B. Dobson

PROCEDURES FOR INTERPROVINCIAL APPORTIONMENT OF THE WATERS OF BATTLE, LOUSE AND MIDDLE CREEKS

NATURAL FLOW

FEBRUARY, 1983

Revised

PRAIRIE PROVINCES WATER BOARD
CANADA ALBERTA SASKATCHEWAN MANITOBA

PROCEDURES

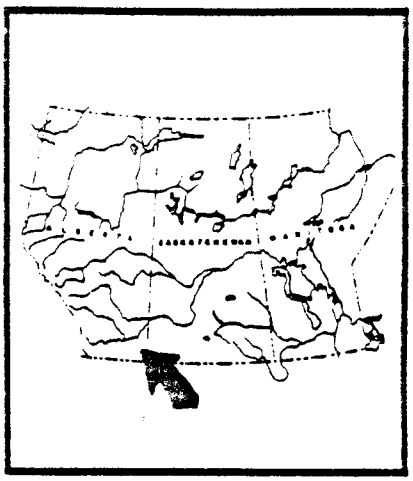
FOR

INTERPROVINCIAL APPORTIONMENT OF THE WATERS

OF BATTLE, LODGE AND MIDDLE CREEKS

FEBRUARY 1983

TABLE OF CONTENTS

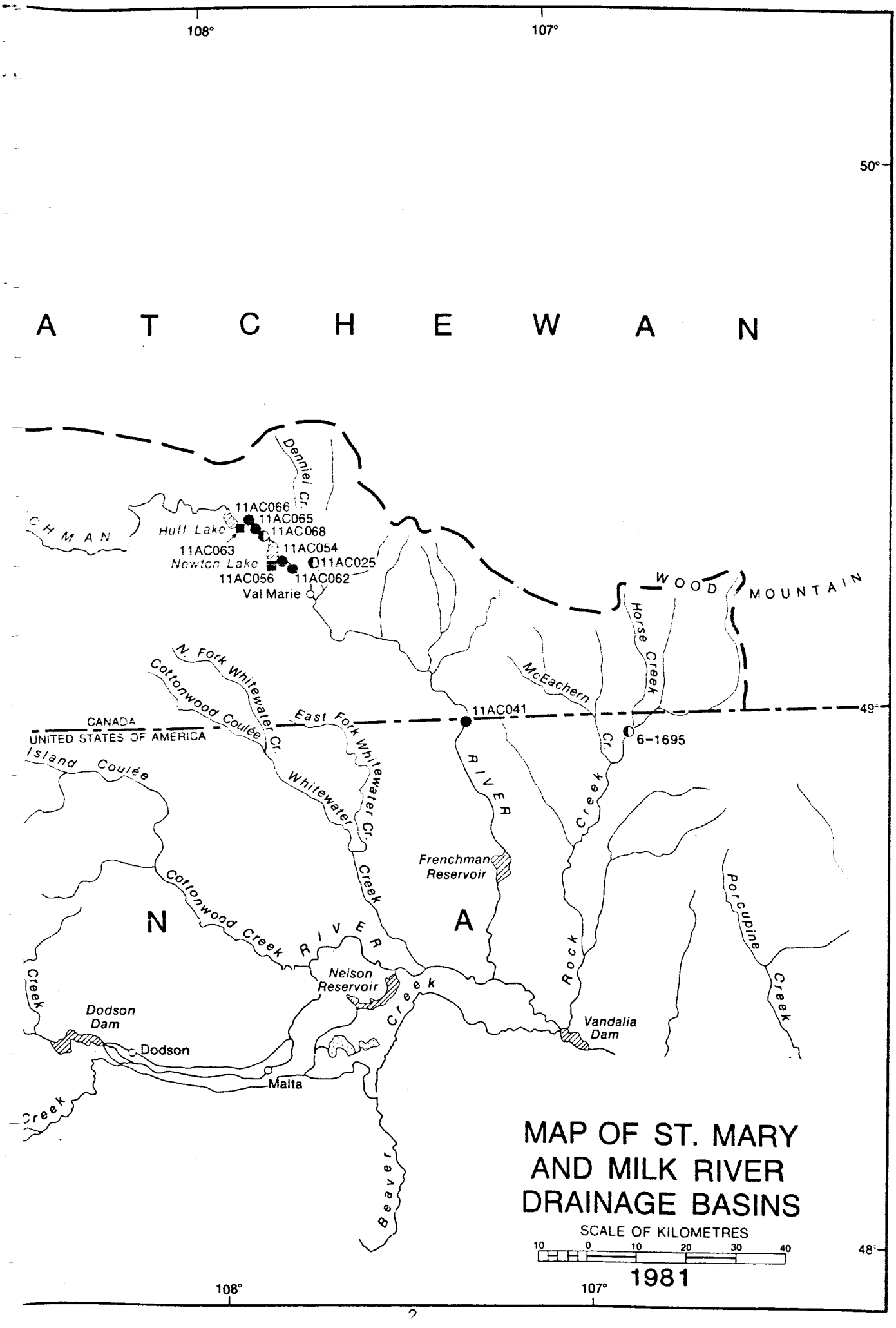


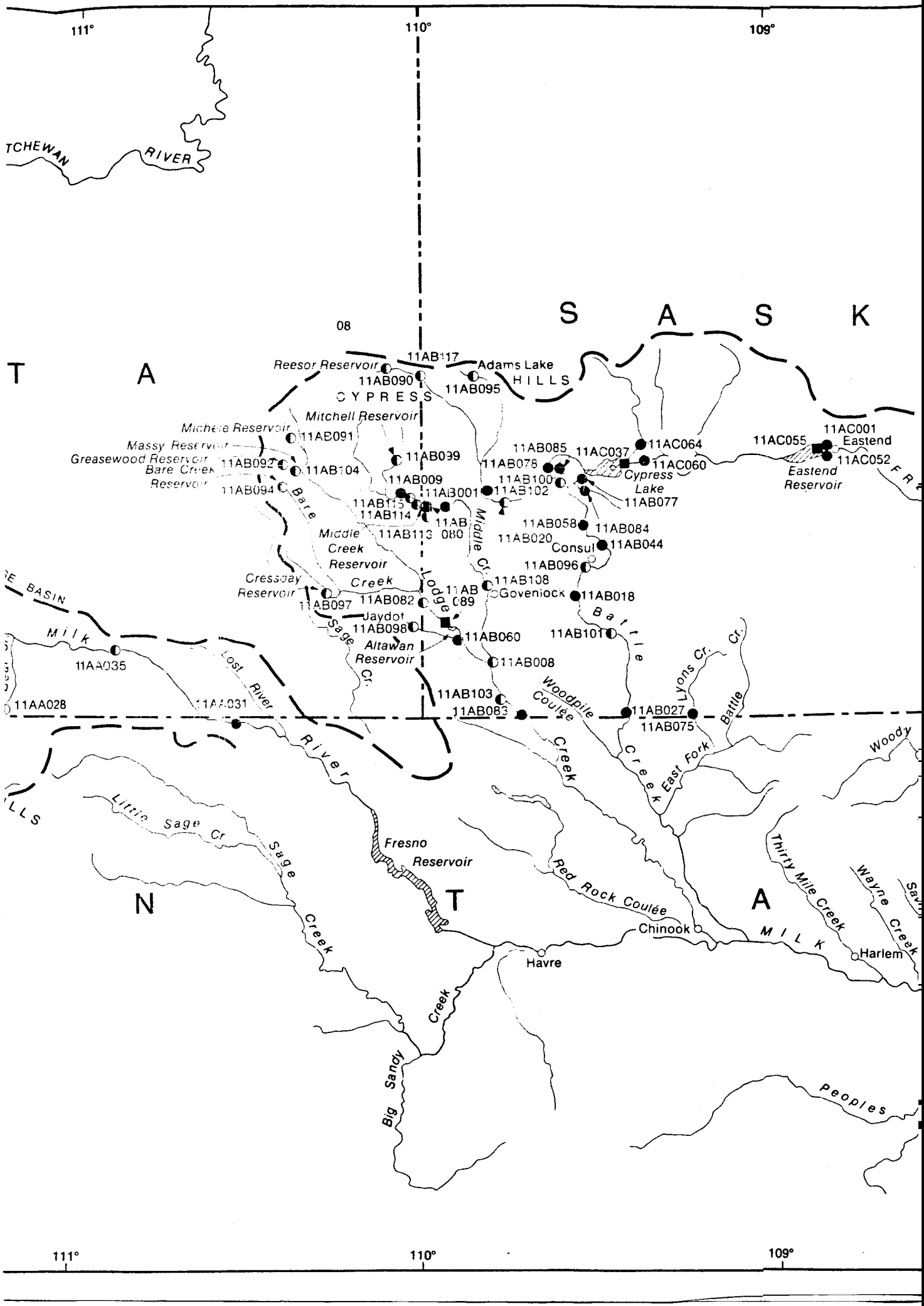
CHAPTER I

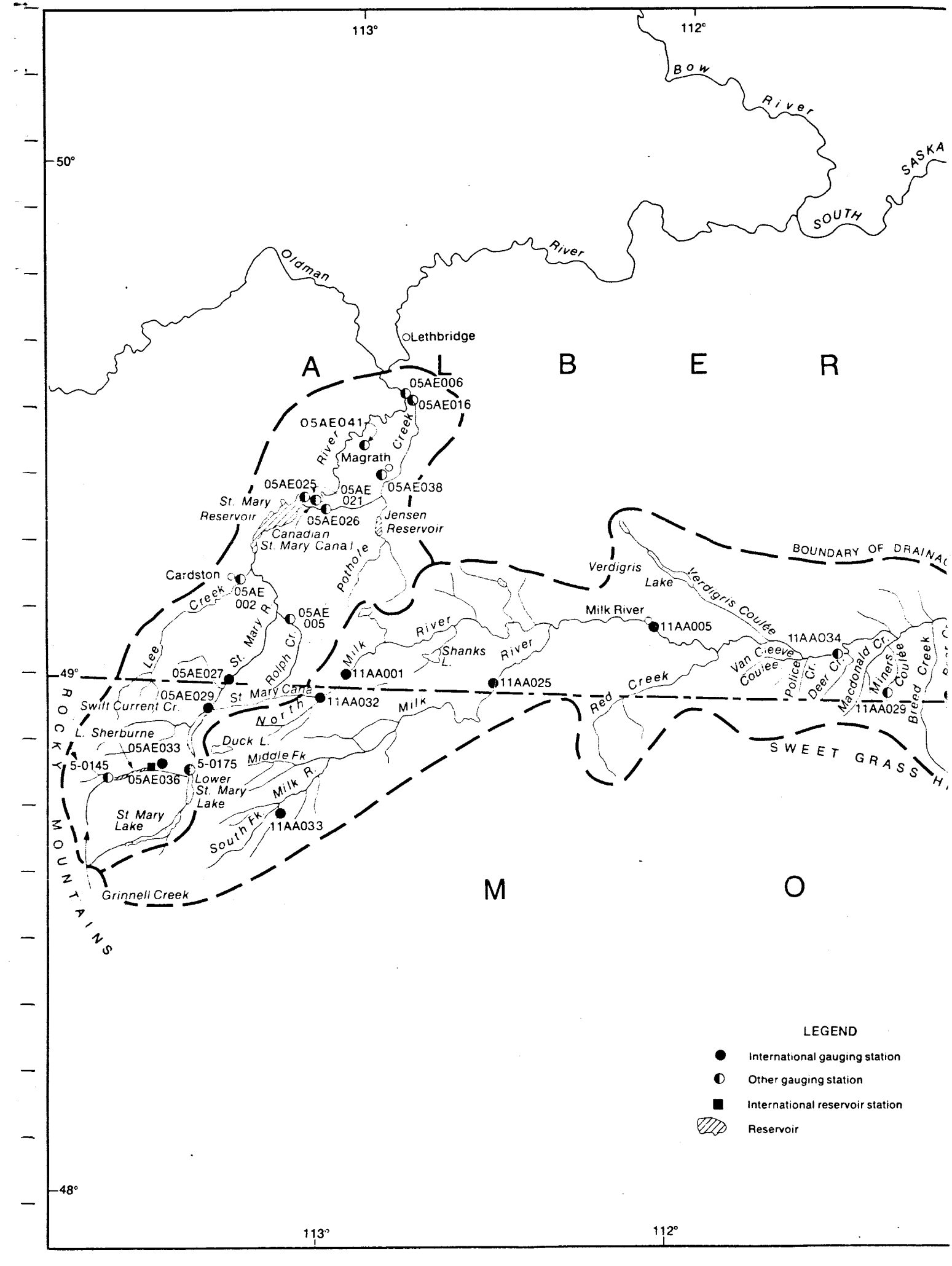
INTRODUCTION

The apportionment between Canada and the United States of the waters of the Milk River, including its tributaries, is governed by the Boundary Waters Treaty of 1909, which specifies the proportion of the natural flow to which each country is entitled. The subsequent Order of the International Joint Commission, dated October 4, 1921 gives general procedural guidelines for determining natural flow. As indicated in the map, Battle, Lodge and Middle Creeks arise in Alberta, flow southeast through Saskatchewan and join the Milk River in the United States.

The natural flow computations are performed on an interim basis to provide current information needed for the effective operation of reservoirs and to ensure that each country receives its share of the natural flow on a continuing basis. In order to provide real-time information, it is necessary to use prelimianry data, some of which may be based on approximations; therefore, the natural flow computations are repeated annually when all input data become available in final form. The annual computations represent a final account of the apportionment and are included in the annual report to the International Joint Commission (IJC).


108°
107°
50°
A T C H E W A N
Dennie Cr.
C H M A N
Huff Lake
11AC066
11AC065
11AC068
11AC063
11AC054
Newton Lake
11AC025
11AC056
11AC062
Val Marie
WOOD MOUNTAIN
Horse Creek
McEachern
N. Fork Whitewater Cr.
Cottonwood Coulée
East Fork Whitewater Cr.
11AC041
49°
CANADA
UNITED STATES OF AMERICA
6-1695
Island Coulée
Whitewater Cr.
RIVER
Creek
Frenchman Reservoir
Cottonwood Creek
N
A
RIVER
Rock Creek
Porcupine Creek
Creek
Neison Reservoir
Creek
Dodson Dam
Dodson
Vandalia Dam
Malta
Creek
Beaver Creek
MAP OF ST. MARY AND MILK RIVER DRAINAGE BASINS
SCALE OF KILOMETRES
10 0 10 20 30 40
48°
1981
108°
107°


111°
110°
109°
TCHEWAN RIVER
08
S A S K
T A
11AB117
Reesor Reservoir
11AB090
Adams Lake
11AB095
HILLS
CYPRESS
Mitchell Reservoir
Michele Reservoir
11AB091
Massy Reservoir
Greasewood Reservoir
11AB092
Bare Creek Reservoir
11AB104
11AB094
11AB039
11AB009
11AB001
11AB102
11AB085
11AB078
11AC037
11AC064
11AC060
Cypress Lake
11AB077
11AB100
11AC055
11AC001
Eastend
11AC052
Eastend Reservoir
11AB115
11AB114
11AB113
11AB 080
Middle Cr.
Middle Creek Reservoir
11AB058
11AB084
11AB020
Consul
11AB044
11AB096
Cressday Reservoir
Creek
Lodge
11AB 089
11AB108
Goveniock
11AB018
11AB097
11AB082
Jaydot
11AB098
Sage Cr.
Altawan Reservoir
11AB060
11AB101
Battle
11AB008
Lyons Cr.
Cr.
E BASIN
Milk
11AA035
Lost River
11AA028
11AA031
11AB103
11AB083
Woodpile Coulee
11AB027
11AB075
Battle
Creek East Fork
Creek
River
Woody
LLS
Little Sage Cr.
Sage Creek
Fresno Reservoir
Red Rock Coulée
Thirty Mile Creek
Wayne Creek
N T A
Chinook
MILK
Harlem
Havre
Creek
Big Sandy
Peoples
111°
110°
109°


113°
112°
50°
49°
48°
Bow River
SASKA
SOUTH
Oldman River
Lethbridge
ALBERTA
05AE006
05AE016
05AE041
Magrath
05AE025
05AE 021
05AE038
St. Mary Reservoir
05AE026
Jensen Reservoir
Canadian St. Mary Canal
Pothole Creek
Cardston
Lee Creek
05AE 002
St. Mary R.
05AE 005
Rolph Cr.
Milk River
Verdigris Lake
Verdigris Coulee
11AA005
11AA034
Milk River
Shanks L.
05AE027
11AA001
11AA025
Van Cleeve Coulee
Police Cr.
Deer Cr.
Macdonald Cr.
Miners Coulee
Bread Creek
11AA029
Red Creek
Swift Current Cr.
05AE029
St Mary Canal
11AA032
North
Milk
L. Sherburne
Duck L.
05AE033
Middle Fk
5-0145
05AE036
5-0175
Lower St. Mary Lake
Milk R.
St Mary Lake
South Fk.
11AA033
Grinnell Creek
ROCKY MOUNTAINS
SWEET GRASS H
BOUNDARY OF DRAINA
LEGEND
International gauging station
Other gauging station
International reservoir station
Reservoir

Apportionment of Battle, Lodge and Middle Creeks is also governed by the 1969 Prairie Provinces Water Board Master Agreement on Apportionment.

The Prairie Provinces Water Board (PPWB) Committee on Interjurisdictional Agreements Administration (COIAA) was given the specific assignment of developing a methodology for the efficient administration of the waters of the Battle, Lodge and Middle Creek Basins at the March 20, 1973 meeting of the Board. The assignment resulted in part from a Battle-Lodge Creek study previously carried out for the Board by Environment Canada (1). The previous study had not addressed the third term of reference, 'to develop procedures for the efficient administration of interjurisdictional agreement'.

The COIAA, in its report (2), recommended in part to the Board, that:

1) *The annual flow of each of the three watercourses known as Battle Creek, Lodge Creek, and Middle Creek be apportioned at the Alberta-Saskatchewan boundary with Alberta permitting a quantity of water equal to 75% of the natural flow of each watercourse to flow into the Province of Saskatchewan.*

2) *Apportionment, balance and audit periods be established on Battle Creek, Lodge Creek, and Middle Creek at the Alberta-Saskatchewan boundary to implement apportionment. The approach used is similar to that employed in balancing flow in other streams at interprovincial boundaries. The periods should be:*

A. *One apportionment period per year extending from January 1 to December 31.*

B. *One balance period per year not to extend beyond the current apportionment period.*

C. *Three audit periods; one in spring, one in summer and one in the fall, as indicated below.*

	Spring	*Summer*	*Fall*
Battle Creek	*May 19*	*July 29*	*October 25*
Lodge Creek	*May 18*	*July 29*	*October 29*
Middle Creek	*May 17*	*July 28*	*October 28*

The procedures for determining natural flow at the interprovincial boundary are to be based on the procedures used in the international natural flow computations, and if the international flow procedures are modified, the interprovincial procedures will be revised accordingly.

The intent of this report is:

1. to document procedures and assumptions used in determining natural flow at the interprovincial boundary;
2. to provide some insight into the philosophy or reason for certain procedures or assumptions;
3. to act as a user's manual for computing natural flow at the interprovincial boundary on an interim and annual basis.

CHAPTER II

DEFINITIONS

Many of the words and phrases used have specific meanings that must be defined for the purposes of this report. They are:

Agreement - means the Master Agreement on Apportionment (including Schedules A to D inclusive) executed the Thirtieth day of October, 1969, by Canada, Alberta, Saskatchewan and Manitoba.

Apparent Natural Flow - is the calculated flow at the boundary including streamflow storage changes, evaporation, diversions, return flow and channel losses.

Apportionment Flow - is the volume of flow subject to apportionment.

Apportionment Period - The Agreement states in Section 3 of Schedule A that the apportionment period for volumetric flow between Alberta and Saskatchewan shall be the calendar year.

Audit Period - is a specified period of less than twelve months for which natural flows are calculated and comparisons with actual flows are made to determine the flow adjustments necessary to effect apportionment.

Balance Period - is the period, following an audit period, within which the flow adjustments necessary to effect apportionment are made. This period may not extend beyond the current apportionment period.

Board - means the Prairie Provinces Water Board (PPWB).

COH - means the Committee on Hydrology.

COIAA - means the Committee on Interjurisdictional Agreements Administration.

Commission - means the International Joint Commission (IJC).

Discharge - means a rate of streamflow.

Diversion - means a man-made transfer of water from a stream for use at some other location.

Flow - means a volume of flow.

Master Agreement - means the Master Agreement on Apportionment not including Schedules A to D inclusive.

Monitor - the term *"monitor"* when used in the Master Agreement, has two distinct meanings. Section 7 of the Master Agreement states that "... *the parties agree that the monitoring of the quantity and quality ...*" will be the responsibility of Canada. The term *"monitoring"* in this context means the actual measurement of flow or the measurement of concentration of various constituents in the water bodies crossing the interprovincial boundaries. In Section 10 of the Master Agreement the term *"monitoring"* is used as follows: *"... The Prairie Provinces Water Board shall monitor and report on the apportionment of water..."*. In this context, monitor means review or administer.

Natural Flow - means the quantity of water which would naturally flow in any watercourse had the flow not been affected by human interference or human intervention.

Shortage - A shortage has occurred if, at the end of an apportionment period, the terms of the Agreement have not been met at a specific apportionment point, or if a discharge criterion has not been met.

WSC - means the Water Survey of Canada.

CHAPTER III

BACKGROUND

Battle, Lodge and Middle Creeks rise in the Cypress Hills area of southeastern Alberta and southwestern Saskatchewan and flow in a southeasterly direction. Water use in the basins dates back to the early 1900's and, because of the arid nature of the area, water use has grown steadily in the ensuing years. Water Survey of Canada has calculated a ten-day balance period of natural flow for Battle and Lodge Creeks at the International Boundary since 1956 and 1961 respectively. Based on the ten-day natural flow calculations, Canada attempts to ensure each period that 50% of the natural flow is passed to the United States. Normally the water rights administrative agencies in each province attempt to allocate water up to the median natural flow of the stream. The result, in lower than normal years, is that some portions of the basin suffer varying degrees of shortage. International commitments must be met first, as the Boundary Waters Treaty takes precedence over provincial legislation.

Since these streams lie within a semi-arid area, the flows are highly variable, as illustrated in the following table.

TABLE 1

VARIABILITY OF FLOW IN
TRIBUTARIES OF THE MILK RIVER

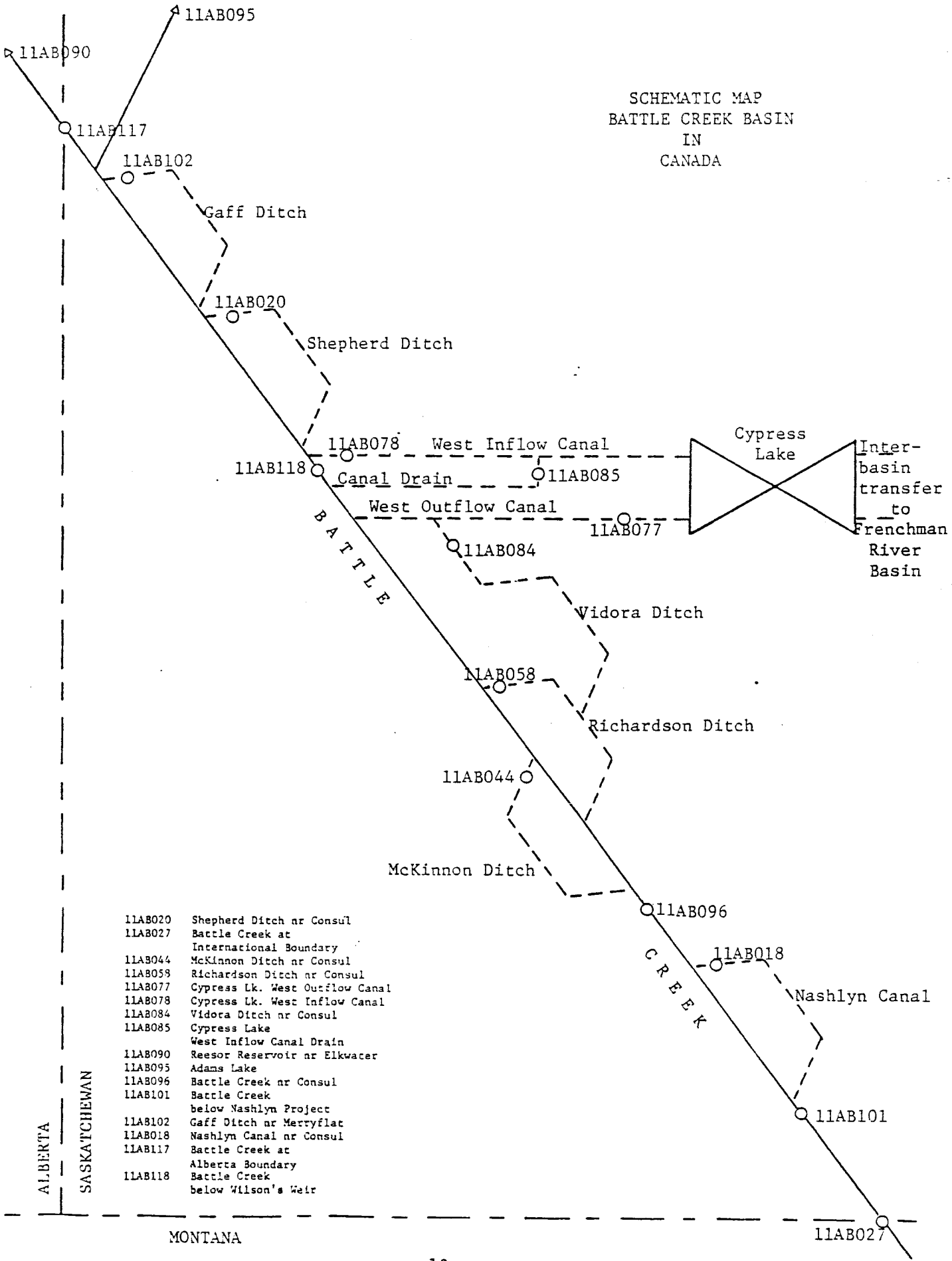
March-October Natural Flow
at International Boundary

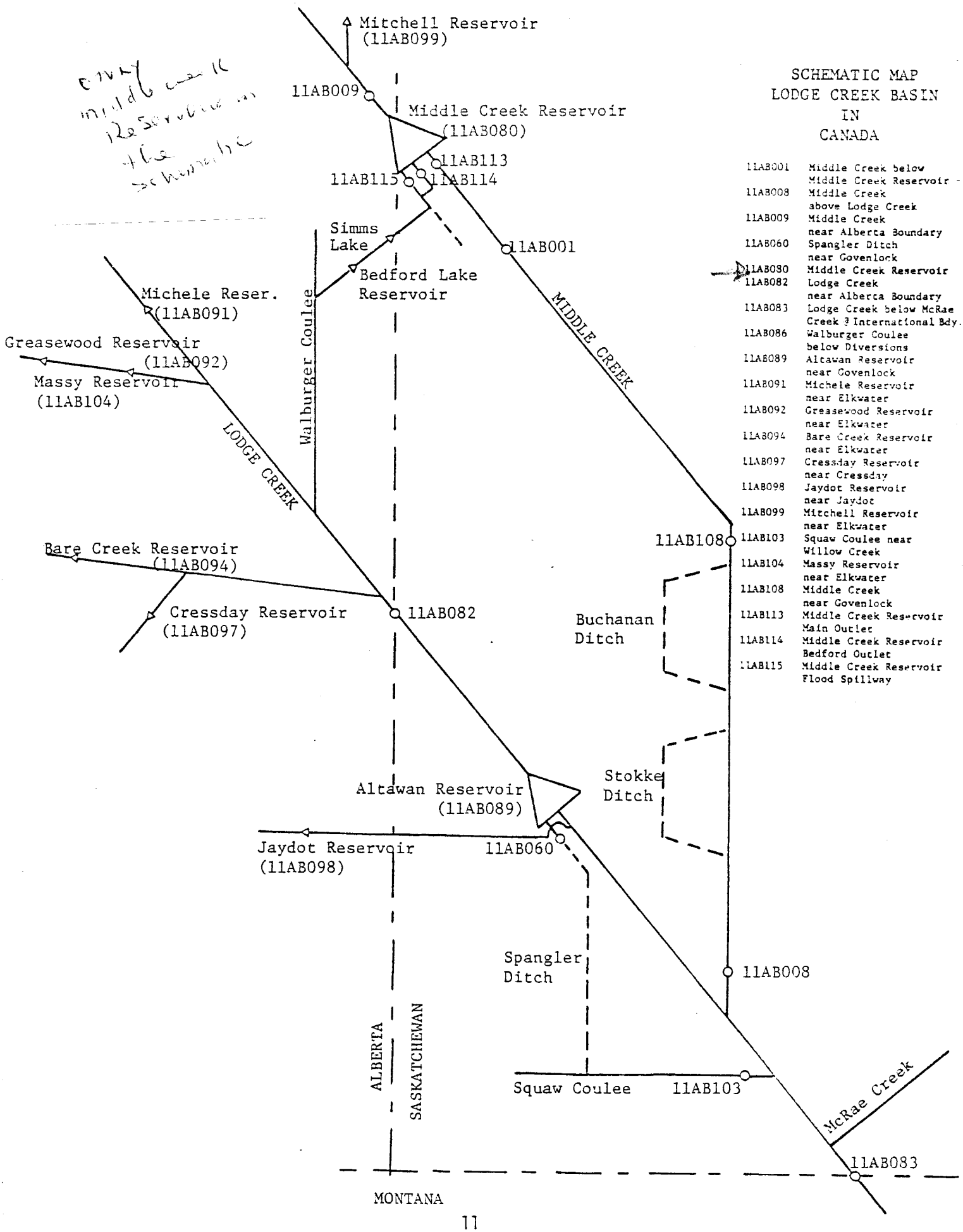
Tributary	Maximum (dam^3)	Minimum (dam^3)	Mean (dam^3)	Gross Drainage Area (km^2)	Yield (dam^3/km^2)
BATTLE CREEK(1)	138 000	1 650	33 700	2411	14.0
LODGE CREEK(2)	161 000	1 230	38 100	2119	18.0

(1) Based on period of record 1956 to 1981

(2) Based on period of record 1961 to 1981 and at the International Boundary includes Middle Creek.

The schematic maps on pages 10 and 11 depict the Battle, Lodge and Middle Creek Basins.


SCHEMATIC MAP
BATTLE CREEK BASIN
IN
CANADA
11AB095
11AB090
11AB117
11AB102
Gaff Ditch
11AB020
Shepherd Ditch
11AB078
West Inflow Canal
11AB118
Canal Drain
11AB085
West Outflow Canal
11AB077
Cypress Lake
Inter-basin transfer to Frenchman River Basin
11AB084
Vidora Ditch
11AB058
Richardson Ditch
11AB044
McKinnon Ditch
11AB096
11AB018
Nashlyn Canal
11AB101
11AB027
BATTLE CREEK
ALBERTA
SASKATCHEWAN
MONTANA
11AB020 Shepherd Ditch nr Consul
11AB027 Battle Creek at International Boundary
11AB044 McKinnon Ditch nr Consul
11AB058 Richardson Ditch nr Consul
11AB077 Cypress Lk. West Outflow Canal
11AB078 Cypress Lk. West Inflow Canal
11AB084 Vidora Ditch nr Consul
11AB085 Cypress Lake West Inflow Canal Drain
11AB090 Reesor Reservoir nr Elkwater
11AB095 Adams Lake
11AB096 Battle Creek nr Consul
11AB101 Battle Creek below Nashlyn Project
11AB102 Gaff Ditch nr Merryflat
11AB018 Nashlyn Canal nr Consul
11AB117 Battle Creek at Alberta Boundary
11AB118 Battle Creek below Wilson's Weir



SCHEMATIC MAP
LODGE CREEK BASIN
IN
CANADA

11AB001	Middle Creek below Middle Creek Reservoir
11AB008	Middle Creek above Lodge Creek
11AB009	Middle Creek near Alberta Boundary
11AB060	Spangler Ditch near Govenlock
11AB080	Middle Creek Reservoir
11AB082	Lodge Creek near Alberta Boundary
11AB083	Lodge Creek below McRae Creek & International Bdy.
11AB086	Walburger Coulee below Diversions
11AB089	Altawan Reservoir near Govenlock
11AB091	Michele Reservoir near Elkwater
11AB092	Greasewood Reservoir near Elkwater
11AB094	Bare Creek Reservoir near Elkwater
11AB097	Cressday Reservoir near Cressday
11AB098	Jaydot Reservoir near Jaydot
11AB099	Mitchell Reservoir near Elkwater
11AB103	Squaw Coulee near Willow Creek
11AB104	Massy Reservoir near Elkwater
11AB108	Middle Creek near Govenlock
11AB113	Middle Creek Reservoir Main Outlet
11AB114	Middle Creek Reservoir Bedford Outlet
11AB115	Middle Creek Reservoir Flood Spillway

CHAPTER IV

PROCEDURE FOR DETERMINING NATURAL FLOWS

The method utilized to determine the natural flow is based on the procedure used in computing the natural flow at the international boundary (3). The method is similar to the Project Depletion Method, as described in an earlier COH report (4) to the Board. Required input to determine the natural flow and procedures for determining the values are described herein and the chapter concludes with the computational form to be utilized.

DIVISION PERIODS

International

The waters of Lodge and Battle Creeks at the international boundary are divided in accordance with the Order of the International Joint Commission dated October 4, 1921 which stipulates that "The natural flow of the eastern (otherwise known as the Saskatchewan or northern) tributaries of the Milk River at the points where they cross the international boundary shall be divided equally between the two countries". This rule could be interpreted to mean the division of water be made on a daily basis; however, it was recognized by the Commission that a daily division was impractical so compilation of the natural flows at

the international boundary is done three times a month during the irrigation season, from March 1 to October 31. The periods were planned to cover the monthly dates 1-10, 11-20, 21-30 or 31. This approach to division periods is complicated by a diversion or a realease not producing an instantaneous change in the flow at the boundary. In order to account for travel time, the entire river length has been divided into several segments and the dates of the division periods lagged proportionally. Another complication in the case of Battle Creek is the fact that Cypress Lake is used as a storage reservoir and for inter-basin transfer of water between Battle Creek and Frenchman River. In order to account for any inter-basin transfer between the two basins in the same time period and because of different travel times to the boundary on Battle Creek and Frenchman River, it was necessary to adjust the division dates for Battle Creek at the international boundary so that periods cover the monthly dates 5-14, 15-24 or 25, 25 or 26-4 of the following month. In order to have the same number of division periods in the Battle Creek, Lodge Creek and Frenchman River basins, it was necessary to adjust the first and last division periods for Battle Creek to cover the time period March 1 - March 14 (14 days) and October 26-31 (6 days) respectively.

Interprovincial

Although the interprovincial division of natural flow involves three audit periods, and one apportionment period, the computations are done on the same ten-day basis as for the international division. Considering the travel times previously noted, the February 23 - March 8 period at the interprovincial boundary for Battle Creek would correspond to the March 1 to 14 period at the international boundary. Similarly,

on Lodge Creek, a variety of periods, depending upon the location of the projects, varying from February 25 - March 6, to February 27 - March 8 at the interprovincial boundary would correspond to the period March 1-10 at the international boundary and on Middle Creek the February 26 to March 7 period at the interprovincial boundary would correspond to the period March 1-10 at the international boundary.

RESERVOIRS

Storage Changes

Any water that is stored in a reservoir during a division period depletes the natural flow and is considered positive (+); that is, a charge against the province in which the storage occurs. Conversely, any water released during a division period augments the natural flow and is considered negative (-); that is, a credit for the province that releases the water. The amount of water stored or released during a division period is computed as the difference in reservoir contents between 0000 hours on the first day of the division period and 2400 hours on the last day of the period.

Evaporation

The construction of a reservoir with the resultant impoundment of runoff greatly increases the amount of water lost to the atmosphere. This increase in evaporation is considered as a depletion and is determined by utilizing the evaporation data collected at meteorological stations established in co-operation with the Atmospheric Environment Service in each tributary basin. The evaporation station consists of a class "A" evaporation pan, rain gauge, maximum and minimum air and water

thermometers and a wind velocity indicator. The water in the evaporation pan in maintained at a constant level by either adding or removing water, as required, on a daily basis.

For the purposes of natural flow computations "evaporation is defined as precipitation plus the change in the pan water level where the change in water level is positive (+) if water must be added to the pan and negative (-) if water must be removed from the pan". Application in this manner considers evaporation as a use by the upstream jurisdiction and allows the same jurisdiction a credit for water storage created by the existence of the reservoir.

It is accepted that water evaporates at a greater rate from a pan than from a reservoir due primarily to different heat storage characteristics. Because of the uncertainty in computing reservoir evaporation from pan evaporation and to keep the computations as uncomplicated as possible, reservoir evaporation is defined as:

RESERVOIR EVAPORATION = 0.70 (previous day pan reading - current day pan reading)

The pan reading is taken at the same time each day according to observation time instructions issued by the Atmospheric Environment Service.

The reservoir evaporation thus gives a net reservoir evaporation as a depth over the reservoir. This depth is converted to a volume each day by multiplying it by the surface area of the reservoir at the mean elevation for the ten-day period. Daily evaporations are then summed and applied as a total evaporation over the ten-day computation period. Reservoir evaporation in the Battle, Lodge and Middle Creek basins is computed using actual data from the Altawan evaporation station.

Following is a list of the reservoirs in the Alberta portion of the Battle, Lodge and Middle Creek basins for which evaporation and storage must be calculated in the determination of interprovincial flow for apportionment:

BATTLE CREEK BASIN

Reesor Reservoir

LODGE CREEK BASIN

Bare Creek Reservoir
Cressday Reservoir
Greasewood Reservoir
Jaydot Reservoir
Massy Reservoir
Michele Reservoir

MIDDLE CREEK BASIN

Mitchell Reservoir

CHANNEL LOSSES

The application of channel losses falls into the following two general categories:

(a) Losses which would have occurred in the natural state to water which is now stored in reservoirs or diverted for irrigation in Canada.

(b) Losses to water which is released to the stream from existing reservoirs or which is returned to the stream from irrigated land.

The channel function that is applied to flow depletions and return flows consists of a loss constant and a variable loss factor to reflect seasonal variations in channel losses.

$$L = KD + P (Q - KD)$$ INTERNATIONAL BOUNDARY EQUATION

WHERE

L is gross potential channel loss in cubic decametres over period D,
D is number of days in the flow period (10 or 11 days),
K is loss constant in cubic metres per second for a particular river reach, x 86.4 to convert to dam^3/day,
P is variable loss factor for a particular river reach and season,
Q is gross flow depletion; that is, total depletion less return flow for a particular river reach. (dam^3)

Battle Creek Basin Loss Factors

Because of the high groundwater contribution in the Battle Creek Basin, the variable loss factor (P) is considered to be zero. The only loss constant (K) in the basin above the interprovincial boundary is for the reach from Reesor Reservoir to the boundary. The loss constant (K) for this reach has been calculated to be 1.231 dam^3/day. This calculation was made on the basis that this reach constituted approximately 25% of the reach between Reesor Reservoir and Gaff Ditch, and the difference between their loss constants to the international boundary (3) was used as the base for determining 'K'.

Lodge Creek Basin Loss Factors

The loss constants (K) and variable loss factors (P) to the international boundary have been calculated by Canada and the United States, and are as follows:

Upper Lodge Creek Area (Michele, Greasewood, Massy and Bare Creek Reservoirs)

Loss Constant

$K = 7.344 \text{ dam}^3/\text{day}$

Variable Loss Factor

Period	P
to Mar 27	.06
Mar 28 to Apr 26	.09
Apr 27 to May 27	.15
May 28 to Aug 27	.24
Aug 28 to Sep 26	.15
Sep 27 to Oct 27	.09

Cressday Reservoir Area

Loss Constant

$K = 4.925 \text{ dam}^3/\text{day}$

Variable Loss Factor

Period	P
to Mar 28	.04
Mar 29 to Apr 27	.06
Apr 28 to May 28	.10
May 29 to Aug 28	.16
Aug 29 to Sep 27	.10
Sep 28 to Oct 28	.06

Jaydot and Altawan Reservoir Areas

Loss Constant

$K = 2.419 \text{ dam}^3/\text{day}$

Variable Loss Factor

Period	P
to Mar 29	.02
Mar 30 to Apr 28	.03
Apr 29 to May 29	.05
May 30 to Aug 29	.08
Aug 30 to Sep 28	.05
Sep 29 to Oct 29	.03

Development of a method for estimating channel losses from the aforementioned areas to the interprovincial boundary was made on the basis of the following assumptions:

a) that the following equation holds,

$$\Delta L = L_1 - L_2$$

WHERE ΔL - loss from an area to the interprovincial boundary
L_1 - loss from the area to the international boundary
L_2 - loss from the interprovincial boundary to the international boundary

therefore,

$$\Delta L = L_1 - L_2$$

$$\Delta L = [K_1 D + P_1(Q - K_1 D)] - [K_2 D + P_2(Q - K_2 D)]$$

$$\Delta L = (K_1 - K_2)D + (P_1 - P_2)Q - [(P_1 K_1 - P_2 K_2)D]$$ INTERPROVINCIAL BOUNDARY EQUATION

b) that the loss on Lodge Creek from the interprovincial boundary to the international boundary is the same as the loss from the Altawan Reservoir Area to the international boundary.

Based on these assumptions and the following calculations of loss constants (K) and variable loss factors (P), the channel losses for each area in the Lodge Creek Basin to the interprovincial boundary have been developed as:

Upper Lodge Creek Area (Michele, Greasewood, Massy and Bare Creek Reservoirs

Loss Constant

$K_1 - K_2 = 7.344 - 2.419$
$= 4.925 \text{ dam}^3/\text{day}$

Variable and Combined Loss Factors and Constants

Period	P_1	P_2	$P_1 - P_2$	$P_1 K_1$	$P_2 K_2$	$P_1 K_1 - P_2 K_2$
to Mar 27	.06	.02	.04	0.44	0.05	0.39
Mar 28 to Apr 26	.09	.03	.06	0.66	0.07	0.59
Apr 27 to May 27	.15	.05	.10	1.10	0.12	0.98
May 28 to Aug 27	.24	.08	.16	1.76	0.19	1.57
Aug 28 to Sep 26	.15	.05	.10	1.10	0.12	0.98
Sep 27 to Oct 27	.09	.03	.06	0.66	0.07	0.59

Channel loss to Interprovincial Boundary

WHERE $K = K_1 - K_2$

$P = P_1 - P_2$

$C = P_1K_1 - P_2K_2$

the INTERPROVINCIAL BOUNDARY EQUATION can be expressed as:

$$\Delta L = KD+PQ-CD$$

and, based on the calculated loss constants and variable loss factors, the channel loss from the Upper Lodge Creek Area to the interprovincial boundary can be expressed as:

$$\Delta L = 4.925\ D+P(Q - \frac{C}{P} D)$$

Since $C \simeq 10P$ in the calculated variable and combined loss factors and constants, the unit $\frac{C}{P} = 10$, and the channel loss equation to be utilized is:

$$\Delta L = 4.925\ D+P(Q-10D)$$

Cressday Reservoir Area

Loss Constant

$K_1 - K_2 = 4.925 - 2.419$

$= 2.506\ dam^3/day$

Variable and Combined Factors and Constants

Period	P_1	P_2	P_1-P_2	P_1K_1	P_2K_2	$P_1K_1-P_2K_2$
to Mar 28	.04	.02	.02	0.20	0.05	0.15
Mar 29 to Apr 27	.06	.03	.03	0.30	0.07	0.23
Apr 28 to May 28	.10	.05	.05	0.49	0.12	0.37
May 29 to Aug 28	.16	.08	.08	0.79	0.19	0.60
Aug 29 to Sep 27	.10	.05	.05	0.49	0.12	0.37
Sep 28 to Oct 28	.06	.03	.03	0.30	0.07	0.23

Channel loss to International Boundary

WHERE $K = K_1 - K_2$

$P = P_1 - P_2$

$C = P_1K_1 - P_2K_2$

the INTERPROVINCIAL BOUNDARY EQUATION can be expressed as:

$$\Delta L = KD+PQ-CD$$

and, based on the calculated loss constants and variable loss factors, the channel loss from Cressday Reservoir to the interprovincial boundary can be expressed as:

$$\Delta L = 2.506\ D+P(Q-\frac{C}{P}D)$$

Since $C \simeq 7P$ in the calculated variable and combined loss factors and constants, the unit $\frac{C}{P} = 7$, and the channel loss equation to be utilized is:

$$\Delta L = 2.506\ D+P(Q-7D)$$

Jaydot Reservoir Area

Since the channel loss constant and variable loss factor to the international boundary are the same for Jaydot and Altawan reservoirs, the channel loss to the interprovincial boundary is considered negligible. Technically, this procedure isn't correct, but due to the proximity of Jaydot Reservoir to the interprovincial boundary and its small storage capacity, the resultant error is a negligible portion of the natural flow.

Middle Creek Basin Loss Factors

It can be assumed that the channel loss on Middle Creek from the interprovincial boundary to the international boundary is the same as the loss from the Middle Creek Reservoir area to the international boundary. Also, since the channel loss constant and factor are the same for Mitchell and Middle Creek reservoirs, the channel loss to the interprovincial boundary is considered negligible for Middle Creek. As with Jaydot Reservoir, this assumption for Mitchell Reservoir isn't technically correct, but again the proximity of the reservoir to the interprovincial boundary and its small storage capacity result in any error being a negligible portion of the natural flow.

MINOR DIVERSIONS

For international computations, it has long been considered impractical to establish gauging stations on diversions such as small irrigation projects. The same philosophy holds true for interprovincial computations. As a result, minor diversions are calculated by indirect methods.

The Water Rights Branches of Alberta Environment and Saskatachewan Environment solicit information by July 1 and October 31 from the licensees of minor projects within the contributing drainage area and derive estimates of the total seasonal and annual use in these small projects based on the licensees' responses and field inspection, if required.

The natural flow computations to July 29 are adjusted, if necessary, based on the reported water use of July 1. The reported water use to October 31 is used for the final natural flow report.

Battle Creek

For Battle Creek there is only one small minor diversion in Alberta with an optimum annual utilization of 55 dam^3. Because of the small volume involved, this usage is not considered in the first audit period; adjusted or applied, if necessary, after the second audit period based on water use returns; and again not considered for the final audit period. The final apportionment report is prepared on the basis of reported water use to October 31.

Lodge and Middle Creeks

Lodge and Middle Creek utilize a variety of inputs to determine minor diversions during the interim reports. Calculated utilization in the Stokke-Buchanan project in Saskatchewan comprises a major portion of

minor diversions. Other minor diversion use is calculated by applying a percentage value, estimated by previous years' records to the calculated utilization of the Stokke-Buchanan project. Further modifications, including the percentage value to be applied, are made on the basis of a field knowledge of what is actually occurring in these basins.

Although the procedure may appear rather crude, a close approximation can be made utilizing this method as minor diversions are relatively fixed for low, medium and high flow years. During a low flow year the percentage value used may be as high as 60% and in a high flow year it may be as low as 2%. As previously noted, the final natural flow computations are adjusted based on water use reports submitted by provincial agencies.

DOMESTIC PROJECTS

A domestic project is defined as a small reservoir which is used for household and/or stockwatering purposes. In the calculation of natural flow for international apportionment, the domestic project usage is calculated for the Battle Creek Basin, but isn't calculated for the Lodge and Middle Creek Basins as domestic usage is a very small percent of the natural flow. For interprovincial apportionment of Battle Creek the same criteria as for Lodge and Middle Creeks can be applied as domestic usage is essentially non-existent since Battle Creek above the interprovincial boundary is located within the undeveloped area of Cypress Hills Provincial Park.

TABULAR COMPUTATIONS

The natural flow computations for Battle, Lodge and Middle Creek Basins are made by utilizing a standard form for each stream. The forms shown on pages 25 to 29 are straight forward and utilize the values previously discussed and developed in this chapter.

Appendix I contains sample natural flow calculations for each of the three basins. The sample calculations are prepared for the 1977 low flow year as this is the period when the most significant problems with apportionment occur, and it is worthwhile documenting this type of event to formulate water management plans.

NATURAL FLOW OF BATTLE CREEK AT INTERPROVINCIAL BOUNDARY

	1	2	3	4	5	6	7	8	9	10
Period at Inter-provincial Boundary	Reesor Lake Storage	Channel Loss to Interprov. Boundary	Net Depletion to Interprov. Boundary	Battle Creek at the Interprov. Boundary	Apparent Nat. Flow of Battle Crk. at the Interprov. Boundary	Adjustment for minor Diversions in Alberta	Nat. flow of Battle Crk. at the Interprov. Boundary	Sask. Share of Natural Flow	Excess flow to Saskat-chewan.	Total Excess Flows to Date
	Observed	Computed	1-2	Measured	3+4		5+6	75% of 7	4-8	Σ Col. 9
Feb.23-Mar.8										
Mar.9-19										
Mar.20-29										
Mar.30-Apr.8										
Apr.9-18										
Apr.19-28										
Apr.28-May 8										
May 9-19										
May 20-29										
May 30-Jun.8										
Jun.9-18										
Jun.19-28										
Jun.29-Jul.8										
Jul.9-19										
Jul.20-29										
Jul.30-Aug.8										
Aug.9-19										
Aug.20-29										
Aug.30-Sep.8										
Sep.9-18										
Sep.19-28										
Sep.29-Oct.8										
Oct.9-19										
Oct.20-25										
Total dam^3										

NATURAL FLOW OF LODGE CREEK AT INTERPROVINCIAL BOUNDARY

	1	2	3	4	5	6	7			
Period Upper Reservoirs	Michele Reservoir Storage	Greasewood Reservoir Storage	Massy Reservoir Storage	Bare Creek Reservoir Storage	Total Storage Change Upper Lodge Reservoirs	Channel Loss to Interprov. Boundary	Net Depletion Upper Lodge			
	Observed	Observed	Observed	Observed	1+2+3+4	Computed	5-6			
Feb.25-Mar.6										
Mar.7-16										
Mar.17-27										
Mar.28-Apr.6										
Apr.7-16										
Apr.17-26										
Apr.27-May 6										
May 7-16										
May 17-27										
May 28-Jun.6										
Jun.7-16										
Jun.17-26										
Jun.27-Jul.6										
Jul.7-16										
Jul.17-27										
Jul.28-Aug.6										
Aug.7-16										
Aug.17-27										
Aug.28-Sep.6										
Sep.7-16										
Sep.17-26										
Sep.27-Oct.6										
Oct.7-16										
Oct.17-27										
Total dam^3										

NATURAL FLOW OF LODGE CREEK AT INTERPROVINCIAL BOUNDARY

	8	9	10		11	12	13	14	15	
Period Cressday Reservoir	Cressday Reservoir Storage	Channel Loss to Interprov. Boundary	Net Depletion Cressday Reservoir	Period at Inter-provincial Boundary	Jaydot Reservoir Storage	Net Depletion in Alberta	Minor Irrigation Diversions in Alberta	Lodge Creek at the Interprov. Boundary	Natural Flow of Lodge Creek	
	Observed	Computed	8-9		Observed	7+10+11	Estimated	Observed	12+13+14	
Feb.26-Mar.7				Feb.27-Mar.8						
Mar.8-17				Mar.9-18						
Mar.18-28				Mar.19-29						
Mar.29-Apr.7				Mar.30-Apr.8						
Apr.8-17				Apr.9-18						
Apr.18-27				Apr.19-28						
Apr.28-May 7				Apr.29-May 8						
May 8-17				May 9-18						
May 18-28				May 19-29						
May 29-Jun.7				May 30-Jun.8						
Jun.8-17				Jun.9-18						
Jun.18-27				Jun.19-28						
Jun.28-Jul.7				Jun.29-Jul.8						
Jul.8-17				Jul.9-18						
Jul.18-28				Jul.19-29						
Jul.29-Aug.7				Jul.30-Aug.8						
Aug.8-17				Aug.9-18						
Aug.18-28				Aug.19-29						
Aug.29-Sep.7				Aug.30-Sep.8						
Sep.8-17				Sep.9-18						
Sep.18-27				Sep.19-28						
Sep.28-Oct.7				Sep.29-Oct.8						
Oct.8-17				Oct.9-18						
Oct.18-28				Oct.19-29						
Total dam^3										

NATURAL FLOW OF LODGE CREEK AT INTERPROVINCIAL BOUNDARY

	16	17	18							
Period at Inter-provincial Boundary	Sask. Share of Natural Flow	Excess flow to Saskat-chewan.	Total Excess flows to date							
	75% of 15	14-16	Σ Col. 17							
Feb.27-Mar.8										
Mar.9-18										
Mar.19-29										
Mar.30-Apr.8										
Apr.9-18										
Apr.19-28										
Apr.29-May 8										
May 9-18										
May19-29										
May 30-Jun.8										
Jun.9-18										
Jun.19-28										
Jun.29-Jul.8										
Jul.9-18										
Jul.19-29										
Jul.30-Aug.8										
Aug.9-18										
Aug.19-29										
Aug.30-Sep.8										
Sep. 9-18										
Sep.19-28										
Sep.29-Oct.8										
Oct.9-18										
Oct.19-29										
Total dam^3										

NATURAL FLOW OF MIDDLE CREEK AT INTERPROVINCIAL BOUNDARY

	1	2	3	4	5	6	7			
Period at Inter-provincial Boundary	Mitchell Reservoir Storage	Minor Irrigation Diversions in Alberta	Middle Crk. at the Interprov. Boundary	Nat. flow of Middle Crk. at the Interprov. Broundary	Sask. Share of Natural Flow	Excess flow to Saskat-chewan.	Total Excess Flows to date			
	Observed	Estimated	Observed	1+2+3	75% of 3	3-5	Σ Col. 6			
Feb.26-Mar.7										
Mar.8-17										
Mar.18-28										
Mar.29-Apr.7										
Apr.8-17										
Apr.18-27										
Apr.28-May 7										
May 8-17										
May 18-28										
May 29- Jun.7										
Jun.8-17										
Jun.18-27										
Jun.28-Jul.7										
Jul.8-17										
Jul.18-28										
Jul.29-Aug.7										
Aug.8-17										
Aug.18-28										
Aug.29-Sep.7										
Sep.8-17										
Sep.18-27										
Sep.28-Oct.7										
Oct. 8-17										
Oct.18-28										
Total dam^3										

CHAPTER V

SUMMARY OF PROCEDURES

This user's manual describes in detail the procedures to be utilized in determination of the natural flow of Battle, Lodge and Middle Creeks at the interprovincial boundary; however, a brief summation herein is also provided for the information of Board agency staff not directly involved in the computations, but who are responsible for the management of the water resource.

APPORTIONMENT, BALANCE AND AUDIT PERIODS

Apportionment Period

There is one apportionment period per year extending from January 1 to December 31. The apportionment of water at the interprovincial boundary is an Alberta share of 25% of the natural flow, and a Saskatchewan share of 75% of the natural flow.

Balance Period

The balance period of once per year won't extend beyond the current apportionment period.

Audit Periods

Audit periods will be made in the spring, summer and fall on the following dates:

	Spring	Summer	Fall
Battle Creek	May 19	July 29	October 25
Lodge Creek	May 18	July 29	October 29
Middle Creek	May 17	July 28	October 28

DEFINITIONS

Apparent Natural Flow - is the calculated flow at the boundary, including streamflow storage changes, evaporation, diversions, return flow, and channel losses.

Apportionment Period - The Agreement states in Section 3 of Schedule A that the apportionment period for volumetric flow between Alberta and Saskatchewan shall be the calendar year.

Audit Period - is a specified period of less than twelve months for which natural flows are calculated and comparisons with actual flows are made to determine the flow adjustments necessary to effect apportionment.

Balance Period - is the periof following an audit period, within which the flow adjustments necessary to effect apportionment are made. This period may not extend beyond the current apportionment period.

Board - means the Prairie Provinces Water Board (PPWB).

COH - means the Committee on Hydrology.

Discharge - means a rate of streamflow.

Diversion - means a man-made transfer of water from a stream for use at some other location.

Flow - means a volume of flow.

Natural Flow - means the quantity of water which would naturally flow in any watercourse had the flow not been affected by human interference or human intervention.

Shortage - A shortage has occurred if, at the end of an apportionment period, the terms of the Agreement have not been met at a specific apportionment point, or if a discharge criterion has not been met.

WSC - means the Water Survey of Canada.

PROCEDURE FOR DETERMINING NATURAL FLOW

General

The method utilized to determine the natural flow was based on the procedure used in computing the natural flow at the international boundary. This method is similar to the Project Depletion method, as described in an earlier COH report to the Board.

Division Period

Although the interprovincial division of natural flow involves three audit periods and one apportionment period, the computations are done on the same ten-day basis as for the international division. Division periods at the international boundary have been adjusted to corresponding periods at the interprovincial boundary based on travel times between the interprovincial and international boundary.

Reservoirs

Water stored in a reservoir is a charge against Alberta where the storage occurs, and conversely water released during a division period augments the natural flow and is a credit to Alberta. Evaporation is computed on a ten-day basis using actual data from the Altawan evaporation pan station. Evaporation is defined as precipitation plus the change in the pan water level where the change in water level is positive if water must be added to the pan and negative if water must be removed from the pan.

Channel Loss

The application of channel losses falls into the following two general categories:

(a) Losses which would have occurred in the natural state to water which is now stored in reservoirs or diverted for irrigation in Alberta.

(b) Losses to water which is released to the stream from existing reservoirs or which is returned to the stream from irrigated land.

The channel function that is applied to flow depletions and return flows consists of a loss constant and a variable loss factor to reflect seasonal variations in channel losses.

Because of the high groundwater contribution in the Battle Creek Basin, the variable loss factor was considered to be zero. The only loss constant in the basin above the interprovincial boundary is for the reach from Reesor Reservoir and this was calculated to be 1.231 dam^3/day.

The Lodge Creek Basin is more complex and channel losses are applied for three reaches. These reaches are Upper Lodge Creek Area (Michele, Greasewood, Massy and Bare Creek Reservoirs), Cressday Reservoir Area, and Jaydot Reservoir Area. Calculated loss constant, and variable and combined loss factors and constants, are presented in the report for each of these reaches.

The only development in the Middle Creek Basin which would require the application of channel losses is Mitchell Reservoir; however, due to the proximity of this reservoir to the interprovincial boundary and its small storage capacity, it was assumed that channel losses were negligible and weren't considered.

Minor Diversions

As it is impractical to establish gauging stations on diversions such as small irrigation projects, these minor diversions are calculated by indirect methods. The Water Rights Branch of Alberta Environment solicit information by July 1 and October 31 from the licensees of minor projects. Natural flow computations to July 29 are adjusted, if necessary, based upon the reported water use of July 1. The reported water use to October 31 is used for the final natural flow report. Procedures to determine minor diversions for the ten-day division period vary between the Battle Creek Basin and the Lodge and Middle Creek Basins. This variance and the procedure utilized, is outlined in the report.

Domestic Projects

A domestic project is defined as a small reservoir which is used for household and/or stockwatering purposes. Within all three basins, above the interprovincial boundary, the domestic usage is either a very

small percent of the natural flow or non-existent. Therefore, this usage hasn't been considered in the calculation of natural flow.

Tabular Computations

The natural flow computations for Battle, Lodge and Middle Creek Basins are made by utilizing a standard form for each stream. These forms, contained in the report, are straight forward and utilize the input previously discussed in this section on procedures.

CHAPTER VI

BIBLIOGRAPHY

1. REPORT TO THE PRAIRIE PROVINCES WATER BOARD ON WATER USE AND WATER SUPPLY STUDIES OF BATTLE AND LODGE CREEK BASINS. WATER PLANNING AND MANAGEMENT BRANCH, CANADA DEPARTMENT OF THE ENVIRONMENT. NOVEMBER, 1972.

2. BATTLE AND LODGE BASINS APPORTIONMENT STUDY. PRAIRIE PROVINCES WATER BOARD. MARCH, 1981.

3. PROCEDURES FOR THE DIVISION OF THE WATERS OF ST. MARY AND MILK RIVER. UNITED STATES GEOLOGICAL SURVEY AND WATER SURVEY OF CANADA. 1979.

4. SOUTH SASKATCHEWAN RIVER BELOW RED DEER RIVER, NATURAL FLOW. COMMITTEE ON HYDROLOGY. MARCH, 1974.

APPENDIX I

NATURAL FLOW CALCULATIONS OF BATTLE, LODGE, & MIDDLE CREEKS

In an attempt to evaluate the probability of problems arising from interprovincial apportionment of these streams, natural flow calculations were carried out for each stream in 1977. Natural flow calculations of Battle Creek at the international boundary are available from 1940. During the 43-year period from 1940 to 1982 the 1977 natural flow was the second lowest on record, only being exceeded by 1949. Lodge Creek natural flow calcualtions at the international boundary are available for 33 years from 1950 to 1982. The natural flow of Lodge Creek during 1977 was the lowest on record during this period.

It is readily apparent when reviewing the natural flow computations for each stream that a minor diversion usage in Alberta hasn't been applied, which is contrary to the method described in the manual. The reason for this is that there were no reported minor diversions for these basins in Alberta during 1977. As they aren't available and weren't used in 1977 when computing international natural flow for apportionment, an attempt wasn't made to estimate them for these sample computations.

The calculations for Battle Creek presented in tabular form indicate that although deficits in delivery occurred during some ten-day division periods, there was excess flow delivered to Saskatchewan during each audit period.

An examination of the computations for Lodge Creek creates an entirely different picture. Deficits in delivery essentially occurred during the first audit period and carried on throughout the year.

International division period deficits at the interprovincial boundary only occurred during two ten-day periods on Middle Creek; however, during each audit period, Saskatchewan received an excess delivery of flow. As noted in the report, the storage capacity of Mitchell Reservoir in Alberta is small and unless further development occurs in Alberta, there will be an annual excess flow to Saskatchewan.

NATURAL FLOW OF BATTLE CREEK AT INTERPROVINCIAL BOUNDARY

	1	2	3	4	5	6	7	8	9	10
Period at Inter-provincial Boundary	Reesor Lake Storage	Channel Loss to Interprov. Boundary	Net Depletion to Interprov. Boundary	Battle Creek at the Interprov. Boundary	Apparent Nat. Flow of Battle Crk. at the Interprov. Boundary	Adjustment for minor Diversions in Alberta	Nat. flow of Battle Crk. at the Interprov. Boundary	Sask. Share of Natural Flow	Excess flow to Saskat-chewan.	Total Excess Flows to Date
1977	Observed	Computed	1-2	Measured	3+4		5+6	75% of 7	4-8	Σ Col. 9
Feb.23-Mar.8	-127	-17	-110	247	137	0	137	103	144	144
Mar.9-19	-122	-14	-108	376	268	0	268	201	175	319
Mar.20-29	54	12	42	64	106	0	106	80	-16	303
Mar.30-Apr.8	51	12	39	638	677	0	677	508	130	433
Apr.9-18	-66	-12	-54	568	514	0	514	386	182	615
Apr.19-28	-49	-12	-37	296	259	0	259	194	102	717
Apr.28-May 8	-24	-14	-10	213	203	0	203	152	61	778
May 9-19	-27	-14	-13	298	285	0	285	214	84	862
May 20-29	-15	-12	-3	201	198	0	198	149	52	914
May 30-Jun.8	49	12	37	91	128	0	128	96	-5	909
Jun.9-18	46	12	34	75	109	0	109	82	-7	902
Jun.19-28	56	12	44	50	94	0	94	71	-21	881
Jun.29-Jul.8	39	12	27	32	59	0	59	44	-12	869
Jul.9-19	5	5	0	69	69	0	69	52	17	886
Jul.20-29	5	5	0	47	47	0	47	35	12	898
Jul.30-Aug.8	0	0	0	33	33	0	33	25	8	906
Aug.9-19	24	14	10	52	62	0	62	47	5	911
Aug.20-29	20	12	8	39	47	0	47	35	4	915
Aug.30-Sep.8	17	12	5	45	50	0	50	38	7	922
Sep.9-18	5	5	0	32	32	0	32	24	8	930
Sep.19-28	2	2	0	34	34	0	34	26	8	938
Sep.29-Oct.8	0	0	0	50	50	0	50	38	12	950
Oct.9-19	37	14	23	62	85	0	85	64	-2	948
Oct.20-25	22	6	16	33	49	0	49	37	-4	944
Total dam^3	24	52	-50	3645	3595	0	3595	2701		

NATURAL FLOW OF LODGE CREEK AT INTERPROVINCIAL BOUNDARY

	1	2	3	4	5	6	7			
Period Upper Reservoirs	Michele Reservoir Storage	Greasewood Reservoir Storage	Massy Reservoir Storage	Bare Creek Reservoir Storage	Total Storage Change Upper Lodge Reservoirs	Channel Loss to Interprov. Boundary	Net Depletion Upper Lodge			
1977	Observed	Observed	Observed	Observed	1+2+3+4	Computed	5-6			
Feb.25-Mar.6	2	10	7	0	19	19	0			
Mar.7-16	5	7	22	5	39	39	0			
Mar.17-27	27	15	29	32	103	54	49			
Mar.28-Apr.6	56	22	29	37	144	52	92			
Apr.7-16	42	7	10	17	76	50	26			
Apr.17-26	32	12	7	17	68	50	18			
Apr.27-May 6	2	2	2	7	13	13	0			
May 7-16	37	5	-5	5	42	42	0			
May 17-27	-7	7	-5	17	12	12	0			
May 28-Jun.6	2	5	-17	-29	-39	-39	0			
Jun.7-16	0	0	-22	-56	-78	-50	-28			
Jun.17-26	2	2	-19	-49	-64	-50	-14			
Jun.27-Jul.6	5	0	-15	-37	-47	-47	0			
Jul.7-16	7	0	7	10	24	24	0			
Jul.17-27	5	-2	10	12	25	25	0			
Jul.28-Aug.6	0	0	5	-7	-2	-2	0			
Aug.7-16	-2	2	0	-49	-49	-49	0			
Aug.17-27	0	2	0	-51	-49	-49	0			
Aug.28-Sep.6	0	0	0	-49	-49	-49	0			
Sep.7-16	2	0	0	-27	-25	-25	0			
Sep.17-26	0	-64	66	-24	-22	-22	0			
Sep.27-Oct.6	-2	0	34	-24	8	8	0			
Oct.7-16	0	0	-12	-12	-24	-24	0			
Oct.17-27	0	0	-10	-10	-20	-20	0			
Total dam3	215	32	123	-265	105	-28	112			

NATURAL FLOW OF LODGE CREEK AT INTERPROVINCIAL BOUNDARY

	8	9	10		11	12	13	14	15	
Period Cressday Reservoir	Cressday Reservoir Storage	Channel Loss to Interprov. Boundary	Net Depletion Cressday Reservoir	Period at Inter-provincial Boundary	Jaydot Reservoir Storage	Net Depletion in Alberta	Minor Irrigation Diversions in Alberta	Lodge Creek at the Interprov. Boundary 11AB082	Natural Flow of Lodge Creek	
1977	Observed	Computed	8-9		Observed	7+10+11	Estimated	Observed	12+13+14	
Feb.26-Mar.7	2	2	0	Feb.27-Mar.8	0	0	0	1	1	
Mar.8-17	0	0	0	Mar.9-18	0	0	0	3	3	
Mar.18-28	-2	-2	0	Mar.19-29	0	49	0	3	52	
Mar.29-Apr.7	2	2	0	Mar.30-Apr.8	0	92	0	117	209	
Apr.8-17	2	2	0	Apr.9-18	0	26	0	66	92	
Apr.18-27	2	2	0	Apr.19-28	2	20	0	0	20	
Apr.28-May 7	-2	-2	0	Apr.29-May 8	-2	-2	0	0	0(-2)	
May 8-17	2	2	0	May 9-18	2	2	0	1	3	
May 18-28	5	5	0	May 19-29	5	5	0	2	7	
May 29-Jun.7	7	7	0	May 30-Jun.8	0	0	0	0	0	
Jun.8-17	0	0	0	Jun.9-18	-2	-30	0	0	0(-30)	
Jun.18-27	0	0	0	Jun.19-28	0	-14	0	0	0(-14)	
Jun.28-Jul.7	2	2	0	Jun.29-Jul.8	0	0	0	0	0	
Jul.8-17	5	5	0	Jul.9-18	0	0	0	0	0	
Jul.18-28	2	2	0	Jul.19-29	0	0	0	0	0	
Jul.29-Aug.7	-2	-2	0	Jul.30-Aug.8	0	0	0	0	0	
Aug.8-17	0	0	0	Aug.9-18	2	2	0	0	2	
Aug.18-28	0	0	0	Aug.19-29	-2	-2	0	0	0(-2)	
Aug.29-Sep.7	0	0	0	Aug.30-Sep.8	0	0	0	0	0	
Sep.8-17	0	0	0	Sep.9-18	0	0	0	0	0	
Sep.18-27	2	2	0	Sep.19-28	2	2	0	0	2	
Sep.28-Oct.7	-2	-2	0	Sep.29-Oct.8	-2	-2	0	0	0(-2)	
Oct.8-17	0	0	0	Oct.9-18	0	0	0	0	0	
Oct.18-28	0	0	0	Oct.19-29	0	0	0	0	0	
Total dam^3	25	25	0		5	148	0	193	391	

NATURAL FLOW OF LODGE CREEK AT INTERPROVINCIAL BOUNDARY

	16	17	18							
Period at Inter-provincial Boundary	Sask. Share of Natural Flow	Excess flow to Saskat-chewan.	Total Excess flows to date							
1977	75% of 15	14-16	Σ Col. 17							
Feb.27-Mar.8	1	0	0							
Mar.9-18	2	1	1							
Mar.19-29	39	-36	-35							
Mar.30-Apr.8	157	-40	-75							
Apr.9-18	69	-3	-78							
Apr.19-28	15	-15	-93							
Apr.29-May 8	0	0	-93							
May 9-18	2	-1	-94							
May19-29	5	-3	-97							
May 30-Jun.8	0	0	-97							
Jun.9-18	0	0	-97							
Jun.19-28	0	0	-97							
Jun.29-Jul.8	0	0	-97							
Jul.9-18	0	0	-97							
Jul.19-29	0	0	-97							
Jul.30-Aug.8	0	0	-97							
Aug.9-18	2	-2	-99							
Aug.19-29	0	0	-99							
Aug.30-Sep.8	0	0	-99							
Sep. 9-18	0	0	-99							
Sep.19-28	2	-2	-101							
Sep.29-Oct.8	0	0	-101							
Oct.9-18	0	0	-101							
Oct.19-29	0	0	-101							
Total dam^3	294	-101								

NATURAL FLOW OF MIDDLE CREEK AT INTERPROVINCIAL BOUNDARY

	1	2	3	4	5	6	7			
Period at Inter-provincial Boundary	Mitchell Reservoir Storage	Minor Irrigation Diversions in Alberta	Middle Crk. at the Interprov. Boundary	Nat. flow of Middle Crk. at the Interprov. Broundary	Sask. Share of Natural Flow	Excess flow to Saskat-chewan.	Total Excess Flows to date			
1977	Observed	Estimated	Observed	1+2+3	75% of 3	3-5	Σ Col. 6			
Feb.26-Mar.7	0	0	8	8	6	2	2			
Mar.8-17	0	0	13	13	10	3	5			
Mar.18-28	0	0	12	12	9	3	8			
Mar.29-Apr.7	0	0	11	11	8	3	11			
Apr.8-17	5	0	9	14	11	-2	9			
Apr.18-27	0	0	12	12	9	3	12			
Apr.28-May 7	0	0	8	8	6	2	14			
May 8-17	2	0	4	6	5	-1	13			
May 18-28	0	0	7	7	5	2	15			
May 29- Jun.7	-2	0	6	4	3	3	18			
Jun.8-17	0	0	8	8	6	2	20			
Jun.18-27	0	0	4	4	3	1	21			
Jun.28-Jul.7	-2	0	2	0	0	2	23			
Jul.8-17	0	0	8	8	6	2	25			
Jul.18-28	-2	0	3	1	1	2	27			
Jul.29-Aug.7	0	0	2	2	2	0	27			
Aug.8-17	0	0	1	1	1	0	27			
Aug.18-28	0	0	1	1	1	0	27			
Aug.29-Sep.7	0	0	3	3	2	1	28			
Sep.8-17	0	0	2	2	2	0	28			
Sep.18-27	0	0	1	1	1	0	28			
Sep.28-Oct.7	0	0	5	5	4	1	29			
Oct. 8-17	0	0	8	8	6	2	31			
Oct.18-28	0	0	12	12	9	3	34			
Total dam^3	1	0	150	151	116	34				