

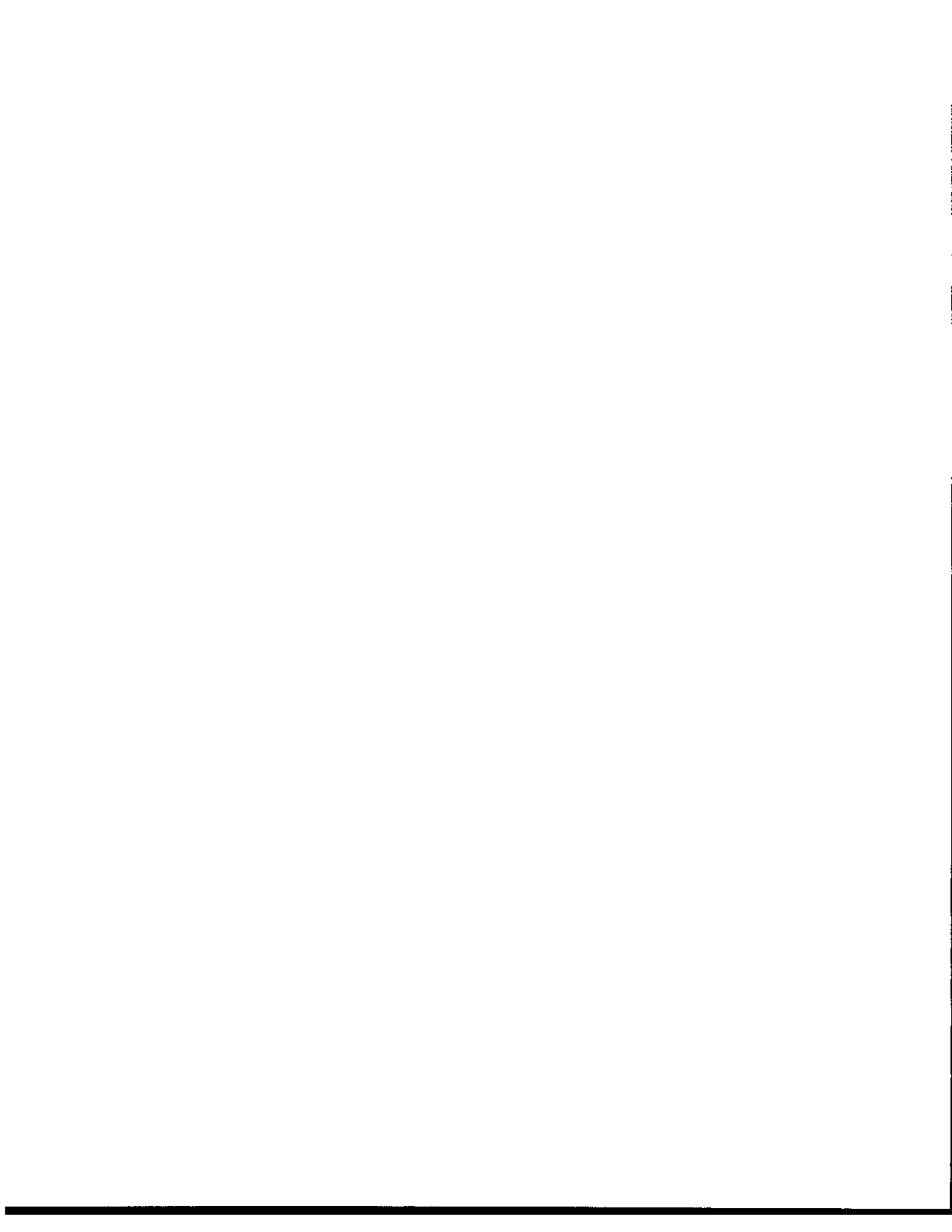
A SUMMARY OF
PRAIRIE PROVINCES WATER BOARD
COMMITTEE ON HYDROLOGY ACTIVITIES
FROM
1972 TO 1985

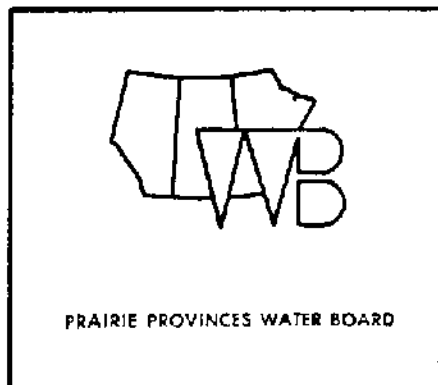
NOVEMBER 1986
PPWB REPORT NO. 83

**A SUMMARY OF
PRAIRIE PROVINCES WATER BOARD
COMMITTEE ON HYDROLOGY ACTIVITIES
FROM
1972 to 1985**

NOVEMBER 1986

**Prepared by:
The Secretariat of
Prairie Provinces Water Board
PPWB Report No. 83**





SYNOPSIS

The Committee on Hydrology (COH), as a standing committee of the Board (Prairie Provinces Water Board or PPWB), has conducted and directed a variety of water resources tasks and studies directly related to the surface water management of interprovincial basins in the prairie provinces. The result of this work has enabled the Board to make decisions and recommendations to member agencies concerning the apportionment and management of eastward flowing interprovincial waters.

This report summarizes the activities of the COH for the period 1972 to 1985 inclusive. It divides the activities of the COH into eight different categories, namely: Natural Flow, Forecasting, Apportionment, Monitoring, Evaporation, Drainage, Watershed Management and Impact Assessment. A description has been made for each of these categories highlighting the work completed by the COH for the Board.

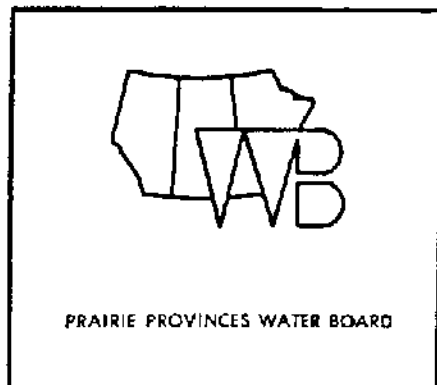


TABLE OF CONTENTS

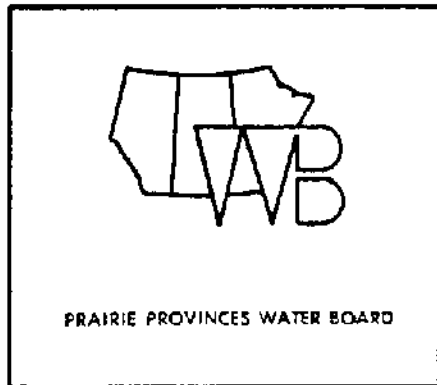
	<u>Page</u>
SYNOPSIS	(i)
TABLE OF CONTENTS	(iii)
1. INTRODUCTION	1
2. HISTORICAL BACKGROUND	3
Sub-Committee on Mapping	4
Sub-Committee on New Gauging Stations	5
Assiniboine - Qu'Appelle Study Committee	5
Pollution Committee	6
Apportionment Committee	7
Data Network Planning Committee	8
Summary	9
3. COMMITTEE ON HYDROLOGY TERMS OF REFERENCE AND MEMBERSHIP	11
4. NATURAL FLOW	15
Natural Flow Studies for Five Major Interprovincial River Basins	15
Qu'Appelle River SSARR Model	17
South Saskatchewan River Natural Flow Calculation	19
Natural Flow Calculation Procedures For the Battle, Lodge and Middle Creeks	19
Natural Flow Studies for Small Interprovincial Basins	20
Return Flows From Irrigation Districts	22

TABLE OF CONTENTS CONTINUED

	<u>Page</u>
5. FLOW FORECASTING	25
6. FLOW APPORTIONMENT	29
Administration of the Apportionment Agreement	29
Westward Flowing Streams and Tributaries Evaluation	30
7. FLOW MONITORING	33
Blackfoot Creek and Battle River at the Alberta-Saskatchewan Boundary	33
Saskatchewan River at the Saskatchewan-Manitoba Boundary	35
Cumberland Marshes Project	36
Network Required For Future Monitoring of Small Interprovincial Streams	37
Field Investigation of Interprovincial Basins	38
Annual Review of Board Hydrometric Monitoring Stations List	38
8. EVAPORATION	41
Evaporation Calculations For the Prairie Provinces	41
Evaporation Calculations For Gleniffer (Dickson) Reservoir	42
9. DRAINAGE	45
The Impact of Artificial Drainage on Downstream Watersheds	45
The Langenburg - Russell Drainage Study	47
10. WATERSHED MANAGEMENT	49
11. IMPACT ASSESSMENT AND OTHER ACTIVITIES	51
Activities Related to Impact Assessment for Projects That May Have Interprovincial Implications	51
Activities Related to Technical Seminars and Field Investigations	52
1. SSARR River Routing Workshop	53
2. Runoff Simulation Workshop	54
3. SSARR Model Workshop	54
4. STANFORD and SIMPAK Models Workshop	54
5. Prairie Hydrology Workshop No. 1	54
6. Prairie Hydrology Workshop No. 2	55

TABLE OF CONTENTS CONTINUED

	<u>Page</u>
12. ACKNOWLEDGEMENTS	57
 <u>APPENDICES</u>	
APPENDIX A - DATE AND LOCATIONS OF COMMITTEE ON HYDROLOGY MEETINGS	A-1
APPENDIX B - LIST OF PARTICIPANTS COH MEETINGS NO. 1 to 50	B-1
APPENDIX C - COMMITTEE ON HYDROLOGY ACTIVITIES AND TIME FRAMES	C-1
APPENDIX D - LIST OF REPORTS RELATED TO THE ACTIVITIES OF COMMITTEE ON HYDROLOGY	D-1



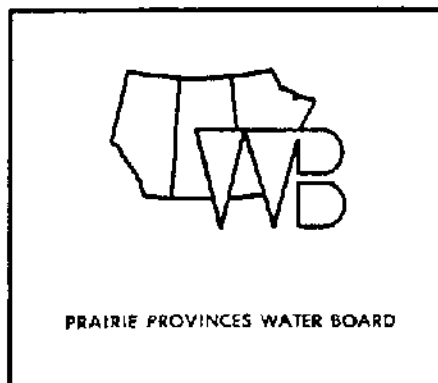
Chapter 1

INTRODUCTION

Since the reconstitution of the Board on October 30, 1969, activities related to interprovincial surface water management in the prairie provinces have been dealt with by the Board through its Committee on Hydrology (COH), and its forerunner the Data Network Planning Committee (DNPC). The COH serves as a technical advisor to the Board on matters pertaining to hydrology and management of interprovincial basins.

A variety of water resources related tasks are carried out by the COH on a continuing basis. Those works include studies of natural flow, flow forecasting, apportionment, monitoring, evaporation, drainage, watershed management and impact assessment. The results of these studies provide a basis for the Board to make decisions, or to recommend to member agencies, on the apportionment of interprovincial eastward flowing surface waters.

This report summarizes the activities of the Committee on Hydrology, and highlights the projects that have been completed by the committee from 1972 to 1985. Mention is also made of the work of committees with similar duties, appointed by the Board from 1948 to 1972.



Chapter 2

HISTORICAL BACKGROUND

On July 28, 1948, Manitoba, Saskatchewan, Alberta and Canada signed an agreement (1948 Agreement) that established the first Prairie Provinces Water Board. Article 4 of that agreement specified the duties of the Board as follows:

- "(a) to collate and analyze the data now available relating to the water and associated resources of interprovincial streams with respect to their utilization for irrigation, drainage, storage, power, industrial, municipal, navigation and other purposes;*
- (b) to determine what other data are required from time to time in order to reach decisions on questions referred to it and to make recommendations to the appropriate governmental organizations concerned for the carrying out of such field surveys, power investigations, soil surveys, establishment of gauging stations, economic studies relating to drainage and flood control and all similar work which the Board considers necessary to supply information required for the proper performance of its duties;*
- (c) upon the request of any one of the three Provinces or the Dominion to recommend the allocation of the waters of any interprovincial stream among the respective Provinces;*
- (d) to report on any questions relating to specific projects for the utilization or control of common river or lake systems on the request of one or more of the Ministers or authorities charged with the administration of such river or lake systems."*

During the first twenty-two years of operation (1948 to 1969 inclusive), forty-two meetings were held by the Board and six ad hoc Board committees were established to carry out specifically assigned tasks.

The six ad hoc Board committees were:

1. Sub-Committee on Mapping,
2. Sub-Committee on New Gauging Stations,
3. Assiniboine - Qu'Appelle Study Committee,
4. Pollution Committee,
5. Apportionment Committee, and
6. Data Network Planning Committee (DNPC).

Each committee received specific directions from the Board and reported through the Board members or the Board Engineering Secretary.

The Engineering Secretary to the Board was a Federal Government Prairie Farm Rehabilitation Administration (PFRA) employee who served in this capacity as part of his regular duties. The support staff and office accommodation during the 22-year period (1948 to 1969) was provided by PFRA in Regina.

The activities of Board committees during the period 1948 to 1969 inclusive are summarized in the following paragraphs.

Sub-Committee on Mapping

The Sub-Committee on Mapping was established by the Board at its first meeting held on November 1, 1948 in Regina. The primary function of the sub-committee was to gather information on existing maps and to prepare a base map that contained all major streams, lakes, cities and towns, Indian reserves, forest reserves and national parks in the prairie provinces.

The sub-committee met in February 1950 to discuss ways and means of reproducing a base map. They suggested to the Board, in April 1950, the scale of base maps, how the maps could be reproduced and the number of copies required.

The mapping project was started in 1949 and completed in 1951. Some 2500 copies of maps printed in four colors and 500 copies printed in five colors were produced and distributed.

Sub-Committee on New Gauging Stations

The sub-committee on New Gauging Stations was established by the Board at its Meeting No. 1 on November 1, 1948. The sub-committee was to assemble information on existing and abandoned hydrometric stations and to recommend the establishment of future hydrometric stations if required.

The sub-committee, on February 2, 1949, presented a brief report to the Board. It included a list of active and discontinued gauging stations on streams that cross the Alberta-Saskatchewan Boundary and/or the Saskatchewan-Manitoba Boundary. The report and its accompanying maps were accepted by the Board at its second meeting held on February 2, 1949.

The sub-committee, after the February 2, 1949 meeting, prepared a brief report indicating streams of importance along the two interprovincial boundaries, and recommended to the Board new gauging stations that would be required to monitor interprovincial waters.

The report was discussed by the Board at its third meeting held on May 6, 1949. The Board agreed that the report should be used to analyze the feasibility of establishing these gauging stations.

Assiniboine - Qu'Appelle Study Committee

The Board, at Meeting No. 23 held on December 6, 1961, initiated a study to support a Manitoba request for water to be diverted from Lake Diefenbaker to Manitoba through the Qu'Appelle River. The work was also to include a study of existing water uses in the Qu'Appelle and Assiniboine River Basins.

The study was completed by the Hydrology Division of PFRA, working with water resource personnel from the provinces of Saskatchewan and Manitoba. The final report entitled "Estimated Water Requirements - Qu'Appelle and Assiniboine River Basins", PPWB Report No. 9, was submitted to the Board in June 1964. No further action was taken by the Board.

Pollution Committee

The Pollution Committee was established by the Board at Meeting No. 27 on March 4, 1964 as a direct result of discussions concerning the Assiniboine - Qu'Appelle Study Committee. The Board agreed that the committee should prepare and present a report to the Board including:

- "(a) recommendations as to the development of common criteria to be used in interprovincial pollution studies;*
- (b) the general magnitude of the present pollution problem in the Assiniboine and other interprovincial basins and the approximate quantities of dilution water needed;*
- (c) observations as to future problems; and*
- (d) recommendations as to action the Board might take."*

The committee was unable to achieve its objectives as set down in the terms of reference. In June 1966, the committee presented an interim report entitled "Problems Associated with the Determination of Dilution Water Requirements on Interprovincial Streams". The conclusions in that report were that:

- (a) the nature of water management problems respecting quantity and quality control is such that jurisdictional and administrative functions are generally divided among various departments of government;
- (b) the inter-relation and interdependence of these functions dictates the need for suitable organizational mechanisms to coordinate these functions;
- (c) three divergent forms of organization exist in the prairie provinces to provide this coordination; and
- (d) the Prairie Provinces Water Board, in the exercise of its mandate, has a necessary and legitimate responsibility to include water requirements for dilution purposes in its studies and that no other agency adequately fulfills this need.

In view of the potentially heavy demand for water for dilution purposes on interprovincial streams, the Pollution Committee recommended the establishment of a new committee whose general objective was to determine the quantities of water required for dilution purposes and whose terms of reference was to report to the Board on:

- "(a) recommendations as to the development of common criteria to be used in determining interprovincial dilution water requirements;*
- (b) the general magnitude of the present pollution problem in interprovincial streams and the approximate quantities of dilution water required;*
- (c) observations as to future problems; and*
- (d) recommendations as to further action the Board might take."*

A new committee under the name "Committee on Dilution Water Requirements" was established by the Board on May 18, 1967, but the new committee was not active during the next two years and was dissolved when the Board was reconstituted in 1969.

Apportionment Committee

The Apportionment Committee was formed by the Board at its 28th meeting held on June 16, 1964. The purpose of this committee was to consider and report on:

- "(a) Methods of apportioning the water of interprovincial streams between the Provinces of Alberta, Saskatchewan and Manitoba;*
- (b) Methods of determining natural flow, depletions and any other factors necessary for apportionment of the waters of the Saskatchewan-Nelson River system;*
- (c) Methods and administrative arrangements necessary to implement apportionment; and*
- (d) Apportioning the water of the Saskatchewan-Nelson River system between the three prairie provinces."*

Several meetings were held by the committee to discuss methods that might be used to apportion interprovincial waters and methods that could be used to determine natural flow for apportionment purposes. The committee also communicated with the Upper Colorado Commission to obtain information on U.S.A. Interstate water compacts for developing a method for apportionment of the waters of the Saskatchewan-Nelson River system.

A report of the Apportionment Committee entitled "Apportionment of the Water of Interprovincial Streams Between the Provinces of Alberta, Manitoba and

Saskatchewan - November 1965" (PPWB Report No. 11), was completed and presented to the Board in February 1966. The report deals with apportionment principles such as: Most Beneficial Use or Equitable Division; Final Apportionment or Periodic Review; Total or Partial Apportionment; Percentage or Lump-Sum Apportionment; Existing Uses and Rights; Inclusion of Groundwater; Storage Reservoirs for Interprovincial Use; and Tributary Flow as well as the four methods (Stream Depletion, Project Depletion, Inflow-Outflow and Consumptive Use Methods) of determining natural flow at the interprovincial boundary. The report was accepted by the Board, on June 2, 1966, as a working paper for further discussions of the apportionment question. It provided the essential information needed to negotiate interprovincial apportionment of waters and formed the basis for the subsequent drafting of the 1969 Master Agreement on Apportionment.

Data Network Planning Committee (DNPC)

The Data Network Planning Committee was established by the Board at its 34th meeting held on June 2, 1966. The main objective of the committee was to prepare and keep under review an overall plan for an "interprovincial hydro-meteorological network which will provide data that will meet the provincial requirements for forecasting the runoff of interprovincial streams at the interprovincial boundary, and at other locations where such information is desired for water management and flood control purposes."

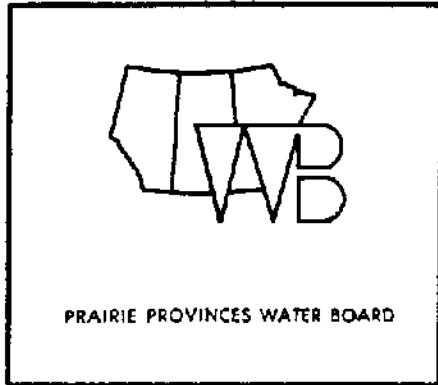
Four meetings were held by the committee in the period from June 2, 1966 to October 30, 1969 (the date the Master Agreement on Apportionment was signed). The major activities were discussing and exchanging information on new developments in network planning and forecasting activities in the prairie provinces and reviewing a consultant's proposal for a study to determine a basic inventory hydrometric network in the three prairie provinces and the Northwest Territories.

When the Master Agreement on Apportionment was signed in October 1969, the committee was given a new assignment to develop procedures for administration of the Apportionment Agreement.

From October 1969 to October 1972, eleven meetings were held by the committee. The primary activities of the committee during this period of time included reviewing and supervising various consultant studies related to hydro-metric and meteorologic networks planning, natural flow determination and flow forecasting. The name of the committee was changed to the Committee on Hydrology at the Board's seventh meeting on October 17, 1972. The new committee was also given revised terms of reference at that meeting as described on page 11 of this report.

Summary

All six ad hoc committees established by the Board were intended to deal with specific tasks assigned by the Board and, with the exception of the Data Network Planning Committee, all were dissolved before the reconstitution of the Prairie Provinces Water Board on October 30, 1969.



Chapter 3

COMMITTEE ON HYDROLOGY

TERMS OF REFERENCE

AND MEMBERSHIP

The Prairie Provinces Water Board held its seventh meeting on October 17, 1972. The members, at this meeting, agreed that the work being done by the Data Network Planning Committee could become quite broad and might cover the entire field of hydrology. Thus, a change in name and in the terms of reference for the committee would be appropriate. The DNPC was renamed the Committee on Hydrology and the following terms of reference were adopted for the committee.

Committee on Hydrology

Terms of Reference

At the request of, and under the direction of the PPWB, the Committee on Hydrology shall investigate, oversee, review, report and recommend on matters pertaining to hydrology of interprovincial or interjurisdictional basins.

The committee may consider such things as natural flow; forecasting; network design; collection, processing and transmission of data; basin studies and other items of interprovincial interest involving hydrology.

(Board Minute 7-11)

The Board, at the same meeting, agreed that the Committee on Hydrology would consist of one member from each of the following agencies of governments:

1. Environment Canada - Water Management Service;
2. Environment Canada - Atmospheric Environment Service;
3. Department of Regional Economic Expansion - PFRA;
4. Alberta;
5. Saskatchewan; and
6. Manitoba.

(Board Minute 7-12)

The Board also agreed, at the same meeting, that the Board Executive Director would be the Chairman of the Committee on Hydrology and the Secretary would be provided by the Board Secretariat. It was further agreed that the Committee on Hydrology would have seven voting members: one member from each of the Provinces of Alberta, Saskatchewan and Manitoba; two members from Environment Canada; one member from PFRA; and the Board Executive Director. The Chairman would vote only in the event of a deadlock by committee members. In fact, however, the committee acts only by consensus or near consensus of the members.

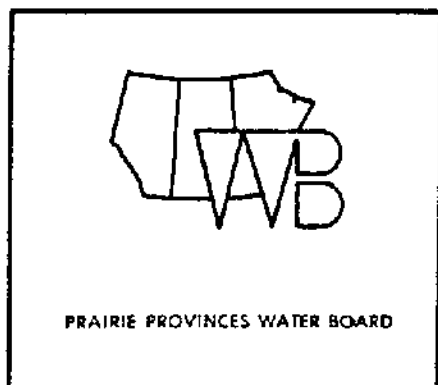
Fifty meetings of the Committee on Hydrology were held between its formation in 1972 and the end of 1985. The date and location of these meetings are listed in Appendix A, and the participants at these meetings are listed in Appendix B.

The Committee on Hydrology is a standing committee. It reports, on a continuing basis, to the Board through the Executive Director at each Board meeting. During the past fourteen years (1972 to 1985) of operation, the committee has dealt with a series of tasks assigned to it by the Board. Most of these tasks can be classified into the following eight categories:

1. Natural Flow;
2. Flow Forecasting;
3. Flow Apportionment;
4. Flow Monitoring;
5. Evaporation;
6. Drainage;
7. Watershed Management; and
8. Impact Assessment.

These tasks are directly related to both surface-water hydrology and interprovincial water management. They are described in more detail in Chapters 4 to 11 inclusive. Other activities of the committee during this period

are also itemized and included in Chapter 11. A table showing the Committee on Hydrology activities and the time frame for each activity is included in Appendix C.



Chapter 4

NATURAL FLOW

Under the terms of the 1969 Master Agreement on Apportionment, each province agrees to limit net depletion of each eastward flowing watercourse to fifty percent of the natural flow arising within its boundaries and to fifty percent of any water received from an upstream province. Schedule A of the agreement also specifies the minimum flow criteria of $42.5 \text{ m}^3/\text{s}$ or 50 percent of natural flow, whichever is less, for the South Saskatchewan River below Red Deer River. Natural flow volume during a 12-month period at the interprovincial boundary is the basis for apportionment between upstream and downstream provinces. Natural flow is defined as the quantity of water which would naturally flow in any watercourse had the flow not been affected by human interference or human intervention. To ensure that the apportionment of flow between upstream and downstream provinces is "equitable from time to time", the estimate of natural flow volume for interprovincial streams at the boundary should be sufficiently accurate. One responsibility of the Board, under Schedule C of the 1969 Agreement, is to review, collate, and analyze streamflow data; prepare reports; and make recommendations on the apportionment of water.

The Board, in 1971, instructed the DNPC to assess various methods of determining natural flow and to investigate the associated data gathering network. When the Committee on Hydrology was formed in 1972, it undertook the completion of this task.

Natural Flow Studies for Five Major Interprovincial River Basins

The Board contracted with the Calgary office of Canada Water Resources Branch (CWRB) to prepare natural flow studies for the South Saskatchewan, North Saskatchewan, Saskatchewan, Qu'Appelle, and Churchill River Basins tributary to

interprovincial boundaries. The studies were conducted under the direction of the Committee on Hydrology.

The work started in 1971. A thorough review of existing methods of natural flow determination was undertaken, a pilot project was initiated and several different natural flow computation methods were tested. These included the project depletion, stream depletion, inflow-outflow and consumptive use methods. The Saskatchewan-Nelson Basin Board (SNBB) approach to natural flows was also considered. It was concluded that the project depletion method produced the most accurate results and was the easiest to apply, particularly for the South Saskatchewan River Basin. The project depletion method relies heavily upon information from hydrometric stations and places less emphasis on meteorological data. The net depletion for each irrigation project is calculated as the difference between the gross diversion and the measured or estimated return flow. Storage and evaporation losses from main stream reservoirs also constitute a net depletion. Net depletions or additions (main stream reservoir releases) are routed to the interprovincial boundary and added or subtracted from the recorded flow at that point to calculate the natural flow.

Studies in other drainage basins were similar to those undertaken for the South Saskatchewan River Basin. The project depletion method was suitable for the North Saskatchewan, Saskatchewan, Qu'Appelle and Churchill River Basins. In the Qu'Appelle River Basin, the project depletion method was supplemented by a Streamflow Synthesis and Reservoir Regulation (SSARR) computer model that was used primarily to perform the complex routing procedures necessitated by the hydrologic characteristics of the basin.

During the period 1971 to 1976, a series of natural flow study reports and natural flow calculation procedure manuals were completed and approved by the Committee on Hydrology. These reports are:

PPWB Report No. 45

South Saskatchewan River Basin	-	Main Report
South Saskatchewan River Basin	-	User Manual
North Saskatchewan River Basin	-	Main Report
Saskatchewan River Basin	-	Main Report
Qu'Appelle River Basin	-	Main Report
Qu'Appelle River Basin	-	User Manual
Churchill River Basin	-	Main Report

Natural Flow Network Evaluation

The natural flow study reports for all five basins were completed in 1976.

These reports and manuals provide the basis for computation of natural flow at the interprovincial boundaries for the five major interprovincial rivers in the prairie provinces.

As a part of COH's continuing efforts in natural flow determination for eastward flowing streams at the interprovincial boundary, the COH has also developed and/or updated a series of natural flow calculation procedures. The work related to such activity is described in the following sections.

Qu'Appelle River SSARR Model

The model used for computing natural flow of the Qu'Appelle River at the Saskatchewan-Manitoba boundary required major modifications both to convert the model to System International (S.I.) units and to improve the accuracy of the model. To deal with the use of the SSARR Model for the Qu'Appelle River Basin, the Committee on Hydrology at its Meeting No. 28 held on October 10-12, 1979 established an ad hoc sub-committee (the SSARR Model Sub-Committee) to determine what had to be done to accomplish these tasks, to make recommendations to the COH on what work was required, and to estimate the cost to undertake these modifications.

During the seven-year period 1979 to 1985, the SSARR Model Sub-Committee was actively involved in studies that would improve the effectiveness of the

model. The sub-committee agreed that the following aspects should be addressed before converting the model to S.I. units:

- 1) Checking all existing and revised tables;
- 2) Model Configuration;
- 3) Municipal Sewage Effluent;
- 4) Reservoir Regulation Cards for Lakes;
- 5) Overbank Flow;
- 6) Use of Index Reservoirs;
- 7) Routing parameters for discharges under $2.8 \text{ m}^3/\text{s}$; and
- 8) SSARR vs SIMPAK (River Simulation Package).

As recommended by the COH at its Meeting No. 32 held on June 25-26, 1980, a contract was made with the Hydrology Branch, Saskatchewan Environment for conducting three separate studies to deal with items No. 4, 6 and 8. As of December 1985, two study reports were approved by the COH. They are:

- 1) A Review of the SSARR Versus SIMPAK Models for the Qu'Appelle River Basin (May 1984), PPWB Report No. 73; and
- 2) Estimating minor project use in the Qu'Appelle River system at the Saskatchewan-Manitoba Boundary (November 1985), PPWB Report No. 75.

A final report entitled "Effects of Reservoir Regulation and Evaporation on the Qu'Appelle River SSARR Natural Flow Model" was being prepared.

With respect to item 3, Municipal Sewage Effluent, the sub-committee suggested that return flow from the City of Regina be determined using the recorded outflow of the Regina tertiary treatment plant, and that return flow from Moose Jaw be assumed to be zero since all the effluent is used for irrigation.

The main reason for considering switching from SSARR to SIMPAK was because the cost of computer runs for SIMPAK was much cheaper. With the use of in-house microcomputers or minicomputers, however, the cost of computer runs is no longer a concern.

The SSARR Model Sub-Committee after investigating the feasibility of converting the SSARR Model to S.I. units, agreed that it would not be cost-effective to convert the Qu'Appelle River SSARR Model to S.I. units.

South Saskatchewan River Natural Flow Calculation

Since 1974, the natural flow calculations for the South Saskatchewan River below Red Deer River have been done by the Canada Water Resources Branch (Calgary office) for the Board on a contract basis using the procedure developed in 1974. Some revisions to this procedure were required to incorporate the newly constructed Gleniffer Reservoir, the regression equations recommended in a report entitled "Return Flow From Irrigation - Southern Alberta" October 1985, PPWB No. 72, and to convert the calculation to S.I. units.

As directed by the Committee on Hydrology, the CWRB (Calgary office) in April 1985 completed the updating of the natural flow computation procedures and prepared a report entitled "Natural Flow South Saskatchewan River Below Red Deer River - User Manual Text". The report was approved by the Committee on Hydrology and the updated computation procedure has replaced the old one.

Natural Flow Calculation Procedures for the Battle, Lodge and Middle Creeks

The Board Committee on Interjurisdictional Agreements Administration (COIAA) in March 1981 completed a report entitled "Battle and Lodge Basins Apportionment Study". It recommended to the Board on how the flow of Battle and Lodge Basins should be apportioned. The COIAA also recommended that the methodology for computing natural flow of each creek at the interprovincial boundary be the same as that used to calculate natural flow for the eastern or northern tributaries of the Milk River system under international agreements.

The Committee on Hydrology, at its July 1982 Meeting (COH Meeting No. 39), agreed that there was a need to develop the procedures for determining natural flow of Battle, Lodge and Middle Creeks at the interprovincial boundary for apportionment purposes. Under the direction of the COH, the Canada Water Resources Branch (Calgary office) completed a report entitled "Procedures for Interprovincial Apportionment of the Waters of Battle, Lodge and Middle Creeks" in February 1983 outlining the procedures and assumptions used in determining natural flow at the interprovincial boundary on a ten-day basis. The proce-

dures were similar to those being used to determine natural flow at the international boundary.

These procedures were later used in the calculation of natural flow for 1983 and a number of deficit related problems on the Lodge Creek were identified. To deal with the problem, a meeting and field trip were held on September 26, 1983 to examine the situation of Upper Lodge Creek reservoirs and make suggestions as to how flow deficits might be made up. The field trip group agreed among other things that the first audit date of May 19th was too late in the year to be effective and suggested that it be changed to April 28th. The suggestion was approved by the Board at its November 1983 Meeting and was implemented by the CWRB in the spring of 1984.

When an Order-in-Council for an amendment to Article 6, Schedule A of the Master Agreement on Apportionment was signed by the Ministers of Member Agencies in July 1984, the COH recommended to the Board that formal monitoring of apportionment for Battle, Lodge and Middle Creeks be implemented in 1985 (COH Minute 47-38).

Additional changes in the natural flow calculation procedure for Lodge Creek at the interprovincial boundary were made at the February 1985 Meeting (COH Minute 48-45). Those changes to the natural flow calculation of Lodge Creek at the interprovincial boundary were implemented in 1985.

Natural Flow Studies for Small Interprovincial Basins

After the completion of a series of natural flow study reports and the development of computer procedures for calculating natural flow on the five major interprovincial rivers in the prairie provinces, the Board felt there was a need to investigate small interprovincial streams in order to assess water uses in each basin, to determine historical natural flow, to evaluate each basin's existing hydrometric network and to determine if monitoring of apportionment is required for specific interprovincial basins.

The Committee on Hydrology initiated this work in 1976 by establishing, in discussion with the Board, a priority list for natural flow studies of small

interprovincial basins. Based on that priority list, contracts were granted to member agencies for conducting natural flow studies of interprovincial basins for the Board. The following is a list of small interprovincial basins natural flow study reports that have been completed and approved by the Committee on Hydrology and the Board since 1976:

1. Antler River at Saskatchewan-Manitoba Boundary - Natural Flow (December 1978). PPWB Report No. 52.
2. Pipestone Creek at Saskatchewan-Manitoba Boundary - Natural Flow (March 1979). PPWB Report No. 55.
3. Assiniboine River at Saskatchewan-Manitoba Boundary - Natural Flow (November 1980). PPWB Report No. 57.
4. Graham Creek at Saskatchewan-Manitoba Boundary - Natural Flow (July 1981). PPWB Report No. 62.
5. Boxelder Creek and Mackay Creek at Alberta-Saskatchewan Boundary - Natural Flow (September 1981). PPWB Report No. 56.
6. Gainsborough Creek at Saskatchewan-Manitoba Boundary - Natural Flow (June 1982). PPWB Report No. 63.
7. Battle River at Alberta-Saskatchewan Boundary - Natural Flow (June 1982). PPWB Report No. 64.
8. Beaver River at Alberta-Saskatchewan Boundary - Natural Flow (May 1984). PPWB Report No. 69.
9. Eyehill Creek at Alberta-Saskatchewan Boundary - Natural Flow (July 1984). PPWB Report No. 68.
10. Big Gully Creek at Alberta-Saskatchewan Boundary - Natural Flow (October 1984). PPWB Report No. 73.
11. Swan River at Saskatchewan-Manitoba Boundary - Natural Flow (September 1985). PPWB Report No. 81.
12. Woody River at Saskatchewan-Manitoba Boundary - Natural Flow (September 1985). PPWB Report No. 82.

The completion of these twelve natural flow studies provides the essential hydrologic information for each of these small interprovincial basins enables the COH to make decisions or to form recommendations to the Board on how the flow of each of these small interprovincial streams may be dealt with.

The natural flow study for Birch River at the Saskatchewan-Manitoba Boundary is currently being conducted by the Saskatchewan Water Corporation. The Board's Secretariat is conducting studies on four small basins (Jackson Creek, Bosshill Creek, Gopher Creek and Stony Creek) and PFRA has agreed to study the Overflowing and Red Deer (Saskatchewan) Rivers. No agreement has been made to study Elm Creek, the only remaining basin of the twenty originally identified by the Committee on Hydrology.

In addition to recognizing the work necessary to complete these seven remaining natural flow studies, the COH determined that the methodology for calculating natural flows in the Pipestone Creek Basin as presented in the Pipestone Creek Natural Flow Study report of March 1979 did not provide a sufficiently accurate estimate of monthly natural flow. The COH agreed that the natural flow study report of the Pipestone Creek Basin should be reviewed in the near future to address concerns that have arisen since the study was completed.

Return Flows from Irrigation Districts

The Apportionment Agreement monitoring program requires that natural flow be calculated at interprovincial boundaries. The project depletion method utilized by the Board to calculate natural flow for the South Saskatchewan River at the Alberta-Saskatchewan Boundary needs quantitative irrigation return flow data.

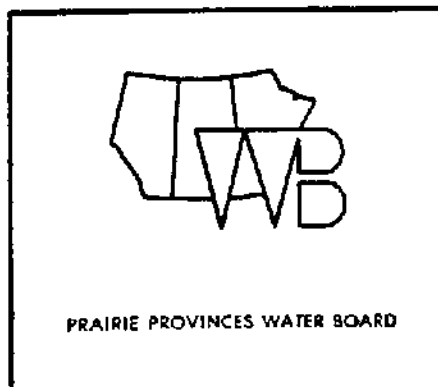
Since 1956, an annual program of measurement and analysis of return flows for the Western Irrigation District (WID), the Eastern Irrigation District (EID), and the Bow River Irrigation District (BRID) has been conducted by the Canada Water Resources Branch (Calgary office). Annual reports have been prepared to report on diversion, water use, irrigated area, and other related data.

Prior to 1973, the irrigation return flows for the St. Mary River Irrigation District, the Taber Irrigation District, and the Lethbridge Northern

Irrigation District were estimated by those irrigation districts. At the request of, and under contract to the Board, the Canada Water Resources Branch made a series of field measurements during the 1971 and 1972 irrigation seasons to more accurately determine return flow from these three irrigation districts. The results of these measurements were analysed, using multiple regression techniques, to provide a basis for the selection of several key return flow stream gauging stations. A report on this study, entitled "Determination of Irrigation Return Flow in Southern Alberta - Natural Flow", March 1974, was completed by the CWRB and approved by the Committee on Hydrology. The return flow equations based on this study were incorporated into the computer program for computing natural flow of the South Saskatchewan River at the Alberta-Saskatchewan Boundary.

In 1982, the Committee on Hydrology speculated that the characteristics of irrigation return flow in Southern Alberta irrigation districts were changing due to the increased use of mechanized sprinkler irrigation. The committee recommended to the Board that the Canada Water Resources Branch be asked to conduct a study of the irrigation return flow index stations being used to estimate return flow from Alberta irrigation districts. The report of that study was completed in 1985 by the Calgary office of the Canada Water Resources Branch and was approved by the COH in February 1985 (COH Meeting No. 48). The COH agreed that the new return flow equations recommended in the report be used to estimate irrigation return flows, and that a full return flow monitoring program be carried out in the field every five to ten years. The new return flow equations have been incorporated in the new (1985) natural flow calculation computer program for the South Saskatchewan River.

The Calgary office of the Canada Water Resources Branch, in September 1985, proposed to the COH a two-year field program to gather irrigation return flow data in the EID, WID, and BRID for regression analysis purposes and to develop new return flow equations for use in these irrigation districts. The committee agreed that the methods of irrigation in this area have changed and are now at the stage where a better estimate of return flow is needed.



Chapter 5

FLOW FORECASTING

References to flow forecasting in the prairie provinces were made in 1966 when the Data Network Planning Committee was established. The primary duty of the committee was to provide data that would meet provincial requirements for forecasting the runoff of interprovincial streams.

The DNPC in its seven years of operation (1966 to 1972) established the basic framework needed for conducting flow forecasting studies. When the Committee on Hydrology replaced the DNPC in 1972, it proceeded with further work on flow forecasting.

In 1971, the Board contracted the Calgary office of Canada Water Resources Branch for a study to develop streamflow forecasting procedures for the South Saskatchewan, North Saskatchewan, Saskatchewan, Qu'Appelle and Churchill River Basins. The study began by consultation with member agencies as to the types of forecasts used, and the types of forecasts required. Based on these consultations and discussions, the need for procedures to perform long-range volume or water supply forecasts, as well as real-time daily flow forecasts, were identified. For water supply forecasts, a regression approach was used which included evaluating existing regression relationships on streams where they had been developed, modifying these relationships and developing new sets of regression relationships.

Real-time flow forecasts can be separated into the two general categories of basin simulation and flow routing. Basin simulation uses meteorological data to make preliminary estimates of the streamflow at gauging stations in the headwaters. Flow routing requires recorded or simulated upstream discharges which are routed to predict discharges at specific downstream points. Computer

models were made operational and a model, or combination of models giving the best result for a particular basin, was identified for each basin.

The study was completed in 1977. The following is a list of reports and manuals that were published during the course of this study.

PPWB Report No. 44:

South Saskatchewan River Basin - Main Report
South Saskatchewan River Basin - Combined User Manual
South Saskatchewan River Basin - User Manual Water Supply
South Saskatchewan River Basin - User Manual Routing
South Saskatchewan River Basin - User Manual Basin Simulation

North Saskatchewan River Basin - Main Report
North Saskatchewan River Basin - Combined User Manual
North Saskatchewan River Basin - User Manual Water Supply
North Saskatchewan River Basin - User Manual Routing
North Saskatchewan River Basin - User Manual Basin Simulation

Saskatchewan River Basin - Main Report
Saskatchewan River Basin - Combined User Manual
Saskatchewan River Basin - User Manual Water Supply
Saskatchewan River Basin - User Manual Routing

Qu'Appelle River Basin - Main Report
Qu'Appelle River Basin - Combined User Manual
Qu'Appelle River Basin - User Manual Water Supply
Qu'Appelle River Basin - User Manual Routing
Qu'Appelle River Basin - User Manual Simulation

Churchill River Basin - Main Report
Churchill River Basin - Combined User Manual
Churchill River Basin - User Manual Water Supply
Churchill River Basin - User Manual Routing

Forecast Network Evaluation

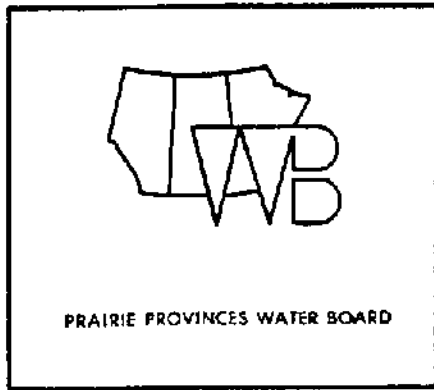
Forecast Centre Investigation

Computer Program Documentation

It has since been agreed that forecasting of river flow for water management purposes is the responsibility of each individual province and the Board's role is *"to ensure the coordination of such technical programs as water quantity and quality monitoring and streamflow forecasting required for the effective apportionment of water ..."*

[Schedule C, Section 4(f) of the 1969 Agreement].

To promote the exchange and coordination of forecast information among the three prairie provinces and to encourage the interactions between forecast agencies, the Committee on Hydrology, in 1980, prepared a summary table entitled "Hydrologic Forecasts and Existing Conditions Reports in the Prairie Provinces" outlining the type of forecast information that may be obtained from the forecast agencies. This summary table is updated annually by the Committee on Hydrology.



Chapter 6

FLOW APPORTIONMENT

Administration of the 1969 Master Agreement on Apportionment is the primary function of the Board. To ensure that every aspect of the agreement will be carried out effectively, there is a need to interpret the terms of the agreement and adequately define the intent of the agreement.

Administration of the Apportionment Agreement

In dealing with the terms of the 1969 Master Agreement on Apportionment, the Board in June 1975 (Board Meeting No. 12) instructed the Committee on Hydrology to investigate and report with recommendations on the mechanism required to administer the Apportionment Agreement.

The assignment was discussed at fourteen Committee on Hydrology Meetings (Meeting No. 18 to Meeting No. 31 inclusive). In April 1980, the Committee on Hydrology completed a report entitled "Report on Administration of the Apportionment Agreement" (PPWB Report No. 58). Certain aspects of the Agreement such as apportionment, balance and audit periods, the role and duties of the Board and participating agencies, procedures in the event of shortages, forecasting, and effects of storage and diversion were interpreted in this report. The report also included 12 recommendations, three dealing with the administrative procedures that should be continued to administer the Agreement; one concerning the procedures to be followed in the event of a shortage; one concerning a proposed change to the By-Laws; two dealing with forecasting and five with the apportionment of streamflow in the five major basins.

The Committee on Hydrology was invited by the Board to attend its November 1980 meeting (Board Meeting No. 24) to discuss the "Report on Administration of

the Apportionment Agreement". After this discussion, the Board approved the report at that same meeting.

At the request of the Board, a brief report entitled "Guidelines for Negotiating Equitable Apportionment" (PPWB Report No. 58a) was subsequently prepared by the COH. A step-by-step procedure was suggested describing how the three provincial agencies and the Board could maintain an equitable apportionment of interprovincial waters. The report on Guidelines was approved by the Board at its May 1981 meeting (Board Meeting No. 25).

Both the "Report on the Administration of the Apportionment Agreement" and "Guidelines for Negotiating Equitable Apportionment" were forwarded to the Ministers of member agencies. With the forwarding of these two reports, the assignment given to the COH in 1975 was completed and the reports became available for use as reference documents to administer the 1969 Master Agreement on Apportionment.

Westward Flowing Streams and Tributaries Evaluation

Apportionment of westward flowing waters was discussed at the ninth meeting of the Board on November 6, 1973. The Board agreed that it would be appropriate to consider the apportionment of westward flowing waters and directed the Committee on Hydrology to "identify westward flowing streams and tributaries, consider possible apportionment problems, and speculate on solutions, taking into account any relevant precedents".

In dealing with the above assignment, the Committee on Hydrology divided the study of westward flowing streams into two types as follows:

1. Westward Flowing Tributaries of Eastward Flowing Streams - Streams that cross an interprovincial boundary in a westerly direction and are tributary to eastward flowing streams; and
2. Westward Flowing Streams - Streams whose final crossing of an interprovincial boundary is in a westerly direction and are not tributary to eastward flowing streams.

1. Westward Flowing Tributaries of Eastward Flowing Streams

The Committee on Hydrology on November 17, 1982 (Board Meeting No. 29) submitted to the Board a report entitled "Westward Flowing Tributaries of Eastward Flowing Streams Apportionment Study" (Board Report No. 65). The report interpreted the intent of the 1969 Agreement in relation to westward flowing tributaries, outlined the extent of the problem, analyzed methods that may be used to apportion westward flowing tributaries of eastward flowing streams and provided recommendations to the Board on how these westward flowing tributaries might be apportioned. The committee concluded that any westward flowing tributary of an eastward flowing stream might be apportioned in accordance with the basic principles of the 1969 Apportionment Agreement and that, in doing so, there would be no violation of that Agreement. Based on this conclusion, the COH recommended that the "Rational Method" described in the report be considered, when appropriate, for the apportionment of westward flowing tributaries of eastward flowing streams. For such westward flowing waters, the "Rational Method" specifies that the province in which the water originates is entitled to 50 percent of that water and the other 50 percent is divided equally between the downstream provinces.

To further explain the "Rational Method" described in the report, the Committee on Hydrology, in November 1983, presented to the Board a brief report entitled "Application of the Proposed Apportionment Method to the Martineau and Reindeer Lake Basins".

At the November 27, 1985 Board Meeting (Board Meeting No. 35), the Board discussed the content of the report entitled "Westward Flowing Tributaries of Eastward Flowing Streams Apportionment Study" with the COH and suggested that the wording used in the report's recommendation be revised to allow for more flexibility in the selection of an appropriate apportionment method. The proposed wording changes were discussed at COH Meeting No. 50 held on November 27-28, 1985 and agreement was reached on how the report's recommendation could be revised. The committee agreed that a method termed the Mutual Agreement Method may also be considered for dealing with specific problem areas if the Rational Method is not deemed appropriate. The Mutual Agreement Method

considers the westward flowing tributary basins as a part of the total basin (i.e. eastward flowing stream basin) in which flow at provincial boundaries is subject to apportionment based on the terms of the 1969 Agreement. The province could, based on current and future water requirements, make individual arrangements on each westward flowing tributary of an eastward flowing stream to best suit their combined purposes. The revised report was accepted at Board Meeting No. 36.

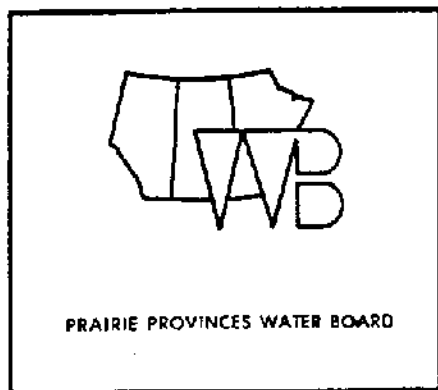
2. Westward Flowing Streams

The Committee on Hydrology, in April 1983, submitted to the Board a brief report entitled "Interprovincial Apportionment of Westward Flowing Streams". In that report, the committee identified the number of westward flowing streams in the prairie provinces, considered the jurisdictions involved if the flow of westward flowing streams was to be apportioned and speculated on future apportionment principles.

The committee concluded that:

- "1. The only westward flowing streams identified are part of the Mackenzie River basin. In the future, these streams may be apportioned among Alberta, Saskatchewan, and the Northwest Territories.*
- 2. There is no immediate need to apportion the flow of westward flowing streams crossing the Saskatchewan-Alberta boundary because present uses are small in comparison to the total basin yield of each of the four westward flowing streams and Lake Athabasca."*

This brief report and its conclusions were accepted by the Board on May 17, 1983 (Board Meeting No. 30).



Chapter 7

FLOW MONITORING

Monitoring of streamflow, return flow, or water use is the first step in the estimation of natural flow. The accuracy of recorded flow data has a direct effect on the accuracy of natural flow estimates at the interprovincial boundary. For the purposes of computing natural flows for interprovincial apportionment, over one hundred hydrometric stations in the prairie provinces have been designated as Board hydrometric monitoring stations. Flow at these stations is monitored mainly for the purposes of interprovincial apportionment. Flow measurement accuracy at these stations is subject to monitoring criteria set up by the Board.

Evaluation of hydrometric gauging stations to ensure that the performance of these stations is adequate for Board purposes has been the responsibility of the COH. Since 1972, a variety of studies relating to monitoring have been dealt with by the committee. The following is a brief review of monitoring studies that have been completed by the Committee on Hydrology.

Blackfoot Creek and Battle River at the Alberta-Saskatchewan Boundary

Blackfoot Creek is a small tributary that contributes flow to the main stem of Battle River between the hydrometric stations Battle River near Unwin and Battle River near the Saskatchewan Boundary. The Unwin station had been the Board monitoring station until 1980, when the Canada Water Resources Branch became concerned that the channel at the site was silt-bottomed and was actively meandering. Attempts were made to construct a stable concrete control at the site but these were unsuccessful due to the quicksand-like condition of the channel bottom. Silting problems at the station eventually resulted in total loss of data collection capability in August 1979. The Canada Water Resources

Branch moved the station to the present site of Battle River near the Saskatchewan Boundary to improve the quality of data collection.

The Committee on Hydrology, in dealing with the problem, suggested that the hydrometric stations Blackfoot Creek near the Saskatchewan Boundary and Battle River near the Saskatchewan Boundary be run concurrently in 1980 to determine the flow relationship between the two stations and to see if the inflow from Blackfoot Creek had a measurable effect on the volume and peak flow of Battle River between the station near the boundary and the station near Unwin.

As suggested by the COH, a temporary station Blackfoot Creek near the Saskatchewan Boundary was installed in 1980 by the CWRB (Regina office) and the data obtained from that station were used in a report entitled "Hydrometric Evaluation Blackfoot Creek near the Saskatchewan Boundary", March 1983. The report concluded that:

- "1. On a monthly basis there are minor differences in the flows between Battle River near the Saskatchewan Boundary and Battle River near Unwin. However, on an annual basis these differences are negligible.*
- 2. The contributing flows of Blackfoot Creek near the Saskatchewan Boundary represent a percentage of flow of the Battle River near the Saskatchewan Boundary that is less than the allowable error of 5 per cent using standard streamflow measurement procedures.*
- 3. The length of record at Blackfoot Creek near the Saskatchewan Boundary is of insufficient length to conclusively state that there is a significant correlation between Blackfoot Creek and similar streams in the area.*
- 4. For the present level of water usage, the costs of upgrading and maintaining the station Blackfoot Creek near the Saskatchewan Boundary, do not appear to be justified for the express purpose of apportionment."*

Based on these conclusions, the committee agreed that the temporary hydro-metric gauging station Blackfoot Creek near the Saskatchewan Boundary be discontinued, and that the present hydrometric station Battle River near the Saskatchewan Boundary be designated as the Board station to replace the hydro-metric gauging station Battle River near Unwin.

Saskatchewan River at the Saskatchewan-Manitoba Boundary

The hydrometric gauging station Saskatchewan River near the Manitoba Boundary had been chosen by the Board as an interprovincial flow apportionment monitoring site. Since its establishment, many operational problems had occurred with substantial loss of water level records. Due to the operational difficulties at this station, the CWRB (Winnipeg office) concluded that the station was not suitable for flow measurement.

Flow monitoring problems for the gauging station Saskatchewan River near the Manitoba Boundary were discussed at COH Meeting No. 42 and at subsequent meetings. At COH Meeting No. 44, the committee reviewed a report entitled "Saskatchewan River Monitoring Study - August 31, 1983" and agreed with the report's recommendations that:

- "1. The station Saskatchewan River near Manitoba Boundary should be discontinued.*
- 2. The station Saskatchewan River at The Pas should be identified as the key Board station for computing Saskatchewan River apportionment flows near the Saskatchewan-Manitoba Boundary and the frequency of discharge measurements should be increased at this site.*
- 3. The proposed procedure of Saskatchewan River at The Pas recorded discharge minus 1.31 times Carrot River near Turnberry recorded discharge should be adopted by the Board for computation of annual discharge of Saskatchewan River near Manitoba Boundary."*

The hydrometric gauging station on the Saskatchewan River at The Pas is characterized by unsteady and non-uniform flow preventing the use of a consistent rating curve. To deal with this problem and to determine the frequency of discharge measurement required for gauging station Saskatchewan River at The Pas, the CWRB (Winnipeg office) conducted a study which investigated different methods that are available to solve the discharge rating problem and developed a new method to improve the accuracy of flow measurement. The result of that study was documented in a report entitled "Computation of Open Water Discharges Saskatchewan River at The Pas". The COH, at its February 27-28, 1985 Meeting (COH Meeting No. 48) reviewed the report's recommendations and agreed that:

1. The new "VARSL0P" method be applied to compute the daily flow at The Pas for 1984 and following years.

2. A minimum of one discharge measurement per month, during the open water period, be taken at The Pas to check "VARSLIP" method on a regular basis.

More specifically, the following ranges in flow and stage should be monitored:

- a) flow higher than 1 550 m³/s for each variation of 140 m³/s above 1 550 m³/s or for each variation of 0.3 m of the water level at The Pas above 259.7 m;
 - b) flow lower than 700 m³/s for each variation of 85 m³/s below 700 m³/s or for each variation of 0.3 m of the water level at The Pas below 257.9 m.
3. A user manual be supplied to the operational CWRB staff at The Pas sub-office on the use of VARSLIP.
 4. When flows are over 1 550 m³/s, the falling and rising limbs be metered to more accurately define the rating curve. The moving boat method be considered for this metering program.

Cumberland Marshes Project

Monitoring of water quantity/quality in the Cumberland Marshes area was initiated by the Board in 1977 when Ducks Unlimited began to build diversion structures in the area. The Board, at its Meeting No. 17 held on November 9, 1977, agreed that Saskatchewan Environment, with the support of CWRB (Regina office), ensure that Ducks Unlimited fund the program, and that CWRB (Regina office) produce annual reports on the monitoring results including the description of the extent of development and the method of operation.

At the beginning of 1978, a series of annual reports entitled "Water Quantity/Quality Monitoring Program - Cumberland Marshes Project" was published by the Canada Water Resources Branch. The Committee on Hydrology was requested by the Board to review the water quantity aspects of the monitoring program, and to advise the Board on the effect that the project might have on downstream water quantity.

After reviewing five annual monitoring reports, the Committee on Hydrology at its September 1983 Meeting (COH Meeting No. 44) concluded that the effect of the project on water quantity at the interprovincial boundary was minimal. The committee also recommended to the Board that:

- "1. The water quantity monitoring program for the Cumberland Marshes Project should be continued to support the water quality sampling program.
2. The existing monitoring station on the Birch River should be maintained to provide a continuous recorded period of flow for the proposed natural flow study of the Birch River at the Saskatchewan-Manitoba Boundary."

Further discussion as to whether the monitoring program should be continued was carried out at the Board level. The Board, at its June 11-12, 1985 Meeting (Board Meeting No. 34), reviewed the recommendations of the Committee on Water Quality (COWQ) and an Inland Waters Directorate report entitled "Water Quality in the Cumberland Marshes 1979-1984 - June 1985". Based on the information outlined in the report, the Board agreed that:

- "1. Mitigative measures implemented by Ducks Unlimited (Canada) to enhance dissolved oxygen levels in Cut Beaver Lake and minimize winter entrapment of fish within and below the Cumberland Marshes project should be continued.
2. Monitoring of the chemical characteristics of the inflow and outflow from the Cumberland Marshes project area has been adequately addressed related to interprovincial concerns and can therefore be discontinued. A need for future monitoring may become apparent if major fish kills are observed in forthcoming years, if new construction or other significant project changes occur, or if new water uses are proposed."

Network Required for Future Monitoring of Small Interprovincial Streams

Hydrometric gauging stations required for monitoring the flow of small interprovincial streams have been addressed in small interprovincial basin natural flow study reports. When the need for monitoring the flow of such an interprovincial basin becomes evident, the monitoring network must be revised to ensure that there is adequate hydrometric gauging station coverage for apportionment purposes.

To deal with this problem, the Committee on Hydrology in March 1983 asked the Canada Water Resources Branch (Calgary office) to prepare a handbook outlining the natural flow calculation procedure, existing network and its limitations, and to recommend the monitoring network required for apportionment pur-

poses for each small interprovincial basin. That handbook has now been completed and distributed. It will be updated by the Committee on Hydrology when additional natural flow studies have been completed.

Field Investigation of Interprovincial Basins

As part of its monitoring responsibilities, the COH has been closely monitoring the flow balance of eastward flowing streams at interprovincial boundaries to ensure that the terms of the 1969 Master Agreement on Apportionment are met. In the past years, two interprovincial basins (Lodge and Pipestone Creek Basins) have been identified in which interprovincial apportionment appeared to be a problem.

As part of the investigations into these two apportionment problems, the COH conducted the following two field investigations:

1. Lodge Creek Basin - September 26, 1983, and
2. Pipestone Creek Basin - October 3, 1984.

The conclusion and recommendation resulting from these field investigations were used by the COH to recommend to the Board on how existing monitoring networks and procedures may be improved.

Annual Review of Board Hydrometric Monitoring Stations List

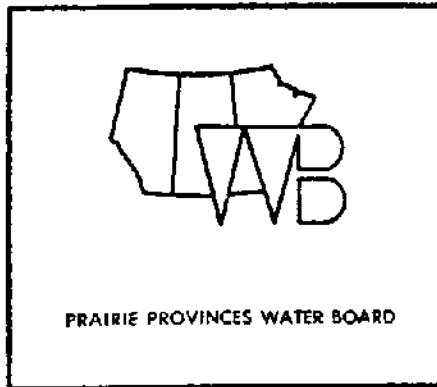
There are over one hundred hydrometric gauging stations in the prairie provinces where the flow records are used to calculate natural flow at apportionment sites. Each site is designated as a Board hydrometric monitoring station.

The Committee on Hydrology, as part of its continuing responsibility, annually reviews and recommends to the Board an updated Board hydrometric monitoring station list.

In addition to these activities, the Committee on Hydrology also, on a case-by-case basis, has reviewed specific monitoring problems on several east-

ward flowing streams and has made recommendations to the Board on how these specific monitoring problems may be resolved. These specific problems include:

- 1) Determination of open water flow of the Red Deer River near Bindloss and the South Saskatchewan River at Highway No. 41,
- 2) Use of South Saskatchewan River at Medicine Hat to determine winter stream-flow,
- 3) Definition of flow in Eastern Irrigation District (EID) canals that record diversion from the Bow River, and,
- 4) Accuracy of streamflow records of the Qu'Appelle River near Welby (Board Minute 25-55).



Chapter 8

EVAPORATION

Evaporation is one of the components considered in the computation of natural flow of interprovincial streams at the boundary. Reservoir evaporation data for St. Mary Reservoir, Waterton Reservoir, Lake Diefenbaker and Tobin Lake have been computed and published by the Regina office of Atmospheric Environment Service (AES) using the Meyer formula that was approved by the COH in 1973 (COH Minute 4-21). The data have been used by the CWRB (Calgary office) and the Board Secretariat for natural flow computation purposes.

Evaporation Calculations for the Prairie Provinces

The Meyer formula is still used but, in 1980, Alberta Environment while updating the historical monthly natural flow data in Alberta portion of the South Saskatchewan River Basin, suggested that the F.I. Morton model of lake evaporation be used to compute reservoir evaporation for reservoirs and lakes in the Alberta portion of the South Saskatchewan River Basin. To support the above recommendation, a report entitled "Assessment of F.I. Morton's Model of Lake Evaporation" was prepared by Alberta Environment and tabled at COH Meeting No. 33. Committee Members were unable to come to a consensus on the computation of evaporation but felt that since evaporation is only a small portion of natural flow, a small difference in evaporation estimates would not have a significant effect on the calculated magnitude of natural flow. They agreed that if Alberta Environment applied the Morton Model to estimate reservoir evaporation in the South Saskatchewan River Basin in Alberta, the resulting flows would be compatible with those calculated by the Board.

At the September 25-26, 1980 Meeting (COH Meeting No. 33), the committee reviewed a report entitled "Evaluation of F.I. Morton's Lake Evaporation Model

and Its Application to the Canadian Prairies" prepared by the AES (Regina office). Based on the analysis and conclusions provided in the report, the committee reached the consensus that Morton's potential evaporation provides a good estimate of pan-derived lake evaporation at Regina and Swift Current but does not adequately compensate for wind effects and reservoir depth. These parameters were considered to be significant in estimating lake evaporation on the Canadian Prairies. The committee agreed that Morton's method was still in the research stage and that the model was not yet suitable for general use in the prairie provinces, and that the "Meyer Method" should continue to be used until a proven better method is identified.

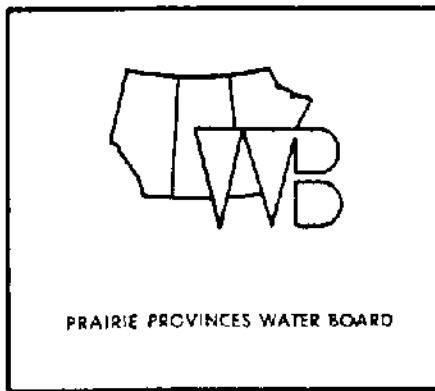
Additional discussions with respect to the application of F.I. Morton's Model were held at subsequent COH meetings. At Meeting No. 34 held on January 20-21, 1981, the committee agreed that a detailed water budget study of a prairie reservoir should be conducted to test and compare the performance of the Morton and Meyer methods. A report that outlines the results of such a water budget study is being prepared by the Atmospheric Environment Service (Regina office) and will be reviewed by the Committee on Hydrology in the near future.

Evaporation Calculations for Gleniffer (Dickson) Reservoir

In May of 1983, the filling of Gleniffer Reservoir (located on the Red Deer River in central Alberta about 35 kilometres southwest of the City of Red Deer) began upon completion of Dickson Dam. Evaporation losses from the reservoir became a component of South Saskatchewan River natural flow calculation. The question as to how the evaporation losses from Gleniffer Reservoir should be calculated was raised at COH Meeting No. 42. The committee felt there was a need to examine alternative methodologies and select the best methodology for use. The committee asked the Regina office of AES to evaluate reservoir evaporation of Gleniffer, St. Mary and Waterton Reservoirs and to prepare a report for the consideration of the COH.

Discussion of a report entitled "Estimation of Evaporation from Gleniffer Reservoir for Natural Flow Calculations" took place at COH Meetings No. 45 to 48 inclusive. The committee, at its February 27-28, 1985 Meeting (COH Meeting

No. 48), approved the report and agreed that evaporation from Gleniffer Reservoir be calculated using mean annual gross evaporation less actual precipitation in the monitoring procedure but, that for consistency with the computation of natural flow throughout the South Saskatchewan River Basin in Alberta, Morton Model lake evaporation less actual precipitation be used in the final calculation of natural flow.



Chapter 9

DRAINAGE

The Impact of Artificial Drainage on Downstream Watersheds

The issue of artificial drainage and its impact on downstream watersheds was first brought up by the Board on November 21, 1979 (Board Meeting No. 22). The Board, at that meeting, agreed that the Committee on Hydrology should:

"...consult with hydrologic specialists and should advise the Board on how an applied hydrology research program might be developed to determine the effects of artificial drainage on downstream flows in prairie streams."

Discussion regarding this assignment was held at COH Meeting No. 29 and at subsequent meetings. Several related technical papers and study reports were reviewed by the committee to determine if techniques or approaches in Canada and the United States might be applied to similar situations in the prairie provinces.

At COH Meeting No. 31, held on March 18-19, 1980, the committee invited Mr. R.S. Pentland of the Hydrology Branch, Saskatchewan Environment to present a discussion paper entitled "The Agricultural Drainage Impacts in Saskatchewan". After the presentation, the committee discussed the concept with Mr. Pentland and the possible application of the methodology for assessing the impacts of artificial drainage in the prairie provinces.

The committee presented to the Board, at Board Meeting No. 26 held on November 18-19, 1981, a brief report entitled "Applied Hydrology Research to Determine the Impact of Artificial Drainage on Downstream Flow". In that report, the committee commented on the applied hydrology research conducted by

the three prairie provinces, the National Hydrology Research Institute (NHRI) and the United States Army Corps of Engineers. Based on the information described in the report, the committee recommended that:

- "1. The Board, acting through the Committee on Hydrology, maintain a watching brief on the drainage research studies presently underway provincially, federally and in the Red River basin in the United States.*
- 2. The Board, as an interim working procedure, use the approach developed by Saskatchewan Environment to assess post-drainage runoff problems.*
- 3. Each member agency continue to inform the Board, through its standing committees, of the agency's activities on the assessment of drainage impacts."*

The Board in discussing Recommendations 1 and 2, agreed that the Committee on Hydrology should maintain a watching brief and report on drainage research studies which could be used to determine the effects of artificial drainage on downstream flows in prairie streams and that, as an interim working procedure, the Board would use the approach developed by Saskatchewan Environment to assess post-drainage runoff problems.

With respect to recommendation No. 3, the Board directed the Committee on Hydrology to develop a practical procedure to permit the Board to maintain a watching brief on drainage projects that may have a significant impact on the quality or quantity of flow in interprovincial streams.

Discussion concerning this assignment continued at COH Meetings No. 37 to 44 inclusive. At Board Meeting No. 31 held on November 8, 1983, the COH presented to the Board a brief report entitled "A Recommended Procedure to Deal with the Impact of Artificial Drainage on Downstream Flow". The report provided a brief review of background information related to the impact of artificial drainage, the NHRI's research project and problem complexity and proposed two practical procedures; a) the objective method and b) the subjective method. The Board at the same meeting accepted the report and also instructed the COH to provide reports outlining the drainage activities in each province that may have effects on downstream flow.

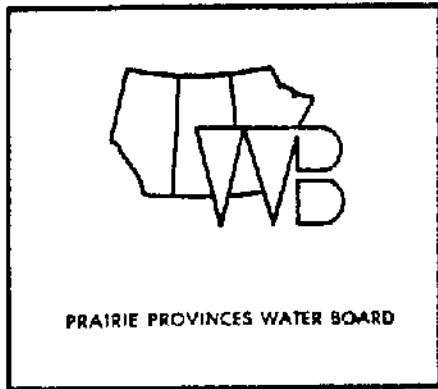
Discussion concerning the procedures that could be used to report drainage activities took place at COH Meeting No. 46. It was agreed that the COH provincial members should devise a reporting procedure and report that procedure to the COH. At Meeting No. 48, the COH provincial members presented a reporting procedure which outlined the report's format, updating procedures, and a procedure for presenting the report to the Board. The reporting procedure was accepted by the COH at the same meeting (COH Minute 48-65).

A drainage activities report for 1984 was prepared and presented to the Board at its Meeting No. 34 held on June 11-12 1985. The Board agreed to the reporting procedure proposed by the COH including the proposal that the COH will provide a list of drainage projects on an annual basis at each spring Board meeting (Board Minute 34-49).

The Langenburg-Russell Drainage Study

The Board, at Meeting No. 23 held on May 6, 1980, accepted a specific reference from the provinces of Saskatchewan and Manitoba to deal with a problem involving artificial drainage in a series of small interprovincial streams that affect the Rural Municipalities of Langenburg, Churchbridge, Shellmouth and Russell. A Task Force consisting of the Executive Director of the Board Secretariat and one member each from Saskatchewan and Manitoba was formed. After a field tour of the area in the summer of 1980, the Task Force in November 1981 proposed, and the Board agreed, that the province of Saskatchewan would determine firstly the effect of existing drainage works on the volume and intensity of flow at the affected boundary points, and secondly the potential effect that future drainage might have on these same streams. A report summarizing the results of this study was forwarded to the Task Force members by the Saskatchewan Water Corporation in March 1985. After reviewing the study report, Manitoba Department of Natural Resources conducted field surveys of watercourses and roadcrossings and undertook backwater calculations for the existing and proposed drainage channels. The Manitoba Task Force member is now preparing a report on how much upgrading would be required to alleviate the problems caused by increased drainage.

When the work of this Task Force has been completed, their findings will be reported to the Committee on Hydrology and the committee will recommend an appropriate course of action to the Board.



Chapter 10

WATERSHED MANAGEMENT

The issue concerning the possibility of managing the watershed in the eastern slopes of the Rockies to increase streamflow and to alter the hydrograph shape was first brought up at the September 20-22, 1976 meeting of the COH (COH Meeting No. 18). At that meeting, the members heard a presentation by Mr. R.H. Swanson of the Northern Forest Research Centre, Canadian Forestry Service, on present research efforts towards increasing water yields from the eastern slopes.

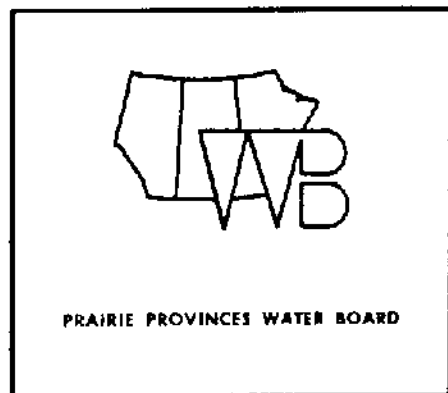
Mr. Swanson described pilot studies which had been done in the Marmot Creek, Streeter Creek and James River Basins to investigate the effects of watershed management practices on water yields from the eastern slopes of the Rocky Mountains. The studies appeared to indicate that water yields could be increased by pattern cutting to increase the snowfall reaching the ground and reduce snowpack losses due to evaporation.

The Board, at its May 18, 1977 Meeting (Board Meeting No. 16), agreed that the Committee on Hydrology should undertake an examination of the increased yield available by watershed management practices, the timing and benefits of increased yield, and the total increase in yield that may be expected from major river basins with their headwaters in the eastern slopes area (Board Minute 16-33).

This Board assignment was discussed at COH Meetings No. 22 to 25 inclusive. During that period, Alberta was embarking on a study of the potential for increasing the yield in the Oldman River Basin through watershed management. It was suggested that the results of that study be obtained before starting the assignment. A consultant report on the feasibility of increasing

yields in the Oldman River Basin was released in 1978. Reactions to that study were varied, and the Committee on Hydrology felt a further study would be premature in view of the continuing work being contemplated by Alberta.

The committee presented to the Board, at its April 28, 1978 Meeting (Board Meeting No. 18), an interim report outlining the watershed management study activities in Alberta and the Board suggested that the Committee on Hydrology continue to maintain an active interest in the progress of research and/or operations in Alberta. This contact is maintained through the Alberta COH member.



Chapter 11

IMPACT ASSESSMENT AND OTHER ACTIVITIES

In addition to those committee activities described in previous chapters of this report, there are a number of related activities that have been managed by the Committee on Hydrology such as reviewing the effect of a project that may have interprovincial implications; organizing technical seminars or workshops; and/or conducting field investigations.

Activities Related to Impact Assessment for Projects that May Have Interprovincial Implications

As the hydrotechnical advisor to the Board, the COH has, from time to time, reviewed the possible impact of a project or proposal, and made recommendations to the Board on how the matter may be dealt with. The COH also maintains a watching brief to the Board on projects that may have interprovincial implications.

The following is a list of projects or study proposals that have been dealt with by the Committee on Hydrology in the past fourteen years (1972 to 1985):

1. Dickson Dam (Gleniffer Reservoir) Project.
 - COH Minute 26-28
 - Board Minute 20-35
2. Qu'Appelle River Conveyance Project.
 - COH Minutes 26-29, 32-52, 33-22, 36-21 and 38-41.
 - Board Minutes 28-74 and 31-29 to 31-35 inclusive.
3. Nipawin Hydroelectric Project.
 - COH Minutes 26-30, 32-49, and 33-21.
 - Board Minute 24-37.

4. Cluff Lake Uranium Project.
 - COH Minute 34-37.
 - Board Minute 25-19.
5. Bredenbury Potash Mine Project.
 - COH Minute 37-36.
 - Board Minute 26-23.
6. Proposed Esso Cold Lake Oil Sands Project.
 - COH Minutes 19-44, 28-18 and 49-17.
 - Board Minutes 19-44 and 21-13 to 21-15 inclusive.
7. Cumberland Marshes Project.
 - COH Minutes 36-34 to 36-36 inclusive.
 - Board Minutes 26-13 to 26-15 inclusive.
8. Husky Heavy Oil Project, Lloydminster.
 - COH Minute 48-15.
 - Board Minutes 33-16 to 33-18 inclusive.

Activities Related to Technical Seminars and Field Investigations

The following technical seminars, or field investigations, have been organized by the COH in the period 1972 to 1985 inclusive.

June 26, 1973 - Mr. B.A. Walker and Mr. O.S. Roscoe of Communications Canada made a presentation to the COH concerning a satellite system study carried out by Communications Canada (COH Minutes 4-02 and 4-03).

September 18, 1974 - Mr. H.S. Loijens of the National Hydrology Research Institute (NHRI), Inland Waters Directorate, Environment Canada presented a paper entitled "An Experimental Gamma-Ray Spectrometer Snow Survey Over Southern Ontario" to the COH. After the presentation, the members asked many questions on the applicability of this method to the prairies. It was noted that the method works well on flat terrain, where the snow water equivalent is less than 0.3 m and that underestimation of water equivalent would probably result in areas where gullies and coulees trap large amounts of snow (COH Minute 8-50).

- December 9, 1975 - Miss J. Heyworth and Mr. J. Boychuk of WATDOC, Planning and Management Branch, Inland Waters Directorate, Environment Canada provided the COH with a demonstration of the WATDOC system (COH Minute 14-03).
- September 20, 1976 - Mr. R.H. Swanson of the Northern Forest Research Centre provided the COH with a presentation on watershed management studies in the eastern slopes of the Rockies (COH Minutes 18-03 to 18-05 inclusive).
- September 21, 1976 - The COH held a field tour to the Brazeau and Bighorn Dams following Meeting No. 18.
- March 18, 1980 - Mr. R.S. Pentland of Saskatchewan Environment presented a discussion paper entitled "The Agricultural Drainage Impacts in Saskatchewan" to the COH (COH Minute 31-22).
- June 25, 1980 - The COH toured the Alberta River Forecast Centre after Meeting No. 32 held in Edmonton.
- January 21, 1981 - Mr. S. Edey of Agriculture Canada provided the COH members with a presentation on the soil moisture evaluation project (SMEP) (COH Minutes 34-55 to 34-59 inclusive).

In addition to the above activities the COH has also organized the following technical workshops for member agencies' staff.

1. SSARR River Routing Workshop

A workshop was held on November 8-9, 1973 in Calgary, Alberta with the Calgary office of Canada Water Resources Branch hosting the meeting. Topics discussed at the workshop included SSARR Model River routing theory, model configuration and routing parameters.

2. Runoff Simulation Workshop

The workshop was held on May 28-29, 1974 in Calgary, Alberta. Its purpose was to discuss the model used for runoff simulation in the forecasting section of the Board forecasting study. The Calgary office of Canada Water Resources Branch hosted this workshop.

3. SSARR Model Workshop

The workshop was held on June 17-18, 1975 in Regina, Saskatchewan. The purpose of this workshop was to demonstrate to member agencies' staff the application of the SSARR Model in river routing, reservoir regulation and runoff simulation. The Calgary office of Canada Water Resources Branch hosted this workshop.

4. STANFORD and SIMPAK Models Workshop

The workshop was held on May 25-26, 1976 in Calgary. Canada Water Resources Branch (Calgary office) hosted this workshop. Technical staff from each agency attended to ensure that the agencies would have a common understanding of the way that CWRB applied these models to the water supply and forecasting studies being done for the Board.

5. Prairie Hydrology Workshop No. 1

The workshop was held on February 9-11, 1982 in Lloydminster, Alberta. The Hydrology Branch, Alberta Environment hosted this workshop.

The major topics discussed at the workshop were:

1. Evaporation and Evapotranspiration;
2. Agricultural Drainage Impact Assessment;
3. Generation of Historical Streamflow; and
4. Prairie Snow Accumulation and Snowmelt.

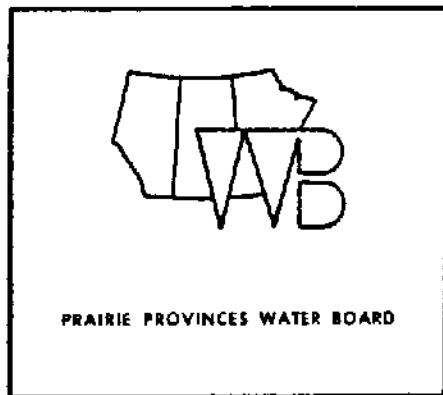
6. Prairie Hydrology Workshop No. 2

The second Prairie Hydrology Workshop was held on October 16-17, 1984 in Brandon, Manitoba. The workshop was hosted by the Winnipeg office of Canada Water Resources Branch, Environment Canada.

The following topics were discussed at the workshop:

1. Generation of Historic Natural Flow Data;
2. Estimation of Probable Maximum Floods (PMF);
3. Frequency Analysis for Flood and Drought; and
4. Operational Procedures for Reservoir Regulation.

Discussion notes for each of these four topics and a listing of topics that might be considered at similar future seminars were summarized in a report entitled "Prairie Hydrology Workshop No. 2 in Brandon, Manitoba", PPWB Report No. 77.



Chapter 12

ACKNOWLEDGEMENTS

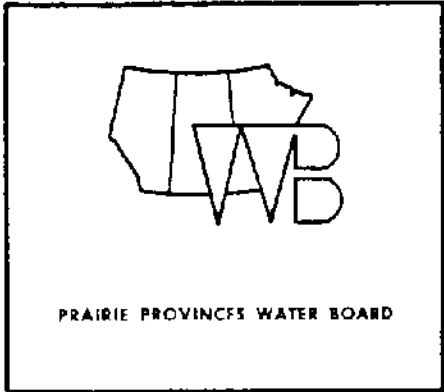
The summary report of the Prairie Provinces Water Board Committee on Hydrology Activities was prepared by A.J. Chen, Operations Engineer of the Prairie Provinces Water Board with editorial assistance from the Committee on Hydrology of the Prairie Provinces Water Board. Their comments and advice have improved the value of the final report. That help is gratefully acknowledged.

A special note of thanks must be given to Mrs. G. Mason, for her patience in typing the numerous report drafts.

APPENDICES

	<u>Page</u>
APPENDIX A - DATE AND LOCATION OF COMMITTEE ON HYDROLOGY MEETINGS.	A-1
APPENDIX B - LIST OF PARTICIPANTS COH MEETINGS NO. 1 TO 50	B-1
APPENDIX C - COMMITTEE ON HYDROLOGY ACTIVITIES AND TIME FRAMES	C-1
APPENDIX D - LIST OF REPORTS RELATED TO THE ACTIVITIES OF COMMITTEE ON HYDROLOGY	D-1

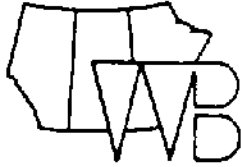




APPENDIX A
DATE AND LOCATIONS
OF COMMITTEE ON
HYDROLOGY MEETINGS

PPWB COMMITTEE ON HYDROLOGY MEETINGS

<u>Meeting No.</u>	<u>Date</u>	<u>Year</u>	<u>Location</u>	<u>City</u>
1.	November 21	1972	Brent Building	Regina
2.	January 17	1973	Brent Building	Regina
3.	March 28	1973	Milner Building	Edmonton
4.	June 26-27	1973	Brent Building	Regina
5.	October 9	1973	Brent Building	Regina
6.	February 8	1974	Taylor Building	Winnipeg
7.	June 7	1974	Brent Building	Regina
8.	September 17-18	1974	100th Ave. Building	Edmonton
9.	December 12	1974	Brent Building	Regina
10.	February 6	1975	Taylor Building	Winnipeg
11.	March 13	1975	SPC Building	Regina
12.	May 21	1975	SPC Building	Regina
13.	October 15-16	1975	100th Ave. Building	Edmonton
14.	December 9-10	1975	SPC Building	Regina
15.	February 10-11	1976	WSC Building	Calgary
16.	March 23-24	1976	Dublin Building	Winnipeg
17.	June 3-4	1976	SPC Building	Regina
18.	September 20-22	1976	Milner Building and WSC Building	Edmonton Calgary
19.	December 13-14	1976	Motherwell Building	Regina
20.	February 21-22	1977	Motherwell Building	Regina
21.	June 8-9	1977	Dublin Building	Winnipeg
22.	September 29-30	1977	Dublin Building	Winnipeg
23.	January 9-10	1978	Motherwell Building	Regina
24.	April 6-7	1978	Oxbridge Place	Edmonton
25.	October 11-12	1978	Motherwell Building	Regina
26.	March 5-6	1979	Dublin Building	Winnipeg
27.	April 9-10	1979	Humford House	Regina
28.	October 10-12	1979	Federal Building	Calgary
29.	December 12	1979	Motherwell Building	Regina
30.	February 6-7	1980	Dublin Building	Winnipeg
31.	March 18-19	1980	Humford House	Regina
32.	June 25-26	1980	Oxbridge Place	Edmonton
33.	September 25-26	1980	Humford House	Regina
34.	January 20-21	1981	Post Office Building	Winnipeg
35.	March 26	1981	Motherwell Building	Regina
36.	September 9-10	1981	Federal Building	Calgary
37.	December 8-9	1981	Motherwell Building	Regina
38.	March 30-31	1982	Dublin Building	Winnipeg
39.	July 7-8	1982	Motherwell Building	Regina
40.	September 21-22	1982	Oxbridge Place	Edmonton
41.	January 11-12	1983	Motherwell Building	Regina
42.	March 21-22	1983	Dublin Building	Winnipeg
43.	June 7-8	1983	Motherwell Building	Regina
44.	September 15-16	1983	Federal Building	Calgary
45.	January 24-25	1984	Motherwell Building	Regina
46.	May 10-11	1984	Dublin Building	Winnipeg
47.	September 18-19	1984	Sask-Tel Building	Regina
48.	February 27-28	1985	Oxbridge Place	Edmonton
49.	September 18-19	1985	Motherwell Building	Regina
50.	November 27-28	1985	Victoria Place and Motherwell Building	Moose Jaw Regina



PRAIRIE PROVINCES WATER BOARD

APPENDIX B

LIST OF PARTICIPANTS

COH MEETINGS NO. 1 to 50

MTG. NO.	PWNB (CHAIRMAN)	CANADA					CANADA		CANADA		OTHERS
		ALBERTA	SASKATCHEWAN	MANITOBA	CANADA	AEI	PERA	(SECRETARY)			
26	R.B. GODWIN	R.K. DEEPROSE	D.L. MACLEOD	V.M. AUSTFORD	G.F. MORTON	E. EINARSSON	D.W. LAWSON	R.W. HARRISON	A. COULSON		
27	R.B. GODWIN	R.K. DEEPROSE	D.L. MACLEOD	V.M. AUSTFORD	G.J. MORTON	D.J. BAUER	D.W. LAWSON	N. WYNGAARDEN	A. COULSON		
28	R.B. GODWIN	R.K. DEEPROSE	D.L. MACLEOD	V.M. AUSTFORD	G.F. MORTON	R.F. HOPKINSON	D.W. LAWSON	A.J. CHEN	A. COULSON		
29	R.B. GODWIN	R.K. DEEPROSE	D.L. MACLEOD	V.M. AUSTFORD	G.H. MORTON	R.F. HOPKINSON	D.W. LAWSON	A.J. CHEN	A. COULSON		
30	R.B. GODWIN	R.K. DEEPROSE	D.L. MACLEOD	V.M. AUSTFORD	G.H. MORTON	R.F. HOPKINSON	D.W. LAWSON	A.J. CHEN	A. COULSON		
31	R.B. GODWIN	R.K. DEEPROSE	D.L. MACLEOD	V.M. AUSTFORD	G.H. MORTON	R.F. HOPKINSON	D.W. LAWSON	A.J. CHEN	A. COULSON		
32	R.B. GODWIN	R.K. DEEPROSE	D.L. MACLEOD	V.M. AUSTFORD	G.H. MORTON	R.F. HOPKINSON	D.W. LAWSON	A.J. CHEN	A. COULSON		
33	R.B. GODWIN	R.K. DEEPROSE	D.L. MACLEOD	V.M. AUSTFORD	G.H. MORTON	R.F. HOPKINSON	D.W. LAWSON	A.J. CHEN	A. COULSON		
34	R.B. GODWIN	R.K. DEEPROSE	D.L. MACLEOD	V.M. AUSTFORD	G.H. MORTON	R.F. HOPKINSON	D.W. LAWSON	A.J. CHEN	A. COULSON		
35	R.B. GODWIN	R.K. DEEPROSE	D.L. MACLEOD	V.M. AUSTFORD	G.H. MORTON	R.F. HOPKINSON	D.W. LAWSON	A.J. CHEN	A. COULSON		
36	R.B. GODWIN	R.K. DEEPROSE	D.L. MACLEOD	V.M. AUSTFORD	G.H. MORTON	R.F. HOPKINSON	D.W. LAWSON	A.J. CHEN	A. COULSON	F.R.J. MARTIN	
37	R.B. GODWIN	R.K. DEEPROSE	D.L. MACLEOD	V.M. AUSTFORD	G.H. MORTON	R.F. HOPKINSON	D.W. LAWSON	A.J. CHEN	A. COULSON		
38	R.B. GODWIN	R.K. DEEPROSE	D.L. MACLEOD	V.M. AUSTFORD	G.H. MORTON	R.F. HOPKINSON	F.R.J. MARTIN	A.J. CHEN	A. COULSON		
39	R.B. GODWIN	R.K. DEEPROSE	D.L. MACLEOD	V.M. AUSTFORD	G.H. MORTON	R.F. HOPKINSON	F.R.J. MARTIN	A.J. CHEN	A. COULSON		
40	R.B. GODWIN	R.K. DEEPROSE	D.L. MACLEOD	V.M. AUSTFORD	G.H. MORTON	R.F. HOPKINSON	F.R.J. MARTIN	A.J. CHEN	A. COULSON		
41	R.B. GODWIN	R.K. DEEPROSE	D.L. MACLEOD	V.M. AUSTFORD	G.H. MORTON	R.F. HOPKINSON	F.R.J. MARTIN	A.J. CHEN	A. COULSON		
42	R.B. GODWIN	R.K. DEEPROSE	D.L. MACLEOD	V.M. AUSTFORD	G.H. MORTON	R.F. HOPKINSON	F.R.J. MARTIN	A.J. CHEN	A. COULSON		
43	R.B. GODWIN	R.K. DEEPROSE	D.L. MACLEOD	V.M. AUSTFORD	G.H. MORTON	R.F. HOPKINSON	F.R.J. MARTIN	A.J. CHEN	D.W. FARLEY		
44	R.B. GODWIN	R.K. DEEPROSE	D.L. MACLEOD	V.M. AUSTFORD	G.H. MORTON	R.F. HOPKINSON	F.R.J. MARTIN	A.J. CHEN	D.W. FARLEY		
45	R.B. GODWIN	R.K. DEEPROSE	D.L. MACLEOD	V.M. AUSTFORD	G.H. MORTON	R.F. HOPKINSON	F.R.J. MARTIN	A.J. CHEN	D.W. FARLEY		
46	R.B. GODWIN	R.K. DEEPROSE	D.L. MACLEOD	V.M. AUSTFORD	G.H. MORTON	R.F. HOPKINSON	F.R.J. MARTIN	A.J. CHEN	D.W. FARLEY		
47	R.B. GODWIN	R.K. DEEPROSE	D.L. MACLEOD	V.M. AUSTFORD	G.H. MORTON	R.F. HOPKINSON	F.R.J. MARTIN	A.J. CHEN	D.W. FARLEY	A.B. BANGA	
48	R.B. GODWIN	A.M. MUSTAPHA	A.B. BANGA	V.M. AUSTFORD	G.H. MORTON	R.F. HOPKINSON	F.R.J. MARTIN	A.J. CHEN	D.W. FARLEY		
49	R.B. GODWIN	R.K. DEEPROSE	G.R. RICHARDS	V.M. AUSTFORD	G.H. MORTON	R.F. HOPKINSON	F.R.J. MARTIN	A.J. CHEN	D.W. FARLEY		
50	R.B. GODWIN	R.K. DEEPROSE	A.B. BANGA	V.M. AUSTFORD	G.H. MORTON	R.F. HOPKINSON	F.R.J. MARTIN	A.J. CHEN	D.W. FARLEY		



PRAIRIE PROVINCES WATER BOARD

APPENDIX C

COMMITTEE ON HYDROLOGY ACTIVITIES AND TIME FRAMES

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
1. Natural Flow.														
- South Saskatchewan River														
- North Saskatchewan River														
- Saskatchewan River														
- Du Appelle River														
- Churchill River														
- Assiniboine River														
- Pipestone Creek														
- Hexalder and Mackay Creeks														
- Assiniboine Creek														
- Battle River														
- Granum Creek														
- Evelyn Creek														
- Beaver River														
- Big Belly Creek														
- Swan River														
- Moody River														
- Birch River														
- Return Flow from Irrigation Districts														
- Network Evaluation														
- Determination of Natural Flow														
- Proc. for Battle, Lodge & Middle Cr.														

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
2. Flow Forecasting:														
- South Saskatchewan River														
- North Saskatchewan River														
- Saskatchewan River														
- Du Appelle River														
- Churchill River														
- Forecast Network Evaluation														
- Forecast Centre Investigation														
- Computer Program Documentation														
- Streamflow Forecasting for Water Mgt.														
- Sask. R. Basin Rainfall Intensities														

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
3. Flow Apportionment:														
- Westward Flowing Tributaries														
- Westward Flowing Streams														
- Administration of the Agreement														
- Guidelines for Regulating Apportion.														

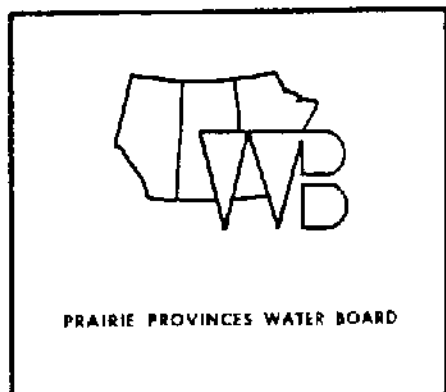
	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
4. Flow Monitoring:														
- Blackfoot R. and Battle R. at A/S Bury														
- Sack. R. At The S/M Boundary														
- Cumberland Marsh Project														
- Network Required For Small Basins														

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
5. Evaporation:														
- Glenlivet Reservoir														
- Prairie Provinces														

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
6. Drainage:														
- Impact of Artificial Drainage														
- Procedure to Deal With Drainage Impact														
- Lagenburg-Russell Study														

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
7. Watershed Management:														
- Effects of Watershed Management														

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
8. Impact Assessment:														
- Dickson Dam Project (Mienfifer Reservoir)														
- Og Applelie River Conveyance Project														
- Niowain Hydroelectric Project														
- Cliff Lake Uranium Project														
- Breckenbury Petash Mine Project														
- Proposed Esse Cold Lake Project														
- Husky Heavy Oil Project														



APPENDIX D
LIST OF REPORTS RELATED
TO THE ACTIVITIES OF
COMMITTEE ON HYDROLOGY

REPORTS RELATED TO NATURAL FLOW (In chronological order)

Estimated Water Requirements - Qu'Appelle and Assiniboine River Basins (June 1964) PFRA Hydrology Division, Regina. PPWB Report No. 9.

South Saskatchewan River Below Red Deer River - Natural Flow (March 1974) Water Survey of Canada, Calgary. PPWB Report No. 45.

Determination of Irrigation Return Flow in Southern Alberta - Natural Flow (March 1974) Water Survey of Canada, Calgary. PPWB Report No. 43.

Churchill River at Saskatchewan-Manitoba Boundary - Natural Flow (October 1975) Water Survey of Canada, Calgary. PPWB Report No. 45.

Qu'Appelle River at Saskatchewan-Manitoba Boundary - Natural Flow (December 1975) Water Survey of Canada, Calgary. PPWB Report No. 45.

North Saskatchewan River at Alberta-Saskatchewan Boundary - Natural Flow (March 1976) Water Survey of Canada, Calgary. PPWB Report No. 45.

Saskatchewan River at Saskatchewan-Manitoba Boundary - Natural Flow (March 1976) Water Survey of Canada, Calgary. PPWB Report No. 45.

Determination of Natural Flow For Apportionment Purposes (May 1976) PPWB Committee on Hydrology. PPWB Report No. 48.

Churchill River, North Saskatchewan River, Qu'Appelle River, Saskatchewan River, South Saskatchewan River - Natural Flow Network Evaluation (June 1976) Water Survey of Canada, Calgary. PPWB Report No. 45.

Antler River at Saskatchewan-Manitoba Boundary - Natural Flow (December 1978) PFRA Hydrology Division, Regina. PPWB Report No. 52.

Pipestone Creek at Saskatchewan-Manitoba Boundary - Natural Flow (March 1979) PFRA Hydrology Division, Regina. PPWB Report No. 55.

Assiniboine River at Saskatchewan-Manitoba Boundary - Natural Flow (November 1980) PFRA Hydrology Division, Regina. PPWB Report No. 57.

Graham Creek at Saskatchewan-Manitoba Boundary - Natural Flow (July 1981) PFRA Hydrology Division, Regina. PPWB Report No. 62.

Boxelder and MacKay Creeks at Alberta-Saskatchewan Boundary - Natural Flow (September 1981) Water Survey of Canada, Regina. PPWB Report No. 56.

Battle River at Alberta-Saskatchewan Boundary - Natural Flow (June 1982)
Alberta Environment, Hydrology. PPWB Report No. 64.

Gainsborough Creek at Saskatchewan-Manitoba Boundary - Natural Flow (June
1982) PFRA Hydrology Division, Regina. PPWB Report No. 63.

Procedures for Interprovincial Apportionment of the Waters of Battle, Lodge
and Middle Creeks - Natural Flow (February 1983) Environment Canada, Water
Resources Branch, Calgary. PPWB Report No. 67.

A Review of the SSARR Versus SIMPAK Models for the Qu'Appelle River Basin
(May 1984) D.R. Richards, Saskatchewan Environment, Hydrology Branch.
PPWB Report No. 73.

Beaver River at Alberta-Saskatchewan Boundary - Natural Flow (May 1984)
PPWB Secretariat. PPWB Report No. 69.

Eyehill Creek at Alberta-Saskatchewan Boundary - Natural Flow (July 1984)
Environment Canada, Water Resources Branch, Calgary. PPWB Report No. 68.

Big Gully Creek at Alberta-Saskatchewan Boundary - Natural Flow (October
1984) PFRA Hydrology Division, Regina. PPWB Report No. 74.

Natural Flow South Saskatchewan River Below Red Deer User Manual Text
(April 1985) Environment Canada, Water Resources Branch, Calgary. PPWB
Report No. 45.

Return Flow From Irrigation - Southern Alberta (October 1985) Environment
Canada, Water Resources Branch, Calgary. PPWB Report No. 72.

Estimating Minor Project Use in the Qu'Appelle River System at the
Saskatchewan-Manitoba Boundary (November 1985) R.B. Godwin. PPWB Report No.
75.

Swan River at Saskatchewan-Manitoba Boundary - Natural Flow (September 1985)
PFRA Hydrology Division, Regina. PPWB Report No. 81.

Woody River at Saskatchewan-Manitoba Boundary - Natural Flow (September 1985)
PFRA Hydrology Division, Regina. PPWB Report No. 82.

REPORTS RELATED TO FLOW FORECASTING

Saskatchewan River Basin Rainfall Intensities and Topographical Features
(June 1974) Water Survey of Canada, Calgary. PPWB Report No. 46.

Streamflow Forecasting - Computer Program User Manual (February 1975)
Water Survey of Canada, Calgary. PPWB Report No. 44.

North Saskatchewan River - Streamflow Forecasting User Manual, Water
Supply, Simulation, Routing (March 1975) Water Survey of Canada, Calgary.
PPWB Report No. 44.

Saskatchewan River - Streamflow Forecasting, User Manual, Water Supply,
Routing (March 1975) Water Survey of Canada, Calgary. PPWB Report No. 44.

South Saskatchewan River Below Red Deer River - Streamflow Forecasting, User Manual, Water Supply, Simulation, Routing (March 1975) Water Survey of Canada, Calgary. PPWB Report No. 44.

Churchill River at Saskatchewan-Manitoba Boundary - Streamflow Forecasting, User Manual, Water Supply, Routing (November 1975) Water Survey of Canada, Calgary. PPWB Report No. 44.

Qu'Appelle River at Saskatchewan-Manitoba Boundary - Streamflow Forecasting, User Manual, Water Supply, Simulation, Routing (November 1975) Water Survey of Canada, Calgary. PPWB Report No. 44.

Streamflow Forecasting for Water Management and Flood Control (December 1977) PPWB Committee on Hydrology. PPWB Report No. 47.

REPORTS RELATED TO FLOW APPORTIONMENT

Apportionment of the Water of Interprovincial Streams Between the Provinces of Alberta, Manitoba and Saskatchewan (November 1965) PPWB Apportionment Committee. PPWB Report No. 11.

Administration of the Apportionment Agreement (April 1980) PPWB Committee on Hydrology. PPWB Report No. 58.

Battle and Lodge Basins Apportionment Study (March 1981) PPWB Committee on Interjurisdictional Agreements Administration. PPWB Report No. 61.

Guidelines for Negotiating Equitable Apportionment (May 1981) PPWB Committee on Hydrology. PPWB Report No. 58(a).

Boxelder Creek Basin Apportionment Study (May 1984) PPWB Committee on Interjurisdictional Agreements Administration. PPWB Report No. 71.

Moosomin Dam and Its Effect on the Apportionment of Pipestone Creek Flows (October 1985) the PPWB Secretariat and PFRA Hydrology Division. PPWB Report No. 76.

Westward Flowing Tributaries of Eastward Flowing Streams Apportionment Study (May 1986) PPWB Committee on Hydrology. PPWB Report No. 65.

REPORTS RELATED TO FLOW MONITORING

Water Quantity/Quality Monitoring Program Cumberland Marshes Project Annual Reports prepared by Water Resources Branch of Environment Canada in Cooperation with Ducks Unlimited, the Saskatchewan Water Corporation and the Water Quality Branch of Environment Canada.

Hydrologic Evaluation Blackfoot Creek Near the Saskatchewan Boundary (March 1983) Environment Canada, Water Resources Branch, Regina.

Saskatchewan River Monitoring Study (August 31, 1983) Environment Canada, Water Resources Branch, Winnipeg.

Computation of Open Water Discharges Saskatchewan River at The Pas - 05KJ001 A Method for Unsteady and Non-Uniform Flow Calculations (February 1985) P.M. Pelletier, Environment Canada, Water Resources Branch, Winnipeg.

REPORTS RELATED TO EVAPORATION

Assessment of F.I. Morton's Model of Lake Evaporation (July 1980), R.B. Bothe, Alberta Environment, Hydrology Branch.

Evaluation of F.I. Morton's Lake Evaporation Model and Its Application to the Canadian Prairies (September 1980) R.F. Hopkinson, Atmospheric Environment Service, Environment Canada.

Estimation of Evaporation From Gleniffer (Dickson) Reservoir for Natural Flow Calculations (March 1984) R.F. Hopkinson, Environment Canada, Atmospheric Environment Service, Regina.

REPORTS RELATED TO DRAINAGE

Agricultural Drainage Impacts in Saskatchewan (May 1980) R.S. Pentland, Hydrology Branch, Saskatchewan Environment.

REPORTS RELATED TO FOREST MANAGEMENT

Watershed Management for Increased Water Yield (1977) prepared for Oldman River Basin Study Management Committee, Edmonton, Alberta by the Northwest Hydraulic Consultants Ltd.

REPORTS RELATED TO IMPACT ASSESSMENT AND OTHER ACTIVITIES

A statement to the Prairie Provinces Water Board on the Effect of the Proposed Dickson Dam on Streamflow at the Alberta-Saskatchewan Boundary (November 1978) Alberta Environment.

Qu'Appelle Conveyance Report to Prairie Provinces Water Board (November 1978) Qu'Appelle Implementation office.

Nipawin Hydroelectric Project Effects on River Flows Downstream of Squaw Rapids (May 1980) Crippen Acres Limited.

Potential Impact of the Cluff Lake Project at the Alberta-Saskatchewan Boundary (May 1980) S.H. Whitaker, Silverspoon Research and Consulting Ltd.

Environmental Impact Study Proposed Bredenbury Potash Mine Abstracted Summary Volume 1B (November 1981) Clifton Associates Ltd.

Prairie Hydrology Workshop No. 2, Brandon, Manitoba - October 16-17, 1984 prepared by the PPWB Secretariat. PPWB Report No. 77.