THE UNIVERSITY OF MANITOBA

A DISTRIBUTION SYSTEM OF IRRIGATION WATER FOR MANITOBA

by

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ABSTRACT

A DISTRIBUTION SYSTEM OF IRRIGATION WATER FOR MANITOBA

This study of irrigation in Manitoba concentrates on the preliminary design and costing of a proposed distribution system. It attempts to define the total water requirements for irrigation in terms of upset or limit values. Arbitrary assumptions on land suitability and availability of water have been made to limit the extent of this study and some of the related subjects are only briefly discussed.

The gross area considered suitable for irrigation in Manitoba equals 6.4 million acres with an average consumptive use requirement of 1.72 million acre feet, an average annual diversion requirement of 4.5 million acre feet and a maximum annual diversion requirement of 15.0 million acre feet. These requirements compare with an estimated available supply of water to this area in the order of 50 million acre feet. It appears that there is a surplus water in the order of 35 million acre feet per year.

Costs of water diverted for delivery to the farm vary from $10 to $58 per acre foot depending on relative location of source and farm. Average costs for the Province are $20 to $30. The economics of canal lining are dependent on the cost of water supplied to Southern Manitoba. The costs in this study are based on water available in the upper Assiniboine River. If all water had to be obtained in Lake Manitoba, all of the foregoing costs would be appreciably higher.

Further study is recommended in the general areas of smaller irrigation district design, methods of water application, use of return flows, drainage improvement requirements, ground water movements, and pumping costs. Also with particular reference to this study, the long term storage requirements, local runoff and return flow use, and the irrigation of clay soils warrant further attention.

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A DISTRIBUTION SYSTEM OF IRRIGATION WATER FOR MANITOBA

1.0 INTRODUCTION

This study of a water distribution system related to irrigation feasibility is part of an overall study on the Water Resources of Western Canada being carried out by the University of Manitoba as an inter-disiplinarian project. The overall project is concerned with assessment of Western Canada water resources and requirements, and the cost and effects of major water diversions to Southern Canada or the United States.

2.0 SCOPE AND LIMITATIONS

2.1 SCOPE

The purpose of this study is to define the extent of potential irrigation in South-Western and South-Central Manitoba as governed by soil types and topography, provide a ceiling type estimate of irrigation water requirements and to estimate the cost of transporting water from the point of supply to the farm fields. Emphasis has been placed on the preliminary design and costing of a major water distribution network for the South-Western and South-Central portions of the province. The detailed classification of land for irrigation and the precise irrigation water requirements are considered to be of secondary importance. The subjects of future land use and irrigation methods are only briefly touched on. Geomorphology and groundwater as related subjects are dealt with to the extent deemed necessary. Water requirements for municipal, industrial and other uses are considered where applicable as these would have significant impact on an analysis of benefits.

2.2 LIMITATIONS

Certain very obvious limitations are inherent in this study due to the large volume of work covered in relatively short period of time. Specifically the following arbitrary assumption is made to limit the extent of this study; the required water for irrigation and other purposes is available in either the Assiniboine River at the Saskatchewan border or in Lake Manitoba. The amount of water available in Lake Manitoba or the Assiniboine River has been estimated by others at 50 million acre feet annually. Local runoff and groundwater derived from both natural precipitation and irrigation return flows have not been used to offset the amounts of water required from outside sources. The values sought in this study for irrigation water requirements are outside or upper limit

2.2 LIMITATIONS - continued

figures and not necessarily design values. These upper limit values have been used in the preliminary design of the water distribution networks. Cost estimates have been prepared without consideration of construction staging and must be considered to have relative value only.

The areas east of the Red River have not been included in this study, the source of supply being from the Winnipeg River and Lake of the Woods, and as such not really related to the prairie water system.

3.0 GEOMORPHIC & HISTORICAL BACKGROUND

3.1 GLACIAL HISTORY OF MANITOBA

The physical features of Manitoba are essentially all of glacial origin. The Ice Age and its associated lacustrine developments have left many land forms as a reminder of the more ancient history of this area. The development of delta areas and lake flats is probably most significant to this study. However, spillway channels and beach areas also merit consideration.

The land area within Manitoba's boundaries has undergone extensive periods of intensive glacial activity. The northern portions of Manitoba have been essentially stripped of the softer sedimentary type rock and exist as exposed igneous rock surfaces. Southern portions of the province are generally covered with 50 - 200 feet of ground moraine or boulder till. Appendix Plan A-1, duplicated in part from the "Economic Atlas of Manitoba"[1] shows the origin of most of the larger overburden types and their relationship to glacial history. (Elson [4] and Davies [6]).

The glacial lake eras, which existed during and after various retreats of the glacier, can be described as 3 lake phases; Lake Souris, Lake Agassiz I and Lake Agassiz II.

The Lake Souris phase, which was partially coincident in time with the Lake Agassiz I phase, was responsible for the development of the Souris basin with its sandy and medium textured soils. It also resulted in the creation of the Pembina River Valley due to the overflow from the Lake paralleling the ice front. The end of the Lake Souris phase came as the ice front retreated northward and erosion cut the narrow Tiger Hills moraine. This resulted in a new outlet for the Souris basin and the abandonment of the Pembina Valley channel.

The Lake Agassiz I phase began at essentially the same time as the Souris Lake Phase, however, it did not end when the latter did.

3.1 GLACIAL HISTORY OF MANITOBA - Continued

The significant developments within Manitoba came later. Retreat of ice front to the north permitted the development of a new outlet for the Assiniboine River. The Assiniboine, which had previously dumped its sediment into the Lake Souris Basin, now flowed eastward and entered Lake Agassiz near Brandon. Large volumes of sediment entering the lake during the prolonged period resulted in the vast Assiniboine River Delta and supplied much of the Lake bottom clays and silts. Well defined beaches(known as Herman Beaches) were formed during this period.

The development of an eastern outlet for the lake is believed to have brought about the end of Lake Agassiz I.

The re-advance of the ice front forced the return of a southern outflow from the lake and brought about Lake Agassiz II.

Agassiz II phase is thought to have been of long duration as indicated by the prominent beach lines known as the Campbell Beaches which exist on both sides of the Red River Valley and extend north of the west side to the Dauphin area. During this period the Assiniboine River cut into the earlier formed delta and began the formation of a new delta at a lower level. This degradation persisted well into modern times, and at progressively reduced lake levels extended the delta eastward. The end result is the somewhat "perched" condition of the Assiniboine channel east of Portage La Prairie. This condition, and the presence of numerous beaches at varying levels, are responsible for some of the drainage problems in the former Agassiz basin.

The significance of the glacial history in this study relates largely to the classification of basic soil types and their suitability for agriculture and irrigation. Glacial origin of various soils is an excellent indicator of

3.1 GLACIAL HISTORY OF MANITOBA - Continued

the success of irrigation and the irrigation water requirements. A major exception, however, is the till soils. These soils do not lend themselves to generalized classifications and must be treated as isolated small units.

The Pembina River Valley is probably the most prominent physical feature created in the glacial era. This valley was created by an ice front river during the Lake Souris and related stages. Other ice front streams resulted in such features as the Dand Channel, Blind Souris Valley and White Mud Creek Channel.

The glacial Lake Agassiz era formed both the upper and lower Assiniboine deltas. The Carberry desert is a prominent result. Epinette Creek represents a large former channel of the glacial Assiniboine River.

3.2 POST-GLACIAL DEVELOPMENTS

The more recent development of the physical land features is related to the existing streams and rivers. These have altered the post-glacial land forms considerably and have also created new forms such as deltas and abandoned channels. Figure A-2 in Appendix "A" shows some of the more prominent physiographic features.

The most recent history related to the physical development of land areas within Manitoba is the clearing, draining, and cultivation of lands suitable for agriculture. As no significant previous irrigation has been carried out in Manitoba, it will be necessary to relate drainage and cultivation practices of dry land farming to this new development. These are the forerunners of irrigation, and as such are an indication of effects to be anticipated. The drainage ditches and channels will serve a vital function in the operation of each and every irrigation system. Problems encountered in this previous phase of development can perhaps be avoided or otherwise the harmful effects can be minimized.

3.3 CLIMATE

The portion of Manitoba under study lies on the borderline between semi-arid and sub-humid regions. The available moisture from precipitation during the average crop growing season is not sufficient to meet evapotranspiration demand. Soil moisture storage is necessary to insure complete crop maturity.

Appendix Map A-3 shows the average annual precipitation distribution. The south-west corner of the province has lower available precipitation and this coupled with higher evapotranspiration losses results in relatively lower success of dry-land farming. Further east, in the Red River Valley, a better precipitation-evaporation balance, aided by ample soil moisture storage, makes for extremely successful dry-land farm operation.

The seasonal variation in rainfall emphasizes the soil moisture storage importance. The following table illustrates this seasonal variation in average precipitation.

TABLE 3.1

AVERAGE PRECIPITATION (INCHES)

LOCATION	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
PORTAGE LA PRAIRIE	.77	.61	.87	1.21	1.95	3.21	2.67	2.23	1.97	1.20	.87	.73
MINNESODA	.77	.66	.84	1.11	1.89	3.11	2.61	2.13	1.63	1.15	.77	.62
SOUTH-WEST	.88	.73	.95	1.17	1.76	3.15	2.40	2.33	1.57	1.11	.88	.79

4.0 LAND CLASSIFICATION

The arable land types in Manitoba are related to essentially four general soil types. These are:

- Lacustrine Clays
- Medium Textured Alluvial Soils
- Sands, Alluvial or Aeolian
- Glacial Tills

The suitability of the above soils for irrigation is dependent on factors such as permeability, topography and texture. Further, suitable land use is limited by the need for urban development, road and drainage works and by farm service areas. The estimated gross acreage for irrigation use of the various land types in south-western and south-central Manitoba is as follows:

Lacustrine Clays	2,000,000	acres
Medium Textured Alluvial Soils	1,800,000	acres
Alluvial or Aeolian Sands	1,700,000	acres
Till Soils	1,000,000	acres
TOTAL	6,500,000	acres

The net irrigation acreage is not likely to exceed 70% of the above values. The classification of soils as suitable for irrigation assumes that generally problems of drainage, lack of soil nutrients, and uncleared condition can be solved. Severe stoniness, salinity and excessive slopes or extremely irregular topography are considered conditions not lending themselves to reasonable solution and as such render land unacceptable for irrigation. Certainly this generalized approach to soil classification is subject to serious faults, but it does offer a relatively simple answer to a very complex problem.

Topographic limitations on the suitability of land for irrigation are dependent on the type of irrigation system proposed. Slopes up to 5% and greater are acceptable for sprinkler irrigation systems, however, slopes of 2% must be considered limiting for flood type irrigation for all except row crop farming. Flood irrigation imposes further limitations on the degree of irregularities and on transverse slope. Irregularities, especially of the hummock form, preclude completely successful flood irrigation. Transverse slope in excess of 0.2% requires re-arrangement of the points of water application.

This study of land classification for irrigation has not been very intensive. Topographic detail obtained from Dominion Topographic Series Maps with a contour interval of 25 feet was used for defining acceptable irrigation land. All unacceptable irregularities will not have been eliminated. The net irrigable land will be lower than indicated.

Appendix Map E-1 shows the areas considered suitable for future irrigation.

The scope of this study is too broad to permit a proper evaluation of special means for irrigation that might be employed in these areas. No consideration has been made of the type of irrigation water application, whether flood, furrow, or sprinkler system, to be used. Each individual area will have its own peculiar problems that require consideration. It is generally anticipated that flood irrigation is more economical where topography and soil conditions permit, but that furrow and sprinkler irrigation are required to solve problems of low or high permeability, adverse topography and drainability.

5.0 IRRIGATION CONSUMPTIVE USE

The water requirements for irrigation are taken equal to the growing season moisture deficit plus water losses. The seasonal moisture deficiencies selected for design purposes are summarized as follows:

	Average Req'ment	Maximum Req'ment	Years Water Req'd
Medium Textured Soils	4.0"	11.4"	80%
Clay and Till Soils	2.0"	10.0"	55%
Coarse Textured Soils	4.4"	11.4"	95%

As illustrated by Appendix Map A-3, the water requirements for the southern portion of Manitoba are generally uniform; the Souris River Valley area being the only significant exception, where lower precipitation and higher evapotranspiration rates lead to requirements 20 to 25% greater than for the more easterly or more northerly areas.

The basic background information used in this section was drawn from Laycock (15), (16), PFRA (7), Sonmor (17), and Underhill (18).

A review of the foregoing reports brought out the following:

- Evaporation from free water surfaces of Lakes and Reservoirs = (0.50-1.30) x Class "A" Pan Evap.
- Evaporation from free water surfaces of Small Dugouts = 0.70 x Class "A"
- Consumptive Use for Various Crops (as per PFRA Manual Table 17) = (0.50-0.68) x Class "A" Pan Evap.

Use of Lake Evaporation Data compares favourably with Consumptive Use Values as Given by Sonmor (PFRA Manual)

The amount of water required for irrigation is dependent on soil types and on crop type, and is further subject to substantial variation from season to season. Laycock's Water Deficiency Patterns in the Prairie Provinces lead to the following general conclusions regarding water requirements in Manitoba based on a 4" soil storage capacity:

- Maximum Deficit approximately 12 inches
- Average Moisture Deficit approximately 6 inches

Appendix Figure C-1 illustrates the effect of storage capacity of soils on average soil moisture deficits. Tables 5.1, 5.2 and 5.3 are abstracted from Laycock (1) to illustrate the relationship of soil type to storage capacity. Appendix Figure C-2 shows the effect of crop type on the water deficits for 4" storage capacity conditions.

The establishment of consumptive use factors for irrigation water requirements is considerably complicated by the crop type. Since crop type influences the length of the time period over which irrigation water must be supplied, it is necessary to set criteria for the purpose of estimating water needs. Future crop selection for the lands within the prairie region is at best guesswork. It has been suggested that wheat or more generally grain crops provide the greatest food value per unit of production cost and therefore can be expected to maintain a position of high demand in the world food market. Forage crops, however, represent a most favourable monetary return for moneys invested in irrigation and will therefore remain in a very competitive position in the near future.

It is deemed necessary to arbitrarily select a water requirement which will be on the high side. The use of a three-month growing season and a water consumption equal to 70% of Class "A" Pan Evaporation results (and approximately equal to calculated water losses from prairie lakes and reservoirs) has been taken for the purposes of this study. It is suggested that a sufficient reserve of water is provided in this manner to insure an adequate supply for the future needs.

A review was made of monthly lake evaporation date for the Winnipeg area as per P. P. W. B. Report #5 and monthly Winnipeg rainfall. The following general assumptions were made:

- Medium textured soils can store sufficient moisture to carry over any surpluses from month to month during the May to July growing season and require irrigation water equal for the net growing season deficit.

- Lacustrine clays can retain moisture on annual basis and require irrigation water only where the annual moisture deficit is greater than average. Fall irrigation to replenish soil moisture may be of considerable value.

- Coarse textured soils cannot retain sufficient moisture to carry surplus moisture from month to month and irrigation water is required to offset any moisture deficits during the May to July growing season.

Appendix Figure C-3 shows the respective annual irrigation water requirements in inches for the three types of soil conditions based on the foregoing assumptions.

Table 5.4 comparison of Winnipeg Precipitation and Evaporation Data, Table 5.5 Summary of Water Requirements (based on Laycock), and Table 5.6 Design Moisture Deficiencies.

TABLE 5.1

MOISTURE CONTENT OF DIFFERENT SOIL TYPES

(INCHES OF WATER/FT. OF SOIL DEPTH)

Soil Text	Pore Saturation	Detention Storage	Field Capacity	Retention Storage	Wilting Point
Sand	5.0	4.1	0.9	0.5	0.4
Sandy Loam	5.0	3.2	1.8	1.1	0.7
Loam	5.0	2.3	2.7	1.6	1.1
Clay Loam	5.4	2.0	3.4	1.7	1.7
Clay	5.4	0.4	5.0	2.5	2.5

TABLE 5.2

INCHES OF WATER AVAILABLE FOR CROPS

FOR DIFFERENT DEPTHS OF MOIST SOIL

Depth of Moist Soil (in.)	Sandy Loam	Loam & Silty Loams	Clay Loam & Silt Loams	Clay & Heavy Clays
1	0.10	0.13	0.15	0.17
6	0.60	0.78	0.90	1.02
12	1.20	1.56	1.80	2.04
24	2.40	3.12	3.60	4.08
36	3.60	4.68	5.40	6.12
48	4.80	6.24	7.20	8.16

TABLE 5.3

WATER STORAGE CAPACITIES FOR VARIOUS SOIL & CROP TYPES

(IN INCHES)

	Cereals (annual)	Forage Crops (perennial)	Forest Trees (early Maturity)
Sand	1	2	6
Sandy Loam	2	4	8
Loam & Silt Loam	3	7	11
Clay Loam	4	8	12
Clay	5	8	11

TABLE 5.4

COMPARISON OF AVERAGE WINNIPEG

PRECIPITATION & EVAPORATION DATA

	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	YR.
Precipitation (Inches)	.89	.85	1.11	1.11	2.17	3.16	3.00	2.49	2.27	1.47	1.11	.92	20.67
Evaporation (Inches)	0.14	0.18	0.42	1.10	1.87	3.90	5.31	5.63	4.68	3.16	0.61	0.22	27.22

TABLE 5.5

SUMMARY OF WATER REQUIREMENTS

(BASED ON LAYCOCK)

Upper Quartile (4" storage) Moisture Deficit

10" + Souris

8" Brandon & Portage

8" + Red River Valley

Maximum Deficit (4" storage)

12" + Souris R. and West Lake

12" - 10" Red River and Inter-Lake

Average Deficit (4" storage)

6" for all of Southern Manitoba

TABLE 5.6

DESIGN MOISTURE DEFICIENCIES

For Medium Textured Soils

Seasonal	Av. Req'ment	=	4.00"	(Water Required 35 of 43 years)
(3 Months)	Max. Req'ment	=	11.38"	

For Clay Soils and Till Soils

Seasonal	Av. Req'ment	=	2.0"	(Water required 25 of 43 years)
(3Months)	Max. Req'ment	=	9.99"	

For Coarse Textured Soils

Seasonal	Av. Req'ment	=	4.42"	(Water required 41 of 43 years)
(3 Months)	Max. Req'ment	=	11.38"	

6.0 TOTAL WATER REQUIREMENTS AND SUPPLY SOURCES

6.1 TOTAL WATER REQUIREMENTS FOR IRRIGATION

The total water requirements for southern Manitoba are essentially based on the irrigation water requirement for an average growing season with allowance for losses due to inefficient use and distribution. Water requirements for municipal and industrial use are minor in comparison with irrigation requirements. Water required for sewage dilution can generally be provided by return flows from irrigation during the growing season. The sewage dilution requirements during the balance of the year will require special releases and are not covered in this report.

The estimated total irrigation water requirements are as follows:

Average Annual Consumptive Use	1,700,000 acre feet
Average Annual Diversion Demand (unlined canals)	4,500,000 acre feet
Maximum Annual Consumptive Use	5,600,000 acre feet
Maximum Annual Diversion Demand (unlined canals)	15,100,000 acre feet

A system of lined canals would reduce the above diversion demand values by 20 to 30%. Consideration of local runoff and return flows from upstream irrigation will reduce the above requirements especially in average years. It is suggested that the total diversion demand for a large irrigation district might rarely exceed the average demand and that the design of the major supply system on the basis of average demand be adopted.

The total irrigation water requirement is made of:

(a). consumptive use
(b). leaching requirements
(c). farm losses due to inefficiency
(d). canal seepage

6.1 TOTAL WATER REQUIREMENTS FOR IRRIGATION - Continued

Consumptive use has been discussed in detail in Section 5.0. Leaching water is required to remove excess salts from the soil strata and in this manner prevent the salinization of the farm soils. The amount usually estimated for this purpose is 10% of the consumptive use (Prof. Murray [8]). Farm losses occur due to such inefficiencies of operation as over irrigation or water wastage. The generally accepted maximum in use efficiency that can be achieved on large scale irrigation works is 60% of the water delivered to the farm. The use of sprinkler systems instead of flood systems might improve this value. Canal losses vary appreciably depending on soil conditions and extent of canal lining, if any. Losses in the order of 30% of the gross diversion has been suggested by Prof. Murray (8) for unlined canals. Lined canals would substantially reduce this value and could in fact almost eliminate this loss. No seepage loss allowance is considered in this study for lined canals. Table 6.1 shows the breakdown of irrigation water requirements for both lined and unlined canals.

TABLE 6.1

IRRIGATION WATER REQUIREMENTS

	Unlined Canals	Lined Canals
Consumptive Use	X	X
Leaching Requirements	0.1 X	0.1 X
Farm Losses	0.7 X	0.7 X
Canal Losses	0.8 X	0
Total Diversion Requirements	2.6 X	1.8 X

X = Consumptive use for a given soil type based on potential evapotranspiration

6.2 RETURN FLOWS

Water used for leaching of soil or water wasted by over irrigation or by operational inefficiencies, returns to the ditches, streams or lakes below the particular irrigation area from which it originated. These return flows could amount to 50 - 60 of the gross diversion. Unless special provision is made for the recovery of this return flow, very little will be re-used. Where drainage systems from an upstream irrigation area discharge into the supply system of another irrigation area, complete re-use might in some cases be achieved. However, the dependability of this return flow for re-use is questionable. The timing of irrigation water application and the time required for return flows to reach a point of recovery preclude the consideration of this water as a dependable source of supply.

Appendix Plan F-1 shows the water requirements for various Irrigation Districts. A summary of these requirements based on unlined canals, by soil type, is as follows in Table 6.2:

TABLE 6.2

ANNUAL DIVERSION REQUIREMENTS

	Average Annual Diversion	Maximum Annual Diversion
Medium Textured Soils	1,550,000 acre ft.	4,400,000 acre ft.
Clay Soils	860,000 acre ft.	4,300,000 acre ft.
Sandy Soils	1,640,000 acre ft.	4,250,000 acre ft.
Till Soils	430,000 acre ft.	2,150,000 acre ft.
TOTALS	4,480,000 acre ft.	15,100,000 acre ft.

6.3 DOMESTIC AND INDUSTRIAL WATER REQUIREMENTS

The present population of Manitoba is under the one million mark. Approximately half of these people live in the metropolitan Winnipeg area. Of the remainder, roughly a quarter of a million live on farms and the balance live in small urban centres.

The distribution of population within the province is changing from a rural to an urban predominance. This change is in part due to the increase in farm unit sizes and the accompanying reduction in the number of farm residences. Another factor involved is the increased importance of mining, manufacturing, and service industries to the economy of Manitoba. Agriculture is no longer the only major production activity.

Figure D-1 illustrates the history of population growth trends for the province. The long term rate of population increases have been as follows:

TABLE 6.3

POPULATION GROWTH AND DISTRIBUTION

LONG TERM GROWTH RATES

	Linear	Uniform Percentage
Manitoba (Total)	10,000/yr.	2% per year
Metro Winnipeg	6,300/yr.	2 1/2% per year
Manitoba (Urban - excluding Metro Winnipeg and Northern communities	1,200/yr.	Not applicable
Manitoba (Rural)	2,500/yr.	Not applicable

6.3 DOMESTIC AND INDUSTRIAL WATER REQUIREMENTS - Continued

The future growth rate for the Manitoba population is difficult to predict. The future distribution of population is perhaps even more difficult to forecast.

Mining and industrial development of the future may bring about increased rates of growth for the centres like Thompson and Winnipeg. Tourism may substantially increase in the future, and with it, the population of certain resort centres will expand. The agricultureal areas of southern and south-western Manitoba, however, are not likely to change their rates of population growth under the present farming systems.

The advent of a large scale irrigation development in the southern portions of Manitoba, will almost certainly bring an increase in the population of these areas. Increased farm labour forces will be required in areas of specialty crop growths. Operation and maintenance will bring additional people and also increased service industry development into the region.

The net effect of irrigation development on Manitoba's population will be an increase in the rate of growth. Table 6.4 shows the assumed growth in population considered for design in this study.

TABLE 6.4

POPULATION ESTIMATES

Manitoba (Urban- excluding Metro Winnipeg and Northern communities	100,000	160,000 (1 1/2% per yr.)
Metro Winnipeg	470,000	1,100,000 (2 1/2% per yr.)
Manitoba (Rural)	360,000	470,000 (2,500 per yr.)
Southern Manitoba		
TOTAL	930,000	1,730,000

6.3 DOMESTIC AND INDUSTRIAL WATER REQUIREMENTS - Continued

Table 6.5 shows the basic design assumptions used in arriving at domestic and industrial water requirements. These requirements have been used for both urban and rural populations, on the assumption that living conditions and water use will, in the future, be more similar for both groups.

TABLE 6.5

WATER CONSUMPTION RATES

Domestic		20 - 50 gpcd
Commercial and Industrial		10 -100 gpcd
Public		10 gpcd
Loss and Waste		20 gpcd
	TOTAL	60 -180 gpcd

Using the maximum value of 180 gpcd, for all population groups, except the rural, where 50 gpcd was used, the following Table 6.6 gives the total water requirements.

TABLE 6.6

TOTAL WATER REQUIREMENTS

FOR DOMESTIC AND INDUSTRIAL USE

	2000 A.D.
Metro Winnipeg	200 mgpd (300 cfs)
Urban Manitoba (excluding Winnipeg& northern community)	30 mgpd (45 cfs)
Rural Manitoba	25 mgfd (35 cfs)
Manitoba (TOTAL)	265 mgfd (380 cfs)

The design value for domestic and industrial water requirements should be somewhere in excess of 380 cfs or 275,000 acre feet per year. The choice of an absolute time element for design does not appear necessary in this study.

6.0 TOTAL WATER REQUIREMENTS AND SUPPLY SOURCES - Continued

6.4 TOTAL WATER REQUIREMENTS

The net effect of domestic and industrial requirements on the total water diversion requirements probably would not exceed 10% and certainly in the event of early rapid irrigation development would be almost negligible.

Since gross land areas were used in arriving at irrigation water requirements, the assumption that domestic and industrial requirements can be met within the estimated average irrigation demands appears justified. No extra water has therefore been allotted for these purposes.

The problem of sewage dilution has not been considered in this study. Certainly with increased water supplies to a given area, the base flow in that watershed should be substantially improved. Whether or not such improvement is sufficient will have to be established by a more detailed study of individual areas.

6.5 SUPPLY SOURCES

The total water requirements for irrigation in Manitoba are based on an average annual 3 month growing season consumptive use. The amount to be provided is equal to 2.6 times the average consumptive use.

This report presumes that the required water will be available as continuous flow in either the Assiniboine River or Lake Manitoba. The supply of water to these systems is not dealt with in this report. The Assiniboine River water comes from the south Saskatchewan River basin, a subject under study in part by Mr. P. Abel. The diversion of northern waters to Lake Manitoba is being covered by Mr. Filmon and Mr. Madder. The water available for southward diversion from Lake Manitoba is estimated at 70,000 cfs continuous.

6.0 TOTAL WATER REQUIREMENTS AND SUPPLY SOURCES - Continued

6.5 SUPPLY SOURCES - Continued

The supply of water for the largest portion of the proposed irrigation areas will come from the Assiniboine River. Points of major diversion and the average annual diversion requirments are as follows:

A.	Between St. Lazare and Virden	190,000 acre feet
B.	Oak Lake	710,000 acre feet
F.	Souris River Valley	765,000 acre feet
G.	Epinette Creek (South of Carberry)	265,000 acre feet
I.	Escarpment to North	660,000 acre feet
H.	Cypress River	155,000 acre feet
J.	Escarpment to South	1,115,000 acre feet

Lesser annual diversions totalling 220,000 acre feet will be made near the Minnedosa River, Little Souris River, Epinette Creek and downstream of Portage la Prairie.

The total average annual water to be drawn from the Assiniboine River is equal to 4 million acre feet or 5600 cfs continuous. An additional 400,000 acre feet will be drawn from Lake Manitoba to serve the Delta area and the Interlake area via the Portage Diversion or the Long Lake Supply Canal.

6.6 POTENTIAL STORAGE SITES

Storage reservoirs are required to convert large or out-of-season available water supplies into useful irrigation season diversion supply quantities. These should preferably be established in lands designated as non-arable either due to soil conditions or topography. The magnitude of the required storage will all but eliminate agricultural activities in the valleys of the Assiniboine and Pembina Rivers. Other river or stream systems will not have such extensive storage requirements.

6.0 TOTAL WATER REQUIREMENTS AND SUPPLY SOURCES - Continued

6.6 POTENTIAL STORAGE SITES - Continued

The most obvious storage sites are located in the valleys of the Assiniboine and Pembina Rivers as illustrated by Figures F-2 and F-4.

Lesser storage sites are located on Pipestone Creek, Stoney Creek, Jackson Creek, Gainsborough Creek and Antler River (Figure F-3). Figure F-5 shows the sites on the Upper Pembina River above Pelican Lake and Figure F-6 locates the proposed reservoirs on Cypress River. In addition to the foregoing, many smaller sites for storage are found on both the north and south escarpments, the Inter-Lake areas and the Minnedosa-Carberry region.

Lake Manitoba has, in this study, been used as a secondary source and storage reservoir of water for irrigation, serving only the Delta and Inter-Lake areas. Conceivably, however, the Lake might in fact be the primary source of water in the event that diversion of more northerly rivers is given early favourable consideration.

7.0 IRRIGATION DISTRICTS

Appendix Plan E-1 shows the areas considered suitable for irrigation sub-divided on the basis of source of supply. EAch district thus created is further sub-divided into soil types. The areas listed on the plan represent total areas in square miles without reductions for land utilized for roadways, canals, ditches, farm service areas, residential areas, etc. The supply of water for irrigation will have to combat some water losses from all these areas in addition to the land cultivation and therefore the entire land areas have been used in calculating water requirements. However, when irrigation benefits are considered, these areas would have to be reduced to the actual acreages under cultivation.

8.0 WATER DISTRIBUTION NETWORKS

8.1 GENERAL

The problem of establishing a distribution network requires intensive study of all aspects of topography, soil conditions, operational methods and controls and road systems. On a study of this extent, such a detailed approach is not practical. A number of simplifying assumptions have been made to reduce the work load but keeping in mind the influence of the above factors on the ultimate cost of irrigation water distribution.

The assumptions are as follows:

(a). The canal systems are sized for the maximum growing season water re-requirements uniformly distributed over a 3-month period.

(b). The main canals are essentially parallel to contour lines spaced at approximately 5-mile intervals, with an average design gradient of 0.04%. (An exception is made for very level acres involving clay-type soils.)

(c). Secondary canals or laterals are limited to approximately 4 miles in length, are perpendicular to main canals or follow section lines and have an average design gradient of 0.16%.

(d). The canals are designed for balanced cut and fill where possible; the dykes have a 2 ft. freeboard and an 8 ft. top width with 4:1 side slopes. (Lined canals utilize steeper side slopes.)

(e). The main canals have a 24' roadway on one side to minimize traffice interference and also to reduce major crossings.

(f). Where possible existing roadways form the required dyke on one side of secondary canals.

(g). The individual laterals have a minimum capacity of 60 cfs for unlined canals and 40 cfs for lined canals to permit a degree of flexibility in the operation of local areas.

8.0 WATER DISTRIBUTION NETWORKS - Continued

8.1 GENERAL - Continued

(h). The number of diversion control structures are limited to 2 per mile of lateral canal.

(i). No direct diversions to farm field from main canals are permitted and control structures on main canals are limited to entrance, overflow and gradient controls.

Appendix Plan F-1 shows the proposed water distribution network and the design requirements.

8.2 CLAY SOIL ACRES

The function of irrigation in certain acres of good clay soils is essentially limited to drought period water applications. Where such an area has a highly developed drainage system such as on both sides of the Red River Valley, the irrigation network would utilize existing drains for water transport. The construction of small check dams permits pumping from these drains to the farm fields. No local storage would be practical, and only sufficient pondage to permit efficient pumping is required. Some deepening of existing drainage laterals is required to permit flow reversals.

The relative proportion of control structures and pumping capacity to channel excavation is higher than in more conventional irrigation systems. However, considerable detailed work would be required in order to properly establish a network for these areas. The same assumptions as above will therefore be applied.

8.3 CANAL LINING

In all soil types, other than clay, the lining of canals is considered to be a very desirable feature for irrigation systems. The cost of lining, however,

8.3 CANAL LINING - Continued

cannot be justified economically, where water is available to an irrigation district at little or no cost.

Lining permits a reduction of the roughness coefficient from 0.030 to 0.015. It also reduces the design discharge capacity by 20-30% due to elimination of most seepage losses. These two factors permit a substantial reduction in the required cross-section area and right-of-way width required for an irrigation supply canal. Costs of crossings, major control structures and pumping installations are also decreased. Where excessive slopes of land result in erosion problems, lining can provide further economics in eliminating grade control structures and at the same time reducing the channel cross-section.

A comparison of the cost unlined versus lined canals is an extremely complicated procedure. Table 8-1 gives a comparison of cost for concrete lined and unlined main canals for various capacities, without considering the cost of pumping or of lining the laterals. The cost effects of bridges, right-of-way, and excavation with and without concrete lining are considered.

TABLE 8.1

COST COMPARISON

CONCRETE LINED VERSUS UNLINED IRRIGATION SYSTEM

Discharge Capacity of Canal		*Cost/Mile		Ratio of Costs
Uplined	Lined	Uplined	Lined	Lined to Unlined
120 cfs	83 cfs	$ 14,000	$ 37,000	2.64
480 cfs	340 cfs	29,000	62,700	2.16
960 cfs	670 cfs	44,800	83,100	1.85
1440 cfs	1000 cfs	56,500	98,400	1.74
2900 cfs	2000 cfs	107,000	153,000	1.43
5800 cfs	4000 cfs	189,000	249,000	1.32
11500 cfs	8000 cfs	346,000	443,000	1.28

* Costs are based on main canals with unit costs as per Appendix "H".

For lateral canals up to 100 cfs capacity, the ratio costs lined to unlined is in the order of 4 to 1. The cost per mile of laterals is approximately $6000 for unlined canals and $23,000 for concrete lined canals.

The effect of lining on pumping cost is rather complicated and difficult to assess. However, diversion works serving 1200 sq. miles from the Assiniboine River West of Brandon requires a capital cost of approximately $30 million for unlined canals and approximately $20 million for lined canals. The permissible cost premium on canal lining amounts to approximately $10 million or roughly $10,000 per mile of canal serving the area, on the basis of capital cost alone. The average annual cost of pumping this water at a power cost of $0.01 per Kilowatt hour is 1.4 million for unlined canals and $1.0 million for lined canals. The annual power saving of $4000,000 at present day interest rates would probably justify an additional expenditure for canal lining of $4-6 million, or $4000-6000/mile of canal.

It would appear that canal lining on an overall basis cannot be justified economically unless water lost through seepage has a value in the order of $25-30 per acre foot at the point of major supply.

9.0 DRAINAGE

Adequate drainage is vital to the satisfactory performance of any irrigation system. Areas of coarser textured soils do not require as extensive drainage systems as the areas of fine textured soils. However, ground water level control is essential in either case. EAch area has its own problems with respect to drainage and in every case a detailed study is required of this aspect. As an example, the Red River Valley below the West escarpment has a well developed artifical surface drainage system. The design of these systems is based on rapid surface drainage of agricultural lands after summer rainfalls. The permeability of the soils in the largest part of this area is not sufficient to facilitate leaching of the soils under sustained irrigation water application. The feasibility of improving permeability requires investigation.

The entire cost of drainage is not necessarily chargeable to irrigation. Some clay soil areas presently under cultivation and would benefit from further drainage works whether or not an irrigation system is developed. Coarse textured soils requiring drainage works to lower the water table for irrigation are not adequately drained at present. Drainage works in areas where irrigation produces an abnormally high water table, are properly charged to irrigation costs.

Irrigation waste waters including leaching and seepage losses, must be disposed of through a proper drainage system. Appendix Plan G-1 shows the areas that most likely will require special drainage measures to insure the proper functioning of an irrigation system. The exact nature of the required drainage works has not been established and would require further study.

10.0 GROUNDWATER

10.1 GENERAL

Groundwater is a factor for consideration in irrigation as a subsurface drainage problem, as a water supply source and as a storage resevoir for irrigation water supplies. No detailed study has been made of these aspects for this report, but attention is directed on these for future study.

10.2 SUBSURFACE DRAINAGE

The problems of subsurface drainage of irrigation lands are considerably aggravated by the presence of a high groundwater level. Depending on the extent of the problem, surface ditching may or may not be a solution. However, a failure to solve this difficulty may lead to a salinization of the soils and render them unfit for agriculture.

10.3 GROUNDWATER AS A SOURCE

Groundwater as an irrigation water supply source has merit providing that an acquifer of sufficient capacity is available at a reasonable depth. The requirement of approximately 600 acre feet per square mile (maximum consumptive demand) must be available. A pumping installation of sufficient size to provide water for one section of land, depending on the depths at which water is available, is expected to cost as follows:

TABLE 10.1

WELL PUMPING COSTS

Pumping Life Req'd	Total Cost/Sq. Mile	Total Cost/Acre
10 feet	$ 2,500	$ 4.00
50 feet	12,500	20.00
100 feet	25,000	40.00
200 feet	50,000	80.00

10.0 GROUNDWATER - Continued

10.3 GROUNDWATER AS A SOURCE - Continued

Pumping depths less than 100 feet would make for an economical groundwater supply for most areas within southern Manitoba.

A further aspect for consideration of groundwater as a source of supply is the amount of dissolved minerals present in the water. Large amounts of salts in the water would create difficulties for lands under irrigation and could probably result in a salinization of the soils.

10.4 GROUNDWATER AS A STORAGE RESERVOIR

To serve as an acquifer reservoir, the sub-surface material must be extremely pervious, extensive in area, at least partially confined by impervious soils adjacent to it, readily available to a source of water supply and within reasonable depths at the point of demand. Areas that might serve for this purpose are located in the Upper Assiniboine River delta, the West side of the Souris River Valley, the Oak Lake area and the Sandilands region of Eastern Manitoba. Smaller areas such as Eskers, Kames, etc. also may function in this fashion.

The cost information provided in Section 10.1 is applicable, but an additional cost of supplying the water and introducting it into the acquifer must be considered. A very preliminary review of this aspect does not indicate a very fabourable cost.

11.0 SUMMARY OF COST ESTIMATES

The following table summarizes the irrigation costs for various irrigation districts. These costs are for the transport only of water to the land from the Assiniboine River or Lake Manitoba.

Irrigation District	Irrigation Cost/Acre of Irrigated Land*	Irrigation Water Costs per Acre Ft.**
A. Upstream ov Virden	$268	$33.70
B. Oak Lake	$250	$37.60
C. Minnedosa River	$168	$25.10
D. Little Souris River	$237	$25.90
E. Spruce Woods	$144	$14.80
F. Souris River	$195	$58.00
G. Carberry Area	$184	$20.70
H. Cypress River	$213	$29.40
I. North Escarpment	$179	$19.10
J. South Escarpment	$150	$24.00
K. Portage la Prairie	$ 85	$ 9.25
L. Lake Manitoba Delta	$ 78	$ 8.80
M. Long Lake	$ 87	$14.60

* Cost based on net irrigation acreage assumed equal to 70% of gross area considered.

** Irrigation water costs per acre foot of water diverted into the irrigation district.

12.0 SUMMARY AND CONCLUSIONS

The total gross area considered suitable for irrigation in the South Western and South Central portions of Manitoba is 6,400,000 acres. Average consumptiveuse for this area is 1,720,000 acre feet per year. The average annual diversion of water required is 4,500,000 acre feet. A maximum diversion requirement in the extreme dry year is 15,000,000 acre feet. This compares with an estimated available supply of water in the order of 50 million acre feet per year.

Using average annual demand for supply sources and storage requirements and maximum demands for canal and pumping station design, this study indicates that the most favourable irrigation acres from a water supply cost view point are located adjacent to water sources and of moderate elevation in relation to the source. The average cost per acre foot of water diverted for delivery in the most favourable irrigation districts is $10 to $15. The average range of cost per acre for the entire province is $20 to $30. The least favourable areas economically are located in the Pembina River Hill Plains with costs up to $58 per acre foot.

Extremely high pumping plant costs and annual pumping costs for large scale diversions dictate that generally the shortest route (elevation wise) be selected. For example the cost of providing water to the Western Slopes of the Red River Valley from the Pembina River over to the escarpment is approximately 50% higher than the selected canal system along the escarpment.

The cost of lining canals is not justified where the irrigation water requirements are available at less than $25 - 30 per acre foot in the Assiniboine River watershed. When costs of providing water to this basin are considered, lining of canals in sandy acres such as Carberry, Spruce Woods and the Upper escarpment regions is worthy of further consideration.

12.0 SUMMARY AND CONCLUSIONS - Continued

This study did not examine individual aspects of the project in any great detail. A number of assumptions were made which may be overly conservative and require more detailed analysis. Each and every aspect of this project requires more intensive analysis. A few specific areas that should provide scope for future studies are listed as follows:

- detailed study of a smaller specific irrigation district with emphasis on the design of the distribution network, the method of water application, the use of return flows and the drainage improvement requirements.
- groundwater movements with respect to irrigation water supply and/or return flows,
- supply of water for irrigation to Manitoba via the Assiniboine River, including the review of long term storage requirements, the use of local runoff and the recapturing of return flows,
- supply of water for irrigation of clay soils including an investigation of fall water applications and its possible reduction of pumping plant, reservoir and diversion canal costs,
- pump capacity cost relationships for large scale projects such as irrigation or flood control.

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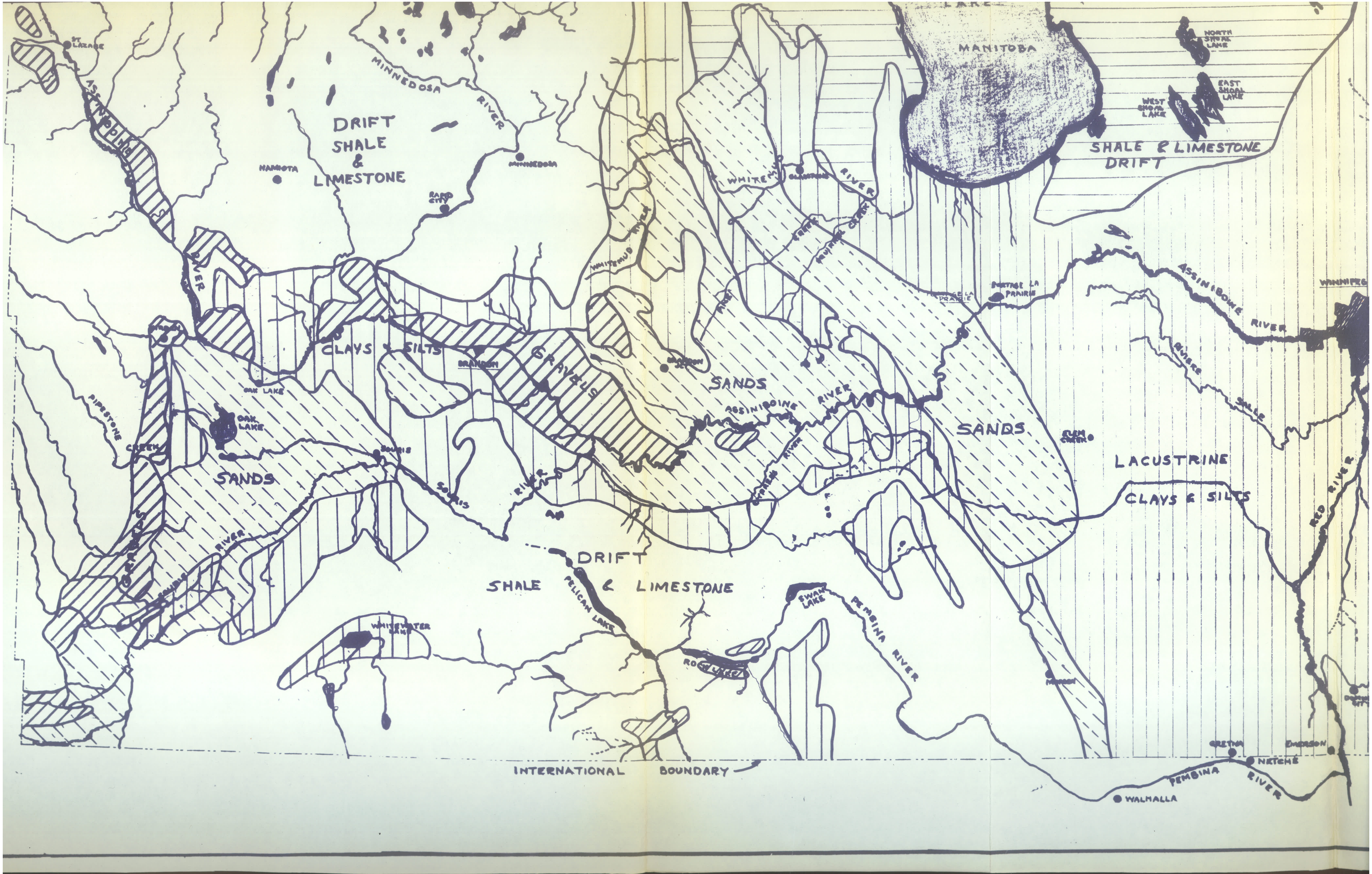
MAP A-1
SURFACE DEPOSITS
IN
MANITOBA


ST LAZARE
MINNEDOSA RIVER
DRIFT SHALE & LIMESTONE
MINNEDOSA
RAPID CITY
MANITOBA
NORTH SHOAL LAKE
EAST SHOAL LAKE
WEST SHOAL LAKE
SHALE & LIMESTONE DRIFT
WHITEMUD RIVER
CLAYS & SILTS
BRANDON
GRAVELS
SANDS
OAK LAKE
PIPESTONE CREEK
SOURIS
SOURIS RIVER
ASSINIBOINE RIVER
PORTAGE LA PRAIRIE
WINNIPEG
SANDS
ELM CREEK
LACUSTRINE CLAYS & SILTS
RED RIVER
DRIFT SHALE & LIMESTONE
PELICAN LAKE
SWAN LAKE
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WHITEWATER LAKE
ROCK LAKE
INTERNATIONAL BOUNDARY
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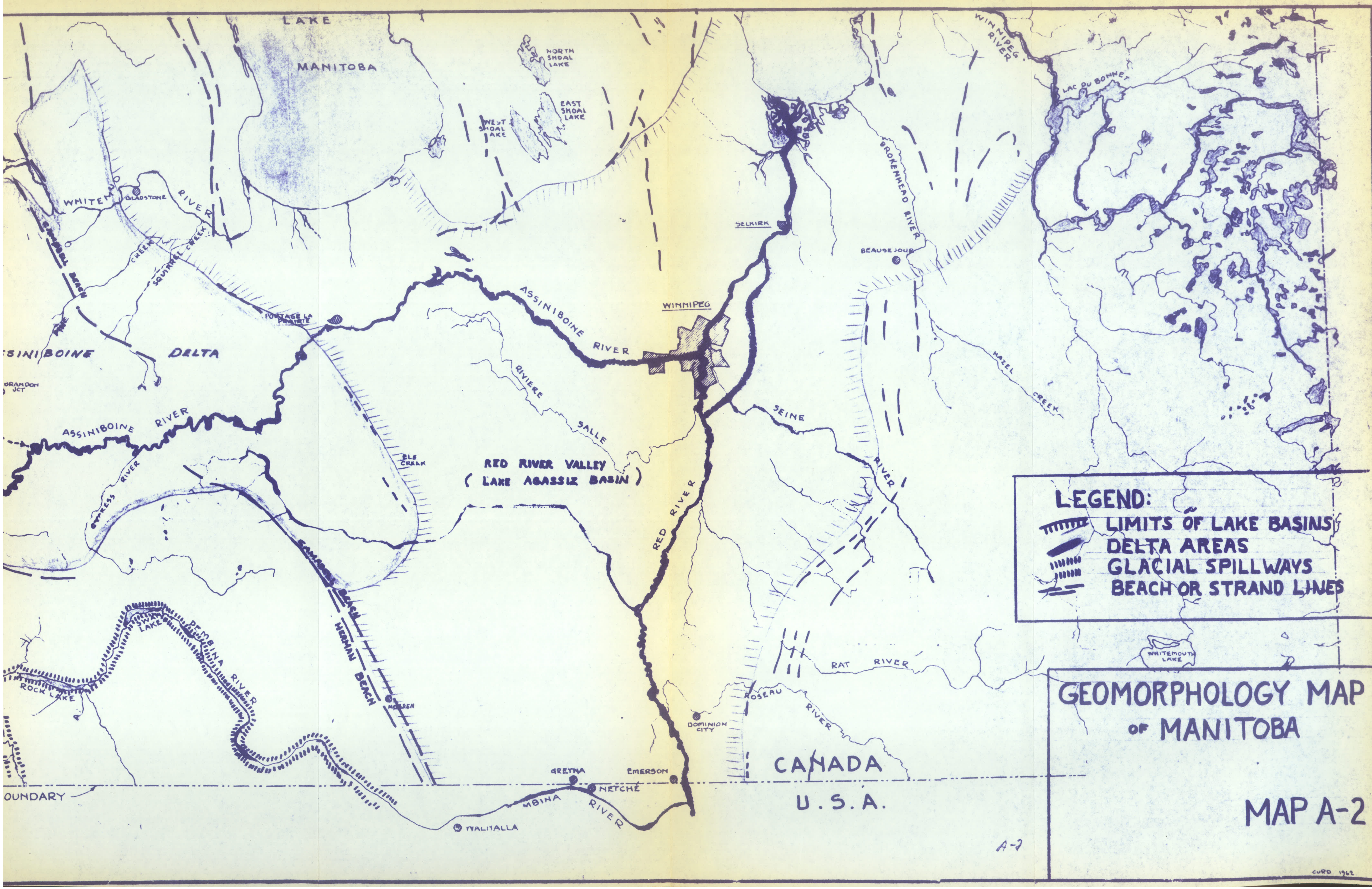
EMERSON
PEMBINA RIVER
WALHALLA


LAKE MANITOBA
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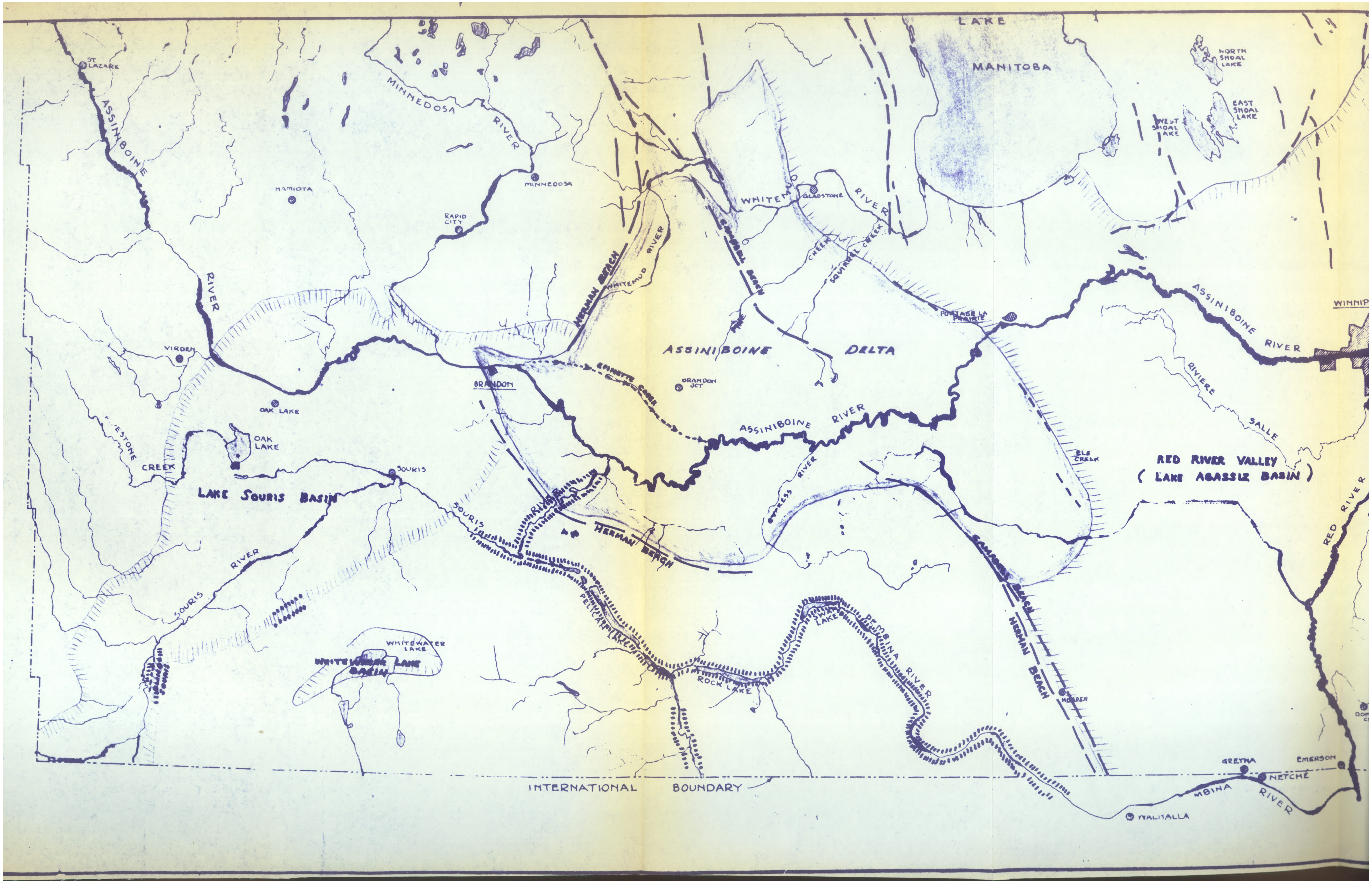
BEAUSEJOUR
BROKENHEAD RIVER
WINNIPEG
RIVIERE SALLE
SEINE RIVER
HAZEL CREEK
RED RIVER VALLEY
(LAKE AGASSIZ BASIN)
RED RIVER
HERMAN BEACH
MORDEN
PEMBINA RIVER
ROCK LAKE
GRETNA
EMERSON
WALHALLA
DOMINION CITY
ROSEAU RIVER
RAT RIVER
WHITEMOUTH LAKE
CANADA
U.S.A.
BOUNDARY
LEGEND:
LIMITS OF LAKE BASINS
DELTA AREAS
GLACIAL SPILLWAYS
BEACH OR STRAND LINES
GEOMORPHOLOGY MAP OF MANITOBA
MAP A-2
A-2


LAKE MANITOBA
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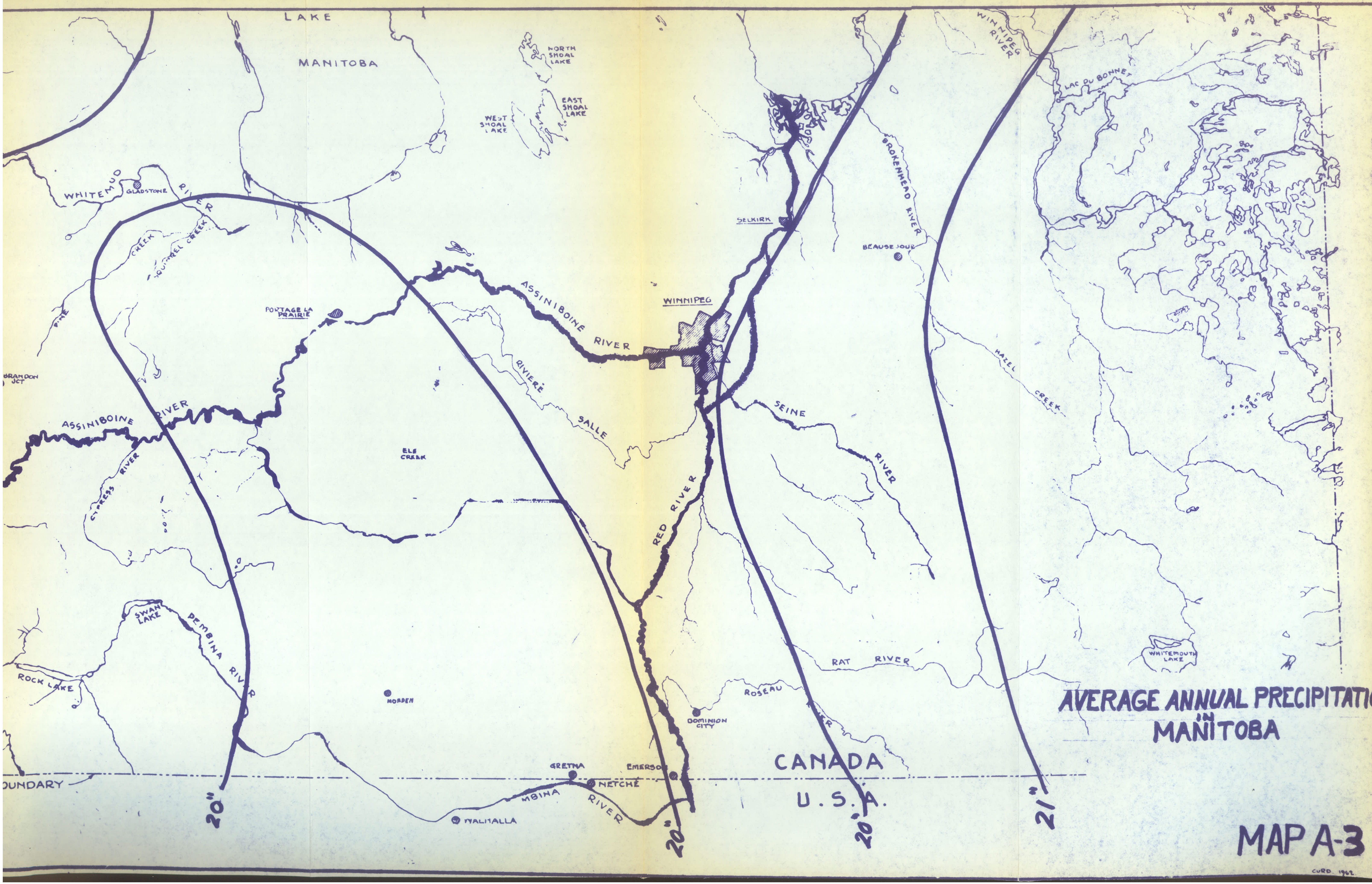

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MBINA
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CANADA
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AVERAGE ANNUAL PRECIPITATIO
IN
MANITOBA
MAP A-3

LAKE
MANITOBA
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WEST SHOAL LAKE
ST LAZARE
ASSINIBOINE
RIVER
MINNEDOSA
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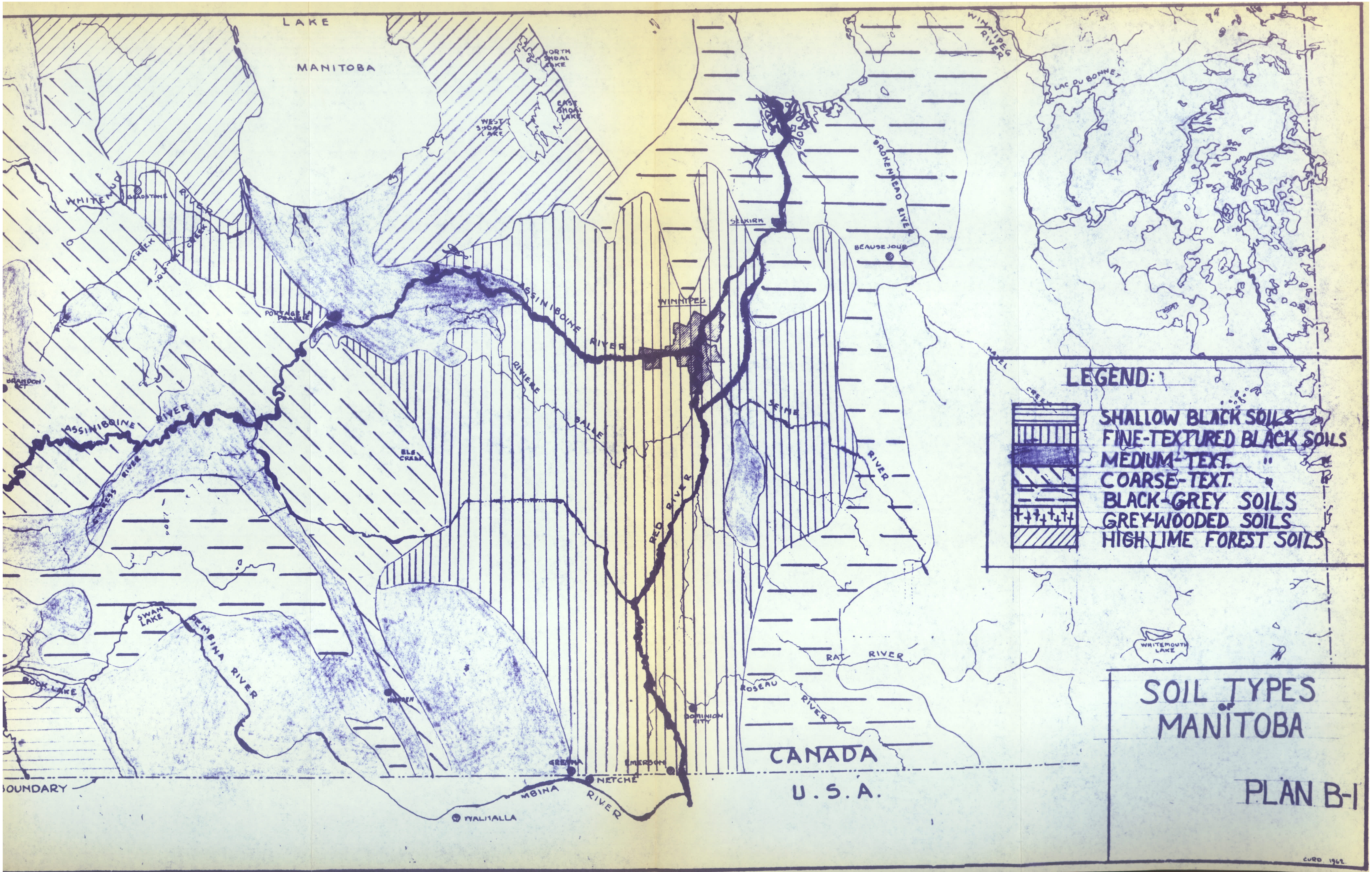

LAKE
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EMERSON
NETCHE
WALHALLA
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BOUNDARY
LEGEND:
SHALLOW BLACK SOILS
FINE-TEXTURED BLACK SOILS
MEDIUM-TEXT. "
COARSE-TEXT. "
BLACK-GREY SOILS
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HIGH LIME FOREST SOILS
SOIL TYPES OF MANITOBA
PLAN B-1
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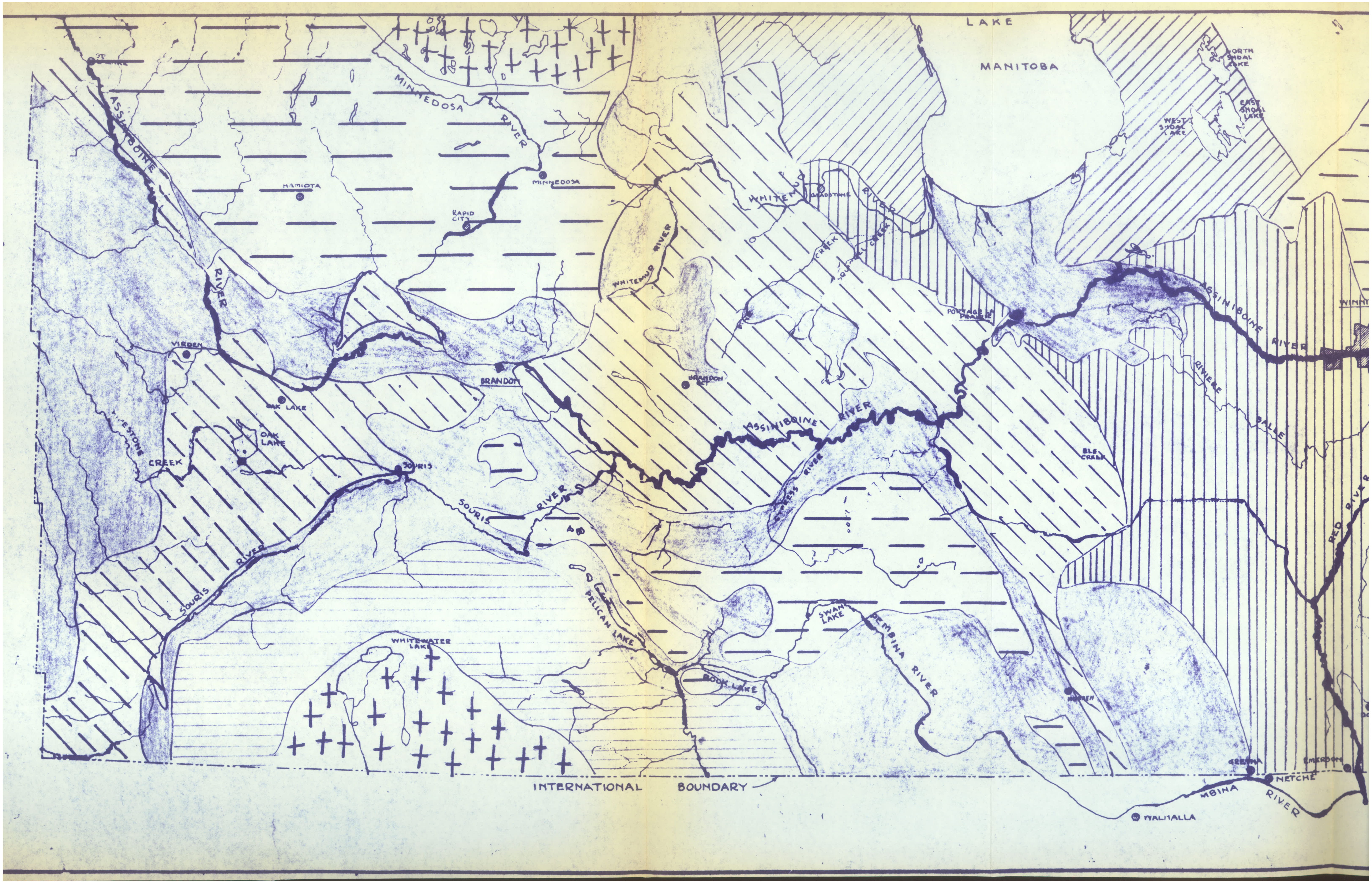
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PORTAGE LA PRAIRIE
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OAK LAKE
OAK LAKE
CREEK
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SOURIS RIVER
ASSINIBOINE RIVER
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RIVIERE SALE
PELICAN LAKE
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INTERNATIONAL BOUNDARY
WALHALLA
RIVER

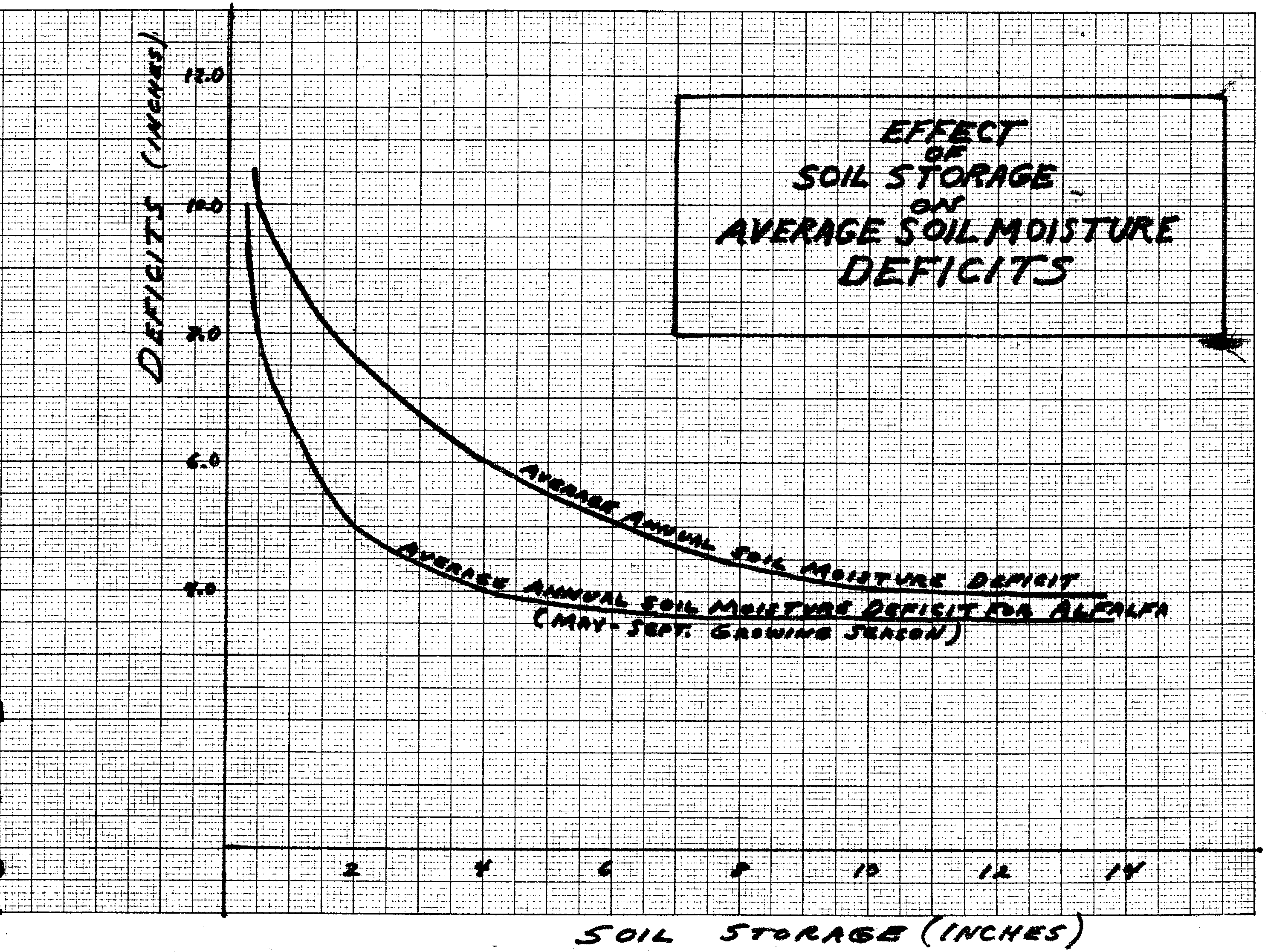
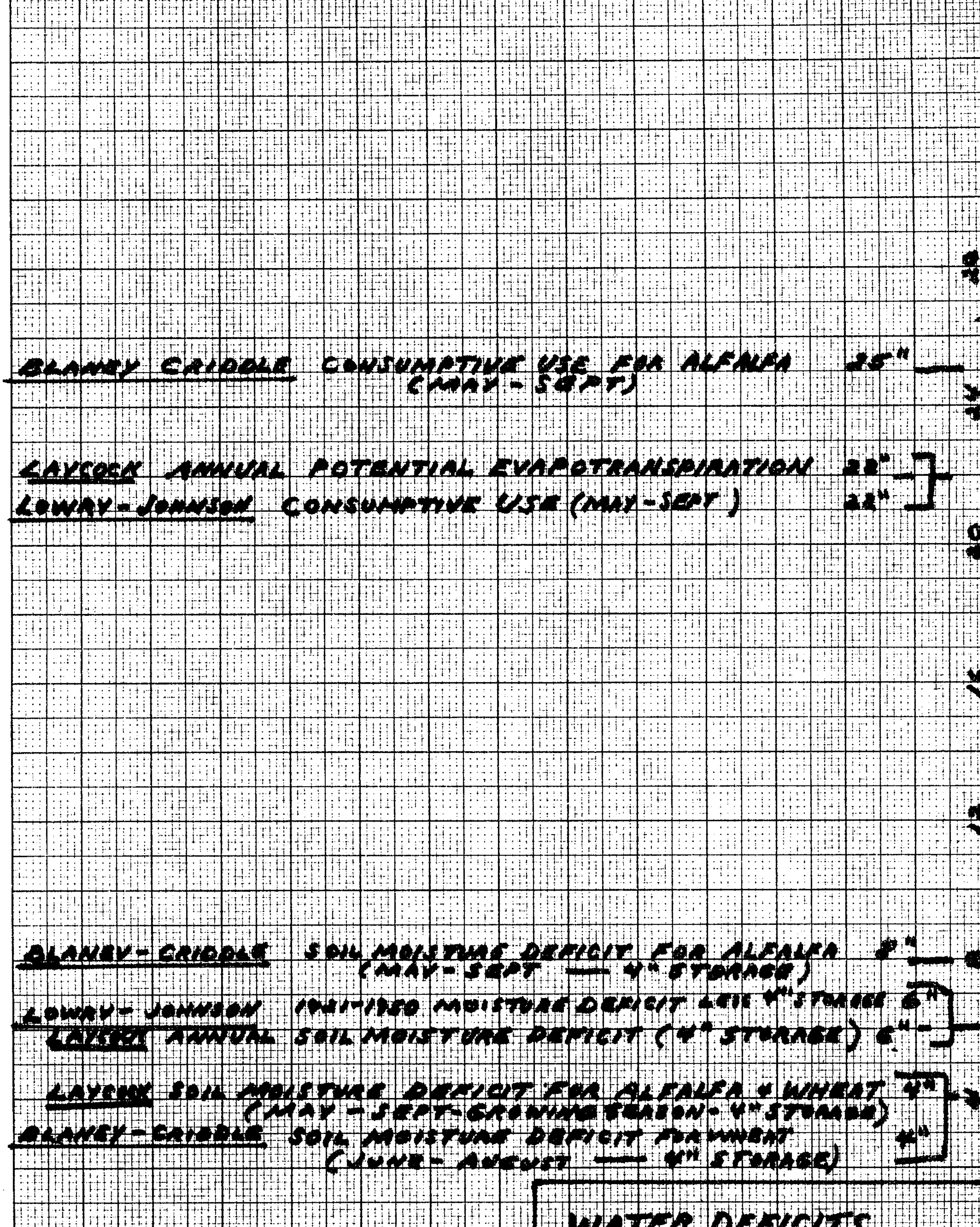
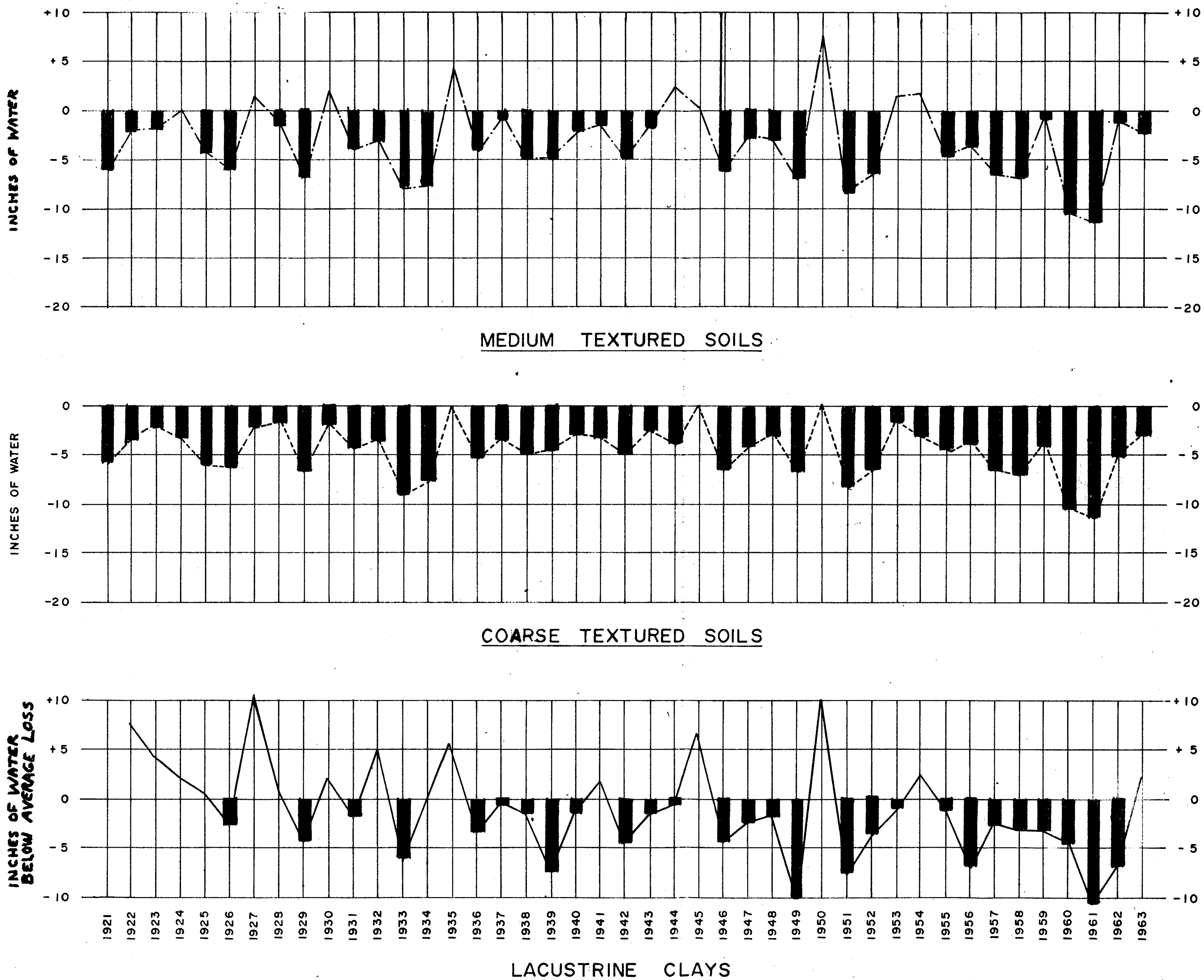

EFFECT OF SOIL STORAGE ON AVERAGE SOIL MOISTURE DEFICITS
DEFICITS (INCHES)
12.0
10.0
8.0
6.0
4.0
AVERAGE ANNUAL SOIL MOISTURE DEFICIT
AVERAGE ANNUAL SOIL MOISTURE DEFICIT FOR ALFALFA (MAY-SEPT. GROWING SEASON)
2
4
6
8
10
12
14
SOIL STORAGE (INCHES)

FIGURE C-1



WATER DEFICITS
FOR
VARIOUS CROP TYPES

FIGURE C-2



NET GROWING SEASON EVAPORATION LOSSES FOR DIFFERENT SOIL TYPES

FIGURE C-3

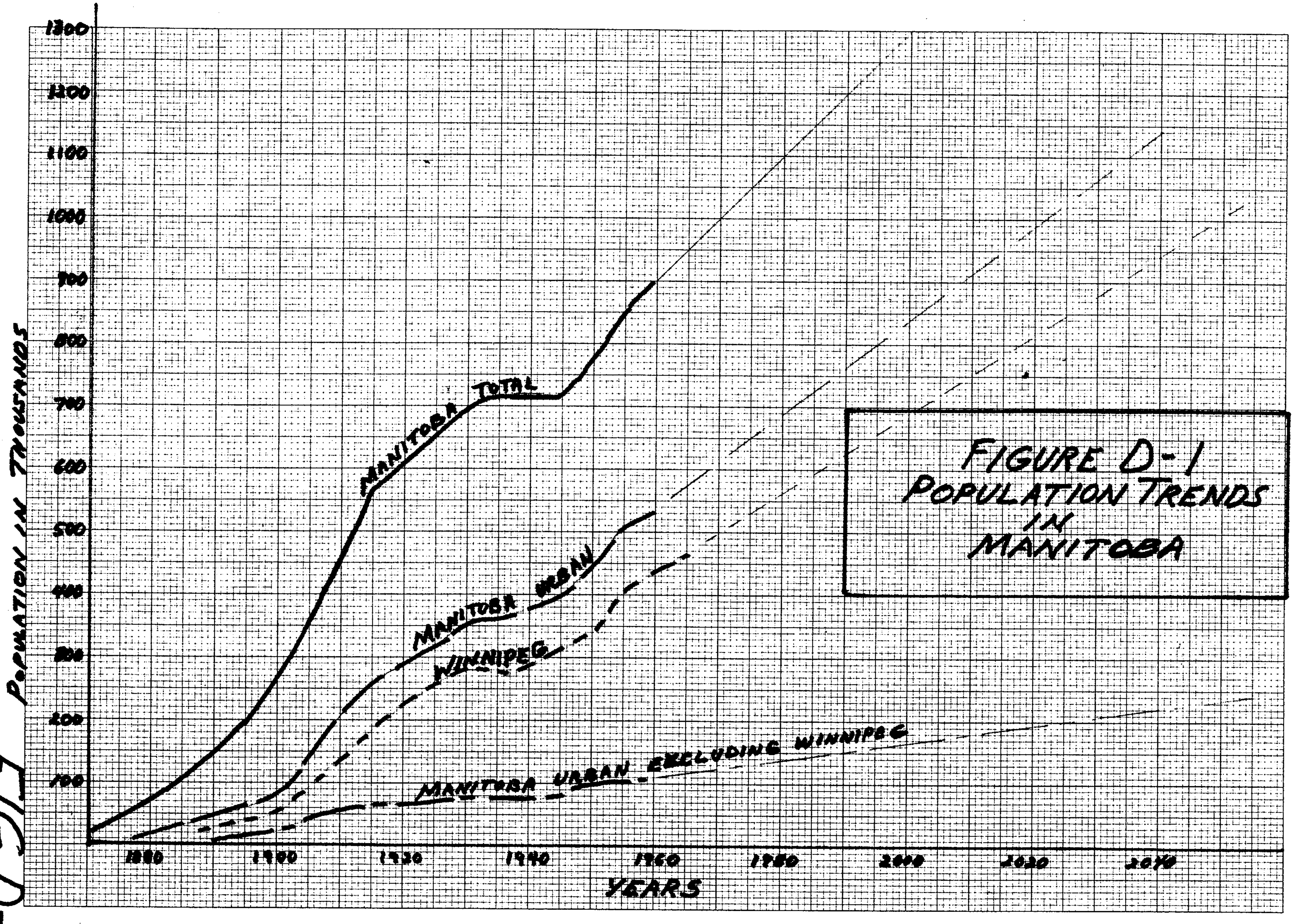
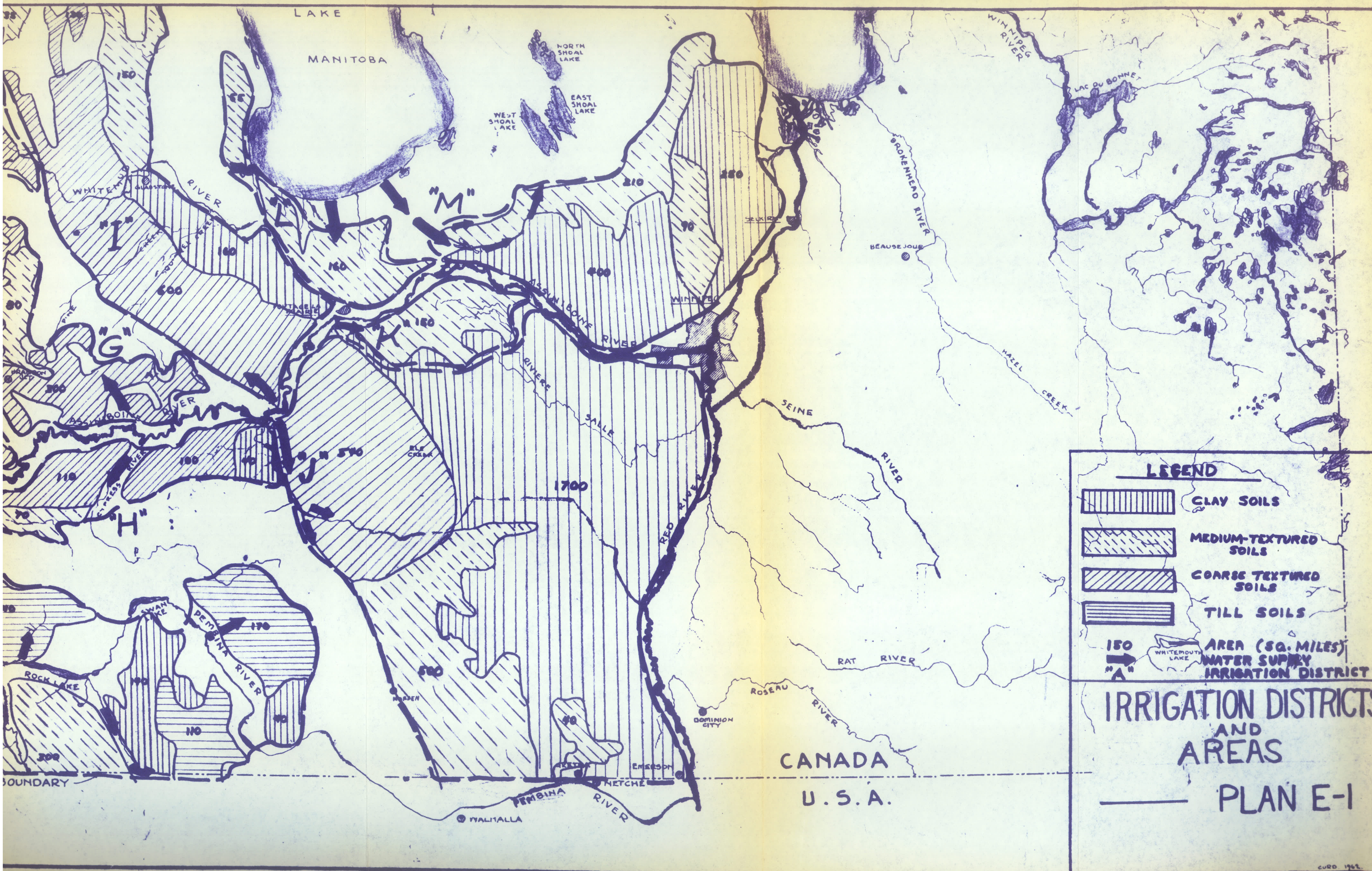
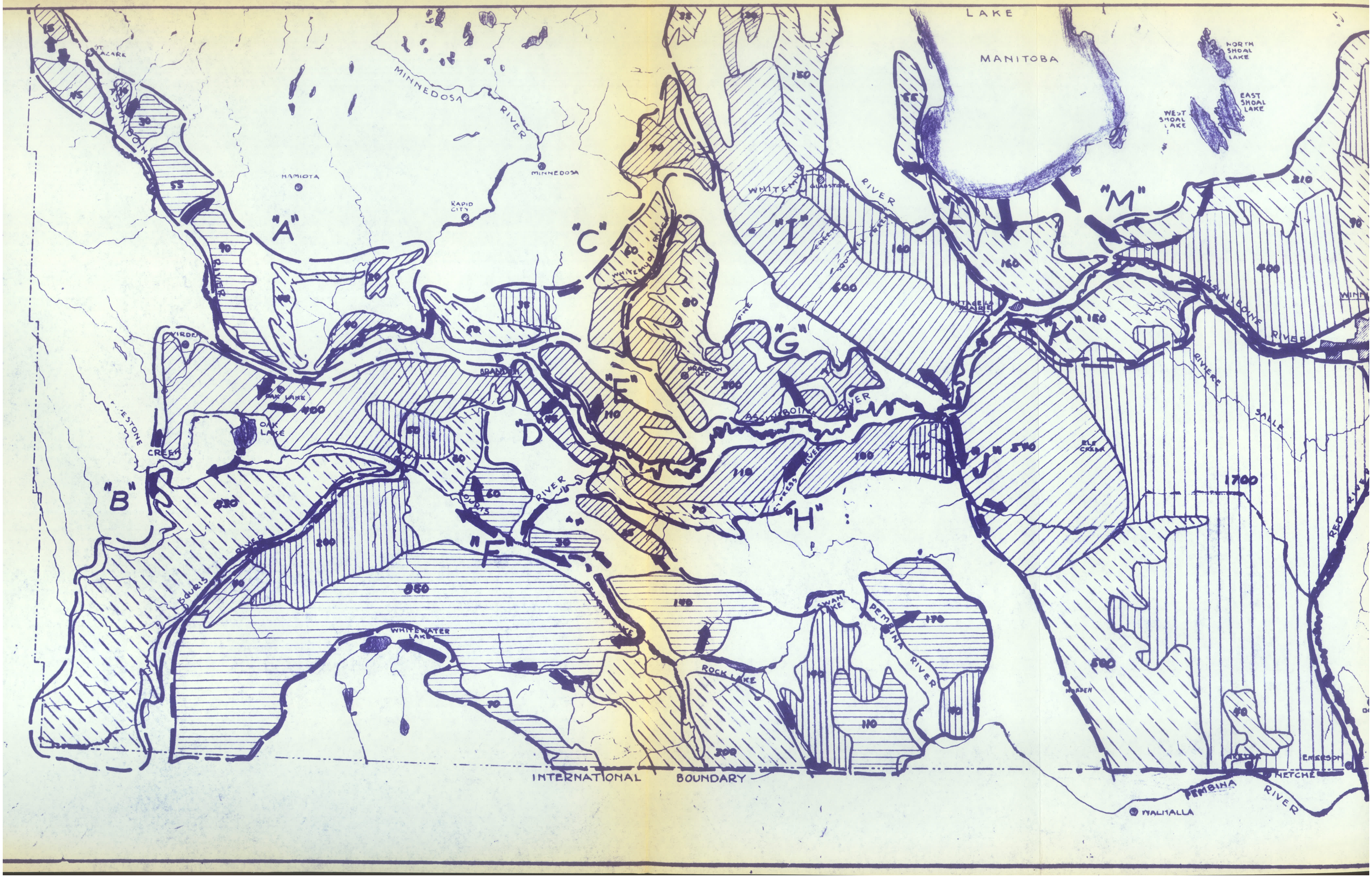


FIGURE D-1
POPULATION TRENDS
IN
MANITOBA

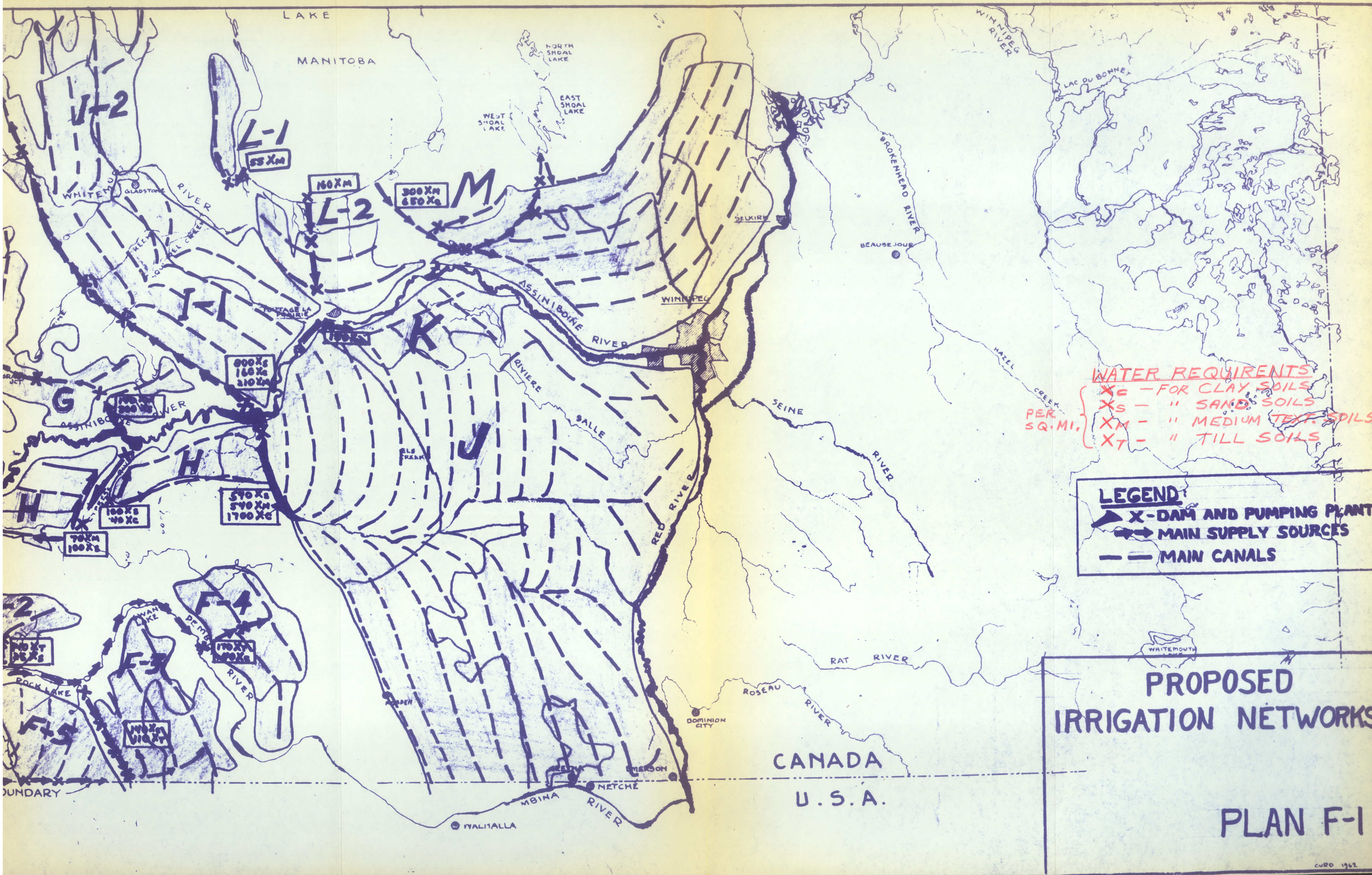
FIG. D-1



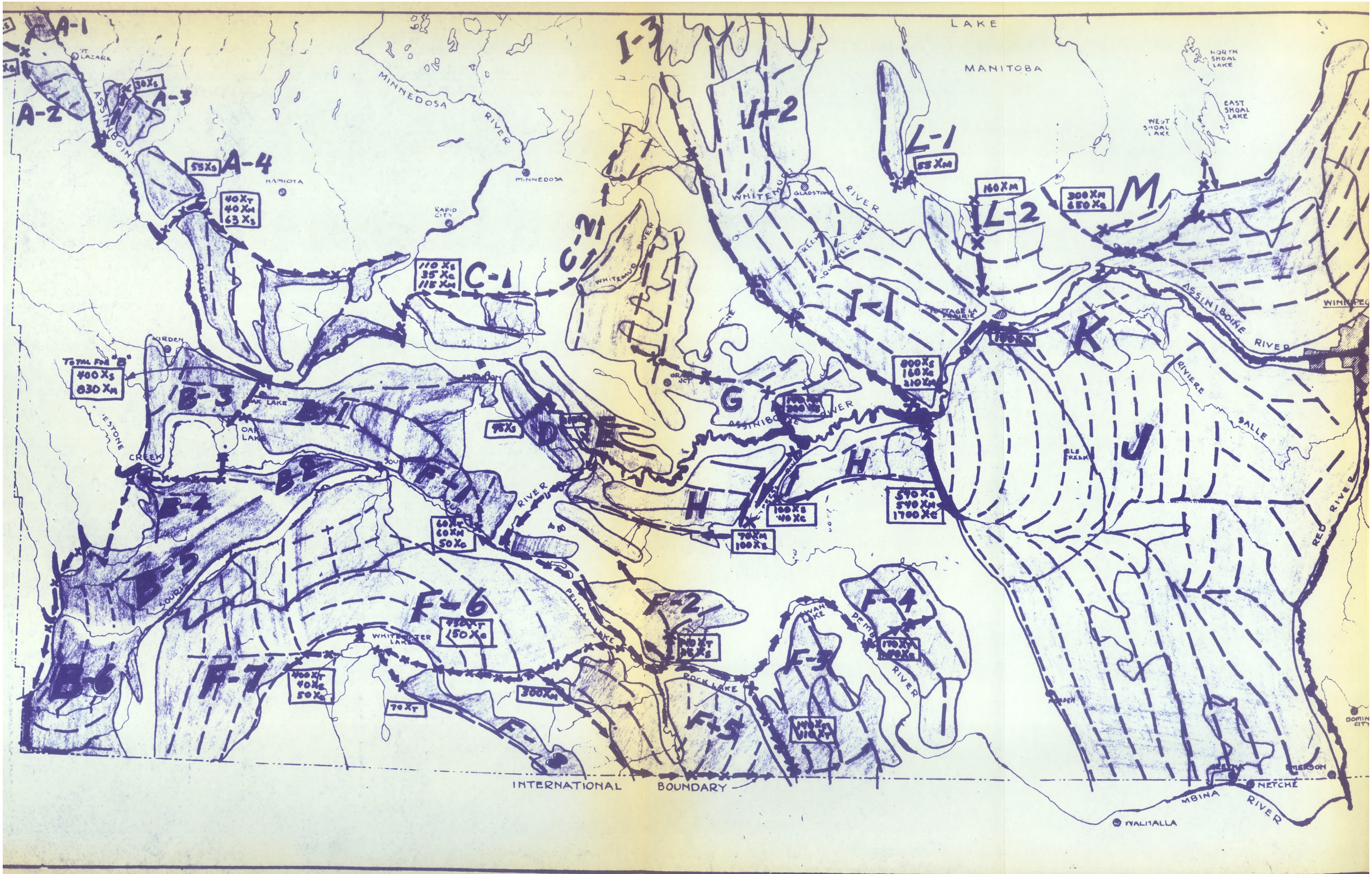
LAKE
MANITOBA
NORTH SHOAL LAKE
EAST SHOAL LAKE
WEST SHOAL LAKE
WINNIPEG RIVER
LAC DU BONNET
BROKENHEAD RIVER
BEAUSEJOUR
SELKIRK
WINNIPEG
"M"
"L"
"I"
"G"
"K"
"J"
"H"
WHITEMUD RIVER
ASSINIBOINE RIVER
RIVIERE SALLE
SEINE RIVER
HAZEL CREEK
RED RIVER
RAT RIVER
ROSEAU RIVER
PEMBINA RIVER
ROCK LAKE
SWAN LAKE
DOMINION CITY
EMERSON
WALHALLA
BOUNDARY
CANADA
U.S.A.
150
210
280
70
160
600
400
150
300
540
1700
100
110
70
170
110
500
40
300
LEGEND
CLAY SOILS
MEDIUM-TEXTURED SOILS
COARSE TEXTURED SOILS
TILL SOILS
150 AREA (SQ. MILES)
WATER SUPPLY
"A" IRRIGATION DISTRICT
IRRIGATION DISTRICTS AND AREAS
PLAN E-1
CURD 1962



LAKE
MANITOBA
NORTH SHOAL LAKE
EAST SHOAL LAKE
WEST SHOAL LAKE
MINNEDOSA RIVER
MINNEDOSA
HAMIOTA
RAPID CITY
"A"
"B"
"C"
"D"
"E"
"F"
"G"
"H"
"I"
"J"
"K"
"L"
"M"
VIRDEN
OAK LAKE
CREEK
BRANDON
WHITEMUD RIVER
RIVER
ASSINIBOINE RIVER
SOURIS RIVER
PORTAGE LA PRAIRIE
RIVIERE SALLE
RED RIVER
WHITEWATER LAKE
ROCK LAKE
SWAN LAKE
PEMBINA RIVER
MORDEN
EMERSON
WALHALLA
INTERNATIONAL BOUNDARY
1700
850
600
540
500
400
300
230
210
200
170
150
110
100
90
70
60
55
50
30



LAKE MANITOBA
NORTH SHOAL LAKE
WEST SHOAL LAKE
EAST SHOAL LAKE
WINNIPEG RIVER
LAC DU BONNET
BROKENHEAD RIVER
BEAUSEJOUR
SELKIRK
WINNIPEG
GLADSTONE
RIVER
PORTAGE LA PRAIRIE
ASSINIBOINE RIVER
RIVIERE SALLE
RED RIVER
SEINE RIVER
HAZEL CREEK
RAT RIVER
ROSEAU RIVER
DOMINION CITY
EMERSON
PEMBINA RIVER
WALHALLA
ROCK LAKE
WHITEMOUTH
BOUNDARY
CANADA
U.S.A.
V-2
L-1
55 XM
160 XM
L-2
300 XM
650 XC
M
I-1
K
J
G
H
F-4
F-3
F-5
800 XS
160 XC
210 XM
540 XS
540 XM
1700 XC
100 XS
40 XC
70 XM
100 XS
WATER REQUIREMENTS
PER SQ. MI.
XC – FOR CLAY SOILS
XS – " SAND SOILS
XM – " MEDIUM TEXT. SOILS
XT – " TILL SOILS
LEGEND
X - DAM AND PUMPING PLANT
MAIN SUPPLY SOURCES
MAIN CANALS
PROPOSED IRRIGATION NETWORKS
PLAN F-1
CURO 1962



A-1
A-2
A-3
A-4
30Xs
55Xs
40XT 40XM 63Xs
ASSINIBOINE
MINNEDOSA RIVER
HAMIOTA
MINNEDOSA
RAPID CITY
C-1
110 Xs 35 XG 115 XM
C-2
I-3
J-2
LAKE MANITOBA
L-1
55 XM
L-2
160 XM
M
300 XM 650 XS
NORTH SHOAL LAKE
EAST SHOAL LAKE
WEST SHOAL LAKE
WHITEMUD
GLADSTONE
RIVER
I-1
PORTAGE LA PRAIRIE
K
ASSINIBOINE RIVER
WINNIPEG
RIVIERE SALLE
J
RED RIVER
800Xs 160XG 210XM
540Xs 540XM 1700XG
G
H
D
E
45Xs
VIRDEN
TOTAL FOR "B" 400 Xs 830 XM
B-1
B-2
B-3
B-4
B-5
B-6
OAK LAKE
CREEK
F-1
F-2
F-3
F-4
F-5
F-6
F-7
60XT 60XM 50XG
450XT 150XG
WHITEWATER LAKE
400XT 40XG 50XG
300XM
70XT
PELICAN LAKE
ROCK LAKE
SWAN LAKE
PEMBINA RIVER
100Xs 40XG
70XM 100XS
INTERNATIONAL BOUNDARY
EMERSON
WALHALLA
DOMINION CITY

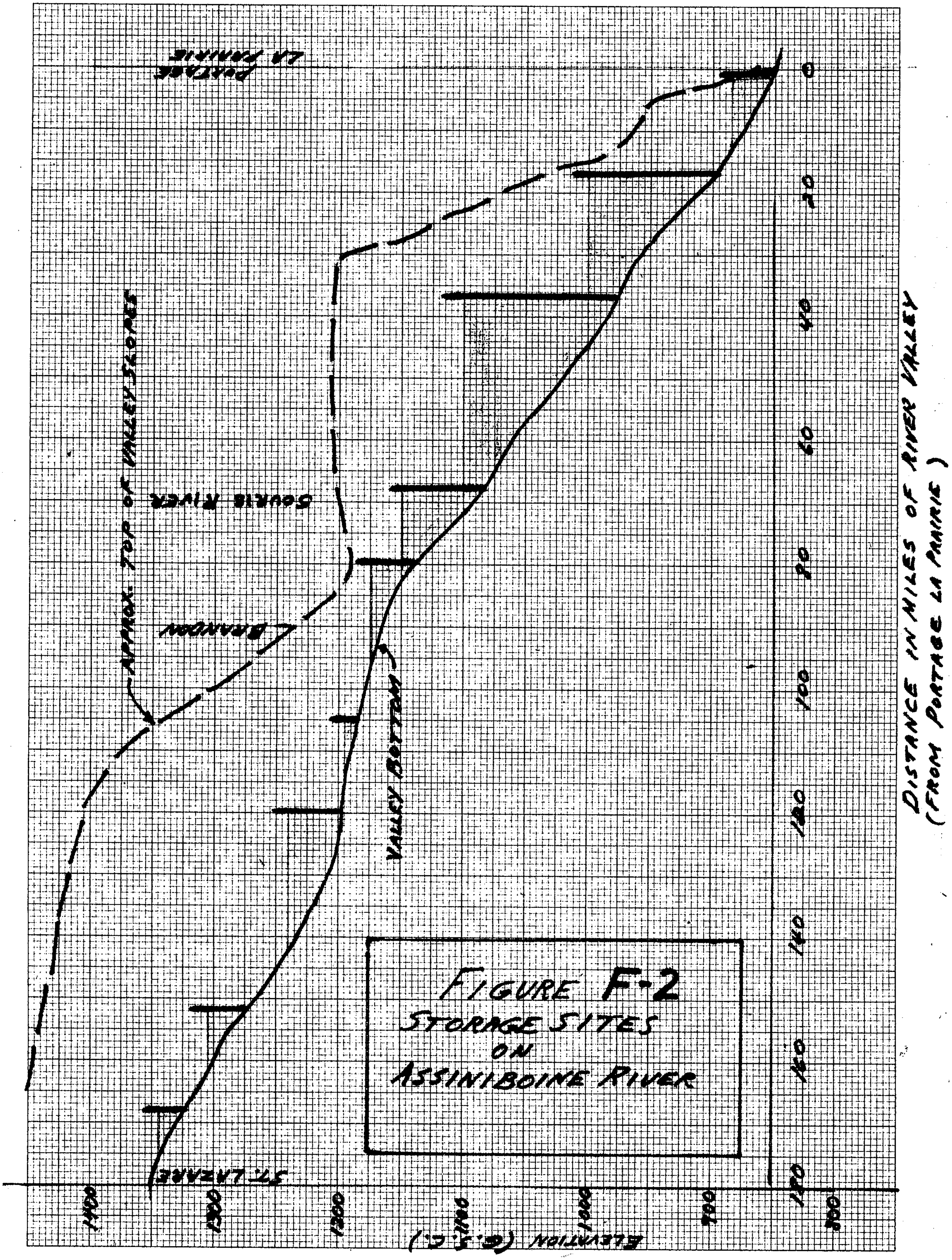
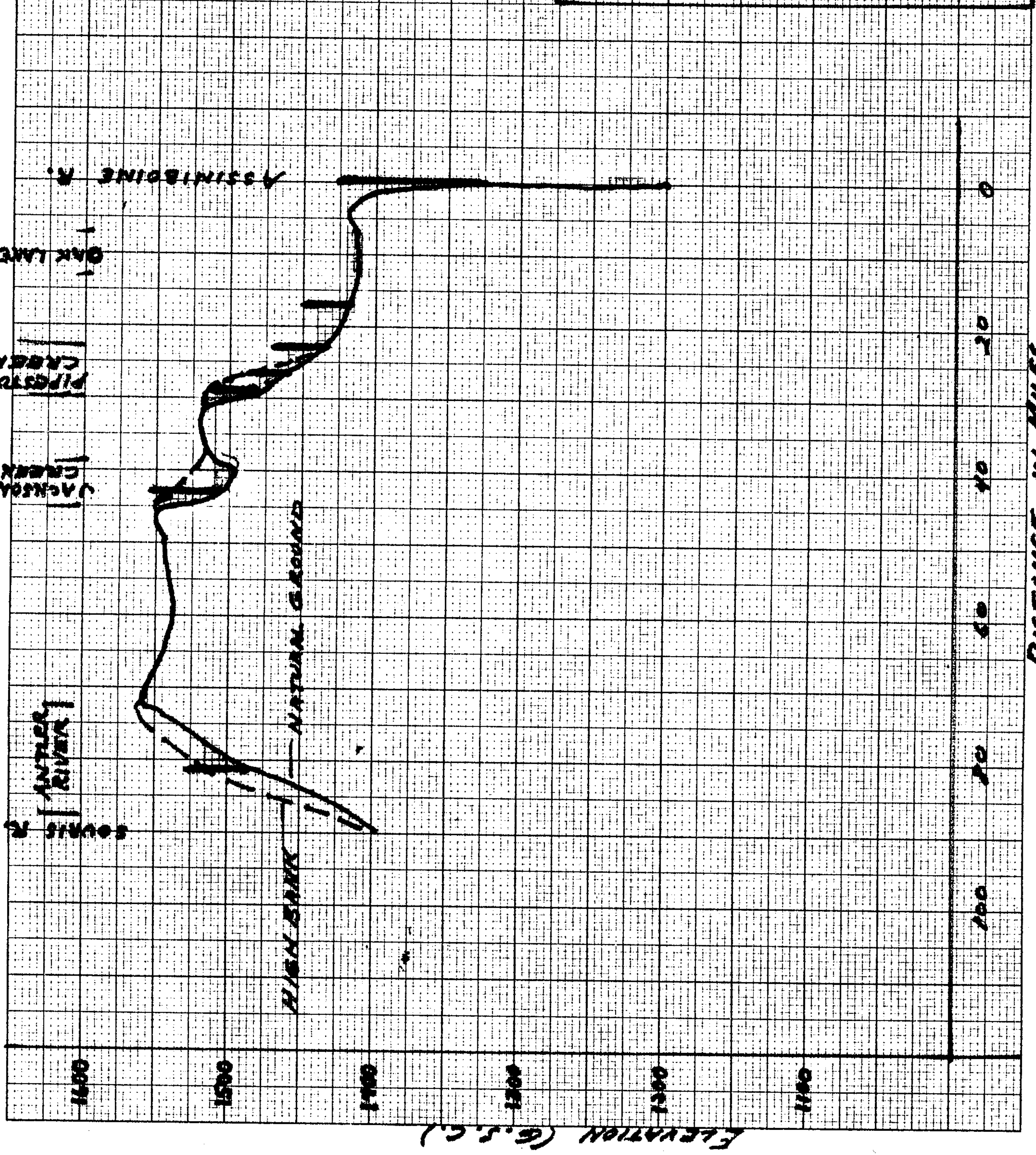


FIGURE F-2
STORAGE SITES
ON
ASSINIBOINE RIVER
PORTAGE LA PRAIRIE
SOURIS RIVER
BRANDON
ST. LAZARE
APPROX. TOP OF VALLEY SLOPES
VALLEY BOTTOM
DISTANCE IN MILES OF RIVER VALLEY
(FROM PORTAGE LA PRAIRIE)
ELEVATION (G.S.C.)
0
20
40
60
80
100
120
140
160
180
1400
1300
1200
1100
1000
900
800

FIGURE F-3
STORAGE AND PUMPING SITES
WEST BOUNDARY OF MANITOBA



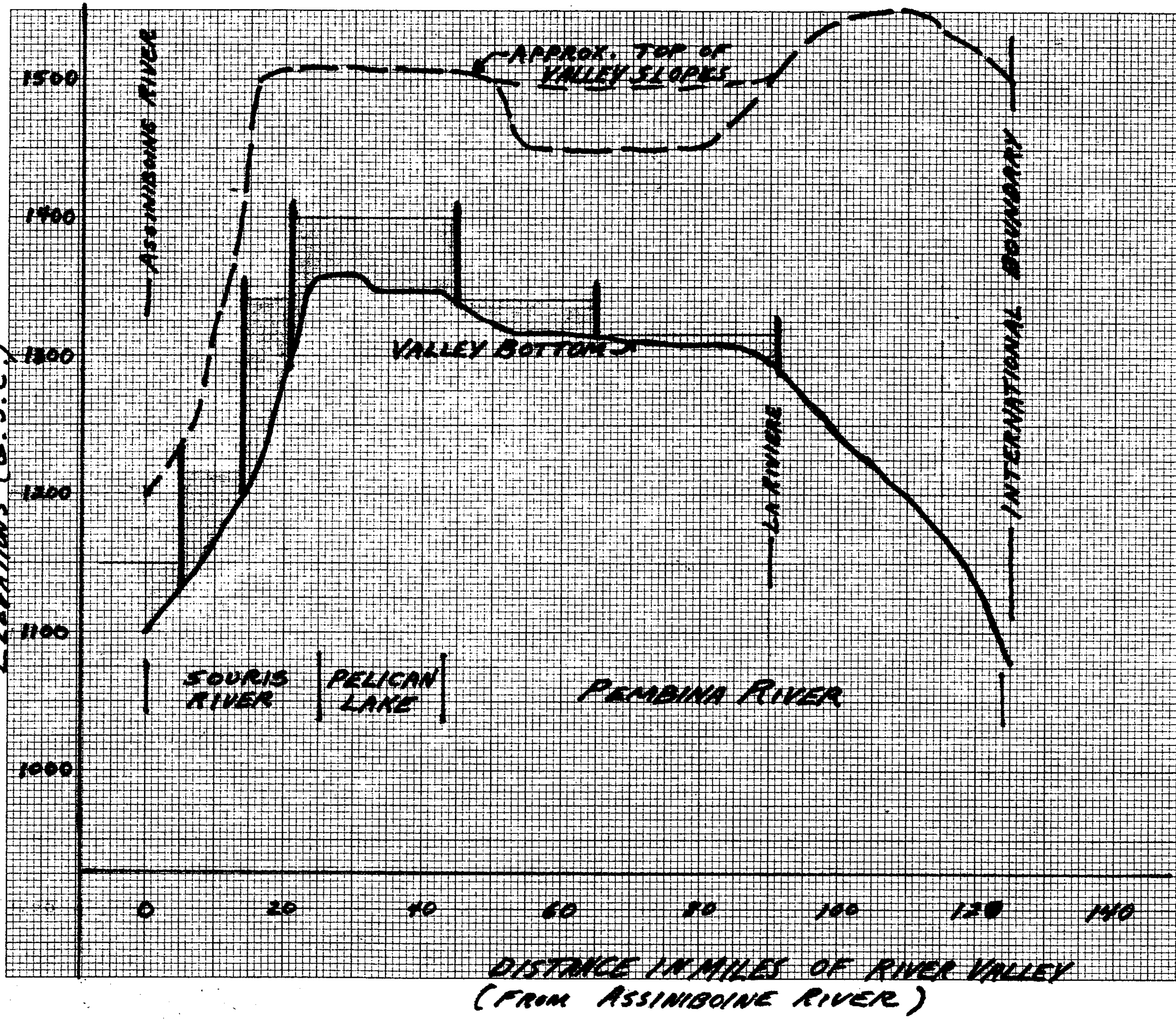


FIGURE F-4
STORAGE SITES
ON
SOURIS – PEMBINA
SYSTEMS

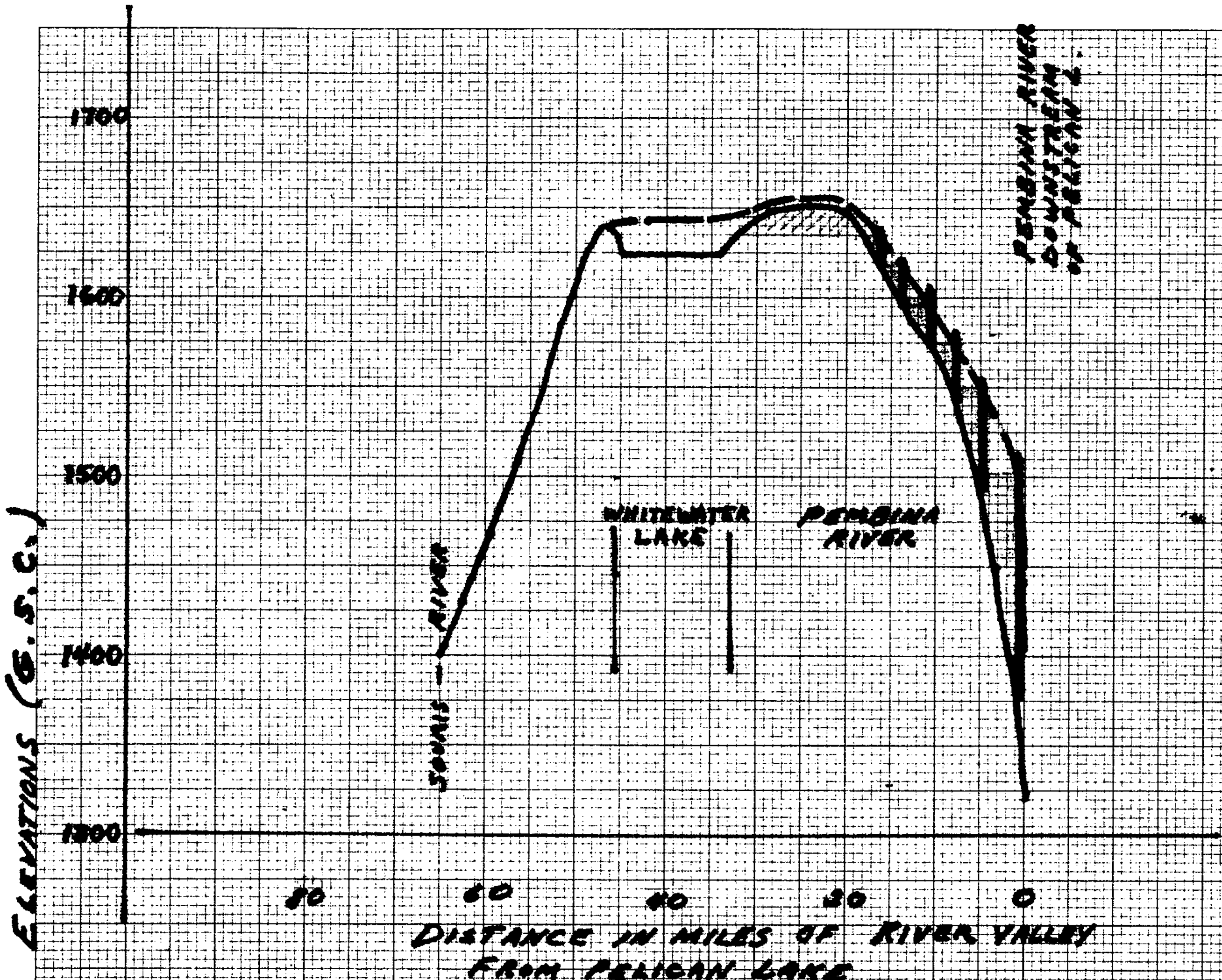


FIGURE F-5
STORAGE & PUMPING SITES ON PEMBINA RIVER UPSTREAM OF PELICAN LAKE

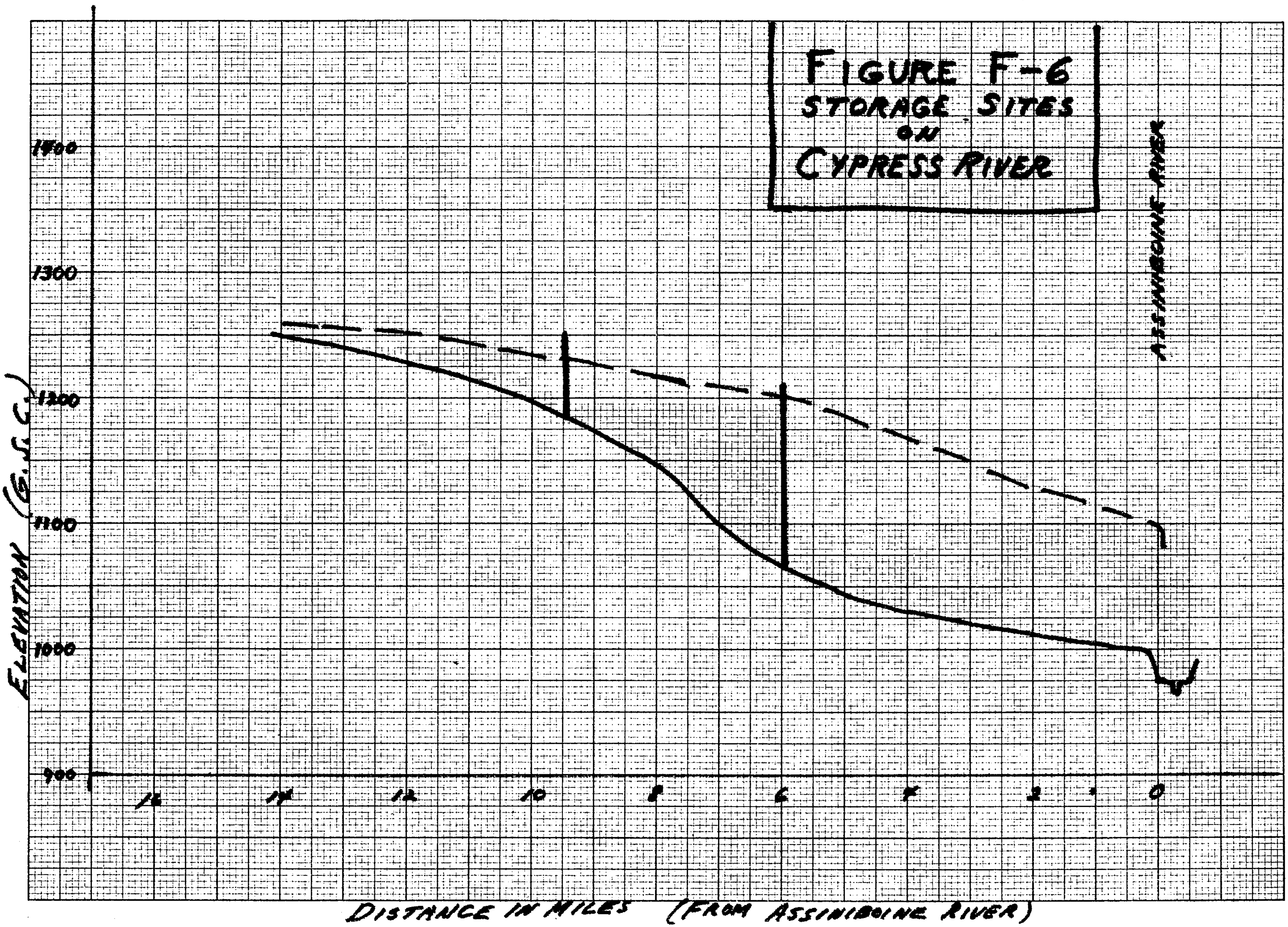
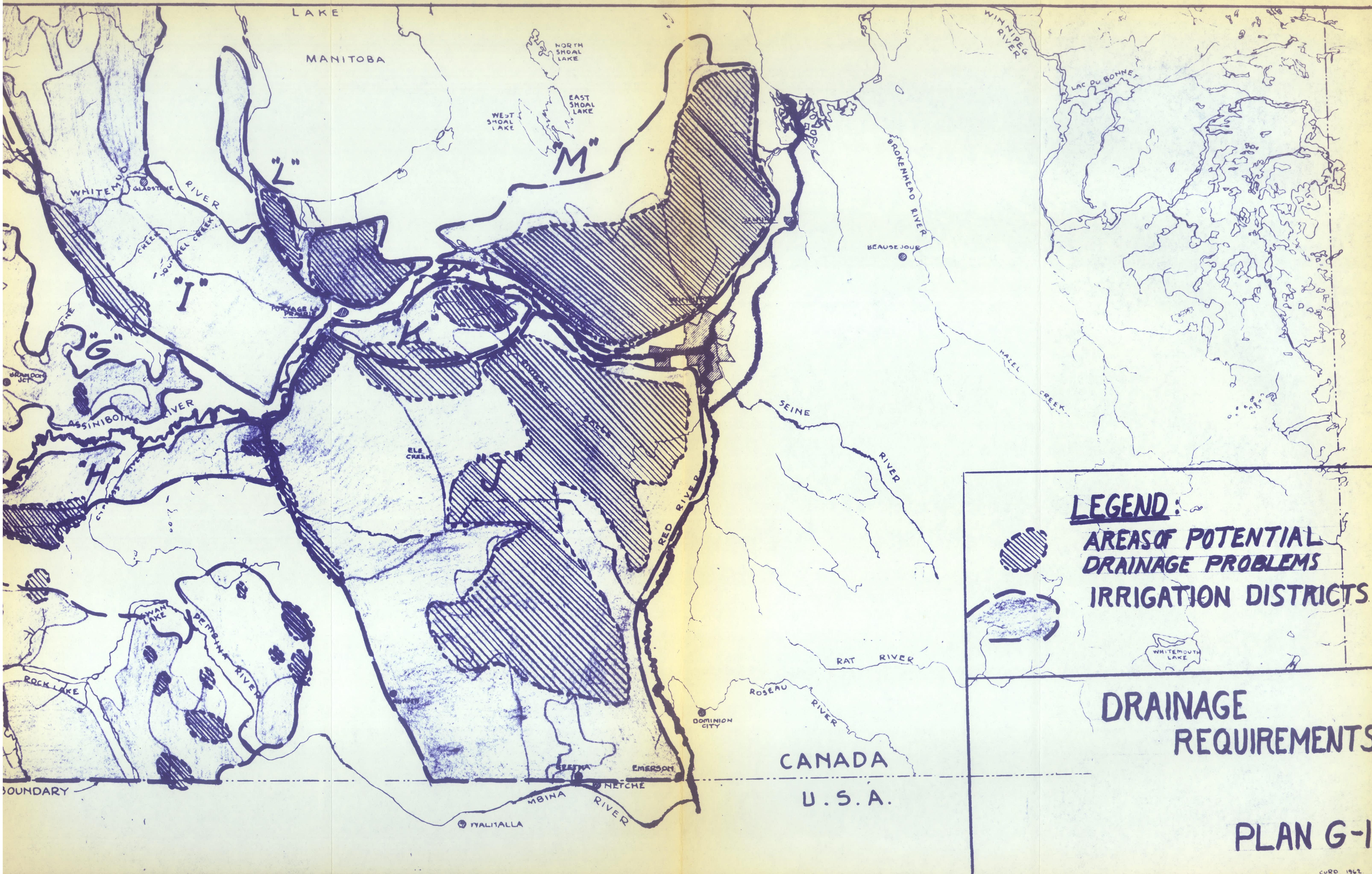
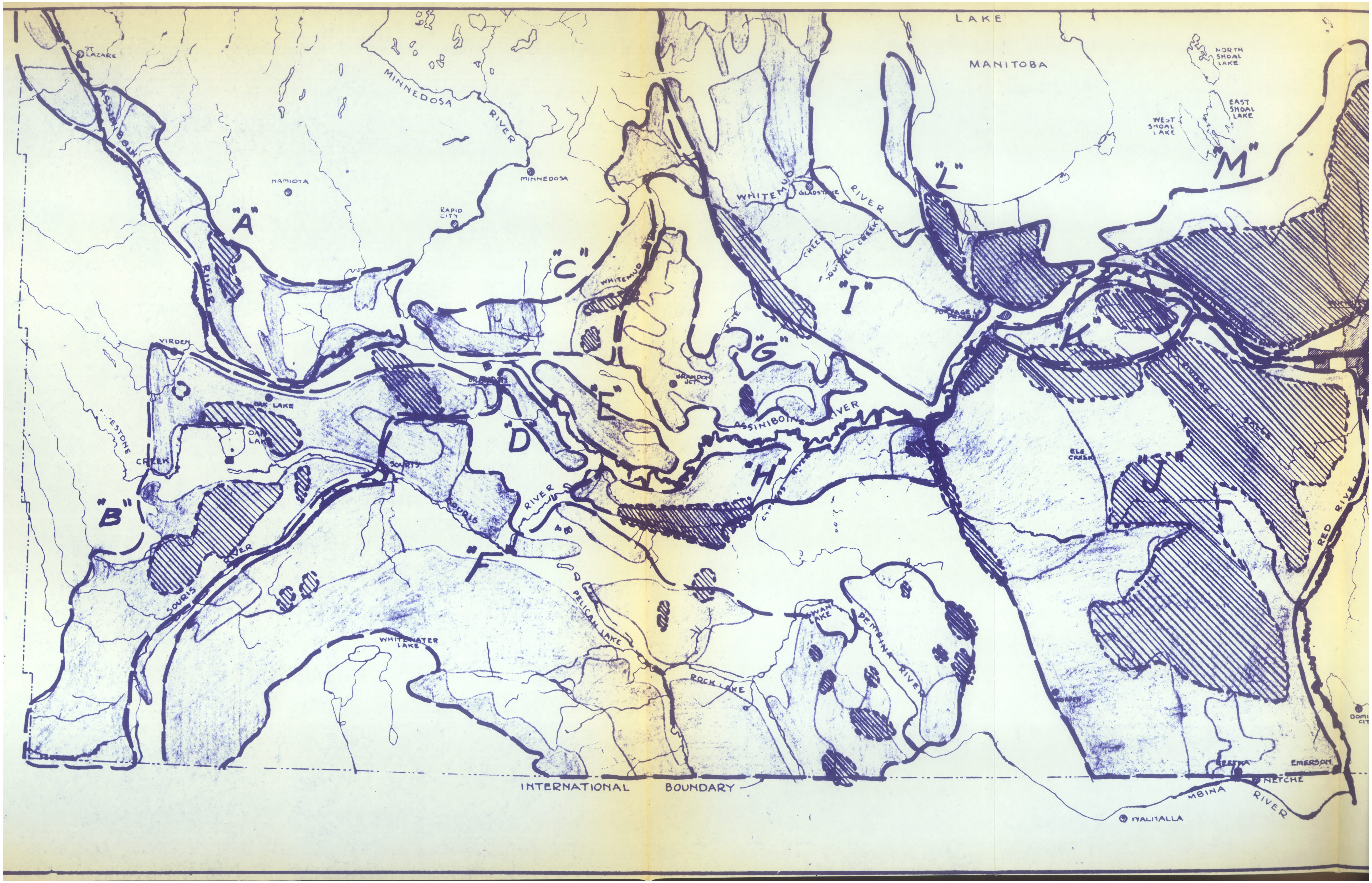


FIGURE F-6
STORAGE SITES
ON
CYPRESS RIVER
ASSINIBOINE RIVER
1400
1300
1200
1100
1000
900
ELEVATION (G.S.C.)
16
14
12
10
8
6
4
2
0
DISTANCE IN MILES (FROM ASSINIBOINE RIVER)


LAKE
MANITOBA
NORTH SHOAL LAKE
EAST SHOAL LAKE
WEST SHOAL LAKE
WINNIPEG RIVER
LAC DU BONNET
"L"
"M"
WHITEMUD
GLADSTONE
RIVER
SQUIRREL CREEK
CREEK
"I"
PORTAGE LA PRAIRIE
BRANDON JCT
"G"
"K"
ASSINIBOINE RIVER
"H"
ELE CREEK
J
BROKENHEAD RIVER
BEAUSEJOUR
HAZEL CREEK
SEINE RIVER
RED RIVER
RAT RIVER
ROSEAU RIVER
DOMINION CITY
WHITEMOUTH LAKE
SWAN LAKE
PEMBINA RIVER
ROCK LAKE
BOUNDARY
EMERSON
CANADA
U.S.A.
MBINA RIVER
WALHALLA
LEGEND:
AREAS OF POTENTIAL DRAINAGE PROBLEMS
IRRIGATION DISTRICTS
DRAINAGE REQUIREMENTS
PLAN G-1
CURD 1962


LAKE
MANITOBA
NORTH SHOAL LAKE
EAST SHOAL LAKE
WEST SHOAL LAKE
"M"
"L"
ST LAZARE
MINNEDOSA RIVER
MINNEDOSA
HAMIOTA
RAPID CITY
"A"
RIVER
"C"
WHITEMUD
GLADSTONE
RIVER
"I"
"G"
VIRDEN
BRANDON
"E"
OAK LAKE
"D"
ASSINIBOINE RIVER
CREEK
"K"
"J"
"B"
SOURIS
RIVER
"H"
"F"
SOURIS
RIVER
PELICAN LAKE
WHITEWATER LAKE
ROCK LAKE
SWAN LAKE
PEMBINA RIVER
RED RIVER
INTERNATIONAL BOUNDARY
EMERSON
RIVER

APPENDIX "H"

COST BACKGROUND INFORMATION AND DETAILED COST ESTIMATES

H-1.0 Cost Background

A summary of the relevant cost information used in this study is included. The cost information is broken down as follows:

(a) Right-of-Way

The cost of right-of-way is extremely variable. Some of the lands required for this irrigation system are crown land with only nominal costs of acquisition, others are marshland of low value, while still others are prime agricultural properties valued at several hundred dollars per acre. In this study a constant value of $100.00 per acre has been placed on all right-of-way to be purchased.

(b) Canal Construction

The estimated cost of canal construction is based on the following:

- excavation @ $0.40 per cubic yard,
- concrete canal linings @ $0.40 per square foot,
- culvert crossings on lateral drains assumed to be incidental,
- main canal bridges for major roads and rail lines $500 per lineal foot
- main canal bridges on secondary roads $150 per lineal foot,
  (Assumption: 1 - Major Bridge every 6 miles
  1 - Secondary Bridge per mile)
- diversion control structures on lateral canals $3000 each (1 per mile)

Figure H-1 shows relationship of capacity versus cost for the typical main canal cross-section used in this study.

H-1.0 Cost Background - continued

(c) Pumping Plant Installation

Pumping plant, including pumps, motors, etc., were estimated at approximately $160 per installed horsepower.

Figure H-2 related capacity of pumping plants in terms of (cfs x head in ft.) to cost of installation. These costs are based on current price information for relatively small plant sizes and may therefore be overly conservative.

On the basis of 1.5¢ Kw-Hr, the operating cost of $1.70 per (cfs months x head in ft.) was established. The source of power or the feasibility of providing same was not investigated.

(d) Dam and Reservoir Construction

Figure H-3, showing the cost height relationship for the specific earth dam cross-section, was utilized for cost purposes for all areas considered in this study. An average unit price of $0.50/cy was used for all earthwork, including slope protection. Higher unit costs would be associated with reduced cross-sections.

Control works were priced as follows using cost relationships drawn from recent major studies of large dams and reservoirs by various government agencies.

- Spillways $40 per cfs of Capacity
- Conduit Outlets $50 per cfs of Capacity

H-1.0 Cost Background - continued

(e) Unit Cost Data

The cost information used in this study was drawn from a variety of sources. A few specific ones are listed as follows:

- Reports on Pembina River Studies by P. F. R. A. and Water Control and Conservation.
- Report on Investigation into Measures for the Reduction of Flood Hazards in the Greater Winnipeg Area.
- Current prices on Floodway, Portage Diversion and Other Similar Construction.

(f) Amortization and Maintenance

Capital costs have been amortized over a 50-year period at 6½%. This period of time was selected as an average value for the life of the project. Land values do not generally depreciate and the inclusion of land costs in the capital costs being amortized tends to offset the shorter life of items such as pumping equipment and canals.

The cost of operating and maintaining the irrigation water distribution system is likely to be quite significant in the establishment of water costs. An annual allowance of 5% of capital cost was arbitrarily selected for this purpose.

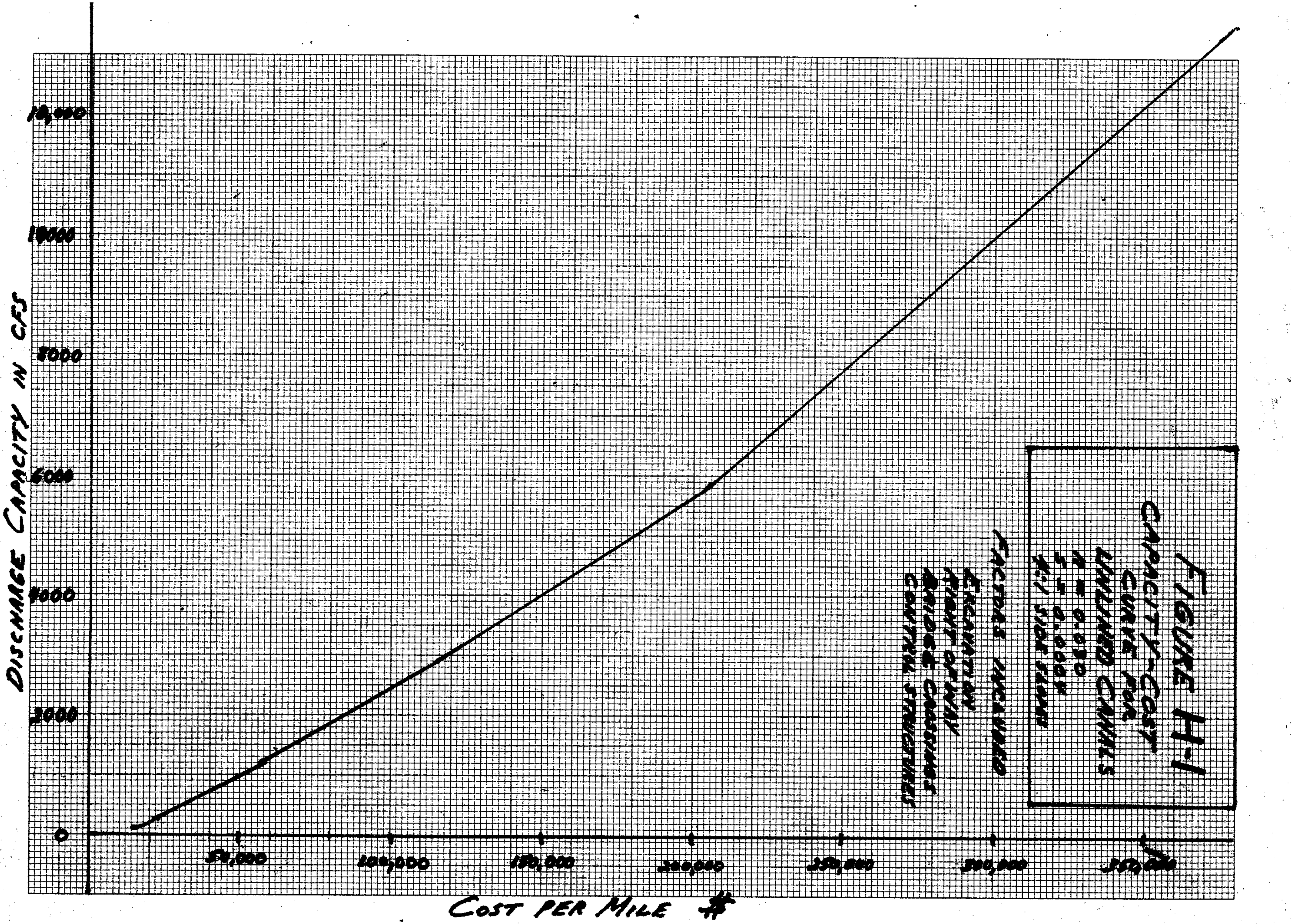
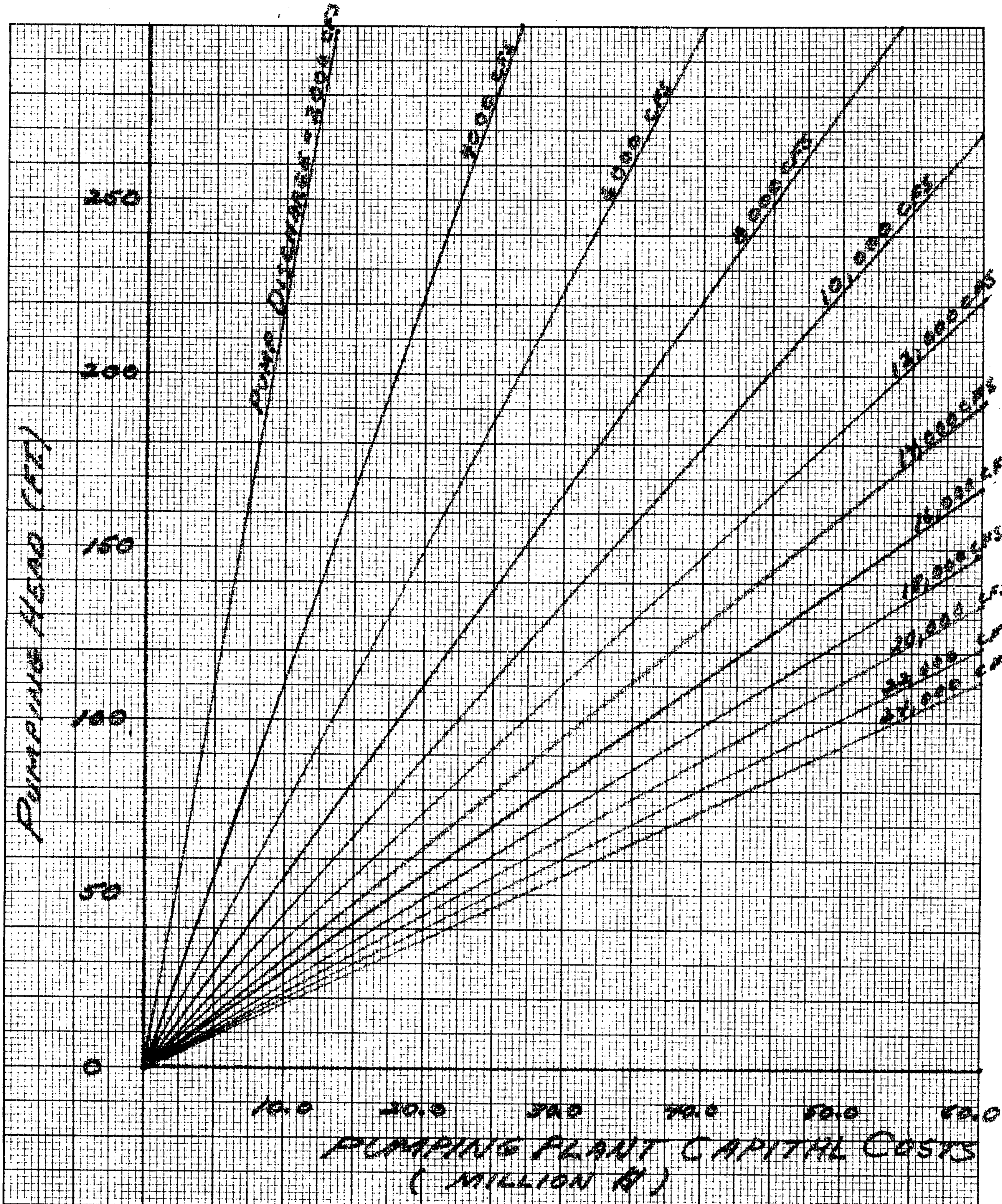
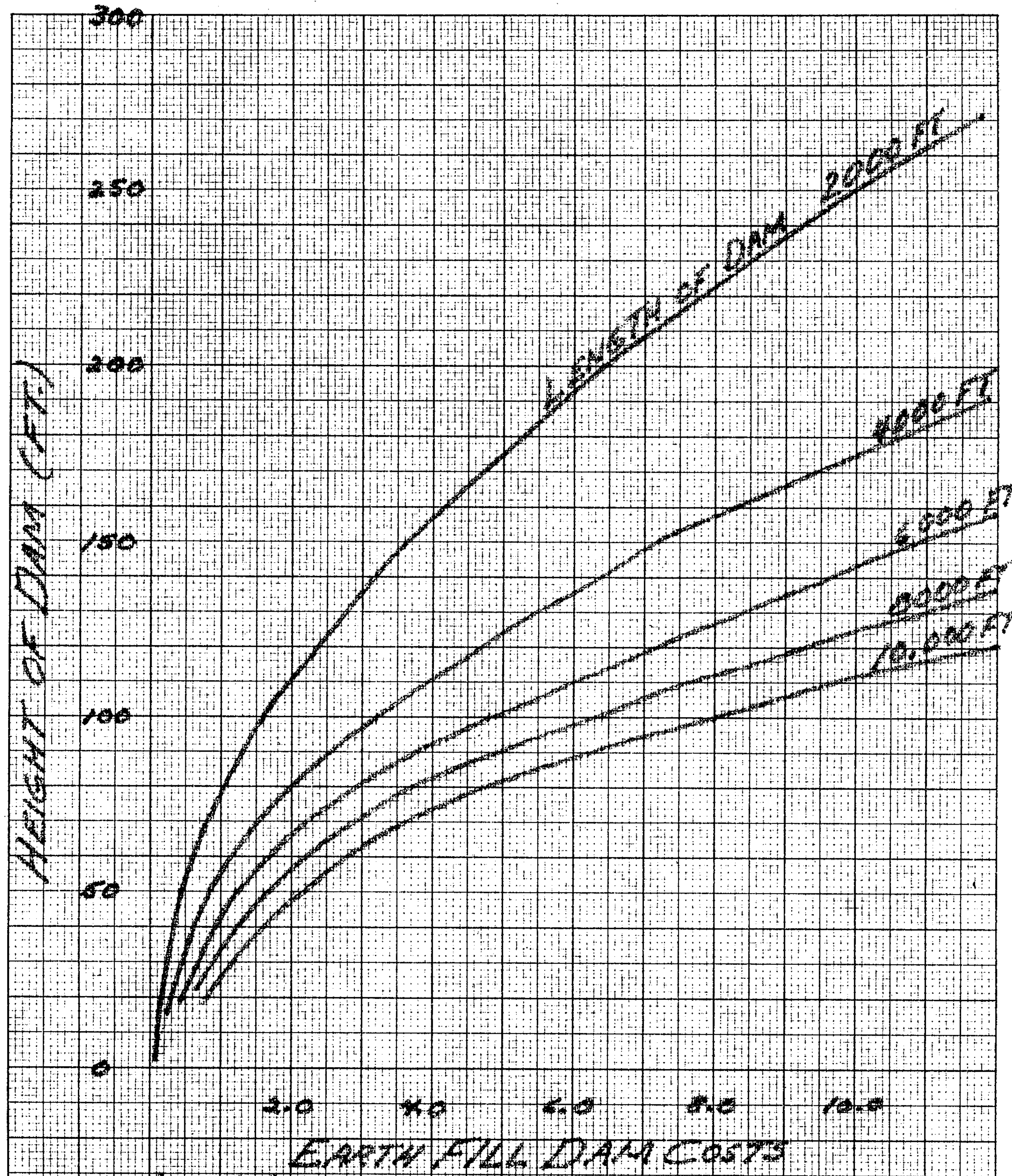


FIGURE H-1
CAPACITY-COST CURVE FOR UNLINED CANALS



PUMPING PLANT
COSTS
FIGURE H-2



COST
OF
DAM CONSTRUCTION

FIGURE H-3

H-2.0 Detailed Cost Estimates

A. DIVERSIONS UPSTREAM OF VIRDEN

Diversion A-1 (N.W. of St. Lazare)

Area 15 sq. miles - sandy soils
Average Annual requirement 160 cfs months
Required Pumping Capacity 135 cfs
Pumping Head 200 ft.
Storage Requirements 8,000 acre feet

Cost of Lateral Canals 8 miles @ $6,000	$ 48,000
Cost of Main Canals 4 mi. @ $20,000	80,000
Pumping Plant Cost 27000 cfs ft. @ $22.50	605,000
Storage Cost $\frac{160}{640}$ x 1,150,000	290,000
Contingency Allowance	250,000
	$1,273,000

Average Annual Pumping Costs $60,000

Diversion A-2 (S.W. of St. Lazare)

Area 45 sq. miles - sandy soils
Average Annual requirement 480 cfs months
Required Pumping Capacity 405 cfs
Pumping Head 200 ft.
Storage Requirements 24,000 acre ft.

Cost of Lateral Canals 20 mi. @ $6000	$ 120,000
Cost of Main Canals 16 miles @ $25,000	400,000
Pumping Plant Cost 81,000 cfs ft. @ $22.50	1,815,000
Storage Cost $\frac{480}{640}$ x 1,150,000	870,000
Contingency Allowance	600,000
TOTAL CAPITAL COSTS	$3,805,000

Average Annual Pumping Costs $180,000

NOTE: Dam and Reservoir on Qu'Apelle to serve A-1 and A-2 requires 32,000 acre feet of storage

Dam cost 2000 ft. length	$ 350,000
Spillway (10,000 cfs capacity)	300,000
Conduit (6000 cfs capacity)	300,000
Reservoir Costs	200,000
TOTAL	$1,150,000

Dam height required approximately 40 ft.

Diversion A-3 (Birdtail Creek)

Area 40 sq. miles - sandy till soils
Average Annual Requirement 410 cfs months
Required Pumping Capacity 355 cfs
Pumping Head 200 ft.
Storage Requirements 18,000 acre feet

Cost of Lateral Canals 18 mi. @ $6,000	$ 48,000
Cost of Main Canals 10 mi. @ $22,000	220,000
Pumping Plant Cost 71,000 cfs ft. @ $22.50	1,600,000
Storage Costs - Dam on Assiniboine River (30 ft. high 3,000 ft. long)	215,000
- Reservoir (3,000 acres)	300,000
- Spillway (20,000 cfs capacity)	800,000
- Conduits (6,000 cfs capacity)	300,000
- Contingency Allowance	600,000
TOTAL CAPITAL COSTS	4,083,000
Average Annual Pumping Costs	140,000

Diversion A-4 (Arrow River)

Area 250 sq. miles - sandy and till soils
Average Annual Requirement 2070 cfs months
Required Pumping Capacity 3100 cfs
Pumping Head 250 ft.
Storage Requirements 93,000 acre ft.

Cost of Lateral Canals 120 mi. @ $6,000	$ 840,000
Cost of Main Canals 100 miles	4,800,000
Pumping Plants 775,000 cfs ft. @ $22.50	17,500,000
Storage Costs Dam on Assiniboine River	
- (40 high - 4000 ft. long)	480,000
- Spillway (20,000 cfs capacity)	800,000
- (Conduits 6,000 cfs capacity)	300,000
- Reservoir (6400 acres)	640,000
- 2 Dams on Arrow River (each 100 ft. high - 1000 ft. long) inch Spillways & Conduits	2,000,000
- Contingency Allowance	5,000,000
TOTAL CAPITAL COSTS	$32,360,000

Average Annual Pumping Costs $880,000

TOTAL CAPITAL COST $42,621,000
(Capital Cost per Irrigated Acre = $268)

Annual Charges

Pumping	$ 1,260,000
Amortization	2,890,000
Operation & Maintenance	2,150,000
TOTAL	6,300,000

Average Cost of Water = $ 33.70

B. OAK LAKE DIVERSION

General

Area 1230 sq. mile sandy and medium textured soils
Average Annual Requirement 11,850 cfs mo.
Required Pumping Capacity 10,950 cfs
Storage Requirements 615,000 acre feet

Reservoirs

Dam on Assiniboine River (50' high - 4000 ft.)	$ 2,850,000
Improvements to Oak Lake Control	500,000
Dam on Pipestone Creek (50' high - 10,000 ft.)	2,800,000
Dam #1 on Stony Creek (35'high - 2000 ft.)	280,000
Dam #2 on Stony Creek (60' high - 2000 ft.)	680,000
Dam on Jackson Creek (40' high - 6000 ft.)	1,050,000
Dam on Graham Creek (30' high - 1000 ft.)	70,000
Dam on Gainsborough Creek (30' high - 1500 ft.)	100,000
Dam on Antler River	200,000

Pumping Plants

Plant on Assiniboine River (11,000 cfs - 200 ft.)	49,500,000
Plant South of Plum Lake (8400 cfs - 20 ft.)	3,800,000
Low Lift Series of Plants (7400 cfs - 100 ft. total)	6,700,000
Plant for Virden Diversion (1000 cfs - 40 ft.)	900,000
Plant for Diversion South (6400 cfs - 40 ft.)	5,750,000
Plant on Stony Creek (6000 cfs - 60 ft.)	8,100,000

Canals

Diversion Canal to Oak Lake (8 miles)	2,800,000
Diversion Canal to Pipestone Creek Dam (17 mi.)	4,330,000
Diversion Canal to Stony Creek (12 miles)	3,350,000
Diversion Canal to Jackson Creek (6 miles)	1,260,000
Diversion Canal to Gainsborough Creek (18 mi.)	2,700,000
B-1 Main Canal (60 miles)	2,310,000
Lateral (150 miles)	900,000
B-2 Main Canals (20 miles)	650,000
Laterals (60 miles)	360,000
B-3 Main Canals (40 miles)	1,550,000
Laterals (60 miles)	360,000
B-4 Main Canals (12 miles)	300,000
Laterals (24 miles)	150,000
B-5 Main Canals (45 miles)	2,300,000
Laterals	600,000
B-6 Main Canals (50 miles)	1,200,000
Laterals	600,000
Contingency Allowance	20,000,000
Total Capital Cost	$138,000,000

Capital Cost per Irrigated Acre = $250

Annual Charges

Pumping	$ 6,820,000
Amortization	9,400,000
Operation & Maintenance	6,900,000
TOTAL	$23,120,000

Average Cost of Water = $37.60 per acre ft.

C. MINNEDOSA RIVER DIVERSION

General

Area 220 acres medium textured sandy and clay soils
Average annual requirement 2000 cfs months
Required pumping capacity 1920 cfs
Required pumping head (at Assiniboine River) 250 ft.
Storage required 120,000 acre feet

Reservoirs

Storage provided on Assiniboine River	80,000 acre ft.
Dam (25' high - 500 ft. long)	250,000
Flooded Area (9500 acres)	950,000
Spillway (30,000 cfs capacity)	1,200,000
Conduits (4200 cfs capacity)	210,000
Dam & Reservoir (50,000 acre ft. storage) on Minnedosa River (130 ft. high - 5000' long)	680,000
Spillway (15,000 cfs capacity)	600,000
Conduits (1000 cfs capacity)	50,000
Flooded Area (2500 acres)	250,000

Pumping Plants

Pumping Plant on Assiniboine River (1000 cfs - 250 ft.)	5,600,000
Pumping Plant on Minnedosa River (1920 cfs - 50 ft.)	2,170,000

Canals

C-1	Main Canals (40 Miles)	2,320,000
	Laterals (45 miles)	270,000
C-2	Main Canals (40 miles)	1,550,000
	Laterals (65 miles)	390,000
	Control Structures	500,000
Contingency Allowance		2,000,000
Total Capital Cost		16,840,000

Capital Cost per Irrigated Acre = $168

Annual Charges

Pumping	1,020,000
Amortization	1,150,000
Operation & Maintenance	840,000
Total	3,010,000

Average Cost of Water = $25.10 per acre ft.

D. LITTLE SOURIS DIVERSION

General

Area 45 sq. miles - sandy soil
Average Annual Requirement 465 cfs months
Required Pumping Capacity 400 cfs
Required Storage Capacity 30,000 acre feet

Reservoirs

Storage Reservoir on Assiniboine River		
(Serving area E as well)	100,000 acre ft.	
Dam (45' high - 5000 ft. long)	800,000	30% of
Flood Area (9000 acres)	900,000	-3,490,000
Spillway (40,000 cfs capacity)	1,600,000	= 1,050,000
Conduits (3800 cfs capacity)	190,000	
3 -50 ft. high 1000 ft. long dams on Little Souris River		600,000

Pumping Plant

Pumping Plants (400 cfs - total head 200')	1,800,000

Canals

Main Canals (18 miles)	580,000
Laterals (25 miles)	150,000
Contingency Allowance	600,000
Total Capital Cost	$ 4,780,000

Total Capital Cost per Irrigated Acre = $237

Annual Charges

Pumping (1 plant)	160,000
Amortization	325,000
Operation and Maintenance	240,000
Total	$ 725,000

Average Cost of Water = $25.90 per acre foot

E. SPRUCE WOODS

General

Area 110 sq. miles - sandy soil
Average Annual Water Requirements 1130 cfs months
Required Pumping Capacity 1000 cfs
Required Storage Capacity 70,000 acre feet

Reservoirs

70% of Storage Reservoir Cost at Mile 80 on Assiniboine River	2,450,000

Pumping Plant

Pumping Plant (1000 cfs - 100 ft.)	2,250,000

Canals

Main Canals (30 miles)	900,000
Laterals (55 miles)	330,000
Contingency Allowance	1,200,000
Total Capital Cost	$7,130,000

Annual Charges

Pumping	190,000
Amortization	485,000
Operation & Maintenance	360,000
Total	1,035,000

Average Cost of Water = $14.80/acre ft.

F. SOURIS RIVER DIVERSION

General

Area 2285 sq. miles till, clay and medium textured soils
Average Annual Requirement 12,750 cfs months
Total Storage required in System 765,000 acre ft.

Canal Systems

F-1	Main Canals (40 miles)	1,570,000
	Laterals (80 miles)	480,000
150	Pumping Plant (1250 cfs - 200 ft.)	5,620,000
sq. mi.	Diversion Dam (200 ft. high - 2000 long)	6,400,000
	Dam on Souris River (40 ft. high - 1000')	130,000
	Spillway and Conduits (10,000 cfs capacity)	500,000
F-2	Main Canals (65 miles)	2,400,000
	Laterals (100 miles)	600,000
195	Pumping Plant (1600 cfs - 180 ft. head)	6,500,000
sq. mi.	Dam on Baldur Creek incl. Spillway (150 high - 1000 ft.)	1,800,000
	Additional Pumping Plant (500 cfs - 50 ft. head)	680,000
F-3	Main Canals (50 miles	1,400,000
	Laterals (120 miles)	720,000
250	5 Pumping Plants (1950 cfs - 300 ft. total head)	13,100,000
sq. mi.	4 Dams incl. Spillways (80 ft. high - 2000 ft.)	4,100,000
	Flooded Area (300 acres)	300,000
F-4	Main Canals (45 miles)	1,650,000
	Laterals (100 miles)	600,000
210	4 Pumping Plants (1600 cfs - 300 ft. total head)	10,800,000
sq. mil.	2 Pumping Plants (1000 cfs - 80 ft. total head)	1,800,000
	4 small Dams on Mary Jane Creek (80 ft. high - 1500 ft.)	3,000,000
	Flooded Area (1300 Acres)	130,000
F-5	Main Canals (75 miles)	2,100,000
	Laterals (150 miles)	900,000
300	Dam on Badger Creek (40' high - 1000 ft. long)	130,000
sq. mi.	Dam on Whitemud Creek (40' high - 2000 ft. long)	260,000
	Flood Areas (1500 acres)	150,000
	2 Pumping Plants (500 cfs - 50 ft. total head)	560,000
F-6	Main Canals (140 miles)	6,210,000
	Laterals (280 miles)	1,680,000

F. SOURIS RIVER DIVERSION - continued

F-7	Pumping Plant (320 cfs - 50 ft. head)	360,000
	Main Canals (125 miles)	4,660,000
	Laterals (210 miles)	1,260,000
F-8	2 Pumping Plants (540 cfs - 280 ft. total head)	3,400,000
	2 Dam (80 ft. high - 3000 ft. long)	3,000,000
	Conduits (5,000 cfs)	250,000
	Main Canals (30 miles)	1,200,000
	Laterals (30 miles)	180,000

Reservoirs

Dam on Assiniboine River (mile 68) (75 ft. high - 3000 ft.)	4,000,000
Dam on Souris River (mile 5) (90 ft. high - 4000 ft.)	3,700,000
Dam on Souris River (mile 14) (150 ft. high - 4000 ft.)	8,300,000
Dam on Pembina Valley (mile 21) (100 ft. high - 6000 ft.)	4,800,000
Dam on Pembina River (mile 45) (75 ft. high - 5000 ft.)	3,100,000
Dam on Pembina River below Crystal Creek (mile 55)(35 ft. high - 4000 ft.)	1,300,000
Dam on Pembina River (near La Riviere) (mile 114)(35 ft. high - 4000 ft.)	1,900,000
Dams on Upper Pembina River	
Mile 1 (150' high - 2000 ft.)	3,900,000
Mile 5 (60' high - 2000 ft.)	800,000
Mile 8 (35' high - 1000 ft.)	200,000
Mile 11 (35' high - 1000 ft.)	200,000
Mile 14 (35' high - 1000 ft.)	200,000
Mile 16 (35' high - 1000 ft.)	200,000
Canal to Whitewater Lake	1,700,000
	34,300,000

Pumping Plants

Plants on Souris River	
Mile 5 (1000 cfs - 150 ft.)	3,400,000
Mile 14 (1000 cfs - 200 ft.)	4,500,000
Plant on Pembina Valley	
Mile 21 (1000 cfs - 100 ft.)	2,200,000

F. SOURIS RIVER DIVERSION - continued

Plants on Upper Pembina River	
Mile 1 (6500 cfs - 150 ft.)	22,000,000
Mile 5 (6000 cfs - 60 ft.)	8,100,000
Mile 8 (5500 cfs - 40 ft.)	4,900,000
Mile 11 (5000 cfs - 40 ft.)	4,500,000
Mile 14 (4500 cfs - 40 ft.)	4,100,000
Mile 16 (3900 cfs - 40 ft.)	3,500,000
Contingency Allowance	70,000,000
Total Capital Cost	253,000,000

Capital Cost per Irrigated Acre = $195

Annual Charges

Pumping	14,400,000
Amortization	17,200,000
Operation & Maint.	12,700,000
Total	$44,300,000

Average Cost of Water = $58.00 per acre ft.

G. CARBERRY AREA DIVERSION

General

Area 380 sq. miles of sandy and medium textured soils
Average Annual Requirement 3840 cfs months
Required Pumping Capacity 3400 cfs
Required Storage Capacity 230,000 acre feet

Reservoir

Storage Reservoir on Assiniboine River at mile 35 11% of $21,300,000	2,350,000
Dam Canal 100 ft. high - 1000 ft. long	800,000
Dam Canal 50 ft. high - 1000 ft. long	200,000

Pumping

Pumping Plant (3400 cfs - 100' head)	7,650,000
Pumping Plant (3300 cfs - 80' head)	5,950,000
Pumping Plant (3250 cfs - 40' head)	2,920,000
Pumping Plant (700 cfs - 40' head)	630,000
Pumping Plant (1000 cfs - 40' head)	900,000

Canals

Diversion Canal (15 miles)	1,950,000
Main Canals (58 miles)	1,700,000
Laterals (200 miles)	1,200,000
Contingency Allowance	5,000,000
Total Capital Cost	$31,250,000

Capital Cost per Irrigated Acre = $184

Annual Charges

Pumping	1,570,000
Amortization	2,120,000
Operation & Maint.	1,060,000
Total	4,750,000

Cost of Water = $20.70 per acre

H. CYPRESS RIVER

General

Area 310 square miles - sand and clay soils
Average Annual Requirement 2580 cfs months
Required Pumping Capacity 2640 cfs
Required Storage Capacity 155,000 acre feet

Available Storage on Cypress River = 40,000 acre feet
Required Storage on Assiniboine River = 115,000 acre feet

Reservoir

Reservoir on Assiniboine River at mile 35	
7.5% of $21,300,000	1,600,000
Reservoir on Cypress River	
100' dam - 2000' long	2,000,000
130' dam - 2000' long	3,100,000
50' dam - 1000' long	600,000

Pumping Plants

Pumping Plants (2650 cfs - 100' head)	6,000,000
(2100 cfs - 150' head)	7,100,000
(550 cfs - 60' head)	750,000

Canals

Main Canals (85 miles)	2,650,000
Laterals (160 miles)	960,000
Contingency Allowance	5,000,000
Total Capital Cost	29,760,000

Capital Cost per Irrigated Acre = $213

Annual Charges

Pumping	1,040,000
Amortization	2,020,000
Operation & Maintenance	1,490,000
Total	4,550,000

Cost of Water = $29.40 per acre

I. DIVERSION ALONG NORTH ESCARPMENT

General

Area 1000 sq. miles sandy and medium textured soils.
Average Annual Requirement 10,300 cfs months
Required Pumping Capacity 9,700 cfs
Required Storage 620,000 acre feet

Reservoirs

Dam on Assiniboine River at mile 20 (120' high - 7000 ft.)	11,600,000
Dam on Squirrel Creek and Pine Creek	500,000
Dam on Whitemud River near Halston (30' high - 1000 ft.)	300,000
Dam on Whitemud River near Arden (30' high - 1000 ft.)	300,000

Pumping Plants

Pumping Plant (9,700 cfs - 100 ft. head)	22,000,000
2 Pumping Plants (Squirrel & Pine Creeks) (5000 cfs - 30 ft.)	6,750,000
Pumping Plant near Arden (1200 cfs - 40 ft. head)	1,080,000
Pumping Plants near Kelwood (1200 cfs - 40 ft. head)	1,080,000

Canals

	Main Diversion Canals (50 miles)	11,900,000
I-1	Main Canals (120 miles)	3,500,000
	Laterals (250 miles)	1,700,000
I-2	Main Canals (90 miles)	4,130,000
	Laterals (180 miles)	
I-3	Main Canals (50 miles)	2,510,000
	Laterals (65 miles)	390,000

Contingency Allowance	12,000,000
Total Capital Costs	$80,740,000

Capital Cost per Irrigated Acre = $179

Annual Charges

Pumping	2,240,000
Amortization	5,450,000
Operation & Maint.	4,030,000
Total	11,720,000

Average Cost of Water = $19.10 per acre ft.

J. DIVERSION ALONG SOUTH ESCARPMENT

General

2780 square miles of sandy, medium textured and clay soils
Average Annual Requirement 18,600 cfs months
Required Pumping Capacity at Assiniboine River 22,900 cfs
Required Storage on Assiniboine River 1,120,000 acre ft.

Reservoirs

Share of Assiniboine River Storage Costs 55% of $21,300,000	11,700,000
3 - 40 ft. dams on Boine River	4,200,000
40 minor Control Structures	6,000,000

Pumping Plant

At Assiniboine River (23,000 cfs - 150' head)	77,000,000
On Sale River (1400 cfs - 50' head)	1,600,000

Canals

Main Diversion Canal (40 miles)	24,000,000
Main Canals (640 miles)	27,100,000
Laterals (1000 miles)	6,000,000
Contingency Allowance	30,000,000
Total Capital Cost	187,600,000

Capital Cost per Irrigated Area = $150

Annual Charges

Pumping	4,750,000
Amortization	12,750,000
Operation & Maint.	9,400,000
Total	26,900,000

Average Cost of Water = $24.00 per acre ft.

K. PORTAGE LA PRAIRIE DIVERSION

General

Area 150 sq. miles medium textured soils
Average Annual Requirement 1400 cfs months
Required Pumping Capacity 1330 cfs
Required Storage 84,000 acre feet

Reservoir

Storage Reservoir on Assiniboine River at mile 3	
Dam (40' high - 4000' long)	500,000
Flood Area (5000 acres)	500,000
Spillway (20,000 cfs capacity)	800,000
Conduits (2000 cfs capacity)	120,000

Pumping Plant

Pumping Plant (1330 cfs - 40 ft. head)	1,200,000

Canals

Main Canals (22 miles)	1,200,000
Laterals (70 miles)	420,000
Contingency	900,000
Total Capital Cost	5,740,000

Total Capital Cost per Irrigated acre = $85.00

Annual Charges

Pumping (1 plant)	95,000
Amortization	390,000
Operation & Maint.	290,000
Total	775,000

Cost of Water = $9.25/acre ft.

L. LAKE MANITOBA DELTA DIVERSION

General

Area 215 sq. miles medium textured soils
Average Annual Requirement 2000 cfs months
Required Pumping Capacity 1880 cfs
Required Storage 120,000 acre feet
(Available in Lake Manitoba at no cost.)

Pumping Plants

Pumping Plant at Portage Diversion Outlet (including alteration to outlet)(1400 cfs - 30 ft.)	1,450,000
Lift Pump Plants and Alteration to Drop Structures	
(1400 cfs - 30 ft.)	1,200,000
(800 cfs - 30 ft.)	790,000
Pumping Plant at Whitemud River (480 cfs - 50 ft. head)	540,000

Canals

L-1	Main Canal (40 miles)	1,000,000
	Laterals (80 miles)	480,000
L-2	Main Canal (20 miles)	650,000
	Laterals (30 miles)	180,000

Contingency Allowance	1,280,000
Total Capital Cost	7,570,000

Capital Cost per Irrigated Acre = $78

Annual Charges

Pumping	163,000
Amortization	515,000
Operation & Maint.	378,000
Total	$1,056,000

Average Cost of Water = $8.80 per acre ft.

M. LONG LAKE DIVERSION

General

Area 950 sq. miles of dry and medium textured soils
Average Annual Requirement 5850 cfs months
Required Pumping Capacity at Lake Manitoba 7750 cfs
Required Storage in Lake Manitoba = 350,000 acre feet

Pump Plants

Average Annual Pumping Cost	300,000
Pumping Plant (7750 cfs - 30 ft. head)	5,250,000
Pumping Pumps (4000 cfs - 40' head)	3,600,000
Pumping Pumps (2600 cfs - 40' head)	2,350,000
Pumping Pumps (1300 cfs - 40' head)	1,050,000
Average Annual Pumping Cost (3 plants)	410,000

Canals

Long Lake Diversion Canal (20 miles)	5,000,000
Main Canals (270 miles)	11,200,000
Laterals (490 miles)	2,950,000
Contingency Allowance	6,000,000
Total Capital Cost	37,400,000

Total Capital Cost per Irrigated Acre = $87.50

Annual Changes

Pumping (4 plants)	710,000
Amortization	2,540,000
Operation & Maint.	1,870,000
Total	5,120,000

Average Cost of Water = $14.60/acre ft.