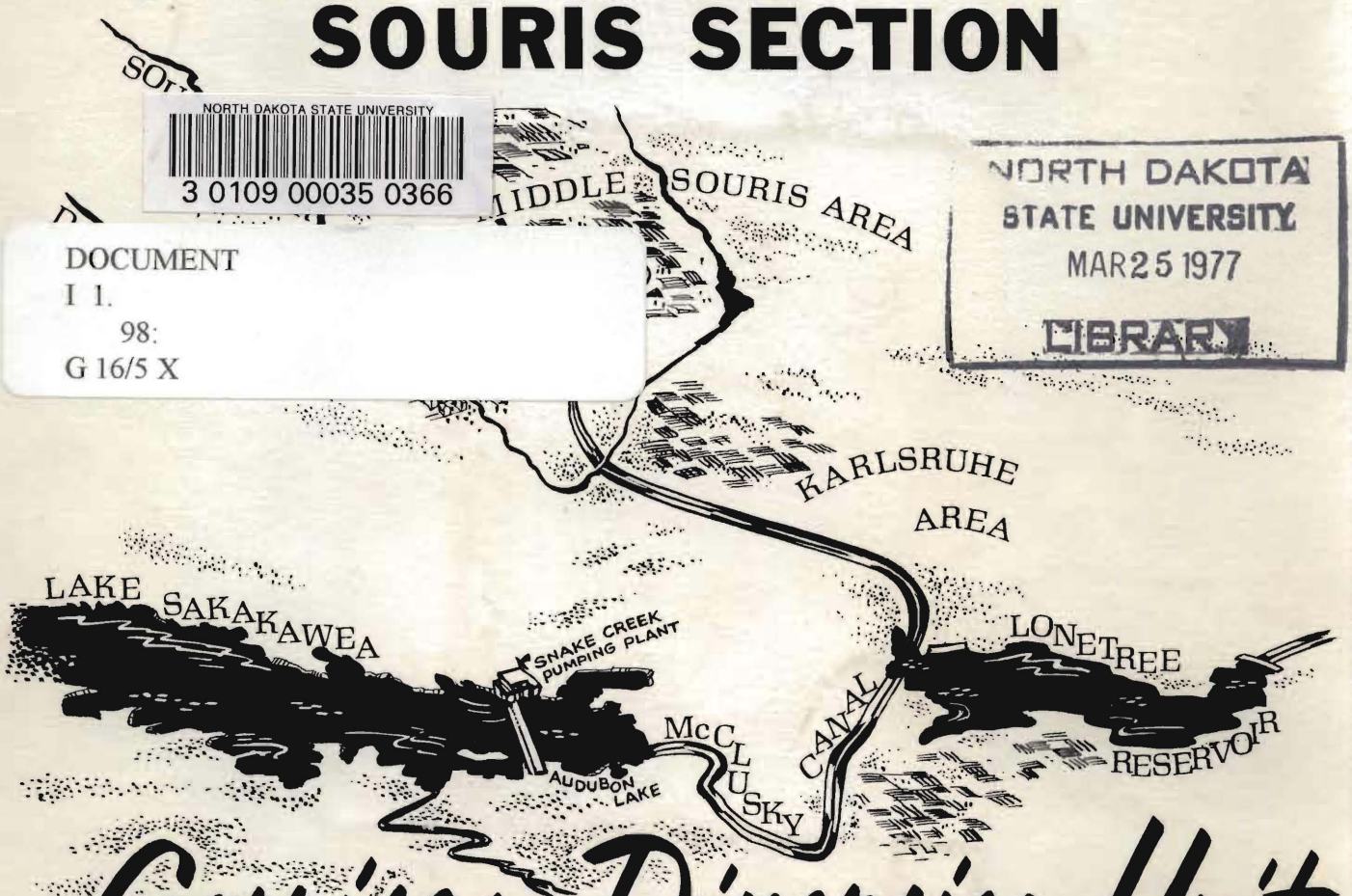
INVESTIGATION OF ALTERNATIVES in the SOURIS SECTION



Garrison Diversion Unit
NORTH DAKOTA

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

June 1976

UNITED STATES
DEPARTMENT OF THE INTERIOR

BUREAU OF RECLAMATION

REPORT ON

INVESTIGATION OF ALTERNATIVES IN THE SOURIS SECTION

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TABLE OF CONTENTS

TABLE OF CONTENTS
(cont.)

Page

Drawing

Tables and Figures

SUMMARY

The initial stage of Garrison Diversion Unit will divert Missouri River water in North Dakota to irrigate 250,000 acres of land, provide water supplies for municipalities and industries, enhance fish and wildlife, and restore the Devils Lake Chain. Principal areas to be served by the Garrison Diversion Unit are the Souris Section, Central Section, and LaMoure and Oakes Section. Construction of the principal supply works (consisting of Snake Creek Pumping Plant, McClusky Canal and Lonetree Reservoir) began in 1967 and is scheduled for completion in 1978. Environmental impact statements will be prepared for each of the three areas to be served by the principal supply works prior to initiation of construction in these areas.

Garrison Diversion Unit development will affect quality and quantity of flows in the Souris, Red, Sheyenne, Wild Rice and James Rivers by introducing Missouri River water into these receiving streams via return flows. Return flows will accrue to these rivers as a result of irrigation development, fish and wildlife developments, and from municipalities and industries using Missouri River water.

About 46 percent of the Garrison Diversion Unit irrigated lands are located in the Souris River Basin, 33 percent in the Red River Basin, 13 percent in the James River Basin, and the remaining irrigated lands are in the Devils Lake and Lonetree drainage basins. Of the two rivers that enter Canada, the Souris River will be affected the most because of the percentage of irrigated lands in the basin, return flows from the city of Minot, and the relatively small size of the Souris River. Median annual Souris River flow at Westhope is 107,740 acre-feet, compared to annual median flow of 2,136,000 acre-feet in the Red River at Emerson, Manitoba. Garrison Diversion Unit development in the Souris Section will measurably change the Souris River, and the Bureau of Reclamation has conducted several studies to predict the effects Garrison Diversion Unit return flows may have on the Souris River and Canada.

Since initiation of construction of the principal supply works in 1967, Canada has repeatedly expressed concern about the effects return flows will have on the Souris River in Canada. Several meetings among Canadian and United States representatives were held to discuss the international implication of the Garrison Diversion Unit, and in 1975 the International Joint Commission was requested to conduct a study and report on the transboundary implications of the Garrison Diversion Unit. The possible need for studies of alternatives in the Souris Section was recognized in 1973 and consequently, some limited studies were initiated. In 1975 the Bureau of Reclamation initiated a sub-feasibility level study of alternatives for dealing with Souris Section return flows. Although the study level is subfeasibility, each alternative plan was examined in sufficient depth to determine practicability of construction, approximate costs, effects on the Souris River, and probable social and environmental effects in North Dakota and Canada.

This study of alternatives is not intended to preclude development of the Souris Section as presently planned. With the addition of return flows in the Souris River, historic periods of zero or low flow (and associated poor water quality) which occur in the late summer, fall and winter will be eliminated; however, return flows will also increase flows during high-flow periods and will slightly degrade overall water quality during periods of high flows.

The Department of the Interior decided to conduct the alternative study, in addition to the water quality studies, to explore possible actions that might be initiated in the event an amicable solution to the issue of return flows entering the Souris River cannot be reached with Canada, either through negotiations or through the efforts of the International Joint Commission. This alternative study would be used as a planning guide for more detailed feasibility studies if it is determined that return flows discharged into the Souris River violate the 1909 Boundary Waters Treaty with Canada and that the presently authorized plan for Garrison Diversion Unit must be altered.

This study investigates 12 alternative plans which could be developed in the Souris Section to reduce the effects of return flows on the Souris River. The alternatives investigated are divided into four categories as follows:

A. Reuse of return flows in North Dakota.
B. Dilution of return flows entering the Souris River.
C. Partial development of the Souris Section.
D. Treatment of return flows, either in North Dakota or Canada.

Alternative A, Reuse, consists of collecting return flows that accrue to the subsurface drains and diverting this collected water to either Lake Sakakawea, Lonetree Reservoir or Devils Lake. Two basic concepts were used in this alternative. One concept was to divert all the collected water to one of the three bodies of water and the other concept was to reuse a portion of the collected water for irrigation application water during the irrigation season and divert the remaining collected water to one of the three bodies of water. A total of six plans were investigated. All six plans under this alternative have the same effect on the Souris River. After full development, median annual return flows to the river would be 44,200 acre-feet at 700 milligrams per liter (mg/l) total dissolved solids (TDS) (see page 15 for definition), as compared to 91,600 acre-feet at 870 mg/l TDS for the authorized unit. Construction costs for the plans range from about $96,000,000 to $133,000,000.

Alternative B, Dilution, consists of releasing water from the Velva Canal directly into the Souris River. Water would be released into the river to prevent TDS levels from exceeding 1,000 mg/l in the Souris River at Westhope, North Dakota. During wet years, very little or no dilution would be required because TDS levels in the river would probably remain below 1,000 mg/l throughout the year. In a dry year, dilution would be required during December, January and February. Although the releases for dilution are small and within the design capacities of the canal structures, additional construction costs associated with this alternative would be required to make the canal operational during the winter season.

Alternative C, Partial Development, consists of three plans which investigate varying levels of development of the Souris Section. The authorized unit calls for development of 116,000 acres in the Souris Section. The alternative plans investigate development at 90,800 acres, 51,200 acres, and deletion of the Souris Section. Median annual volume of return flows entering the river after full development would be reduced from 91,600 acre-feet for the authorized unit to 76,300 acre-feet, 54,600 acre-feet, and zero acre-feet, respectively.

Alternative D, Treatment, consists of two plans which either desalt return flows at the source in North Dakota or provide reimbursement to two Canadian communities for increased water softening costs as a result of return flows. The desalting plan could desalt return flows to maintain TDS in the Souris River at the historic annual median level; however, operation and energy costs on this alternative are extremely high. Increased annual water softening costs encountered by the Canadian communities of Souris and Portage La Prairie could be about $3,000 (35 percent) and $5,000 (6 percent), respectively.

The alternative plans in this study are set forth in a manner to permit an analysis of the alternatives in accordance with a specific objective in mind, e.g., improve return flow quality, reduce return flow quantity, etc. The following summary table presents an overview of the alternatives investigated.

INTRODUCTION

A major point of concern in the development of the Garrison Diversion Unit in North Dakota is the effect return flows will have on the Souris River and Canada. The Bureau of Reclamation has conducted many studies to arrive at the present plan of development for the Souris Section. Many of these studies examined existing conditions in the Souris River, predicted the quality and quantity of return flows to the river from Garrison Diversion Unit development in the Souris Section, evaluated the effects of the water upon the river, revised plans for irrigation in the area to derive a project with acceptable return flows, and provided information about the effects the project will have on the Souris River. This study investigates some of the alternatives to the present Souris Section plan of development that probably could be implemented to reduce or eliminate the effects the project will have on the Souris River and Canada.

The multipurpose Garrison Diversion Unit will divert, store and deliver water from Lake Sakakawea on the Missouri River for irrigation, municipal and industrial supply, fish and wildlife enhancement, and restoration of Devils Lake Chain. With a series of pumping plants, reservoirs, canals and laterals, the water will be delivered to three major areas: the LaMoure & Oakes Section, the Central Section, and the Souris Section.

The Study

Although the level of the study is subfeasibility, each alternative plan was examined in sufficient detail to determine practicability of construction, approximate costs, effects on the Souris River, and probable social and environmental effects in North Dakota. Alternatives B and D also evaluated the social, economic and environmental effects in Canada. As a result of this study, the most viable alternatives to the proposed development of the Souris Section were selected and their relative merits determined. A total of 12 alternative plans were examined for the study.

Need for the Alternative Study

During a two-decade period beginning in 1945, considerable communication and exchange of data transpired between the United States and Canada regarding the Garrison Diversion Unit. The original plan for the Garrison Diversion Unit envisioned an ultimate irrigation development of 1,007,000 acres and an initial stage development capable of serving 407,000 acres. The plan was subsequently modified to provide for an initial stage development of 250,000 acres and was authorized by Public Law 89-108 dated August 5, 1965.

During this two-decade period, plans to import water into the Souris River Basin were favorably accepted by Canadian water resource personnel. The plans for long-range development were generally known in both countries, and methods to develop satisfactory streamflows in the Souris and Red Rivers were generally thought to be helpful.

Following the initiation of construction of Garrison Diversion Unit facilities in 1967, the Canadian Government began expressing concerns about the effects return flows may have on the Souris River and Canada. The first formal notice expressing their concerns was in the form of a diplomatic note from the Department of External Affairs to the U.S. State Department delivered on April 29, 1969. Several subsequent exchanges of correspondence (April 1969, April 1970, October 1971 and January 1973) occurred between the two countries concerning the effects of return flows on the quality and quantity of water in the Souris and Red Rivers in Canada.

Meetings among Canadian and United States representatives were held in Washington, D.C. in February 1973, Bismarck, North Dakota in June 1973, Ottawa, Canada in August 1974, and again in Washington, D.C. in January 1975 to discuss the international implications of the Garrison Diversion Unit. At the January 1975 meeting it was mutually agreed that the two governments would select an appropriate mechanism to undertake an examination of the transboundary effects resulting from development of the Garrison Diversion Unit. On October 22, 1975, the United States and

Canada jointly referred the question of transboundary effects to the International Joint Commission.

During the course of discussions with Canada, it became apparent that the Bureau of Reclamation should conduct additional studies to help answer questions regarding effects Garrison Diversion Unit development may have on Canada. Ongoing water quality studies were accelerated and modified to include additional water quality parameters and complementary studies were initiated.

Objective of the Study

The Department of the Interior decided to explore possible actions that might be initiated in the event an amicable solution to the issue of return flows entering the Souris River cannot be reached with Canada, either through negotiations or through the efforts of the International Joint Commission. The objective of this study is to outline some of these possible actions. Plans for the study were formulated in 1974 and early 1975, and in June 1975 the Bureau of Reclamation initiated the study. This study of alternatives does not preclude future negotiations between the United States and Canada, nor does it preclude development of the Souris Section as presently authorized.

Coordination with Other Agencies

During the course of the study, various State and Federal agencies were contacted to obtain comments and information. Following is a listing of these agencies:

1. NORTH DAKOTA STATE HEALTH DEPARTMENT - Obtained information and assistance on water treatment.

2. U.S. BUREAU OF MINES - Obtained information on coal deposits in North Dakota.

3. U.S. FISH AND WILDLIFE SERVICE and NORTH DAKOTA STATE GAME AND FISH DEPARTMENT - Meetings were held on January 16, 1976, and March 1, 1976, with these two agencies to coordinate fish and wildlife aspects of the study.

4. NORTH DAKOTA STATE WATER COMMISSION - Obtained information on deep well injection and discussed (informally) other alternatives.

5. PROVINCE OF MANITOBA, DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT - Obtained information on water treatment utilized by communities whose water sources are the Souris and Assiniboine Rivers.

Study Area

The Souris Section is located in the Souris River drainage basin. The general area and major features of the project are identified on the frontispiece map entitled "Alternative Investigations."

Under the present plans for the Garrison Diversion Unit, the Souris Section will be supplied with approximately 222,000 acre-feet of water from the Missouri River each year. Water will be pumped from Lake Sakakawea by the Snake Creek Pumping Plant, discharged into Audubon Lake, and conveyed by gravity through the McClusky Canal to Lonetree Reservoir, the principal distribution point for all project water. A gravity outlet from the reservoir will discharge water into Velva Canal. Velva Canal will traverse a distance of about 84 miles in a northerly direction to deliver water to the irrigated lands of the Souris Section. The initial delivery of water to the area is scheduled for 1988.

The Garrison Diversion Unit will provide irrigation water for 116,000 acres of land in the Souris Section without utilization of local streamflow. In addition, water will be provided for municipal and industrial use and fish and wildlife development. The irrigable land is identified as the Middle Souris Area (64,200 acres in the Middle Souris Irrigation District and 39,600 acres in the Mouse River Irrigation District) and the Karlsruhe Area (12,200 acres). Irrigable lands in the Middle Souris and Karlsruhe Areas are located on beach, delta and lake deposits which are bounded by the ground moraine plain on the west (boundary of dense glacial till deposits) and the Souris River on the east. Karlsruhe Area lands are situated mainly on glacial outwash plain deposits.

Return flows from irrigation in the Souris Section will accrue to the Souris River via drains and tributary streams. These flows will consist of irrigation return flows, canal and lateral seepage losses, and operational wastes of the Souris Section irrigation system. When discharged into the Souris River, the TDS concentration of the irrigation water from the Missouri River will have increased through crop evapotranspiration and salts dissolving in the soil profile. In addition to return flows resulting from irrigation, return flows will also accrue to the river from fish and wildlife developments and municipal and industrial (M&I) water systems that use Garrison Diversion Unit water. During periods of low flow in the Souris River, return flows will improve the water quality and provide a dependable water supply that will eliminate periods of no flow in the Souris River. During high-flow conditions, return flows will slightly degrade the water quality in the river, and the increased quantity will tend to aggravate flooding conditions.

The Souris River

From its origin in southeastern Saskatchewan, the Souris River flows in a southeasterly direction from the international boundary near Sherwood, North Dakota, to Velva (25 miles southeast of Minot), then in an easterly and northerly direction back into Canada near Westhope, North Dakota. The area in the United States bounded by the river and the international boundary is known as the Souris Loop Area. After crossing into Canada, the Souris River continues flowing in a northeasterly direction to its confluence with the Assiniboine River near Treesbank, Manitoba. The Assiniboine then flows eastward and joins the Red River (at Winnipeg, Manitoba) which flows into Lake Winnipeg about 40 miles north of this confluence.

The Souris River drainage basin, measured upstream from the international gaging station near Westhope, North Dakota, consists of approximately 16,900 square miles of land. In this drainage basin, about 6,600 square miles directly contribute to the flows in the river and 10,300 square miles are noncontributing. About 54 percent of the drainage basin (9,130 square miles) lies within the United States.

Historically, annual flows have varied from periods of no flow to very low flows of poor quality and to very high flows of good quality. Flows in the Souris River have fluctuated widely during the period of record. The total annual runoff at the Westhope gaging station has ranged from a low of only 100 acre-feet in 1937 to a high of 841,501 acre-feet in 1975. At the Sherwood gaging station, annual flows ranged from a low of 1,130 acre-feet in 1937 to a maximum of 395,200 acre-feet in 1975. The median monthly flow in the river during the period used for return flow studies (1953 to 1974) was 2,000 acre-feet at Westhope and 800 acre-feet at Sherwood.

The Souris River has a similar wide range of monthly runoff volumes and instantaneous discharges. The peak flows in the river normally occur during the months April through June due to snowmelt and general spring and early summer precipitation. A maximum instantaneous discharge of 6,400 cubic feet per second (ft^3/s) was recorded at the Westhope gage in 1949 and 12,400 ft^3/s at the Sherwood gage in 1969. The lowest discharges usually occur during the winter months of December to March. There have been extended periods of zero flow or flows less than 50 acre-feet per month in the river during both winter and summer months. At the Westhope and Sherwood gaging stations, flow completely ceased for 11 months in 1937. In the 10 years 1930-1940, there was little or no flow past the Westhope gage for 49 of the 120 months (41 percent of the time) or past the Sherwood gage for 66 of the 120 months (55 percent of the time).

Water quality of the Souris River is dependent upon the volume of flow in the river and varies through wide limits. During periods of high flow (1,500 ft^3/s or more), TDS concentrations have been as low as 200 mg/l, but during low-flow periods (less than 10 ft^3/s) concentrations have exceeded 1,000 mg/l regularly. At Westhope near where the river leaves the United States, the median monthly TDS concentration during the 1953 to 1974 study period is 606 mg/l, with maximum and minimum recorded values of 3,650 mg/l and 163 mg/l, respectively.

Due to the extremely short period of record, quality data at Sherwood are inadequate to analyze water quality of the Souris River entering the United States. The best source of such water quality data is the Glen Ewen, Saskatchewan gaging station. Based on data from 1960 to 1974 provided by the Water Quality Branch, Inland Waters Directorate of the Department of the Environment in Ottawa, Ontario, the median monthly concentration of TDS for the period is 736 mg/l, with maximum and minimum values of 2,141 mg/l and 213 mg/l, respectively.

Dissolved oxygen (DO) levels in lower reaches of the river fall to zero nearly every year during winter months when flows are low. The biochemical oxygen demand (BOD), coliform count, and total nutrient loading of the river and its impoundments are usually very high. These biological water quality problems are caused and compounded by animal and waterfowl wastes from feedlots, farm operations, and wildlife refuges along the river. The lack of rapids, falls or associated fast-moving water for natural reaeration insures rather poor biological water quality.

Although there are several structures that provide some regulation of the river, the main hydraulic controls are the shallow slope of the stream channel and the extreme meander pattern. These natural characteristics of the riverbed retard the flow of the river, lengthen the travel time of a flood wave, reduce flood peaks, and increase the river's susceptibility to ice formation.

In addition to the natural controls of the Souris River, flow is regulated by two major storage facilities and several small diversion structures. The two major storage facilities are Lake Darling and J. Clark Salyer National Wildlife Refuge. Lake Darling near Foxholm is used to supply water to the J. Clark Salyer National Wildlife Refuge during periods of low flow. This refuge contains five low-head dams between Upham and Westhope which store water for wildlife and waterfowl propagation.

THE ALTERNATIVES

When considering alternative development plans for the Souris Section, there are a multitude of plans which could be investigated because of the wide range of possibilities as to what constitutes acceptable return flow. Plans which would produce return flows acceptable to Canada could possibly range anywhere from development of the Souris Section as authorized to an alternative with virtually no effect on the existing water quality or quantity in the Souris River. In addition to alternatives associated with physically changing the plan of development for the Souris Section, there are alternatives which would involve treatment of return flows either before or after they enter the Souris River and other alternatives which would involve mitigation of adverse effects that return flows may have on the Souris River and Canada.

Four basic types of alternatives were selected for study, each including one or more plans. A total of 12 alternative plans were developed and analyzed. Table 1 contains a listing of these alternative plans, and the frontispiece map identifies the general configuration of these alternatives.

Several other types of alternatives (see Table 1) were considered but were not selected for investigation for various reasons. These alternatives were not investigated because they would either require extensive research and could not be investigated because of time constraints and funding limitations, because they are primarily political in nature and are not within the scope of the study, or because they do not appear to be as viable as the alternatives selected for investigation.

The narrative explanation for each alternative plan identifies both beneficial and adverse environmental impacts. Impacts investigated include water pollution, disposal of desalinization byproducts, alteration of the character of natural wetlands, alteration of existing water management programs on wildlife areas, channelization of natural

Table 1

SOURIS SECTION ALTERNATIVES STUDY

ALTERNATIVES INVESTIGATED

Alternative A - Reuse

1. Divert collectable return flows to Lonetree Reservoir with reuse in Souris Section.
2. Divert collectable return flows to Lake Sakakawea with reuse in Souris Section.
3. Divert collectable return flows to the Devils Lake Chain with reuse in Souris Section.
4. Divert collectable return flows to Lonetree Reservoir.
5. Divert collectable return flows to Lake Sakakawea.
6. Divert collectable return flows to the Devils Lake Chain.

Alternative B - Dilution

Release project water from the Velva Canal into the Souris River.

Alternative C - Partial Development

1. Develop 90,800 acres.
2. Develop 51,200 acres.
3. Delete the Souris Section.

Alternative D - Treatment

1. Desalinization plant on Deep River.
2. Water softening for two communities in Canada.

OTHER ALTERNATIVES CONSIDERED

1. Use of collectable return flows for industrial purposes.
2. Exchange of Souris River and Velva Canal waters.
3. Multipurpose dam on the Souris River.
4. Deep well injection of collectable return flows.
5. Irrigation development in Canada using Souris River water.
6. Extend the Velva Canal to Canada for Canadian use.
7. Channelization of the Souris River in Canada.
8. Desalinization plants for two communities in Canada.
9. Control subsurface drainage during winter months.

waterways, disturbance and/or reduction of upland habitat, alteration of existing fish habitat, changes in water quantity and quality as affects fish, and development and management of wildlife lands as mitigation features. These impacts, both beneficial and harmful, are compared to those predicted for the authorized plan of development for the Souris Section.

Effects on archaeological and historical resources were not determined for this study. However, these resources are being investigated in the Garrison Diversion Unit area and would be addressed in any future detailed studies that may be initiated.

The economic analyses for the alternatives are based on the current updated (January 1975) benefits and costs of the Garrison Diversion Unit. Two benefit-cost ratios are computed for each alternative based on a 100-year period of analysis at the effective interest rate at the time of project authorization (3.125 percent) and the current fiscal year interest rate (6.125 percent). Although the analyses are sub-feasibility grade, adequate detail has been included to provide reliable economic data.

Social impacts associated with the alternatives were considered but not quantified in the evaluation of the various alternative plans. The social factors are generally nonmonetary in character and are not measured in the benefit-cost ratios computed for each alternative plan.

The quantities of return flows are based on equilibrium conditions with full development of the Souris Section. Average and median values for quantity and quality of return flows are interchangeable in this study.

References to TDS made in this report refer to a TDS defined as follows: filterable solids capable of passing through a standard glass fiber filter and dried to constant weight at 180° C., expressed in mg/l.

The following four sections discuss the four major types of alternatives studied and the plan or plans under each. The fifth section discusses briefly other alternatives which were considered but not investigated in any detail.

Alternative A - Reuse

This alternative consists of six plans for using collectable return flows in North Dakota. Collectable return flows are flows which can be collected by subsurface pipe drains located in the irrigable areas of the Souris Section. The six plans are similar in scope. The main differences in the plans are (1) whether a portion of the collected return flows is reused in the Souris Section and (2) which areas in the State would receive the collected water.

Total volume of return flows resulting from irrigation of 116,000 acres (full development) in the Souris Section, municipal and industrial requirements, and fish and wildlife development will be about 91,600 acre-feet annually, with a TDS concentration of 870 mg/l. These median annual return flows consist of irrigation return flows (42,700 acre-feet), canal and lateral seepage (17,400 acre-feet), project operational wastes (6,200 acre-feet), fish and wildlife development area seepage (9,800 acre-feet) and municipal and industrial water effluent (15,500 acre-feet).

The objective of this alternative is to reduce the quantity and improve the quality of return flows entering the Souris River by collecting the flows that accrue in the subsurface drains in the Souris Section and reusing this water in North Dakota. The Souris Section would be developed as presently planned, with the addition of a system to collect the return flows. Approximately 52 percent (47,400 acre-feet) of the total average annual return flows are collectable through the subsurface drains and are considered to be the "collectable return flows." Return flows not collected by subsurface drains are project operational wastes, canal and lateral seepage, fish and wildlife development area seepage, and municipal and industrial water effluent which will accrue to the Souris River through subsurface and surface drainage.

With this alternative, an average of 44,200 acre-feet of uncollectable project operational wastes, canal seepage, M&I effluent, and fish and wildlife seepage at a TDS concentration of 700 mg/l would enter the Souris River annually. Most of these flows would enter the river during

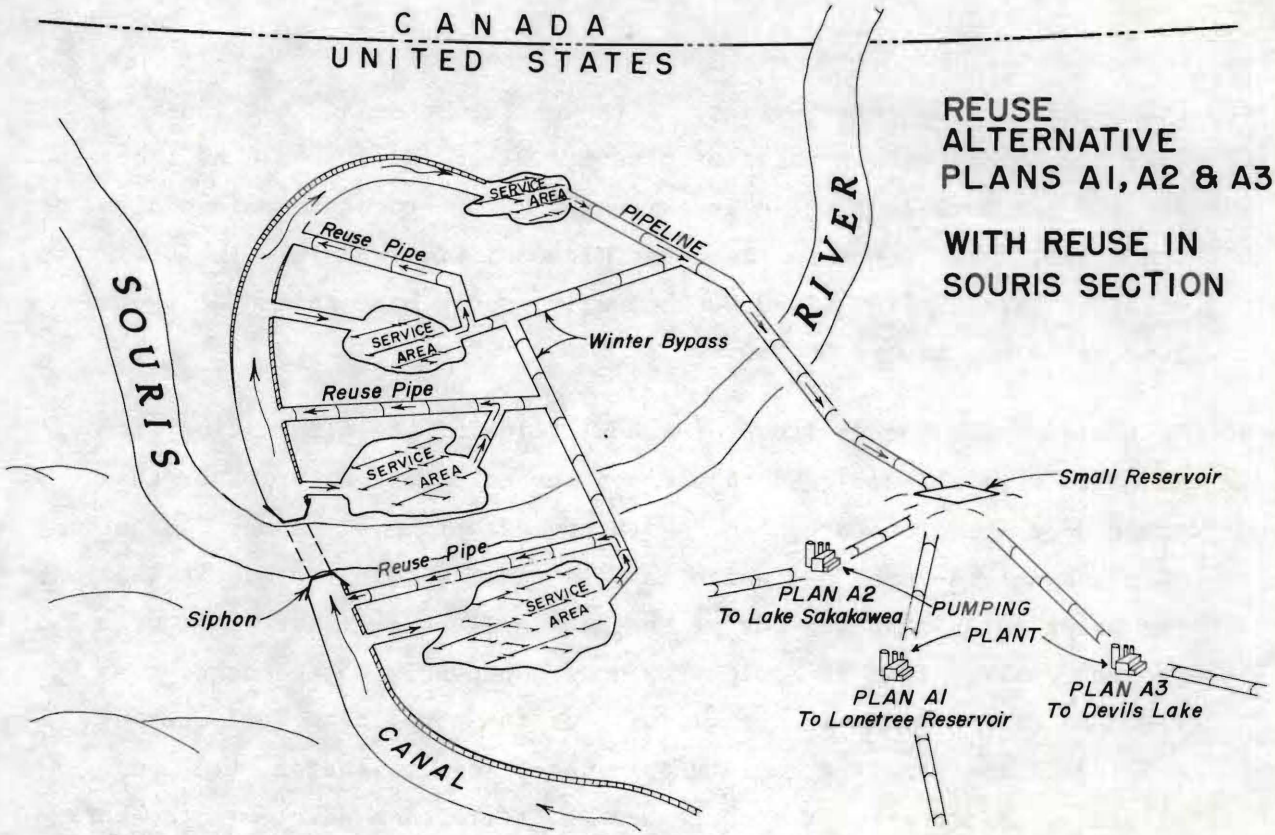
the irrigation period. Fish and wildlife seepage accounts for most of the return flows (4,900 acre-feet) entering the river during the non-irrigation period. The collectable return flows--47,400 acre-feet annually at a TDS concentration of 1,020 mg/l--would be reused in North Dakota.

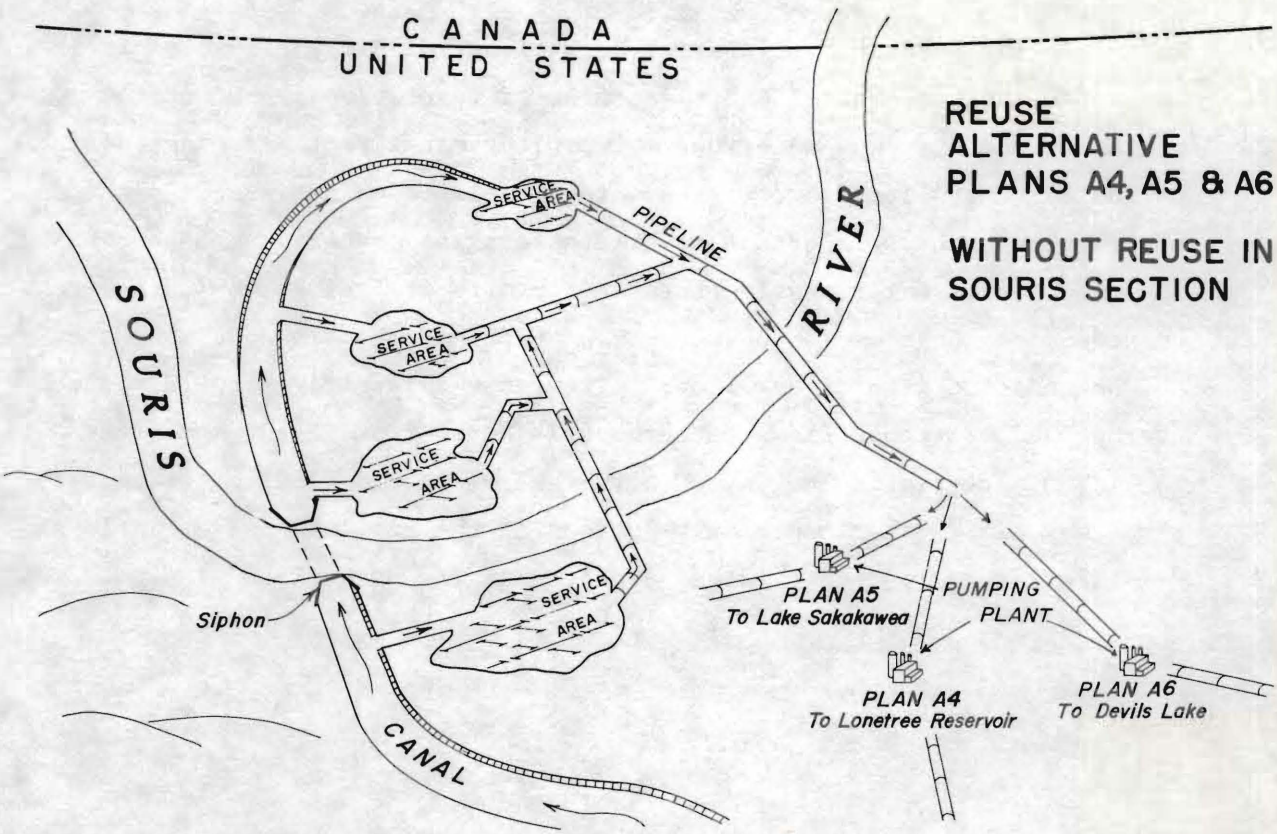
As illustrated in Figure 1, the reuse alternative includes two basic approaches in reusing the collected water in North Dakota. One approach used in plans A-1, A-2 and A-3 is to reuse a portion of the collectable return flows for irrigation water on the Souris Section and convey the remaining water to Lonetree Reservoir, Lake Sakakawea or Devils Lake, respectively. The other approach, used in plans A-4, A-5 and A-6, is to convey all collectable return flows directly to Lonetree Reservoir, Lake Sakakawea or Devils Lake, respectively.

All pipelines associated with this alternative would be pressure pipe ranging in size from 18 to 84 inches in diameter. Pipeline routing would generally parallel section-lines and when possible would be installed on canal right-of-way.

The pipe would be buried at sufficient depths to prevent freezing. Pumping stations would be installed on pipeline routes, and water would be conveyed by pressure or gravity. Pipe collection and conveyance systems for this alternative are sized to handle the predicted maximum return flows that will accrue to the subsurface drains. Open canals were not considered for conveyance systems because of freezing problems which would be encountered during winter operation as a result of the relatively small water quantities involved and because of the environmental problems associated with open canals.

Each of the six plans of this alternative reduces the total water requirements from the Missouri River of the authorized unit and the savings is reflected in the annual operation, maintenance and replacement costs. These plans would increase the water use efficiency and conserve about 47,000 acre-feet of water annually at full development. For the purposes of this study, a value of $20 per acre-feet was used to determine


CANADA
UNITED STATES
REUSE ALTERNATIVE PLANS A1, A2 & A3
WITH REUSE IN SOURIS SECTION
SOURIS
RIVER
SERVICE AREA
PIPELINE
Reuse Pipe
Winter Bypass
Small Reservoir
Siphon
CANAL
PLAN A2
To Lake Sakakawea
PUMPING PLANT
PLAN A1
To Lonetree Reservoir
PLAN A3
To Devils Lake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UNITED STATES
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SOURIS
RIVER
SERVICE AREA
PIPELINE
Siphon
CANAL
PLAN A5
To Lake Sakakawea
PUMPING PLANT
PLAN A4
To Lonetree Reservoir
PLAN A6
To Devils Lake

Figure 1

the benefits from this savings. Although future demand may indicate that the per acre-foot value of Missouri River water should be increased, the $20 per acre-foot value is currently being quoted to potential industrial water users in the upper Missouri River Basin. The ultimate value of this benefit ($940,000 annually) would have an annual equivalent value of about $700,000.

In the economic and environmental evaluation of the alternative plans, benefits were not assigned to uses of the collected water other than those described for each plan. With the exception of summer operation of plans A-1, A-2 and A-3 which involve reuse within the Souris Section, the water being conveyed out of the Souris River drainage basin will be of such quality that it could provide a dependable water source for resource developments in the vicinity of the pipeline. Turnouts installed in the pipeline could supply water for irrigation, fish and wildlife enhancement, stream freshening, recreation developments, rural water systems, stockwater ponds, and municipal and industrial water supplies.

Water passing through J. Clark Salyer National Wildlife Refuge pools is regulated for the control and management of vegetation important to migratory and breeding waterfowl. The water management plan includes periodic, controlled drawdowns of water levels to maintain soil-plant water relationships important to desirable plant species. Changes in the quantity of water passing into and through the refuge would require corresponding changes in the management plan and the drawdown schedule may be modified with higher flows. The reuse alternatives would reduce average annual return flows to the Souris River from 91,600 acre-feet to 44,200 acre-feet. The 44,200 acre-feet of return flows entering the river may limit water management options at the J. Clark Salyer National Wildlife Refuge, but to a lesser degree than the authorized plan.

Wetlands located on lands within the pipeline easement would be temporarily altered during construction. Construction of pipelines through natural wetlands could be accomplished with a loss of only one production season per wetland. This loss would specifically affect waterfowl, other shorebirds, mammals such as muskrats and mink, and amphibians which rely on wetland habitat for food and cover.

To assure that only a temporary effect is associated with installation of the pipeline, the following construction procedures would be used:

1. Restoration of the original wetland basin contour.
2. Sufficient compaction of backfill to prevent settling and unnatural seepage caused by breaking the natural basin seal, and to assure resealing.
3. Disposal of excess soil away from wetlands so as to prevent partial filling.
4. Conservation and replacement of topsoil.
5. Reseeding native grasses on all grasslands disturbed by construction.
6. Completion of construction and restoration in a specific wetland during a single season.

Upland game and upland habitat would be adversely affected within the 100-foot pipeline construction easement on grasslands, shrubs and woodlands. Effects on cultivated lands and grassland would be temporary as topsoil conservation and replacement and reseeding to existing vegetation on grasslands would be required.

Disturbance of cultivated lands by pipeline construction would have an adverse effect on openland wildlife. Loss of nesting, resting and escape habitat would occur to ground-nesting upland birds and waterfowl and to small mammals.

Grassland, pastureland and hayland within the pipeline construction easement would be disturbed during construction, with an adverse effect

on upland wildlife. Native grasslands would be reestablished by replacement of topsoil and reseeding with native species. Pasture and haylands would be reseeded with the locally adapted grasses presently existing on individual fields.

Trees and shrubs would be removed within the pipeline construction easement, with subsequent adverse effects on deer, small mammals, and upland game birds and non-game birds. Windbreaks of trees and shrubs would be established on project works to offset this loss.

Under the present plan, flows to the Souris River would provide conditions suitable for year-around survival of game fish in water presently devoid of dissolved oxygen during certain periods of the year. These conditions are also suitable for the survival of rough fish, i.e. carp, if such species were introduced in areas where they are not presently established. The reuse alternatives, however, would result in return flows to the river during the non-irrigation season of approximately 4,900 acre-feet, and the river would continue to have reaches with dissolved oxygen concentrations insufficient to support fish in the winter months.

Under these alternatives, water would be available for beneficial use at State and Federal wildlife areas. Turnouts could be installed to provide supplemental water for wetland recharge during low precipitation periods. Turnouts could be located at the request of and managed by the U.S. Fish and Wildlife Service or the North Dakota Game and Fish Department for use on wildlife areas.

Following is a summary of environmental effects for Alternative A:

Alternative A - Summary of Environmental Effects

Impact	Alternative Plan A-1	A-2	A-3	A-4	A-5	A-6
Beneficial						
A potential reduction in return flows to refuge	Yes	Yes	Yes	Yes	Yes	Yes
Potential reduction in rough fish survival in Souris River	Yes	Yes	Yes	Yes	Yes	Yes
Option - Turnouts to wetlands	Yes	Yes	Yes	Yes	Yes	Yes
Adverse						
Miles of pipeline through wildlife wetland habitat	92	110	125	77	95	110
Potential reduction of fishery in Souris River	Yes	Yes	Yes	Yes	Yes	Yes
TDS increase in Lonetree Reservoir over authorized	11%	--	--	18%	--	--
TDS increase in Lake Sakakawea over authorized	--	negligible	--	--	negligible	--
TDS increase in Devils Lake over authorized	--	--	20%	--	--	40%
Total average annual flows to Souris River	44,200	44,200	44,200	44,200	44,200	44,200

Cost estimates for the reuse alternatives are based on January 1975 prices and were added to the total Garrison Diversion Unit costs to reflect the total cost of the unit including the alternatives. Modifications of the authorized plan to implement these alternatives would have no impacts on potential economic benefits of the authorized plan. The additional expenditures for this alternative reduce the benefit-cost relationship; however, comparison of total project benefits to costs with inclusion of the various plans under this alternative still indicate economic justification. Benefit-cost ratios vary from 2.31:1 to 2.45:1 as compared to 2.91:1 for the authorized plan.

The reuse alternatives would benefit farms and rural communities near the pipeline route because better quality water would be available for household and municipal use than presently is being utilized. Water would also be available in varying quantities for the freshening of stockwater ponds, fisheries, recreation areas, and streams. However, a decrease in return flows in the Souris River would result in fewer potential benefits to the area along the river in North Dakota and Canada. These social impacts are not included in the economic analysis because basic data were not available to make a quantitative assessment. The social well-being of the State of North Dakota and downstream Missouri

basin states would be enhanced by the 47,000 acre-feet of water which would be available in the Missouri River Basin for other uses.

Following are discussions of each of the six plans under Alternative A and then a general discussion of the alternative.

Plan A-1

Description of the Plan.--This plan consists of collecting the return flows which accrue to the subsurface drains, reusing a portion of this collected water for irrigation in the Souris Section, and diverting the remaining collected water to Lonetree Reservoir.

The irrigated lands in the Souris Section would be divided into six block areas and the subsurface drains from these areas would be interconnected by a buried pipe network. Figures 2 and 3 show a schematic arrangement of block areas and pipe collection system. During the irrigation season, return flows from each of the first five block areas would be returned to either the Velva Canal or Mouse Canal. This water would be mixed in the canal with water being delivered from Lonetree Reservoir and would be reused as irrigation water. The return flows from the last area would be collected in a small 150-acre-foot man-made reservoir and then diverted to Lonetree Reservoir. During the non-irrigation season, the subsurface drains from all six areas would drain directly into the 150-acre-foot reservoir and be diverted to Lonetree Reservoir. The following tabulation shows quality and quantity of collected return flows being returned to Lonetree Reservoir and the Velva and Mouse Canals.

ALTERNATIVE PLAN A-1

Use of Collected Return Flows 1/

Recipient	Irrigation Season			Non-Irrigation Season			Annually		
	%	(acre-feet)	(mg/l)	%	(acre-feet)	(mg/l)	%	(acre-feet)	(mg/l)
Lonetree Reservoir	7	1,800	1,620	100	19,500	1,170	45	21,300	1,210
Mouse and Velva Canals	93	26,100	1,060	--	--	--	55	26,100	1,060
TOTAL	100	27,900	1,100	100	19,500	1,170	100	47,400	1,130

1/ Quality of return flows in TDS.

REUSE OF
COLLECTABLE RETURN FLOWS
IN
SOURIS SECTION

Irrigation Period
(April 15 – Oct 15)

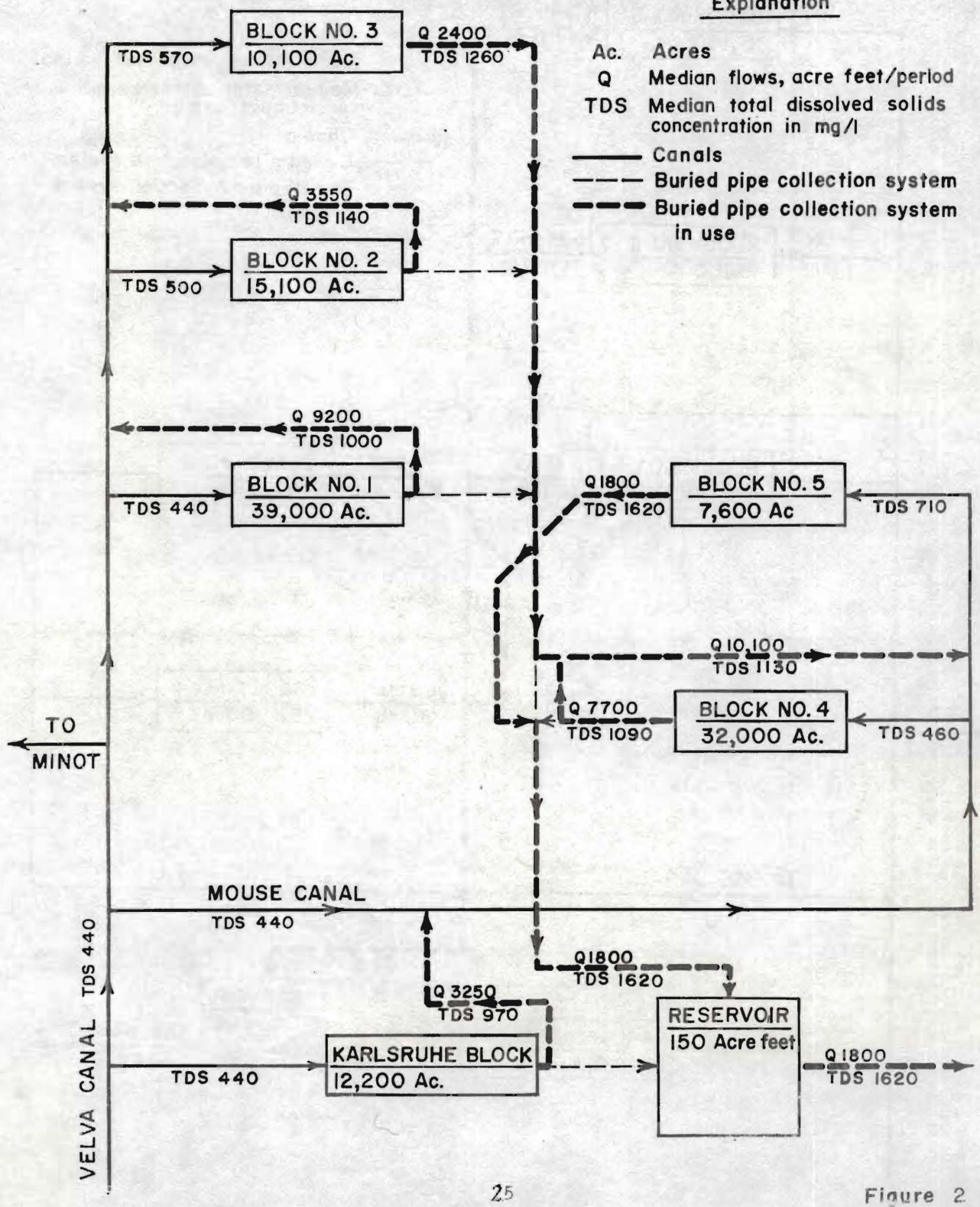

Figure 2

REUSE OF
COLLECTABLE RETURN FLOWS
IN
SOURIS SECTION

Non-Irrigation Period
(Oct 15 — April 15)

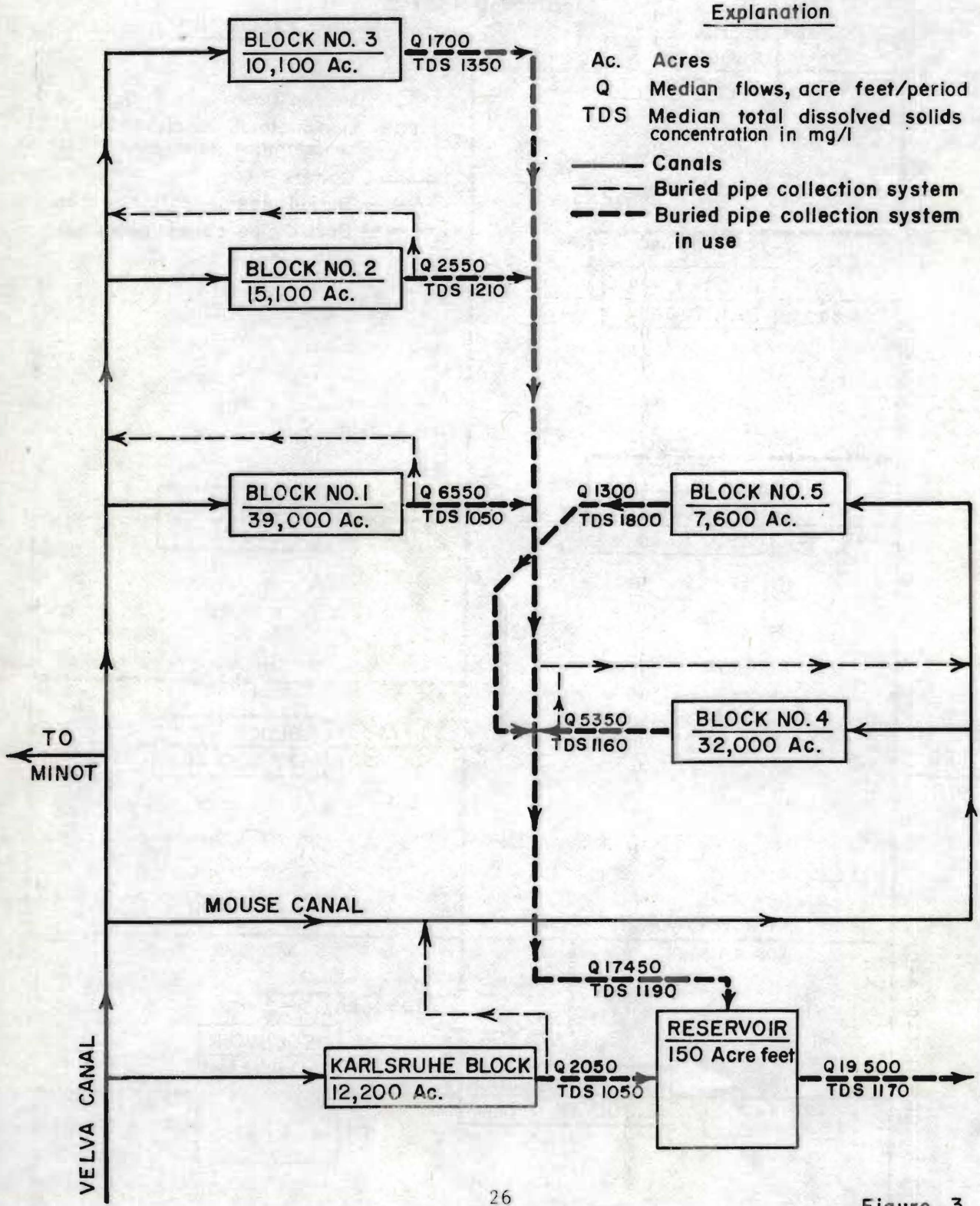

Figure 3

The quality of water being supplied to the irrigation block areas, as shown in Figure 2, would vary from unblended water at a TDS concentration of 440 mg/l to a blended mixutre of canal water and return flow water at a maximum TDS concentration of 710 mg/l being delivered to the last block. Although the quality of application water would vary between the block areas, it is well below the maximum TDS levels recommended for irrigation application water for the type of crops that will be irrigated.

Following is a tabulation of salinity tolerances and some of the different types of respective crop plants anticipated to be irrigated in the Souris Section:

Crop Plant	Salinity Tolerance TDS (constituents) - mg/l [1/]
Corn	1,100
Sugar Beets	4,200
Barley Hay	3,400
Alfalfa	1,200
Wheat	2,900
Oats	2,500
Rye	3,000

The above salinity tolerances represent the points at which a 10 percent yield reduction would occur.

To interconnect the six bock areas and deliver water to the 150-acre-foot reservoir, a pipe collection system approximately 130 miles in length would be installed. Pipeline diameters for the collection system vary from 12 to 60 inches. Nine pumping stations ranging in capacity from 15 to 65 cubic feet per second (ft^3/s) at pumping heads varying from 68 to 147 feet would be installed on the pipeline. The pipeline to convey water from the 150-acre-foot reservoir to Lonetree Reservoir would be about 37 miles long, range in diameter from 45 to 69 inches, and would require three pumping stations with a maximum capacity of 73 ft^3/s at pumping heads ranging from 92 to 111 feet.

1/ Joint Administrative Committee of the Santa Margarita and San Luis Rey Watershed Planning Agencies, Comprehensive Water Quality Management Study, December 1973, Volume I. TDS (constituents) is the sum of the ionic constituents in an analyzed water sample.

The first 17 miles of this pipeline would generally parallel section-lines until it intersects the Velva Canal near Bergen, North Dakota. From Bergen, the pipeline would be installed on Velva Canal right-of-way until it reaches Lonetree Reservoir.

Receiving Waters.--Receiving waters with this plan are the Souris River and Lonetree Reservoir. Return flows entering the Souris River as a result of irrigation in the Souris Section would be reduced by 52 percent, from 91,600 to 44,200 acre-feet with this alternative. Irrigation and lateral seepage return flows which accrue to the subsurface drains would be collected and would not enter the river. Canal seepage and operational wastes are not collectable by the subsurface drains and would accrue to the Souris River. In addition to return flows associated with irrigation development, Garrison Diversion Unit will also introduce Missouri River water into the Souris River through municipal and industrial water use and fish and wildlife developments. The following tabulation shows the median flows which would enter the river with the domestic use alternative and the resultant effects these additional flows would have on water quality (TDS) in the river:

ALTERNATIVE A - REUSE [1]

RETURN FLOWS AND EFFECTS ON SOURIS RIVER

Item	Flows					
	Irrigation Season (Apr. 15 - Oct. 15)		Non-Irrigation Season (Oct. 15 - Apr. 15)		Annual Median [3]	
	Quantity (ac. ft.)	Quality TDS (mg/l)	Quantity (ac. ft.)	Quality TDS (mg/l)	Quantity (ac. ft.)	Quality TDS (mg/l)
Return Flows						
Canal Seepage	12,700	1,000	- negligible -		12,700	1,000
Operational Wastes	6,200	440	-0-	-	6,200	440
M&I Effluent	15,500	440	-0-	-	15,500	440
F&WL Area Seepage	4,900	880	4,900	880	9,800	880
Total	39,300	680	4,900	880	44,200	700
Souris River Flows						
Existing Flows [2]	67,400	510	20,000	630	107,700	540
Existing Flows with Authorized Souris Section Return Flows	134,600	670	44,200	800	199,300	690
Existing Flows with Reuse Alternative	106,700	580	24,900	660	151,900	590

1/ Data presented in this table is applicable for all six reuse plans.
2/ Based on a 21-year period from 1953 to 1974, median values at Westhope.
3/ Quantity values shown are median values and do not necessarily equal the summation of irrigation and non-irrigation median flows.

Collected return flows that are diverted to Lonetree Reservoir would be mixed with water supplied from the McClusky Canal and reused in North Dakota. With full development of the Garrison Diversion Unit, an average of 570,000 acre-feet annually would flow through Lonetree Reservoir. Collected annual return flows diverted to Lonetree Reservoir would average 21,300 acre-feet at 1,210 mg/l TDS and would increase the irrigation period TDS concentration in Lonetree Reservoir from 440 to 500 mg/l over a period of about 10 years. Equilibrium would be achieved at 520 mg/l at end of non-irrigation period and at 480 mg/l at end of irrigation period. This increase is insignificant and would have no measurable effect on consumptive use of the water. However, while consumptive use may not be significantly affected, some requirement for leaching might occur, especially during the early years of development.

Environmental Effects.--Environmental impacts for this plan include the effects of 92 miles of pipeline constructed through valuable wetland and upland wildlife habitat. Average concentrations of natural wetlands in these areas range from approximately 60 acres to more than 100 acres per section. Prime upland wildlife habitat ranges from approximately 13 to 35 percent of the affected area. The anticipated fishery in the Souris River may not materialize because of the reduction of return flows.

No additional major adverse effects are anticipated by the 21 miles of pipeline construction on the Velva Canal rights-of-way or construction of the holding reservoir and pumping plants. The return flows of 21,300 acre-feet annually being diverted to Lonetree Reservoir would eventually increase the average TDS in the reservoir from an estimated 440 mg/l to 500 mg/l, but this is not considered detrimental to the fishery.

Economics.--The economic analysis of the authorized Garrison Diversion Unit including this reuse alternative indicates that the total project cost would be $603 million and the benefit-cost ratio would be 2.45 to 1 as shown in the following tabulation:

Economic Analysis - Plan A-1
(in $Thousands)

Item	Authorized Unit	Alternative (Plan A-1)	Total (Authorized Plan with Plan A-1)
Construction Cost	507,200	95,971	603,171
Annual Equivalent Cost 1/	18,563	3,420 (6,030)	21,983 (24,593)
Annual OM&R	1,852	690	2,542
Annual Benefits	59,496	700 2/ (540) 2/	60,196 (60,036)
Benefit-Cost Ratio	2.91	0.17 (0.08)	2.45 (2.21)
Net Benefits	39,081	--	35,671 (32,901)

1/ Based on cost plus interest during construction.

2/ Direct benefits only - there are no secondary benefits.

Note: Parentheses enclose values which reflect a 6-1/8 percent discount rate used in analysis of alternative. Other figures reflect a 3-1/8 percent discount rate.

Economic benefits realized from this plan would be removal of less water from Lake Sakakawea resulting from reuse of Souris Section irrigation and lateral seepage return flows. The 47,400 acre-feet of water conserved annually in Lake Sakakawea would be available for other water resource developments in the Missouri River Basin.

Plan A-2

Description of the Plan.--This plan consists of collecting the return flows which accrue to the subsurface drains, reusing a portion of the collected water for irrigation in the Souris Section and diverting the remaining collected water to Lake Sakakawea.

This plan is similar to plan A-1 except that in lieu of conveying remaining flows from the 150-acre-foot reservoir to Lonetree Reservoir, these flows would be conveyed to Lake Sakakawea.

The pipeline to convey the flows from the 150-acre-foot reservoir to Lake Sakakawea would be about 56 miles long and range in diameter from 54 to 69 inches. Six pumping stations would be required on this pipeline, with a maximum capacity of 73 ft^3/s at pumping heads ranging from 47 to 164 feet.

The first 17 miles of this pipeline would generally parallel section-lines until it intersects the Velva Canal near Bergen, North Dakota. From Bergen, the pipeline would be installed cross-country to Lake Sakakawea.

Receiving Waters.--Receiving waters with this plan are the Souris River and Lake Sakakawea. Effects on the Souris River are identical to those discussed in plan A-1. Return flows diverted to Lake Sakakawea would average 21,300 acre-feet annually at 1,210 mg/1 TDS. These return flows would have no measurable effect on the water quality in Lake Sakakawea.

Environmental Effects.--Environmental impacts of this plan include the effects of 110 miles of pipeline constructed through valuable wetland and upland wildlife habitat. Average concentrations of natural wetlands in these areas range from approximately 60 acres to more than 100 acres per section. Prime upland wildlife habitat ranges from approximately 13 to 35 percent of the affected area. The anticipated fishery in the Souris River may not materialize because of the reduction of return flows.

No additional major adverse effects are anticipated by construction of the holding reservoir and pumping plants. The return flows diverted to Lake Sakakawea would have no appreciable effect on the average TDS concentration in Lake Sakakawea.

Economics.--The cost of this plan would increase the overall project cost to $618 million. The benefit-cost ratio for Garrison Diversion Unit would decrease to 2.38 to 1 as shown in the following tabulation:

Economic Analysis - Plan A-2
(in $Thousands)

Item	Authorized Unit	Alternative (Plan A-2)	Total (Authorized Plan with Plan A-2)
Construction Cost	507,200	110,582	617,782
Annual Equivalent Cost 1/	18,563	4,006 (7,058)	22,569 (25,621)
Annual OM&R	1,852	847	2,699
Annual Benefits	59,496	700 2/ (540) 2/	60,196 (60,036)
Benefit-Cost Ratio	2.91	0.14 (0.07)	2.38 (2.12)
Net Benefits	39,081	--	34,928 (31,716)

1/ Based on cost plus interest during construction.

2/ Direct benefits only - there are no secondary benefits.

Note: Parentheses enclose values which reflect a 6-1/8 percent discount rate used in analysis of alternative. Other figures reflect a 3-1/8 percent discount rate.

Economic benefits realized from this plan are the same as plan A-1. Reuse of 26,100 acre-feet in the Souris Section during the irrigation season and returning 21,300 acre-feet annually to Lake Sakakawea would result in 47,400 more acre-feet annually in Lake Sakakawea that would be available for other water resource developments in the Missouri River Basin.

Plan A-3

Description of the Plan.--This plan consists of collecting the return flows which accrue to the subsurface drains, reusing a portion of these flows in the Souris Section and diverting remaining collected water to the Devils Lake Chain.

This plan is also similar to plan A-1 except that in lieu of conveying remaining flows from the 150-acre-foot reservoir to Lonetree Reservoir, these flows would be conveyed to the Devils Lake Chain. The water would enter the west end of the chain near the community of Minnewaukan and would be used to freshen the Devils Lake Chain.

The pipeline to convey the flows from the 150-acre-foot reservoir to the west end of the Devils Lake Chain would be about 70 miles long and would range in diameter from 39 to 84 inches. Four pumping stations would be required on this pipeline with a maximum capacity of 73 ft^3/s at pumping heads ranging from 48 to 141 feet.

Receiving Waters.--Receiving waters with this plan are the Souris River and Devils Lake chain lakes. Effects of return flows entering the Souris River with this plan are identical to those discussed in plan A-1. Return flows conveyed to Devils Lake would be used for freshening the chain. The Devils Lake chain lakes are located in a closed drainage basin and there are several methods that could be employed to freshen these lakes. The Devils Lake Chain consists of five lakes, namely: Devils Lake, East Bay Devils Lake, East Devils Lake, West Stump Lake and East Stump Lake.

The Bureau of Reclamation has conducted studies for freshening the Devils Lake chain lakes and has described these studies in a 1975 preliminary information report, Water Quality Studies - Devils Lake Chain Lakes. The Devils Lake study considered delivery of Garrison Diversion Unit water to Devils Lake via a Devils Lake Feeder Canal and investigated different methods of freshening the pools in the chain. A basic plan was developed for the study which called for maintaining the five lakes at various elevations in addition to development of four fish and wildlife pools located west of Devils Lake. In addition to the basic plan, the study investigated 10 other plans which called for varying levels of development and freshening of the lakes and fish and wildlife pools. Each one of the plans involved using one or two of the lakes for a final evaporation pool because the lakes are located in a closed drainage basin.

For plan A-3, return flows collected from the Souris Section would be used in conjunction with water from the Devils Lake Feeder Canal for freshening the lakes. Only one freshening plan, the basic plan as described in the 1975 information report, was investigated for this alternative. Water from the Devils Lake Feeder Canal would be discharged into Devils Lake and supplemented by return flows--21,300 acre-feet

annually at 1,210 mg/l TDS. The following tabulation shows TDS levels in the Devils Lake chain lakes after freshening, both with and without return flows:

FINAL LAKE CONTENTS AND TDS CONCENTRATIONS [1/]

Lake	Historic 1956-70 TDS (mg/l)	Basic Plan Content (ac. ft.)	Basic Plan TDS (mg/l)	With Return Flows (Plan A-3) Content (ac. ft.)	With Return Flows (Plan A-3) TDS (mg/l)
F&WL Development Areas	2/	82,600	2/	82,600	2/
Devils Lake	8,360	313,000	1,300	313,000	1,550
East Bay Devils Lake	8,330	136,000	2,730	136,000	3,260
East Devils Lake	51,370	80,000	4,080	80,000	4,880
West Stump Lake	6,820	85,000	9,580	85,000	11,440
East Stump Lake	98,790	116,000	62,660	116,000	69,140

1/ Inflow consists of return flows, natural inflow and Devils Lake Feeder Canal releases.
2/ TDS concentrations were not calculated for these areas.

The basic freshening plan as described in the 1975 information report calls for water to be pumped from Devils Lake to the headwaters of the fish and wildlife areas near Minnewauken. Implementation of plan A-3 would eliminate this pumping requirement as return flows would be released in this area. However, a pipeline would probably still be required to bypass surplus return flows directly to Devils Lake.

Environmental Effects.--Environmental impacts for this plan include the effects of 125 miles of pipeline constructed through valuable wetland and upland wildlife habitat. Average concentrations of natural wetlands in these areas range from approximately 60 acres to more than 100 acres per section. Prime upland wildlife habitat ranges from approximately 5 to 35 percent of the affected area. The anticipated fishery in the Souris may not materialize because of the reduction in return flows.

The return flows would increase the average TDS level in the Devils Lake Chain in comparison to the basic plan as outlined in the preceding tabulation.

Information received from the U.S. Fish and Wildlife Service and the North Dakota Game and Fish Department indicates that fish considered for Devils Lake would be northern pike, walleye, white bass and yellow perch. These fish can survive in water containing TDS (constituents) concentrations of 3,500 to 4,000 mg/l. Reproduction would be impossible at these high concentrations; however, fish do run up the freshwater tributaries of the lake (Big Coulee, Mauvais Coulee, etc.) to spawn. Introduction of return flows into these freshwater tributaries may eliminate present natural spawning areas.

The maximum range of TDS (constituents) concentration that can be tolerated for spawning is shown below:

Type of Fish	TDS (constituents) - mg/l [1/]
Northern pike	900 - 1,100
Walleye	800 - 1,000
Perch	800 - 1,000
White bass	Not Available

Thus fish could survive in Devils Lake and East Bay Devils Lake under either the basic plan or plan A-3. However, fish could not spawn under either plan.

Economics.--The total cost of the Garrison Diversion Unit would increase to $633 million with inclusion of this plan. As shown in the following tabulation, the cost-benefit ratio would decrease to 2.35 to 1.

1/ TDS (constituents) is the sum of the ionic constituents in an analyzed water sample.

Economic Analysis - Plan A-3
(in $Thousands)

Item	Authorized Unit	Alternative (Plan A-3)	Total (Authorized Plan with Plan A-3)
Construction Costs	507,200	125,434	632,634
Annual Equivalent Cost 1/	18,563	4,433 (7,819)	22,966 (26,382)
Annual OM&R	1,852	811	2,663
Annual Benefits	59,496	700 2/ (540) 2/	60,196 (20,036)
Benefit-Cost Ratio	2.91	0.13 (0.06)	2.35 (2.07)
Net Benefits	39,081	--	34,567 (30,991)

1/ Based on cost plus interest during construction.

2/ Direct benefits only - there are no secondary benefits.

Note: Parentheses enclose values which reflect a 6-1/8 percent discount rate used in analysis of alternative. Other figures reflect a 3-1/8 percent discount rate.

Economic benefits realized from this plan are identical to those identified for plan A-1. The water being diverted out of the Souris River drainage basin would be used for freshening the Devils Lake Chain in lieu of being introduced into Lonetree Reservoir.

Plan A-4

Description of the Plan.--This plan consists of collecting return flows which accrue to the subsurface drains and diverting these flows to Lonetree Reservoir.

The subsurface drains in the Souris Section would be connected by a closed pipe system and the flows from the drains would be conveyed directly to Lonetree Reservoir. This plan would not require holding or storage reservoirs. The collection system associated with this plan would consist of 103 miles of pipe ranging in diameter from 12 to 75 inches and six pumping stations having capacities varying from 9 to 120 ft^3/s at pumping heads varying from 68 to 147 feet. The conveyance

system would consist of 37 miles of pipeline ranging in diameter from 60 to 84 inches. Three pumping stations would be installed on the conveyance pipeline, with maximum pumping capacities of 135 ft^3/s at pumping heads varying from 91 to 110 feet. Pipeline routing for the conveyance system would be the same as plan A-1.

A total of 47,400 acre-feet annually with an average TDS concentration of 1,020 mg/l would be diverted to Lonetree Reservoir with this plan. Return flows collected during the irrigation period would be 27,900 acre-feet at a TDS concentration of 1,000 mg/l. Flows during the non-irrigation period would be 19,500 acre-feet (41 percent of the annual collectable return flows) and would have a TDS concentration of 1,050 mg/l.

Receiving Waters.--Receiving waters with this plan are the Souris River and Lonetree Reservoir. Effects on the Souris River are identical to those discussed in plan A-1. Collected return flows that are diverted to Lonetree Reservoir would be mixed with water supplied from the McClusky Canal and reused in North Dakota. With full development of the Garrison Diversion Unit, an average of 570,000 acre-feet annually would flow through Lonetree Reservoir. Collected annual return flows diverted to Lonetree Reservoir would average 47,400 acre-feet at 1,020 mg/l TDS and would increase the average irrigation period TDS concentration in Lonetree Reservoir from 440 to 540 mg/l over a period of about 12 years. Equilibrium would be achieved at 580 mg/l at end of non-irrigation period and 500 mg/l at end of irrigation period. This increase is insignificant and would have no measurable effect on consumptive use of the water. However, while consumptive use may not be significantly affected, some requirement for leaching might occur, especially during the early years of development.

Environmental Effects.--Environmental impacts for this plan include the effects of 77 miles of pipeline constructed through valuable wetland and upland wildlife habitat. Average concentrations of natural wetlands in these areas range from approximately 60 acres to more than 100 acres per section. Prime upland wildlife habitat ranges from approximately 13 to

35 percent of the affected area. The anticipated fishery in the Souris may not materialize because of the reduction of return flows.

Additional adverse effects are not anticipated by the 21 miles of pipeline construction on the Velva Canal rights-of-way. The return flows of 47,400 acre-feet annually being diverted to Lonetree Reservour would eventually increase the average TDS level in the reservoir from 440 to 540 mg/l, but this is not considered detrimental to the fishery.

Economics.--The cost of this plan would increase the overall project cost to $609 million. The benefit-cost ratio for Garrison Diversion Unit would decrease to 2.43 to 1 as shown in the following tabulation:

Economic Analysis - Plan A-4
(in $Thousands)

Item	Authorized Unit	Alternative (Plan A-4)	Total (Authorized Plan with Plan A-4)
Construction Cost	507,200	101,727	608,927
Annual Equivalent Cost [1/]	18,563	3,680 (6,483)	22,243 (25,046)
Annual OM&R	1,852	707	2,559
Annual Benefits	59,496	700 [2/] (540) [2/]	60,196 (60,036)
Benefit-Cost Ratio	2.91	0.10 (0.08)	2.43 (2.17)
Net Benefits	39,081	--	35,394 (32,431)

1/ Based on cost plus interest during construction.

2/ Direct benefits only - there are no secondary benefits.

Note: Parentheses enclose values which reflect a 6-1/8 percent discount rate used in analysis of alternative. Other figures reflect a 3-1/8 percent discount rate.

The discount benefit realized from this plan is a reduction in water removed from Lake Sakakawea. The 47,400 acre-feet of water conserved annually in Lake Sakakawea would be available for other resource developments in North Dakota.

Plan A-5

Description of the Plan.--This plan consists of collecting the return flows which accrue to the subsurface drains and diverting these flows to Lake Sakakawea.

This plan is identical to plan A-4 except that in lieu of diverting the collected flows to Lonetree Reservoir, the water would be diverted to Lake Sakakawea. The conveyance system associated with this plan consists of 56 miles of pipe ranging in diameter from 57 to 84 inches. Six pumping stations with a maximum capacity of 135 ft^3/s, with pumping heads ranging from 40 to 150 feet, would be required to convey the water to Lake Sakakawea. Pipeline routing for the conveyance system would be the same as plan A-2.

Receiving Waters.--Receiving waters with this plan are the Souris River and Lake Sakakawea. Effects on the Souris River are identical to those discussed in plan A-1. Return flows diverted to Lake Sakakawea would average 47,400 acre-feet annually at a TDS concentration of 1,020 mg/l. These return flows would have no measurable effect on the water quality in Lake Sakakawea.

Environmental Effects.--Environmental impacts for this plan include the effects of 95 miles of pipeline constructed through valuable wetland and upland wildlife habitat. Average concentrations of natural wetlands in these areas range from approximately 60 acres to more than 100 acres per section. Prime upland wildlife habitat is approximately 13 to 35 percent of the affected area. The anticipated fishery in the Souris River may not materialize because of the reduction of return flows.

The return flows of 47,400 acre-feet would have no appreciable effect on the average TDS in Lake Sakakawea.

Economics.--The cost of this plan would increase the overall project cost to $632 million. The benefit-cost ratio for Garrison Diversion Unit would decrease to 2.32 to 1 as shown in the following tabulation:

Economic Analysis - Plan A-5
(in $Thousands)

Item	Authorized Unit	Alternative (Plan A-5)	Total (Authorized Plan with Plan A-5)
Construction Cost	507,200	124,775	631,975
Annual Equivalent Cost 1/	18,563	4,614 (8,120)	23,177 (26,683)
Annual OM&R	1,852	931	2,783
Annual Benefits	59,496	700 2/ (540) 2/	60,196 (60,036)
Benefit-Cost Ratio	2.91	0.13 (0.06)	2.32 (2.04)
Net Benefits	39,081	--	34,236 (30,570)

1/ Based on cost plus interest during construction.

2/ Direct benefits only - there are no secondary benefits.

Note: Parentheses enclose values which reflect a 6-1/8 percent discount rate used in analysis of alternative. Other figures reflect a 3-1/8 percent discount rate.

The economic benefits realized for this plan are identical to those described for plan A-4.

Plan A-6

Description of the Plan.--This plan consists of collecting the return flows which accrue to the subsurface drains and diverting these flows to the Devils Lake Chain.

This plan is also similar to plan A-4 except that in lieu of diverting the collected flows to Lonetree Reservoir, the water is diverted to the Devils Lake Chain. The conveyance system associated with this plan consists of 70 miles of pipe ranging in diameter from 48 to 78 inches. Four pumping stations with a maximum capacity of 135 ft^3/s and pumping heads ranging from 79 to 146 feet would be required to convey the water to the Devils Lake Chain. The pipeline routing for the conveyance system will be the same as plan A-3.

The water would enter the west end of the Devils Lake Chain near the community of Minnewaukan and would be used to freshen the chain. The effect of this plan on the Devils Lake Chain is similar to plan A-3 except that a larger volume of return flows would result in slightly higher TDS concentrations in the lakes.

Receiving Waters.--Receiving waters with this plan are the Souris River and Devils Lake chain lakes. Effects of return flows entering the Souris River with this plan are identical to those discussed in plan A-1. Return flows conveyed to Devils Lake with this plan would be used to freshen the Devils Lake chain lakes in conjunction with water being supplied from the Devils Lake Feeder Canal. The freshening concept used for this plan is similar to the one discussed for plan A-3 except that return flow volumes are larger.

Return flows (47,400 acre-feet at TDS concentrations of 1,020 mg/l) would be used in conjunction with water from Devils Lake Feeder Canal to freshen the lakes. The following tabulation shows the TDS levels in the Devils Lake chain lakes based on the basic plan as described in the 1975 preliminary information report, Water Quality Studies - Devils Lake Chain Lakes, after freshening with and without return flows.

FINAL LAKE CONTENTS AND TDS CONCENTRATIONS [1/]

Lake	Historic 1956-70 TDS (mg/l)	Basin Plan Content (ac. ft.)	Basin Plan TDS (mg/l)	With Return Flows (Plan A-6) Content (ac. ft.)	With Return Flows (Plan A-6) TDS (mg/l)
F&WL Development Areas	2/	82,600	2/	82,600	2/
Devils Lake	8,360	313,000	1,300	313,000	1,790
East Bay Devils Lake	8,330	136,000	2,730	136,000	3,765
East Devils Lake	51,370	80,000	4,080	80,000	5,640
West Stump Lake	6,820	85,000	9,580	85,000	13,205
East Stump Lake	98,790	116,000	62,660	116,000	75,295

1/ Inflow consists of return flows, natural inflow and Devils Lake Feeder Canal releases.
2/ TDS concentrations were not calculated for these areas.

The basic plan as described in the 1975 information report calls for water to be pumped from Devils Lake to the headwaters of the fish and wildlife areas near Minnewaukan. Implementation of plan A-6 would eliminate this pumping requirement as return flows would be released in this area; however, a pipeline would probably still be required to bypass surplus return flows directly to Devils Lake.

The possibility of eliminating the Devils Lake Feeder Canal with this plan was explored; however, it did not appear to be practicable. Without additional water from the feeder canal to supplement the return flows, adequate control of pool elevations cannot be achieved.

Environmental Effects.--Environmental impacts for this plan include the effects of 110 miles of pipeline construction through valuable wetland and upland wildlife habitat. Average concentrations of natural wetlands in these areas range from approximately 60 acres to more than 100 acres per section. Prime upland wildlife habitat ranges from approximately 5 to 35 percent of the affected area. The planned beneficial fishery in the Souris may not materialize because of the loss of anticipated return flows.

The return flows would increase the average TDS level in the Devils Lake Chain, in comparison to the basic plan, as outlined in the preceding table.

The effects on fish in the lake chain would be essentially the same as plan A-3.

Economics.--The cost of this plan would increase the overall project cost to $640 million. The benefit-cost ratio for Garrison Diversion Unit would decrease to 2.31 to 1 as shown in the following tabulation:

Economic Analysis - Plan A-6
(in $Thousands)

Item	Authorized Unit	Alternative (Plan A-6)	Total (Authorized Plan with Plan A-6)
Construction Cost	507,200	132,736	639,936
Annual Equivalent Cost 1/	18,563	4,772 (8,409)	23,335 (26,972)
Annual OM&R	1,852	853	2,705
Annual Benefits	59,496	700 2/ (540) 2/	60,196 (60,036)
Benefit-Cost Ratio	2.91	0.12 (0.06)	2.31 (2.02)
Net Benefits	39,081	--	34,156 (30,359)

1/ Based on cost plus interest during construction.

2/ Direct benefits only - there are no secondary benefits.

Note: Parentheses enclose values which reflect a 6-1/8 percent discount rate used in analysis of alternative. Other figures reflect a 3-1/8 percent discount rate.

Economic benefits realized from this plan are identical to those described for plan A-4. Additional benefits may be realized from this plan by reducing the capacity of the Devils Lake Feeder Canal. This benefit, however, was not quantified for this study.

Discussion

As shown in the reuse plans, the irrigation return flows collected from the subsurface drains are of good quality and are suitable for further resource development. Water is still plentiful in this region and as a result it is presently a rather inexpensive commodity. However, this condition could easily change as more demands are placed upon Missouri River water in North Dakota for both reuse (within North Dakota) and release for downstream consumption. In the foreseeable future, it may not only be economically feasible to collect and use these irrigation return flows in North Dakota, but it also could be socially desirable.

The six plans investigated in this alternative considered the most probable uses for collected water; however, further feasibility level studies would be able to firmly define prospective water uses. Further studies may identify uses for the collected water that would preclude the requirement to divert collected return flows to a receiving reservoir or lake.

One method that could be employed to encourage water use from the return flow conveyance pipeline would be to provide the capability of diverting Velva Canal water directly into the conveyance pipeline. Providing Velva Canal water in the pipeline would insure adequate supplies during the irrigation development period when irrigation return flows would be low and it could also supplement return flow volumes if necessary after irrigation development is completed.

All collection and conveyance systems in this alternative are designed to accommodate maximum peak flows. In those plans which involve reuse in the Souris Section, some economy is realized because reuse significantly reduces capacity requirements and costs of the return flow conveyance system. Another method that could be investigated to reduce collection and conveyance system costs would be to design the systems for something less than peak flows. System capacities and costs could be significantly reduced by releasing excess collected flows into the Souris River during August through October when maximum subsurface drain flows occur.

Plans A-2 and A-5 which divert the collected water to Lake Sakakawea appear to be the least viable of the reuse alternative plans. Diversion to Lake Sakakawea is not the most economical plan and it transfers water from an area that has inadequate supplies of good quality water to an area that has an abundant supply of good quality water.

Alternative plans for conveyance to Lonetree Reservoir are the most economical; however, possibilities for use of the water along the pipeline routing are limited. The plans for conveying water to Devils Lake

are the most expensive, but these plans also offer the most opportunities for water resource developments along the pipeline route.

If a reuse alternative was implemented, identification of prospective water users along the pipe route and assigned benefits from these uses would be instrumental in selection of the plan to be developed.

Any freshening plan employed for the Devils Lake Chain, with or without the use of return flows, may entail some rather unique land acquisition problems as ownership of the lands below the meander line or highwater mark of the west end of the Devils Lake Chain is questionable. Until recent years, pool levels were generally below the meander line and these lands were occupied by adjacent landowners. These occupants have claimed ownership and any freshening plan employed in the Devils Lake Chain may involve land ownership disputes regarding those lands lying below the meander line.

Alternative B - Dilution

This alternative consists of providing a turnout at the Velva Canal - Souris River siphon crossing and periodically releasing Velva Canal water into the Souris River.

There are essentially three ways that a dilution alternative could be operated. Dilution water could be regulated to maintain Souris River quantity or quality, or both quantity and quality. For this alternative, dilution water is regulated to maintain a given quality; that is, to maintain TDS at or below a given level.

Description of the Plan

The presently planned combination wasteway/turnout structure at the siphon crossing would be used to release Velva Canal water into the Souris River. Under the authorized plan the structure would serve as a wasteway and would also be used for canal dewatering. Water quality would be monitored at the Westhope gaging station and dilution water would be regulated to prevent TDS levels in the river from exceeding 1,000 mg/l. This alternative would require year-around operation of the Velva Canal because most of the dilution requirements occur during the winter months when river flows are low.

Dilution to 1,000 mg/l was selected since this value compares with the acceptable potable water quality standards established for the Souris River in North Dakota by the North Dakota State Health Department. Attempts to dilute to lower TDS levels would require large volumes of water. When Souris River TDS levels are in the 800 to 900 mg/l range, river flows are quite high and proportionately more dilution water would be required to affect water quality. Dilution to lower TDS levels may also tend to compound flooding and erosion problems.

Historic data (Westhope gaging station) for a 21-year study period from 1953 to 1974 indicate TDS levels in the Souris River ranged from a low of 163 mg/l in April 1969 to a high of 3,650 mg/l in February 1961. During the study period, TDS concentrations exceeded 1,000 mg/l during

48 months. Median TDS concentrations exceeding 1,000 mg/l usually occurred in December, January or February when river flows were extremely low. No-flow conditions occurred in 9 months of the 21-year study period.

Annual median return flows accruing to the Souris River after planned development (116,000 acres) would be about 91,600 acre-feet at a TDS concentration of approximately 870 mg/l. These flows would range from about 67,200 acre-feet at TDS concentrations of 810 mg/l during the irrigation period (April 15 - October 15) to 24,400 acre-feet at TDS concentration of 1,020 mg/l occurring during the non-irrigation season (October 15 - April 15). After development of the authorized Souris Section, TDS levels of composite flows (historic flow plus return flows) in the Souris River will generally increase during periods of high flows and decrease during periods of low flows as compared to historic TDS levels of flows in the river. See Figure 4 for comparison of median TDS values. Normally, Souris Section return flows will decrease TDS concentrations in the river during December, January and February and increase TDS concentrations during the other months. However, during extreme periods similar to historic low flows and high TDS levels, return flows would lower TDS concentrations in the river during five months of the year.

Dilution requirements for this alternative are based on a 21-year hydrologic cycle with the addition of Garrison Diversion Unit return flows over a 63-year period. The 63-year period represents the time-frame in which development of Garrison Diversion Unit would be completed and most of the irrigated lands would reach a salt balance. During the 63-year period, composite flow TDS concentrations in the river would range from a low of 177 mg/l to a high of 1,541 mg/l. River TDS concentrations would exceed 1,000 mg/l for 137 months and would usually occur in December, January and February.

To limit maximum TDS concentrations in the Souris River to 1,000 mg/l, Velva Canal water at an average TDS concentration of 440 mg/l would be released into the river. Maximum releases would be about 7,200 acre-feet

per year with full Souris Section development. This amount of dilution would have occurred in year 1971 if the Souris Section had been fully developed. See Figures 6 and 7, respectively, for projected composite flows and TDS levels with full development of Garrison Diversion Unit and historic river flows and TDS levels. Dilution water would generally be required only during the months of January and February. Median releases would amount to only 1,600 acre-feet per year. See Figure 5 for median flows. No dilution would be required during periods of above normal flows.

The Velva Canal presently is not designed to operate during the winter months. In order for the canal to be operational during the winter season, modifications would be required to the regulating and control structures (between Lonetree Reservoir and Souris River) in the canal to prevent freezing. Costs associated with these modifications and operation of the canal will increase; however, they were not quantified for this study.

Dilution requirements for this alternative are based on requirements after full development of the Souris Section. However, the same TDS level (1,000 mg/l) could be maintained in the river once the Velva Canal is operational. During Souris Section staged development (first 26 years after initial construction in area), lack of augmentation from return flows may require additional quantities of dilution water to maintain river TDS levels below 1,000 mg/l. Dilution will be required only during low-flow periods; consequently, it will not affect flood flows.

Environmental Effects

Dilution flows would add to the effects attributed to anticipated return flows and would limit water control and management options at the J. Clark Salyer National Wildlife Refuge.

Water passing through the refuge is regulated for the control and management of vegetation important to wildlife, specifically migratory and breeding waterfowl. The water management plan includes periodic,

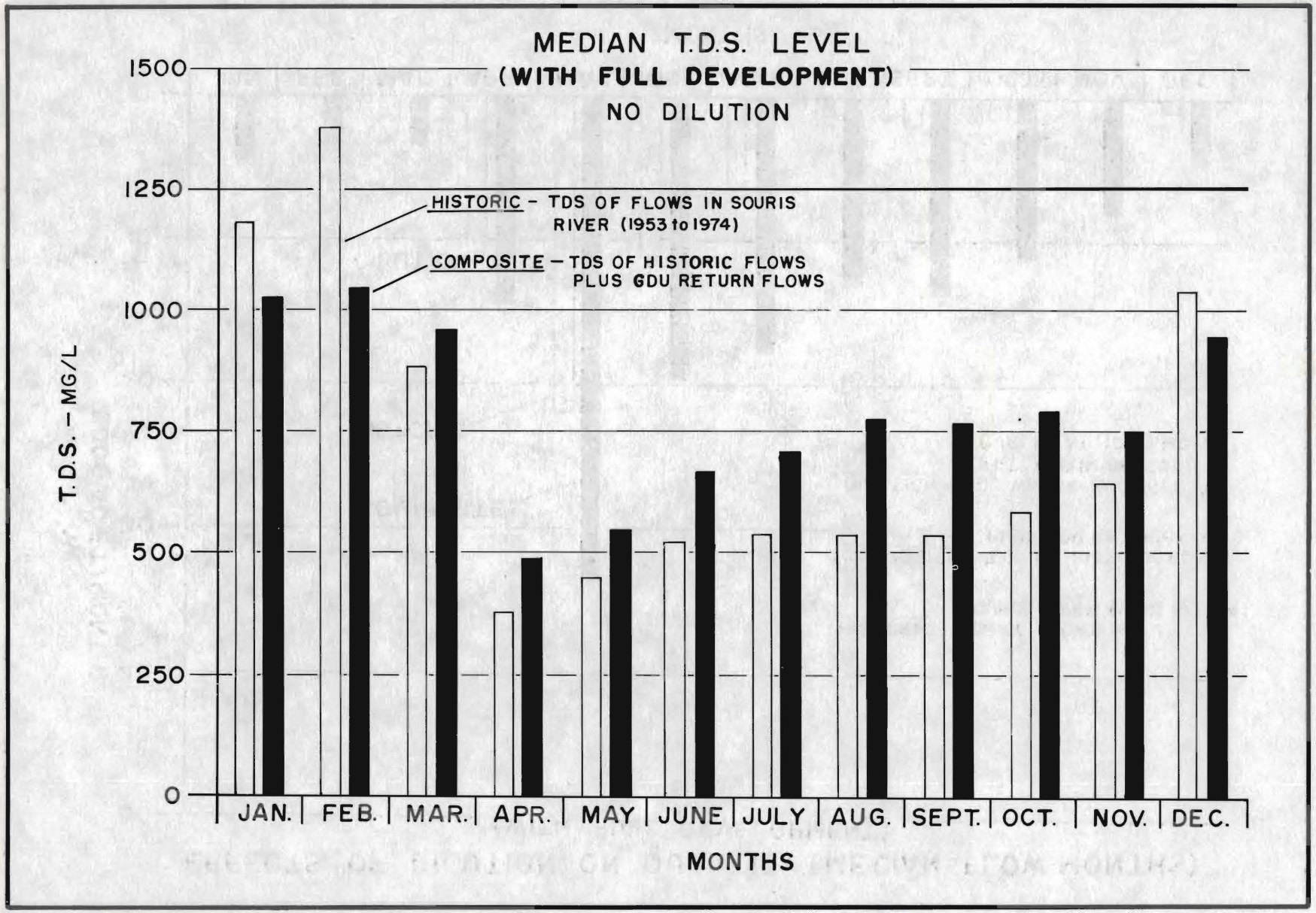
MEDIAN T.D.S. LEVEL
(WITH FULL DEVELOPMENT)
NO DILUTION
HISTORIC - TDS OF FLOWS IN SOURIS RIVER (1953 to 1974)
COMPOSITE - TDS OF HISTORIC FLOWS PLUS GDU RETURN FLOWS
T.D.S. - MG/L
1500
1250
1000
750
500
250
0
JAN.
FEB.
MAR.
APR.
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
MONTHS

Figure 4

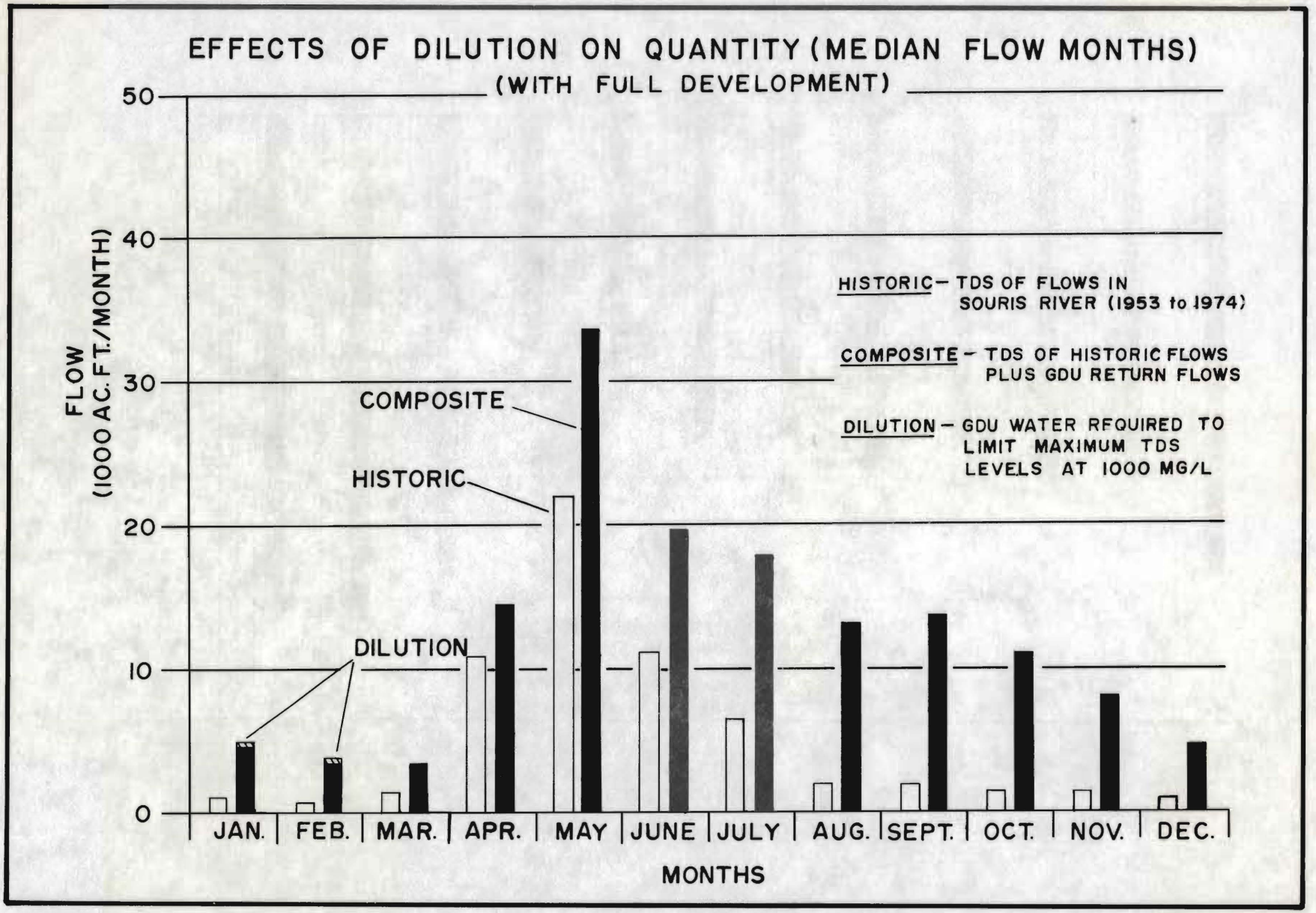
EFFECTS OF DILUTION ON QUANTITY (MEDIAN FLOW MONTHS)
(WITH FULL DEVELOPMENT)
FLOW (1000 AC. FT./MONTH)
50
40
30
20
10
0
COMPOSITE
HISTORIC
DILUTION
HISTORIC – TDS OF FLOWS IN SOURIS RIVER (1953 to 1974)
COMPOSITE – TDS OF HISTORIC FLOWS PLUS GDU RETURN FLOWS
DILUTION – GDU WATER REQUIRED TO LIMIT MAXIMUM TDS LEVELS AT 1000 MG/L
JAN.
FEB.
MAR.
APR.
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
MONTHS

Figure 5

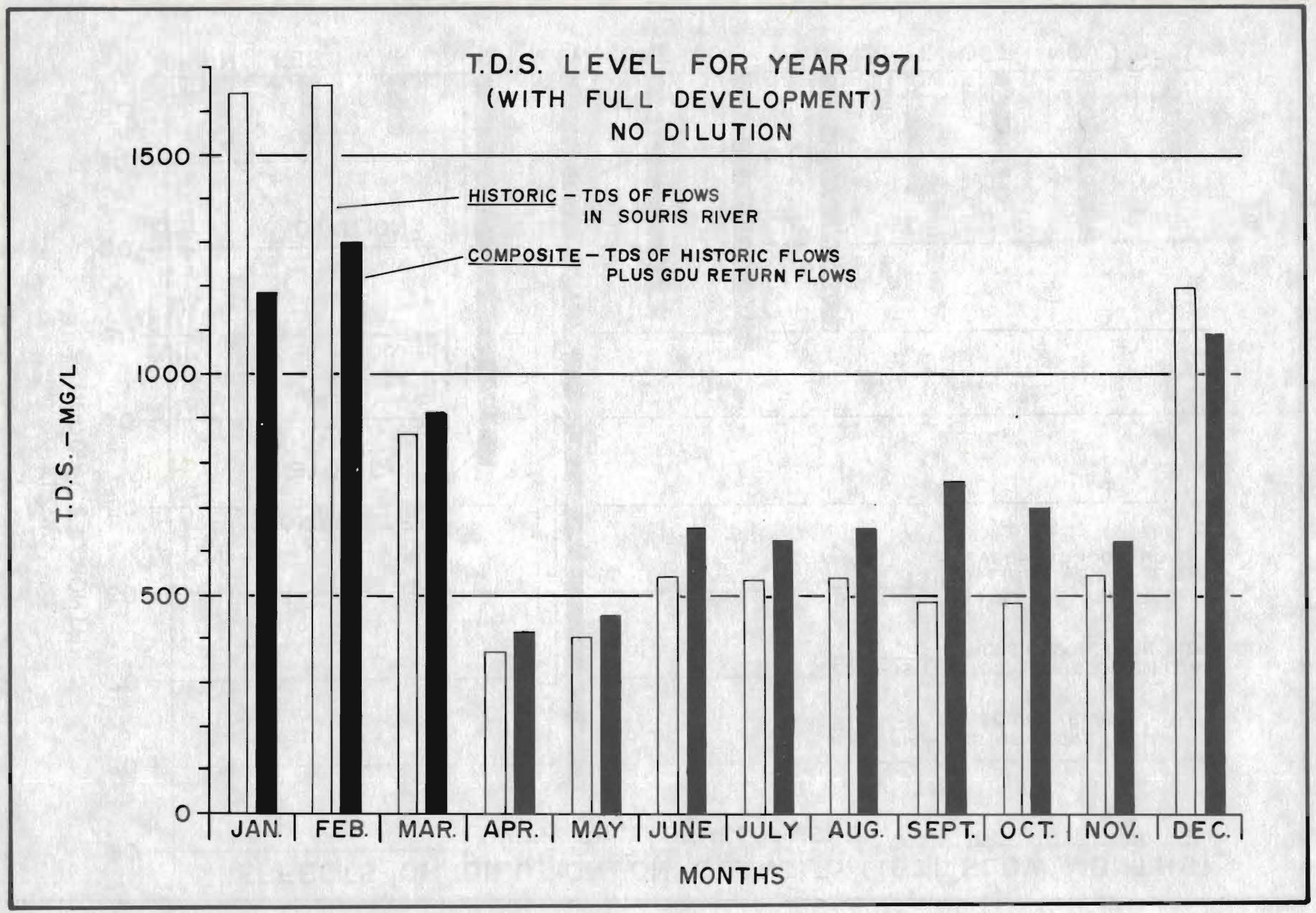
T.D.S. LEVEL FOR YEAR 1971
(WITH FULL DEVELOPMENT)
NO DILUTION
HISTORIC – TDS OF FLOWS IN SOURIS RIVER
COMPOSITE – TDS OF HISTORIC FLOWS PLUS GDU RETURN FLOWS
T.D.S. – MG/L
1500
1000
500
0
JAN.
FEB.
MAR.
APR.
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
MONTHS

Figure 6

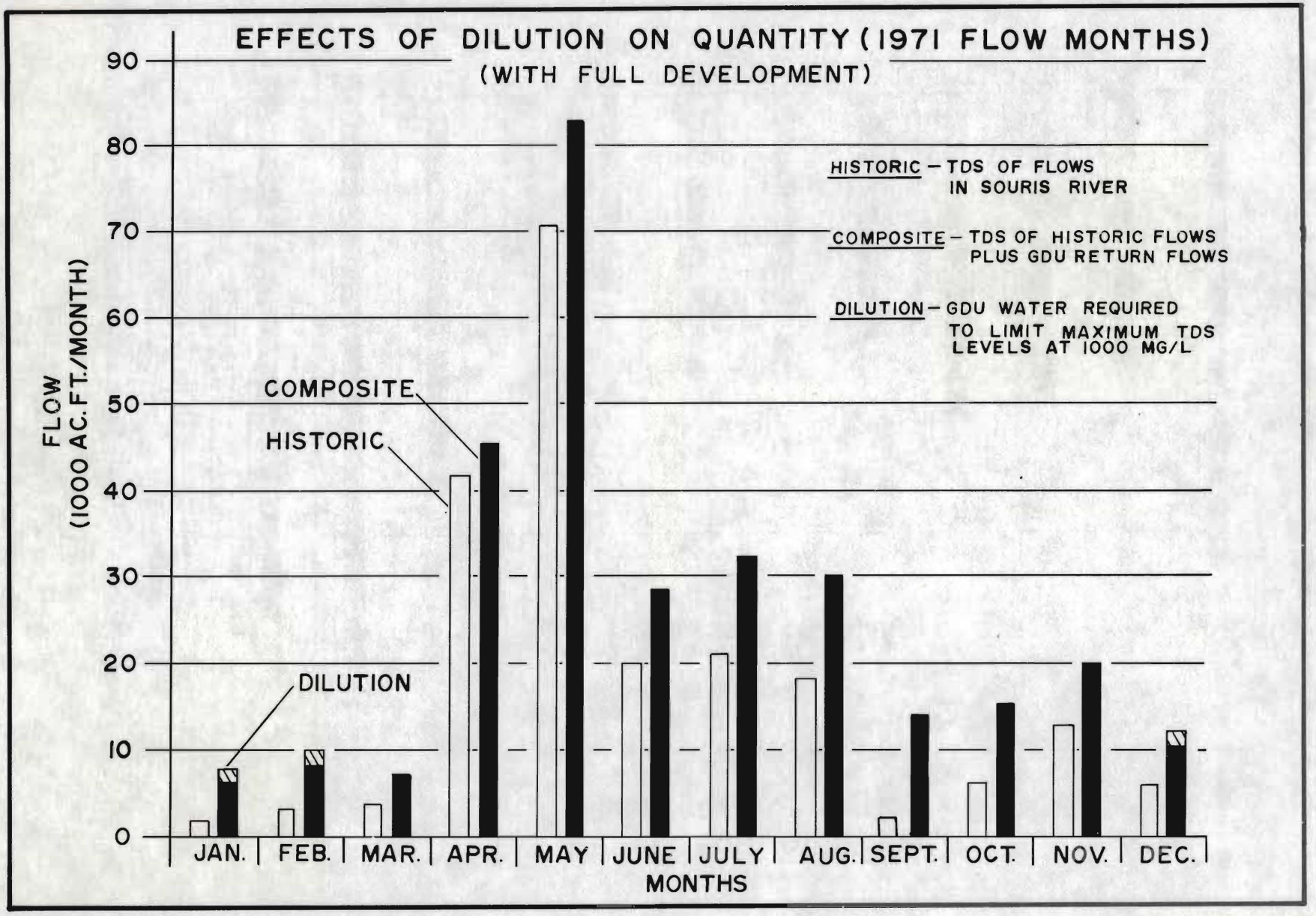
EFFECTS OF DILUTION ON QUANTITY (1971 FLOW MONTHS)
(WITH FULL DEVELOPMENT)
HISTORIC – TDS OF FLOWS IN SOURIS RIVER
COMPOSITE – TDS OF HISTORIC FLOWS PLUS GDU RETURN FLOWS
DILUTION – GDU WATER REQUIRED TO LIMIT MAXIMUM TDS LEVELS AT 1000 MG/L
FLOW (1000 AC.FT./MONTH)
90
80
70
60
50
40
30
20
10
0
COMPOSITE
HISTORIC
DILUTION
JAN.
FEB.
MAR.
APR.
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
MONTHS

Figure 7

controlled water level drawdowns to maintain soil/plant relationships important to desirable plant species. Additional water passing into and through the refuge during the winter months would limit water control management options during this 3-month period.

The increased amounts of water movement attributed to the return flows and dilution water may change the limnology of refuge waters. Changes in population composition of zooplankton and phytoplankton may occur, which could reduce the amount of food organisms available for resident and migratory waterfowl and other wetland wildlife.

The riverine environment would be enhanced by the freshening effect of the return flows and dilution waters. This would provide conditions suitable for increased populations of game fish as well as rough fish, should they be introduced.

Return flows mixing with natural flows of the Souris River downstream from its confluence with Deep River may result in additional periods of open water during winter months. If large areas of open water remain during extended winter periods, they could attract ducks and geese, delay their migration, and expose them to winter storms. If this occurs, starvation losses may be increased, as well as losses from increased incidence of disease. Open water would be highly beneficial to fish by providing oxygenation during a portion of the winter season. Increased oxygen along with increased streamflow would improve the fishery of the stream, lower the biochemical oxygen demand (BOD), stabilize organic matter, and provide a general improvement of water quality in the river. Dilution flows would not measurably increase the amount or duration of ice-free areas in the Souris River.

The impacts of this alternative on fish could be both beneficial and adverse. The improved water quality and quantity would allow year-around survival of game fish in the fishery. It would also allow for survival of rough fish if they were introduced. Rough fish such as carp would compete with the game fish for food and habitat. If large populations are established, rough fish may also compete with waterfowl for

food and reduce aquatic vegetation utilized by waterfowl. Carp are presently found in the lower Souris River; however, the carp have not immigrated into the United States portion of the river. With increased flows, an additional control structure may be required to prevent carp movement upstream into refuge pools.

Following is a summary of environmental effects for Alternative B:

Alternative B - Summary of Environmental Effects

Impact	
Beneficial	Adverse
Reduction of 3 and 5 percent in median TDS level (January and February, respectively).	Increase in flows of 1,600 acre-feet per year (median year) to J. Clark Salyer National Wildlife Refuge, affecting management plan, limnological regime, etc.
Increased fishery potential for game and rough fish survival - Souris River.	Open winter water may concentrate waterfowl.
	Increase in potential rough fish survival - Souris River.

Economics

No additional water conveyance structures would be required for this alternative and consequently the project cost of the authorized unit would not change. The value of the extra water released from Velva Canal for dilution will range from a median value of $32,000 to a maximum value of $144,000 under full development of the Souris Section. (These amounts are based on a value of $20 per acre-foot, the same value used for water conserved under Alternative A.) This value of increased water use from Lake Sakakawea has no significant impact on the benefits of the Garrison Diversion Unit or on the costs of this alternative.

Operation, maintenance and replacement costs would consist of monitoring the releases from Velva Canal. This operational function would be required during the off-season months for the regular OM&R personnel and could be incorporated into the work schedule of the staff in charge of basic authorized unit features.

Although the economic benefits were assessed, they were not quantified for the dilution alternative. The value of the additional Missouri River water diverted for dilution, when subtracted from the benefits of the authorized plan, does not change the 2.91 benefit-cost ratio.

Social Effects

Beneficial effects can be anticipated to occur in Canada from controlled releases into the Souris River. The Province of Manitoba is predominately rural, and rural communities depend on agriculture and business establishments for their living. Recreational activities are centered around water impoundments and public parks. The additional water in the Souris River could be used to enhance agricultural and industrial production, improve rural water supplies, and facilitate recreational and other water resource developments. Descriptions of landforms along the Souris River in Manitoba indicate that some lands could benefit from sustained irrigation development.

Added releases from Velva Canal would improve water quality and assure a stabilized volume of water in the Souris River. Offensive odor, poor color and taste problems experienced periodically could be alleviated. Poor quality water at recreational sites could be enhanced through controlled releases from Velva Canal.

These added releases could be beneficially used by industries that depend on Souris River water during periods of low flow with high TDS and colloidal concentrations. A more uniform water quality at a higher rate of flow could help alleviate some of the poor water conditions faced by these industries in Manitoba.

Discussion

Addition of dilution water into the Souris River would stabilize river water quality. This alternative does not appreciably affect Garrison Diversion Unit costs and improved Souris River quality should be beneficial to both the United States and Canada.

Although the dilution plan seems to be the most logical plan to consider at this time, it is possible that other dilution plans could be studied which would provide additional benefits to Canada during any part of a given year. Once the dilution objective has been defined, methods could be explored to achieve that goal. Potential benefits which could be realized by Canada with different dilution schemes are a constant and adequate water supply for domestic use, irrigation, and industrial use. Some problems which may be encountered with providing this constant water supply to Canada are limited canal capacity and greater volumes of water required to have a significant impact in improving water quality when flows are high in the river. Difficulties such as operation of the canal during winter months will also be encountered.

Alternative C - Partial Development

This alternative consists of three plans with varying levels of development of the Souris Section. The authorized plan for the Souris Section includes irrigation development of 116,000 acres, development of 27,650 acres for fish and wildlife areas, and provisions for providing water for municipal and industrial purposes.

This alternative investigates the effects on Garrison Diversion Unit and the Souris River if irrigation development in the Souris Section was reduced to 90,800 acres, to 51,200 acres, or to no irrigation development in the Souris Section. Each plan includes a reduction in fish and wildlife areas and municipal and industrial water benefits.

The environmental impacts associated with partial development are both beneficial and adverse. The effect of the impacts depends on the extent of development. Major impacts of these plans are:

1. The amount of channelization in natural watercourses would be reduced or eliminated. These watercourses are valuable for waterfowl production and other wetland wildlife because adjacent farmlands are intensively used for agricultural production. The watercourses retain water in the spring, early summer, and after precipitation periods, and provide high quality wetland habitat for wildlife. During the winter they provide the winter food and cover for upland birds and mammals that is not available on adjacent farmlands.

2. Canals through cropland, rangeland, woodland and natural wetland habitat would be reduced in length or eliminated. Elimination of canals which would affect woodland, rangeland and wetland will be beneficial because these lands are presently of value to wildlife. Elimination of canals will result in a net loss in cropland habitat value if acres lost to right-of-way construction are compared with acres of planned permanent upland habitat on canal rights-of-way. The value of this permanent upland habitat will depend on the right-of-way width and whether these seeded right-of-way areas ever approach the plant diversity of a natural plant community. Average width of the seeded

area on the total length of the Velva Canal will be approximately 90 feet on each side. Those sections of canal which meet or exceed this average width should be of substantial value to waterfowl, upland game and non-game birds, deer, fox and other small mammals.

The width of seeded area on the northern 18 miles of the Velva Canal will be 30 feet or less on each side, as will the seeded area on the Mouse Canal. Wildlife value associated with right-of-way on these two sections will be very limited because of the narrow width of the strips. These narrow strips tend to congregate nesting birds and small mammals, making them far more susceptible to predation than would larger and wider blocks of cover. The strips also tend to fill with snow and provide little or no winter cover and protection.

3. The quantity of return flows discharged into J. Clark Salyer Refuge would be reduced or eliminated. This would lessen the possible water management problems of the refuge.

4. The alteration or loss of natural wetlands because of irrigation systems and associated land improvements would be reduced or eliminated.

5. The reduction in the amount of land to be developed as permanent wildlife habitat would be proportional to the reduction in irrigated acreage.

6. Effects of the quantity and quality of reduced return flow on the Souris River fishery would vary with the reduction in return flows as compared to the authorized plan.

Following is a summary of environmental effects for Alternative C:

Alternative C - Summary of Environmental Effects

Impact	Alternative Plan C-1	C-2	C-3
Beneficial			
Reduction in miles of planned channelization	49	49	78
Reduction in miles of canals planned through wildlife habitat	18	48	114
Reduction in flows to J. Clark Salyer National Wildlife Refuge	15,300 ac. ft./yr.	37,000 ac. ft./yr.	91,600 ac. ft./yr.
Reduction in loss of natural wetlands to irrigation systems	3,780 1/	9,720 1/	17,400 1/
Reduction in return flows affecting potential fishery in the Souris River	15,300 ac. ft./yr.	37,000 ac. ft./yr.	91,600 ac. ft./yr.
Adverse			
Reduction in planned permanent vegetative cover on canal right-of-way	18 miles	48 miles	114 miles
Reduction in amount of wildlife development areas	370 ac.	2,630 ac.	27,650 ac.
Reduction in return flows causing reduced fishery potential	15,300 ac. ft./yr.	37,000 ac. ft./yr.	91,600 ac. ft./yr.

1/ Estimated wetlands are computed as follows: irrigation acres deleted x 15 percent.

Potential economic and social effects of this alternative are the loss of benefits from increased farm income and associated business activity, the loss of opportunity to increase food production, and the loss of associated employment opportunity. There are also seven communities in the Souris Section which are depending on Garrison Diversion Unit for a future water supply. The potential irrigation and municipal and industrial water development eliminated by this alternative will mean loss of benefits ranging from $5.6 million to $25.6 million annually and will adversely affect the social well-being of 1,200 to 87,000 people.

Following are discussions of each of the plans under this alternative plus a general discussion.

Plan C-1

Description of the Plan.--This plan consists of reducing development in the Souris Section from 116,000 acres to 90,800 acres, or 22 percent. The objective is to reduce the volume of return flows entering the Souris River.

For the purposes of evaluating this alternative, it is assumed that the Garrison Diversion Unit development would be reduced from 250,000 to 224,800 acres. Souris Section development of 90,800 acres would include all of the Karlsurhe Area (12,200 acres) and 78,600 acres in the Middle Souris Area. Fish and wildlife areas would probably be reduced from 27,650 acres to 27,280 acres, and possibilities for M&I water facilities would be eliminated for two communities.

Length of the Velva Canal would be reduced from 84 miles to approximately 66 miles. Capacity of the Velva Canal would also be reduced. Drainage and supply laterals would be reduced approximately in proportion to the reduction in acres in the area.

Annual water releases into Velva Canal for Souris Section use would be reduced from 222,000 to 183,000 acre-feet. Return flows entering the Souris River would be reduced from 91,600 to 76,300 acre-feet annually as shown in the following tabulation:

MEDIAN RETURN FLOWS TO THE SOURIS RIVER[1/]

	Authorized Unit				Plan C-1			
	Irrigation Period		Non-Irrigation Period		Irrigation Period		Non-Irrigation Period	
	Quantity (ac. ft.)	Quality (mg/l)	Quantity (ac. ft.)	Quality (mg/l)	Quantity (ac. ft.)	Quality (mg/l)	Quantity (ac. ft.)	Quality (mg/l)
Irrigation Return Flows	23,200	1,050	19,500	1,050	18,100	1,050	15,300	1,050
Canal & Lateral Seepage	17,400	930	negligible		13,100	930	negligible	
Operational Wastes	6,200	440	-	-	4,800	440	-	-
M&I Effluent	15,500	440	-	-	15,400	440	-	-
F&WL Area Seepage	4,900	880	4,900	880	4,800	880	4,800	880
Total	67,200	810	24,400	1,020	56,200	790	20,100	1,010

1/ Quality of return flows in TDS

Receiving Waters.--Return flows entering the Souris River as a result of Garrison Diversion Unit development in the Souris Section would be reduced by about 17 percent with this plan as a result of the 22 percent reduction in irrigated areas in the Souris Section.

PLAN C-1

RETURN FLOWS AND EFFECTS ON SOURIS RIVER

Item	Flows					
	Irrigation Season (Apr. 15 - Oct. 15)		Non-Irrigation Season (Oct. 15 - Apr. 15)		Annual Median 1/	
	Quantity (ac. ft.)	Quality TDS (mg/l)	Quantity (ac. ft.)	Quality TDS (mg/l)	Quantity (ac. ft.)	Quality TDS (mg/l)
Return Flows						
Irrigation Return Flows	18,100	1,050	15,300	1,050	33,400	1,050
Canal and Lateral Seepage	13,100	930	- negligible -		13,100	930
Operational Wastes	4,800	440	-	-	4,800	440
M&I Effluent	15,400	440	-	-	15,400	440
P&WL Area Seepage	4,800	880	4,800	880	9,600	880
Total	56,200	790	20,100	1,010	76,300	850
Souris River						
Existing Flows 2/	67,400	510	20,000	630	107,700	540
Existing Flows with Authorized Souris Section Return Flows	134,600	670	44,200	800	199,300	690
Existing Flows with Plan C-1	123,600	650	40,100	780	184,000	670

1/ Quantity values shown are median values and do not necessarily equal the summation of the irrigation and non-irrigation median flows.
2/ Based on a 21-year period from 1953 to 1974, median values at Westhope.

Environmental Effects.--Environmental impacts of this alternative include reduction of various components of the irrigation system. These include the elimination of 49 miles of channelization planned for Little Deep Creek, Spring Coulee, and South Egg Creek; the elimination of 18 miles of the Velva Canal through 260 acres of cropland, rangeland, woodland and wetland habitat; the reduction in quantity of the return flows entering J. Clark Salyer Refuge; and the reduction in the amount of wetland losses attributed to conversion from dryland farming to irrigation.

For purposes of this study, major fish and wildlife areas in the Souris Section were not reduced under this plan where those areas could still be served with Garrison Diversion Unit water. Proposed wildlife development would probably be reduced as shown on the following tabulation:

FISH AND WILDLIFE AREAS INCLUDED
IN THE PLANS FOR THE SOURIS SECTION [1/]

Area	Fish & Wildlife Acres to be Developed	
	Authorized Plan	Plan C-1
Stink Lake - Stink Creek	2,535	2,535
Upper Wintering River	10,320	10,320
Wintering River	2,215	2,215
Buffalo Lodge Lake	8,200	8,200
Nead Lake	1,680	1,680
Herrington Lake	1,000	1,000
Small Unidentified Areas	1,700	1,330 [2/]
Estimated Total Acres to be Developed	27,650	27,280

1/ Data presented in this table determined for analysis purposes only. Specific acreages may vary if the plan is implemented.

2/ Reduced in proportion to reduction in irrigable acreage.

Economics.--This plan would reduce the total project cost to $498 million. The benefit-cost ratio would be 2.73 to 1 as shown in the following tabulation:

Economic Analysis - Plan C-1
(in $Thousands)

Item	Authorized Unit	Authorized Unit Modified by Alternative (Plan C-1)
Construction Cost	507,200	497,850
Annual Equivalent Cost [1/]	18,563	18,115
Annual OM&R	1,852	1,665
Annual Benefits	59,496	54,071
Benefit-Cost Ratio	2.91	2.73
Net Benefits	39,081	34,291

1/ Based on cost plus interest during construction.

Loss of benefits from the assumed reduced irrigation development in the Souris Loop Area (25,200 acres) would amount to about $5.4 million each year. Annual losses to municipalities due to the lack of an adequate supply of potable domestic use water were valued at $10,000.

Social Effects.--Irrigation would be reduced by 25,200 acres with this plan, and potential income from irrigation and associated benefits from increased services and expanded employment opportunities would be lost. Elimination of potential municipal and industrial water delivery to the communities of Lansford and Glenburn would adversely affect the social well-being of 1,200 people in these communities.

Plan C-2

Description of the Plan.--For purposes of evaluating this alternative, this plan consists of reducing development in the Souris Section from 116,000 acres to 51,200 acres. The objective is to reduce the volume of return flows entering the Souris River.

Garrison Diversion Unit development would be reduced from 250,000 to 185,200 acres. Souris Section development of 51,200 acres would include all of the Karlsruhe Area (12,200 acres) and 39,000 acres in the Middle Souris Area. For purposes of evaluating this alternative plan, it is assumed that fish and wildlife areas would be reduced from 27,650 acres to 25,020 acres, and possibilities for M&I water facilities would be eliminated for three communities.

Length of the Velva Canal would be reduced from 84 miles to approximately 66 miles and the Mouse Canal would be eliminated. Capacity of the Velva Canal would also be reduced. Drainage and supply laterals would be reduced approximately in proportion to the reduction in irrigated acres.

Total annual water released into the Velva Canal for Souris Section use would be reduced from 222,000 to 120,000 acre-feet. Return flows entering the Souris River would be reduced from 91,600 to 54,600 acre-feet annually as shown in the following tabulation:

MEDIAN RETURN FLOWS TO THE SOURIS RIVER [1/]

	Authorized Unit				Plan C-2			
	Irrigation Period		Non-Irrigation Period		Irrigation Period		Non-Irrigation Period	
	Quantity (ac. ft.)	Quality (mg/l)	Quantity (ac. ft.)	Quality (mg/l)	Quantity (ac. ft.)	Quality (mg/l)	Quantity (ac. ft.)	Quality (mg/l)
Irrigation Return Flows	23,200	1,050	19,500	1,050	10,200	1,050	8,600	1,050
Canal & Lateral Seepage	17,400	930	negligible		8,800	940	negligible	
Operational Wastes	6,200	440	-	-	2,700	440	-	-
M&I Effluent	15,500	440	-	-	15,300	440	-	-
F&WL Area Seepage	4,900	880	4,900	880	4,500	880	4,500	800
Total	67,200	810	24,400	1,020	41,500	750	13,100	990

1/ Quality of return flows in TDS.

Receiving Waters.--Return flows entering the Souris River as a result of Garrison Diversion Unit development in the Souris Section would be reduced by about 40 percent with this alternative, as a result of the 56 percent reduction in irrigated acres in the Souris Section.

PLAN C-2

RETURN FLOWS AND EFFECTS ON SOURIS RIVER

Item	Flows					
	Irrigation Season (Apr. 15 - Oct. 15)		Non-Irrigation Season (Oct. 15 - Apr. 15)		Annual Median [1/]	
	Quantity (ac. ft.)	Quality TDS (mg/l)	Quantity (ac. ft.)	Quality TDS (mg/l)	Quantity (ac. ft.)	Quality TDS (mg/l)
Return Flows						
Irrigation Return Flows	10,200	1,050	8,600	1,050	18,800	1,050
Canal and Lateral Seepage	8,800	940	- negligible -		8,800	940
Operational Wastes	2,700	440	-	-	2,700	440
M&I Effluent	15,300	440	-	-	15,300	440
F&WL Area Seepage	4,500	880	4,500	880	9,000	880
Total	41,500	750	13,100	990	54,600	880
Souris River						
Existing Flows [2/]	67,400	510	20,000	630	107,700	540
Existing Flows with Authorized Souris Section Return Flows	134,600	670	44,200	800	199,300	690
Existing Flows with Plan C-2	108,900	620	31,100	710	162,300	660

1/ Quantity values shown are median values and do not necessarily equal the summation of the irrigation and non-irrigation median flows.

2/ Based on a 21-year period from 1953 to 1974, median values at Westhope.

Environmental Effects.--Environmental impacts of this alternative include the reduction of various components of the irrigation system. These include the elimination of 49 miles of channelization of natural watercourses; elimination of approximately 18 miles of the Velva Canal and elimination of all of the estimated 30 miles of the Mouse Canal through approximately 1,360 acres of cropland, rangeland, woodland and wetland habitat; the reduction in quantity of return flows entering J. Clark Salyer Refuge; and a reduction in the amount of wetland losses attributed to conversion from dryland farming to irrigation.

For purposes of this study, major fish and wildlife areas in the Souris Section were not reduced under this plan where those areas could still be served with Garrison Diversion Unit water. Proposed wildlife development would probably be reduced as shown in the following tabulation:

FISH AND WILDLIFE AREAS INCLUDED
IN THE PLANS FOR THE SOURIS SECTION 1/

Area	Fish & Wildlife Acres to be Developed	
	Authorized Plan	Plan C-2
Stink Lake - Stink Creek	2,535	2,535
Upper Wintering River	10,320	10,320
Wintering River	2,215	2,215
Buffalo Lodge Lake	8,200	8,200
Nead Lake	1,680	-0- 3/
Herrington Lake	1,000	1,000
Small Unidentified Areas	1,700	750 2/
Estimated Total Acres to be Developed	27,650	25,029

1/ Data presented in this table determined for analysis purposes only. Specific acreages may varry if the plan is implemented.
2/ Reduced in proportion to reduction in irrigable acreage.
3/ Not feasible to develop as it would be served by the Mouse Canal.

Economics.--This plan would reduce the total project cost to $434 million. The benefit-cost ratio would be 2.66 to 1 as shown in the following tabulation:

Economic Analysis - Plan C-2
(in $Thousands)

Item	Authorized Unit	Authorized Unit Modified by Alternative (Plan C-2)
Construction Cost	507,200	434,261
Annual Equivalent Cost 1/	18,563	15,745
Annual OM&R	1,852	1,372
Annual Benefits	59,496	45,509
Benefit-Cost Ratio	2.91	2.66
Net Benefits	39,081	28,392

1/ Based on cost plus interest during construction.

Irrigation in the Souris Section would be reduced by 64,800 acres with this plan, resulting in a $13.8 million loss in annual benefits. The communities of Glenburn, Lansford and Granville would be eliminated from municipal and industrial water service which the authorized unit would provide. Collectively, these three communities would lose $97,000 in municipal and industrial water benefits annually.

Social Effects.--This plan would reduce the irrigable acreage by 64,800 acres, and beneficial social effects of increased services and employment from this acreage would be lost in the Souris Area. Also lost would be the potential for a dependable good quality water supply planned for the towns of Lansford, Glenburn and Granville, potentially affecting a total population of 2,400 people.

Under the authorized plan, industry is expected to enter the Souris Section irrigation area and will tend to stabilize year-around economic, social and community activities. Plan C-2 would eliminate the potential for development of an agricultural produce processing complex in the Towner area and could deprive the area of substantial employment opportunities.

Plan C-3

Description of the Plan.--This plan consists of deleting the Souris Section from the Garrison Diversion Unit. The objective is to eliminate flows entering the Souris River.

With this plan, all development in the Souris Area and Karlsruhe Area and the Velva Canal would be eliminated. For the purpose of evaluating this alternative, it is assumed that the Garrison Diversion Unit would be reduced from 250,000 acres to 134,000 acres.

Environmental Effects.--Environmental impacts resulting from this alternative plan are both beneficial and adverse. All of the adverse impacts associated with construction and operation of the Souris Section would be eliminated. The 27,650 acres of permanent wildlife development would not be established.

Economics.--This plan would reduce the total project cost to $358 million. The benefit-cost ratio would be 2.44 to 1 as shown in the following tabulation:

Economic Analysis - Plan C-3
(in $Thousands)

Item	Authorized Unit	Authorized Unit Modified by Alternative (Plan C-3)
Construction Cost	507,200	358,446
Annual Equivalent Cost[1/]	18,563	12,901
Annual OM&R	1,852	993
Annual Benefits	59,496	33,877
Benefit-Cost Ratio	2.91	2.44
Net Benefits	39,081	19,983

1/ Based on cost plus interest during construction.

For the purpose of this study, this plan would eliminate the entire 116,000-acre Souris Section from the authorized unit. Loss of irrigation benefits would amount to nearly $25 million annually. Annual municipal and industrial water benefits would be lost to the communities of Bantry, Drake, Deering, Lansford, Glenburn, Granville, Minot and Upham, amounting to about $625,000. Of these communities, Minot will be most severely affected. The city is depending on Garrison Diversion Unit facilities for a dependable good quality water supply for its projected 2020 population of about 32,000 as discussed in the Feasibility Report on Minot Extension, Garrison Diversion Unit.

Social Effects.--Deletion of the Souris Section would reduce social benefits and would greatly impact the potential well-being of the people in north-central North Dakota where the 116,000 acres of irrigable land are located. Potentially, irrigation development would provide many beneficial social effects, not just for farmers, but for the general economy. Intensified farming would increase the demand for machinery, fertilizers, chemicals and other services which would promote new agribusiness and provide increased economic growth. Additional agricultural processing and marketing plants may be required to process new and different kinds of crops and would increase retail and wholesale trade volumes. A corresponding increase in employment opportunity would also be realized.

Historically, towns and communities with populations of 1,000 or less have lost populations to the larger urban centers. However, irrigation development could increase or stabilize the population of the communities of Bantry, Deering, Drake, Lansford, Glenburn, Granville and Upham. Although the population of Minot is growing, irrigation development would further increase its growth.

Minot presently has a water supply shortage. The city relies on the Souris River and the Minot aquifer for its supply. The quality of water from both sources is marginal, requiring expensive treatment, and quantities are limited. Almost every summer since 1960, peak

demands have exceeded the supply, causing excessive drawdown of the aquifer and forcing the city to restrict water use. Minot cannot always fulfill its contractual obligation to deliver 2.5 million gallons per day to the Minot Air Force Base. The base has cooperated in rationing water use during critical periods. The average per capita use for Minot is 80 gallons per day, about half the national average for similar size cities.

Problems of the city in obtaining a satisfactory water supply to meet present and future needs have been described in the Feasibility Report on Minot Extension, Garrison Diversion Unit, July 1969. The city has long looked to the Garrison Diversion Unit as a dependable source of good quality water. However, adequate funding for construction of supply features of the unit has not been available in most years since initiation of construction in 1967. The original schedule provided for availability of water in Velva Canal for service to the city in 1972; the present schedule calls for availability of water after 1981. Because of a possible continuing slow rate of construction on Garrison Diversion Unit facilities, the city of Minot became interested in temporary measures that would provide supplemental water until the early 1980's.

In response to this interest, the Bureau of Reclamation modified the plan in the 1969 report by the supplemental report of March 1970. This modification includes, as a first phase development, ground water conveyance facilities using ground water from Sundre aquifer near the city until water is available from the Garrison Diversion Unit. Construction of this first phase is essentially complete. Based on projected population growth for Minot, it is estimated that the Sundre aquifer will provide an adequate water supply until about 1985, at which time another source will be required. The most feasible alternative supply would be the second phase of the Minot Extension which is dependent upon construction of the Garrison Diversion Unit. Second phase development provides for diversion of 22,953 acre-feet of Missouri River

water through Garrison Diversion Unit facilities by 2020 to meet long-term municipal and industrial needs.

The projected population for the communities in the Souris Section which would possibly be dependent upon the Garrison Diversion Unit for a dependable source of potable water was estimated to be 87,000 by the year 2020.

Light agriculture-related industry would normally enter the area and along with more intense livestock production would tend to stabilize year-around economic, social and community activities. These benefits and the associated employment opportunities would be lost in the Souris Section with implementation of this plan.

Discussion

Analyses of the partial development plans show the Souris Section could be reduced in size or eliminated and a favorable benefit-cost ratio can still be retained for Garrison Diversion Unit, although net benefits would be reduced. Return flow effects would be reduced or eliminated. However, it should be recognized that the 250,000-acre Garrison Diversion Unit as formulated and authorized by Congress provides the most efficient plan to serve all project purposes. Loss of potential irrigation would reduce potential agricultural production and its allied social and economic benefits.

Implementation of a partial development alternative would adversely impact the potential well-being of the people in central North Dakota. Communities in the area are depending on Garrison Diversion Unit to provide water supplies for municipal and industrial purposes. The city of Minot is completely dependent on the Garrison Diversion Unit to provide an economical and dependable water supply to alleviate their projected water supply problems.

A major component of the authorized Missouri Basin Program includes provisions to compensate North Dakota for negative benefits that have resulted from loss of 569,000 acres of fertile agricultural bottomlands in the Oahe and Garrison Reservoirs. A reduction in the size of the Garrison Diversion Unit as a result of eliminating a portion or all of the Souris Section will reduce offsetting benefits North Dakota would obtain from these reservoirs.

It should also be noted that any reductions in the Souris Section would reduce beneficial impacts expected to accrue to Canada as a result of increased river flows in the Souris River. The dilution alternative in this report explains benefits that could accrue to Canada from return flows and added flows to the Souris River.

Alternative D - Treatment

Return flows entering the Souris River will have both beneficial and adverse effects in the United States and Canada. Beneficial effects are improved water quality during periods of low flow, stabilization of river flows, and elimination of no-flow periods. Adverse effects are compounding of flooding problems and decreased water quality during periods of other than low flow. This alternative includes two methods of reducing some of the adverse impacts resulting from return flows.

The alternative consists of developing the Souris Section as presently authorized and either desalting the return flows or reimbursing Canadian communities for increased water treatment costs resulting from return flows. One plan involves desalting return flows at Deep River before they enter the Souris River, and the other provides reimbursement to the cities of Souris and Portage La Prairie in Canada for additional water treatment costs incurred as a result of Garrison Diversion Unit return flows.

A summary of environmental effects for Alternative D is shown below:

Alternative D - Summary of Environmental Effects

Impact	Alternative Plan	
	D-1	D-2
Beneficial		
Improved water quality conditions for game and rough fishes	Yes	Same as authorized plan
Reduction in TDS of flows to Souris River	Yes	Same as authorized plan
Adverse		
Elimination of fish migration route by dam	Yes	Same as authorized plan
Increase in rough fish survival - Souris River	Yes	Same as authorized plan
Loss of lands for dam	1,000 ac.	Same as authorized plan
Loss of lands for deslating plant and ponds	2,600 ac.	Same as authorized plan
Loss of lands for landfill	466 ac.	Same as authorized plan

Following are discussions of each of the plans under this alternative plus a general discussion:

Plan D-1

Description of the Plan.--This plan consists of constructing a small diversion dam at the mouth of Deep River, desalting a portion of the flows, and releasing treated water to the Souris River to form a blend equivalent to the historic annual median TDS level of flows in the Souris River. The objective is to improve the water quality of Garrison Diversion Unit return flows.

Most of the irrigation return flows, canal and lateral seepage, and operational wastes from the Souris Section will accrue to the Souris River via Deep River. A small regulating reservoir will be constructed at the mouth of Deep River to divert water to the desalting plant. The reservoir will have a capacity of about 4,000 to 5,000 acre-feet, a depth of 20 feet, and a surface area of about 1,000 acres. The water surface elevation would fluctuate considerably because of desalting plant drawdown and varying river flows.

The desalting plant would be installed near the reservoir site. A portion of the Deep River flows would be diverted through the desalting plant and released into the Souris River at 400 mg/l TDS to provide a blended mixture with a TDS concentration of about 540 mg/l when mixed with the remaining return flows. Treatment of return flows to 540 mg/l TDS would approximate the historic annual median TDS concentration in the Souris River.

The desalting plant would have a capacity of about 48 million gallons per day (54,000 acre-feet per year). Initial investigations indicate that a reverse osmosis process is the most economical type of plant; however, this would require further study prior to implementation of a desalting plan. The plant site would require about 5 acres and brine evaporation ponds would require about 3,100 acres of land. About 5,000 acre-feet annually of brine would be evaporated in the ponds. About 41,000 tons of salt per year would be removed from return flows.

Receiving Waters.--Implementation of this alternative would not appreciably affect Souris River flows as compared to the authorized plan; however, it would improve water quality in the river. As compared to the authorized unit, median TDS levels in the Souris River would decrease from 670 to 530 mg/l during the irrigation period, 800 to 580 mg/l during the non-irrigation period, and from 690 to 540 mg/l annual median value.

Environmental Effects.--Impacts associated with a desalinization plant on Deep River are related to return flow water quality, land use changes, and disposal of byproducts.

Since salts would be removed from the return flows prior to entering the Souris River, a reduction in the total dissolved solids would be achieved as compared with untreated return flows. This improvement in water quality would not affect the local fishery. The major adverse impacts would be those associated with loss of lands--cropland, wildlife land, rangeland, and woodland--for the plant site. Total acreage requirements for the plant, including the evaporation ponds, would be about 3,100 acres. Technological advances in possible reuse of brine or new disposal processes may decrease the land requirements for evaporation ponds. Disposal of byproducts would require about 200 acres for a landfill, assuming a 100-year lifespan.

Construction of the diversion reservoir would result in the loss of about 1,000 acres of upland and wetland habitat and would eliminate the annual northern pike spawning run into Buffalo Lodge and North Lakes.

Economics.--Construction of a desalting plant for reduction of total dissolved solids from Garrison Diversion Unit return flows in the Souris Section will add about $90 million to the cost of the authorized unit, bringing the total cost to $598 million. The annual cost for the plant would be about $10 million, of which the operation, maintenance and replacement costs would be about $7 million. Of the plant operation, maintenance and replacement, power cost would comprise about 10 percent or $730,000 annually. The benefit-cost ratio for the Garrison

Diversion Unit including this plan would be 1.94 to 1 as shown in the following tabulation:

Economic Analysis - Plan D-1
(in $Thousands)

Item	Authorized Unit	Alternative (Plan D-1)	Total (Authorized Plan with Plan D-1)
Construction Cost	507,200	90,348	597,548
Annual Equivalent Cost 1/	18,563	3,146 (5,554)	21,709 (24,117)
Annual OM&R	1,852	7,043	8,895
Annual Benefits	59,496	-0-	59,496
Benefit-Cost Ratio	2.91	-0-	1.94 (1.80)
Net Benefits	39,081	--	28,892 (26,484)

1/ Based on cost plus interest during construction.

Note: Parentheses enclose values which reflect a 6-1/8 percent discount rate used in analysis of alternative. Other figures reflect a 3-1/8 percent discount rate.

Social Effects.--Evaluation of the social benefits of this plan indicated that the communities along the Souris River would have access to a water supply of improved quality during low-flow periods. Also, operation and maintenance of the plant would potentially provide limited employment opportunity in the area. However, it was estimated that no other significant impacts on the social well-being of the local people would be created from implementation of this plan.

Plan D-2

Although Souris Section return flows (authorized plan) will stabilize flows in the Souris River and improve the water quality during periods of low flow, they will also increase hardness and TDS levels of Souris River water. This increase in hardness will increase operational costs of municipal treatment plants that use Souris River water as a source.

The Initial Stage Garrison Diversion Unit Final Environmental Statement, January 1974, listed the Canadian communities of Souris, Portage La Prairie and Wawanesa as obtaining Souris River water for municipal purposes. The town of Wawanesa does not currently obtain water from the Souris River; however, it was listed in the Final Environmental Statement because existing well problems may require the city to obtain water from the Souris River. This report will deal only with those communities which presently obtain water from the Souris or Assiniboine Rivers. There are no Canadian industrial users currently obtaining water directly from the Souris River. Souris (population 1,700 - 1971) and Portage La Prairie (population 13,000 - 1971) are the only two Canadian communities that would be appreciably affected by increased hardness of Souris River water.

Description of the Plan.--The community of Souris obtains municipal water directly from the Souris River and provides softening by the sodium zeolite process. Portage La Prairie obtains municipal water from the Assiniboine River downstream from the Souris River confluence and provides softening and total water treatment by the lime-soda ash process. Investigations indicate that existing softening facilities at both of these communities have sufficient capacity to treat the expected increase in hardness resulting from Garrison Diversion Unit return flows. New facilities will not be required and the principal impact on the communities resulting from return flows would be an increase in chemical costs to operate existing softening facilities. This plan would provide subsistence to the two communities to offset additional treatment costs.

Monthly median hardness (for the study period) of Souris River water at the Westhope gaging station will increase from 280 to 424 mg/l calcium carbonate with the addition of return flows. At the community of Souris, Souris River monthly median hardness will increase from 329 to 500 mg/l with the addition of return flows. This increase in hardness will require additional chemicals for softener recharge and will increase median annual operational costs for the community of Souris by about 35 percent. In 1974, total annual operational costs of the community's treatment plant was $9,000. A 35 percent increase in operational costs

would have increased the 1974 operational cost to about $12,200. The maximum increase in annual operational costs would be about 45 percent, which would have increased the 1974 operational cost to about $13,100.

Return flows will increase the monthly median hardness of Assiniboine River water at the community of Portage La Prairie from 340 to 380 mg/l calcium carbonate. This increase in hardness will result in an increase in the operational cost of the city's treatment plant. In 1974, operational costs of the Portage La Prairie water treatment plant were about $175,000. With average return flow conditions, the 1974 operational cost would have increased to approximately $180,000. Maximum return flow conditions would have increased the 1974 operational cost to approximately $184,000.

Economics.---This plan would provide reimbursement to two communities in Canada for treatment costs incurred due to introduction of return flows from the Souris Section into the Souris River. In each case, the cost of chemicals required for proper treatment of Souris River water would comprise most of the total annual cost of the plan. These costs, based on median and maximum annual treatment requirements, will range from $3,000 to $4,000 for the city of Souris and from $5,000 to $9,000 for Portage La Prairie. Total annual cost of the plan will range from $8,000 to $13,000. The cities' existing facilities are adequately sized to accommodate the additional water treatment requirements. No economic benefits were identified for this plan.

Social Effects.--The stabilized quality of water made available to the cities of Souris and Portage La Prairie will have a beneficial effect on the social well-being of the people in the two communities. The plan would provide no additional social impacts as the increased treatment could be accomplished with the cities' existing facilities and personnel.

Discussion

Desalting of return flows at Deep River does not appear to be a very practical plan. Initial costs and annual OM&R costs are very high, and

the desalting plant would consume large quantities of electrical energy. Although desalting would improve Souris River water quality, it would only decrease water quantity resulting from return flows by 5,000 acre-feet (evaporation).

Providing subsistence to the communities of Souris and Portage La Prairie in Canada for increased treatment costs may satisfy requirements of these two communities. However, the obvious shortcoming of this alternative plan is that it does not include provisions for future users of Souris River water, such as the town of Wawanesa, that may be adversely affected by increased hardness resulting from return flows. Return flows also will increase sulfate levels in the Souris River water. As discussed in Desalinization Plants for Two Communities in Canada under "Other Alternatives," sulfate is not treatable by conventional softening facilities.

Other Alternatives

In the process of selecting alternatives for this study, several alternatives were identified but were not chosen as alternatives to be investigated for reasons discussed on page 13. However, exclusion of these alternatives in this study would not necessarily preclude them from being investigated in any future studies of alternatives for the Souris Section. Following is a discussion of those alternatives considered but not selected for investigation in the study:

Use of Collectable Return Flows for Industrial Purposes in the Souris Area

In lieu of collecting and diverting the return flows out of the Souris River drainage basin as described in Alternative A, this water would be collected and offered for sale to industry and municipalities in the Souris Loop Area. The return flows would be collected and conveyed by pipe to one or more point sources for use by industry, municipalities, and rural water users. The amount of water available for this purpose would average about 47,000 acre-feet annually.

Municipal and rural use could consume a portion of the water, but industry would have to use most of the water supply. Although there are several types of industries that could be developed in the area to use the water, the most probable type is one that is coal-related. A sufficient quantity of mineable surface coal deposits exists in the Souris Loop Area to provide a potential for a coal-related resource development in the area. The coal resource could be developed to produce electrical power for export, or to produce synthetic natural gas. A coal gasification development is considered for purposes of this discussion.

A coal gasification plant could be constructed in the vicinity of Voltaire, North Dakota, where surface coal deposits are estimated to be in excess of 50 million tons. The plant would consume 18,000 acre-feet of water and 10 million tons of coal annually, have a lifespan of 30 to 35 years, and produce 250 million cubic feet daily of high-BTU pipeline quality synthetic natural gas. While most of the coal deposits in the

area are located south of Lake Sakakawea, this plant and perhaps one or two more could use the coal at the Voltaire site or use coal shipped by rail from Burke and Renville Counties near Kenmare (125 million tons) and/or from Williams County (1,130 million tons).

About 47,000 acre-feet of collectable return flows is available annually, which is sufficient to meet the water requirements for three coal-using complexes. Annual revenues from sale of return flows would be nearly $1 million at $20 per acre-foot.

The location of the Voltaire coal field is about 23 miles southwest of a proposed holding reservoir site (as discussed in the reuse alternatives) situated in the Karlsruhe irrigation area. The reservoir could be used for collection of return flows in the Souris Section.

Exchange of Velva Canal and Souris River Waters

A structure could be constructed at the point where the Velva Canal crosses the Souris River and be capable of exchanging Velva Canal and Souris River waters during the irrigation season. The structure could either be a pumping plant to pump Souris River water into the Velva Canal or a dam of sufficient height to allow Souris River water to flow into the canal.

During periods of high streamflow, water from the Souris River could be diverted into the Velva Canal for use in the Souris Section. Up to 1,700 cubic feet per second could be diverted into the canal. This would reduce flood peaks or high flows in the river below the diversion, reduce pumping requirements at the Snake Creek Pumping Plant, and in some cases provide irrigation water of better quality than would be available from Lonetree Reservoir.

During periods of normal streamflow, water from the Souris River could also be diverted into the Velva Canal and be replaced with water from Lonetree Reservoir. The water of questionable quality from the river would be diluted in the canal with project water before being applied to Souris Loop Area lands. Replacement water could be released to the

river to provide fresh water to the river and dilute return flows and low quality natural streamflows further down the river, or it could be withheld to reduce high streamflow levels downstream.

During periods of low streamflow, the entire flow of the Souris River could be diverted into the Velva Canal. It would be mixed with project water to be used for irrigation in the Souris Loop Area, and the same quantity or more of good quality mixed water could be returned to the river. This good quality water discharged into the river would displace stagnant poor quality water normally in the river during low-flow periods and would dilute return flows when they accrue to the river without adding large additional streamflow to the river.

The most apparent drawback on this alternative is the physical features that would be required to accomplish the exchange of waters. At the Souris River siphon, the canal is about 125 feet above the river and to get river water into the canal would require either a relatively large dam or a smaller holding reservoir with a large pumping plant. The river grade is less than 1 foot per mile, and a dam high enough to discharge water into the canal would require a reservoir whose tailwater would be near the city of Minot. The reservoir would inundate several miles of the river as well as cropland, woodland, rangeland, etc., and could adversely affect the communities of Velva and Sawyer, North Dakota. A pumping plant large enough to supply water for this plan would approach the size of Snake Creek Pumping Plant and would be very costly.

This alternative appears to be economically, socially and environmentally unacceptable.

Multipurpose Dam and Reservoir on the Souris River

The possibility exists that a multipurpose dam could be constructed on the Souris River to help regulate the effects of return flows being released into the Souris River as a result of development of the Souris Section. The dam site could be located upstream from the city of Minot for the purpose of providing flood protection for the city.

The dam and reservoir could provide a constant water supply for recreation, fishing, flood control, irrigation development both in Canada and the United States, regulation of effects of return flows, and freshening of Souris River during low-flow periods. A multipurpose dam upstream from the Souris Section could regulate flows to provide a stable flow pattern in the river.

Construction of a multipurpose dam on the Souris River could assure Canada a more stable supply of water at a more dependable quality for use by irrigators, municipalities, industries, and rural water systems. Although construction of the dam and reservoir appears rather beneficial to residents downstream in the drainage basin, there would be some critical environmental effects on the river and the fish and wildlife developments presently existing in the Souris River in the United States. Mitigative measures would be required for the destruction of Upper Souris National Wildlife Refuge and wildlife habitat loss on J. Clark Salyer National Wildlife Refuge. Special measures would have to be adopted to prevent foreign rough fish from entering J. Clark Salyer Refuge. Carp are not presently established in the Souris River in the United States. It is assumed that some channel improvement in the river may be required; however, the extent of this improvement is not known. Replacement in-kind of fish and wildlife habitat would be required.

Comprehensive studies would be required to fully analyze the beneficial and negative impacts resulting from construction of a multipurpose dam and reservoir on the Souris River.

Deep Well Injection of Collectable Return Flows

Deep well injection of Souris Section return flows would probably be environmentally unacceptable and may be physically and economically impractical. Existing permeable formations underlying the Souris Section, such as the Dakota Sandstone Formation, contain large quantities of marginal quality water and may have the potential of holding a considerable volume of additional water. The additional capacity that

is available in these sandstone formations is not known; however, it is known that deep wells drilled into these formations will be under artesian pressure. Consequently, all return flows disposed by the use of deep wells would require pumping.

Deep wells in the Souris Section would be to depths in excess of 2,500 feet before the upper layers of the Dakota aquifer could be intercepted. Wells would probably have diameters ranging from 5.5 to 7.0 inches and preliminary investigations by the petroleum industry show that the best wells developed in the area would take about 5,000 barrels (210,000 gallons) per day. Capacity design of well field needed to accommodate disposal of 47,000 acre-feet of return flows would require about 415 deep wells.

The drilling of such an extensive well field to dispose of the collectable return flows appears impractical. Environmental impacts could be immense since it is not known what effects continuous injection into any geologic formation may have due to unbalancing of natural conditions. Also, considerable adverse impacts to the environment could result from installation of the well field. If this plan were implemented, the estimated initial construction cost would be in excess of $20 million and the annual operation and maintenance costs would be about $20 million a year.

Extend the Velva Canal to Canada for Canadian Use

Garrison Diversion Unit water could be conveyed directly to Canada as direct mitigation for any adverse effects return flows from the Souris Section may have on the Souris River. This water could be used by municipalities and industries whose water supplies were affected by return flows from the unit or for the development of new irrigation, industries, or municipal supply.

Approximately 22,000 acre-feet of water could be made available to Canada from offpeak surplus water in the last reach of Velva Canal. Delivery of this water could be made with a 30-mile extension of Velva

Canal to the Canadian border. A canal of 150 ft^3/s capacity would be required to carry this water to Canada. It would cost about $7 million and have an annual operation, maintenance and replacement cost of about $50,000. These costs do not include Canadian regulatory storage, which would probably be necessary. Storage required for irrigation or most M&I uses of 22,000 acre-feet of water would be about 12,000 acre-feet. About 5,000 acres of land could be developed for irrigation with 12,000 acre-feet of water annually.

Another possibility would be to increase the capacity of the Velva Canal to provide more than 22,000 acre-feet of water annually to Canada.

Channelization of the Souris River in Canada

Limited channelization of the Souris River from the vicinity of the international boundary downstream to near Hartney, Manitoba, could provide relief from natural flooding and additional flooding from Garrison Diversion Unit return flows. Channelization accomplished through dredging and construction of berms in the early 1900's from the vicinity of the international boundary northward to a point just south of the village of Coulter, Manitoba, appears to have become relatively ineffective due to a lack of maintenance and has resulted in diminished channel capacity. USGS records at the Westhope gaging station located near the international boundary indicate flooding occurs at flows of approximately 1,200 ft^3/s, while immediately downstream flooding is reported by the Province of Manitoba to occur at flows in excess of 150 ft^3/s.

Widening, deepening and removal of the old dredge berms in this previously-channelized 6-mile reach would be required. The remainder of the stream from just south of Coulter downstream to near Hartney, with the exception of a few constructed meander cutoffs, appears to be in its natural state. Some bank stabilization and construction of additional highwater meander cutoffs with widening and deepening of the lower capacity reaches would be necessary to increase channel capacity through this area.

Historic flow data at Westhope show the majority of higher flows normally occur from April through June. Projection of natural flows during these months with Garrison Diversion return flows indicates that a channel capacity of approximately 3,000 ft^3/s will handle the most frequently occurring flood flows.

Although improvement of the water-carrying characteristics of this flatter section of the Souris River will alleviate all but the most severe flooding, it will have the tendency to shift the problem downstream. Higher flood crests of longer duration on the remaining downstream reaches of the Souris as well as on the Assiniboine River become distinct possibilities.

Cost estimates were not made for channelization of the river. It would probably be economically prohibitive and environmentally unacceptable.

Desalinization Plants for Two Communities in Canada

Presently, the cities of Souris and Portage La Prairie are the only two communities in Canada using Souris River water as a source of domestic and industrial water supply.

Souris Section return flows entering the Souris River will cause problems to existing and potential water users as relates to certain water quality parameters. Conventional treatment plants (precipitation and zeolite types) along the Souris and Assiniboine Rivers are effective for hardness removal, etc.; however, problems occur with a constituent such as sulfate. Return flows will increase sulfate levels in the Souris River and sulfate cannot be removed by conventional treatment plants.

The U.S. Public Health Service and Environment Canada both recommend an upper limit of 250 mg/l of sulfate in waters intended for human consumption. Of the historical monthly values at Westhope, about 70 percent are below the 250 mg/l level, while after Souris Section development about 40 percent of the values will be below the 250 mg/l level. The town of Souris, Manitoba, has a historical median monthly

sulfate level of about 170 mg/l. After development, this level will be increased to about 330 mg/l.

Souris Section return flow effects in the Assiniboine River are diminished because of mixing between the Souris and Assiniboine Rivers. Historical median sulfate value at Portage La Prairie on the Assiniboine River is about 175 mg/l. The 360 mg/l median monthly composite value at Westhope increases the median monthly sulfate level at Portage La Prairie by about 30 mg/l to 200 mg/l. This value is still below recommended sulfate limits.

For the community of Souris, a desalting plant with a capacity of 0.5 million gallons per day would initially cost about $2 million. Annual operating costs would be about $400,000 a year.

Installation of a desalting plant at the community of Souris does not appear to be practical. Although sulfate levels are above recommended limits, they are still tolerable. While return flows may adversely affect sulfate levels in the river, this adverse effect will be partially offset by improvement of other water quality parameters, particularly during periods of low flow.

Control Subsurface Drainage During Winter Months

This alternative plan would be expensive to construct, operate and maintain, and there are no experience data to show that it would be effective. The plan consists of (1) plugging drain outlets during the winter season (November 12 to April 15) and using a collection system similar to the "Reuse" alternative in the Souris Section (plans A-1, A-2 or A-3), (2) plugging drain manholes at each 1-foot rise in pipe invert elevation to prevent flooding downslope, and (3) installing additional drains as necessary and enlarging the outlets to accommodate higher flows in the spring. Controlling drain flows may reduce the annual amount of water conveyed out of the Souris Section which otherwise would be drained out during the non-irrigation season. These flows could be stored in the soil profile and pumped back in the spring for irrigation. The conveyance system presumably would be less costly because it would not have to be designed for winter operation.

In order to accommodate the draining of the irrigable lands during the irrigation season, the total miles of pipe drain and diameters of all outlet pipes must be increased. Total length of spur-type drains which control water levels in low areas adjacent to irrigated lands would increase about 25 percent, and the average mileage cost for the drains would increase about 20 percent to accommodate increases in pipe sizes to handle return flows only during the irrigation period.

The drainage system cannot be plugged by gating the outlets alone. A special manhole and gate would be required at every 1-foot rise in pipe elevation. Without these gates, the water would go to the lower drain elevations, causing seeps on lands adjacent to the drain. The OM&R cost for this alternative system would be about 2 to 4 times the OM&R for the presently planned system.

Some risks would be involved with the implementation of this alternative. The soils of the Souris Section are generally near saturation following the spring thaw. Many years (some in succession) have shown that a large amount of water (snowmelt and rain) must percolate downward toward the water table to enable the farmers to plant crops early in the spring. Should the storage for this water not be available, the farmers may have to endure a complete season with no cash or feed crops in the low portions of their fields. Also, water in excess of what could be stored in the soil profile would have to be handled as surface flows or sub-surface drains operated in such a manner as to eliminate this build-up. This alternative may cause more problems than it would solve.