and a 75 percent reduction in walleye, sauger, and lake herring populations. Reductions of this magnitude would threaten the existence of the commercial fishery of Lakes Manitoba and Winnipeg.

To reduce this potential for the inter-basin transfer of undesirable fish species, fish larvae, fish eggs, fish diseases and other biota, the United States Bureau of Reclamation has under construction in the McClusky Canal a large, but as yet unproven, fish screen. The Board has reported that the structure as presently designed would not prevent the inter-basin transfer of all fish, fish diseases, fish fry or fish eggs. The larvae of rainbow smelt and Utah chub can pass through the screens and, because of spaces between screen panels, fish eggs, fish larvae and perhaps even small adults could pass around them.

Two fish diseases are likely to be introduced into Canada as a result of the inter-basin transfer of Missouri River waters to the Red and Souris Rivers;

infectious hemopoietic viral necrosis (IHVN), and enteric redmouth (ERM), a bacterial disease. These pathogens can be carried directly by a water medium, although the usual mode of transfer is through the transfer of diseased fishes. A paddlefish parasite, Polypodium sp. may be introduced and infect lake sturgeon of the Hudson Bay Drainage Basin. The potential introduction of other fish diseases and fish parasites that would have an impact on fish appears to be low.

It is estimated that GDU as envisaged would result in an average annual loss of 177,500 ducks in North Dakota due to changes in wetland habitat. This figure is made up as follows: project wetland drainage, 94,500 birds; stream channelization, 9000 birds; alteration of National Wildlife Refuges and the Devils Lake Basin, 54,900 birds; and private drainage, 22,100 birds. The new drains and canals would add approximately 3000 birds to the Mississippi Flyway. Because of spring and fall transboundary movement by ducks produced in North Dakota, this loss of 177,500 ducks in North Dakota would mean an average annual loss of approximately 35,000 ducks to Manitoba.

There may be additional waterfowl losses due to conversion of grasslands to irrigated croplands in North Dakota, increased incidence of waterfowl diseases such as fowl cholera, botulism and duck viral enteritis in the GDU reservoirs and altered goose migration patterns.

When floods occur in the Souris River, blackflies become more numerous and are a significant problem, especially to poultry. Sufficient information was not available to assess whether the GDU flow increment would significantly increase blackfly population. However, they could be expected to become more common.

Nutrients derived from GDU could cause at least a two to threefold increase in the average summer algal biomass in the Souris River, and a 50 percent increase in the algal biomass of the Assiniboine River. These nutrients would also accrue to Lakes Winnipeg and Manitoba and would accelerate the eutrophication of these waters.

It is expected that GDU would have no impact on upland game and bird hunting, furbearer harvest, amphibians, reptiles or rare and endangered species.

Impacts on Uses

The Board predicted that the return flows from GDU would degrade the water quality of the Souris, Assiniboine and Red Rivers. The Souris River would suffer the greatest impact. The best estimate of the changes in water quality has been used throughout this report to indicate their order of magnitude. At the present state of the art, it is unlikely that further refinement of the estimates can be achieved without field verification. Verification may show the chemical constituents entering the receiving streams to be significantly different from those predicted.

Municipal treatment costs would be increased as a result of degraded water quality caused by GDU. As a minimum measure, the six Manitoba water treatment plants currently installed or planned on the Souris, Assiniboine and Red Rivers will have to be operated at peak treatment capacity to produce the best quality water of which they are capable. This would increase total chemical costs by $59,000 (Can.) annually. Operated in this manner the plants would reduce hardness and produce a water that is microbiologically safe and free of colour,

turbidity, taste and odour. However, should the concentrations of nitrates, sulphates and sodium in the receiving waters be unacceptably high, then the addition of chemicals in the existing treatment process would not produce finished water that is suitable for domestic and industrial use. Sodium concentrations would be increased if the ion exchange process is used to reduce hardness which would be increased by GDU return flows.

The best estimate of nitrogen concentrations is only slightly below 10 g/m^3 which is the critical level for the health of infants. The Board predicted that nitrate concentrations under extreme conditions could possibly reach 20 g/m^3 in the Souris River. Verification and research is essential to provide greater confidence in these estimates. Should these high estimates be confirmed, then a more elaborate water treatment method such as reverse osmosis would be necessary. Such treatment would not only mitigate the high nitrate concentrations, but also sulphates, sodium, and other constituents. The annual additional cost would be approximately $2 million (Can.). However, the Commission points out that, although the best estimate is below the critical level, considering current knowledge of the complex nitrogen cycle in the Souris River, the concentration at the point of use may be either higher or lower.

The Garrison Diversion Unit would have adverse impacts on rural domestic, industrial, and agricultural water use in Manitoba. These are discussed in detail in the Board's report.

The commercial fishing industry would suffer an adverse impact as a result of GDU. Based on a 50 percent reduction in fish catches, the Board estimated related annual losses to be approximately $6 million (Can.), including the losses sustained in processing, transportation and marketing.

Under such conditions the commercial fishing industry could be eliminated with all the attendant consequences.

Fish losses for subsistence use in Lakes Manitoba and Winnipeg as a result of the introduction of foreign species would reach 220,000 pounds or 100,000 kilograms (kg) annually by the year 2000, or about half the estimated subsistence requirements. Such a loss would have a severe impact on Treaty Indians and other local residents who rely on fish for food.

Fish and wildlife will be affected by GDU in ways which will have adverse effects on recreational activities in Canada. An annual loss of 35,000 ducks in Manitoba as a result of drainage and alterations of wetlands in North Dakota has been predicted.

Possible Benefits to Canada

The Board identified some potential benefits to Canada which could result from the addition of GDU return flows to the Souris and Red Rivers. These benefits were not quantified. The average winter flow on the Souris River is less than 100 cfs (3 m^3/s). During the drought of the 1930's, prolonged periods of low flow were experienced on the Souris. GDU return flows would supplement these low flows so that they would be increased to the range of 40 to 150 cfs (1.1 to 4.2 m^3/s). As a result, there would be an improvement in water quality during these critical periods. Specifically, concentrations of TDS and its constituents would be reduced and dissolved oxygen concentrations would be increased.

Approximately 5200 additional acres in the Souris River Valley and 1900 acres in the Red River Valley might be irrigated using GDU return flows. This potential could be realized only if the increased flow is

assured, if an irrigation demand actually exists for that water, and if the water quality of the irrigation waters is suitable for the soils and crops to be irrigated.

The return flows from the Garrison Diversion Unit which are not used for irrigation would eventually enter Lake Winnipeg. They could theoretically be used for hydro-electric generation on the Nelson River during those periods when there is not a surplus of water.

CHAPTER VI
MODIFICATIONS TO THE GARRISON DIVERSION UNIT AND REMAINING IMPACTS

The impacts on Canada of the Garrison Diversion Unit as envisaged were discussed in Chapter V. This chapter describes the possible modifications, alterations or adjustment to the Project, their estimated costs, their effectiveness, remaining impacts on Canada, and measures that could be taken in Manitoba to mitigate these impacts.

The Board developed a number of modifications on the basis of their effect on Canadian uses, their engineering feasibility, their impact on GDU as envisaged, their effect on the environment, and their capital, operation and maintenance costs. These do not represent all of the alternatives which might have been studied, but only those which appeared to be the most effective and practical. Time and funding constraints precluded an intensive and extensive investigation.

Some were rejected because they would not achieve the desired results or were technically or economically questionable. For example, dilution of the Souris River with water from the Velva Canal would not reduce concentrations of total dissolved solids (TDS) to historic levels. Furthermore, unless passed through a sand filter of prohibitive cost, it would provide a direct connection between the Missouri River and the Hudson Bay Drainage Basin. Also, passing the entire flow of the McClusky Canal through a sand filter or microstrainers was neither practical nor economical. Ozonation of McClusky Canal waters was considered, but found not feasible. The five modifications selected for a detailed review were reduction of highly-saline soils, adoption of the wetland restoration concept, modification

of the McClusky fish screen, implementation of a closed water distribution system, and lining the Velva Canal.

Reduction of Highly-Saline Soils

The concentration of salts in soils is directly proportional to the electrical conductance of the soil. Soils containing soluble salt concentrations which produce an electrical conductivity greater than 4 microsiemens per centimetre are designated Class A by the United States Bureau of Reclamation. Soils less saline are designated as Class 1, 2 or 3 relative to their suitability for irrigation.

During the sensitivity studies on the Detailed Return Flow Salinity and Nutrient Simulation Model, it was found that by reducing the acreage of such Class A saline soils there could be substantial reduction of total dissolved solids in the irrigation return flows. The Board developed two proposals to replace acreages of Class A soil in the Souris Area which were to be irrigated by the Garrison Diversion Unit with equivalent amounts of less saline soils to reduce the impact on the Souris River. It was proposed to either replace 1900 acres of Class A soil with an equal amount of Class 1 soil, or replace 3600 acres of Class A soil and 5500 acres of Class 1 soil with 2500 acres of Class 2 and 6600 acres of Class 3 soils. These two proposals would reduce the concentration of total dissolved solids in the Souris River and to a lesser extent in the Assiniboine. It is anticipated that these changes would not have any effect on the predicted nitrate concentrations.

Wetland Restoration

The Garrison Diversion Unit as envisaged would cause a loss of 35,000 ducks in Manitoba due to wetland drainage and habitat alteration in North Dakota. A new wetland restoration concept has been developed by the United States Fish and Wildlife Service and endorsed by the United States Bureau of Reclamation. It provides that the areas lost to drainage and construction would be replaced by many small wetland complexes which would use natural inflows rather than water supplied by GDU. The Board proposed that the reclaimed wetlands should make up the major portion of the lands acquired, and that such lands should be capable of producing, on the average, 1.1 fledged ducks per acre. The wetland areas should be selected in a manner which will have the least impact on agricultural land use yet still provide the biological capability to eliminate the duck loss to Manitoba.

Specific estimates of cost for this concept were not made for the reason that the specific plan is yet to be developed. The implementation of this wetland restoration concept would eliminate the waterfowl loss. It would reduce the return flows from GDU to the Souris River by 12 percent. Since the quantity of total dissolved solids (TDS) would not be changed, this reduction in water quantity would be accompanied by an increase in the TDS concentration from August to March.

The return flows to the Red River would be increased about 13 percent in the summer and reduced by about 20 percent in the winter. There would be no change in TDS concentrations in the Red River compared to GDU as envisaged.

Modifications to McClusky Canal Fish Screen

The fish screen, located on the lower end of the McClusky Canal, is in an advanced stage of construction. Its purpose is to act as a barrier to the migration of fish, fish eggs, and fish larvae from the Missouri River into the Lonetree Reservoir. It is not known that fish screens of similar magnitude have been built and operated. The McClusky Canal fish screen must be regarded as a large prototype experiment.

The Board and two of its Committees undertook a detailed review to assess its effectiveness. A number of changes were recommended in the design and operation of the fish screen to improve its effectiveness. These are discussed in detail in the Board's report. The capital cost of these modifications would be approximately $2 million (US).

It is doubtful that the McClusky Canal fish screen even with modifications would be a reliable and effective barrier to the transfer of foreign biota from the Missouri River to the Hudson Bay Drainage Basin. It would have to be demonstrated through testing that the fish screen is capable of preventing the passage of fish, fish eggs, fish larvae and fish parasites into Lonetree Reservoir before reliance could be placed upon it.

The Closed System

The spillway from Lonetree Reservoir into the Sheyenne River and the operational wastes from the irrigation system, as well as the effluents from municipalities, industries, and fish and wildlife developments using GDU water, would provide a direct transfer of undesirable fish species, fish eggs, fish diseases and fish parasites into the Hudson Bay Drainage Basin.

As described in Chapter V, this would have a severe and irreversible impact on the biological resources of Manitoba.

To avoid such a situation, the Board developed a "closed system" concept in which no Missouri River water would be permitted to enter the Souris, Sheyenne or Wild Rice Rivers without first passing through a sand filter or the soil profile in the irrigated areas. This would remove all Missouri River biota and is considered to be the only possible effective barrier to inter-basin transfer of biota.

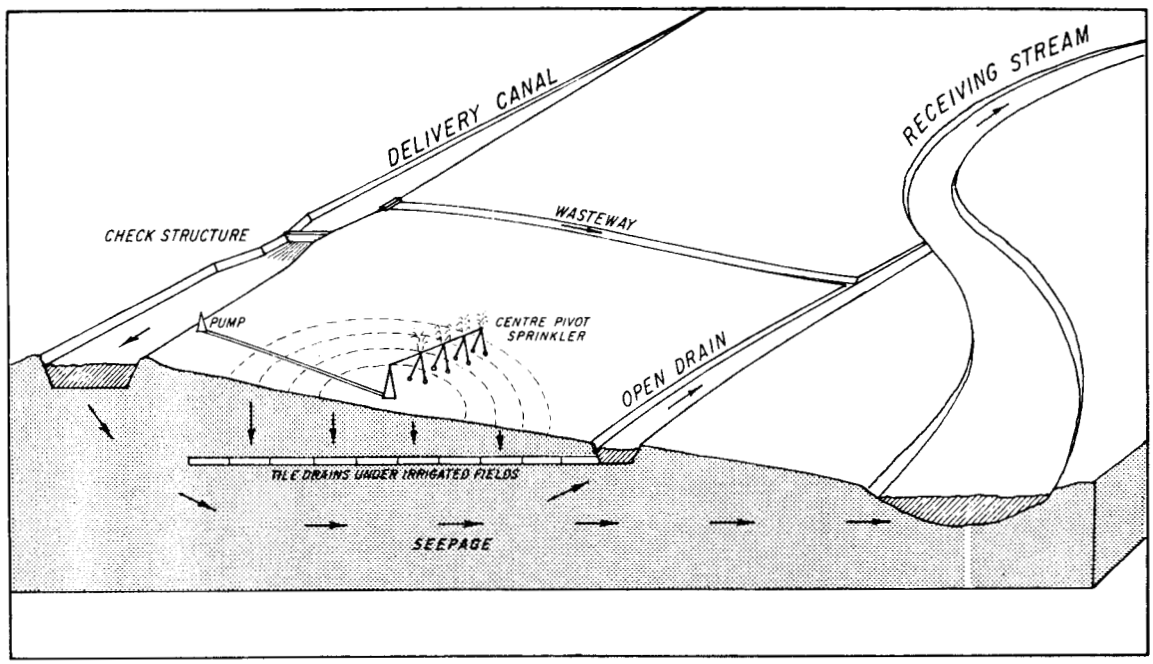
Under GDU as envisaged it is proposed to install a 400 cubic feet per second (cfs) or 11.3 cubic metres per second (m^3/s) capacity gated structure to drain the water in Lonetree Reservoir into the Sheyenne River. This outlet should be eliminated. If it were determined that evacuation of the Reservoir is required, the outlet should be relocated so as to discharge into the James River Basin and avoid a direct connection with the Hudson Bay Drainage Basin. The cost for full evacuation of the Reservoir to the James River, including excavation to deepen and straighten the River, would be $25.5 million (US). If partial evacuation were required then it may be possible to install pumps to reduce the amount of excavation required in the James River.

Wasteways generally are required on irrigation canals and distribution systems to dispose of surplus water resulting from the operation of water control structures. They have a function similar to spillways on dams. The surplus or excess water flows by gravity downstream into a smaller canal or control works with a reduced capacity. If wasteways were not provided the water in the canals and supply laterals would rise and overtop the banks. Wasteways safeguard the water conveyance facilities from damage and ensure continuous operation of the irrigation project.

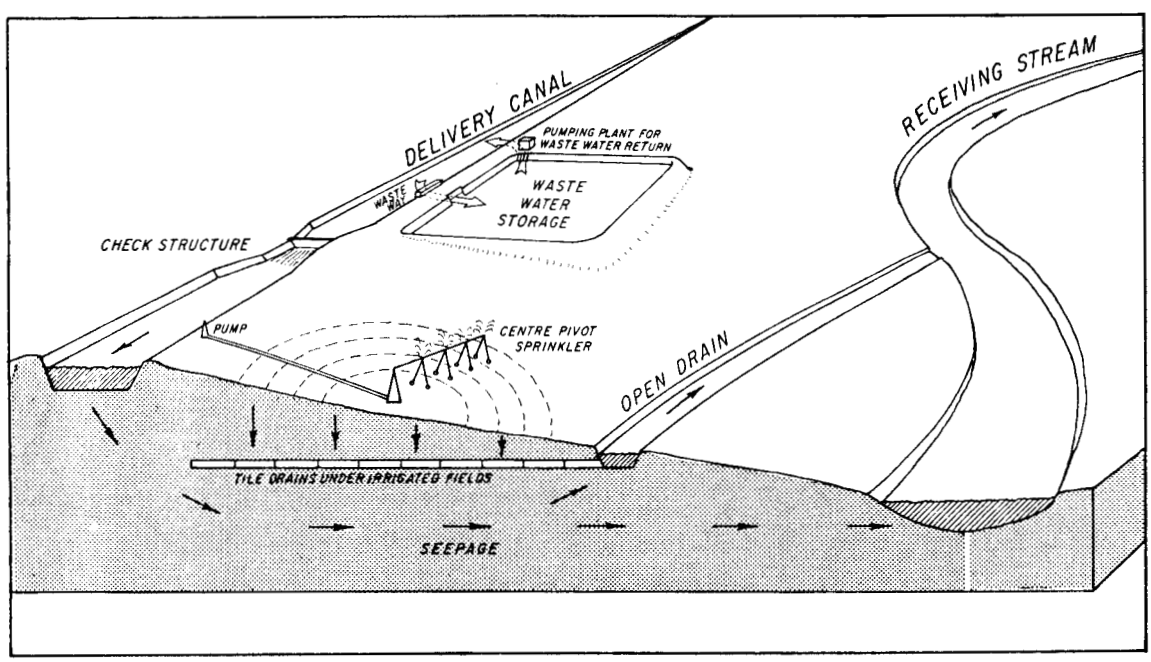
It is general practice to have wasteways discharge surplus water into ditches that lead to natural watercourses. With GDU as envisaged the operational wastewaters from irrigation canals would eventually enter the Souris, Sheyenne and Wild Rice Rivers in the Hudson Bay Drainage Basin, thus providing a direct connection with the Missouri River.

One method for eliminating these direct connections to the wasteways would be to discharge the wastewater into storage ponds adjacent to the canals and laterals. The collected wastewater would be pumped back into the canal as soon as practicable. Operational constraints would be imposed to ensure the isolation of operational water from each segment of the conveyance system to prevent overloading of the storage ponds. The estimated capital cost for the implementation of this component would be $22 million (US). Figure 4 illustrates the difference between irrigation and drainage as proposed by GDU as envisaged and that proposed by the closed system.

Another important feature of GDU is that water would be pumped by the farmer from the delivery canal through buried pipelines to a centre-pivot sprinkler. The sprinklers are located to minimize the possibility of overland flow to the open drains and receiving streams. The layout for each irrigated farm would be designed to prevent overland flow into open drains and receiving streams by including such features as the proper location of sprinklers and border dykes. This replaces the traditional open farm ditches and water application by the wild flooding or furrow systems. The proper use of sprinkler irrigation combined with the storage and proper re-use of wastewater would provide that all return flows



IRRIGATION AND DRAINAGE AS PROPOSED



IRRIGATION AND DRAINAGE IN A CLOSED SYSTEM

FIGURE 4

from the irrigated areas would pass through the soil profile before entering watercourses in the Hudson Bay Drainage Basin. However, the possibility remains that, through the operation of sprinklers, overland flow from the irrigated fields might occur resulting in an inadvertent transfer of foreign biota.

There is provision in GDU as envisaged for two outlets for municipal and industrial water supply. One, having a capacity of 20 cfs (0.6 m^3/s), is located in Lonetree Dam to supply communities in the Sheyenne River Valley. The second has a capacity of 80 cfs (2.3 m^3/s) and is located on the Velva Canal. It would supply water to the Livingston Reservoir for the City of Minot. To prevent the direct transfer of foreign biota these outlets could be modified by the installation of sand filters at Lonetree Reservoir and at the point of diversion from the Velva Canal. The estimated capital cost of the former would be approximately $2 million (US) and the latter about $9 million (US).

GDU as envisaged would also divert 20 cfs (0.6 m^3/s) to the proposed Kindsche Lake Fish and Wildlife Area through a screened outlet upstream of the McClusky Canal fish screen. Outflows from the Lake would enter the Lonetree Reservoir, thereby providing a direct connection to the Hudson Bay Drainage Basin. This direct connection can be eliminated by improving the effectiveness of the fish screen, providing a sand filter, or by eliminating the turnout. The Board has suggested that it be eliminated.

Lining of the Velva Canal

The Velva Canal traverses 24 miles or 39 kilometres (km) of outwash deposits composed of sand and gravel and 60 miles (97 km) of glacial till made up

of mixed clay, sand, gravel and boulders. GDU as envisaged provides for a clay lining on the section through the outwash, but the glacial till section would be unlined. Canal seepage is estimated to be 17,400 acre-feet or 21,500 cubic decametres (dam^3) per year with a TDS concentration of 3600 grams per cubic metre (g/m^3). About 37 percent of the total canal seepage would be from the glacial till sections.

To reduce the seepage from the Velva Canal the Board examined two alternatives; lining the entire length of the canal with membranes such as polyvinylchloride or butyl rubber, or membrane lining of the glacial till sections combined with clay lining of the sections through outwash deposits. Either alternative would require an additional expenditure of $14 million (US). Both would reduce the quantity of return flows and the concentration of total dissolved solids during the irrigation season, April to October.

Cost of Modifications

The estimated total cost of the modifications is $75 million (US) based on 1975 costs. This cost includes $25.5 million for the provision of a 400-cfs (11.3-m^3/s) capacity outlet from the Lonetree Reservoir to the James River and $14 million for membrane lining of the entire length of the Velva Canal. The reduction of Class A soils and the implementation of the wetland restoration concept are not included in this cost because they would not require additional expenditures.

Effectiveness of Modifications

Return flows from GDU to the Souris and Assiniboine Rivers with the above modifications would be reduced from an average of 82,000 acre-feet (100,000 dam^3) per year to

approximately 53,000 acre-feet (65,000 dam^3). The modifications to the Garrison Diversion Unit would reduce the mean annual flow of the Souris River at the Boundary from 350 cfs (9.9 m^3/s) for GDU as envisaged to 310 cfs (8.9 m^3/s). Similarly, the mean annual flow for the Assiniboine River below the Portage Diversion would be reduced from 1620 cfs (45.9 m^3/s) to 1590 cfs (45 m^3/s). The average annual additional flooded area on the Souris River between the International Boundary and Souris would be reduced from 200 acres to 130 acres.

Average annual return flows to the Red River would be reduced from 32,800 acre-feet (40,500 dam^3) to 27,900 acre-feet (34,400 dam^3). There would be virtually no change in mean annual flows.

Return flows from the Garrison Diversion Unit to the Souris River with the above modifications would reduce the concentration of total dissolved solids, sulphates, sodium and hardness below the concentrations which would result from GDU as envisaged. This is due to less canal seepage through glacial till as a result of membrane lining of the total length of the Velva Canal and replacement of highly-saline soils. On the other hand, the concentrations of phosphorus and nitrogen would tend to increase because the application of fertilizer to the irrigated farms remains constant, and the volume of return flows is less. There would in fact be little or no difference in the water quality of the Red River between GDU as envisaged and GDU as modified.

The mean monthly concentrations of selected constituents for historic median, GDU as envisaged and GDU as modified are compared for the Souris River near Westhope in Table 1. A similar comparison for the Red River at Emerson is in Table 2.

It is difficult to predict nitrate concentrations because of a lack of data and because the complex chemical and biological reactions and interactions of nitrogen are unknown. This is unfortunate because the form and concentration of nitrogen are important to users. Nevertheless, the Board's best estimate was that nitrate concentrations in the Souris River would increase from 9 g/m^3 to about 12 g/m^3 or 35 percent higher than those which could result from GDU as envisaged. There would be an increase in the nitrate concentrations, as yet unquantified, in the Assiniboine River and Lake Winnipeg. There would be little change in nitrate concentrations in the Red River at Emerson in comparison with GDU as envisaged.

The Garrison Diversion Unit as modified is less likely to have a major impact on the biological resources of Manitoba than GDU as envisaged. The fish losses of GDU as envisaged would theoretically be avoided through implementation of the closed system, the effectiveness of which is yet to be proven. For instance, the risk of inter-basin transfers of biota by way of overland flow from the irrigated fields must be eliminated. The duck losses associated with GDU as envisaged would be offset by implementation of the wetland restoration concept.

Municipal water treatment costs will depend largely on nitrate concentrations. Since these would be increased by the modifications, the impact of GDU on municipal water treatment even as modified would not be reduced. There would be no significant change in treatment requirements for industrial and rural domestic uses compared with GDU as envisaged. The apparent irrigation and power generation benefits in Manitoba would be reduced.

Table 1. HISTORIC AND PROJECTED WATER QUALITY FOR THE SOURIS RIVER NEAR WESTHOPE

Concentrations are in grams per cubic metre.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
TOTAL DISSOLVED SOLIDS												
Historic Median	1295	1560	483	390	429	563	546	495	531	725	702	937
GDU As Envisaged	1425	1425	1289	533	624	897	995	1183	1193	1352	1270	1450
GDU Modified	1336	1364	1191	467	524	737	806	965	978	1056	1129	1325
SULPHATE												
Historic Median	401	465	152	138	141	169	154	158	148	209	205	283
GDU As Envisaged	701	739	675	224	265	407	474	613	614	687	654	764
GDU Modified	638	698	618	186	204	305	355	488	488	521	575	693
HARDNESS AS CALCIUM CARBONATE												
Historic Median	631	756	231	197	230	290	253	250	248	280	335	457
GDU As Envisaged	742	747	678	277	322	464	509	617	621	698	655	767
GDU Modified	687	705	619	241	267	374	400	493	498	533	573	694
SODIUM												
Historic Median	240	246	80	68	83	97	102	117	116	131	142	164
GDU As Envisaged	159	141	127	77	92	109	116	125	125	142	136	140
GDU Modified	158	139	121	73	87	101	106	113	113	119	127	131
TOTAL PHOSPHORUS												
Historic Median	0.28	0.62	0.62	0.21	0.23	0.21	0.38	0.40	0.33	0.25	0.12	0.24
GDU As Envisaged	0.19	0.19	0.22	0.20	0.29	0.33	0.43	0.45	0.44	0.57	0.81	0.18
GDU Modified	0.22	0.23	0.27	0.21	0.31	0.39	0.54	0.63	0.61	0.67	0.96	0.20

Note: Values for Souris River with GDU are best estimates of constituent concentrations during the peak impact period.

Table 2. HISTORIC AND PROJECTED WATER QUALITY FOR THE RED RIVER AT EMERSON

Concentrations are in grams per cubic metre.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
TOTAL DISSOLVED SOLIDS												
Historic Median	348	303	332	310	383	384	371	378	352	355	404	401
GDU As Envisaged	385	338	350	312	390	395	392	426	402	392	431	437
GDU Modified	385	337	350	312	389	395	392	426	401	391	431	437
SULPHATE												
Historic Median	61	46	60	75	111	105	94	85	75	70	88	84
GDU As Envisaged	84	67	71	76	115	111	106	114	104	92	104	106
GDU Modified	83	66	70	76	114	111	105	112	103	91	104	106
HARDNESS AS CALCIUM CARBONATE												
Historic Median	277	258	256	218	273	294	277	267	256	251	287	305
GDU As Envisaged	303	282	269	208	285	296	281	312	288	268	305	324
GDU Modified	303	281	268	208	285	296	281	312	288	268	305	324
SODIUM												
Historic Median	33	23	24	24	27	28	30	34	33	30	37	37
GDU As Envisaged	35	25	25	24	28	28	31	37	35	32	39	39
GDU Modified	35	25	25	24	28	28	31	37	35	32	39	39
TOTAL PHOSPHORUS												
Historic Median	0.17	0.16	0.23	0.19	0.20	0.31	0.19	0.20	0.19	0.15	0.16	0.18
GDU As Envisaged	0.17	0.16	0.23	0.19	0.20	0.31	0.19	0.20	0.19	0.15	0.16	0.18
GDU Modified	0.17	0.16	0.23	0.19	0.20	0.31	0.19	0.20	0.19	0.15	0.16	0.18

Note: Values for Red River with GDU are best estimates of constituent concentrations during the peak impact period.

Remaining Impacts

The Garrison Diversion Unit as modified would have an impact on the flows of the Souris, Assiniboine and Red Rivers. The mean annual flow of the Souris River at Westhope would increase from the historic value of 230 cfs (6.5 m^3/s) to 310 cfs (8.9 m^3/s), an increase of 35 percent; in the Assiniboine River, below the Portage Diversion, from an historic value of 1510 cfs (43 m^3/s) to 1590 cfs (45 m^3/s), an increase of 5 percent; and in the Red River from an historic value of 3810 cfs (108 m^3/s) to 3850 cfs (109 m^3/s), an increase of 1 percent. The return flows would on the average flood an additional 130 acres annually. Additional flooding on the Assiniboine and Red Rivers would be insignificant.

The concentrations of total dissolved solids, sulphates, hardness, sodium and phosphorus would be increased in comparison with historic levels. These increases would be much larger for the Souris than for the Red River. The mean monthly concentrations of these parameters presented in Tables 1 and 2 illustrate the remaining impact of GDU as modified on the Souris and Red Rivers.

As noted previously, it is difficult to predict nitrate concentrations. Nevertheless, the Board's best estimate was that the nitrate concentration in the Souris River would increase from a historic median of 0.5 g/m^3 to about 12 g/m^3. There would be little change in nitrate concentrations in the Red River at Emerson.

Algal production is expected to increase three-fold in the Souris River and by a smaller, but unquantified, amount in the Assiniboine River and Lake Winnipeg.

Since the return flows from GDU as modified would degrade water quality, a higher degree of water treatment would be necessary to produce water of suitable quality for municipal, industrial and rural domestic uses.

Mitigating Measures in Canada

At present 3.5 million gallons (16,000 cubic metres) of water are withdrawn daily from the Souris, Assiniboine and Red Rivers in Manitoba for municipal and industrial uses by six communities. By the year 2000 these withdrawals are expected to increase to 5 million gallons (22,700 cubic metres) per day. To maintain water quality for these uses, additional treatment would be required. As a minimum, the added chemical costs would be $59,000 (Can.) annually. This is based on the operation of existing treatment plants at peak capacity to produce water of a tolerable hardness, and free of colour, turbidity, taste and odour. Should the concentration of nitrates, sulphates and sodium be a threat to health, then additional treatment such as reverse osmosis would be mandatory. The added cost of this treatment is estimated to be as high as $2 million (Can.) annually. Water treatment for rural domestic use would be similarly increased by about $30,000 (Can.) annually. Added treatment costs for Manitoba Hydro's Selkirk Generating Station would be in the range of $1600 to $93,500 (Can.) annually.

Since these added costs are extremely high, the Board examined the possibilities for alternative water supplies. For example, water could be supplied to the Town of Souris from an aquifer located about 8 miles (13 km) northwest of the town. The capital cost would be approximately $1.5 million (Can.) for the well, pipeline and ancillary works. The operation and maintenance costs would likely be similar to those for the existing water treatment plant. Three alternative sources were examined for Portage la Prairie. The capital cost of

each alternative would exceed $6 million (Can.). Operation and maintenance costs would likely vary from $120,000 to $1.4 million annually. Further study is required to determine the feasibility and suitability of these alternatives. Detailed studies would be necessary to find alternative sources for each rural domestic user.

With regard to mitigating measures to reduce flooding, the Board examined the possibility of enlarging the channel of the Souris River. The cost of channel enlargement including the acquisition of 1800 acres of pasture and 200 acres of cultivated land for channel excavation and disposal areas would be $5.8 million (Can.). The area required for these works would be considerably more than the additional area that would be flooded.

CHAPTER VII
PUBLIC HEARINGS

The eight public hearings conducted by the International Joint Commission were an integral part of the inquiry. The purpose of these hearings, held during both the daytime and evening hours, was to provide convenient opportunity for all those interested in the potential transboundary effects of the Garrison Diversion Unit (GDU) on Manitoba to present their views.

Three initial hearings were held in November 1975 to obtain opinions about the possible effects of the Project, views on the Commission's Directive to the International Garrison Diversion Study Board, and guidance in planning the investigation from concerned individuals, private organizations, public agencies and governmental jurisdictions. After distribution of the Board's report, the Commission held five public hearings in the study area during March 1977.

At all public hearings all those interested were given an opportunity to express their views orally or present documentary evidence. The Commission also accepted written submissions received subsequent to the respective hearings. Statements were made by elected representatives, private individuals, citizen groups, business and industrial representatives and officials from federal, state and municipal agencies. The names of the more than 90 persons who testified at the hearings are listed in Appendix E.

Verbatim transcripts of all hearings and copies of all written submissions made at, and subsequent to, the hearings are on file and available for examination at the offices of the Commission in Ottawa and Washington, D.C.

The Commission reviewed 2054 pages of testimony taken at the eight public hearings and all correspondence. As is inevitable in a series of hearings such as this, much of the evidence was repetitious. Many earnest but conflicting opinions were heard. The essence and salient points of the testimony and letters are summarized below.

Initial Hearings

Initial hearings on the inquiry were held in Minot, North Dakota on November 18 and 19, in Grand Forks, N.D. on November 19 and in Winnipeg, Manitoba on November 20, 1975. As a result of testimony received at the Winnipeg hearings, the Commission requested a briefing by the United States Bureau of Reclamation on the status of the Garrison Diversion construction, and the Bureau's plans for future construction. This briefing, which was held at Grand Forks on January 12, 1976 was open to the public.

Much of the testimony received at the hearings in Minot was in favour of the Project because of its many benefits to North Dakota. The witnesses who testified at Winnipeg were overwhelmingly opposed to the Project because of its many potential adverse effects on Canada. In Grand Forks the Commission received some testimony supporting the Project and some opposing it.

The testimony presented to the Commission at the initial hearings is summarized and paraphrased in the following paragraphs:

> In Winnipeg, the Commission was told of the potential adverse effects that the Garrison Diversion Unit (GDU) would have on water quality in Canada. The total dissolved solids concentrations

would increase by 16 percent in the Souris River and 9 percent in the Assiniboine River during the first 20 to 25 years after development. Sulphate concentrations might reach such high levels that they would restrict the water use.

Several witnesses in Minot described the severe social and economic hardships which were experienced in the severe drought of the "Dirty Thirties". The GDU would provide an assured water supply for irrigation, stabilize agriculture and therefore save the State from a recurrence of these hard times. The State's economy would be boosted through the expansion and diversification of agriculture, and many new jobs would be created.

The Commission was told that the method of analysis used by the Bureau to predict the impacts of GDU on the Souris River tends to mask out the high and low concentration for various water quality parameters. The Project would result in increased concentrations of total dissolved solids, sulphates and total hardness in the Souris River, but a lack of information precludes predictions of the potential impacts of increased concentrations of nitrogen, phosphorus, trace elements and pesticides entering Canada as a result of irrigation activities in the Souris Loop. The Commission was told that very little consideration has been given in the Bureau studies to the Project's potential effects on the Red River system and on Lake Winnipeg.

Several witnesses in Minot suggested that the salinity levels predicted to occur by the Bureau as a result of GDU were overestimated.

At both Grand Forks and Winnipeg concern was expressed over the amount of fertilizers, pesticides and herbicides there would be in the return flows from the Project. Many of these materials are persistent, toxic and some bio-accumulate. The Commission was told that, although good management practices might help to minimize the adverse effects, further studies are required.

Several witnesses in Minot suggested that the Project would add 107,000 acre-feet per year to streamflows in Canada which could be used for irrigation in Manitoba. Witnesses in Winnipeg testified that increased salinity, resulting from GDU, would reduce the food-producing potential in irrigated areas in Manitoba, including market gardens in the Portage la Prairie and Winnipeg areas, and could hamper livestock watering. In addition, proposals for major irrigation development in Manitoba based on the waters of the Assiniboine River could be hindered.

Witnesses in Minot testified that the Project would provide a much-needed dependable water supply for municipal and industrial purposes in fourteen communities which presently rely on inadequate groundwater and surface sources.

At Winnipeg the Commission was told that the Project would increase treatment costs for communities drawing municipal supplies from the Souris, Assiniboine and Red Rivers in Manitoba. Colour, odour and taste problems could also be experienced. Health problems associated with sulphates might also occur. The Town of Selkirk's plans to change its water supply source from inadequate groundwater sources to the Red River, and

Portage la Prairie's similar plans to draw water from the Assiniboine River, could both be jeopardized. Concern was also expressed that the high potential of the area for the establishment of food processing and other industries would be seriously reduced as a result of water quality deterioration.

The Commission was told by supporters of the Project that it would have benefits to recreation, waterfowl and fish and wildlife habitat. Augmentation of low flows in rivers of the area by the Project return flows would reduce or eliminate fish kills. Residents of the Devils Lake area suggested that the return flows could stabilize the level of Devils Lake to the benefit of fish, waterfowl, recreation and irrigation in the area.

However, the Commission was told of the potential adverse effects of the Project on the ecology by numerous witnesses in Grand Forks and Winnipeg. It was suggested that GDU might permit the transfer of plant and aquatic organisms from the Missouri Basin to the Hudson Bay Drainage Basin. The Commission was told that, of the at least thirteen fish species in the Missouri Basin which are not now in the Hudson Bay Drainage Basin, the gizzard shad is of particular concern. If introduced into Lake Winnipeg it could spread rapidly. It has no value as a food, sport or bait fish but would compete with more desirable native species, including the commercially-important whitefish, ciscoes, walleye and sauger. The Lake Winnipeg commercial fishery has great cultural and economic significance. Concern was also expressed

about the possibility of the spread of foreign parasites and disease organisms with serious resultant harm to fish.

At Grand Forks several witnesses questioned the adequacy of the proposed fish screens as a means to avoid transferring foreign biota into neighbouring basins. One witness recommended that screening systems be designed with many backups. Others stated that no practical methods are available to prevent the invasion of foreign biota into Canadian waters. The Commission was told that foreign biota may spread to the entire Hudson Bay System. The adverse effects would probably be irreversible because they are difficult to control once they have become established. The Project could also increase the nutrient loadings to Lake Winnipeg.

Several proponents of GDU stated that plans for the provision of 146,000 acres of water, marsh, and dryland devoted to waterfowl were designed to offset losses due to the drainage of wetlands in the areas to be irrigated in North Dakota. The Commission heard in Winnipeg, however, that this provision is inadequate, and that the Project would result in a loss of 350,000 ducks per year. This would affect hunting and recreation in Manitoba because many ducks move from North Dakota to Manitoba before they fly south for the winter. An Indian representative said that the Project would be a violation of the Migratory Birds Convention and also of Indian rights in Manitoba. The potential effects of the Project on waterfowl should be assessed by the International Garrison Diversion Study Board.

Several witnesses in Winnipeg testified that the Souris Valley is an especially important habitat for whitetail deer and has good outdoor recreation capabilities. Increased flooding, as a result of the Project, might destroy these unique capabilities.

Witnesses in Winnipeg testified that GDU would increase flood stages and their duration. Flooding and erosion are also problems on the Assiniboine and Red Rivers.

Several witnesses testified that payment of compensation to Manitoba is not an acceptable way of dealing with the adverse effects of the Project, because of the difficulties in fairly assessing and distributing these monies.

Numerous witnesses expressed concern over the inadequacy of the Bureau's Environmental Impact Assessment and the large and serious deficiencies in information and analysis concerning the Project's potential impacts in Canada. Many witnesses in Winnipeg held that construction which is underway in the United States would, according to available information, result in adverse impacts on Canada and should therefore cease until the potential problems have been adequately assessed.

Numerous witnesses expressed concern over the short time frame given to the study, noting that much of the information which would be required to give definitive answers to questions raised will not be available for several years.

Public Briefing by the United States Bureau of Reclamation

The testimony presented to the Commission by the United States Bureau of Reclamation on January 12, 1976 is summarized and paraphrased in the following paragraphs.

> The Commission was told that the portions of the Project which are presently under construction are all required to bring water to a point from which it can be routed to meet the needs of the Souris, Red, or James River Basins. It was stated that these principal supply works must be constructed whether or not irrigation development takes place in the Souris River Basin, and hence their construction does not necessarily mean that irrigation development must take place as proposed.
>
> The first area to be developed which would affect Canada is the East Oakes area, and construction will not start there until 1978. The Bureau representative stated that this leaves sufficient time for the issues in question to be resolved.
>
> The Bureau representative concluded that the works under construction would not cause violation of the Boundary Waters Treaty. The Bureau is investigating alternatives to minimize adverse impacts on Canada, and it will make the results of this study available to the International Garrison Diversion Study Board. It was noted, however, that this study is very preliminary, and would not assess the feasibility or costs of these alternatives.

The 1977 Hearings

At the conclusion of the International Garrison Diversion Study Board's investigation, public hearings were conducted by the International Joint Commission to hear

comment on the Board's report and to receive further views on the impact of GDU on Canadian waters.

Public hearings were held at Minot, North Dakota on March 8; Souris, Manitoba March 9; Winnipeg, Manitoba March 10 and 11; Portage la Prairie, Manitoba March 14; and Grand Forks, N.D. on March 15, 1977.

Most witnesses concurred with the Board's findings. Many expressed concern about the effects of GDU on Manitoba as predicted by the Board. The majority were of the opinion that GDU as envisaged could not proceed, but there were varying views on the effectiveness of the proposed modifications to the Project. Some witnesses discussed the data deficiencies and assumptions in the Board's report. Most agreed that further testing was required.

The testimony presented to the Commission at the 1977 hearings is summarized and paraphrased in the following paragraphs.

> At Minot, the Province of Manitoba stated that it generally concurred with the findings of the Board and that these findings confirmed the Province's expectations of the adverse effects which would occur in Manitoba if the Project were to proceed as envisaged. These adverse effects would, in the Province's opinion, violate the Boundary Waters Treaty of 1909. The Province recognized that the modifications to the Project, as recommended by the Board, would ameliorate some of the adverse effects. Uncertainties with respect to the ultimate effectiveness of these modifications do exist, and even with the modifications, serious adverse impacts would still remain. The Province stated that the United States must pursue alternative

irrigation development possibilities which would not add return flows to the Souris and Red Rivers. Manitoba must be provided adequate assurances that adverse impacts in Canada which occur as a result of GDU would be adequately dealt with by the United States. Many witnesses during the course of the hearings supported the Province's brief.

The State of North Dakota officially gave its support to the Project. The benefits to the State were cited. They included expansion and stabilization of agriculture and thus the economy of the whole State; the provision of a basis for industrial development; and the possible reversal of the trend for residents to leave the State in search of better employment opportunities. It was noted that the current drought sharpens the image of these benefits. The State believes that the Project must proceed with proper environmental safeguards, and it therefore supports many of the Board's recommendations.

The Commission was told by the State of North Dakota that the Boundary Waters Treaty of 1909 gives North Dakota the right to use its water as it sees fit, provided that it passes the water into Canada in a useable form. The State suggested that its own strict water quality standards would guarantee the utility of return flows passed into Canada. In any event, the Treaty does provide for a remedy should injury to health or property in Canada occur since Canadians may claim for damages in United States courts. This was held to be right and proper since the United States must bear the ultimate responsibility for the consequences of the Project. It was noted that such responsibility does not require that measures such

as the provision of improved treatment facilities in Canada be constructed prior to the occurrence of actual injury in Canada. The State noted that the Board's report did not thoroughly investigate the potential benefits of the Project to Canada which include increased hydro-generation, improvement of water quality during low flows, and the elimination of zero flows. It was stated that these benefits should be handled, in the final accounting, in the same manner as the adverse effects.

Many witnesses in Canada expressed concern over the effects of GDU, as predicted by the Board, on municipal, industrial and rural domestic water users in Canada, both now and in the future. Treatment costs would be greatly increased as a result of water quality deterioration caused by GDU. Many witnesses felt that residents of Manitoba must not be required to pay for such additional treatment; rather, the United States should be responsible in perpetuity for the payment of all additional treatment necessary to restore the quality of these water supplies to pre-project levels. It was noted that the high nitrate, sulphate and sodium levels which would result from GDU could not be handled by conventional treatment, and that sophisticated treatment processes, such as reverse osmosis, might be required. Doubts were expressed concerning the reliability and cost effectiveness of such treatment, and several witnesses suggested that the development of alternative water supplies which would not be affected by GDU should be considered where possible. Others noted that the Project should not be allowed to affect Canadian waters until appropriate measures have been undertaken to protect water users in Canada.

Many witnesses, particularly in Canada, felt that the impact of the Project on water quality would be greater than predicted by the Board because "Best Management Practices" (BMP) would not be followed as had been assumed by the Board. Failure to practice BMP would increase the impacts of the Project on water users in Canada through higher concentrations of constituents such as total dissolved solids, fertilizers and pesticides. On the other hand, much testimony was received at Minot and Grand Forks supporting the opposite view. Both academics and farmers testified that BMP are in fact presently being followed by many irrigators in North Dakota. The need to ensure that such practices are followed was recognized by the majority of witnesses who testified on this topic.

Considerable testimony relating to the biological aspects of the Board study was received. With respect to the inter-basin transfer of foreign biota and the subsequent reduction in fish population in Lakes Winnipeg and Manitoba, several witnesses said such reductions would not result in a proportionate decrease of fishing revenues, but rather would result in total abandonment of the industry. Others noted that the Board calculated lost commercial fishing revenues on the basis of the historic value of catches, thereby underestimating the potential value of the commercial fishery.

Many witnesses testified that the closed system concept developed by the Board, if properly designed and implemented, would provide a reasonable degree of protection against such transfers. However, several witnesses stated that the need for the implementation of such an expensive concept could not be

established on the basis of the inadequate data used in the Board's investigations. Particular reference was made to the presence of one of the potential problem species, the rainbow smelt, in the Rainy River, a tributary to Lake Winnipeg, a fact which might render the closed system redundant. Several witnesses noted that full protection against inter-basin transfers does not exist naturally, and questioned the need for GDU to provide full protection.

Among those witnesses who spoke about the fish screen, there was almost total agreement that it would not provide an adequate degree of protection against the transfer of foreign biota to the Hudson Bay Drainage Basin. Many witnesses questioned the need for a fish screen at all if the closed system concept is implemented.

With respect to waterfowl, the Commission heard that the Board's recommendations concerning the implementation of a new wetland restoration concept are inadequate, since they would not compensate for losses from channelization, the destruction of 50,000 acres of native prairies, the creation of 57,000 acres of hazardous hayland nesting cover, the introduction of rough fish into prairie lakes and wetlands and increased disease. Other witnesses said that the Board's estimates of waterfowl losses were too high due to double counting of certain losses.

Several witnesses expressed concern over the Board's prediction that blackfly populations could increase. These witnesses noted that black-flies are already a problem for persons working outdoors.

One witness noted that the Board's investigation of the potential impacts of the Project on archaeological resources in Manitoba consisted of a limited library research. He stated that such resources must be preserved in place wherever possible for the use of future generations.

The Commission was told that some of the adverse effects not quantified in the Board's report could be more severe than the quantified effects. The long-term effects of projects are often not fully realized or discovered for decades. The Commission was told that compensation for these adverse impacts is not acceptable because of the difficulty of fairly evaluating the unquantified and long-term effects.

Many witnesses in both countries commented on the lack of data which the Board encountered in certain areas of their study. Most supported the Board's recommendations for surveillance, monitoring, and testing. Several witnesses, however, disagreed specifically with the Board's recommendation that a test be conducted on about 15,000 acres in the Souris Loop. Some felt that this area was too small because it must be sufficiently large as to encompass all of the soil types, and cropping patterns, which could influence the quality of the return flows. A larger area, 50,000 acres, was suggested. On the other hand, the Commission was told that the test area in the Souris Loop area must be the minimum size possible in order to protect Manitoba from unanticipated adverse effects. It was suggested that 5000 to 6000 acres would be adequate. The Commission was told in Grand Forks that the necessary testing might be done in the Oakes area and the results

transferred to the Souris area to minimize the risks of unexpected impacts on Canada arising from the testing.

The Commission received testimony from several witnesses concerning the Project effects on native peoples in Canada. These witnesses concurred with the Board's findings and pointed out that the Project as envisaged would cause serious injury to the health and property of Indians. These witnesses also expressed concerns relating to the adequacy of the proposed modifications. The Commission was also told that the Project would violate the Migratory Birds Convention as well as Indian rights in Manitoba. The Commission was warned that it must consider these violations during the course of its deliberations.

CHAPTER VIII
CONSIDERATIONS AND CONCLUSIONS

The Governments of Canada and the United States asked the International Joint Commission a number of questions regarding the transboundary implications of the Garrison Diversion Unit (GDU). The Commission's response is based on its consideration of the International Garrison Diversion Study Board's report, the testimony given at the eight public hearings and written submissions.

In the Commission's opinion, despite the severe time constraint the Board's method of determining the existing conditions in the study area and the probable impacts of the Garrison Diversion Unit as envisaged on Manitoba, as well as of assessing measures to minimize adverse effects of the Project, permitted a reasonable evaluation. The Comission generally concurs with the Board's findings.

However, there are several areas of concern that remain. The suggested modifications and mitigation measures may not fully protect the present and anticipated uses of the water and related aquatic resources of the Souris, Assiniboine and Red Rivers, and Lakes Manitoba and Winnipeg.

The Commission finds this Reference particularly difficult. In an effort to provide increased food production for a hungry world, the United States has sought to develop a large irrigation project, not unlike those attempted by progressive nations going back to the pre-biblical periods. The benefits for the world at large, and to the people of North Dakota in particular, are apparent. The concept of inter-basin transfer of water is considered a solution to helping chronically water-short areas. It speaks well then that two neighbouring countries could agree that such a project which involves the introduction of Missouri Basin

waters into an entirely different ecosystem, the Hudson Bay Drainage Basin, should be examined critically to determine not only whether the waters of one country are so polluted as to cause injury to the health and property of the other country, but also whether there are other transboundary implications of that project.

TRANSBOUNDARY IMPLICATIONS

In the Commission's view careful consideration must be given to the scope of the concept of "transboundary implications" as stated in the Reference.

The Commission believes that the phrase "transboundary implications" lends itself to two possible approaches: It may be interpreted strictly in relation to the Project which gave rise to the Reference and therefore only to the specific transboundary engineering, water quality and related matters which derive from the Project itself. A more broadly stated view, however, is equally possible. The concept of "transboundary implications" can be taken to indicate the desire of the Governments to have the Commission's opinion on the total environmental or ecological consequences not only of the Project itself but of the many activities geographically or functionally related to it.

The Commission believes that it is in the interests of both countries for the Commission to adopt the wider view for without such perspectives many relevant matters may not be considered and some significant direct or indirect environmental and social benefits or costs in Canada may be overlooked.

The Governments, having asked the Commission to report on the transboundary implications, necessarily have made the Reference more wide-ranging in that the Commission must advise the Governments on matters which go beyond the

traditional concept of pollution. This marks an extremely forward-looking concept which, hopefully, the Governments will continue to follow. No longer will large land use activities be analyzed from a narrow pollution sense, but rather advice will be sought as to the general impacts of projects on the natural resources of the adjoining country.

Experience has taught us that the impact of resource developments must be analyzed from a total systems concept, and the most fundamental system of all is the biosystem. International boundaries may separate countries, but such political arrangements should not divide natural ecosystems.

Throughout the course of this investigation, the study area went beyond the immediate Boundary areas. It included not just the Souris, Assiniboine and Red River Basins and Lakes Manitoba and Winnipeg, but also the streams entering or leaving these latter Lakes since such streams, including the Nelson River, for example, might be affected by possible transfer of Missouri River biota. The Board quite properly considered the impact of GDU on the biological resources of Manitoba, where citizens have an inherent right to be protected from the introduction of foreign species of biota which could adversely affect the indigenous living resources in Manitoba.

The Commission draws attention to this view which underlies all its considerations and conclusions on this Reference.

The Commission concludes that the phrase "trans-boundary implications" in the Reference should be viewed as embracing all of the foreseeable implications involved in the Project from water-quality and water-use viewpoints as well as from the social and environmental aspects.

EXISTING CONDITIONS

The quantities of water flowing in the Souris, Assiniboine and Red Rivers, the water quality of these streams and of Lakes Manitoba and Winnipeg, the biological water resources and water uses, are all described in Chapter III. The Commission has considered the present state of water quality in those rivers, their present and anticipated uses and the effects of present water quality on their uses.

In general, the flows in the Souris, Assiniboine and Red Rivers are high in the spring and low during the summer. The area is subject to both drought and flooding. In the Souris River, flooding occurs frequently between the International Boundary and Souris, Manitoba.

A number of parameters were used to assess the present state of water quality in the Canadian portion of the study area and the effect of present water quality on water uses. Flow fluctuations are accompanied by a wide variation in water quality. For example, in the Souris River, the concentration of total dissolved solids ranged from a winter median of 1126 grams per cubic meter (g/m^3) to a spring median of 395 g/m^3. However, nitrate and phosphorous concentrations did not show seasonal variation. Median values for nitrates as nitrogen ranged from 0.11 to 0.48 g/m^3, while median values for total phosphorus ranged from 0.23 to 0.39 g/m^3.

In a similar manner the Commission considered the biological resources of the study area, particularly fish and waterfowl. It also considered the present and anticipated municipal, industrial, agricultural and rural domestic uses of the water in the area.

The Commission is satisfied that the Board acquired sufficient information to describe adequately existing conditions in the areas in Manitoba which would be affected by the Garrison Diversion Unit.

The Commission concludes that in the rivers of the study area in Manitoba water is often in short supply and the water quality, which varies with flow fluctuations, is marginal, but that with conventional treatment the waters are generally suitable for municipal and industrial supplies. The Commission further concludes that Lake Manitoba and particularly Lake Winnipeg support an important commercial fishery of high quality, while some of the watercourses in Manitoba support a good sports fishery.

IMPACT IN CANADA OF GDU AS ENVISAGED

The impacts in Manitoba that might occur as a result of GDU as envisaged at the time of the Reference are discussed in Chapter V. The expression "GDU as envisaged" means the plan for the Project approved by the United States Government at the time of the Reference, including the original McClusky Canal fish screen, but not the wetlands habitat restoration concept.

Flooding and Flows

Historically, spring floods occur in the study area. The flooded area in the Souris Valley between the Boundary and Souris, Manitoba, now averages 4400 acres, but in years of high flow it exceeds 20,000 acres. The GDU return flows would, on the average, flood some additional 200 acres of agricultural land. That figure in some years may increase to 660 acres. The additional flooding will be confined to the perimeter of the area that would be otherwise inundated. There would be no discernible impact by GDU on flows in the Red River at the International Boundary.

The Board considered the benefits which might accrue to Canada from increased flows with respect to increased capability for irrigation. It concluded that such benefits would be very small and would be more than offset by the damages resulting from the increase in total dissolved solids. Similarly the benefits accruing to Canada from increased power generation arising from increased flows are relatively small.

Increase of Total Dissolved Solids

A substantial increase in the concentrations of most of the constituents that determine water quality is expected on the Souris River. The impact would be less on the Assiniboine River and would be minimal on the Red River. Although there will be increases in the average annual concentrations of selected constituents in Lakes Manitoba and Winnipeg, the impact of these changes, with the possible exception of the nutrients nitrogen and phosphorus, is not expected to be significant.

As a result of nutrients from GDU, the algal production in the Souris River may be increased by as much as 300 percent; and, on the Assiniboine River, by 50 percent. This would require additional water treatment for the removal of taste and odour.

The United States Army Corps of Engineers has been authorized to construct and operate Burlington Dam on the Souris River a few miles upstream from Minot, North Dakota. The dam would provide about 600,000 acre-feet, or 740,000 cubic decametres (dam^3) of flood storage. The operating plan for the releases of the stored water has not definitely been established. Such releases would dilute the return flows from GDU. However, the channel capacity of the Souris River between the International Boundary and Souris, Manitoba is limited. Releases from Burlington Dam

could appreciably increase the duration and amount of overbank flows in the summer, fall and winter. As mentioned in Chapter III, flows in excess of 1000 cubic feet per second (cfs), or 28 cubic metres per second (m^3/s) would inundate over 800 acres of agricultural land in that area.

Nitrogen

The public health aspects of nitrogen raise another problem. The Board's best estimate for nitrate concentrations as nitrogen in the Souris River due to GDU is near 10 g/m^3, the level of concern for municipal use. This is a potential threat which must be further studied before its actual dimensions can be placed in proper perspective. Surely one country should not want to proceed with huge expenditures for such a large irrigation project unless it can reasonably predict the consequences of its actions. The Commission understands there are grounds to hope that further investigation will show that the consequences likely to arise from nitrogen increases may not be quite as severe as one might be led to believe from the Board's report. Indeed the Commission is recommending further research in this area.

Biota Transfer

The McClusky Canal fish screen was not included in original designs for GDU, but was added prior to 1975 in response to concerns over the possible transfer of foreign biota to the Hudson Bay Drainage Basin. This possibility of a transfer of exotics, that is, the transfer of fish species, fish diseases and fish parasites indigenous to the Missouri River Basin into the Hudson Bay Drainage Basin has been a major concern of the Biology Committee, the Board and the Commission itself.

In fact, overriding everything else, as it turns out, has been the necessity that such introduction be prevented at all costs. This is not surprising. As the Biology Committee points out, "the introduction, on a world-wide basis, of exotics has led to significant destabilization of ecosystems". The Committee reminded us that unmanaged introduction of such exotics as hares in Australia, sea lampreys in the Great Lakes and carp in North America, have caused untold damage. They also note that within the United States concern over the possibility of inter-basin transfers of exotic fish has resulted in recent pressures for their regulation. The Commission has recently been asked by its Great Lakes Research Advisory Board to take steps to advise the Governments that further introduction of exotics into the Great Lakes should be regulated jointly by the two Governments.

Unlike some other adverse consequences that can be minimized by additional mitigating measures or by cessation of operation of the Project, remedial measures to control unwanted exotics are oftentimes futile and, what makes it even more difficult, is that it may be some years before the full adverse impact is apparent.

For all these reasons, the Board insisted that the inter-basin transfer problem be examined in great depth. The United States Bureau of Reclamation had already recognized the necessity of controlling such introduction by proposing the use of fish screens as an early modification to their first plans. The ability of these screens to prevent the transfer of foreign biota was thoroughly reviewed and the Biology Committee found that, among other things, the mesh size was large enough to allow some larvae to pass through. Moreover, as the Board pointed out in their report, fish eggs, fish larvae and perhaps even small adults could pass around the screens because of spaces between screen panels.

This is important because the impact of such a transfer would be irreversible and would become apparent in about 10 years, with full impact in 25 to 50 years. If it were to occur, the undesirable foreign species which have a high reproductive potential could successfully compete for food and space, could replace indigenous forage fish, could alter the balance between existing predators and their prey, could carry parasites and could destroy some of the valuable present species. The inter-basin transfer could also introduce fish diseases by a water medium. In addition to the general ecosystem destabilization that could occur, the population of whitefish, walleye and sauger could be reduced by 50 percent in Lakes Winnipeg and Manitoba. This would, in turn, cause an annual loss of $6 million (Can.) to the commercial fishing industry of Manitoba and could possibly eliminate it. The Manitoba sports fishery could experience an annual loss of 26,000 recreation days and $130,000 in related revenue. Although some of these foreign species may eventually have some value, the Commission cannot assess their stability or their economic potential.

The Board emphasized, and the Commission agrees, that with a development of the magnitude of GDU, it is inevitable that some impacts will not have been identified. It is clear, however, that the overall biological impact through the introduction of foreign fish, fish eggs, fish diseases and parasites from GDU as envisaged is potentially severe. The Commission notes with concern that, historically, actions by man which have substantially changed or altered the natural environment often produced results not contemplated when the action took place. Once these changes are made they may be irreversible.

Waterfowl and Wildlife

It has been estimated that 340,000 ducks are produced annually in Canadian and United States portions of the area affected by GDU. About 35,000 ducks would be lost to Manitoba as a result of GDU as envisaged. It is expected that GDU would have no impact on upland game and bird hunting, furbearer harvest, amphibians, reptiles or rare and endangered species. Other impacts on the biological resources of Manitoba are very difficult to quantify and some may have been overlooked.

Irrigation in Canada

Some of the salt-sensitive crops such as vegetables, grains and alfalfa presently being irrigated with surface waters would require additional water, or water from other sources, to maintain present yields if GDU is implemented.

Best Management Practices

The Board assumed in its assessment of the impacts of GDU that "best management practices" would be used by the farmers in North Dakota. These practices are intended to ensure that only the necessary amount of irrigation water is used and that no unnecessary fertilizer is put on fields. The purpose of best management practice is to optimize production and to conserve water and fertilizer and thereby reduce costs to the farmer.

Two important benefits, which would reduce some of the transboundary impacts of GDU, would result from the implementation of best management practices: first, proper control of water application reduces the likelihood of inadvertent or accidental overland flows to drainage ditches which would constitute a temporary but possibly very damaging direct connection to the Hudson Bay drainage area with resultant biota transfers; and second, proper

control of fertilizer applications keeps to a minimum the amount of chemicals on the fields that may pass as leachates to the drainage ditches and ultimately to the receiving waters of the Souris River.

The Commission is uncertain that the Board's assumption that the inherent economic incentives of best management practices are sufficient assurance that these practices will be followed by all Project irrigators. If carelessness, or a mistaken belief that "more is better", were to lead to excess applications, then in the case of water, disastrous biota transfers might occur. In the case of fertilizers, the amounts of nitrogen and phosphorus in the Souris River could be materially increased above the estimated quantities.

The Commission believes the use of best management practices should be ensured to the maximum practical degree by rigorous enforcement of the present regulations if these are adequate, or by the adoption and enforcement of new laws.

Municipal Water Treatment

The additional annual cost of municipal water treatment for six communities would range from $59,000 (Can.), if the existing plants are capable of providing adequate treatment through the use of additional chemicals, to $2 million (Can.) if the construction of reverse osmosis treatment plants is necessary for health reasons. The latter may be required at Souris and Portage la Prairie, where high concentrations of nitrates, sodium and sulphates are expected.

The Commission concludes that the construction and operation of the Garrison Diversion Unit as envisaged would cause significant injury to health and property in Canada as a result of adverse impacts on the water quality and on some of the more important biological resources in Manitoba.

MEASURES TO ALLEVIATE POTENTIAL ADVERSE IMPACTS

The Commission reviewed the modifications, described in Chapter VI, that could be made to the Garrison Diversion Unit as envisaged to relieve or avoid the identified adverse impacts on Canada. It considered the elimination of direct connections between the Missouri River and the Hudson Bay Drainage Basin, referred to in this report as the closed system; the McClusky Canal fish screen; the safety of Lonetree Reservoir and fishing therein; the reduction and replacement of highly-saline soils; lining of the Velva Canal; and the implementation of the wetland restoration concept. The closed system concept would permit no Missouri River water to enter the Souris, Sheyenne or Wild Rice Rivers without first passing through a sand filter or the soil profile in the irrigated areas.

Measures to Eliminate Biota Transfer

The closed system, if properly designed, constructed, operated and monitored, would eliminate direct connections between the Missouri River and the Hudson Bay Drainage Basin. It would eliminate all wasteways which, as originally proposed, would have discharged into watercourses that lead to the Souris and Red Rivers and replace them with retention ponds and pumps which would return the wastewater to the irrigation distribution system. Water used for municipal and industrial purposes would pass through a suitable sand filter. The outlet works from Lonetree Dam which would drain into the Sheyenne River would be eliminated or relocated so as to drain into the James River Basin. Outlets which would provide supplementary water to fish and wildlife developments in the Hudson Bay Drainage Basin would be eliminated.

Nevertheless, overland flow from irrigated fields and accidents present an unacceptable danger of biota transfer that in the Commission's view must be eliminated or disposed of in a way satisfactory to both countries before the Project proceeds.

The estimated cost of works to remove wasteways is $22 million (US). Sand filtration of municipal and industrial withdrawals would cost $11 million (US). The emergency outlet through the James River Dikes would cost up to $25 million (US), depending on the design capacity. The total cost of the closed system could be as high as $58 million (US), but in any event would be not less than $33 million (US).

The Commission believes that the McClusky Canal fish screen as envisaged would not be an effective barrier against the transfer of foreign biota to the Hudson Bay Drainage Basin.

In a good faith effort to make the Project viable by reducing the risk of such introduction of foreign biota as much as possible, the Board recommended certain alterations in the design and operation of the screens which would cost some $2 million (US) and the construction of a closed system as a first line of defence since, in their judgment, the fish screen itself was not sufficient. The exact details as proposed by the Board are set out in their report on pages 184-185. The Commission was impressed not only by the innovative efforts of the Board to prevent the possible introduction of foreign biota, but also by the cost and the complexity of the closed system concept. It appeared at first that this was really going to great lengths to deal with what seemed then a manageable problem. It eventually became clear, however, that the immensity of the possible damage to the biological resources of Manitoba indicated why such effort would be required.

The Board's conclusion was that the implementation of their proposals should virtually eliminate any direct transfer by GDU of fish, fish eggs, fish larvae and fish parasites and would reduce the risk of transfer of fish diseases to the Hudson Bay Drainage Basin. The Board rated the fish screen and the closed system together, as described in the Board's report, as a means which would be effective and feasible in meeting the objective assigned to it.

There is no question in the Commission's mind that the Board's recommendations greatly reduce the risk of an unintentional transfer. There would now be two lines of defence, either one of which by itself might accomplish the desired result. True, the additional cost is quite high and might well adversely affect the overall economics of the Project, a question not before the Commission. The Commission gives great weight to the Board's opinion that these two lines of defence will work. At the same time, the Commission must weigh the consequences to Canada if the Board is wrong. Were the potential consequences ones which could be mitigated or corrected after the fact, the Commission would accept the Board's advice. Were the biological consequences to the Hudson Bay drainage ecosystem predictable in manner and extent, the Commission might accept the Board's approach. The Board has reduced the risk of a biological "time bomb", but not eliminated it. The Commission is concerned that even with the best engineering talent available and with the best operating practices possible, the very complexity of the scheme, the immensity of the physical features, the large numbers of human beings involved in carrying out the responsibility, and the possible mechanical failures, what cannot happen, will happen. The Commission

believes it must advise the two Governments to be conservative and proceed very cautiously with new and untried engineering works, the failure of which might seriously affect the equilibrium of a large natural system such as the Hudson Bay Drainage Basin that has been achieved over many centuries. In due course, it may well be that the adverse consequences foreseen by the Board and the Biology Committee could be overcome by some form of new biological control mechanisms, or that the introduction of foreign biota will occur irrespective of GDU. The two Governments may at some future time decide that the benefits of the Project to the two countries outweigh these adverse biological consequences. If any one of these conditions occur, then GDU should obviously proceed, other things being equal.

Nevertheless, the criteria at the present time should be the one expressed by the Biology Committee: "There must be a 100 percent assurance of fish passage prevention over an infinite time."

The Commission concludes that the McClusky Canal fish screen, even if modified, together with the closed system, cannot be relied upon to prevent the transfer of biota from the Missouri River to the Hudson Bay Drainage Basin. The Commission further concludes that the predicted impacts of a biota transfer are so potentially damaging that the closed system does not provide a sufficient guarantee against such an occurrence.

Lonetree Reservoir

With respect to Lonetree Reservoir, located in the Hudson Bay Drainage Basin, concern was expressed at the hearings about the possibility that Missouri River water would be transferred into the Sheyenne River and tributaries of the Souris and Red Rivers, either intentionally or by failure of a dam. While the Commission recognizes that there are always risks in the construction of any reservoir, it believes that the possibility of failure of the Lonetree and Wintering Dams is very remote.

The Commission further believes all the outlet works from the Reservoir should be relocated so that they discharge only into the Missouri River Basin. Moreover, to prevent inadvertent transfers of biota, fishing in Lonetree Reservoir should be forbidden. These actions would reduce the likelihood of the introduction of foreign biota into the waters of the Hudson Bay Drainage Basin.

The Commission concludes that Lonetree Reservoir and its dams could be constructed without an unacceptable risk to Canada, if all outlet works from the Reservoir are located so as to discharge only into the Missouri River Basin and if fishing in the Reservoir is forbidden.

Saline Soils

The Commission reviewed the proposal to reduce the acreage of highly-saline soils, referred to as Class A soils, that could be irrigated and the replacement of these irrigable areas with an equivalent acreage of soils that are less saline. This would reduce the concentrations and amounts of total dissolved solids in the return flows, particularly to the Souris River, at minimal cost. It was noted that the amount of nitrates in the return flows would

not be reduced because they are a function of the amount and composition of fertilizers applied to irrigated lands.

The Commission concludes that the concentrations of total dissolved solids in the return flows could be reduced by removing irrigable areas with highly-saline soils from the Project and replacing them with a similar acreage of soils less saline but this would not improve the situation with respect to nitrates.

Velva Canal Lining

The primary purpose of the Velva Canal is to convey water from Lonetree Reservoir to irrigate lands in the vicinity of the Souris River. It would pass through areas of permeable sand and gravel outwash deposits where seepage would be high and also through much less permeable glacial till areas. The Commission notes that the seepage water would acquire large amounts of total dissolved solids. Lining the Canal with compacted earth or a membrane would reduce the seepage and thus the amount and concentration of dissolved solids entering return flows and ultimately the Souris River. Since canal lining is expensive, detailed field investigations should be undertaken to determine the extent and type of lining required to minimize seepage losses. It is estimated that lining the Velva Canal would cost $14 million (US).

The Commission concludes that seepage from the Velva Canal would be reduced by lining those areas of the Canal where it is necessary. This would decrease the amount and concentration of total dissolved solids in the return flows attributable to the Velva Canal.

Wetland Habitat Restoration

The Biology Committee predicted certain adverse impacts on Manitoba waterfowl populations by GDU as envisaged and in so doing, of necessity, also assessed the considerable adverse impacts of GDU on North Dakota waterfowl populations. The Committee stated that what the total waterfowl loss meant to international waterfowl populations or how it might be viewed under the International Migratory Birds Convention of 1916 were questions beyond the scope of the Committee's study, but that they were questions which merited answers.

It is very encouraging, therefore, to note that the implementation of the plan based on the wetland habitat restoration concept described in Chapter VI would largely eliminate the waterfowl losses attributable to GDU. This is one of the transboundary implications of the Project that could hardly be said to be strictly a matter under Article IV of the Boundary Waters Treaty. It was recognized by the United States Bureau of Reclamation and the Board that waterfowl are a valuable international resource which support considerable recreation in Canada and the United States. Neither country should build works which will adversely affect such a resource. Similarly, land use activities as they might affect the future of migratory birds in other countries should be a matter for consideration and appear to have been within the intent of the Migratory Birds Convention itself.

It is apparent that both the United States and Canada are becoming increasingly concerned with transboundary environmental and ecological questions. For example, the two Governments have asked the Commission for advice on environmental issues in the Skagit River and Lake Champlain problems. As further evidence of this trend, it may be

noted that in July 1977 at the Commission's annual public meeting dealing with the water quality of the Great Lakes, the thought was advanced that the Great Lakes Water Quality Agreement between Canada and the United States might be more properly viewed as an environmental or ecological agreement rather than strictly a water quality agreement.

In the case of GDU, it was fortuitous that the Reference was so broadly phrased as to be able to include a study of major transboundary impacts of the Project in addition to the impacts arising from the traditional concepts of water pollution. Hopefully, future references will continue to seek advice as to the environmental and ecological consequences that may result from activities in one country to the detriment of the other. It would seem to be a disservice to confine investigations of the transboundary impacts of projects on either side of the Boundary, whether by the IJC or by other bodies, to the traditional concepts of water pollution alone.

In the light of these considerations, the Commission concludes that the adverse impact of the Garrison Diversion Unit on the waterfowl resources of Manitoba would be largely offset by the implementation of the wetland habitat restoration concept.

DELAY OF FURTHER CONSTRUCTION

As has been pointed out, the Project as envisaged unquestionably would have caused pollution to Canada. In order to preserve the obvious benefits of the Project, the Board wrestled long and hard to come up with changes in design and mitigating measures which would make the Project acceptable without undue economic sacrifice. In most cases,

the Board was successful and the Commission concurs, almost without exception, in the Board's suggestions. As a result, from a practical standpoint, the Commission believes that the Project as modified, and operated as intended, would then not significantly pollute the Canadian waters, with a few exceptions such as the uncertain increase in nitrogen in the Souris and the increase in total dissolved solids. However, despite the expenditure of great sums of money and the best intentions of all men, GDU even as modified presents an unacceptable risk of the introduction of unwanted foreign biota to the Hudson Bay Drainage Basin to the detriment of the people of Canada and to the general ecology of the region and beyond.

The Commission therefore concludes that, even if modified as described herein, the Garrison Diversion Unit will still cause adverse impacts in Canada. Only the extent of the impacts is in question. The Commission further concludes that while most of the impacts can be mitigated, those from the possible biota transfers are so threatening that the only acceptable policy at present is to delay construction of those features of the Garrison Diversion Unit which might result in such transfers.

VERIFICATION AND RESEARCH

The Board concluded that the mathematical models used by the United States Bureau of Reclamation to determine the impact of GDU on water quality were the most advanced techniques available to accomplish this goal in the time allotted. However, the models contain inherent assumptions about the actual amount of chemicals that would be leached out of the irrigated soils by the passage of the water through

the soil column and which would appear in the return flows. These assumptions have not been verified by field experimentation under conditions resembling those in the study area. Therefore, the results of the model cannot be viewed with complete confidence and they must be regarded as theoretical and to a large degree uncertain at this time.

The Commission has taken note of the Board's frequent references to the uncertainties of its findings and predictions, especially as to the expected concentration of nitrogen, based on the use of mathematical models. The actual water quality impacts of GDU may be higher or lower than those predicted by the Board. These impacts can only be determined with confidence after verification of the model.

Furthermore, while the concentration of nitrogen in the return flows is subject to the above uncertainty, it is also subject to a great deal of further uncertainty as to its fate as it passes through the drains, ditches and the streams themselves on its way to the point of use of the water. Once again no field studies under suitably similar conditions are available and the estimates of nitrogen forms and concentrations were difficult for the Board and the Commission to accept with a high degree of confidence.

The Commission considers that extensive programs of field measurements and tests should be undertaken to provide reliable data to verify the performance of the mathematical models with respect to the concentrations of chemicals in return flows, and that there is an urgent need for a research program in the Souris River to provide much more knowledge of the fate of nitrogen before it gets to the points of use of the water.

The Commission concludes that it is mandatory to verify both the quality and quantity of return flows from GDU, and to determine by research the ultimate fate of nitrogen in the Souris River before there is irrigation development in the Souris River area.

WATER QUALITY AGREEMENT

The Commission believes that water quality management of transboundary streams in both countries will become increasingly important and that the needs of both countries are such that a common general approach to water quality would be beneficial. The virtues of pursuing a water quality agreement have been demonstrated by the Great Lakes Water Quality Agreement and similar recommendations have recently been made by the Commission in the case of the Saint John River where, as in the Souris, both countries find themselves upstream and downstream on various portions of the River.

Some difficulty may be apprehended in determining the nature of a water quality agreement on a transboundary stream. In a boundary water like the Great Lakes the reciprocal effects of pollution by both co-riparians can be seen without difficulty. This results in a reciprocal interest in all aspects of a commonly-shared resource since the political boundary does not impede the movement of water running across this line.

But, in the case of a transboundary river or lake, upstream in one country and downstream in the other, the same general view of a mutuality of interest may not be so readily evident. Here one party is sovereign on its side of the territorial line and the other equally so across that boundary. What, then, may be a compelling

reason for states to agree to some system which will unite them in a common water quality objective when their own territorial interests may invite a different view of the uses of their share of the river, whether upstream or downstream?

The approach under Article IV of the Boundary Waters Treaty is to simply forbid pollution to the injury of health or property. This requires a frequent determination of "pollution", of "injury", of "health" and of "property" and thus inevitably invites disputes over law and fact, and provokes acrimony between neighbours. Nor does the Boundary Waters Treaty which now provides for such a prohibited regime do more than dictate to each party that "thou shalt not pollute". There is nothing there about remedies or procedures to help prevent conflicts or settle disputes. The emerging doctrine of prior notice and consultation combined with the opportunity to initiate an investigation of an actual or potential conflict, that is a Reference under Article IX of the Treaty, is, of course, available.

While Article IV, therefore, is one approach, it has tended to be "after the fact" and does not envisage any prior joint planning of a shared transboundary water resource where each partner may be upstream in some cases and, in others, downstream.

The other possibility is to develop a water quality management approach which by its very agreement on commonly-shared objectives will prevent disputes and also will likely enhance the possibility of the optimum use of a river without stimulating harassing debates as to who "owns" what with the right to use or abuse "his share" of the water.

At present, Canada and the United States are constrained in resource development activities only by Article IV for the upstream neighbour and by local law and policy for the downstream country. In such a situation the downstream state naturally will seek to utilize, to the fullest extent possible, the potential municipal and industrial uses of its share of the river. It also will demand of the upstream state that the waters come to the boundary free from pollution, at least to the extent defined as "injury". Such debates tend to provoke procedural and negotiating disputes that are likely to be not only distressing but often insoluble. In the Commission's view it would be far better to approach the problem of GDU and other basin developments from the aspect of the equitable utilization of the river basin or watercourse on behalf of both countries, through a system of water quality management based on agreed objectives and standards.

The obligation of the downstream country to manage the uses of its waters is encouraged by the certainty that the upstream country must preserve a level of quality over which there will be no need for concern as that water crosses the boundary. A new sense of mutuality of interest thus is developed and it is expressed by the maintenance of agreed water quality objectives throughout the length of the river. This is not a requirement of the Boundary Waters Treaty but rather is a conception that goes beyond that Treaty; and this recommendation in no way affects or is affected by the recommendation of the Commission with respect to GDU itself since the Commission is making this recommendation with respect to a Water Quality Agreement in and for itself.

The Commission concludes that the two Governments should negotiate appropriate water quality agreements for the Souris and Red Rivers.

* * * * * * * * * * * *

Commissioner Bernard Beaupré, while in general agreement with the majority of conclusions stated in this chapter of the report, differs with some significant aspects of the rationale cited as the basis for those conclusions; in particular, he differs with the approach taken by the Commission in the setting up of a Water Quality Agreement. He has therefore revised the conclusion and the recommendation into what he believes to be more appropriate terms.

Commissioner Beaupré's separate comments with respect to Chapters VIII and IX are set forth on pages 125-128, following Chapter IX.

CHAPTER IX
RECOMMENDATIONS

The International Joint Commission, in the light of its conclusions on this inquiry, recommends:

1. That because the "closed system" and the McClusky Canal fish screen cannot with any certainty prevent biota and disease transfers which would cause severe and irreversible damage to the ecosystem and, in particular, to the commercial and sport fisheries in Canada, those portions of the Garrison Diversion Unit which could affect waters flowing into Canada not be built at this time. This is not intended to preclude construction of Lonetree Reservoir, subject to the conditions set forth in Chapter VIII.

2. That, if and when the Governments of Canada and the United States agree that methods have been proven that will eliminate the risk of biota transfer, or if the question of biota transfer is agreed to be no longer a matter of concern, then the construction of that portion of the Garrison Diversion Unit which would affect waters flowing into Canada may be undertaken provided the following conditions are met:

   (a) Any agreed modifications or other measures required to resolve the inter-basin biota transfer issue are incorporated into the Project.

(b) Modifications to the Garrison Diversion Unit for the reduction of highly-saline soils, wetland habitat restoration and lining the Velva Canal as required, all described in Chapter VI of this Report, are incorporated in the Project.

(c) A program to verify the quality and quantity of return flows from the Project has been carried out and it has subsequently been agreed that concerns on these questions have been resolved.

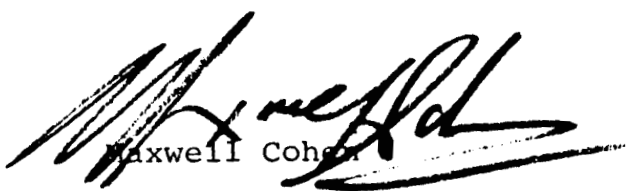
(d) Research to determine the nature and extent of the complex nitrogen transformations in the Souris River and also to determine the ultimate fate of nitrogen in the Souris River with the addition of return flows from the Garrison Diversion Unit has been completed and it has been agreed that concerns about nitrogen have been resolved.

(e) An agreement has been concluded for payment by the United States of the capital and operating costs of the mitigating measures in Canada made necessary by the Garrison Diversion Unit, and

(f) Appropriate agreement has been reached on the efficacy of existing or new regulations or laws ensuring the employment of best management practices.

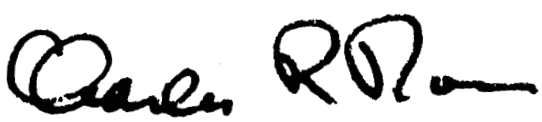
3. That the two Governments negotiate appropriate water quality agreements for the Souris and Red Rivers.

Signed this 12th day of August 1977 as the International Joint Commission's report to the Governments of the United States and Canada on the Transboundary Implications of the Garrison Diversion Unit.



Maxwell Cohen

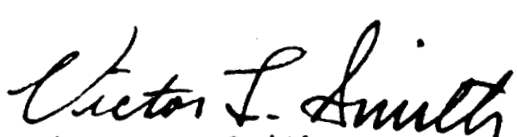
Henry P. Smith III



Charles P. Ross

Bernard Beaupré

Keith A. Henry



Victor L. Smith

SEPARATE OPINION OF COMMISSIONER BERNARD BEAUPRE

While I am in general agreement with most of the conclusions and recommendations of the International Joint Commission's report on the transfrontier implications of the Garrison Diversion Unit, I feel it necessary to differ from certain points of view of my five colleagues, especially as they are expressed in the considerations leading to some of the conclusions of Chapter VIII. This has also led to the rewording of recommendation 3 in Chapter IX.

I would like first though to express my utmost appreciation for the really admirable way in which the members of the International Garrison Diversion Study Board have performed this task. There is no better example of the total impartiality which high level administrators, engineers and scientists can give proof of than the brilliant objective analysis of such a difficult binational problem.

To the members of the International Joint Commission who had to make an assessment of the Garrison project and its transfrontier implications, it was also a very difficult problem. The Commission studied in depth the Board's and the Committees' reports, the transcripts of the public hearings as well as many other submissions and spent long hours in arduous deliberations. Although it would have been generally preferable for the sake of unity within the Commission to arrive at a common understanding on all parts of the report, I have found it impossible to concur with my colleagues on one point, and my analysis now follows:

I disagree strongly to the text on pages 116, 117 and 118 under the heading of Water Quality Agreement. In its report, the Commission has taken for granted that it would be possible and desirable for the two Governments to negotiate and sign, as one possibility, an agreement on water quality for the entire course of the Red and Souris Rivers. The basis for such reasoning emerges from the concept that the upstream country which is forced to undergo heavy expenditures in order to comply with the provisions of the Boundary Waters Treaty of 1909, and to deliver to the downstream country at the Boundary water of an acceptable quality, should be able to require from the downstream

country that the water quality be maintained at an acceptable level all the way therefrom. This reasoning could be summarized by saying: "Why improve the waters that others will pollute?" The Commission's report indicates that the country downstream should manage its waters in order to preserve the quality of the water that it receives from the upstream country.

This might be an ideal solution in a perspective of water management of basins on a global basis, but I find it somewhat unrealistic in the present context. The report further indicates that such a management concept has been recommended by the Commission, earlier in 1977, for the Saint John River. Comparisons can only be made when conditions are similar. Such is not the case here. In the Saint John River Basin, one of the major purposes of basin-wide water management would be the restoration of the salmon run upstream to the spawning grounds located in the Province of New Brunswick as well as in the State of Maine; the salmon run is presently greatly hindered by the poor quality of the water throughout the River, especially in the downstream section wholly located within New Brunswick and in the estuary close to the City of Saint John, which is seriously polluted. An international agreement on water quality management of the Saint John River Basin would therefore have favourable results for the two countries.

No such favourable results are claimed for the Red and Souris Rivers. The reason invoked for a common management of those two rivers might be worded as follows: The downstream country should manage its waters in order not to abuse the good quality of the water that it receives; in other words, the upstream country which is called upon to undergo large expenditures so that the water at the Boundary may be of an acceptable quality in compliance with the provisions of the Boundary Waters Treaty, expects that the downstream country will take similar measures to maintain good water quality along the entire watercourse within its territorial limits.

This, in my view, goes beyond the Boundary Waters Treaty. The fact is that the upstream country must respect its own water quality standards and must, at the same time, comply with the provisions of the Boundary Waters Treaty of 1909, and therefore deliver at the point where the river crosses the Boundary, water which will not cause injury to health and property in the downstream country. As for the downstream country, it also must respect its own water quality standards; whatever it does will, on the other hand, have no adverse effects on the upstream country if there are no major transfrontier transfers of biota upstream from activities downstream, although this will have to be monitored by a binational agency.

Moreover, if we examine the particular problem which gave rise to the present Reference, it must be noted that the Province of Manitoba has been the principal instigator of the Reference. For Manitoba, the Garrison Diversion Unit is the source of serious concerns; GDU may constitute a menace for the proper supply of good, safe water to municipalities in Manitoba on the Souris and Red Rivers, as well as for the commercial and sport fisheries of Lakes Winnipeg and Manitoba. In these two instances, Manitoba's foremost interest is that the quality of the water of said Rivers and Lakes within its territorial limits be maintained at the highest possible level to satisfy and even enhance these objectives; Manitoba would not have to manage its waters in order to satisfy the expectations of the upstream country which must, under all circumstances, comply with the provisions of the Treaty and deliver at the Boundary water which will not cause injury to health and property in the downstream country.

The conclusion written at the end of Chapter VIII, at the bottom of page 118 and repeated as recommendation 3 on page 122 is of a very general nature and encompasses many different options including the option that I submit as more realistic and which would read as follows:

The Commission concludes (or recommends) that the two Governments should negotiate and sign an agreement to determine the water quality objectives to be complied with in the Souris and Red Rivers at all locations where these two Rivers cross the International Boundary between Canada and the United States. Similar objectives should also apply to all transfrontier tributaries of both Rivers at the locations where they cross the Boundary from any one country to the other.

Bernard Beaupré, Commissioner
August 1977

APPENDIX A

TEXT OF REFERENCE

TEXT OF REFERENCE TO THE INTERNATIONAL JOINT COMMISSION

On October 22, 1975, the Secretary of State for External Affairs for the Government of Canada, and the Secretary of State for the Government of the United States sent the following Reference to the International Joint Commission, through identical letters addressed respectively to the Canadian and United States Sections of the Commission:

> I have the honour to inform you that the Governments of Canada and the United States of America recognize that the proposed Garrison Diversion Unit of the Pick-Sloan Missouri Basin Program in the State of North Dakota has a potential for causing pollution of waters flowing across the international boundary into Canada.
>
> The Government of Canada has concluded, on the basis of studies conducted by the United States and Canada, including certain studies conducted by the United States in response to questions raised by Canadian officials, that the Garrison Diversion Unit, as currently envisaged, would have adverse effects on the Canadian portions of the Souris, Assiniboine and Red Rivers, and on Lake Winnipeg, which would cause injury to health and property in Canada in contravention of Article IV of the Boundary Waters Treaty of 1909.
>
> The Government of the United States has reached no final conclusion as to whether the Garrison Diversion Unit, as presently envisaged, would be consistent with the rights of the United States and of Canada to the equitable use of waters crossing the boundary, and with Article IV of the Boundary Waters Treaty. The Government of the United States notes that, at present, waters crossing the boundary have wide natural fluctuations in quality and quantity, and that the Garrison Diversion Unit, as presently envisaged, could have both beneficial and adverse impacts on the quality and quantity of these waters. The Government of the United States has assured the Government of Canada that in any development of features of the Garrison Diversion Unit that will affect Canada, specifically works in the Red River Basin and the Souris Loop, the United States will comply with its obligation to Canada not to pollute water crossing the boundary to the injury of health or property within Canada. The

Government of the United States has similarly assured the Government of Canada that no construction potentially affecting waters flowing into Canada will be undertaken unless it is clear that this obligation will be met.

In light of the views of governments as expressed above, the Governments of Canada and the United States of America have agreed, pursuant to Article IX of the Boundary Waters Treaty of 1909 to request the International Joint Commission to examine into and to report upon the transboundary implications of the proposed completion and operation of the Garrison Diversion Unit in the State of North Dakota; and to make recommendations as to such measures, including modifications, alterations or adjustments to the Garrison Diversion Unit, as might be taken to assist governments in ensuring that the provisions of Article IV of the Boundary Waters Treaty are honoured.

In doing so, the Commission should examine into and report upon the following and such other matters as the IJC may deem relevant:

(a) the present state of water quality in the Souris and Red Rivers, their tributaries and other downstream waters, with particular reference to the Canadian portions thereof, which may be affected by the proposed completion and operation of the Garrison Diversion Unit. The examination should include the following:

    1) total dissolved solids,

    2) sulfate, sodium, chloride, magnesium, calcium and compounds thereof,

    3) bicarbonates,

    4) nutrients, including nitrogen, phosphorus and their compounds,

    5) pesticides and herbicides,

    6) dissolved oxygen, temperature, sediment and other related parameters affecting aquatic life,

    7) trace elements, including boron, selenium, lead and other heavy metals;

(b) the present uses of these waters and those uses which may reasonably be anticipated in the future;

(c) the effects of present water quality on these uses;

(d) the nature, extent and location of impacts on the quality and quantity of these waters to be anticipated as a result of the proposed completion and operation of the Garrison Diversion Unit;

(e) the nature, extent and economic cost of such impacts to be anticipated from the proposed completion and operation of the Garrison Diversion Unit on the present and anticipated future uses of these waters; and

(f) the nature and extent of the impact on commercial and recreational fisheries in Manitoba, particularly Lake Winnipeg, of the possible introduction from the Missouri River system through the Garrison Diversion Unit of foreign species of fish, fish diseases, and fish parasites.

Should the Commission make any recommendations concerning measures which could be taken to avoid or relieve adverse effects on uses in Canada, what would be the approximate cost of such measures?

In the conduct of its investigation and in the preparation of its report, the Commission should make use of information and technical data heretofore available, or which may become available during the course of the investigation. In addition, the Commission should seek the assistance, as required, of specially qualified personnel from both countries.

Both the United States and Canada ascribe particular importance to the views of the Commission on this matter. Accordingly, the Commission is requested to complete its investigation and submit its report in the minimum possible time, consistent with a thorough examination of the subject, but in any case, not later than October 31, 1976.

The Governments shall make available, or as necessary, seek the appropriation of, the funds required to provide the Commission promptly with the resources needed to discharge its obligations fully within the period specified.

APPENDIX B

DIRECTIVE TO THE BOARD

DIRECTIVE TO THE INTERNATIONAL GARRISON DIVERSION STUDY BOARD

On October 23, 1975, the International Joint Commission established the International Garrison Diversion Study Board to undertake the technical investigation and to advise the Commission on all matters which it must consider in reporting to the two Governments. The following Directive to the Board was issued on October 30, 1975:

1. The Governments of the United States and Canada have forwarded the attached Reference, dated October 22, 1975, to the Commission for examination and report pursuant to Article IX of the Boundary Waters Treaty of 1909.

2. The Commission established the International Garrison Diversion Study Board on October 23, 1975, to undertake, through appropriate governmental or other agencies in the United States and Canada, the necessary investigations and studies and to advise the Commission on all matters which it must consider in making its report to Governments under the attached Reference.

3. The Board shall advise the Commission as to the transboundary implications of the proposed completion and operation of the Garrison Diversion Unit and in doing so shall report to it upon the following:

   (a) the present state of water quality in the Souris and Red Rivers, their tributaries and other downstream waters, with particular reference to the Canadian portions thereof, which may be affected by the proposed completion and operation of the Garrison Diversion Unit. The examination should include the following:

      1) total dissolved solids,

      2) sulfate, sodium, chloride, magnesium, calcium and compounds thereof,

      3) bicarbonates,

      4) nutrients, including nitrogen, phosphorus and their compounds,

      5) pesticides and herbicides,

6) dissolved oxygen, temperature, sediment and other related parameters affecting aquatic life,

7) trace elements including boron, selenium, lead and other heavy metals;

(b) the present uses of these waters and those uses which may reasonably be anticipated in the future;

(c) the effects of present water quality on these uses;

(d) the nature, extent and location of impacts on the quality and quantity of these waters to be anticipated as a result of the proposed completion and operation of the Garrison Diversion Unit;

(e) the nature, extent and economic costs of such impacts to be anticipated from the proposed completion and operation of the Garrison Diversion Unit on the present and anticipated future uses of these waters; and

(f) the nature and extent of the impact on commercial and recreational fisheries in Manitoba, particularly Lake Winnipeg, of the possible introduction from the Missouri River system through the Garrison Diversion Unit of foreign species of fish, fish diseases, and fish parasites;

(g) such other matters as the Commission may indicate to the Board during the sourse of the study.

4. The Board shall also advise the Commission as to measures, including but not limited to modifications, alterations or adjustments to the Garrison Diversion Unit which could be taken to avoid or relieve adverse effects, if any, on water uses in Canada; and shall indicate the approximate cost of any such measures.

5. The Board shall prepare and submit for Commission approval, as soon as possible, a plan of study for the investigations that it proposes to undertake, and a schedule of the estimated time and costs involved in the completion of each of the necessary phases and submission of a final report to the Commission. This study plan should include provisions, where appropriate, to afford opportunities for public participation before each major step in the study. This may be in the form of meetings, seminars, and other means of disseminating information and receiving public reaction thereto.

6. The Board shall carry out the program in accordance with the study plan approved by the Commission. If it appears to the Board at any time in the course of its investigations and studies that the program should be modified, it shall so advise the Commission and request instructions.

7. The Board shall submit its final report, and appendices, if any, to the Commission no later than August 1, 1976.

8. In the conduct of its investigation and in the preparation of its report or reports, the Board should make use of information and technical data heretofore available, or which may become available during the course of the investigation.

9. The Board will consist of a United States Section and a Canadian Section, each having six members. The Commission will appoint one member of each Section to be Chairman of that Section. At the request of any member, the Commission may approve in each case an alternate member to act in the place and stead of such member whenever the said member, for any exceptional reason, is not available to act as a member of the Board.

10. Members of the Board, and of its committees and working groups, whether or not employed by departments or agencies of government, are not representatives of their employers. They serve in a personal and professional capacity under the direction of the Commission, and their employers or superior officers are not committed in any way by the actions of the individual members or of the Board.

11. In carrying out its functions under this Directive, the Board will act as a unitary body, carrying out its investigations jointly in both countries as a coordinated and integrated effort.

12. The Chairmen of the two Sections shall be joint Chairmen of the Board and shall be responsible for maintaining proper liaison between the Board and the Commission and between their respective sections of the Board and the corresponding sections of the Commission.

13. Each Chairman shall ensure that the other members of his Section of the Board are informed of all instructions, inquiries and authorizations received from the Commission; also of activities undertaken by or on behalf of the Board, progress made and any developments affecting such progress.

14. A Chairman, after consulting the other members of his Section of the Board, may appoint a Secretary of that Section. Under the general supervision of the Chairman, the Secretary shall carry out such duties as are assigned to him by the Section.

15. The Board may establish such committees and working groups as may be required to discharge its responsibilities effectively and may enlist the cooperation of federal, provincial or state departments or agencies in the United States and Canada. The duties and composition of any such committees shall be subject to approval by the Commission. Members will make their own arrangements for reimbursement of necessary expenditures for travel.

16. The Board shall maintain informal liaison with the International Souris-Red Rivers Engineering Board and the International Souris River Board of Control, so that it may be aware of any activities of these Boards which may be useful to it or may have a bearing on the conduct of its investigations and studies.

17. In addition, the Chairman shall keep the Commission currently informed of the Board's plans and progress and of any developments, actual or anticipated, which are likely to impede, delay or otherwise affect the carrying out of the Board's responsibilities. To this end the Chairmen shall submit, at least monthly and more often if necessary, reports to the Commission describing the progress that has been made and any problems that have arisen in the investigation. All such reports shall be sent to the Secretaries and each member of the Commission.

18. If, in the opinion of the Board there is a lack of clarity or precision in any instruction, directive or authorization received from the Commission, the matter shall be referred promptly to the Commission for appropriate action.

19. The Board shall not conduct public hearings but will be provided with copies of the record of any hearing conducted by the Commission which relates to matters within the Board's terms of reference.

20. In its dealings with the public and the news media, the Board shall observe the principles of the attached Public Relations Policy of the Commission as supplemented by the provisions of the study plan of the Board when approved by the Commission.

APPENDIX C

MEMBERSHIP OF THE BOARD

MEMBERS OF THE INTERNATIONAL GARRISON DIVERSION STUDY BOARD

The International Joint Commission appointed the International Garrison Diversion Study Board on October 23, 1975. When the Board submitted its report to the Commission dated December 1976, the membership of the Board consisted of the following:

United States Section

Lester W. Lloyd, Bureau of Reclamation, U.S. Department of the Interior, *Chairman*
Charles W. Murray, Jr., Region VIII, U.S. Environmental Protection Agency
Allen L. Fisk, Soil Conservation Service, U.S. Department of Agriculture
Peter L. Gove, Minnesota Pollution Control Agency
Forrest T. Gay III, Army Corps of Engineers, U.S. Department of the Army
Howard M. Olson, Carrington Irrigation Branch, North Dakota State University

Canadian Section

Norton H. James, Environmental Management Service, Environment Canada, *Chairman*
James E. Gander, Research Branch, Economic Council of Canada
Arthur A. Guitard, Research Branch, Agriculture Canada
Andrew L. Hamilton, Fisheries and Marine Service, Environment Canada
James N. Warrener, Environmental Management Division, Manitoba Department of Mines, Resources and Environmental Management
Thomas E. Weber, Water Resources Division, Manitoba Department of Mines, Resources and Environmental Management

FORMER BOARD MEMBERS

Donald P. Dubois, Region VIII, U.S. Environmental Protection Agency
Max W. Noah, Army Corps of Engineers, U.S. Department of the Army

APPENDIX D

MEMBERSHIP OF THE TECHNICAL COMMITTEES

MEMBERSHIP OF THE TECHNICAL COMMITTEES

With the approval of the Commission, the International Garrison Diversion Study Board established a number of Committees. When the Board submitted its report, the Committees consisted of the following members:

WATER QUALITY COMMITTEE

United States

Roger E. Frenette, Region VIII, U.S. Environmental Protection Agency, *Chairman*
James W. Bauder, Soil Department, North Dakota State University
Thomas J. Crooks, Bureau of Reclamation, U.S. Department of the Interior
Norman L. Peterson, Division of Water Supply and Pollution Control, N.D. State Department of Health
Lester Petri, Geological Survey, U.S. Department of the Interior
Katherine A. Svanda, Division of Water Quality, Minnesota Pollution Control Agency

Canada

Kenneth W. Reid, Environmental Management Service, Environment Canada, *Chairman*
Paul Campbell, Fisheries and Marine Service, Environment Canada
Robert M. Gale, Environmental Management Service, Environment Canada
Walter Nicholaichuk, Research Branch, Agriculture Canada
Edward A. Sorba, Environment Management Division, Manitoba Department of Mines, Resources and Environmental Management

BIOLOGY COMMITTEE

Dale Henegar, Fisheries Division, N.D. Game and Fish Department, *Chairman*
Mary Bromel, Department of Bacteriology, N.D. State University
Harry L. Holloway, Jr., Department of Biology, University of N.D.
Marvin E. Hora, Division of Water Quality, Minnesota Pollution Control Agency
John C. Peters, Bureau of Reclamation, U.S. Department of the Interior
Erwin W. Steucke, Jr., Fish and Wildlife Service, U.S. Department of the Interior
John S. Loch, Fisheries and Marine Service, Environment Canada, *Chairman*
Arthur J. Derksen, Research Branch, Manitoba Department of Renewable Resources and Transportation Services
William C. McDonald, Research Branch, Agriculture Canada
Robert B. Oetting, Crown Lands Branch, Manitoba Department of Renewable Resources and Transportation Services
Patrick W. Rakowski, Environmental Management Service, Environment Canada

USES COMMITTEE

United States

Neal A. McClure, Soil Conservation Service, U.S. Department of Agriculture, *Chairman*
Keith Demke, Division of Water Supply and Pollution Control, N.D. State Department of Health
John W. Keys, III, Bureau of Reclamation, U.S. Department of the Interior
Barry C. Schade, Division of Water Quality, Minnesota Pollution Control Agency
Delton D. Schulz, Engineering Division, N.D. State Water Commission
Erwin W. Steucke, Jr., Fish and Wildlife Service, U.S. Department of the Interior
Dale J. Vodehnal, Region VIII, U.S. Environmental Protection Agency

Canada

Harold G. Mills, Environmental Management Service, Environment Canada, *Chairman*
Robert B. Oetting, Crown Lands Branch, Manitoba Department of Renewable Resources and Transportation Services
T. Albert Sandercock, Soils and Crops Branch, Manitoba Department of Agriculture
Robert E. Smith, Research Branch, Agriculture Canada
Donald M. Tate, Environmental Management Service, Environment Canada
William M. Ward, Environmental Management Division, Manitoba Department of Mines, Resources and Environmental Management
Larry J. Whitney, Water Resources Division, Manitoba Department of Mines, Resources and Environmental Management

WATER QUANTITY COMMITTEE

J. Robert Calton, Army Corps of Engineers, U.S. Department of the Army, *Chairman*
Eugene J. Doering, Agricultural Research Service, U.S. Department of Agriculture
Richard L. Gold, Bureau of Reclamation, U.S. Department of the Interior
Walter R. Scott, Geological Survey, U.S. Department of the Interior
David A. Sprynczynatyk, Engineering Division, N.D. State Water Commission

Ronald D. Hofer, Environmental Management Service, Environment Canada, *Chairman*
Walter M. Bilozor, Environmental Management Service, Environment Canada
Richard J. Bowering, Water Resources Division, Manitoba Department of Mines, Resources and Environmental Management
E. Harcourt Hobbs, Research Branch, Agriculture Canada
David J. Richards, Environmental Management Service, Environment Canada

ENGINEERING COMMITTEE

United States

C. Fred Hunt, Bureau of Reclamation, U.S. Department of the Interior, *Chairman*
Peter L. Balkan, Soil Conservation Service, U.S. Department of Agriculture
Louis E. Kowalski, Army Corps of Engineers, U.S. Department of the Army
J. Stevens Lanich, Region VIII, U.S. Environmental Protection Agency
Delton D. Schulz, Engineering Division, N.D. State Water Commission

Canada

G. Hugh MacKay, Water Resources Division, Manitoba Department of Mines, Resources and Environmental Management, *Chairman*
George D. Balacko, Environmental Management Division, Manitoba Department of Mines, Resources and Environmental Management
John Bathurst, Environmental Management Service, Environment Canada
Thomas J. Dafoe, Environmental Protection Service, Environment Canada

APPENDIX E

PARTICIPATING AGENCIES

PARTICIPATING AGENCIES

Valuable and cooperative assistance was provided by the following agencies:

In the United States

United States Environmental Protection Agency
North Dakota State University
United States Bureau of Reclamation
North Dakota State Department of Health
United States Geological Survey
Minnesota Pollution Control Agency
United States Army Corps of Engineers
United States Department of Agriculture
North Dakota State Water Commission
North Dakota Game and Fish Department
University of North Dakota
United States Fish and Wildlife Service
United States Soil Conservation Service

In Canada

Environment Canada
Agriculture Canada
Manitoba Department of Mines, Resources and Environmental Management
Manitoba Department of Renewable Resources and Transportation Services
Manitoba Department of Agriculture
Economic Council of Canada

APPENDIX F

PERSONS PRESENTING BRIEFS

OR TESTIMONY AT THE HEARINGS

PERSONS PRESENTING BRIEFS OR TESTIMONY AT IJC PUBLIC HEARINGS

Where witnesses testified more than once at any one of the hearings, only one appearance is recorded.

1975 HEARINGS

November 18, 1975 at Minot, North Dakota

Chester Reiten for the Hon. Milton R. Young, U.S. Senate
Al Kramer for the Hon. Quentin N. Burdick, U.S. Senate
Ernest N. Schmit for the Hon. Mark Andrews, U.S. Congress
Senator Walter Erdmann, North Dakota State Legislature
Garry Bye, State Representative, North Dakota 5th Legislative District
Senator Rolland Redlin, North Dakota State Legislature
Chester Reiten, Mayor, City of Minot, North Dakota
C.W. Baker, Member, Board of Commissioners, Ward County, N.D.
William L. Guy, former Governor, State of North Dakota
Dr. Sean Brady, Department of External Affairs, Government of Canada
C. Morris Anderson, former State Senator, Ward County, N.D.
Mrs. Charles Hawley, Coleharbor, N.D.
Mrs. Herbert Nathan, Coleharbor, N.D.
Albert Klain, Turtle Lake, N.D.
Mr. Lynn Aas, President, Minot Chamber of Commerce
Alvin A. Kramer, President, Upper Missouri Water Users Association (Montana/North Dakota/South Dakota & Wyoming)
Monroe Raugust, farmer
James L. Grahl, Basin Electric Power Cooperative
Colonel Bill Sifford, Commander, 57th Air Division, Minot Air Force Base

November 19, 1975 at Minot, North Dakota

The Reverend Arvin W. Roose, Chairman, North Dakota Group, Dacotah Chapter Sierra Club
Arthur Link, Governor, State of North Dakota
Vernon Fahy, Secretary, North Dakota State Water Commission, Bismarck, North Dakota
John E. Davis, former Governor, State of North Dakota
Rep. Brynhild Haugland, Dean, North Dakota State Legislature
Judge Kelsch (retired) for the Hon. Allen Olson, Attorney-General, North Dakota
Wally Beyer, General Manager, Verendrye Electric Cooperative, Inc., Velva, N.D.
G.N. Geiszler, former Superintendent North Central Agriculture Experiment Station, Minot, N.D.
Hal S. Davies, former publisher, Minot Daily News
Elmer Jesme, former County Commissioner, Landa, N.D.
Norman Moon, Granville, N.D.
Arlon Hazen, Dean, College of Agriculture and Director, Agriculture Experiment Station, North Dakota State U., Fargo

November 19, 1975 at Minot, North Dakota (cont'd.)

Charles M. Smith, Chairman, Department of Soils, North Dakota State U.
W.H. Sallee, President, Middle Souris Irrigation District
John Arnold, City Manager, Minot, N.D.
Norman L. Peterson, North Dakota State Department of Health, Director, Division of Water Supply & Pollution Control
Russ Dushinske, Executive Vice President, North Dakota Water Users Association
Steve Petry, Staff Assistant, Central Power Electric Cooperative
Mrs. Aldarese Klain, Turtle Lake, N.D.
Ms. Paula Ward, for Friends of the Earth
Mr. Valdemar Hovde, Minot, N.D.
Jerome Sabbe, Surrey, N.D.
Mr. Sondrul, McLean County, N.D.
Carl Kuehn, North Dakota Farm Bureau

November 19, 1975, Grand Forks, North Dakota

The Hon. Cyril P. O'Neill, Mayor, City of Grand Forks, N.D.
The Hon. Robert Ralston, Mayor, City of Mayville, N.D.
Neil J. Tillapaugh, for Mayor Brown of New Rockford, N.D.
The Hon. Robert Dahl, Mayor, City of Grafton, N.D.
Dean Hildebrand, Representative, North Dakota State Legislature, District 15, Devils Lake
Dennis L. Riggin, Mayor, Devils Lake, N.D.
John B. Owen, Professor of Biology, University of North Dakota
Henry A. Hendrickson, member, Cass County, North Dakota Board of Commissioners
Dr. Harry Holloway, University of North Dakota
Richard Madson, Assistant Regional Representative, National Audubon Society
Allan Thompson, Chairman, Water Resources Division, Devils Lake Chamber of Commerce
Roy Holand, Director from LaMoure County, Garrison Diversion Conservancy District
Fred Schumacher, Kindred, N.D.
Mrs. Betty Daniels, Director, Dickey-Sargent Irrigation District, Oakes, N.D.
Dale Anderson, for Richard Crockett, Greater North Dakota Association
Dr. Gary L. Pearson for Institute of Ecology, Jamestown, N.D.
Linus L. Tumbleson, Assistant Director, Agricultural Development Burlington Northern, Inc., St. Paul, Minnesota
Kenneth Gilbert, United Family Farmers, James River Valley
Gordon Berg, Chairman, Citizens Advisory Committee, Upper Mississippi River Basin Committee
Ernest W. Hagen, Tri-County Park Board, Devils Lake, N.D.

November 20, 1975 at Winnipeg, Manitoba (3:00 p.m.)

Bernie R. Wolfe, Deputy-Mayor, City of Winnipeg, Manitoba
Dan McKenzie, City of Winnipeg
The Hon. Sidney Green, Minister, Department of Mines, Resources and Environmental Management, Province of Manitoba
Dean Whiteway, M.P., Government of Canada
J. Murta, M.P., Government of Canada
Sean Brady, U.S.A. Division, Department of External Affairs, Government of Canada
Sidney Spivak, Member of the Legislature, Province of Manitoba
J.D. Watt, Member of the Legislature, Province of Manitoba
Donald Craik, Member of the Legislature, Province of Manitoba
Dr. W.G. Bowen, Assistant Deputy Minister, Environmental Management Division, Department of Mines, Resources and Environmental Management, Province of Manitoba
B. Berck, Chairman, Manitoba Environmental Research Committee
Milo W. Hoisveen, resident of Manitoba

November 20, 1975 at Winnipeg, Manitoba (8:00 p.m.)

Dr. J.P. Bruce, Inland Waters Directorate, Environment Canada
Dr. J. Lawler, Fisheries & Marine Services, Environment Canada
Lloyd Wersch, Mayor, Town of Selkirk, Manitoba
D.G. Rodger for City of Portage La Prairie & Town of Souris, Manitoba
Clem Busby, Councillor, Town of Souris
Jesse Rieber for Ojibway Tribal Council, Southwestern Manitoba
Ms. Steidinger)
Ms. Repa) local students
Mrs. Joyce Glendinning, resident of Manitoba
T.G. Thompson for Transcona Game & Fish Association
Mrs. Helle Cosby, resident of Manitoba
Paul Murphy for Manitoba Wildlife Federation
Dr. G.R.B. Webster, University of Manitoba
Ralph Baker, Winnipeg
Kenneth Emberley, Winnipeg
Ralph Oliver, Carberry, Manitoba
Tom Shay, Association of Manitoba Archaeologists, Anthropology
Frank Jones, Souris River Water Commission
Dr. Lansdown, Manitoba Environmental Council
O. Kremers, Manitoba Environmental Council
Percy Brockington for Souris Valley Flooded Farmers Association
Gunter Schoch for Manitoba Parks & Recreation Association
Eric Stefanson for Interlake Development Corporation, Inc.
Robert Sopuck for Manitoba Naturalists Society
Roy Johnstone for Prairie Environmental Defence League
Brian Katz, University of Manitoba
Mrs. Gloria Joshi, Whitmark, Manitoba
Dr. Cas Lindsey, University of Manitoba
Gene Charron, local resident
Mrs. Ora Hlady, local resident
Mrs. R. Turner for United Nations Association in Canada, Winnipeg Branch

1977 HEARINGS

March 8, 1977 at Minot, North Dakota (10:00 a.m.)

Ernest Schmit for the Hon. Mark Andrews, U.S. Congress
Chester Reiten, Mayor, City of Minot, North Dakota, and Senator, North Dakota State Legislature for the Hon. Milton R. Young, U.S. Senate
The Hon. Sidney Green, Minister of Mines, Resources and Environmental Management, Province of Manitoba
Jonathan Eaton, Garrison Conservancy District, Minot, N.D.
Bonaventure Kraft, Mayor, City of Surrey, N.D.
William Ryan, Mayor, City of Harvey, N.D.
G.R. Garnant, Bantry, N.D.
Ivan Goheen, Minot, N.D.
Robert Ebel, Fessenden, N.D.
F.L. Tompkins, Minot, N.D.
Ken Johnson, President, Chamber of Commerce, Minot, N.D.
Arlon G. Hazen, Dean, College of Agriculture, and Director Agricultural Experiment Station, North Dakota State U., Fargo, N.D.
Dr. Kent Horne, Kent Horne & Associates, Bismarck, N.D.

March 8, 1977 at Minot, North Dakota (2:30 p.m.)

Dr. Sean Brady, Department of External Affairs, Government of Canada
David Spryncznatik for Vern Fahy, State Engineer, North Dakota Water Commission
Stephen Hoetzer, Drainage Engineer, North Dakota Water Commission, Bismarck, N.D.
Gene Olson, Balfour, N.D.
Herbert Nathan, Coleharbor, N.D.
Jerome Sabbe, Minot, N.D.
Earl Allen, Minot, N.D.
Norman Moen, Chairman, Mousse River Valley Landowners' Association
Earl C. Stegman, Professor, Agricultural Engineering Department, North Dakota State U., Fargo, N.D.
Gary Pearson, Northern Environmental Council, Duluth, Minn.
Ms Cynthia Andre, Chairman, Sierra Club, Bismarck, N.D.
Monroe Raugust, Chairman, Committee to Save North Dakota, Harvey, N.D.

March 9, 1977 at Souris, Manitoba

The Hon. Walter Dinsdale, Member for Brandon-Souris, Parliament of Canada
Sterling Lyon, Member of Provincial Legislature for Souris-Killarney, Province of Manitoba
William Strath, Souris, Manitoba
Gary Lenton, Norwich, North Dakota
C.K. Lund, Melita, Manitoba
Lorne Watt, Reston, Manitoba

March 10, 1977 at Winnipeg, Manitoba (3:00 p.m.)

Dan McKenzie, Member for Winnipeg South-Centre, Parliament of Canada
Lloyd R. Wersch, Mayor, Town of Selkirk, Manitoba
Miss Simone Imlah, Fisher Branch, Women's Institute, Winnipeg
C.R. Huband, Leader Liberal Party, Province of Manitoba, Winnipeg
W.S. Forester, Municipality of Montcalm, Emerson, Manitoba

March 10, 1977 at Winnipeg, Manitoba (6:00 p.m.)

Dr. W. George Bowen, Assistant Deputy-Minister, Department of Mines, Resources and Environmental Management, Province of Manitoba
Miss Jocelyn Bruyere)
Tony Walker) Manitoba Indian Brotherhood, Winnipeg
Carl Ridd, for Wentworth United Church, Winnipeg
Onno Kremers, Manitoba Environmental Council, Winnipeg
Douglas C. Harvey, Sierra Club, Winnipeg
Dr. Thomas Shay, Association of Manitoba Archaeologists, Winnipeg
Philip A. Ruzzuto, Prairie Region & Northwest Territories Committee of the Canadian Federation of Municipalities, Winnipeg
Geoffrey Scott, Conservation Class, University of Manitoba, Winnipeg
Arthur Erickson, President, Winnipegosis Chamber of Commerce

March 11, 1977 at Winnipeg, Manitoba (10:00 a.m.)

Dr. C. Lindsey, Department of Zoology, University of Manitoba, Winnipeg
Tom Gonsalves, Winnipeg

March 11, 1977 at Winnipeg, Manitoba (2:00 p.m.)

J.M. Froese, former Member of the Provincial Legislature for Rhineland, Winkler, Manitoba
Jesse Rieber, Jesse Rieber & Associates, Winnipeg
Wayne Neiley, Winnipeg

March 14, 1977 at Portage La Prairie, Manitoba

Peter P. Masniuk, Member for Portage La Prairie, Parliament of Canada, Inwood, Manitoba
Dean Whiteway, Member for Selkirk, Parliament of Canada, Winnipeg
Mrs. Karen Devine, Mayor, City of Portage La Prairie
W.C. Patterson, Councillor, Regional Municipality of Portage
Amarjit Chada, Engineer, City of Portage La Prairie
Raymond Sigurdson, Regional Municipality of Gimli
Ed Connery, Portage La Prairie
John D. Paulson, Newspaper Editor, Fargo, North Dakota
Lloyd Henderson, Prairie Flood Control Organization, Brandon, Manitoba
Ronald Roteliuk for Regional Development Corporations of Manitoba

March 15, 1977 at Grand Forks, North Dakota (10:00 a.m.)

Arthur Link, Governor, State of North Dakota, Bismarck, N.D.
Allen Olson, Attorney-General, State of North Dakota
Dr. J. Weisbuch, State Health Officer, North Dakota Department of Health, Bismarck, N.D.
Norman Peterson, Department of Safety and Health of N.D.
William L. Guy, former Governor of North Dakota, Cassleton, North Dakota

March 15, 1977 at Grand Forks, North Dakota (2:00 p.m.)

Richard Hentges, Mayor, Fargo, North Dakota
Robert Ralston, Mayor, Mayville, N.D.
L.C. Loerch for Mayor of Harvey, N.D.
Roy Holand, Attorney, Lamour, N.D.
Bernard Veulek, Crete, N.D.
David Locken, Oakes, N.D.
Michael Sweeney, Fargo, N.D.
Lorin Forens, Fargo, N.D.
Gertrude Lizakowski, Grand Forks, N.D.
Lawrence T. Walker, Maddock, N.D.
William Bosse, Chairman Board of Directors, Garrison District Conservancy District, Cogswell, N.D.
John Sieh, Chairman Oahe Conservancy Sub-District, South Dakota
Joseph Zubriski, Professor of Soils, North Dakota State U., Fargo, N.D.
Prof. Darnell Lundstrom, Extension Agricultural Engineer, Cooperative Extension Service, North Dakota State U., Fargo
Grant Trenbath, Chairman of the Pembina River Basin Association, Neche, N.D.
Kendahl Mork, Attorney-General's office, Hatton, N.D.
L. Roger Johnson, Executive Director, Committee to Save North Dakota, Fargo, N.D.
John Rolczynski, Freelance Writer, Grand Forks, N.D.
Roland Kaser, Vice-President, Harza Engineering Company, Chicago, Illinois
Dr. James Thrall, Harza Engineering Company, Chicago

In addition to the above, over 20 written statements were submitted on behalf of individuals and organizations; a similar amount was received by mail.

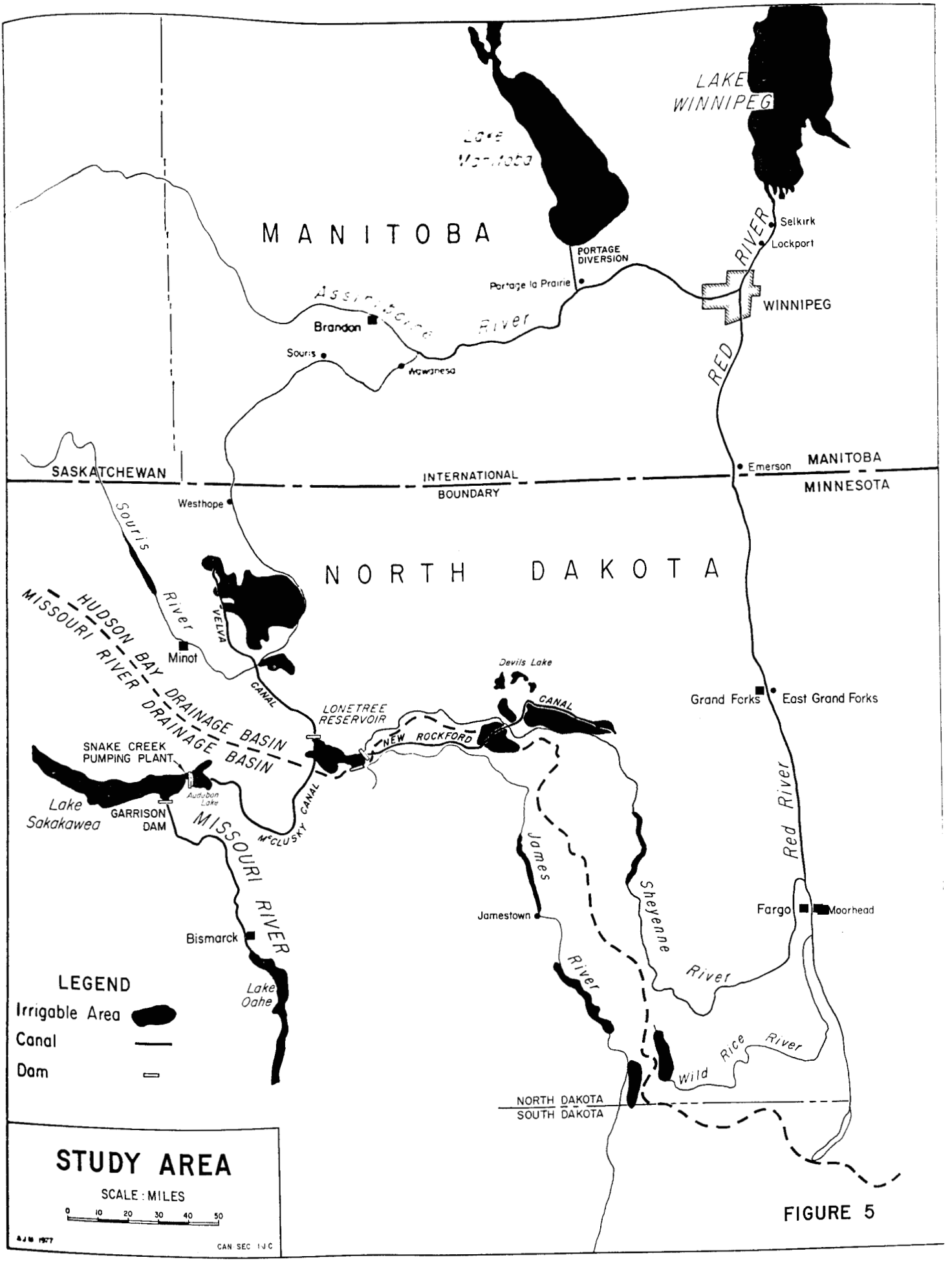

LAKE WINNIPEG
Lake Manitoba
MANITOBA
PORTAGE DIVERSION
Portage la Prairie
Selkirk
Lockport
RED RIVER
WINNIPEG
Assiniboine River
Brandon
Souris
Wawanesa
SASKATCHEWAN
INTERNATIONAL BOUNDARY
Emerson
MANITOBA
MINNESOTA
Westhope
Souris River
NORTH DAKOTA
VELVA CANAL
Minot
HUDSON BAY DRAINAGE BASIN
MISSOURI RIVER DRAINAGE BASIN
Devils Lake
CANAL
LONETREE RESERVOIR
NEW ROCKFORD
Grand Forks
East Grand Forks
SNAKE CREEK PUMPING PLANT
Audubon Lake
Lake Sakakawea
GARRISON DAM
McCLUSKY CANAL
MISSOURI RIVER
James River
Red River
Jamestown
Fargo
Moorhead
Bismarck
Sheyenne River
Lake Oahe
Wild Rice River
NORTH DAKOTA
SOUTH DAKOTA
LEGEND
Irrigable Area
Canal
Dam
STUDY AREA
SCALE : MILES
0 10 20 30 40 50
CAN SEC IJC

FIGURE 5