DETERMINATION OF NATURAL FLOW

FOR APPORTIONMENT PURPOSES

Prepared by the Committee on Hydrology

PPWB Report #48

MAY 1976

PRAIRIE PROVINCES WATER BOARD

CANADA ALBERTA SASKATCHEWAN MANITOBA

PRAIRIE PROVINCES WATER BOARD

FOREWORD

This study, to develop procedures for the determination of natural flows in the South Saskatchewan, North Saskatchewan, Saskatchewan, Churchill and Qu'Appelle River Basins, was done for the Board by the Calgary District Office of Water Survey of Canada under the direction of the PPWB Committee on Hydrology. The study took four years to complete, at a total cost to the Board of $70,500.

The result of the study was the development of a consistent, practical methodology for accurate determination of natural flows at the points of apportionment and the identification of minimal required additions to existing meteorological and hydrometric networks.

The Committee on Hydrology acted in both a management and advisory capacity throughout the study. This working arrangement ensured good liaison between the Board and the study group, enhanced the co-operation between the provincial and federal agencies involved, and provided spin-off advantages for these agencies during the course of the study. In short, involvement in the study has been beneficial to water managers in each jurisdiction in increasing their understanding of the water resources of the prairies.

The Committee believes it is now possible to calculate natural flow in all basins studied in a manner satisfactory to the water managers and hydrologists who will be responsible for the practical administration of the Apportionment Agreement. The accuracy of these methods approximates the accuracy with which the Water Survey of Canada can determine streamflow at apportionment points. The computations can be done relatively easily at a reasonable cost, and administrative arrangements for both monitoring and computation of natural flow can be handled by existing agencies.

The method of routing natural flow in the Qu'Appelle Basin is unique and innovative. This basin is probably one of the most difficult in North America in which to compute natural flow, and the methodology developed during the course of this study must be regarded as a hydrologic achievement of some magnitude. The use of the US Army Corps of Engineers Streamflow Synthesis and Reservoir Regulation (SSARR) Model to achieve that result is a progressive step forward.

The fact that the Water Survey of Canada is involved in natural flow computations on international streams was an asset in terms of expertise and cost reduction. The Study Group was efficient in utilizing resources, gave due consideration to the mass of data available, and completed all assignments requested by the Committee. The co-operation and patience of the Study Office and in particular the Study Director, Mr. G. H. Morton, was noteworthy and greatly appreciated. The cost of the study was probably one-half of what would have been expended by a group unfamiliar with natural flow methodology.

The methods and networks recommended for use in calculating natural flows will not apply for all time. In the future as basin conditions change and projects are developed, the recommended methods and networks will have to be reassessed.

The recommendations of the main reports are summarized in the following paragraphs, with more details presented in the body of this report.

The Project Depletion Method is recommended for use in all five basins. The method basically involves identification and measurement or computation of depletions due to storage, diversion, evaporation and consumptive use, and routing these depletions to the point of apportionment where they are applied to the recorded flows at the point to produce natural flows. In the Qu'Appelle River Basin the Project Depletion Method was supplemented by the SSARR model which was used primarily to perform the complex routing procedures necessitated by the hydrologic characteristics of the basin.

Schedules A and B to the Apportionment Agreement state that for the purposes of apportioning water between two provinces "....the natural flow shall be determined at a point as near as reasonably may be to their said common boundary." Apportionment points on the five rivers considered were chosen on the basis of proximity to the boundary, the hydrologic suitability of the site for acceptable measurement accuracy, and inflow to the watercourse between the site and the boundary. The following apportionment points were selected:

South Saskatchewan River Basin	-	South Saskatchewan River below the confluence with the Red Deer River
North Saskatchewan River Basin	-	North Saskatchewan River near Deer Creek
Saskatchewan River Basin	-	Saskatchewan River near Monitoba Boundary
Qu'Appelle River Basin	-	Qu'Appelle River near Welby
Churchill River Basin	-	Churchill River at the Manitoba Boundary

The recommended frequency of reporting the results of computations of flows required for apportionment purposes varies depending on the level of use in each basin. In the South Saskatchewan River Basin, quarterly reporting based on monthly mean values is recommended with the reporting schedule reverting to monthly when recorded flows drop below 1,500 cfs. Quarterly reporting is also recommended for the Qu'Appelle River Basin. In the North Saskatchewan, Saskatchewan and Churchill River Basins the levels of annual use are well below 50 percent of the natural flow, therefore annual reporting based on monthly means is recommended.

A total of 87 hydrometric gauging stations, composed of 61 flow stations and 26 water level stations, is recommended to provide data for the computation of flows required for apportionment in the five basins. Of this total 83 are existing stations and four will be new stations. The four recommended new stations are water level gauges and the data are required for the determination of small project use in the Qu'Appelle River Basin.

The accuracy of the hydrometric record at apportionment points is the most critical factor in ensuring the accuracy of natural flow computations. Instrumentation, measurement frequency and technique, and computational procedures should be such that the error limit for monthly hydrometric record is four percent during open water and ten percent under ice conditions. The accuracy of the hydrometric record at other monitoring points should be commensurate with the use of the information and the relative impact on accuracy of computation of the apportioned flow. Normal Water Survey of Canada standards would apply in most cases.

Evaporation from many of the large reservoirs in the five basins represents a significant depletion to natural flow. It is therefore recommended that evaporation be computed for these reservoirs. The Meyer formula is recommended for this computation. In order to fulfill the data needs of the Meyer formula, nine meteorologic stations are required. Of these, seven presently exist and two will be new stations. The two new stations are required to provide information to estimate evaporation from the Waterton and St. Mary Reservoirs, using the Meyer formula.

Generally, little is known about the effects of land use changes and groundwater discharge and recharge on natural flow. Limited information available suggests that these effects are minor compared to the magnitude of the flows considered and the depletions applied. It is therefore recommended that these effects not be considered in the natural flow computations.

The table on the following page summarizes the recommendations made in connection with each basin. The body of the report contains more details on these recommendations. A map showing the recommended networks also follows.

Committee on Hydrology

D. A. Davis

D. A. DAVIS — CANADA ENVIRONMENT (EMS)

R K Deeprose

R. K. DEEPROSE — PROVINCE OF ALBERTA

H. F. Cork

H. F. CORK — CANADA ENVIRONMENT (AES)

D. L. MACLEOD — PROVINCE OF SASKATCHEWAN

G. H. MACKAY — PROVINCE OF MANITOBA

R. B. Godwin

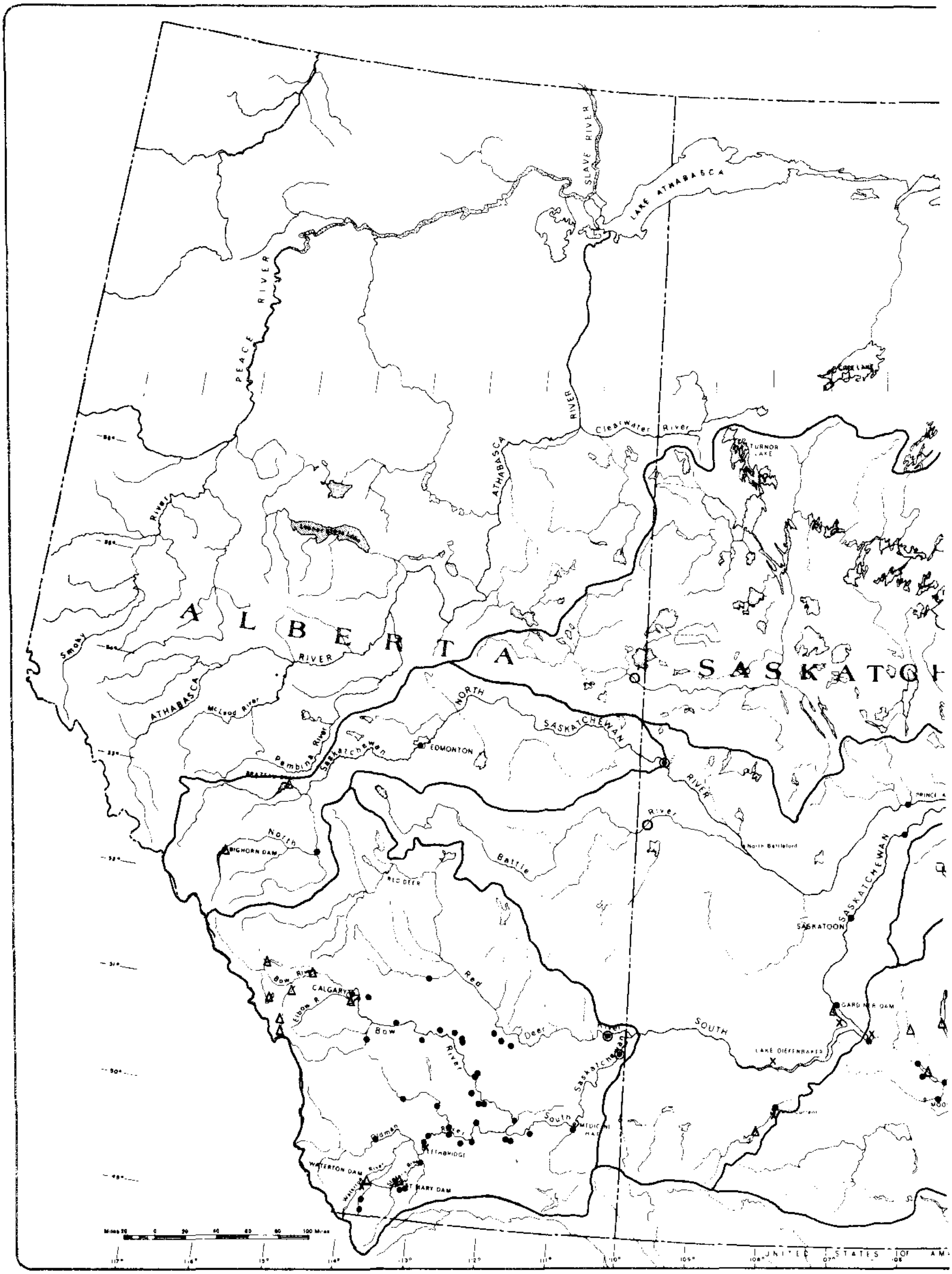
R. B. GODWIN — CANADA - DREE-PFRA

D. J. Berry

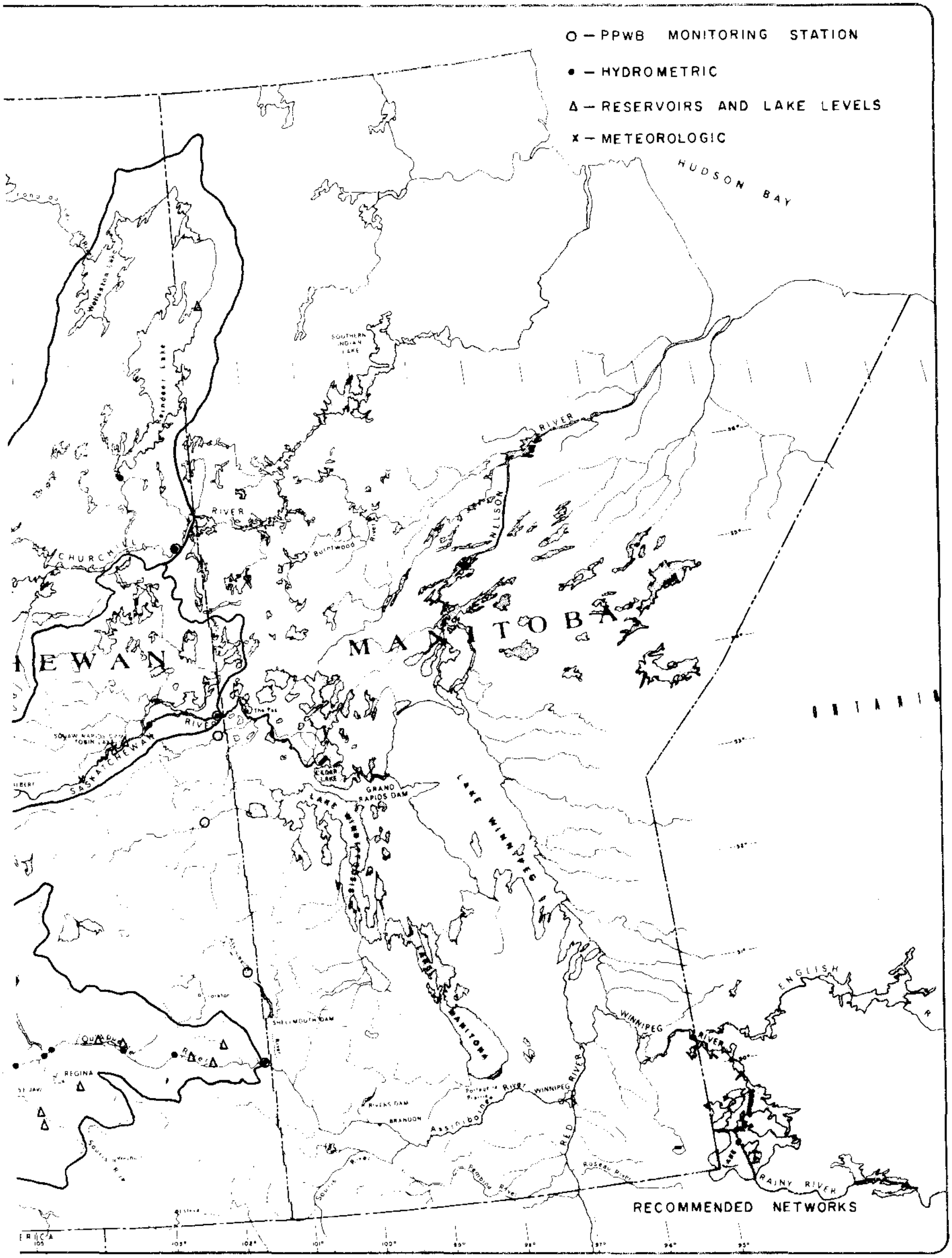
D. J. BERRY — PRAIRIE PROVINCES WATER BOARD

SUMMARY OF RECOMMENDATIONS

APPORTIONMENT POINT	FREQUENCY OF REPORTING	METHOD	REQUIRED HYDROMETRIC STATIONS		EVAPORATION	REQUIRED MET STATIONS	
			EXISTING	NEW		EXIST.	NEW
SOUTH SASKATCHEWAN RIVER BELOW THE CONFLUENCE WITH THE RED DEER RIVER	QUARTERLY (NORMAL) MONTHLY (LOW FLOW)	PROJECT DEPLETION	2 COMPUTATION 3 ROUTING 13 DIVERSION 20 RETURN FLOW 9 LEVEL	0	MEYER FOR WATERTON & ST. MARY	1	2
NORTH SASKATCHEWAN RIVER NEAR DEER CREEK	ANNUALLY	PROJECT DEPLETION	1 COMPUTATION 2 ROUTING 2 LEVEL	0	NOT REQUIRED	0	0
SASKATCHEWAN RIVER NEAR MANITOBA BOUNDARY	ANNUALLY	PROJECT DEPLETION	1 COMPUTATION 3 ROUTING 4 DIVERSION 3 LEVEL	0	MEYER FOR DIEFENBAKER REID & TOBIN LAKES	6	0
QU'APPELLE RIVER NEAR WELBY	QUARTERLY	PROJECT DEPLETION AND SSARR ROUTING	1 COMPUTATION 7 ROUTING 2 DIVERSION 7 LEVEL	4	QU'APPELLE LAKES USING DIEFENBAKER RATE X FACTOR	0	0
CHURCHILL RIVER AT THE SASKATCHEWAN - MANITOBA BOUNDARY	ANNUALLY	PROJECT DEPLETION	2 COMPUTATION 1 LEVEL	0	NOT REQUIRED	0	0



SLAVE RIVER
LAKE ATHABASCA
PEACE RIVER
ATHABASCA
RIVER
Clearwater River
TURNOR LAKE
ALBERTA
SASKATCH
Smoky
RIVER
ATHABASCA
McLeod River
Pembina River
Saskatchewan
NORTH
SASKATCHEWAN
RIVER
EDMONTON
North
BIGHORN DAM
RED DEER
Battle
River
North Battleford
SASKATCHEWAN
SASKATOON
Bow River
CALGARY
Elbow R.
Bow
River
Red
Deer
SOUTH
Saskatchewan
South
GARDINER DAM
LAKE DIEFENBAKER
MEDICINE HAT
LETHBRIDGE
WATERTON DAM
ST MARY DAM
Oldman
Waterton River
UNITED STATES OF AM



O — PPWB MONITORING STATION
• — HYDROMETRIC
Δ — RESERVOIRS AND LAKE LEVELS
x — METEOROLOGIC
HUDSON BAY
MANITOBA
ONTARIO
SASKATCHEWAN
CHURCHILL RIVER
SOUTHERN INDIAN LAKE
NELSON RIVER
SASKATCHEWAN RIVER
The Pas
CEDAR LAKE
GRAND RAPIDS DAM
LAKE WINNIPEG
LAKE WINNIPEGOSIS
LAKE MANITOBA
SHELLMOUTH DAM
RIVERS DAM
BRANDON
Assiniboine River
WINNIPEG
RED RIVER
WINNIPEG RIVER
ENGLISH R
RAINY RIVER
REGINA
Qu'Appelle River
Souris River
Pembina River
Roseau River
RECOMMENDED NETWORKS

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INTRODUCTION

The Prairie Provinces Water Board has responsibility for administering the Master Agreement on Apportionment signed in 1969 by Manitoba, Saskatchewan, Alberta and Canada. The Terms of the Agreement related to apportionment of interprovincial streams require the computation of natural flows arising within a province immediately upstream of a boundary crossing. There are several methods available for estimate natural flows from a basin. To ensure that the best method is used for Board purposes, the Board financed and directed a study of the problem.

This report outlines the results of the study to develop procedures for the determination of flows required for apportionment purposes at interprovincial boundaries. The Board agreed that methods and procedures should be determined for five major interprovincial watercourses in Alberta, Saskatchewan and Manitoba.

The methods developed during the study will compute flows required for apportionment purposes at the boundary crossings. These flows are not necessarily natural flows. In the South Saskatchewan River Basin the amount of water subject to apportionment at the Alberta-Saskatchewan boundary is the natural inflow from Alberta plus the recorded inflow from the US on the St. Mary River. Procedures to calculate this quantity, rather than true natural flows, have been developed in this study. In the North Saskatchewan and Qu'Appelle River Basins, natural flows are required for apportionment at the boundary crossings, therefore the procedures developed do calculate natural flows. Apportionment of the Saskatchewan and Churchill Rivers at the Saskatchewan-Manitoba boundary requires the computation of a quantity which is equal to the sum of the natural local inflow arising in Saskatchewan plus the recorded inflow from Alberta. Therefore, on the Saskatchewan and Churchill Rivers, procedures to calculate flows required for apportionment, rather than natural flows, have been developed.

The study was undertaken for the Board by the Calgary District Office of Water Survey of Canada, Environment Canada. The Atmospheric Environment Service of Environment Canada provided input on the meteorologic aspects of the study. The Board directed its Committee on Hydrology to act in an advisory capacity for the study, and to review the work of the study team and the results produced. In addition, the Committee was requested to review the study reports so that changes and modifications deemed necessary by the Committee would be incorporated in the reports before being submitted to the Board. The Executive Director of the PPWB Secretariat, as Chairman of the Committee, provided liaison between the PPWB and the study group.

The work was done under a financial agreement between the Board and the study group, whereby the Board reimbursed Water Survey of Canada for costs associated with wages, travel, stationery, computer time, consultants and printing. Several other indirect costs such as heat, light, space and salaries for senior personnel were absorbed by Water Survey of Canada resulting in considerable saving to the Board.

The study began in the summer of 1971 with a small pilot study to determine study criteria and computational methods to apply to the investigation. The study outline resulting from this work was approved by the Committee and the Board. The study was completed early in 1976 and the report printing and distribution completed by the spring of 1976.

The total cost of the study to the Board was $70,500.

Methods of determining natural flow from the five basins were derived during the study, and a report was prepared for each basin. The reports prepared are:

Natural Flow - South Saskatchewan River below Red Deer River
Natural Flow - North Saskatchewan River at Alberta-Saskatchewan Boundary
Natural Flow - Saskatchewan River at Saskatchewan-Manitoba Boundary
Natural Flow - Qu'Appelle River at Saskatchewan-Manitoba Boundary
Natural Flow - Churchill River at Saskatchewan-Manitoba Boundary

User Manual - South Saskatchewan River below Red Deer River
User Manual - Qu'Appelle River at Saskatchewan-Manitoba Boundary

Natural Flow Network Evaluation

This Summary Report to the Board contains the recommendations of the Committee on Hydrology based on the conclusions and recommendations presented in the above reports. This report also contains a brief description of some of the technical considerations pertinent to natural flow computations.

PRAIRIE PROVINCES WATER BOARD

TECHNICAL APPROACH

This chapter describes some of the technical considerations involved in the selection of methods to calculate natural flows. Most of the detailed investigations were done during the South Saskatchewan River Basin natural flow studies. A pilot project was initiated and different computation methods were tested. These included the Project Depletion, Stream Depletion, Rimflow and Consumptive Use methods. The Saskatchewan-Nelson Basin Board approach to natural flows was also considered. Based on these investigations it was concluded that the Project Depletion Method produced the most accurate results, and was easiest to apply, particularly for the South Saskatchewan River Basin. Studies in the remaining basins were not as exhaustive and were primarily involved with assessing the adequacy of the Project Depletion Method in the basin under consideration. The Project Depletion Method was found to be suitable also for the North Saskatchewan, Saskatchewan, Qu'Appelle and Churchill River Basins.

The hydrologic complexities of the Qu'Appelle River Basin are such that application of the Project Depletion Method in a similiar manner to that used in the other basins, could not produce a sufficiently accurate result. Although the Project Depletion approach was used, the Streamflow Synthesis and Reservoir Regulation (SSARR) Model was employed in the calculation of natural flows.

The ensuing sections define natural flow, discuss the components of natural flow computation, and describe the basic methods investigated.

NATURAL FLOW DEFINED

The Master Agreement on Apportionment defines natural flow as "the quantity of water which would flow in any watercourse had the flow not been affected by human interference". The definition used for computational purposes differs slightly in that the effects of forestry, land use and groundwater manipulation on natural flows are not considered.

Reclamation of lands which, in their natural state, do not normally contribute flow to the main streams is a practice which has been pursued with increased vigor by landowners in recent years. The practice is particularly widespread in the Qu'Appelle River Basin. Studies by Provincial and Federal agencies have been inconclusive in determining whether or not drainage works contribute significantly to flow volumes. In at least one such study it was concluded that the effects of artificial storage works in the basin offset the effects of drainage works. These studies also show that a fairly complete land use, topographic and soil type inventory, as well as a practical understanding of the effect on hydrologic relationships of these factors, would be a prerequisite if altered precipitation - runoff relationships are to be numerically accounted. Comprehensive data of this type is not available for most of the region being studied. Until conclusive evidence is available which clearly shows that drainage works contribute significantly to flow volumes at interprovincial boundaries, it is recommended that the effect of these works be ignored in natural flow calculations. In any case, the total effect is thought not to be very significant in comparison to the magnitude of present depletions.

Information on the effects of groundwater inflow and recharge on natural flow is lacking. Groundwater storage and sub-surface flow are influenced by forestry and agriculture, and locally by reservoir construction. Very little is known about the changes in the surface runoff and sub-surface flow regimes resulting from changes in land use and reservoir construction. Determining the extent of such modifications and the ultimate result on natural flow would be a major study in itself. It is generally felt that the quantities involved are small with respect to the natural flows being considered and the identifiable sources of error.

Some studies of the groundwater component of return flow of Alberta irrigation districts indicate that this component of return flow can vary considerably. This variation can be attributed either to regional conditions or to the methods of determination. On the basis of existing groundwater data it is felt that a network of wells or piezometers to establish the groundwater component of return flow for all irrigation districts would be a large undertaking. Indications from the examination of streamflow data are that the groundwater component of return flow is very small. For these reasons groundwater has not been considered in this study.

The Report of the Qu'Appelle Basin Study Board, 1972, estimates the groundwater inflow to the Qu'Appelle River System to be 40,000 acre-feet of water annually with Last Mountain Lake receiving the most significant groundwater inflows. The report however, makes no statements on the timing of groundwater inflows and the precise amounts entering Last Mountain Lake. In order to account for this inflow, groundwater, evaporation, and ungauged and unestimated local inflows were treated as a lumped quantity which is determined by a water balance for Last Mountain Lake. This method of handling ungauged inflows is possible through the use of the SSARR model.

COMPONENTS OF NATURAL FLOW COMPUTATIONS

Water Uses

The major uses of water which are considered in the computation of natural flow at any given point are reservoir storage and evaporation losses, and consumptive use, which is primarily for irrigation.

The time effects on riverflows caused by operation of major reservoirs must be included in the calculated downstream natural flows. In addition, any appreciable evaporation losses due to the impoundment of what would otherwise by naturally flowing water must be computed as a consumptive use. In the case of certain reservoirs in the Eastern Rockies headwaters, evaporation losses may be neglected due to consistently cool surface conditions, or a small increase in surface area due to reservoir construction. The remaining reservoirs are located in the Foothills or on the Prairies and generally have a much larger surface area to flow through ratio; therefore, evaporation losses are significant and must be determined.

Irrigation consumptive use can be calculated by simple summation if total diversion, return flow and local natural runoff are known. In most cases the diversion is gauged as is a significant portion of the apparent return flow. The ungauged return flow can be reasonably estimated using regression analysis and verified by measurement or by estimates submitted by irrigation project management. The estimated local natural runoff from irrigated areas must be subtracted from the apparent return flow to produce return flows of irrigation water. Diversion less true return flow equals the consumptive use.

Unmeasured depletions due to small projects have not been considered in most of the basins under consideration. The depletions due to these projects are usually small when compared to the natural flows at apportionment points. Further, these projects usually effect their depletions during the spring runoff period when flows are high. In the Saskatchewan River Basin for example, the mean annual depletion of small projects was estimated from Water Rights files as 16,500 acre-feet. This amounts to only 0.1 percent of the natural flow at the Saskatchewan-Manitoba boundary. For the Qu'Appelle River Basin, the estimated annual small project useage of 10,500 acre-feet can be as high as 33 percent of the natural flow at Welby in a dry year. Provision has therefore been made to compute small project uses in the Qu'Appelle River Basin.

The Natural Runoff Component

The Natural Runoff Component, which is used in connection with natural flow computation methods, is defined as the natural runoff which is produced by a project or area and is not measured. This component of natural flow cannot be measured because it is combined with irrigation return flow. The calculation of a natural runoff component is required for most of the natural flow computation methods although the area from which the natural runoff component is estimated will vary depending on the natural flow computation procedure used.

Three methods were identified for computation of the natural runoff component; the Versatile Soil Moisture Budget, Multiple Regression Techniques, and a Ratio Technique. Of these, the Versatile Soil Moisture Budget is considered to be superior. Due to the estimations that are necessary for any method of determining the natural runaff component, the results can be considered accurate only to ± 30 percent.

The Project Depletion method of natural flow computation requires the computation of the natural runoff component from an irrigated or project area only. When the natural runoff component was calculated for the Pilot Project area for a hydrologic situation which combined the maximum runoff through return flow channels with the minimum seasonal natural flow, the natural runoff component was found to be only 0.6 percent of the natural flow of the South Saskatchewan River at the forks. This is far below the normal three to five percent stream gauging error. The Stream Depletion and Rimflow methods of natural flow computation require calculation of the natural runoff component for a "bulk" area which is much larger than the irrigation project itself. For the same hydrologic situation and the same Pilot Project the natural runoff component was found to be two percent of the natural flow at the forks. It was concluded that the natural runoff component is insignificant for natural flow computation methods using a project area approach but must be taken into account in bulk area methods.

Evaporation

The net change in the water supply delivered at the Provincial boundaries as a result of increased evaporation losses caused by reservoir construction must be included in the calculation of natural flows.

The most basic method of computing evaporation loss from a reservoir makes use of a water budget. This method fails when inflow and outflow are large relative to the area of the reservoir because errors in flow measurements may be as large as evaporation losses. It also fails when errors in the computation of change of storage are of the same magnitude as evaporation losses.

Another basic method makes use of the energy budget to compute evaporation losses. This method requires extensive instrumentation and complex computation, making it unsuited for operational purposes. It may be useful however, for checking the coefficients used in empirical formulae.

Evaporation from shallow reservoirs may be estimated by direct comparison with measurements from an evaporation pan. With the use of these pans, evaporation from deep reservoirs will be overestimated early in the evaporation season and underestimated late in the season due to heat storage in the reservoir, although seasonal totals may be acceptably accurate. Evaporation pans require daily manual observations.

Empirical mass-transfer formulae may be used. These require measurements of atmospheric vapour pressure, surface water temperature and wind speed. Recording instruments may usually be used, making daily manual attention unnecessary. Computations are simple. Since the coefficients used in the equations have usually been determined under somewhat different conditions they may not apply perfectly for different reservoirs. Errors of up to about 10 percent may result from the use of an unsuitable coefficient. Of the many empirical formulae available the Meyer formula has been most widely used, and as far as is known at present, is as accurate as any. Use of the Meyer formula is recommended until some significantly better method can be demonstrated.

Applicable evaporation losses are small if:

(1) the water surface is cool compared to the atmospheric dew point, or
(2) the increase in water surface area due to reservoir construction is small, or
(3) the reservoir surface replaces a densely forested area, since transpiration from dense forest may be nearly as great as evaporation from an open water surface assuming moisture for evaporation is available.

Computed evaporation losses should be compared with the errors to be expected in measuring streamflow. If the streamflow is large and the evaporative losses from a reservoir are small, evaporation from the reservoir may be ignored.

When the Project Depletion method is used, evaporation from reservoirs within the depletion area is included in losses from the project area and need not be computed.

Routing

The factors which affect natural flow and must be applied to the recorded flow to determine natural flow are termed Adjustment Items. These Adjustment Items include changes due to reservoir storage, consumptive uses and diversions into or out of a basin. Adjustments are applied algebraically at the point where natural flow is to be computed.

The points where these adjustments occur are usually different from the point where natural flow is computed, therefore the adjustments must be routed downstream to the natural flow computation point.

Monthly Adjustment Items are computed using data collected on site at each project. The routing consists of a correction factor applied to these figures to compensate for the time of travel from the individual project to the point where natural flow is determined. The travel time for the projects being considered varies considerably. The correction is made by shifting a portion of the monthly adjustment into the following month for the natural flow calculation. The magnitude of the correction depends upon the time of travel and the level of use over the travel period for each item.

In the Qu'Appelle River Basin, traditional application of the Project Depletion Method failed to produce a satisfactory result. An innovative approach using the US Army Corps. of Engineers SSARR Model was tried and found to be successful. The approach involves simultaneous routing of daily recorded and simulated natural flows through the basin taking into account off-channel storage, local ungauged inflow, evaporation and man-made regulation. In order to start the routing process, natural conditions must be assumed at some time. It was felt that conditions throughout the basin immediately following a large flood were sufficiently 'natural' for the model to proceed. Large floods in the basin in 1955, 1974 and 1975 provided the necessary 'natural' conditions.

NATURAL FLOW COMPUTATION METHODS

A review of literature on natural flows and related subjects revealed the following five basic methods for the determination of natural flow:

Project Depletion Method
Stream Depletion Method
Rimflow Method
Consumptive Use Method
Saskatchewan-Nelson Basin Board Method

The Stream Depletion, Rimflow and Project Depletion methods were evaluated using a Pilot Project. The area chosen for the Pilot Project was the reach of the Bow River between Calgary and the confluence with Oldman River. Three major irrigation districts border this reach; the Western Irrigation District, the Eastern Irrigation District and the Bow River Development Project. This area was chosen because of the extent of water use and the length of hydrometric record. Descriptions and evaluations of the four methods follow. The hypothetical water use unit shown on Figure 1 is used to aid in the description of the methods.

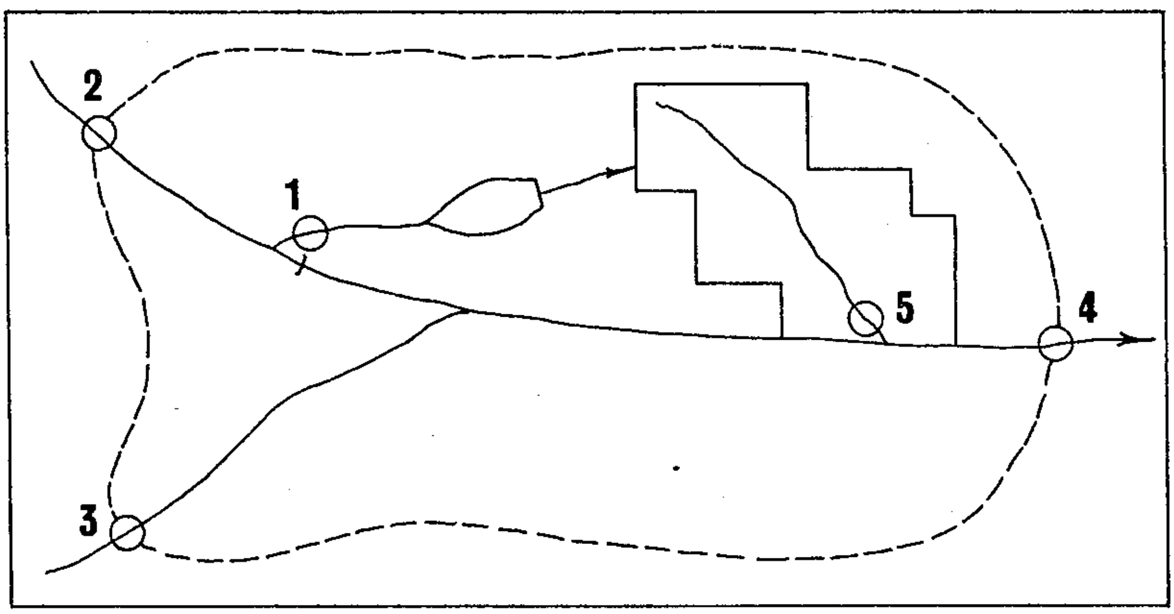


Figure 1 - Hypothetical Water Use Unit

Project Depletion Method

The Project Depletion Method involves direct gauging of diversions to, and return flows from, a project. Referring to Figure 1, gauged streamflows are required at Points 1, 4 and 5. The natural flow at Point 4 is calculated as the recorded flow at Point 4 plus diversion at Point 1 plus the natural runoff component from the project less the return flow gauged at Point 5. As noted previously, the natural runoff component for the project area is small enough to be neglected. The net depletion for the project is calculated as the difference between the total diversion and the return flows.

The Project Depletion method relies heavily upon direct measurement of factors affecting natural flow and places much less emphasis on meteorological, topographic and land use data than other methods. The existing hydrometric network is utilized to a great extent and in the intermediate computations for natural flow all project consumptive uses and changes in storage are estimated. These figures would be available for use in the operation and regulation of the individual projects.

Main stem reservoir evaporation losses must be computed individually if the Project Depletion method is used. Conveyance losses and evoporation losses from storage internal to each project are included in the consumptive use figures since project inflow and outflow are actually measured. All such consumptive uses would be impossible to separate from overall natural losses in statistical correlations and most difficult to determine using empirical relationships. Sources of potential error are minimized in the Project Depletion computations because only the gauged depletions and the recorded flow at or near the point of apportionment are used. Errors in natural flows computed by the Project Depletion method are therefore mainly due to stream gauging. The Project Depletion Method is therefore preferred for the calculation of natural flows.

Stream Depletion Method

The Stream Depletion Method involves the delineation of a "bulk" area which encompasses the project, the point at which natural flows are to be computed, a point upstream of the project where natural flows are known or can be computed, and points on any tributaries to the main stream where natural flows are known or can be computed. Care must be taken when defining the bulk area to avoid inclusion of more than one major river system or severing diversions. In actual practise data requirements would be very high and much estimation would be required to account for the myriad of channels crossing the bulk area boundary. Therefore, the bulk area boundaries generally include several projects located adjacent to a major river. The dotted line in Figure 1 shows the bulk area for the hypothetical water use unit.

The Stream Depletion Method calculates the natural flow at Point 4 (Figure 1) by summing the natural flow at Points 2 and 3, and the natural runoff component from the bulk area. The net depletion for the project is then the difference between the recorded and calculated natural flow at Point 4.

The Stream Depletion Method cannot account for the many natural fluctuations in river flows which are caused by surface evaporation, ice formation and changes in the groundwater table. These effects on flow would be erroneously attributed to manipulation of storage or to consumptive use. Stream depletion storage and consumption figures are derived from total inflow and outflow data. Measurement error in these, combined with any correlation or estimating error for ungauged minor boundary flows, could in theory greatly increase the error in the computed depletions. The requirement to route all flows, as opposed to only the project depletions as in the Project Depletion Method, introduces another source of error.

In a real application of the Stream Depletion Method it would be difficult to monitor all minor inflows and diversions across the bulk area perimeter which is defined for this method. The natural runoff component, with its high 30 percent possible error, introduces a proportionately greater source of error into the Stream Depletion computations than in the Project Depletion Method, because the methodology requires the natural runoff component from the total intervening area. In practise, the integral effects of all shortcomings of the Stream Depletion Method, would produce errors greater than those produced by the Project Depletion Method. Therefore the Stream Depletion Method is not recommended for use in the basins considered.

Rimflow Method

The Rimflow Method also uses a bulk area approach. The method is based on a regression equation in which the natural flow at Point 4 is a function of the natural inflow to the bulk area. The net depletion for the project is determined as the difference between recorded and calculated natural values at Point 4.

The Rimflow Method assumes that a high degree of statistical correlation can be attained by considering only the flows at the upper and lower boundaries of the bulk area. This assumption may not be valid in practise because the areas above the upper and the lower boundaries may not be hydrologically homogeneous. There is also the problem of determining historic natural flows at the bulk area boundaries for use in the regression equations. Natural outflows at the lower boundary would be reconstructed from past main stem flow and project use records. This really means that current natural flow estimates would be based on past estimates and would depend on the extent and accuracy of past record used in the initial analysis. The regression equation produced by the analysis of these natural flows could then presumably be used to determine all future natural outflows.

Another drawback of the method is that, as with other bulk inflow-outflow methods, some correlations involving index stations must be used to account for the numerous lower-order streams which cross the bulk area boundary. In addition, the determination or measurement of rainfall-runoff parameters may be required to improve the resulting regression equations. The complexity of the analysis and the data requirement for implementation rises accordingly. This method is therefore not recommended for use in the basins considered.

Consumptive Use Method

The Consumptive Use Method is heavily oriented to the determination of depletions due to irrigation consumptive use. Depletions due to storage and diversion must be handled in some other manner, presumably by direct gauging. The Method involves computation of the evapotranspiration of irrigation water by crops with the use of empirical formulae. The total project consumptive use is the sum of evapotranspiration plus conveyance and application losses corrected for the natural runoff component. The natural flow at Point 4 (see Figure 1) is then recorded flow at the point plus project consumptive use.

Researchers in this field have devised numerous emperical formulae to determine evapotranspiration. However, the number and variation in parameters required is large, including factors describing meteorological conditions, crop type, farm irrigation practise, soil type, and land preparation and topography. Generally, formulae which have reduced data requirements are limited in their applicability, while less restrictive methods have correspondingly higher requirements for complex data.

An additional drawback is that conveyance and storage losses to evaporation or groundwater have to be estimated separately. The only portion of flow which could be simulated using consumptive use methodology is the diversion which is used by irrigated vegetation. This includes as a consequence of computation what would have been natural runoff from the corresponding areas. It would seem better to estimate this natural runoff directly rather than to compute total areal precipitation and deduct a calculated consumptive use. By the same token, actual irrigation use would be better calculated by direct measurement of diversion and deduction of measured and estimated return flows. Due to the complex data requirements and the requirement for some methodology to handle storage and diversion depletions, this method is not recommended for use in the basins considered.

The Saskatchewan-Nelson Basin Board Method

The Saskatchewan-Nelson Basin Board Method for determination of natural flows was devised in order to simulate long-term natural flows for use in large water supply studies. Irrigation consumptive uses were developed using regression techniques based on seasonal use per irrigated acre and corresponding precipitotion record. This method is not, nor was it intended to be, suited for use in apportionment.

A Summary

In summary the main points in favour of the Project Depletion Method as compared to other methods are:

- The Project Depletion Method can be used in all five basins under consideration.

- The Stream Depletion and Rimflow methods, in essence, use total outflow less total inflow to determine use in the intervening areas. Use items for individual projects are normally only a fraction of inflow. Therefore, by using the inflow rather than the use items themselves, the measurement error is unnecessarily increased.

- Precise routing of all inflow to the bulk area to the lower boundary is essential with bulk inflow-outflow methods since it is the largest single flow item and also probably traverses the greatest distance. Only the depletion items require routing in the Project Depletion method.

- The natural runoff component computed using empirical relationships, is used, year round, for the total development area in the Stream Depletion and Rimflow methods. For the Prairies, the natural runoff component can only be estimated within 30 percent. The Project Depletion Method can ignore determination of the natural runoff component because of the low value of unit runoff in the arid areas being irrigated and relatively small portions of the basin in which natural channels carry both irrigation return flow and natural runoff. Since the major portion of natural runoff occurs during the snowmelt runoff period, which normally occurs before the irrigation season, the two components can often be separated.

- Consumptive Use methodology relies on estimates for irrigation conveyance and storage losses. These losses are a large proportion of project gross useage and their estimation increases the potential for error.

- The Project Depletion Method is not dependent on lengthy, high quality past record and is most suited to the existing data gathering network.

- The application of the Project Depletion Method produces information which can be used for other water mangement purposes. The method requires direct measurement or estimation of evaporation from reservoirs. Transportation and conveyance losses are estimated from direct measurement of diversions and return flows.

- The Project Depletion Method permits the development of a relatively simple data processing procedure to compute the natural flow, and project consumptive use and change in storage.

- The present data networks are most suited to the Project Depletion Method, therefore the method can be made operational sooner and data collection costs will be less than for other methods.

PRAIRIE PROVINCES WATER BOARD

RECOMMENDATIONS

Recommendations are made for the following five major river basins:

South Saskatchewan River Basin to the confluence with the Red Deer River
North Saskatchewan River Basin to the Alberta-Saskatchewan boundary
Saskatchewan River Basin to the Saskatchewan-Manitoba boundary
Qu'Appelle River Basin to the Saskatchewan-Manitoba boundary
Churchill River Basin to the Saskatchewan-Manitoba boundary

The Recommendations made for calculating natural flow at each of the boundary crossings are presented under the following headings:

A. Apportionment Point

B. Method

C. Accuracy of Flow Determination

D. Frequency of Reporting

E. Hydrometric Network

F. Evaporation

G. Meteorologic Network

H. Effects of Land Use Changes

I. Groundwater

J. Routing

SOUTH SASKATCHEWAN RIVER BASIN

A. POINT OF APPORTIONMENT

It is recommended that the point of apportionment of the South Saskatchewan River at the Alberta-Saskatchewan boundary be a point at or as near as reasonably may be below the confluence of the South Saskatchewan and Red Deer Rivers.

Schedule A of the Apportionment Agreement states that the natural flow of any watercourse crossing the interprovincial boundary shall be at the boundary or at a point reasonably near the boundary. In the case of the South Saskatchewan River, Alberta is given the option of apportioning the South Saskatchewan and Red Deer River as a unit below the confluence of the two rivers. In the draft Terms of Reference for the study, apportionment of water below the confluence of the two rivers was specifically mentioned.

The procedures developed compute natural flow on the South Saskatchewan River at Hwy 41 and on the Red Deer River near Bindloss. Both points are very close to the boundary and the natural flow of each river could be apportioned individually using these two points if Alberta so chooses. On the other hond, if apportionment below the confluence is desired, the natural flow of the two rivers at the specified points can be added and apportioned collectively. Both Hwy 41 and Bindloss are sufficiently close to the boundary (approximately 10 and 15 river miles respectively) and the confluence (approximately 20 and 25 miles respectively) that local inflow is negligible and the flow at the confluence can accurately be represented by the sum of the natural flow of the Saskatchewan River at Hwy 41 and the Red Deer River at Bindloss.

Monitoring for apportionment purposes on the South Saskatchewan River at Lemsford was rejected by the Committee. It was felt that the streamflow records at the Lemsford station would not be sufficiently accurate for apportionment purposes. In addition, the Lemsford site is relatively far downstream of the confluence and 50 river miles downstream of the boundary. Local inflow, although not great, would be more significant than in the case of using the sum of the flow recorded on the South Saskatchewan River at Highway 41 and Red Deer River at Bindloss.

B. METHOD

It is recommended that the Project Depletion Method be used to calculate flows required for apportionment on the South Saskatchewan River below the confluence with the Red Deer River.

The Project Depletion Method has been demonstrated to be the most comprehensive method for the computation of natural flows or total depletion of natural flows. Two inherent advantages of this method, when used for computation of natural flows in the South Saskatchewan River basin are: its compatibility with existing data-gathering facilities, and the fact that rather than statistically simulating regional natural state conditions, adjustments are made only for actual depletions to flow. Of the three remaining, commonly accepted, natural flow computational procedures, the Consumptive Use Method is least suited to large-scale determinations. This method requires data relating to a multitude of parameters and does not in itself allow for storage and conveyance losses. The Stream Depletion Method relies heavily on estimates of regional natural runoff which are, at best, questionable. The Rimflow Method is dependent upon high quality, long-term, natural streamflow record of all flows both into and out of the region in question. A high degree of statistical correlation between the established natural flows and meteorological parameters is a further prerequisite of this method's operation. The available long-term record covering the South Saskatchewan River basin does not fulfill these requirements.

C. ACCURACY OF FLOW DETERMINATION

It is recommended that the error limits for monthly hydrometric record at the point of apportionment be four percent under open water and ten percent under ice conditions.

The accuracy of the hydrometric record at the point of apportionment is normally the most critical factor in determining the accuracy of natural flow computations. For that reason hydrometric gauging stations at points of apportionment should be operated as first class stations under standards used by the Water Survey of Canada. Instrumentation, measurement frequency, measurement technique, and computational procedures should be such that the error limit for monthly hydrometric record is four percent during open water and ten percent under ice conditions. Particular attention should be given to the variability of the stage-discharge relationship during low flow periods and adjustments made to the monitoring program as necessary.

The accuracy of the hydrometric record at other monitoring points should be commensurate with the use of the information and the relative impact on accuracy of computation of the apportioned flow. Normal Water Survey of Canada standards would apply in most cases.

D. FREQUENCY OF REPORTING

It is recommended that natural flow computations be reported quarterly, based on monthly means, reverting to a one month reporting period when the recorded flow drops below 1,500 cfs.

Actual use and the potential for use and storage of water in the South Saskatchewan River basin in Alberta are high enough to require quarterly reports of natural flow computations. During the period 1970-1975, use on an annual basis averaged between 10 and 20 percent of the natural flow, however during this period, monthly uses have been as high as 45 percent of the natural flow during the irrigation season. The Committee therefore feels that a quarterly reporting period is required and is sufficient for the present. Increased use in the basin in the future may necessitate monthly reporting, at least during the irrigation season.

Monthly reports are recommended when the recorded flow below the confluence of the South Saskatchewan and Red Deer Rivers drops below 1,500 cfs. Schedule A of the Apportionment Agreement stipulates that Alberta may use 2.1 million acre-feet annually, even if such use is more than one-half the annual natural flow or causes the recorded flow to be less than one half of the natural flow, provided the recorded flow does not drop below 1,500 cfs. When recorded flows drop below 1,500 cfs Alberta must deliver at least one-half the natural flow. The Committee feels that, under these low flow conditions, monthly reporting is required to properly monitor apportionment.

E. HYDROMETRIC NETWORK

It is recommended that data obtained at the following hydrometric gauging stations be used to compute flows for apportionment purposes on the South Saskatchewan River below the confluence with the Red Deer River.

All recommended stations are existing stations and no new stations are required. The stations are listed according to function.

Computation points:

Red Deer River near Bindloss	-	05CK004
South Saskatchewan River at Highway 41	-	05AK001

Routing points:

Bow River at Calgary	-	05BH004
Bow River near the Mouth	-	05BN012
Oldman River near Lethbridge	-	05AD007

Diversions:

Bow River Development Main Canal	-	05AC004
Canadian St. Mary Canal near Spring Coulee	-	05AE026
Eastern Irrigation District East Branch Canal near Lathom	-	05CJ003
Eastern Irrigation District North Branch Canal near Bassano	-	05CJ001
Eastern Irrigation District Springhill Canal near Lathom	-	05CJ004
Lethbridge Northern Irrigation District Canal at Menzaghies Bridge	-	05AB016
Little Bow Canal at High River	-	05BL015
Little Bow River at Carmangay	-	05AC003
Little Bow River below Travers Dam	-	05AC012
Magrath Irrigation District Canal near Spring Coulee	-	05AE021
Mountain View Irrigation District Canal	-	05AD017
United Irrigation District Canal near Hill Spring	-	05AD013
Western Irrigation District Canal near Chestermere Lake	-	05BM003

Return flow points:

Antelope Coulee Spillway (EID)	-	05BN010
Battersea Drain near the Mouth (LNID)	-	05AD038
Bountiful Coulee near Cranford (TID)	-	05AG008
Bow River Development Drain K near Vauxhall (BRD)	-	05BN009
Cairn Hill Spillway near the Mouth (WID)	-	05BM012
Crowfoot Creek near Cluny (WID)	-	05BM008
Drain S-4 near Grassy Lake (SMRID)	-	05AJ002
Drain S-10 near Bow Island (SMRID)	-	05AJ003
Drain T-2 near Taber (TID)	-	05AG023
Drain T-11 near Fincastle (TID)	-	05AG025
Expanse Coulee near the Mouth (BRD)	-	05AG003
Little Bow River near the Mouth (LNID)	-	05AC023
Matzhiwin Creek above Ware Coulee (EID)	-	05CJ007
New West Coulee near the Mouth (BRD)	-	05BN006
Onetree Creek near Patricia (EID)	-	05CJ006
Pigami Drain near Picture Butte (LNID)	-	05AD037
Pothole Creek near Russels Ranch (SMRID)	-	05AE016
Rosebud River at Redland (WID)	-	05CE005
Seven Persons Creek at Medicine Hat (SMRID)	-	05AH005
Ware Coulee above Matzhiwin Creek (EID)	-	05CJ008

BRD - Bow River Development
EID - Eastern Irrigation District
LNID - Lethbridge Northern Irrigation District
SMRID - St. Mary River Irrigation Development
TID - Taber Irrigation District
WID - Western Irrigation District

Lake and reservoir levels:

Barrier Lake near Seebe	-	05BF024*
Ghost Lake near Cochrane	-	05BE005*
Glenmore Reservoir**		
Upper Kananaskis Lake at Main Dam	-	05BF005*
Lower Kananaskis Lake at Pocaterra Dam	-	05BF009*
Lake Minnewanka near Banff	-	05BD003*
St. Mary Reservoir near Spring Coulee	-	05AE025
Spray Reservoir at Three Sisters Dam	-	05BC006*
Waterton Reservoir	-	05AD026

* Record contributed by Calgary Power
** Record contributed by City of Calgary

F. EVAPORATION

It is recommended that evaporation losses from Waterton and St. Mary Reservoirs be included as depletions of natural flow and that these losses be calculated with Meyer's formula using the coefficient C=10.

The combined net evaporation loss from Waterton and St. Mary Reservoirs has been estimated, by the Saskatchewan Nelson Basin Board, to average 18,000 acre-feet annually and to be as high as 30,000 acre-feet annually, based on 1970 levels of development. On an annual basis, this is a very small percentage of the natural flow of the South Saskatchewan River below the Red Deer River. On a monthly basis however, evaporation can be significant. For example, in September 1960 the combined estimated evaporation from the two reservoirs was two percent of the estimated natural flow below the Red Deer River. This value could be as high as four percent if the maximum monthly evaporation is compared with the minimum monthly natural flows during the June to September period.

The seven Calgary Power Reservoirs are in the headwaters of the Bow River system. These reservoirs all have consistently cool surface conditions, a small increase in open water surface due to reservoir construction, and small contents relative to flow through. Under these conditions it was felt that evaporation losses from these reservoirs could be neglected in the natural flow computations.

G. METEOROLOGIC NETWORK

It is recommended that the existing meteorologic station at Lethbridge be retained. It is also recommended that new meteorologic stations be installed at Waterton and St. Mary Reservoirs at least for the period required to develop relationships between Lethbridge evaporation and evaporation at each of the two reservoirs.

The meteorological instrumentation required to estimate evaporation from the Waterton and St. Mary's Reservoirs using Meyer's formula should be installed. Measurements of water surface temperature and wind speed are required for each reservoir. Atmospheric vapour pressure data from Lethbridge should be satisfactory eventually. However, it may be necessary to install humidity measuring equipment for two summers to discover any bias between lakeside measurements and Lethbridge.

H. EFFECTS OF LAND USE CHANGES

It is recommended that effects on runoff of changing land use patterns not be considered in the computation of natural flow.

Little is known about the effects of land clearing for agriculture, drainage, forestry, industrial and urban development and other land use changes on natural runoff. Assessment of these changes would itself require detailed study. Until conclusive evidence is available which clearly shows that the land use changes cited above contribute significantly to increased or decreased flow volumes at interprovincial boundaries, it is recommended that the effect of these changes be ignored in natural flow calculations.

I. GROUNDWATER

It is recommended that changes in natural flow due to groundwater inflow or recharge not be considered in the computations.

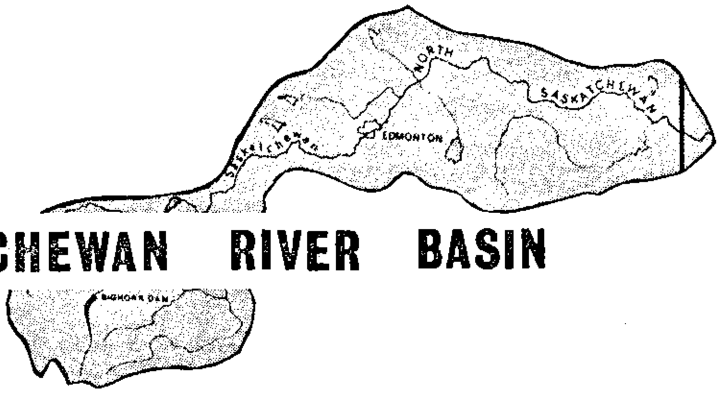
Groundwater storage and sub-surface flow are influenced by forestry and agriculture, and locally by reservoir construction. Little is known about the changes in sub-surface flow regimes resulting from land use change, particularly intensive agriculture and irrigation. Some studies of Alberta Irrigation districts have indicated that the groundwater component of return flow varies considerably. However, analysis of recession curves of major return flow channels indicates that the groundwater component is quite small. For this reason the groundwater component of return flow, which returns to the main stem, has not been considered in this study.

The effects of upstream manipulation, particularly reservoir construction, on regional groundwater systems which cross interprovincial boundaries, should be negligible, especially since the transmissibility in the area is known to be low.

J. ROUTING

It is recommended that calculated depletions due to consumptive use, diversion, and reservoir storage and evaporation be routed to the point of apportionment and applied to the recorded flow in order to determine natural flow.

Project depletions are calculated using on-site data. The correction to monthly quantities due to time of travel from the point of depletion to the point of apportionment can be considerable. For example, in 1973, the monthly routing adjustments to natural flow varied between 0.6 percent and 14 percent of the natural flow of the South Saskatchewan River below the confluence of the Red Deer River.



NORTH SASKATCHEWAN RIVER BASIN

A. POINT OF APPORTIONMENT

It is recommended that the point of apportionment of the North Saskatchewan River at the Alberta-Saskatchewan boundary be the gauging station, North Saskatchewan River near Deer Creek.

The Deer Creek monitoring site is approximately 20 river miles downstream of the boundary. There are no major sources of inflow between the boundary and the site, and the site is well suited for streamflow measurement. Two other sites on the river in the vicinity of the boundary were previously rejected as apportionment points. The North Saskatchewan River at Lea Park is affected by backwater caused by the Vermillion River and was discontinued in 1971. The channel at the Frenchman Butte site is hydrometrically unsuitable.

B. METHOD

It is recommended that the Project Depletion Method be used to calculate natural flows on the North Saskatchewan River at the Alberta-Saskatchewan boundary.

Use of North Saskatchewan River water in Alberta is largely confined to hydro-electric generation at the Big Bend and Bighorn Plants. The Project Depletion method requires only that adjustments be made for the storage increments at these two sites. The method is, therefore, easily implemented. The Project Depletion method is also well suited to include adjustments for future water resource development. Other natural flow computational procedures that warrant consideration are: the Stream Depletion, Rimflow and Consumptive Use methods.

These employ regional relationships of rainfall, runoff and evapotranspiration and do not isolate specific uses. The data requirements with respect to type and number of observation points is greater when any of the last three methods is used. The Project Depletion Method can be put into operation using existing data-gathering facilities.

C. ACCURACY OF FLOW DETERMINATION

It is recommended that the error limits for monthly hydrometric record at the point of apportionment be four percent under open water and ten percent under ice conditions.

The accuracy of the hydrometric record at the point of apportionment is normally the most critical factor in determining the accuracy of natural flow computations. For that reason hydrometric gauging stations at points of apportionment should be operated as first class stations under standards used by the Water Survey of Canada. Instrumentation, measurement frequency, measurement technique, and computational procedures should be such that the error limit for monthly hydrometric record is four percent during open water and ten percent under ice conditions. Particular attention should be given to the variability of the stage-discharge relationship during low flow periods and adjustments made to the monitoring program as necessary.

The accuracy of the hydrometric record at other monitoring points should be commensurate with the use of the information and the relative impact on accurocy of computation of the apportioned flow. Normal Water Survey of Canada standards would apply in most cases.

D. FREQUENCY OF REPORTING

It is recommended that natural flow computations be reported annually, based on monthly means.

The level of development in the basin is low and present uses are such that Saskatchewan receives its apportioned share annually. An annual reporting period is recommended primarily for informational purposes, but also to monitor changing use patterns in the upstream province.

E. HYDROMETRIC NETWORK

It is recommended that data obtained at the following hydrometric gauging stations be used to compute natural flows on the North Saskatchewan River at the Alberta-Saskatchewan boundary for apportionment purposes.

All recommended stations are existing stations and no new stations are required. The stations are listed according to function.

Computation Point:

North Saskatchewan River near Deer Creek	-	05EF001

Routing Points:

North Saskatchewon River at Edmonton	-	05DF001
North Saskatchewan River near Rocky Mountain House	-	05DC001

Reservoir Levels:

Brazeau Reservoir	-	05DD006
Lake Abraham near Nordegg	-	05DC009

There are no diversion or return flow monitoring stations required.

F. EVAPORATION

It is recommended that the evaporation losses from Lake Abraham and Brazeau Reservoir be neglected. It is further recommended that additional evaporation caused by the thermal plant on Wabamun Lake not be considered in the computation of natural flow.

The combined evaporation loss caused by these two reservoirs and Wabamun Lake is less than 25 cfs. This loss is only a fraction of one percent of the main stem river flow.

G. METEOROLOGIC NETWORK

No meteorologic stations are required for computation of natural flow on the North Saskatchewan River at the Alberta-Saskatchewan boundary.

H. EFFECTS OF LAND USE CHANGES

It is recommended that effects on runoff of changing land use patterns not be considered in the computation of natural flow.

Little is known about the effects of land clearing for agriculture, drainage, forestry, industrial and urban development and other land use changes on natural runoff. Assessment of these changes would itself require detailed study. Until conclusive evidence is available which clearly shows that the land use changes cited above contribute significantly to increased or decreased flow volumes at interprovincial boundaries, it is recommended that the effect of these changes be ignored in natural flow calculations.

I. GROUNDWATER

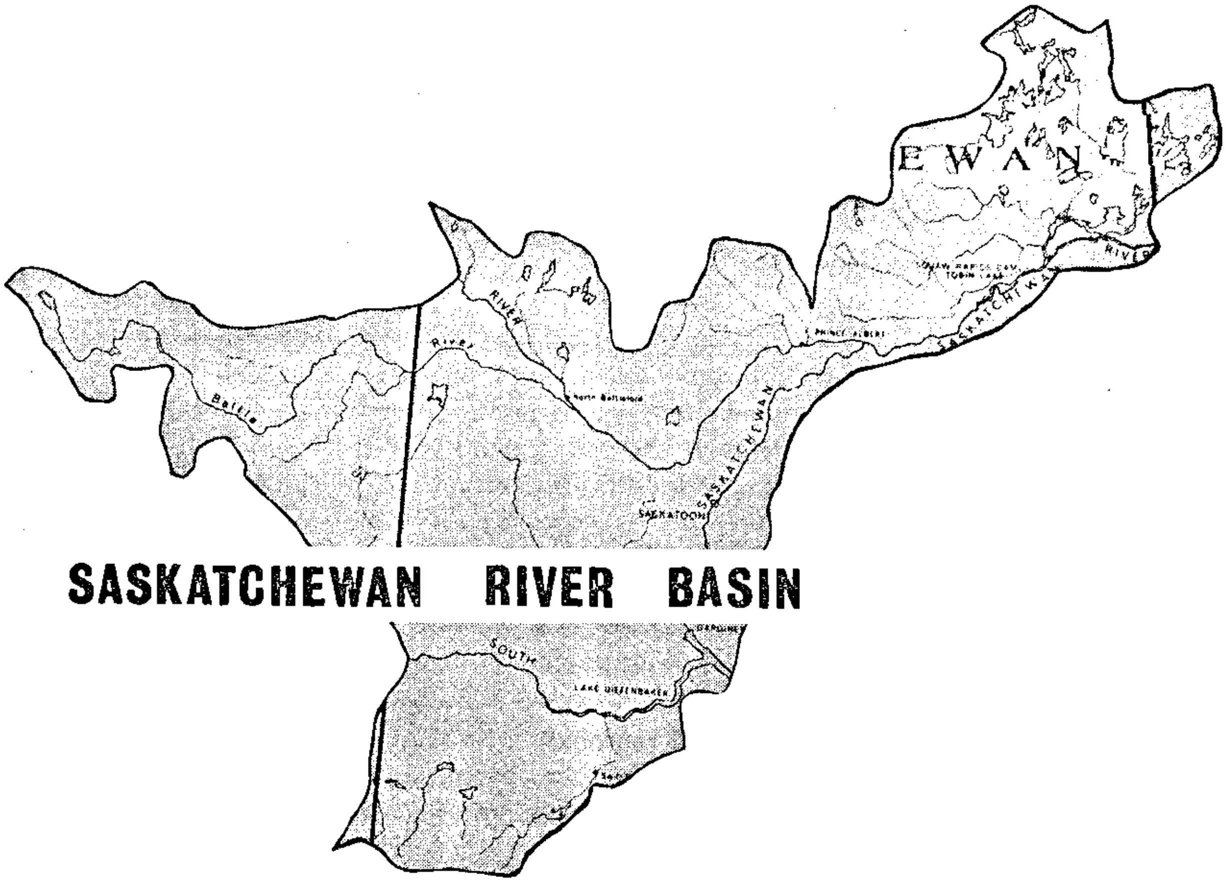
It is recommended that changes in natural flow due to groundwater inflow or recharge not be considered in the computations.

Groundwater storage and sub-surface flow are influenced by forestry and agriculture, and locally by reservoir construction. Very little is known about the changes in the surface runoff and sub-surface flow regimes resulting from changes in land use and reservoir construction. Determining the extent of such modifications and the ultimate result on natural flow would be a major study in itself. It is generally felt that the quantities involved are small with respect to the natural flows being considered and the identifiable sources of error.

J. ROUTING

It is recommended that calculated depletions due to reservoir storage be routed to the point of apportionment and applied to recorded flow in order to determine natural flow.

Project depletions are calculated using on-site data. The correction to monthly quantities due to time of travel from the point of depletion to the point of apportionment can be considerable. In the North Saskatchewan River Basin in Alberta only two projects need be considered in the computation of natural flow; Lake Abraham and Brazeau Reservoir. The monthly routing adjustments for these projects may average four percent of the natural flow of the North Saskatchewan River at the Alberta-Saskatchewan boundary.



SASKATCHEWAN RIVER BASIN

A. POINT OF APPORTIONMENT

It is recommended that the point of apportionment on the Saskatchewan River at the Manitoba-Saskatchewan boundary be the gauging station designated as the Saskatchewan River near Manitoba Boundary.

The site on the Saskatchewan River "near the Manitoba boundary" is only two river miles upstream from the actual boundary. This site is hydrologically acceptable, is close to the boundary so that no significant inflow enters the river between the site and the boundary, and certainly fulfills the stipulation in Schedules A and B of the Apportionment Agreement that "natural flow shall be determined at a point as near as reasonably may be" to the boundary crossing.

B. METHOD

It is recommended that the Project Depletion Method be used to calculate flows required for apportionment on the Saskatchewan River at the Saskatchewan-Manitoba boundary.

Each of the four fundamental methods was considered for use in determination of the Saskatchewan River flows specified for apportionment at the Saskatchewan-Manitoba boundary. The Consumptive Use Method calculates the difference between observed and natural-state runoff through analysis of data relating to evapotranspiration rates due to the various crop types, soil types and conditions, and meteorological factors. Use of this method implies an unweildy data collection program; moreover, the effects of storage and conveyance of water cannot be treated directly when using this method. The Consumptive Use Method was, therefore, rejected. In the Stream Depletion Method gross inflow and natural runoff are compared with recorded outflow from the region in order to assess depletion of the natural runoff component within the region. Estimates of natural-state runoff from the entire area are, therefore, essential to this procedure. The lack of past natural runoff record and corresponding meteorological data, from which relationships for use in simulation of current natural runoff are based, reduces the reliability of the Stream Depletion Method to an unacceptable degree. The Rimflow Method relates the natural outflow from a region to the natural inflow by use of statistical relationships. In the case of the Saskatchewan River basin, past record is not of the quality or completeness to justify the derivation of such relationships. The Project Depletion Method was recommended for use because it considers each depletion to flow individually and, in the main, such data is readily available from the existing hydrometric network.

C. ACCURACY OF FLOW DETERMINATION

It is recommended that the error limits for monthly hydrometric record at the point of apportionment be four percent under open water and ten percent under ice conditions.

The accuracy of the hydrometric record at the point of apportionment is normally the most critical factor in determining the accuracy of computotions of flows required for apportionment. For that reason hydrometric gauging stations at points of apportionment should be operated as first class stations under standards used by the

Water Survey of Canada. Instrumentation, measurement frequency, measurement technique, and computational procedures should be such that the error limit for monthly hydrometric record is four percent during open water and ten percent under ice conditions. Particular attention should be given to the variability of the stage-discharge relationship during low flow periods and adjustments made to the monitoring program as necessary.

The accuracy of the hydrometric record at other monitoring points should be commensurate with the use of the information and the relative impact on accuracy of computation of the apportioned flow. Normal Water Survey of Canada standards would apply in most cases.

D. FREQUENCY OF REPORTING

It is recommended that computations of flows required for apportionment be reported annually based on monthly means.

The total level of development in the basin is low and present uses are such that Manitoba receives its apportioned share annually. An annual reporting period is recommended, primarily for informational purposes, but also to monitor changing use patterns in Saskatchewan.

There is potential for increased use provided by Lake Diefenbaker. If works are built to increase irrigation or divert water out of the basin, it may be necessary to reassess the reporting period with a view to more frequent reporting.

E. HYDROMETRIC NETWORK

It is recommended that data obtained at the following hydrometric gauging stations be used to compute flows for apportionment purposes on the Saskatchewan River at the Saskatchewan-Manitoba boundary.

All recommended stations are existing stations and no new stations are required. The stations are listed according to function.

Computation Point:

Saskatchewan River near the Manitoba Boundary - 05KH008

Routing Points:

North Saskatchewan River at Prince Albert	-	05GG001
South Saskatchewan River at Saskatoon	-	05HG001
South Saskatchewan River at St. Louis	-	05HH001

Diversions:

Broderick Irrigation Project Main Canal below Pumping Station	-	05HF007
Elbow Diversion Canal at Drop Structure	-	05JG006
Saskatchewan River (Dragline Channel) near Squaw Rapids	-	05KH011
Swift Current Canal at Swift Current	-	05HD034

Lake and Reservoir Levels:

Lake Diefenbaker at Gardiner Dam	-	05HF003
Tobin Lake at Squaw Rapids Spillway	-	05KD004
Reid Lake near Duncairn	-	05HD033

There are no return flow stations recommended at the present time. Of the three major diversions, only the Saskatoon South East Project returns a measurable flow of diverted water. The quantities presently involved are, however, considered to be insignificant compared to the calculated apportionment flows. If irrigation diversions increase in the future, it may be necessary to consider return flow as a part of the irrigation use factor. The proposed Ducks Unlimited project in the Cumberland Lake Delta area may produce some direct return flow to the Saskatchewan River in Saskatchewan if additional drains are built. The quantity of this return flow will have to be assessed in relation to natural flows to determine whether or not it is significant.

F. EVAPORATION

It is recommended that evaporation losses from Lake Diefenbaker, Tobin Lake and Reid Lake be included as depletions of natural flow and that these losses be computed using Meyer's formula.

Evaporation losses from these reservoirs are significant. For example, the Saskatchewan-Nelson Basin Board estimated the evaporation loss from Lake Diefenbaker to be three percent of the natural flow on the Saskatchewan River at The Pas for September, 1967. For the same month, evaporation from Tobin Lake was very high and was estimated as two percent of the natural flow. Given drier hydrologic and meteorologic conditions these percentages could be as high as six percent and three percent respectively for the months between June and September. No information is available for evaporation values for Reid Lake.

The depletions due to evaporation losses from Lake Diefenbaker, Reid, and Tobin Lakes should be calculated using the Meyer equation. The physical configuration, size and shape of Lake Diefenbaker are such that meteorologic conditions differ between the upper and lower reaches. Therefore, Lake Diefenbaker should be treated in two sections using the Meyer coefficient (C) of nine for each section. The division between the two sections is the Riverhurst Ferry crossing. The evaporation for Reid Lake should be calculated using the unit evaporation for Lake Diefenbaker multiplied by a factor of 1.10. A Meyer coefficient of ten should be used for Tobin Lake.

G. METEOROLOGIC NETWORK

It is recommended that the following six meteorologic stations be retained to provide data for evaporation computations using the Meyer formula.

All recommended stations presently exist and no new stations are required.

- Elbow
- Lake Diefenbaker (lower)
- Lake Diefenbaker (upper)
- Nipawin
- Swift Current
- Tobin Lake

H. EFFECTS OF LAND USE CHANGES

It is recommended that effects on runoff of changing land use patterns not be considered in the computation of flow required for apportionment.

Little is known about the effects of land clearing for agriculture, drainage, forestry, industrial and urban development, and other land use changes on natural runoff. Assessment of these changes would itself require detailed study. Until conclusive evidence is available which clearly shows that the land use changes cited above contribute significantly to increased or decreased flow volumes at interprovincial boundaries, it is recommended that the effect of these changes be ignored in natural flow calculations.

I. GROUNDWATER

It is recommended that changes in natural flow due to groundwater inflow or recharge not be considered in the computations.

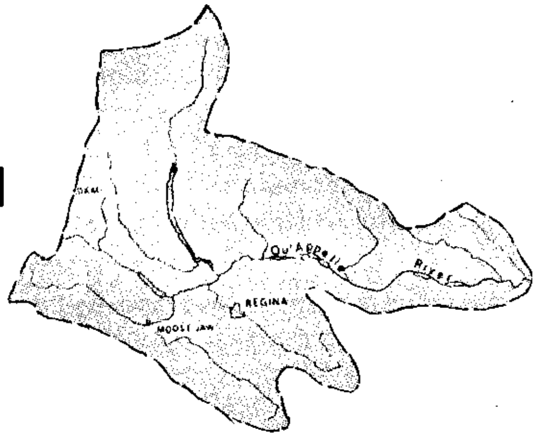
Groundwater storage and sub-surface flow are influenced by forestry and agriculture, and locally by reservoir construction. Very little is known about the changes in the surface runoff and sub-surface flow regimes resulting from changes in land use and reservoir construction. Determining the extent of such modifications and the ultimate result on natural flow would be a major study in itself. It is generally felt that the quantities involved are small with respect to the natural flows being considered and the identifiable sources of error.

J. ROUTING

It is recommended that calculated depletions due to diversion, and reservoir storage and evaporation be routed to the point of apportionment and applied to the recorded flow in order to produce flow values required for apportionment.

Project depletions are calculated using on-site data. The correction to monthly quantities due to time of travel from the point of depletion to the point of apportionment can be considerable. In the Saskatchewan River Basin in Saskatchewan it has been estimated that the monthly routing adjustments for the projects considered average four percent of the flows required for apportionment on the Saskatchewan River at the Saskatchewan-Manitoba boundary.

QU'APPELLE RIVER BASIN



A. POINT OF APPORTIONMENT

It is recommended that the point of apportionment of the Qu'Appelle River at the Saskatchewan-Manitoba boundary be the gauging station Qu'Appelle River near Welby.

The Welby monitoring site is approximately four river miles upstream of the boundary and no appreciable local inflow enters the Qu'Appelle River between the gauging station and the boundary. The site has proven to be hydrometrically stable at medium and high flows and it is expected to display reasonably stable characteristics at low flows.

B. METHOD

It is reccmmended that the Project Depletion Method, supplemented by the routing capabilities of the SSARR Model, be used to calculate natural flows on the Qu'Appelle River at the Saskatchewan-Manitoba boundary.

The Qu'Appelle River Basin is relatively large, whereas the quantities of streamflow are small when compared to basins of similar extent located in more humid areas. Municipal, agricultural and industrial development has placed a very heavy demand on available water supplies. Runoff patterns have been modified by land use, and construction of reservoirs as well as control and diversion structures along stream channels and at the outlets of lakes. The very high order and complexity of water resource development precludes selection of a natural flow computational procedure other than the Project

Depletion Method or variations thereof. Each project causing storage, consumption or diversion must be identified and its effect on the overall natural flow accurately calculated. To attain the degree of precision required, daily routing using the SSARR Model has been incorporated into the computational procedure so that the sequential time effects of each water use project will be reflected in the natural flow calculated at the Saskatchewan-Manitoba boundary.

It is recommended that depletion due to diversions into Eyebrow Lake be approximated by the application of fixed quantities during the summer months.

Eyebrow Lake water levels are maintained during the summer months for waterfowl production by diversions from the Qu'Appelle River. Annual consumption, primarily through evaporation has been estimated as 1250 acre-feet. The fixed quantities which are recommended for use during the summer months are as follows:

May	50 acre-feet
June	250
July	500
August	350
September	100

The monthly adjustments should be applied evenly on a daily basis.

It is recommended that depletion of runoff due to storage in small reservoirs be estimated using four index reservoirs.

Small project uses in the other basins considered have been ignored since they are small in relation to the natural flow. In the Qu'Appelle River Basin the depletion due to small project use has been estimated as 10,500 acre-feet annually. This amount is five percent of the average annual natural flow of the Qu'Appelle River at Welby and may be as high as 33 percent in a dry year. It is therefore necessary to account for these small project uses.

The Qu'Appelle River Basin has been subdivided into 15 tributary basins. Four of these basins, Moose Jaw River, Wascana Creek, Last Mountain Lake and Kaposvar Creek, have an appreciable number of small projects. Gauges should be installed on a representative reservoir in each of these tributary basins and monthly small project uses for the Qu'Appelle River Basin derived using these index reservoirs. The monthly uses determined should then be applied evenly on a daily basis. The selection of the index reservoirs will be done in the near future by the Committee on Hydrology based on a review of the Water Rights files and determination of a "representative" reservoir in each sub-basin.

C. ACCURACY OF FLOW DETERMINATION

It is recommended that the error limits for monthly hydrometric record at the point of apportionment be four percent under open water and ten percent under ice conditions.

The accuracy of the hydrometric record at the point of apportionment is normally the most critical factor in determining the accuracy of natural flow computations. For that reason hydrometric gauging stations at points of apportionment should be operated as first class stations under standards used by the Water Survey of Canada. Instrumentation, measurement frequency, measurement technique, and computational procedures should be such that the error limit for monthly hydrometric record is four percent during open water and ten percent under ice conditions. Particular attention should be given to the variability of the stage-discharge relationship during low flow periods and adjustments made to the monitoring program as necessary.

The accuracy of the hydrometric record at other monitoring points should be commensurate with the use of the information and the relative impact on accuracy of computation of the apportioned flow. Normal Water Survey of Canada standards would apply in most cases.

D. FREQUENCY OF REPORTING

It is recommended that natural flow computations be reported quarterly, based on monthly means.

Historic natural flow computations over the period March 1, 1956 to December 31, 1974 indicate that the annual recorded flow on the Qu'Appelle River near Welby has been less than 50 percent of the annual natural flow on four occasions. Throughout the period the amount delivered on a monthly basis has been less than 50 percent of the natural flow on numerous occasions. Even since the construction of Gardiner Dam in 1966 monthly deliveries at times have been less than 50 percent of the natural flow, particularly during the summer months; although, on an annual basis, Manitoba has received its apportioned share. With the exception of 1968, the annual natural flows experienced during the period since completion of Gardiner Dam (1967-1974), have been above the median annual natural flow of 120,000 acre-feet.

From the historic data, it appears evident that flow regulation and capacity for consumptive use within Saskatchewan is such that quantities in excess of 50 percent of the natural flow may be stored or used by Saskatchewan on both a monthly and an annual basis. It is felt that, in order to aid Saskatchewan in providing Manitoba with the flow specified under the Apportionment Agreement, quarterly reporting on natural flows is necessary. Monthly reporting, particularly during the summer months, may be required if experience shows that quarterly reporting is not sufficiently frequent to ensure equitable apportionment.

E. HYDROMETRIC NETWORK

It is recommended that the following hydrometric gauging stations be used to compute natural flows for apportionment purposes on the Qu'Appelle River at the Saskatchewan-Manitoba boundary.

Of the 21 stations listed below, 17 are existing stations. The four new stations are water level gauges on the four index reservoirs required to determine small project useage.

Computation point:

Qu'Appelle River near Welby	-	05JM001

Routing points:

Moose Jaw River near Burdick	-	05JE006
Qu'Appelle River above Buffalo Pound Lake	-	05JG004
Qu'Appelle River below Moose Jaw River	-	05JG007
Qu'Appelle River near Lumsden	-	05JF001
Qu'Appelle River at Outlet Katepwa Lake	-	05JL001
Qu'Appelle River at Hyde	-	05JM001
Qu'Appelle River below Craven Dam	-	05JK002

Diversions:

Elbow Diversion Canal at Drop Structure	-	05JG006
Buffalo Pound Lake Pumping Plant		

Lake and Reservoir levels:

Avonlea Reservoir near Avonlea	-	05JE007
Buffalo Pound Lake at Pumping Station	-	05JG009
Crooked Lake near Grayson	-	05JM006
Echo Lake at Fish Hatchery	-	05JK005
Katepwa Lake at Outlet Weir	-	05JL004
Last Mountain Lake at Rowan's Ravine	-	05JH004
Round Lake near Whitewood	-	05JM007
Kaposvar Creek Basin Index Reservoir		
Last Mountain Lake Basin Index Reservoir		
Moose Jaw River Basin Index Reservoir		
Wascana Creek Basin Index Reservoir		

F. EVAPORATION

It is recommended that incremental evaporation losses as a result of controls on the Qu'Appelle Basin Lakes be included as depletions of natural flow and that these losses be calculated using unit evaporation data for Lake Diefenbaker.

For Last Mountain Lake and the six lower Qu'Appelle Lakes net evaporation from the natural surface area is computed as a net inflow residual. This residual includes net evaporation, ungauged surface inflow and groundwater inflow. The residual, for any reach, is determined by routing the recorded flow at the head of the reach to a downstream station and substracting the routed quantity from the recorded flow at the downstream station. The residual calculated in this manner will represent the true natural ungauged inflow if the incremental evaporation due to regulation is removed as the upstream flows are routed. This natural residual is then applied to the routed natural flows at the downstream station to determine true natural flows. In order to apply this procedure the net evaporation from the incremental lake area is required. This is computed by applying the Lake Diefenbaker monthly evoporation rates multiplied by the following factors to the incremental lake areas.

January	-	0.0	July	-	1.1
February	-	0.0	August	-	1.1
March	-	0.0	September	-	1.1
April	-	0.0	October	-	1.0
May	-	0.8	November	-	0.6
June	-	1.1	December	-	0.0

For Buffalo Pound Lake the ungauged local inflow can be determined based on the flows of the Qu'Appelle River above the lake and the dry drainage area of the lake. Groundwater inflow is known to be negligible. Since these components of natural flow are known and can be computed, the computation of a net inflow residual is not needed. Evaporation is computed directly from the computed natural lake surface area and applied as natural flows are routed through the reach. The same factors as are shown above are applied to Lake Diefenbaker evaporation rates to determine evaporation from the natural surface area of the lake.

Lake Diefenbaker evaporation losses are computed in order to determine Saskatchewan River natural flow. Consequently, no separate computation procedures are required other than adjustment of the values to compensate for one coefficient in the Meyer equation.

G. METEOROLOGIC NETWORK

There are no meteorologic stations required specifically for natural flow computation in the Qu'Appelle Basin.

The meteorologic facilities required for Lake Diefenbaker evaporation computation have already been recommended in connection with the Saskatchewan River Basin.

H. EFFECTS OF LAND USE CHANGES

It is recommended that effects on runoff of changing land use patterns not be considered in the computation of natural flow.

Little is known about the effects of land clearing for agriculture, drainage, forestry, industrial and urban development, and other land use changes on natural runoff. In the Qu'Appelle River Basin in particular the reclamation of lands which, in their natural state, do not normally contribute significant runoff, has been pursued with increased vigor in recent years. Studies by Provincial and Federal agencies have been inconclusive in determining whether or not drainage works contribute significantly to flow volumes. Until conclusive evidence is available which clearly shows that drainage works and other land use changes contribute significantly to increased or decreased flow volumes at interprovincial boundaries, it is recommended that the effect of these changes be ignored in natural flow calculations.

I. GROUNDWATER

It is recommended that changes in natural flow due to groundwater inflow or recharge be considered to the extent utilized in the natural flow routing model developed by the natural flow study group.

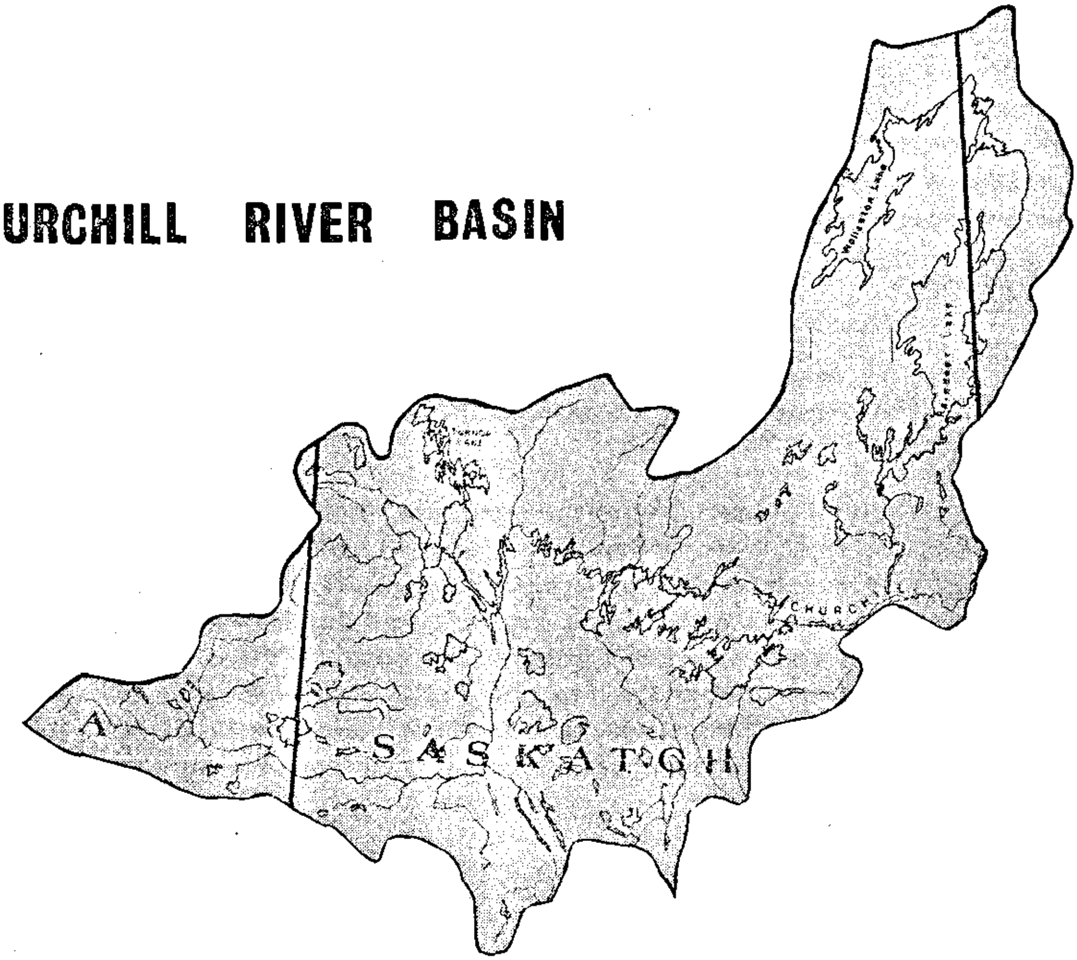
In the Qu'Appelle River Basin some knowledge of the amount and significance of groundwater inflow has had an effect on the handling of natural flow computations. Although the groundwater inflow may be natural, it must be considered in order to properly account for lake contents, particularly the contents of Last Mountain Lake. The model used treats groundwater inflow, net evaporation, and local inflow as a lumped quantity, determined by a water balance based on recorded information, and applied to simulated natural conditions.

J. ROUTING

It is recommended that, for the computation of natural flow for the Qu'Appelle River Basin, the routing procedure as described in this report be adopted.

In the Qu'Appelle River Basin the hydrologic characteristics and effects of man-made projects are such that sophisticated routing procedures are recommended for the computation of natural flow at the point of apportionment. This is due to the complex inflow outflow relationships for Last Mountain Lake and Buffalo Pound Lake and the many other artificially controlled lakes in the basin. The requirement for routing is implicit in the recommended method.

CHURCHILL RIVER BASIN



A. POINT OF APPORTIONMENT

It is recommended that the point of apportionment of the Churchill River be the Churchill River at the Saskatchewan-Manitoba boundary. It is also recommended that the measurement point for determination of flows required for apportionment on the Churchill River be the gauging station Churchill River at Sandy Bay.

Although the site at Sandy Bay is approximately 25 river miles upstream of the boundary, this site is recommended due to the character of the river immediately upstream and downstream of the boundary. Downstream of Sandy Bay the Churchill River becomes a series of lakes and braided channels where stream gauging would be extremely difficult. The actual boundary goes through Ohipwatsikew Lake and its is recommended that flows required for apportionment be synthesized within this lake. The local inflow between Sandy Bay and the boundary is significant and must be taken into account in determining the natural flow at the boundary. This local inflow has been estimated as one percent of the natural flow at Sandy Bay, and therefore the natural flows calculated for Sandy Bay should be incremented by this amount to give a more realistic estimate of the natural flow at the boundary.

B. METHOD

It is recommended that the Project Depletion Method be used to calculate flows required for apportionment on the Churchill River at the Saskatchewan-Manitoba boundary.

Artificial storage in Reindeer Lake constitutes the only significant regulation of Churchill River flows. The geography of the Churchill River basin is such that water resource development will essentially be confined to storage and diversion projects. Of the four recognized natural flow computational procedures, the Project Depletion Method is the most efficient for use in cases where a limited number of projects are distributed over a wide area. The Stream Depletion, Rimflow and Consumptive Use methods determine areal differences in runoff, do not isolate individual project usage, and have greater input data requirements.

C. ACCURACY OF FLOW DETERMINATION

It is recommended that the error limits for monthly hydrometric record at the point of apportionment be four percent under open water and ten percent under ice conditions.

The accuracy of the hydrometric record at the point of apportionment is normally the most critical factor in determining the accuracy of computations of flows required for apportionment. For that reason hydrometric gauging stations at points of apportionment should be operated as first class stations under standards used by the Water Survey of Canada. Instrumentation, measurement frequency, measurement technique, and computational procedures should be such that the error limit for monthly hydrometric record is four percent during open water and ten percent under ice conditions. Particular attention should be given to the variability of the stage-discharge relationship during low flow periods and adjustments made to the monitoring program as necessary.

The accuracy of the hydrometric record at other monitoring points should be commensurate with the use of the information and the relative impact on accuracy of computation of the apportioned flow. Normal Water Survey of Canada standards would apply in most cases.

D. FREQUENCY OF REPORTING

It is recommended that natural flow computations be reported annually, based on monthly means.

The level of development in the basin is low and present uses are such that Manitoba receives its apportioned share annually. An annual reporting period is recommended primarily for informational purposes, but also to monitor changing use patterns in the upstream province.

E. HYDROMETRIC NETWORK

It is recommended that data obtained at the following hydrometric gauging stations be used to compute flows for apportionment purposes on the Churchill River at the Saskatchewan-Manitoba boundary.

All stations are existing stations and no new stations are required. The stations are listed by function.

Computation Points:

Churchill River at Sandy Bay	-	06EA002
Reindeer River at Outlet of Reindeer Lake – contributed by Churchill Power Company		

Lake Level:

Reindeer Lake at Brochet	-	06DB001

There are no routing, diversion or return flow stations required.

F. EVAPORATION

It is recommended that the evaporation loss from Reindeer Lake be neglected in the computation of natural flow of the Churchill River at the Saskatchewan-Manitoba boundary.

A study of precipitation and evaporation in the vicinity of Reindeer Lake indicates that they both average about 16 inches annually. However, SNBB estimates show thot net evaporation con be as high as 4.8 inches in some months. The incremental lake area due to artificial storage is about six percent of the total lake area. A 4.8 inch evaporation rate applied to this area results in a loss of 31,000 acre-feet over the month, or two percent of the estimated natural flow at the boundary. It has been suggested that annual evaporation could have increased by as much as seven inches for the incremental flooded area over the same area in its natural state. This loss amounts to 45,000 acre-feet annually compared to an average annual natural flow at the boundary of about 17 million acre-feet.

G. METEOROLOGIC NETWORK

No meteorologic stations are required for computation of flows required for apportionment on the Churchill River at the Saskatchewan-Manitoba boundary.

H. EFFECTS OF LAND USE CHANGES

It is recommended that effects on runoff of changing land use patterns not be considered in the computation of natural flow.

Assessment of the overall change to the quantity and timing of runoff due to land use changes, particularly land clearing for agriculture and forestry, would require detailed study. It is felt these effects are minimal in the Churchill River Basin because the surficial characteristics of the basin contribute to a generally low level of land use. Until conclusive evidence is available which clearly shows that land clearing and forestry contribute significantly to increased or decreased flow volumes at interprovincial boundaries, it is recommended that the effects of these changes be ignored in natural flow computations.

I. GROUNDWATER

It is recommended that changes in natural flow due to groundwater inflow or recharge not be considered in the computations.

Groundwater storage and sub-surface flow are influenced by forestry and agriculture, and locally by reservoir construction. Very little is known about the changes in the surface runoff and sub-surface flow regimes resulting from changes in land use and reservoir construction. Determining the extent of such modifications and the ultimate result on natural flow would be a major study in itself. It is generally felt that the quantities involved are small with respect to the natural flows being considered and the identifiable sources of error.

J. ROUTING

It is recommended that, at the present time, calculated depletions not be routed to the point of apportionment.

The Whitesand Dam, which regulates the level of Reindeer Lake, is the only structure which merits consideration in the calculation of apportionment flows on the Churchill River at the Saskatchewan-Manitoba boundary at this time. Travel time from Reindeer Lake to the Saskatchewan-Manitoba boundary is in the order of two or three days. The natural outflow is relatively steady so that monthly values calculoted at the outlet of the lake would not differ significantly from those routed to the Saskatchewan-Manitoba boundary. For these reasons it is considered to be unnecessary to route Reindeer Lake natural outflow to the boundary.

PRAIRIE PROVINCES WATER BOARD

ACKNOWLEDGEMENTS

The Committee on Hydrology would like to acknowledge the work and co-operation of Mr. G. H. Morton, study director, and his study team. Throughout the study their co-operation with the Committee was exceptional. In a study such as this, where a Committee acts in both an advisory and a management capacity, close liaison between the Committee and the study director is essential to ensure success.

The individual contributors to the different basin reports are acknowledged in the appropriate report. The Committee extends its appreciation to those individuals including:

Mr. G. H. Morton	Mr. M. N. Botting
Mr. C. P. Robinson	Mr. K. Cornelius
Mr. W. Nemanishen	Mrs. L. H. Folster
Mr. R. E. Kerber	Mrs. O. Kristjanson
Mr. D. R. Graham	Miss I. Cornish
Mr. T. T. Cheng	Mrs. S. Walsh
Mr. M. Banning	Mr. C. Beorchief

The Committee also wishes to acknowledge the co-operation of Mr. R. D. May, District Engineer, Water Survey of Canada, who made his facilities and staff available as required.

Acknowledgements are also due several individuals connected with the Committee on Hydrology. Mr. S. J. Buckler and Mr. E. Einarsson, former members of the Committee representing the Atmospheric Environment Service, provided advice on the meteorologic aspects of the study during their respective terms of membership on the Committee. Mr. A. Coulson, an alternate member of the Committee, provided continuing advice on all aspects of the study. This report was written by Mr. R. J. Wettlaufer, Secretary of the Committee.

PRAIRIE PROVINCES WATER BOARD

APPENDIX

Terms of Reference for studies to develop procedures for the determination of natural flows for apportionment purposes, and for the development of procedures to meet streamflow forecasting requirements on interprovincial streams were requested by the Prairie Provinces Water Board at a meeting on May 27, 1970. The Data Network Planning Committee was instructed to prepare the Terms of Reference and was given some direction as to the content of the Terms of Reference. The Data Network Planning Committee discussed the Board's assignment at its ninth meeting, September 3 & 4, 1970. Contents of the Terms of Reference were discussed and draft Terms of Reference developed.

The draft Terms of Reference were presented to the Board at its third meeting, October 20, 1970. The Terms of Reference were never formally adopted, however the Board gave its approval for the studies.

The draft Terms of Reference were used as guidelines throughout the study by the study group and the Data Network Planning Committee and later by the Committee on Hydrology. The draft Terms of Reference follow.

For reference purposes the Master Agreement on Apportionment is also included in the appendix.

DRAFT

PRAIRIE PROVINCES WATER BOARD

TERMS OF REFERENCE

STUDIES

FOR THE DEVELOPMENT

OF

PROCEDURES

A. FOR THE DETERMINATION OF NATURAL FLOWS FOR APPORTIONMENT PURPOSES.

B. TO MEET STREAMFLOW FORECASTING REQUIREMENTS ON INTERPROVINCIAL STREAMS.

1. The studies shall be performed jointly by the Water Sector of the Department of Energy, Mines and Resources and the Meteorological Services of the Ministry of Transport.

2. Subject to periodic review and approval, and the limitations set out in section 13, the Prairie Provinces Water Board (hereafter called the "Board") authorizes the Department of Energy, Mines and Resources and the Ministry of Transport to carry out their respective duties relative to the studies with such powers and in such a manner as may be necessary to effectively perform the functions outlined in these "Terms of Reference". A final report will be submitted to the PPWB.

3. To complete the studies a Project Manager will be designated and necessary support staff provided as required by the Department of Energy, Mines and Resources and the Ministry of Transport. The appointment of a Project Manager shall receive the approval of the Board.

4. Liaison with the Board shall be provided through the Executive Director of the Secretariat of the Board. Until such time as an Executive Director is appointed, the Project Manager shall report through the Data Network Planning Committee of the Board.

5. Except as noted below, both studies shall receive equal priority and shall be carried out concurrently.

(a) In the conduct of the Study "For the Determination of Natural Flows for Apportionment Purposes" prior attention shall be given to the South Saskatchewan River below the confluence with the Red Deer River near the Alberta-Saskatchewan Boundary. Methods for refining or improving the interim method of apportionment adopted by the Board shall be reported as developed during the course of the studies.

(b) In the conduct of the Study "To Meet Streamflow Forecasting Requirement on Interprovincial Streams" prior attention shall be given to the South Saskatchewan River Basin.

6. The Project Manager shall co-ordinate the development of a system for computation of natural flows in interprovincial streams for the purposes of administration of apportionment agreements, or for other purposes of interprovincial interest.

7. The Project Manager shall co-ordinate the development of a system for determination of flow of interprovincial streams at provincial boundaries and at other locations where such information is desired for water management or for flood control purposes.

8. The development of the procedures for the purposes stated shall include the following:

(a) A determination of streamflow forecast and natural flow requirements on interprovincial streams in terms of location and purposes.

(b) An assessment of existing streamflow forecasting relationships for various locations and purposes, in terms of adequacy and accuracy, and the development of new relationships for those locations for which forecasts are either inadequate or lacking.

(c) The integration of new and existing streamflow forecasting relationships into a single system for forecasting the runoff of interprovincial streams.

(d) An assessment of existing methods of computing natural flows in interprovincial streams in terms of adequacy and accuracy, and the development of new methods for those locations for which existing methods are either lacking or inadequate.

(e) The integration of new and existing methods into a single system for computing natural flows in interprovincial streams.

9. The existing meteorologic, hydrometric or other networks will be identified and assessed with regard to their usefulness, insofar as they relate to the systems developed for forecasting the runoff or computing natural flows in interprovincial streams.

10. As a result of the work outlined above recommendations shall be made for the improvements that may be required meteoralogic, hydrometric or other data networks to increase the accuracy and efficiency of the networks for forecasting runoff and natural flow computational purposes. A system of data collection and transmission from the networks shall be included.

11. In the course of the study the need for a permanent forecasting centre shall be examined. Considerotion should be given to various methods of recording, anolyzing and processing of data, data distribution, administrative and personnel requirements, and cost of setting up and maintaining a forecast centre.

12. The Project Manager shall collaborate with federal and provincial agencies represented on the Board and may utilize the services of the Board's Member agencies having the expertise and capobility to participate. Such participation shall be arranged by the Executive Director on a contractual basis at cost.

13. The studies shall be performed over a period not to exceed three years and at a cost not to exceed $300,000 unless otherwise altered or extended by the Board. Study costs shall be apportioned in accordance with Section 10 of the Prairie Provinces Water Board Agreement.

MASTER AGREEMENT ON APPORTIONMENT

MASTER AGREEMENT ON APPORTIONMENT

THIS AGREEMENT is made in quadruplicate this THIRTIETH day of OCTOBER, 1969, A.D.

BETWEEN:

HER Majesty, the Queen, in right of Canada, represented herein by the Minister of Energy, Mines and Resources

(Hereinafter called "Canada")

- and -

HER Majesty, the Queen, in right of Alberta, represented herein by the Minister in charge of Water Resources for Alberta

(Hereinafter called "Alberta")

- and -

HER Majesty, the Queen, in right of Saskatchewan, represented herein by the Minister in charge of The Water Resources Commission Act of the said Province

(Hereinafter called "Saskatchewan")

- and -

HER Majesty, the Queen, in right of Manitoba, represented herein by the Minister in charge of The Water Control and Conservation Branch Act of the said Province

(Hereinafter called "Manitoba")

WHEREAS under natural conditions the waters of the watercourses hereinafter referred to arising in or flowing through the Province of Alberta would flow into the Province of Saskatchewan and under the said conditions the waters of some of the said watercourses arising in or flowing through the Province of Saskatchewan would flow into the Province of Manitoba;

AND WHEREAS the Governor-in-Council has authorized Canada to enter into this agreement by Order-in-Council P.C. 1969-8/2051 dated October 29, 1969, and the Lieutenant Governors-in-Council for Alberta, Manitoba and Saskatchewan, respectively, have authorized them to enter into this agreement by the following Orders-in-Council:

Alberta	-	O.C. 2053/69
Manitoba	-	O.C. 1359/69
Saskatchewan	-	O.C. 1612/69

AND WHEREAS the parties hereto deem it to be in their mutual interest that an agreement be reached among the four parties as to the apportionment as described in the schedules attached hereto of such interprovincial waters among the three Provinces;

AND WHEREAS Alberta and Saskatchewan have entered into an agreement, which agreement is attached to this agreement as Schedule A, that permits the Province of Alberta to make a net depletion of one-half the natural flow of water arising in or flowing through the Province of Alberta and that permits the remaining one-half of the natural flow of each such watercourse to flow into the Province of Saskatchewan, subject to certain prior rights as are set forth in the said agreement;

AND WHEREAS Saskatchewan and Manitoba have entered into an agreement, which agreement is attached to this agreement as Schedule B, that permits the Province of Saskatchewan to make a net depletion of one-half the natural flow of water arising in, and one-half of the water flowing into the Province of Saskatchewan, and that permits the remaining one-half of the flow of each such watercourse to flow into the Province of Manitoba, subject to such conditions and agreements as therein contained;

AND WHEREAS the parties are desirous that the Prairie Provinces Water Board (referred to herein as the Board), reconstituted by this agreement will be responsible for the administration of this agreement;

AND WHEREAS the parties hereto recognize the continuing need for consultation and co-operation as between themselves with respect to the matters herein referred to so that the interests of all the parties are best served;

NOW THEREFORE, THIS AGREEMENT (hereinafter known as the Master Agreement) witnesseth that each party agrees as follows:

Interprovincial Agreements

1. Alberta and Saskatchewan agree that the agreement between them (hereinafter called the First Agreement), a copy of which is set out in Schedule A to the Master Agreement, will become binding upon them upon the date that the Master Agreement is executed.

2. Saskatchewan and Manitoba agree that the agreement between them (hereinafter called the Second Agreement), a copy of which is set out in Schedule B to the Master Agreement, will become binding upon them upon the date that the Master Agreement is executed.

3. The parties agree to the apportionment of water between Alberta and Saskatchewan and Manitoba as provided in the First and Second Agreements and each party agrees to be bound by the said agreements as they relate to apportionment as if it were a party thereto.

4. The parties agree that the First or Second Agreement, or both, may be altered by an agreement in writing among the four parties to the Master Agreement, but not otherwise.

5. The parties agree that the First and Second Agreements will continue in force and effect until cancelled by an agreement in writing among the four parties to the Master Agreement.

Water Quality

6. The parties mutually agree to consider water quality problems; to refer such problems to the Board; and to consider recommendations of the Board thereon.

Monitoring

7. The parties agree that the monitoring of the quantity and quality of waters as specified in the First and Second Agreements, the collection, compilation and publication of water quantity and quality data required for the implementation and maintenance of the provisions of this agreement shall be conducted by Canada, subject to provision of funds being voted by the Parliament of Canada.

Administration

8. The parties agree, subject to Clause 9 of this agreement that if at any time, any dispute, difference or question arises between the parties with respect to this agreement or the construction, meaning and effect thereof, or anything therein, or the rights and liabilities of the parties thereunder or otherwise in respect thereto, then every such dispute, difference or question will be referred for determination to the Exchequer Court under the provisions of the Exchequer Court Act of Canada and each of the parties hereto agrees to maintain or enact the necessary legislation to provide the Exchequer Court with jurisdiction to determine any such dispute, difference, or question in the manner provided under the Exchequer Court Act.

9. The parties also agree that the Board, with the consent of the parties in dispute, may cause to be prepared, a factual report of the dispute for consideration by the parties hereto prior to the referral of the dispute to the Exchequer Court.

10. The parties agree that the Prairie Provinces Water Board shall monitor and report on the apportionment of waters as set out in the provisions of the First and Second Agreements and ratified by this Master Agreement.

11. The parties agree to revoke the agreement dated July 28, 1948, establishing the Prairie Provinces Water Board and to reconstitute the

Prairie Provinces Water Board in the form of Schedule C hereto and the said Schedule shall form and become part of this Master Agreement.

12. Because the Orders-in-Council referred to in Schedule D hereto will become redundant upon the execution of this Master Agreement, the parties agree to take steps to have them revoked.

13. The parties agree for the future application of the provisions of the Master Agreement (and the First and Second Agreements thereunder), to work together and to co-operate to the fullest extent each with the other for the integrated development and use of water and related resources to support economic growth according to selected social goals and priorities and to participate in the formulation and implementation of comprehensive planning and development programs according to their national, regional and provincial interest and importance.

14. No Member of the Parliament of Canada or Member of the Legislative Assemblies of the Provinces party to this agreement shall hold, enjoy, or be admitted to any share or part of any contract, agreement, commission or benefit arising out of this agreement.

IN WITNESS HEREOF Canada has caused its presents to be executed by its Minister of Energy, Mines and Resources, and Alberta has caused its presents to be executed by its Minister in charge of Water Resources, and Saskatchewan has caused its presents to be executed by its Minister in charge of The Water Resources Commission Act, and Manitoba has caused its presents to be executed by its Minister in charge of The Water Control and Conservation Branch Act on the day and year first mentioned above.

"A. Davidson"
Witness to the signature of the Minister (Energy, Mines and Resources) for Canada

"J.J. Greene"
Minister (Energy, Mines and Resources) for Canada

October 30, 1969
Date

"R. E. Bailey"
Witness to the signature of the Minister in charge of Water Resources for Alberta

"Henry A. Ruste"
Minister in charge of Water Resources for Alberta

October 30, 1969
Date

"Harold W. Pope"
Witness to the signature of the Minister in charge of The Water Resources Commission Act for Saskatchewan

"Allan R. Guy"
Minister in charge of The Water Resources Commission Act for Saskatchewan

October 30, 1969
Date

"Thomas E. Weber"
Witness to the signature of the Minister in charge of The Water Control and Conservation Branch Act for Manitoba

"Lenord S. Evans"
Minister in charge of The Water Control and Conservation Branch Act for Manitoba

October 30, 1969
Date

SCHEDULE A

THIS AGREEMENT is made in quadruplicate this THIRTIETH day of OCTOBER, 1969, A.D.

BETWEEN:

HER Majesty, the Queen, in right of Alberta, represented herein by the Minister in charge of Water Resources for Alberta

(Hereinafter called "Alberta")

- and -

HER Majesty, the Queen, in right of Saskatchewan, represented herein by the Minister in charge of The Water Resources Commission Act of the said Province

(Hereinafter called "Saskatchewan")

WHEREAS under natural conditions the waters of the watercourses hereinafter referred to arising in or flowing through the Province of Alberta would flow into the Province of Saskatchewan and under the said conditions the waters of some of the said watercourses arising in or flowing through the Province of Saskatchewan would flow into the Province of Manitoba;

AND WHEREAS the parties hereto deem it to be in their mutual interest and in the interest of Manitoba that an agreement in principle be reached among the said three Provinces as to the apportionment of such interprovincial waters among them;

AND WHEREAS the parties hereto are of the opinion that an equitable apportionment of such waters as between the adjoining Provinces of Alberta and Saskatchewan would be to permit the Province of Alberta to make a net depletion of one-half the natural flow of water arising in or flowing through the Province of Alberta and to permit the remaining one-half of the natural flow of water of each such watercourse to flow into the Province of Saskatchewan, subject to certain prior rights as are hereinafter set forth or may hereafter be mutually agreed upon in writing;

AND WHEREAS on the basis of the foregoing apportionment as between the Provinces of Alberta and Saskatchewan the parties hereto are of the opinion that in a similar manner, an equitable apportionment of the remainder of the natural flow of the said watercourses that flow into the Province of Manitoba after permitting the Province of Alberta to make its depletion of one-half thereof would be to permit the Province of Saskatchewan to make a net depletion of one-half of the said remainder and to permit the other one-half thereof to flow into the Province of Manitoba; and that the natural flow of any tributaries to the said watercourses which tributaries join the said watercourses in the Province of Saskatchewan without arising in or first flowing through the Province of Alberta could be apportioned one-half to the Province of Saskatchewan and one-half to the Province of Manitoba in a manner similar to the apportionment of waters as between the Provinces of Alberta and Saskatchewan, in all cases subject to such prior rights as may be mutually acknowledged by the said Provinces of Manitoba and Saskatchewan;

AND WHEREAS the parties hereto recognize the continuing need for consultation and cooperation as between themselves and with Manitoba with respect to the matters herein referred to so that the best and most beneficial use of the said waters may be made and the interests of all said provinces best served:

NOW THIS AGREEMENT witnesseth as follows:

1. IN THIS AGREEMENT:

   (a) "Natural flow" means the quantity of water which would naturally flow in any watercourse had the flow not been affected by human interference or human intervention, excluding any water which is part of the natural flow in Alberta but is not available for the use of Alberta because of the provisions of any international treaty which is binding on Alberta.

(b) "Watercourse" means any river, stream, creek, or other natural channel which from time to time carries a flowing body of water from the Province of Alberta to the Province of Saskatchewan and includes all tributaries of each such river, stream, creek or natural channel which do not themselves cross the common boundary between the Provinces of Alberta and Saskatchewan. Such tributaries as do themselves cross the said common boundary between the Provinces of Alberta and Saskatchewan shall be deemed to be "watercourses" for the purpose of this agreement.

2. (a) The parties hereto shall mutually establish a method by which to determine the natural flow of each watercourse flowing across their said common boundary.

(b) For the purpose of this agreement, the said natural flow shall be determined at a point as near as reasonably may be to their said common boundary.

(c) Notwithstanding sub-paragraph (b) the point at which the natural flow of the watercourses known as the South Saskatchewan and Red Deer Rivers is to be determined may be, at the option of Alberta, a point at or as near as reasonably may be below the confluence of the said two rivers.

3. Alberta shall permit a quantity of water equal to one-half the natural flow of each watercourse to flow into the Province of Saskatchewan, and the actual flow shall be adjusted from time to time on an equitable basis during each calendar year, but this shall not restrict or prohibit Alberta from diverting or consuming any quantity of water from any watercourse provided that Alberta diverts water to which it is entitled of comparable quality from other streams or rivers into such watercourse to meet its commitments to Saskatchewan with respect to each watercourse.

4. Notwithstanding paragraph 3 hereof, the following special provisions shall apply as between the parties hereto with respect to the watercourse known as the South Saskatchewan River.

(a) Alberta shall be entitled in each year to consume, or to divert or store for its consumptive use a minimum of 2,100,000 acre-feet net depletion out of the flow of the watercourse known as the South Saskatchewan River even though its share for the said year, as calculated under paragraph 3 hereof, would be less than 2,100,000 acre-feet net depletion, provided however Alberta shall not be entitled to so consume or divert, or store for its consumptive use, more than one-half the natural flow of the said South Saskatchewan watercourse if the effect thereof at any time would be to reduce the actual flow of the said watercourse at the common boundary of the said Provinces of Saskatchewan and Alberta to less than 1,500 cubic feet per second.

(b) The consumption or diversion by Alberta provided for under the preceding sub-paragraph shall be made equitably during each year, depending on the actual flow of water in the said watercourse and the requirements of each Province, from time to time.

5. The parties hereto shall work together and co-operate to the fullest extent, each with the other, for the most effective, economical and beneficial use of waters flowing from the Province of Alberta into the Province of Saskatchewan, including the construction and operation of approved projects of mutual advantage to our Provinces on a cost-share basis proportionate to the benefits derived therefrom by each Province, (the approval of which projects shall not be unreasonably withheld by either of the parties hereto) and shall enter into such other arrangements, agreements or accords with each other, and with the Governments of Canada and other Provinces to best achieve the principles herein agreed upon.

6. This agreement shall not adversely affect any right to water in Battle or Lodge Creeks which has been given by the Government of Canada prior to the transfer of the natural resources to the Provinces and is still subsisting, or any right to such water given by either Province heretofore which has been recognized and approved by both Provinces.

"R. E. Bailey"
Witness to the signature of the Minister in charge of Water Resources for Alberta

7. If at any time any dispute, difference or question shall arise between the parties or their representatives touching this agreement or the construction, meaning and effect thereof, or anything therein, or the rights or liabilities, of the parties or their representatives thereunder or otherwise in respect thereto then every such dispute, difference or question shall be referred for determination to the Exchequer Court under the provisions of The Exchequer Court Act of Canada, and each of the parties hereto agrees to enact the necessary legislation to provide the Exchequer Court with jurisdiction to determine any such dispute, difference or question in the manner provided under Section 30 of The Exchequer Court Act.

"Henry A. Ruste"
Minister in charge of Water Resources for Alberta

8. This agreement shall become effective upon the execution of an agreement by Canada, Alberta, Manitoba and Saskatchewan relative to the apportionment of waters referred to in this agreement.

"Harold W. Pope"
Witness to the signature of the Minister in charge of The Water Resources Commission Act

IN WITNESS WHEREOF Alberta has caused these presents to be executed on its behalf by its Minister in charge of Water Resources, and Saskatchewan has caused these presents to be executed by its Minister in charge of The Water Resources Commission Act, both on the day and year first above mentioned.

"Allan R. Guy"
Minister in charge of The Water Resources Commission Act

SCHEDULE B

THIS AGREEMENT is made in quadruplicate this THIRTIETH day of OCTOBER, 1969, A.D.

BETWEEN:

HER Majesty, the Queen, in right of Saskatchewan, represented herein by the Minister in charge of The Water Resources Commission Act of the said Province

(Hereinafter called "Saskatchewan")

- and -

HER Majesty, the Queen, in right of Manitoba, represented herein by the Minister in charge of The Water Control and Conservation Branch Act of the said Province

(Hereinafter called "Manitoba")

WHEREAS under natural conditions the waters of the watercourses hereinafter referred to arising in or flowing through the Province of Saskatchewan would flow into the Province of Manitoba;

AND WHEREAS the parties hereto deem it to be in their mutual interest and in the interest of Alberta that an agreement in principle be reached among the said three Provinces as to the apportionment of interprovincial waters among them;

AND WHEREAS the parties hereto are of the opinion that an equitable apportionment of such waters as between the adjoining Provinces of Saskatchewan and Manitoba would be to permit the Province of Saskatchewan to make a net depletion of one-half the natural flow of water arising in, and one-half the flow of water flowing into, the Province of Saskatchewan, and to permit the remaining one-half of the flow of water of each such watercourse to flow into the Province of Manitoba, subject to certain rights as may hereafter be mutually agreed upon in writing;

AND WHEREAS on the basis of the foregoing apportionment as between the Provinces of Saskatchewan and Manitoba, the parties hereto are of the opinion that in a similar manner, an equitable apportionment of the natural flow of the said watercourses arising in or flowing through the Province of Alberta would be to permit the Province of Alberta to make a net depletion of one-half thereof, subject to such prior rights as may be mutually acknowledged by the said Provinces of Alberta, Saskatchewan and Manitoba;

AND WHEREAS the parties hereto recognize the continuing need for consultation and co-operation as between themselves and with Alberta with respect to the matters herein referred to so that the interests of all said Provinces are best served;

NOW THIS AGREEMENT witnesseth as follows:

1. IN THIS AGREEMENT:

   (a) "Natural flow" means the quantity of water which would naturally flow in any watercourse had the flow not been affected by human interference or human intervention.

   (b) "Watercourse" means any river, stream, creek, or other natural channel which from time to time carries a flowing body of water from the Province of Saskatchewan to the Province of Manitoba and includes all tributories of each such river, stream, creek or natural channel which do not themselves cross the common boundary between the Provinces of Saskatchewan and Manitoba. Such tributaries as do themselves cross the said common boundary between the Provinces of Saskatchewan and Manitoba shall be deemed to be "watercourses" for the purpose of this agreement.

2. (a) The parties hereto shall mutually establish a method by which to determine the natural flow of each watercourse flowing across their said common boundary.

(b) For the purpose of this agreement, the said natural flow shall be determined at a point as near as reasonably may be to their said common boundary.

3. Saskatchewan shall permit in each watercourse the following quantity of water to flow into Manitoba during the period from April 1 of each year to March 31 of the year following: A quantity of water equal to the natural flow for that period determined at the point referred to in paragraph 2(b) hereof, less

(a) one-half the water flowing into Saskatchewan in that watercourse from Alberta, and

(b) any water which would form part of the natural flow in that watercourse but does not flow into Saskatchewan because of the implementation of any provision of any subsisting water apportionment agreement made between Alberta and Saskatchewan and approved by Manitoba, and

(c) one-half the natural flow arising in Saskatchewan.

The actual flow shall be adjusted from time to time by mutual agreement on an equitable basis during such period but this shall not restrict or prohibit Saskatchewan from diverting, storing or consuming any quantity of water from any watercourse provided that Saskatchewan diverts water to which it is entitled of comparable quality from other streams or rivers into such watercourse to meet its commitments to Manitoba with respect to each watercourse.

4. Saskatchewan shall be entitled during such period to consume or to divert or store for its consumptive use the water it is not required to permit to flow into Manitoba in each watercourse under paragraph 3 hereof, but such consumption or diversion shall be made equitably depending on the actual flow of water in each watercourse and the requirements of each Province from time to time, but Saskatchewan shall permit sufficient water to flow into Manitoba to meet its commitments during such period under paragraph 3 hereof.

5. The parties hereto shall work together and co-operate to the fullest extent, each with the other, for the use of waters flowing from the Province of Saskatchewan into the Province of Manitoba, including the construction and operation of approved projects of mutual advantage to the said Provinces on a cost-share basis proportionate to the benefits derived therefrom by each Province (the approval of which projects shall not be unreasonably withheld by either of the parties hereto) and shall enter into such other arrangements, agreements or accords with each other, and with the Governments of Canada and other Provinces to best achieve the principles herein agreed upon.

6. If at any time any dispute, difference or question shall arise between the parties or their representatives touching this agreement or the construction, meaning and effect thereof, or anything therein, or the rights or liabilities of the parties or their representatives thereunder or otherwise in respect thereto then every such dispute, difference or question shall be referred for determination to the Exchequer Court under the provisions of The Exchequer Court Act of Canada, and each of the parties hereto agrees to maintain or enact the necessary legislation to provide the Exchequer Court with jurisdiction to determine any such dispute, difference or question in the manner provided under The Exchequer Court Act.

7. This agreement shall become effective upon the execution of an agreement by Canada, Alberta, Manitoba and Saskatchewan relative to the apportionment of waters referred to in this agreement.

IN WITNESS WHEREOF Saskatchewan has caused these presents to be executed by its Minister in charge of The Water Resources Commission Act, and Manitoba has caused these presents to be executed by its Minister in charge of The Water Control and Conservation Branch Act on the day and year first above mentioned.

"Harold W. Pope"

Witness to the signature of the Minister in charge of The Water Resources Commission Act

"Allan R. Guy"

Minister in charge of The Water Resources Commission Act

"Thomas E. Weber"

Witness to the signature of the Minister in charge of The Water Control and Conservation Branch Act

"Leonard S. Evans"

Minister in charge of The Water Control and Conservation Branch Act.

SCHEDULE C

PRAIRIE PROVINCES WATER BOARD AGREEMENT

THIS AGREEMENT made this THIRTIETH day of OCTOBER, 1969, A.D.

BETWEEN:

THE GOVERNMENT OF CANADA, hereinafter called "Canada"

- and -

THE GOVERNMENT OF MANITOBA, hereinafter called "Manitoba"

- and -

THE GOVERNMENT OF SASKATCHEWAN, hereinafter called "Saskatchewan"

- and -

THE GOVERNMENT OF ALBERTA, hereinafter called "Alberta"

1. Manitoba, Saskatchewan, Alberta and Canada agree to establish and there is hereby established a Board to be known as the Prairie Provinces Water Board to consist of five members to be appointed as follows:

   (a) two members to be appointed by the Governor General in Council, one of whom shall be Chairman of the Board, on the recommendation of the Minister of Energy, Mines and Resources,

   (b) one member to be appointed by the Lieutenant Governor in Council of each of the Provinces of Manitoba, Saskatchewan and Alberta.

2. Functions

   The Board shall oversee and report on the Master Agreement (including the First and Second Agreements thereunder) executed by Canada, Alberta, Manitoba and Saskatchewan for the apportionment of waters flowing from one Province into another Province; shall take under consideration, comprehensive planning, water quality management and other questions pertaining to water resource management referred to it by the parties hereto; shall recommend appropriate action to investigate such matters and shall submit recommendations for their resolution to the parties hereto.

3. Composition of Board

   The members of the Board shall be chosen from those engaged in the administration of water resources or related duties for Manitoba, Saskatchewan, Alberta or Canada, as the case may be, and shall serve as members of the Board in addition to their other duties.

4. Duties of the Board

   In accordance with its functions, the duties of the Board shall be as follows:

   (a) to review, collate, and analyze streamflow data and prepare reports and recommendations on the apportionment of water,

   (b) to review water quality problems, particularly such problems located at the interprovincial boundaries, and to recommend to the parties hereto, appropriate management approaches for their resolution including the establishment of new institutional arrangements,

   (c) to develop recommendations on other water matters, in addition to problems on water quality, referred to the Board by any party hereto including the review and analysis of existing information and the requesting of additional studies and assistance by appropriate governmental agencies to provide information for formulating its recommendations,

(d) to promote through consultation and the exchange of information the integrated development of water resources of interprovincial streams,

(e) to cause to be prepared with the consent of the parties involved factual reports on disputes arising out of the water apportionment for consideration by the parties hereto,

(f) to ensure the co-ordination of such technical programs as water quantity and quality monitoring and streamflow forecasting required for the effective apportionment of water.

5. Confirmation of the Board's Recommendations

A recommendation of the Board with respect to any matters referred to it under Section 2 shall, subject to the Master Agreement for the apportionment of water, become effective when adopted by Orders-in-Council passed by Canada and each of the Provinces.

6. Authority of Board

The Board shall have authority to correspond with all Governmental organizations and other sources of information in Canada or abroad concerned with the administration of water resources, and such other authority as may be conferred on the Board from time to time by agreement between the parties hereto; all agencies of the four governments having to do with the water and associated resources in the area covered by the Agreement shall be required to supply the Board with all data in their possession requested by the Board.

7. Records

The records relating to the water resources of the three provinces collected and compiled by the P.F.R.A. organization at Regina shall be made available to the Board.

8. Meetings of the Board

The Board shall meet at the call of the Chairman and meetings shall be called at least twice annually; the expenses of the members shall be borne by their respective governments.

9. Reports

The Board shall submit an annual progress report outlining work done and work contemplated in the agreed program to each of the responsible Ministers of the parties hereto and such other reports as may be requested by any one of such Ministers.

10. Operation of the Board

The Secretary for the Board and such other technical and clerical staff as may be required, with a headquarters at Regina, shall be Federal or Provincial public servants. The cost of administration, excluding the cost of monitoring as described in Section 7 of the Master Agreement, but including staff, accommodation, supplies and incidental expenses of the Board, shall be borne by the parties hereto on the basis of one-half by Canada and one-sixth by each of the Provinces. The Board shall prepare for approval of the parties hereto, work program, staff requirements, annual budgets and five-year forecasts and such other reports as may be required in the operation of the Board.

11. Any water development project already constructed or to be constructed by any one of the parties shall be so operated as to maintain the apportionment of water as set out in the Master Agreement (and the First and Second Agreements thereunder) for the apportionment of waters of interprovincial streams.

SCHEDULE D

PREVIOUS ALLOCATIONS OF INTERPROVINCIAL WATERS APPROVED BY ORDERS-IN-COUNCIL BY THE GOVERNMENTS OF CANADA, ALBERTA, MANITOBA, AND SASKATCHEWAN

	Order-in-Council			
Item	Canada	Alberta	Saskatchewan	Manitoba
Allocation of water for specific projects in Alberta	4030/49	857/49	1307/51	1121/49
Allocation of water for specific projects in Saskatchewan	1874/51	1091/51	1310/51	1264/51
Allocation of water for South Saskatchewan River Project in Saskatchewan	973/53	991/53	1271/53	924/53

Location	Apportionment Reporting Dates: March 31	June 30	Sept. 30	Dec. 31	Location of Apportionment Calcs.: S. Sask R. @ Hwy. 41	Red Deer R. @ Bindloss	N. Sask. @ Deer Creek	Sask. R. @ S-M Bdy	Qu'Appelle R. @ Welby	Churchill @ Sandy Bay
SOUTH SASKATCHEWAN RIVER BELOW THE CONFLUENCE WITH THE RED DEER RIVER	○	○	○	○	○	○				
NORTH SASKATCHEWAN RIVER NEAR DEER CREEK				○			○			
SASKATCHEWAN RIVER NEAR MANITOBA BOUNDARY				○				○		
QU'APPELLE RIVER NEAR WELBY	○	○	○	○					○	
CHURCHILL RIVER AT THE SASKATCHEWAN - MANITOBA BOUNDARY				○						○

Location	Existing Hydrometric Stations Required: S. Sask. R. @ Hwy. 41	Red Deer R. near Bindloss	Bow R. @ Calgary	Bow R. near Mouth	Oldman R. near Lethbridge	Diversions	Return Flow	Lake and Reservoir Levels	N. Sask. near Deer Creek	N. Sask. @ Edmonton	N. Sask. near Rocky Mtn. Hs.	S. R. @ S-M Bdy	N. Sask. @ Prince Albert
SOUTH SASKATCHEWAN RIVER BELOW THE CONFLUENCE WITH THE RED DEER RIVER	○	○	(R)	(R)	(R)	○ 13	○ 21	○ 9					
NORTH SASKATCHEWAN RIVER NEAR DEER CREEK								○ 2	○	(R)	(R)		
SASKATCHEWAN RIVER NEAR MANITOBA BOUNDARY						○ 4		○ 3				○	(R)
QU'APPELLE RIVER NEAR WELBY						○ 2		○ 7					
CHURCHILL RIVER AT THE SASKATCHEWAN - MANITOBA BOUNDARY								○ 1					

Location	S. Sask. @ Saskatoon	S. Sask. @ St. Louis	Qu'Appelle R. near Welby	Moose Jaw R. near Burdick	Qu'App. above Buff. Pond L.	Qu'App. below Moose Jaw R.	Qu'App. near Lumsden	Qu'App. @ outlet Katepwa L.	Qu'App. @ Hyde	Qu'App. below Craven Dam	Churchill R. @ Sandy Bay	Outlet Reindeer Lake	Index Reservoirs
SOUTH SASKATCHEWAN RIVER BELOW THE CONFLUENCE WITH THE RED DEER RIVER													
NORTH SASKATCHEWAN RIVER NEAR DEER CREEK													
SASKATCHEWAN RIVER NEAR MANITOBA BOUNDARY	(R)	(R)											
QU'APPELLE RIVER NEAR WELBY			○	(R)	(R)	(R)	(R)	(R)	(R)	(R)			○ 4
CHURCHILL RIVER AT THE SASKATCHEWAN - MANITOBA BOUNDARY											○	○	

Location	New Hydrometric Stations Req'd.: Lethbridge	Elbow	Lake Dief. lower	Lake Dief. upper	Nipawin	Swift Current	Tobin Lake	Existing Met. Stations Req'd.: Waterton Reservoir	St. Mary Reservoir	New Met. Sta. Req'd
SOUTH SASKATCHEWAN RIVER BELOW THE CONFLUENCE WITH THE RED DEER RIVER	○							(E)	(E)	
NORTH SASKATCHEWAN RIVER NEAR DEER CREEK										
SASKATCHEWAN RIVER NEAR MANITOBA BOUNDARY		(E)	(E)	(E)	(E)	(E)	(E)			
QU'APPELLE RIVER NEAR WELBY										
CHURCHILL RIVER AT THE SASKATCHEWAN - MANITOBA BOUNDARY										

19 21 22

(R) - Required for routing

(E) - For evaporation