THE FLOOD OF 1979

SAINT JOHN RIVER BASIN

NEW BRUNSWICK

prepared jointly

by

Inland Waters Directorate, Atlantic Region

Environmental Conservation Service

Environment Canada

Water Resources Branch

Department of the Environment

New Brunswick

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ABSTRACT

During the latter part of April and early part of May 1979, extreme flood conditions occurred in most parts of New Brunswick. These conditions were caused by rainfall combined with heavy snowmelt.

During the winter of 1978-79, snowfall was about average throughout New Brunswick and in adjacent areas of Maine. However, above average snowfall was observed at Chatham in northeastern New Brunswick and at Riviere du Loup and Mont Joli in Quebec. The water equivalent of the snow pack at the end of April was slightly above average in northern New Brunswick and about 50% of average in the southern portion of the Province.

During the period of April 24 to May 7, mean temperatures were well above 0°C. On April 29, a storm system moved into Maine and Quebec and western New Brunswick resulting in precipitation varying from 10 to 22 mm in the northern part of the Saint John River Basin. Daily precipitation as high as 52.5 mm was reported at Bon Accord in north-central New Brunswick. Further rain occurred on April 20 and May 1 resulting in record breaking discharges at 11 hydrometric stations within the Basin.

The maximum daily mean discharge of the Saint John River below Mactaquac during 1979 was 10000 m^3/s. This discharge was the second highest since records began in 1922, exceeded only by the 11130 m^3/s which occurred during the 1973 flood, the largest in recorded history in the Saint John River Basin. The third highest was 8160 m^3/s recorded in 1923 at the Pokiok gauging station. With respect to the stage, the 1979 peak stage at Fredericton was exceeded only three times since 1922. Those were, in descending order, the flood levels in 1936 (ice jam), 1973 and 1923.

Although the 1979 flood was of a high magnitude, it cannot be considered as an isolated occurrence which will not happen again. The Province of New Brunswick, and particularly the Saint John River, has a history of flooding dating back to the arrival of the first settlers. Rough estimates for the Saint John River Basin indicate that within the present century, seven floods have each caused damages in excess of one million dollars.

The magnitude of the flood problem within the Saint John River Basin is sufficient to warrant full consideration of all possible ways to minimize the effects of future floods. There is a critical need for more effective planning and regulation of the use of flood-plain lands. Any program of this nature could benefit from the available information and flood mapping resulting from the Flood Damage Reduction Program.

For protection of existing developments susceptible to flooding, a full range of other alternative flood control measures should be investigated.

During the 1979 flood, forecasting and emergency measures activities were successful in avoiding more serious personal hardship and greater economic losses. The warning, provided through weather and streamflow forecasting, permitted some advance planning as a reaction to the emergency while the Emergency Measures Organization proved its worth in directing the disaster activities.

Continuation and improvement of flood forecasting and emergency measures programs are clearly desirable.

CHAPTER 1

DESCRIPTION OF THE SAINT JOHN RIVER BASIN

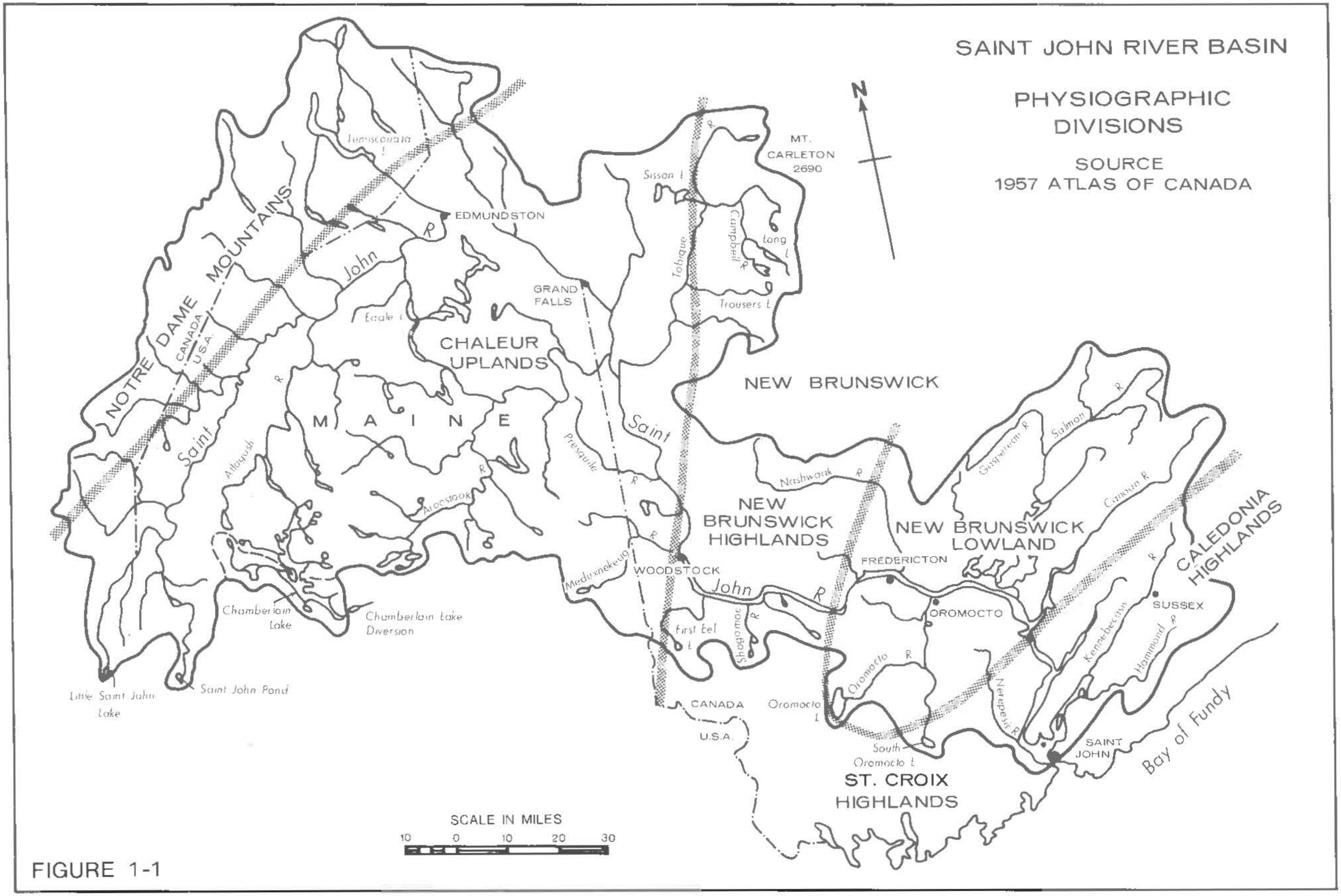
1.1 Geographical Features

The Saint John River lies in a broad arc across southeastern Quebec, northern Maine and western New Brunswick. It extends from a point on the international boundary, about 110 km southeast of Quebec City, to the Bay of Fundy, which is some 300 km to the east. The total drainage area is 55 200 sq km, of which 51 percent or 28 400 sq km lie in New Brunswick, 13 percent or 7 100 sq km in Quebec and the remaining 36 percent or 19 700 sq km in Maine. A map of the Basin showing the main geographical features and physiographic divisions is presented in Figure 1.1.

From its point of origin above Little Saint John Lake, the Saint John River flows northeastward for about 160 km, through the Chaleur Uplands and then swings in a broad arc to the southeast to Grand Falls, New Brunswick. Here it turns south and continues through the Uplands for another 100 km until it enters the New Brunswick Highlands near Woodstock. Below Woodstock, the river flows southeastward and enters the New Brunswick Lowland about 20 km upstream of Fredericton. It continues southeastward through the Lowland until it reaches the Caledonia Highlands, where it turns southward to the famous Reversing Falls at Saint John.

Measured along its streambed the Saint John River is approximately 700 km long, and the total fall between Little Saint John Lake and tide water is about 480 m. River slopes gradually decrease from about 1.5 m per km near the headwaters to 0.6 m per km in the vicinity of Grand Falls and 0.4 m per km in the reach above Fredericton.

In its upper 300 km, the Saint John River is fed from the west and north by numerous short tributaries such as the Daaquam, Big and Little Black, St. Francis and Madawaska rivers, all of which rise in the southeastern slopes of the Notre Dame Mountains. Two important rivers, the Allagash and the Fish enter from the south, from the upland area of Maine. Below Grand Falls, the Saint John River is joined from the west by the Aroostook River whose drainage basin combined with those of the Allagash and Fish rivers comprises most of the Saint John Basin in Maine.


SAINT JOHN RIVER BASIN
PHYSIOGRAPHIC DIVISIONS
SOURCE
1957 ATLAS OF CANADA
N
MT. CARLETON 2690
NOTRE DAME MOUNTAINS
CHALEUR UPLANDS
MAINE
NEW BRUNSWICK
NEW BRUNSWICK HIGHLANDS
NEW BRUNSWICK LOWLAND
CALEDONIA HIGHLANDS
ST. CROIX HIGHLANDS
CANADA
U.S.A.
EDMUNDSTON
GRAND FALLS
WOODSTOCK
FREDERICTON
OROMOCTO
SUSSEX
SAINT JOHN
Saint John R
Temiscouata L
Sisson L
Campbell R
Long L
Tobique
Trousers L
Eagle L
Presquile R
Allagash
Aroostook R
Meduxnekeag R
Nashwaak R
Gaspereau R
Salmon R
Canaan R
Kennebecasis R
Hammond R
Nerepesis R
Oromocto R
Oromocto L
South Oromocto L
First Eel L
Shogomoc R
Chamberlain Lake
Chamberlain Lake Diversion
Little Saint John Lake
Saint John Pond
Bay of Fundy
SCALE IN MILES
10 0 10 20 30
FIGURE 1-1

Below Grand Falls, tributaries from the New Brunswick Highlands begin to enter from the north and east. The Tobique, which enters just below the Aroostook, and the Nashwaak, which joins the Saint John at Fredericton, are the two most important of these. Some of the larger tributaries, listed in downstream order with their respective drainage areas at their confluence with the Saint John River, are presented in Table 1.1.

NAME	DRAINAGE AREA IN SQ KM
Big Black River	1 620
Allagash River	3 260
St. Francis River	1 420
Fish River	2 310
Madawaska River	3 050
Green River	1 180
Aroostook River	6 270
Tobique River	4 320
Meduxnekeag River	1 330
Nashwaak River	1 760
Oromocto River	2 010
Salmon River	3 880
Canaan River	1 520
Kennebecasis River	1 370

TABLE 1.1

In the section between Edmundston and Fredericton, the river has been extensively developed by the New Brunswick Electric Power Commission for three hydro-electric power developments. These are: Grand Falls, with a head of 38 m; Beechwood, located between Woodstock and Grand Falls, which develops a head of 17 m; and Mactaquac, which is located 13 km upstream of Fredericton and presently utilizes a head of about 33 m. The combined capacity of these three developments is 805 megawatts. A bed profile of the river showing the headponds of these three dams is given on Figure 1.2.

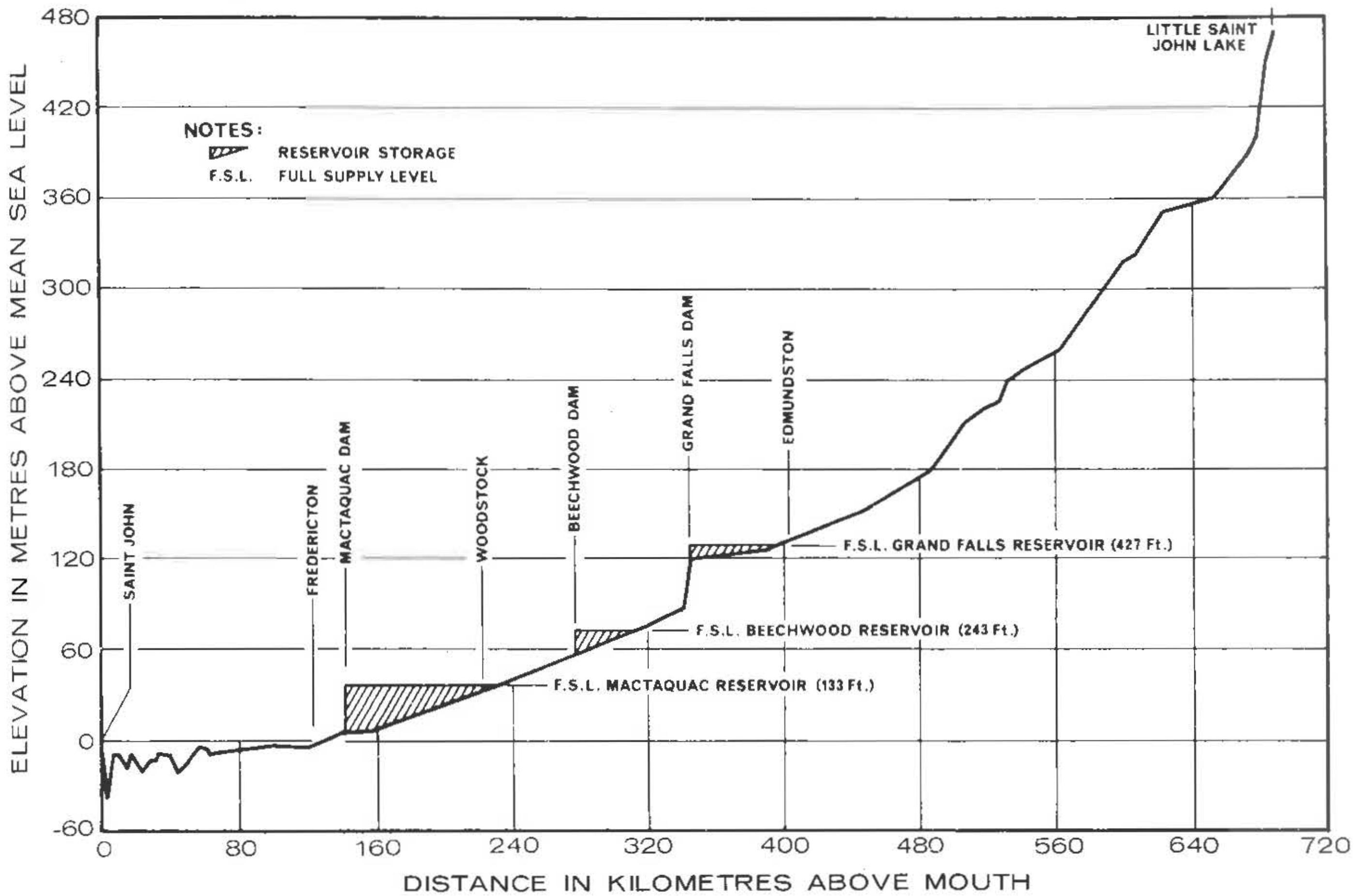


FIGURE 1-2 BED PROFILE- SAINT JOHN RIVER

From Fredericton downstream, the river is influenced by tides, but because of the effect of the Reversing Falls, fluctuations reach only a small fraction of those in the Bay of Fundy. The physical characteristics of this tidal section of the river present a unique condition from the point of view of flooding. The outflow of the river is restricted by the narrow gorge at its mouth and affected by the tidal regime in Saint John Harbour. The duration of flooding along the river below Fredericton is influenced by large bodies of water along and adjacent to the channel. As flood waters are backed up by the Reversing Falls, large volumes go into storage and consequently the river remains relatively high for a few weeks following the peak runoff period.

1.2 Physiography

The physiographic divisions of New Brunswick and adjacent areas of Quebec and Maine, as delineated in the 1957 Atlas of Canada (Ref. 1) are all represented in the Saint John River Basin as shown on Figure 1.1. These divisions are the Notre Dame Mountains, the Chaleur Uplands, the New Brunswick Lowland and the New Brunswick, Saint Croix and Caledonia Highlands.

The preglacial valley of the Saint John River, which was much wider and deeper that its present valley, was filled in with overburden in the Pleistocene Age, consisting mainly of cobbles and boulders deposited in a blanket of varying thickness over bedrock. The cover is generally thin over hills and deeper in the valleys. It is absent on the tops and steep slopes of some hills. The composition of the till generally reflects the characteristics of the underlying bedrock. For example, silty tills predominate over shales, whereas sandy tills predominate over sandstones and conglomerates.

Although the Saint John River still flows in the same valley it has only partially eroded the glacial deposits and has not cut down to its preglacial level. In most stretches of the river, the side slopes and bottom of the old valley are completely obscured by overburden deposits. In a few places, however, the river flows close to the old valley walls and has exposed rock on the banks and sometimes on the bottom of the river.

1.3 Climate

The climate of the Saint John River Basin can be categorized as humid continental with long cold winters, cool summers and no dry season (Ref 2).

1.3.1 Temperatures

Temperatures vary considerably over the Basin with the mean annual temperature decreasing in a northerly direction from 5°C at Saint John to about 2°C in the area north of Edmundston. In the upper part of the Basin minimum temperatures of -34°C are not uncommon. Maximum temperatures often exceed 27°C and have occasionally reached 37°C. The frost-free season varies from approximately 140 days at the mouth of the Saint John River to less than 100 days in northern Maine.

1.3.2 Precipitation

Annual precipitation in the Basin varies from about 900 mm in the headwaters to about 1400 mm in the lower portion near the Bay of Fundy. The mean annual precipitation in that portion of the Basin above Fredericton is about 970 mm. The variability of annual precipitation is not great, the standard deviation being less than 15 percent of the mean. Precipitation is about uniformly distributed over the four seasons, although average monthly values show a variation from 60 mm to nearly 100 mm over that portion of the Basin upstream of Fredericton.

On the average more snow falls in New Brunswick than most other areas in Canada. In the northern and western parts of the Basin 250 to 350 cm may be expected annually. In the southeastern part of the Basin the total snowfall is in the order of 180 to 200 cm per year. About 30 percent of the mean annual precipitation which falls on that portion of the Basin above Fredericton is in the form of snow.

Although winter snow cover usually runs off in April, snowmelt runoff frequently occurs during the first half of May and occasionally in March. In March of an average year prior to spring runoff, snow lies 0.6 to 0.9 metres deep in the coastal area near Saint John. Water equivalent in this snow cover averages about 125 to 180 mm in the area above Fredericton and 50 to 75 mm in the coastal area (Ref. 3).

1.3.3 Relative Humidity and Evaporation

Mean monthly values of relative humidity vary from 70 to 90 percent. Relative humidity is highest during the late summer and fall and lowest during the spring months of April, May and June. The annual potential evapotranspiration varies from about 560 mm in the lower part of the Basin near Saint John to less than 500 mm in the northeastern part.

1.3.4 Sunshine Hours

The Basin receives an annual total of about 1800 hours of bright sunshine per year. This represents 40 percent of the total daylight hours.

1.3.5 Storms

The Basin lies on the path of many extra-tropical storms spawned along the eastern seaboard of the United States and hurricane-type tropical storms originating in the Carribean area. The latter type have generated rainfalls of up to 300 mm in a 72-hour period during their season, which extends from August through October. The extra-tropical storms occur most frequently during the winter season when cold continental air flows over the much warmer surface water of the ocean, but may occur at almost any time of the year. The storm tracks have a southwest to northeast orientation and their isohyetal patterns tend to be elongated around an axis with that directional characteristic. Thus, although rainfall may be general over much of the Basin, the extreme precipitation is usually concentrated in a relatively narrow belt and the intensity falls off rapidly in the southeast and northwest direction from the axis of the storm.

CHAPTER 2

CAUSES OF THE FLOOD

2.1 Climatological Reasons for Flooding

The generally accepted climatological reasons for flooding on the Red River in Manitoba were summarized by Clark (Ref. 4). These reasons are considered valid for any river located in a northern climatic zone, and are as follows:

2.1.1 A very wet autumn.

2.1.2 Severe and continued frost before the first snowfall, sealing up the marshes, lakes and saturated ground.

2.1.3 Heavy accumulation of snow during the winter months.

2.1.4 A late and sudden spring.

2.1.5 Above normal rainfall during the breakup, extending over the drainage basin.

A point by point consideration of these reasons as they relate to the Saint John River flood of 1979 follows:

2.1.1 A Wet Autumn

Data shown below in Table 2.1 indicate that overall precipitation in the Basin was near normal during October and below normal during November.

	October			November		
	Actual	Normal	Difference	Actual	Normal	Difference
Edmundston (Fraser Company)	52.1	94.7	-42.6	76.9	102.5	-25.6
Grand Falls	54.3	88.1	-33.8	62.4	95.5	-33.1
Woodstock	M	78.0	M	50.2	79.7	-29.5
Fredericton (CDA)	154.0	91.1	+62.9	42.8	118.9	-76.1
Saint John (A)	150.5	109.9	+40.6	61.6	154.0	-92.4

(M - refers to missing data)

Precipitation in Millimetres

Table 2.1

2.1.2 Severe Prolonged Frost Before First Snowfall

Weather records indicate that all selected stations experienced temperatures a little (-0.1 to -2.8°C) below normal during the autumn months. From about November 20, maximum daily temperatures were consistently below the freezing point and minimum daily temperatures were on the cold side. As little or no precipitation occurred in the period November 20-26 it may be presumed that frost penetration was sufficient to limit ground absorption during the succeeding winter months.

2.1.3 Heavy Accumulation of Snow During the Winter Months

Average total precipitation accumulated during the four months December through March, as measured by the five index stations, amounted to about 484 mm, or about 136 percent of normal. Total average snowfall was 204 cm at 89 percent of normal. Total average rainfall was 277 mm at 219 percent of normal.

A record proportion of the winter precipitation appeared as runoff. The Saint John River below Mactaquac gauging station record shows about two recharges per month in the period. Although the monthly mean discharge for December was 4th lowest in the 60 years of record, January, February and March, respectively, ranked 7th, 6th and 2nd highest in the record period. Aggregate discharge for these three months was the highest on record, amounting to about 199 mm.

Snowfall recorded during the winter of 1978-79 at selected meteorological stations in New Brunswick, Quebec and Maine is presented and compared with long term monthly averages in Table 2.2. The total snowfall for the season was about average, being somewhat above average in the Upper Basin. Of particular significance was the higher than normal snowfall during April, with five of the ten stations reporting at least twice the normal snowfall.

Generally monthly weather patterns for the Basin during the winter of 1978-79 are described as follows:

<u>November</u>: November temperatures were -2 to -4°C below normal. Rainfall and snowfall were generally below normal but snowfall was above normal in some northern parts of the Basin.

SNOWFALL FOR WINTER 1978-79 (cm)

TABLE 2.2

STATION		OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	ANNUAL TOTAL
RIVIERE DU LOUP	(a)	8.1	16.3	39.9	43.7	55.4	47.5	20.8	4.3	236.0
QUEBEC	(b)	0	27.1	149.4	72.4	43.6	18.4	31.7	0.0	342.6
	(c)	0	166	374	166	78.7	38.7	152	0	145
MONT JOLI (A)	(a)	6.9	31.5	81.3	88.1	79.0	54.4	23.1	2.5	366.8
QUEBEC	(b)	0.6	63.1	142.3	80.4	42.5	25.7	74.2	0	428.8
	(c)	8.7	200	175	91.2	53.8	47.2	321	0	117
EDMUNDSTON	(a)	10.7	34.8	67.8	74.9	71.1	57.2	23.9	3.0	343.7
(FRASER CO.)	(b)	0.0	41.8	122.8	67.5	30.6	44.9	49.6	0.0	357.2
NEW BRUNSWICK	(c)	0	120	181	90	43	78	208	0	104
GRAND FALLS	(a)	4.8	22.4	52.8	62.0	60.2	47.0	15.0	1.0	265.2
NEW BRUNSWICK	(b)	0.0	22.0	96.2	78.2	39.0	9.0	57.0	0.0	301.4
	(c)	0	98	182	126	65	19	380	0	114
WOODSTOCK	(a)	3.3	12.7	48.3	54.1	51.6	34.3	12.2	0.5	217.0
NEW BRUNSWICK	(b)	M	18.4	80.8	74.2	31.0	8.8	26.6	T	239.8
	(c)	-	145	167	137	60	26	218	0	111
FREDERICTON	(a)	2.5	18.8	52.8	55.6	58.9	37.8	16.0	1.0	234.4
(CDA)	(b)	0.0	18.8	64.1	50.4	30.7	12.2	34.9	0.0	211.1
NEW BRUNSWICK	(c)	0	100	121	91	52	32	218	0	87
SAINT JOHN (A)	(a)	1.0	13.2	61.5	78.7	72.9	50.5	16.8	2.0	296.6
NEW BRUNSWICK	(b)	3.0	10.6	66.0	54.6	28.2	24.6	21.2	0	208.2
	(c)	300	80.3	107	69.3	38.7	48.7	126	0	70.2
CHATHAM (A)	(a)	2.8	24.4	57.4	68.1	70.6	54.9	28.4	2.8	309.4
NEW BRUNSWICK	(b)	0.4	13.3	102.4	96.9	49.6	34.4	38.5	0	355.5
	(c)	14.2	54.5	178	142	70.2	62.7	136	0	115
MONCTON (A)	(a)	1.3	18.3	62.5	73.7	70.4	57.7	28.4	1.5	313.8
NEW BRUNSWICK	(b)	5.5	12.5	93.1	65.5	40.9	34.8	35.0	0	287.3
	(c)	423	68.3	149	88.9	58.1	60.3	123	0	91.6
CARIBOU	(a)	6.4	30.5	47.8	54.4	61.0	48.3	16.3	2.5	267.0
MAINE	(b)	0.0	23.4	40.3	81.5	46.0	21.8	37.8	T	250.8
	(c)	0	76.7	84.3	150	75.4	45.1	43.1	1.0	93.9
CLAYTON LAKE	(a)									
MAINE	(b)	0.0	30.5	37.6	62.0	30.7	11.4	50.8	0.0	223.0
	(c)									

(a) - Long term average snowfall in cm.
(b) - Winter 1978-1979 snowfall in cm.
(c) - Winter 1978-1979 snowfall as % of long term average.
T - Trace.

December: Temperatures were about 1°C below normal. Snowfall was generally greater than normal, particularly in the north where several stations reported over 100 cm of snow.

January: The weather in January was generally mild with variable precipitation. Temperatures were about 2°C above normal. Snowfall was greater than normal in the north and below normal in the south.

February: February was generally sunny and cold. Temperatures were 2°C below normal. Snowfall was approximately 50 percent of normal throughout the Basin.

March: March weather was generally cloudy, mild and wet. Temperatures were about 3°C above normal. Snowfall over the Basin was generally less than 50 percent of normal, while rainfall ranged from 200 to 500 percent of normal.

April: The weather in April was generally cloudy and mild. Temperatures overall were about 1°C above normal but were 6 to 7°C above normal during the last week. Snowfall ranged from just over 100 percent in the south to over 300 percent of normal in the north, with many stations reporting in excess of 30 cm. Rainfall was normal to above normal in the Basin.

In recent years many snow survey stations have been established throughout New Brunswick, Quebec and Maine. In each area, groups of stations, usually referred to as networks, are systematically surveyed for the purpose of estimating the water equivalent of the snow pack. In New Brunswick, snow surveys are undertaken by four organizations: the Water Survey of Canada (WSC), the New Brunswick Electric Power Commission (NBEPC), the New Brunswick Department of the Environment (NBDOE), and the University of New Brunswick (UNB). In the Province of Quebec, they are undertaken by the Provincial Department of Natural Resources (RNQ), and in the State of Maine by the Maine Public Service (M.P.S.) Co. and the U.S. Geological Survey (USGS), plus some private companies.

Snow surveys were made in 1979 at the end of January and February and near the middle and the end of both March and April. Data obtained during the month of April are presented in Table 2.3. These data have been used to produce Figures 2.1 and 2.2 which show isohyetal lines for

SELECTED SNOW SURVEY DATA IN NEW BRUNSWICK, QUEBEC, AND MAINE

(APRIL 1979)

TABLE 2.3

Snow Course	Reporting Agency	Elevation (m)	Mid April Survey			End of April Survey		
			Day	Depth (cm)	Water Content (mm)	Day	Depth (cm)	Water Content (mm)
NEW BRUNSWICK								
Becaguimec	NBEPC	137	10	38.1	81	24	7.6	38.0
Beechwood	NBEPC	152	10	0.0	0	24	0.0	0.0
Belleville	NBEPC	145	10	25.4	64	24	0.0	0.0
Clair	WSC	230	10	59.4	152	23	20.8	81.0
Connors	WSC	235	10	54.9	142	23	20.8	79.0
Connors (St. Francis)	WSC	152	10	45.7	152	23	16.3	61.0
Gibson Miilstream	NBEPC	46	10	34.3	117	24	0.0	0.0
Grand Falls	NBEPC	122	10	0.0	0	24	0.0	0.0
Grand River	NBEPC	137	10	35.1	99	24	0.0	0.0
Green River	NBEPC	335	10	60.5	206	24	15.2	57.0
Haley Brook	NBEPC	168	10	36.8	122	24	9.7	24.0
Harrison Ridge	NBEPC	457	9	64.5	244	23	39.9	185.0
Holmesville	WSC	198	9	5.6	15	23	0.0	0.0
Kilmarnock	NBEPC	152				24	18.0	76.0
Little Tobique	NBEPC	244	9	51.0	196	24	35.0	169.0
Long Lake	NBEPC	381	9	86.9	305	23	68.1	312.0
Mactaquac	NBEPC	46	10	44.2	147	24	15.2	51.0
Mapleview	NBEPC	168	10	49.5	155	24	15.7	55.0
McElwain	WSC	183	11	45.7	150	23	0.0	0.0
Nictau Forks	NBEPC	168	10	41.9	144	24	30.5	119.0
Nashwaak	UNB	300				24	48.5	188.0
Oxbow	NBEPC	168	10	17.8	25	24	0.0	0.0
Quisibis	NBEPC	205	10	64.3	210	24	21.6	83.0
Royal Road East	NBEPC	130	11	45.7	130	23	5.5	25.0
Serpentine Lake	NBEPC	381	9	77.2	244	23	61.2	236.0
Sisson Ridge	NBEPC	305	10	25.4	54	24	0.0	0.0
Shogomoc	WSC	76	11	26.4	94	23	Tr	–
Springfield	NBEPC	183	10	63.8	175	24	22.9	102.0
St. Jacques	NBEPC	152	10	53.8	193	24	6.9	21.0
St. Quentin #1	NBEPC	366	10	65.8	198		26.7	108.0
Sussex	WSC	30	10	0.0	0	23	0.0	0.0
Tobique Narrows	NBEPC	152	10	15.2	25	24	0.0	0.0
Tracy	WSC	61	11	19.3	66	23	0.0	0.0
Trouser Lake	NBEPC	381	10	78.7	269	24	62.0	279.0

SELECTED SNOW SURVEY DATA IN NEW BRUNSWICK, QUEBEC, AND MAINE

TABLE 2.3 - CONTINUED

Snow Course	Reporting Agency	Elevation (m)	Mid April Survey			End of April Survey		
			Day	Depth (cm)	Water Content (mm)	Day	Depth (cm)	Water Content (mm)
QUEBEC								
Daaquam	NRQ	381	9	76.5	244	23	34.3	41.0
Estcourt-2	NRQ	243	8	33.0	76	21	12.7	56.0
Lac Abenaquis	NRQ	488	9	33.3	99	23	8.6	41.0
Lac Megantic-2	NRQ	419	10	31.5	91	24	0.8	5.0
Lac Poulin	NRQ	312	10	40.1	117	23	0.0	0.0
Matapedia	NRQ	60	9	49.0	191	23	9.1	33.0
Pelletier	NRQ	366	8	123.2	346	21	79.2	34.0
Price	NRQ	23	7	38.6	114	23	21.3	99.0
St. Alexandre	NRQ	198	8	62.0	193	21	30.2	127.0
St. Etienne	NRQ	99	9	62.7	221	24	Tr	-
St. Moise	NRQ	243	7	75.7	262	23	69.9	325
St. Leon	NRQ	274	9	54.1	158	23	167.6	69.0
St. Ludger	NRQ	274	10	31.2	79	23	0.0	0.0
Ste. Blandine	NRQ	152	7	58.4	201	23	54.3	231.0
Ste. Perpetue-2	NRQ	365	8	98.0	307	23	57.9	254.0
Ste. Rose	NRQ	403	9	52.8	158	23	17.5	74.0
Ste. Rose du Degelis	NRQ	144	8	65.0	221	21	34.3	135.0
Ste Theophile	NRQ	441	10	26.7	53	23	0.0	0.0
Vallee-Jonction	NRQ	259	11	34.8	114	24	0.0	0.0
Whitworth	NRQ	281	8	110.5	310	21	68.6	287.0
MAINE								
Hedgehog MT A	MPS	244	14	Tr	-	23	0.0	0.0
Hedgehog MT B	MPS	244	14	Tr	-	23	0.0	0.0
Squa Pan C	MPS	193	14	Tr	-	23	0.0	0.0
Squa Pan D	MPS	205	14	Tr	-	23	0.0	0.0

NBEPC - New Brunswick Electric Power Commission
WSC - Water Survey of Canada
UNB - University of New Brunswick
NRQ - Quebec Department of Natural Resources
MPS - Maine Public Service

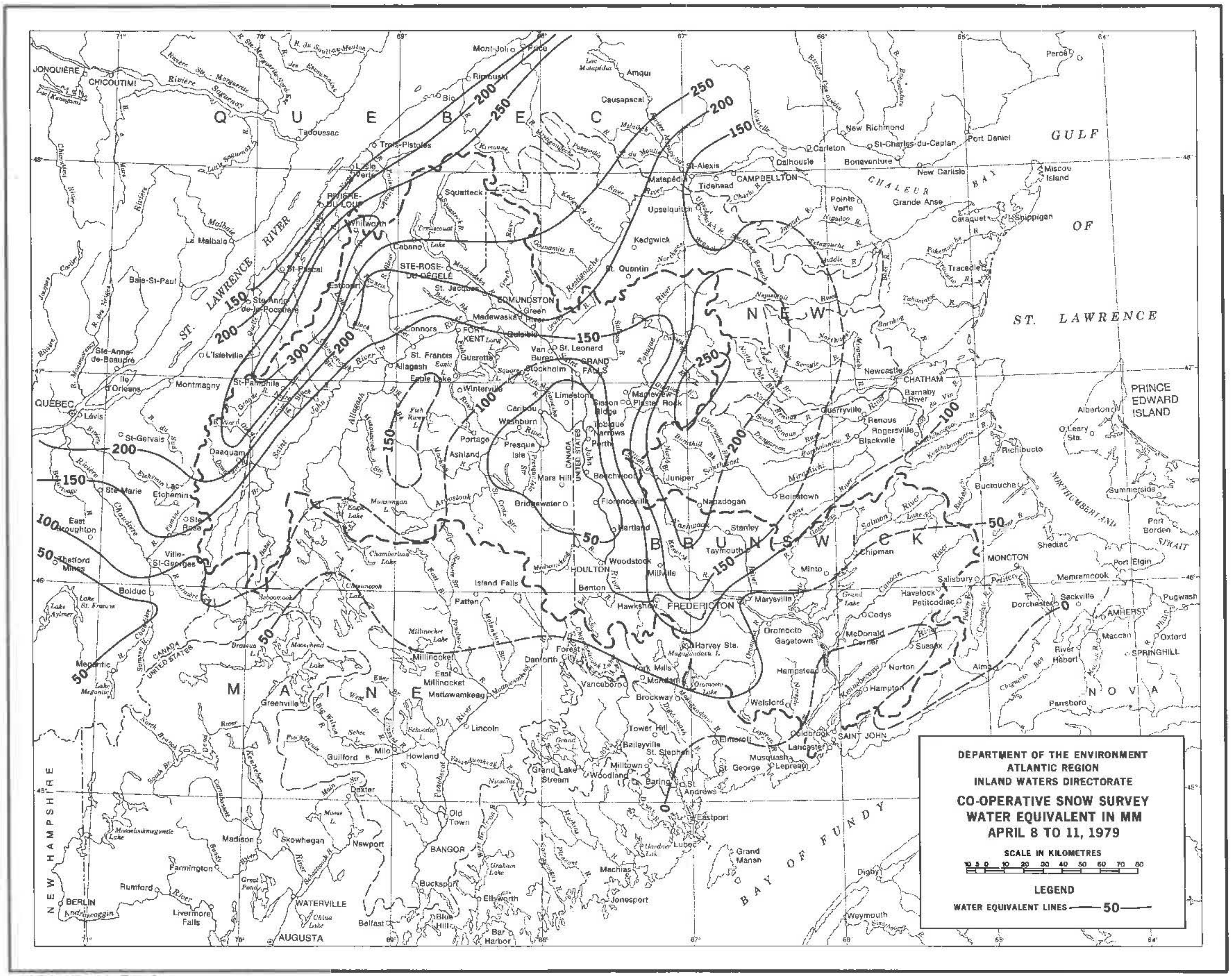

DEPARTMENT OF THE ENVIRONMENT
ATLANTIC REGION
INLAND WATERS DIRECTORATE
CO-OPERATIVE SNOW SURVEY
WATER EQUIVALENT IN MM
APRIL 8 TO 11, 1979
SCALE IN KILOMETRES
LEGEND
WATER EQUIVALENT LINES —50—
QUEBEC
NEW BRUNSWICK
MAINE
NOVA
NEW HAMPSHIRE
PRINCE EDWARD ISLAND
GULF OF ST. LAWRENCE
BAY OF FUNDY
CHALEUR BAY
NORTHUMBERLAND STRAIT
ST. LAWRENCE RIVER
CANADA
UNITED STATES
FREDERICTON
SAINT JOHN
MONCTON
CAMPBELLTON
EDMUNDSTON
CHATHAM
BANGOR
AUGUSTA
WATERVILLE
QUÉBEC
CHICOUTIMI
JONQUIÈRE
AMHERST
SPRINGHILL

FIGURE 2-1

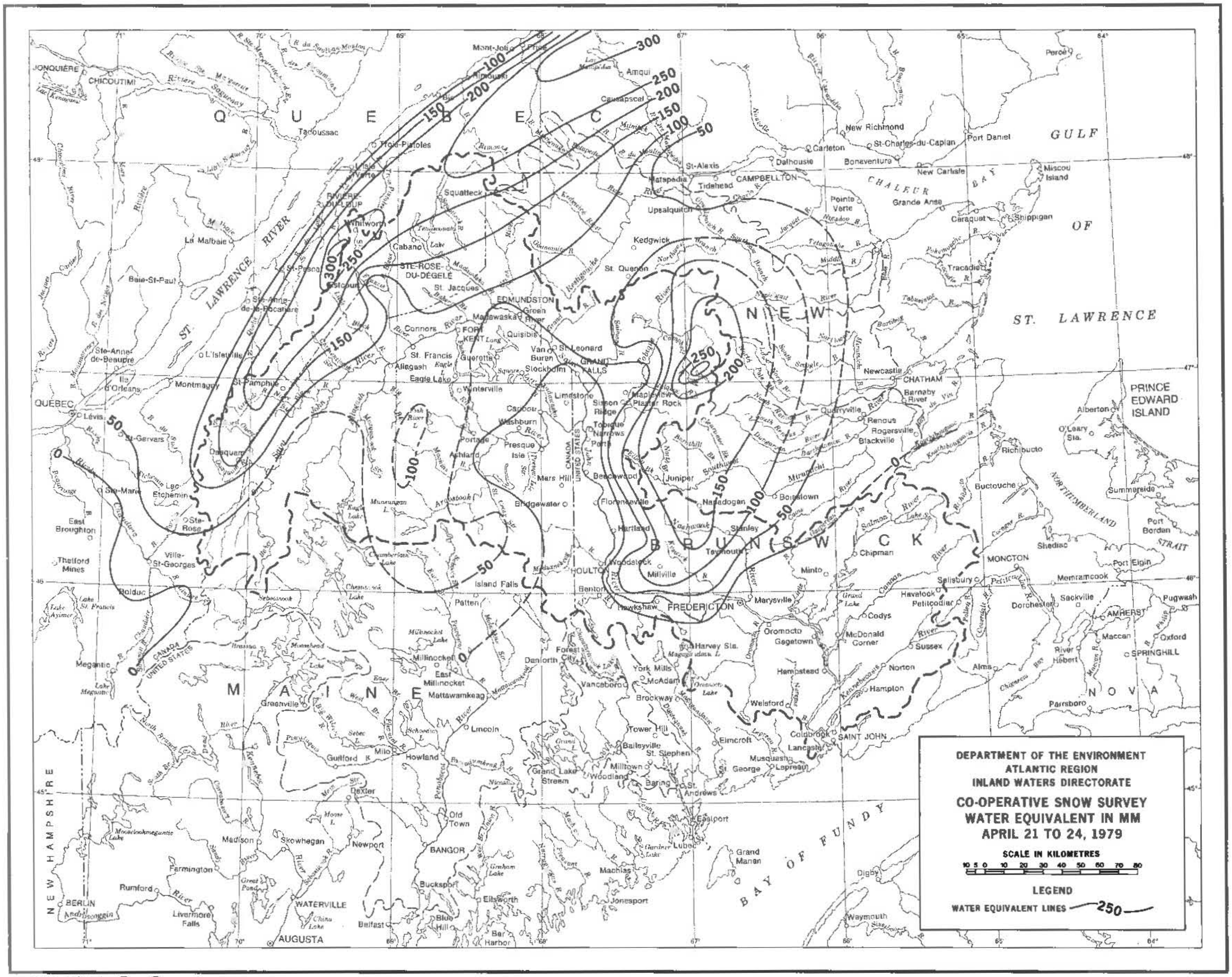

DEPARTMENT OF THE ENVIRONMENT
ATLANTIC REGION
INLAND WATERS DIRECTORATE
CO-OPERATIVE SNOW SURVEY
WATER EQUIVALENT IN MM
APRIL 21 TO 24, 1979
SCALE IN KILOMETRES
10 5 0 10 20 30 40 50 60 70 80
LEGEND
WATER EQUIVALENT LINES 250
QUEBEC
NEW BRUNSWICK
MAINE
NEW HAMPSHIRE
NOVA
PRINCE EDWARD ISLAND
GULF OF ST. LAWRENCE
CHALEUR BAY
BAY OF FUNDY
NORTHUMBERLAND STRAIT
ST. LAWRENCE RIVER
CANADA
UNITED STATES
FREDERICTON
SAINT JOHN
MONCTON
BANGOR
AUGUSTA
EDMUNDSTON
CAMPBELLTON
CHATHAM
HOULTON
300
250
200
150
100
50
0

FIGURE 2-2

water equivalents of the snow pack during the periods April 8-11 and April 21-24 (later referred to as end of April) respectively. For areas where little or no information was available, isohyetal lines are dashed. Data from surveys taken earlier in the year influenced the analysis in these areas.

Quebec was the only area where measurements were taken in May. On May 6, the snowpack at the survey station at Pelletier had a depth of 20 cm and a water equivalent of 85 mm. All other stations were bare or had only a trace of snow remaining.

Table 2.4 presents a comparison of mid-April snow data with historical data for selected snow courses in New Brunswick, Quebec and Maine. In this table, the April 8-11, 1979 water content is compared with the averages and extremes reported during the period of record which, in this case, refers to the number of measurements taken at mid-April and not to the number of years the stations have been in operation. An attempt was made to select stations for this table which have good records but this was not always possible, particularly in the southern part of the Basin. Examination of the data on Table 2.4, shows that the water content of the snow pack in mid-April was about average and varied from 72 to 138 percent of the average at the stations surveyed.

The snow cover in New Brunswick generally reaches its maximum depth and water equivalent about the end of March. In a normal year, the amount of snow added to the cover in April would not contribute significantly to the potential runoff. In 1979, however, the water equivalent was greatest at the end of February. The average values over the area declined through March due to high temperatures, excessive rainfall and relatively low snowfall amounts. By the end of April, water equivalent values were slightly below normal in spite of above normal snowfall during April.

Comparison of Figures 2.1 and 2.2 shows that the general recession of the snow line in the southern and central parts of New Brunswick and Maine is consistent with the seasonal warming trend. Examination of Figure 2.2, however, reveals the presence of significant amounts of snow in the Tobique headwaters and north into the Province of Quebec although the average water equivalent in the Saint John River Basin above Beechwood was only 12 percent above normal at the end of April.

COMPARISON OF MID-APRIL, 1979 SNOW DATA

WITH HISTORICAL DATA

TABLE 2.4

Sta. No.	Snow Course	Period of Record	Mid April Period of Record Water Content in mm			Water Content Mid April, 1979	
			Average	Maximum	Minimum	mm	% of Average
4	Clair	15	158	297	0	152	97
5	Connors	13	188	325	0	152	76
81	Daaquam	15	224	318	13	244	121
9	Green River	13	224	424	23	206	92
11	Harrison Ridge	12	263	439	104	244	93
13	Long Lake	12	274	389	128	305	111
14	Mactaquac	7	107	246	0	147	138
15	Mapleview	12	185	246	116	155	84
54	McElwain	7	135	229	0	150	111
84	Pelletier	17	310	406	0	345	124
19	Quisibis	12	232	335	155	210	90
58	Royal Road East	9	125	216	0	130	104
20	Serpentine Lake	10	285	401	133	244	86
51	Shogomoc	7	131	267	0	94	72
85	St. Alexandre	16	203	325	0	193	107
26	St. Quentin #1	12	228	360	81	198	87
93	Ste. Bandine	16	203	462	0	201	99
90	Ste. Rose du Degelis	16	200	394	0	220	110
61	Tracy	7	72	163	0	66	92
29	Trouser Lake	12	293	381	188	269	92

The average water equivalent of the snow pack at the end of April, 1979 for the Saint John River Basin is estimated as:

Saint John River Basin	92 mm
Saint John River above Beechwood	126 mm
Saint John River below Beechwood	14 mm

2.1.4 A Late and Sudden Spring

There is no standard hydrologic definition of "spring" nor statistics regarding its normal timing. Various methods have been used to establish a location for this event. This could be done by examination of climatic data such as degree day accumulations. A somewhat arbitrary method is to define it as the beginning of the sharp rise of the discharge hydrograph. A more objective method that has been used is based on an analysis of the spring discharge hydrograph where three points are chosen, the initial point being the first day that the mean flow was some number of times the February mean flow for that year, the second point some number of times greater than the first, with the third point the date of the spring peak discharge. Whether the method chosen is based on climatic or hydrometric data should be of little importance as the two are related.

All of these methods have practical problems in their determinations, such as early, indefinite or protracted break-ups, changes in regimes over time, winter recharges and freak occurances. Thus, a relatively simple but arbitrary method was chosen; to assume that the first day of ice free conditions is an index of "spring". A long record of opening dates for the Saint John River at Fredericton exists, dating back to 1825, and extends to 1967 when the installation of the Mactaquac dam altered the natural regime. The average for this 143 year record was determined to be April 17.

The 60 years of available hydrometric record for the Pokiok and Simmons stream gauges yields an average opening date of April 13. This is the accepted index of "spring", and is assumed to be reasonably confirmed by the longer Fredericton record. The latter was observed in the estuarial reach of the river where velocities are lower and the break-up of the ice cover tends to be a few days later than it does in the upstream reach.

"Spring" as determined by this index method occurred on March 27, which indicates it arrived more than two weeks earlier than average. The break-up also occurred during the second significant recharge period in that month, so it is not presumed to have been sudden.

2.1.5 Above Normal Rainfall During Break-up

The peak discharges recorded at main stem gauging stations occurred on either April 29 or April 30. Rainfall accumulation that directly contributed to these peaks can be assumed to be that which began on April 26 and continued through April 29. These ranged from a low of about 2 mm at Sussex to a high of 88 mm at Bon Accord, with the average over the Basin of approximately 43 mm. The greater portion of this rainfall occurred on April 28 and 29.

The latest rainfall intensity-duration frequency curves supplied by the Atmospheric Environment Service indicate that return periods for these events were generally about 2 years.

2.2 Summary of Causes of the Flood

A review of the five "classical" reasons in relation to the 1979 flood indicate that these had little effect. The autumn precipitation was near normal, and although frost penetration did occur before the first snowfall it did not remain beyond the latter part of March. Snow accumulation during the winter months was a little less than normal and declined through March due to high temperatures and excessive rainfall. "Spring" was not late and sudden, but was early and somewhat protracted, occurring coincident with the high water conditions that occurred on March 28 and 29. In effect the flood of late April, 1979 was a post "spring" event. Its causes can be attributed to:

1) Fairly modest but fairly concentrated rainfall occurring over a large portion of the basin, averaging about 43 mm.

2) A significant but variable and very "ripe", late season snow pack averaging about 94 mm of water equivalent.
3) A rapid rise in daily temperatures which caused accelerated snowmelt rates coincident with the concentrated rainfall.
4) A highly saturated watershed resulting from antecedent rainfall and snowmelt.
5) High base flows in most streams in the Basin.
6) Much of the available natural ground and surface water storages were already near their nominal capacities immediately prior to the flood.

2.3 Snowmelt

Potential snowmelt during the period April 24 to May 7 was estimated using equations developed by the United States Army Corps of Engineers (Ref. 5). These equations are a simplified application of the energy budget approach to the snowmelt problem. For each day one of two equations was used depending on whether significant rain fell on the snow covered area. The two equations are as follows:

$$M_1 = 0.074\ (0.53\ T'_a + T'_d)$$

$$M_2 = (0.074 + 0.007\ P_r)\ T_a + 0.05$$

where M_1 is the total daily snowmelt during rain free periods (inches); T'_a is the difference between the air temperature measured at the 10 feet level and the snow surface temperature (°F); T'_d is the difference between the dewpoint temperature measures at the 10 feet level and the snow surface temperature (°F): M_2 is the total daily snowmelt during periods of significant rain: T_a is the temperature of saturated air at the 10 feet level; and P_r is the rate of precipitation (inches per day).

Both equations are applicable to heavily forested areas. The first equation was applied in all cases where the daily rainfall was less than 5 mm. This included all days except the 28th to 30th of April. It was assumed in all cases that the snow surface temperature was 0°C. The temperatures and precipitation required for the calculations were estimated from analyses of these fields provided by the Flood Forecast Centre. Attention was focussed on the northern snow covered part of the Basin.

The results of the calculations are displayed graphically in Figure 2.3. Over the two week period the total estimated potential snowmelt was 314 mm. Much of this snowmelt (203 mm) occurred in the five day period ending at 1200 GMT on April 30.

For comparative purposes, the daily temperature extremes at selected meteorological stations during the period April 24 to May 7 are presented in Table 2.5 and shown in Figure 2.4. The prolonged period with mean temperatures well above 0°C is evident at all stations with the highest temperatures generally occurring on the 27th or 28th. It should also be noted that the warm temperatures were accompanied by relatively high dewpoint temperatures of about 10°C. The occurrence of about 5 mm of rain on the day ending 1200 GMT April 28, along with the high temperatures, resulted in the calculated peak in snowmelt on the date.

2.4 The Synoptic Weather Pattern - April 24 to May 7, 1979

On April 24 a deep low pressure system located east of Newfoundland moved slowly northeastward. A ridge of high pressure had moved over the Saint John River Basin by the morning of the 25th. The ridge had moved east of the district by the morning of the 26th and a southerly flow of air began over the Basin ahead of a frontal trough of low pressure extending from Lake Huron to northern Quebec. Mean temperatures reported from the northern snow covered sections of the Basin rose to about 10°C on the 26th and to near 15°C on the 27th as the southerly flow of mild, moist air continued. A few showers occurred in the northeastern part of the Basin early on the 27th.

By the morning of the 28th the frontal trough had advanced to lie north - south through western Maine. A low moved rapidly northward along the front through central Quebec and a new low formed near Portland, Maine. Rain to the east of the front had moved into most of the Basin by the evening of the 28th and became heavy in some areas during the night. Temperatures continued near 14°C in the northern part of the Basin.

The front remained nearly stationary in the vicinity of the western Maine border until the morning of the 29th. The Portland low moved into

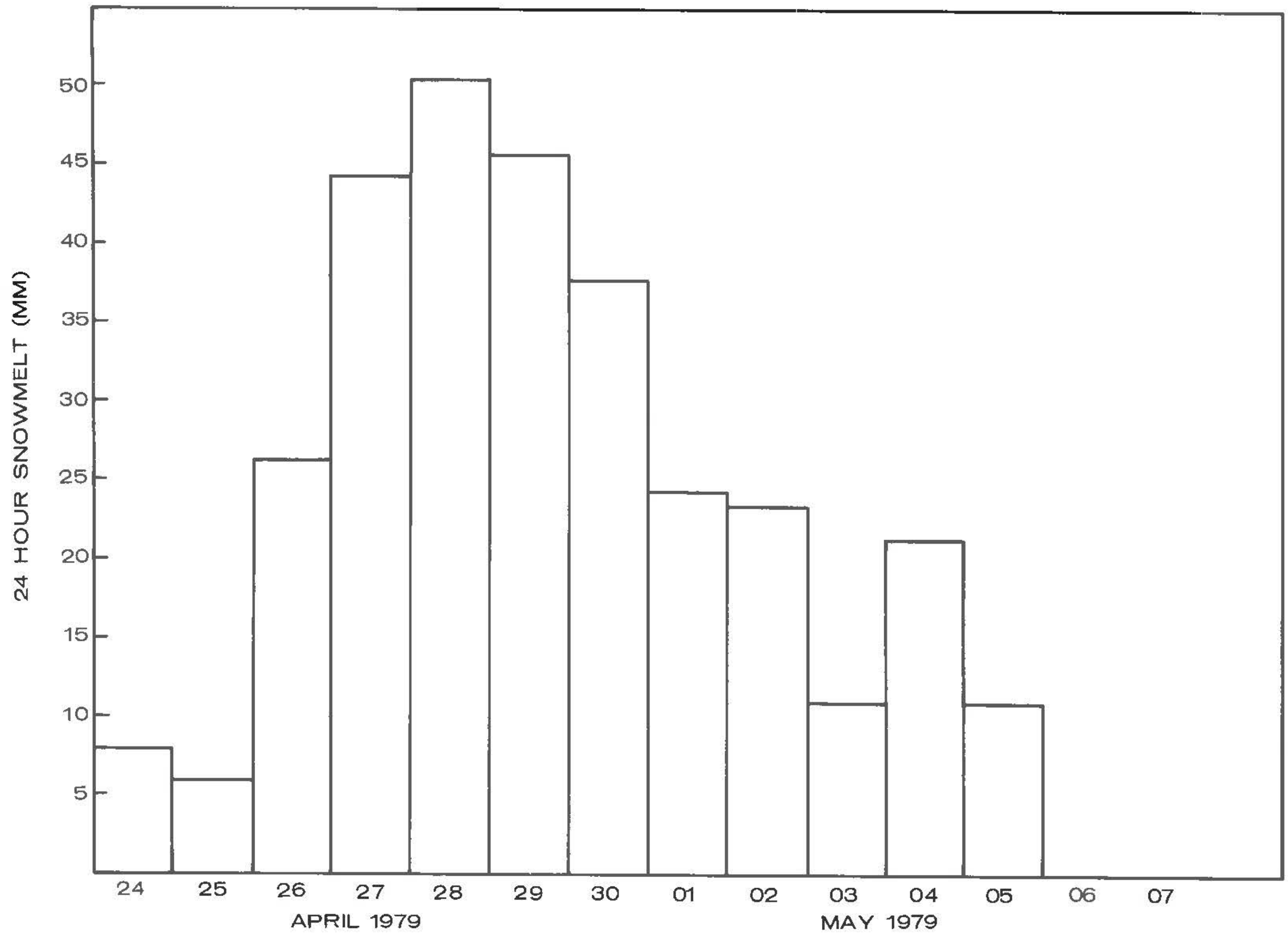


FIGURE 2-3 ESTIMATED AVERAGE POTENTIAL SNOWMELT FOR THE SAINT JOHN RIVER BASIN ,FOR DAY ENDING AT 1200 GMT.

DAILY TEMPERATURE EXTREMES APRIL 24 - MAY 7, 1979

	FREDERICTON		SAINT JOHN		CARIBOU		RIVIERE DU LOUP		CHARLO		PORTLAND		CLAYTON LK	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
24	15.5	0.5	15.2	1.3	14.4	1.7	11.6	2.5	11.6	-0.3	18.9	1.7	13.9	-3.3
25	16.2	-0.3	13.4	-0.1	15.6	0.6	9.7	0.0	11.6	-2.6	13.9	5.6	17.2	-3.9
26	18.1	0.7	13.6	1.5	23.3	6.7	22.6	4.4	11.7	1.1	16.1	6.7	21.7	6.1
27	19.9	0.0	20.1	9.2	17.8	12.2	16.0	8.1	15.0	1.2	11.7	9.4	16.7	1.7
28	17.3	13.4	19.8	9.6	13.9	12.2	15.2	7.1	9.2	5.0	11.1	7.8	13.9	11.1
29	15.4	11.3	12.6	9.6	13.9	11.7	12.8	6.3	6.9	4.7	17.2	9.4	14.4	8.3
30	13.0	9.4	10.4	6.8	11.7	8.3	13.0	2.8	5.6	3.3	18.9	7.2	16.7	3.3
01	11.6	7.6	9.3	6.6	11.1	5.6	5.8	2.0	6.3	3.2	11.7	5.6	16.1	2.8
02	10.6	5.0	10.7	5.4	8.9	4.4	5.8	3.0	9.8	3.8	15.0	2.2	8.3	2.2
03	14.2	3.9	12.7	4.5	15.6	3.9	13.8	3.4	16.1	3.2	16.7	0.0	16.7	-2.8
04	8.0	3.8	7.4	4.1	8.3	6.7	9.6	3.6	7.1	0.8	18.9	9.4	15.0	5.6
05	11.0	1.3	9.7	1.4	9.4	0.6	5.0	0.3	7.0	1.5	13.9	4.4	8.9	6
06	12.7	0.6	12.5	0.0	10.0	0.0	10.0	-0.5	4.2	0.0	17.2	2.8	11.7	-2.8
07	17.2	4.0	16.5	2.8	15.0	2.8	14.6	2.6	15.0	1.1	21.7	0.0	13.9	-1.7

Table 2.5

All Values in ^{o}C

FIGURE 2-4 DAILY TEMPERATURE EXTREMES AT SELECTED METEOROLOGICAL STATIONS

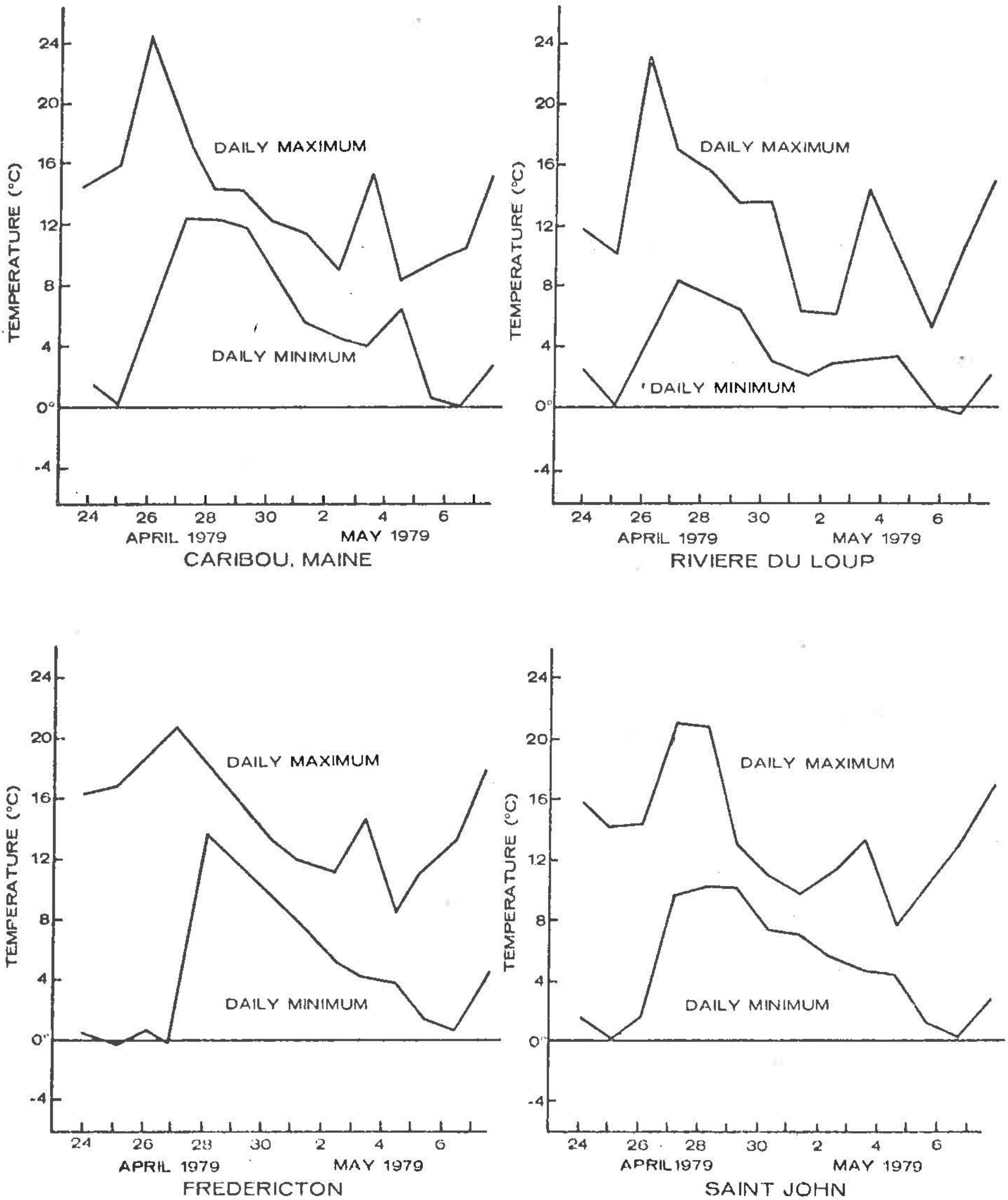
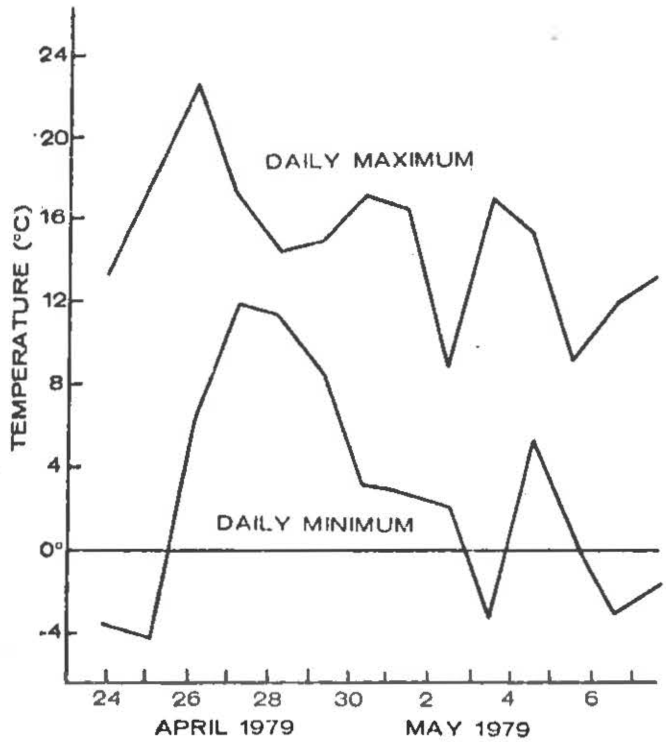
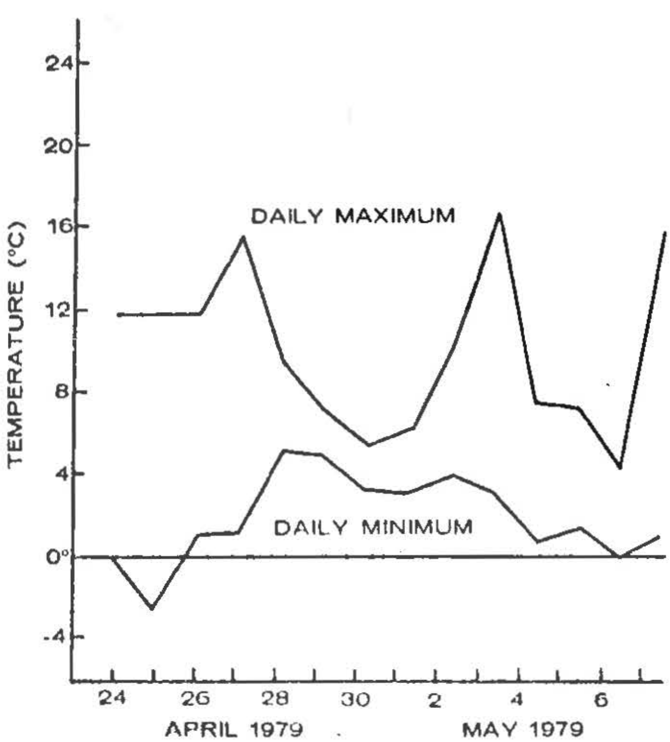


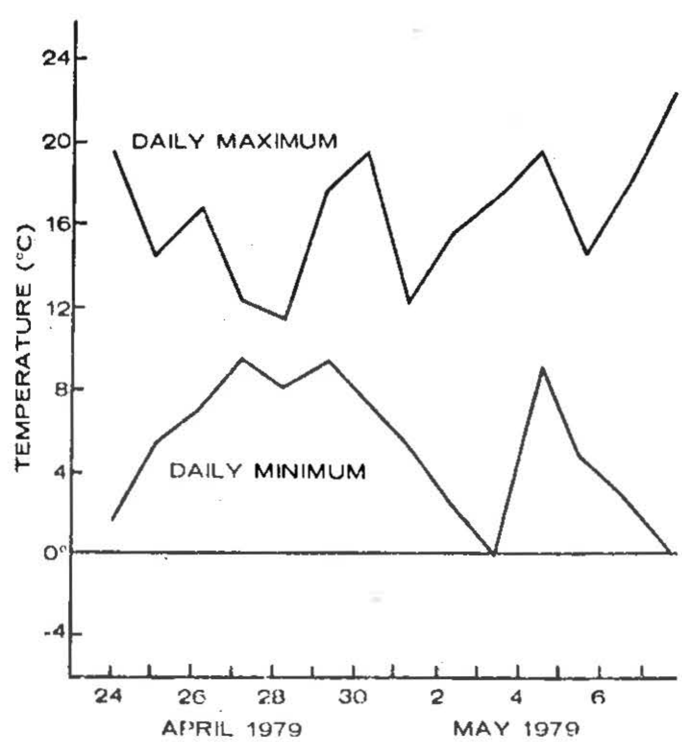
FIGURE 2-4 (CONTINUED) DAILY TEMPERATURE EXTREMES AT SELECTED METEOROLOGICAL STATIONS



CLAYTON LAKE, MAINE



CHARLO



PORTLAND, MAINE

central Quebec by midday on the 29th and another low formed near Cape Cod and moved slowly eastward. Twenty-four hour rainfalls of 10 to 22 mm were reported over the northern half of the Basin on the morning of the 29th. The largest daily amount reported was 52.5 mm at Bon Accord, N.B. Temperatures dropped slightly in the rain but remained near 12°C in snow covered areas.

By the morning of the 30th the front had reached western New Brunswick with a weak low near Yarmouth, N.S.; 24 hour rainfalls near 20 mm were reported in the central parts of the Basin. Temperatures were lowering in the northwestern areas to approximately 10°C behind the front.

On the morning of May 1 the front was still analyzed as being in western New Brunswick but was dissipating rapidly. A 24 hour rainfall of 35 mm was reported in the southeastern part of the Basin but amounts were light upstream of Fredericton. A weak low was stationary in the Gulf of Maine. A second very weak cold front moved into the Basin from the west during the afternoon of the 1st and merged with the original frontal trough. Temperatures were gradually dropping into the 8°C range.

On May 2 an inverted trough of low pressure remained almost stationary through eastern New Brunswick. Precipitation amounts reported over the Basin were light to nil and temperatures were steady near 8°C.

On May 3 the last remains of the frontal trough gave way to a ridge of high pressure as cooler air moved over the Basin. Mean temperatures lowered to about 4°C over the northern areas.

Beginning on May 4 a frontal trough of low pressure moved into the western part of the Basin. This brought about 5 mm of rain to most parts of the Basin before it moved slowly east of the area on May 5. Mean temperatures increased to about 9°C ahead of this trough.

On May 6 and 7, the flow over the Basin was northwesterly. Skies cleared and temperatures lowered to near 3°C.

The major rainfall (and snowmelt) event leading to the flood peak was that which began on April 27 and continued through May 3. Figure 2.5 shows the synoptic situation on the morning of April 29, 1979. An isohyetal analysis of the total rainfall from April 27 through May 3 is

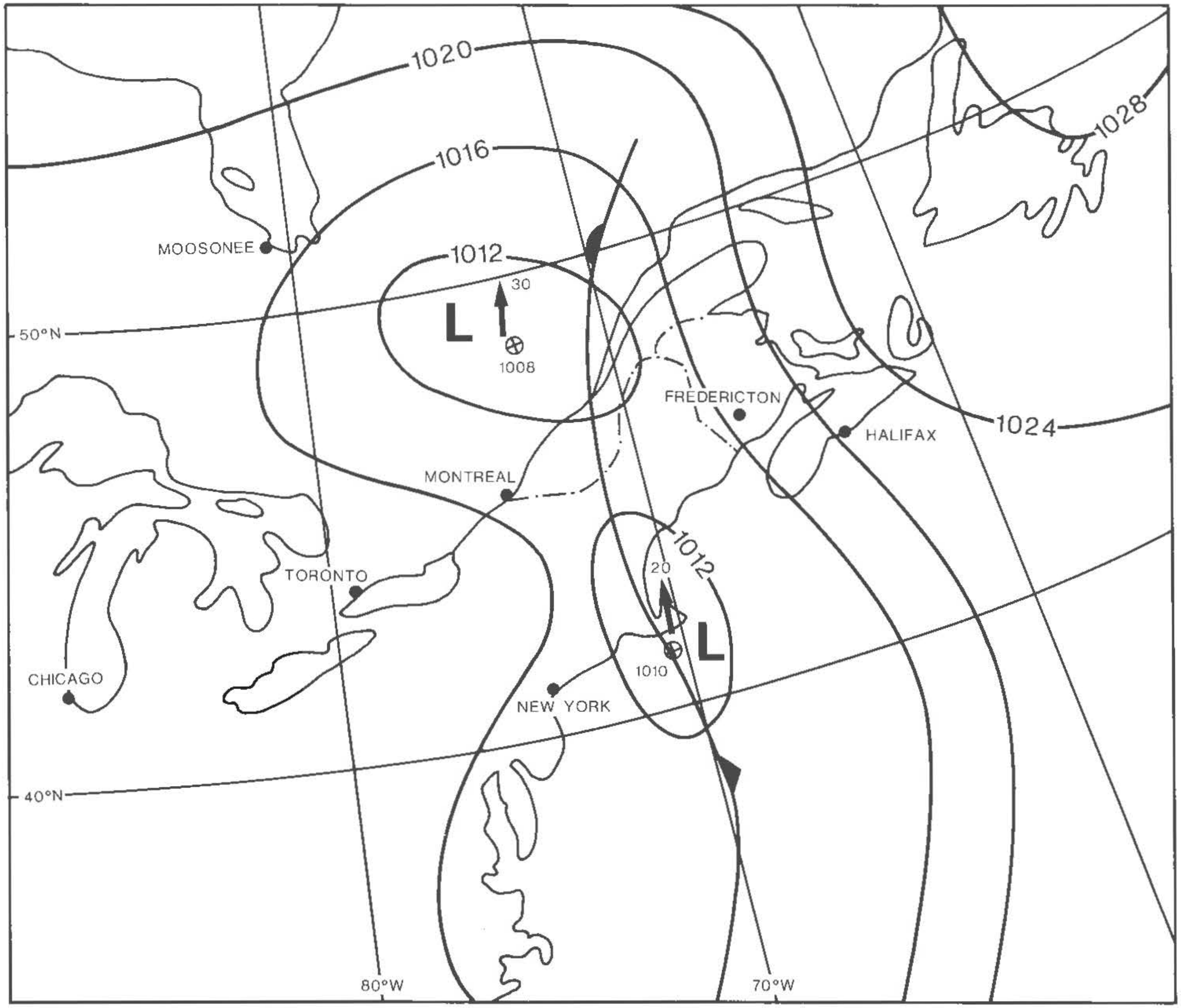


FIGURE 2-5 SYNOPTIC SITUATION ON APRIL 29, 1979

shown in Figure 2.6. This shows that the highest rainfall occurred in the northern and central parts of the Basin. The Bon Accord report of 96.2 mm was the highest in the Basin, but amounts of this magnitude were not widespread. The average precipitation over the Basin was approximately 50 mm. This is significantly less than in the record flood of 1973 when a relatively large part of the Basin received in excess of 75 mm. In the northern part of the basin, however, the contrast between the two events is not as large. Table 2.6 shows the 6 hours and accumulated rainfall at selected stations. This information is also presented in Figure 2.7.

It should be noted that the maximum rainfall associated with the storm fell to the southwest of the Basin in southern Maine. Flooding in the Saint John Basin would probably have been more serious had the precipitation pattern been shifted to the northeast.

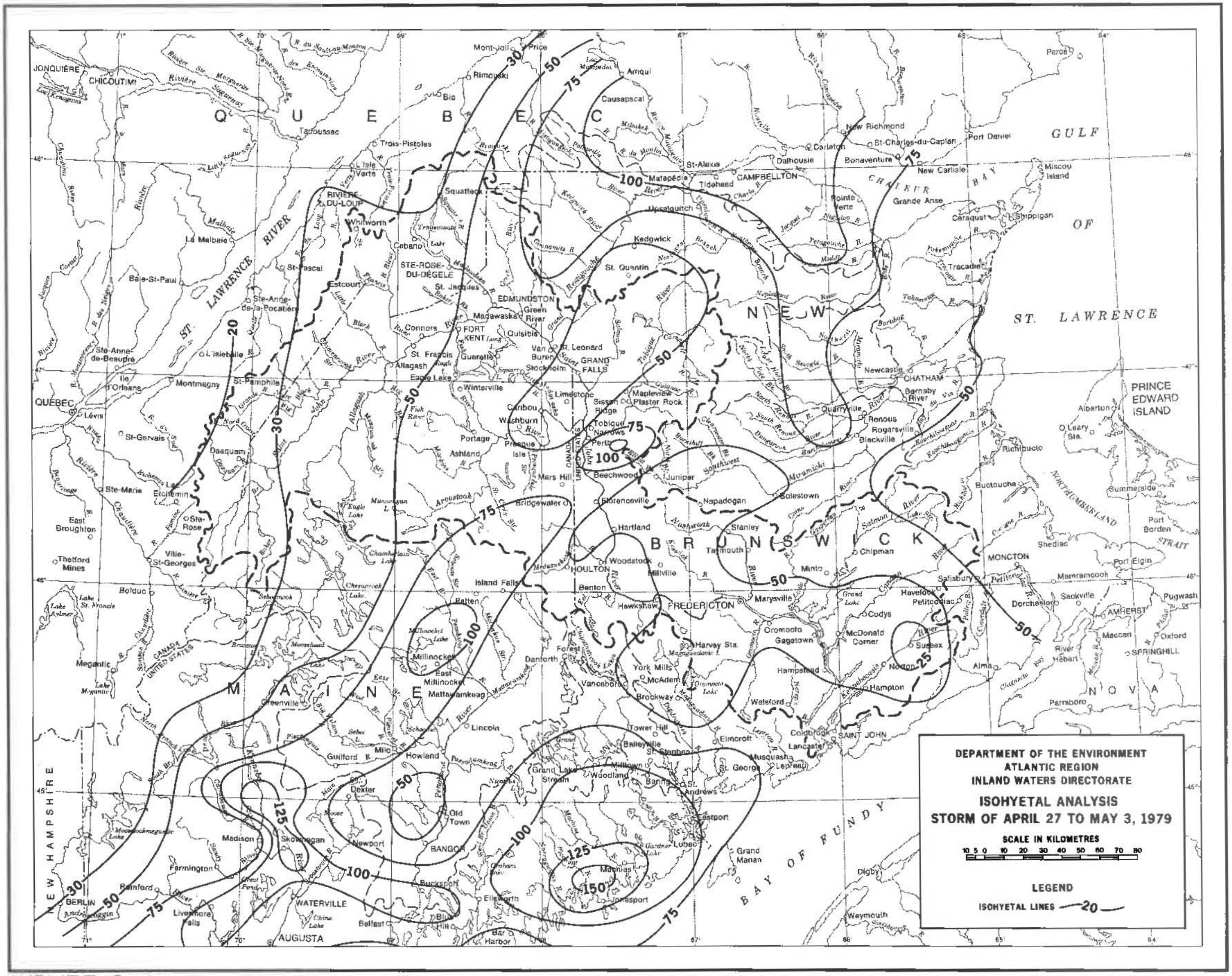

DEPARTMENT OF THE ENVIRONMENT
ATLANTIC REGION
INLAND WATERS DIRECTORATE
ISOHYETAL ANALYSIS
STORM OF APRIL 27 TO MAY 3, 1979
SCALE IN KILOMETRES
10 5 0 10 20 30 40 50 60 70 80
LEGEND
ISOHYETAL LINES 20
QUEBEC
NEW BRUNSWICK
MAINE
NOVA
NEW HAMPSHIRE
PRINCE EDWARD ISLAND
GULF OF ST. LAWRENCE
BAY OF FUNDY
CHALEUR BAY
NORTHUMBERLAND STRAIT
FREDERICTON
SAINT JOHN
MONCTON
BANGOR
EDMUNDSTON
CAMPBELLTON
CHATHAM
AUGUSTA
WATERVILLE
QUEBEC
CHICOUTIMI
JONQUIERE
CANADA
UNITED STATES

FIGURE 2-6

TABLE 2.6- Accumulated 6 Hour Rainfall (mm) at Stations in New Brunswick, Quebec and Maine

Date / Time / Station	April 27		April 28				April 29				April 30				May 1				
	08-14	14-20	20-02	02-08	08-14	14-20	20-02	02-08	08-14	14-20	20-02	02-08	08-14	14-20	20-02	02-08	08-14	14-20	20-02
Fredericton	0.0	0.2	0.8	0.8	4.2	6.4	6.4	7.0	7.6	8.8	17.9	32.9	32.9	33.1	33.9	37.5	38.9	39.5	40.2
Saint John	0.0	0.0	TR	0.6	0.6	0.6	0.6	2.8	15.0	21.0	24.0	27.0	27.4	27.8	31.0	36.2	38.7	39.9	40.9
Charlo	0.3	0.5	3.0	5.4	10.2	17.0	20.1	30.8	22.9	28.0	37.9	55.3	59.7	62.3	66.8	77.4	84.4	93.8	102.5
Chatham	0.0	0.0	0.2	0.4	0.4	0.4	0.4	0.4	3.0	7.3	18.3	26.5	40.3	42.8	53.0	58.2	58.2	58.5	62.3
Moncton	0.0	0.0	0.0	0.0	TR	TR	TR	TR	1.4	7.2	8.8	10.2	20.6	26.2	27.4	27.6	27.6	27.6	31.0
Sherbrooke	TR	TR	0.8	5.0	5.0	5.0	7.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	11.6	11.9	14.3
Quebec	7.2	7.6	9.4	12.0	12.0	12.0	12.0	15.2	15.4	15.4	15.4	15.4	15.4	15.4	15.4				18.5
Mont Joli	0.2	0.8	0.8	0.8	1.0	1.0	3.0	4.4	9.2	15.4	16.0	16.8	18.0	18.2	18.2	19.8	20.4	21.6	23.4
Riviere du Loup	6.4	7.4	8.8	9.0	9.3	9.3	13.1	21.2	22.2	22.2	22.2	22.2	22.2	22.2	22.2	22.2	22.2	22.2	26.8
Caribou	2.0	2.3	2.3	3.1	5.1	12.0	14.8	17.1	29.8	30.8	30.8	31.1	31.4	31.4	31.4	31.9	32.4	32.4	33.2
Portland	37.6	56.9	72.1	73.4	43.4	73.7	74.7	74.7	74.7	74.7	80.3	80.6	80.6	80.6	80.6	80.6	80.6	80.6	80.6

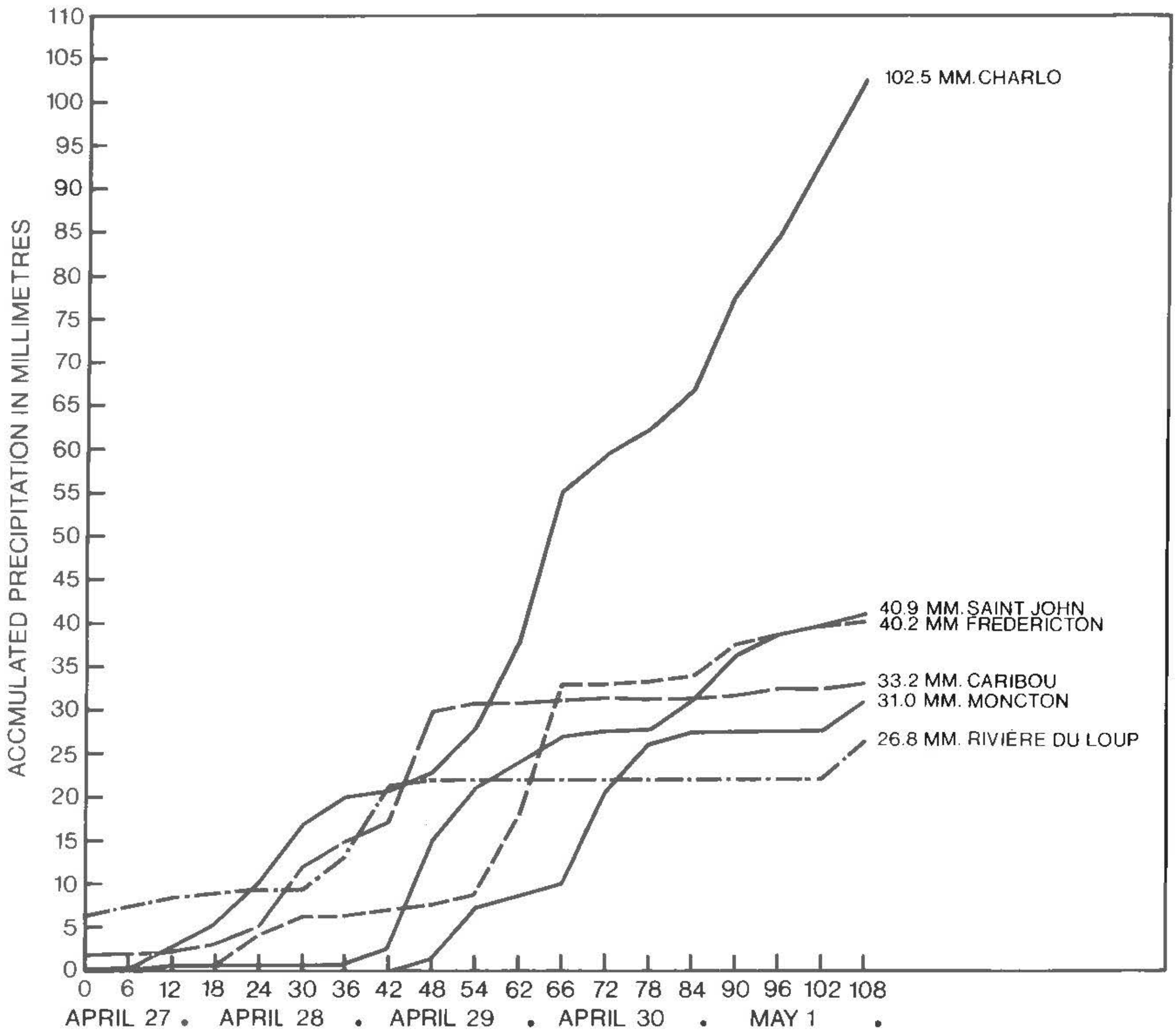


FIGURE 2-7 MASS CURVES OF RAINFALL

CHAPTER 3

CHRONOLOGY AND PROGRESS OF THE FLOOD

This chapter describes the changing conditions of streams within the Saint John River Basin through the period April 10 to May 15, 1979. The upper Basin above the Mactaquac Dam is treated separately from the lower Basin, downstream of the dam. This approach was taken because of basic differences in the two reaches. The lower Basin reach is esturarial in nature, complicated by the action of the "Reversing Falls" together with a large volume of off-channel storage. Consequently, discharge is not measured at main stem gauging stations on the lower reach except for the Mactaquac gauge just downstream from Mactaquac Dam. Water levels are the prime concern in this reach of the river. A complete list of hydrometric gauging stations in operation during the flood period is given in Tables 4.1 and 4.2 in Chapter 4. A map showing the locations of these stations appears as Figure 4.1.

3.1 Saint John River Above Mactaquac Dam

Hydrographs of discharges recorded at several hydrometric stations along the main stem of the Saint John River and on the larger tributaries for the period April 10 - May 15 are shown on Figures 3.1 to 3.4.

These four figures illustrate that the discharges remained relatively steady for the period from April 10 until April 21 as a result of snow melt. On April 21 temperatures throughout this portion of the basin began to rise resulting in a steady increase in discharge at most stations. This trend continued to April 26. During this period there was very little rain reported in the upper portion of the Basin. As the frontal system began influencing the Basin on April 27, the resulting rain and snow melt over the next few days caused water levels and discharges to increase significantly. Most streams reached their peak discharge on April 30.

The recorded peak discharges at various stations in the upper portion of the Basin are shown on Figure 3.5, a time-oriented schematic diagram. These peak discharges were dependent upon the timing and amount of precipitation, the available natural and artificial storage and the remaining snowpack. Generally, the progression of the recorded peaks moved from west to east

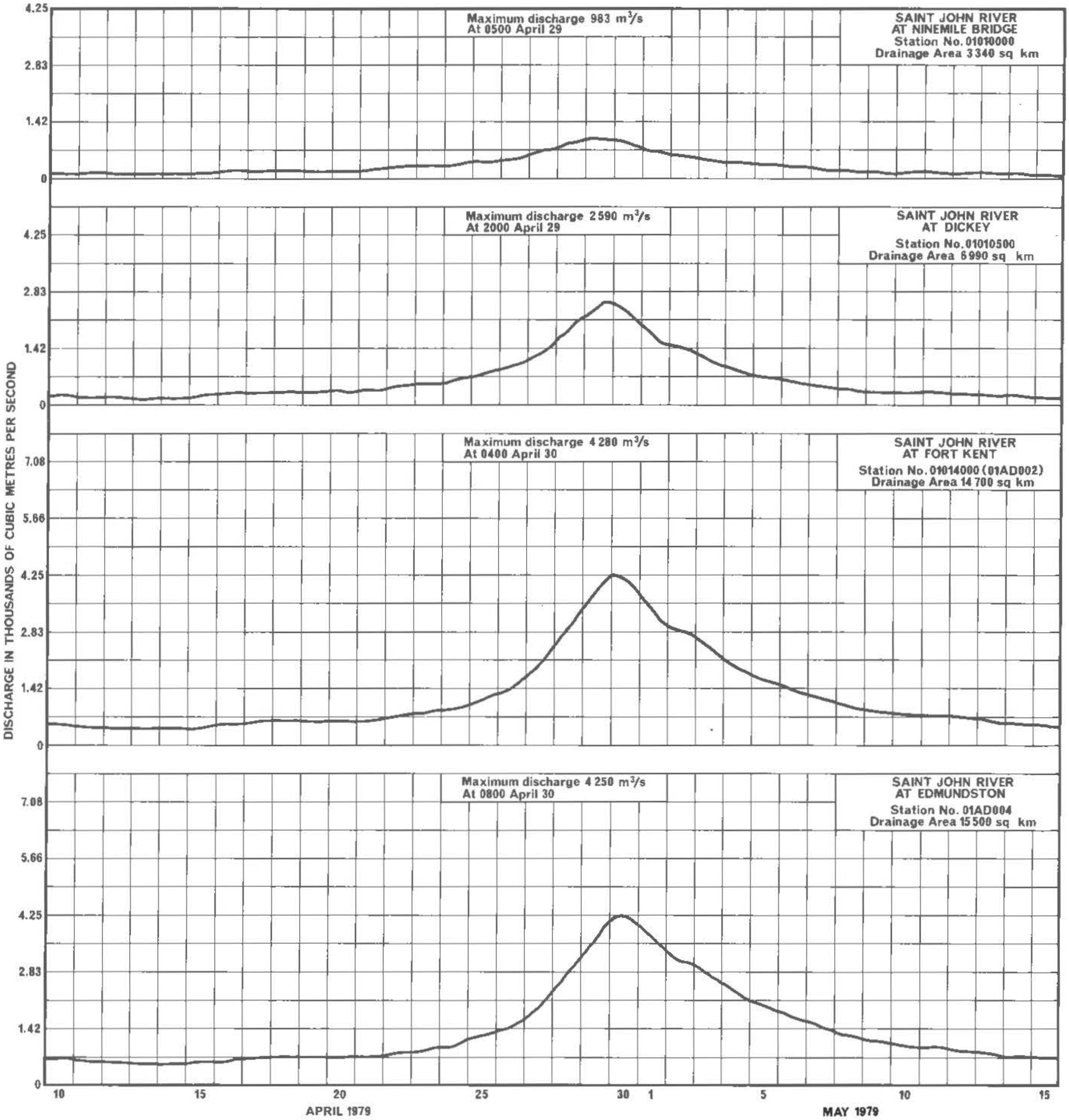


FIGURE 3-1 HYDROGRAPHS OF STREAMFLOW FOR SAINT JOHN RIVER ABOVE GRAND FALLS

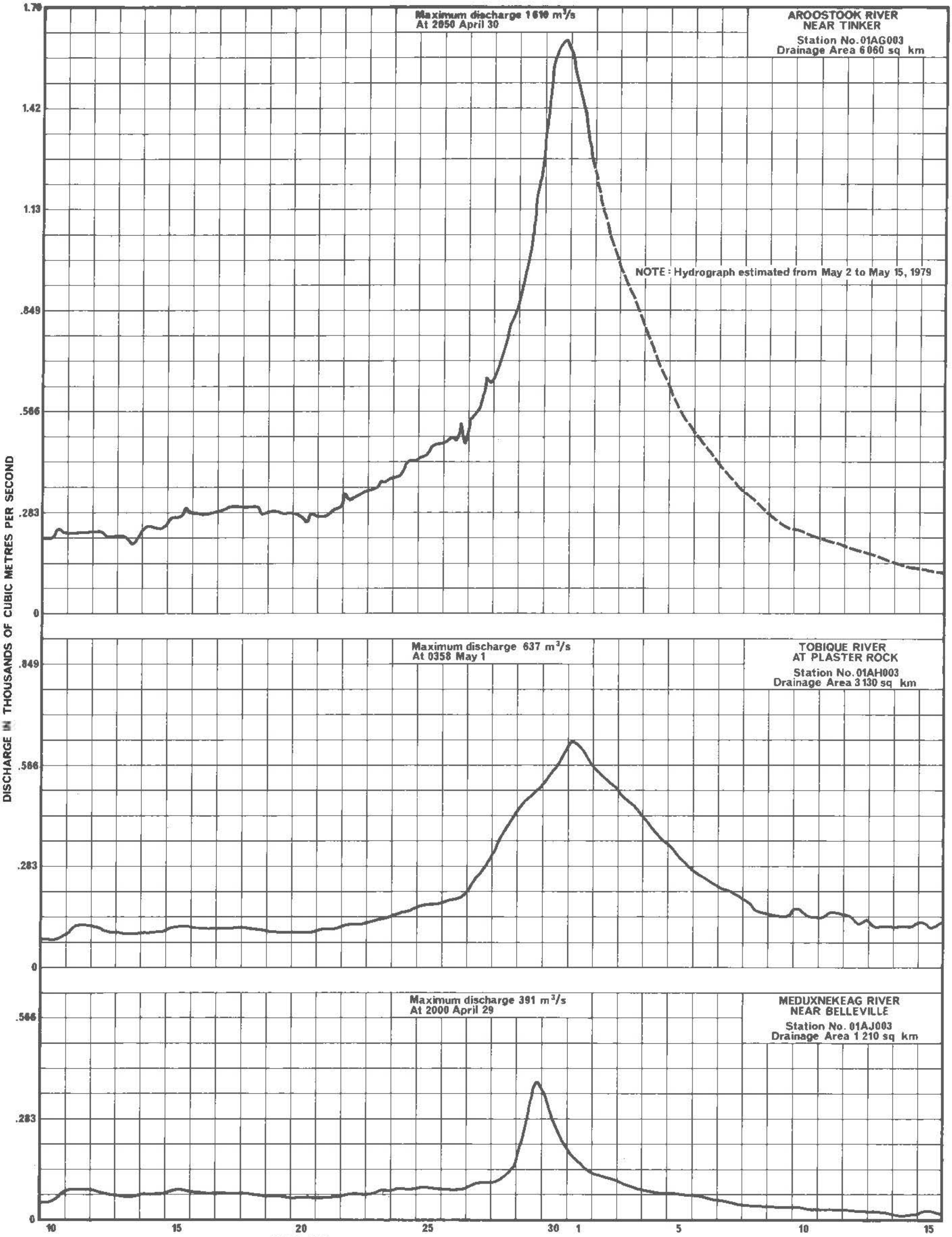


FIGURE 3-2 HYDROGRAPHS OF STREAMFLOW FOR TRIBUTARIES OF SAINT JOHN RIVER BELOW GRAND FALLS

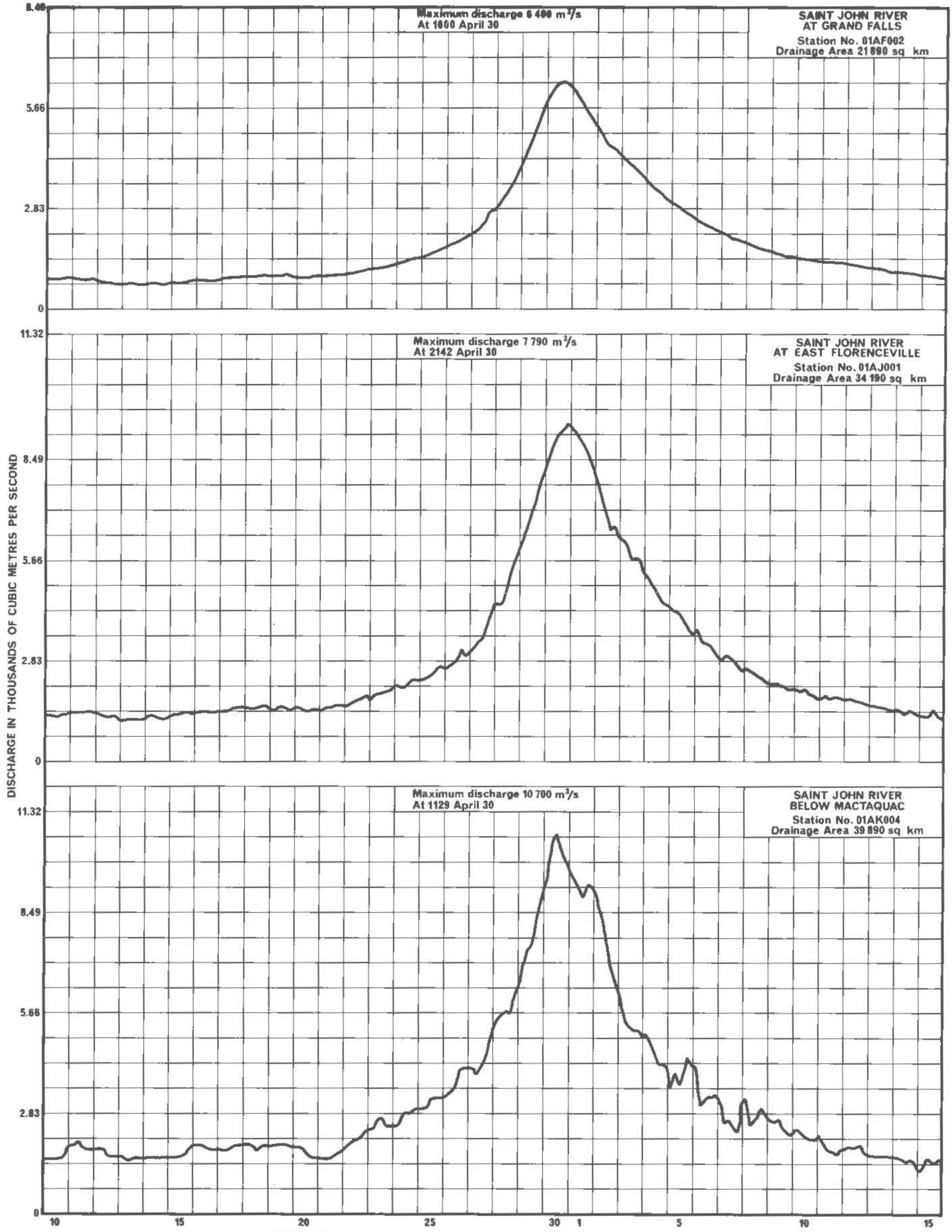


FIGURE 3-3 HYDROGRAPHS OF STREAMFLOW FOR SAINT JOHN RIVER ABOVE FREDERICTON

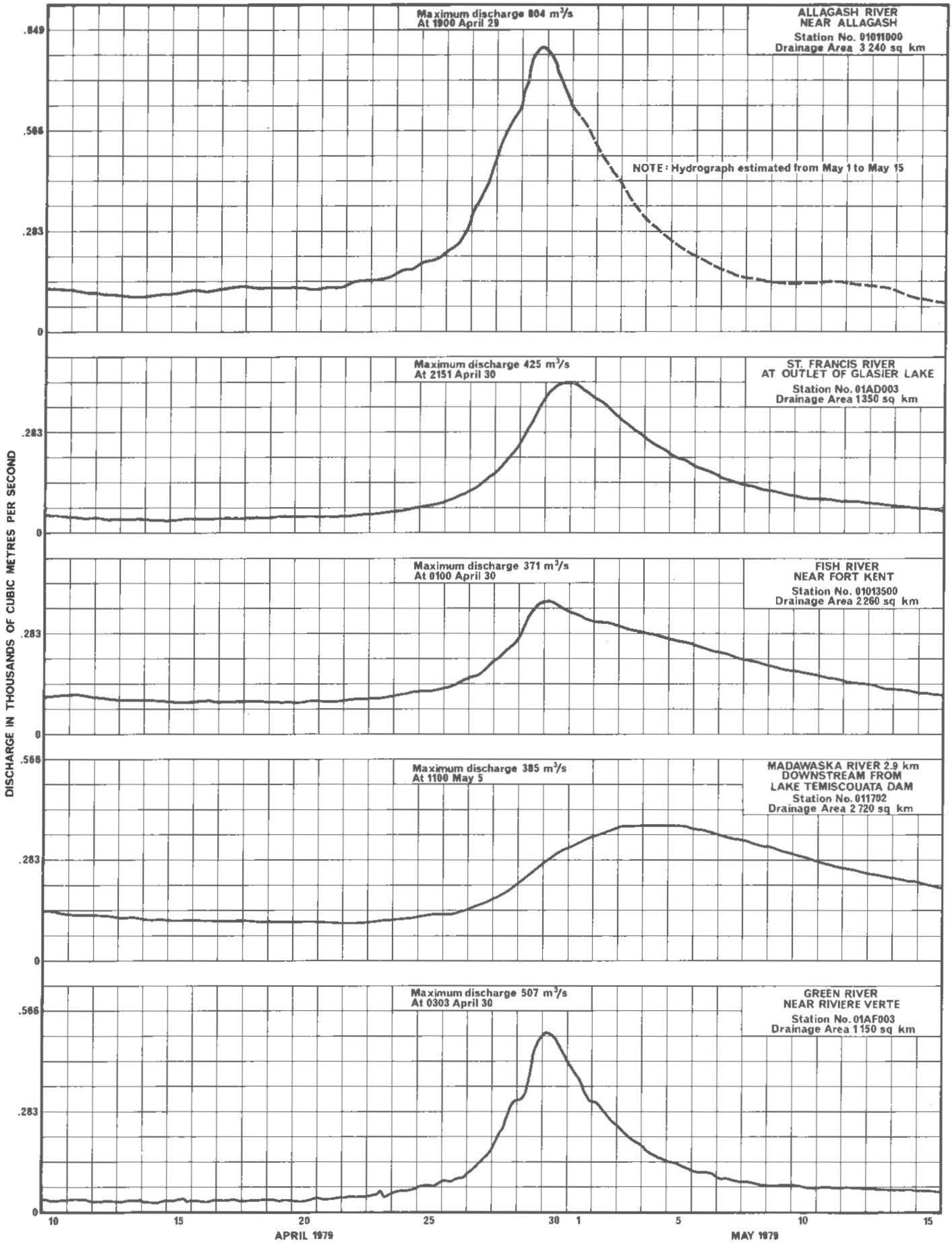


FIGURE 3-4 HYDROGRAPHS OF STREAMFLOW FOR TRIBUTARIES OF SAINT JOHN RIVER ABOVE GRAND FALLS

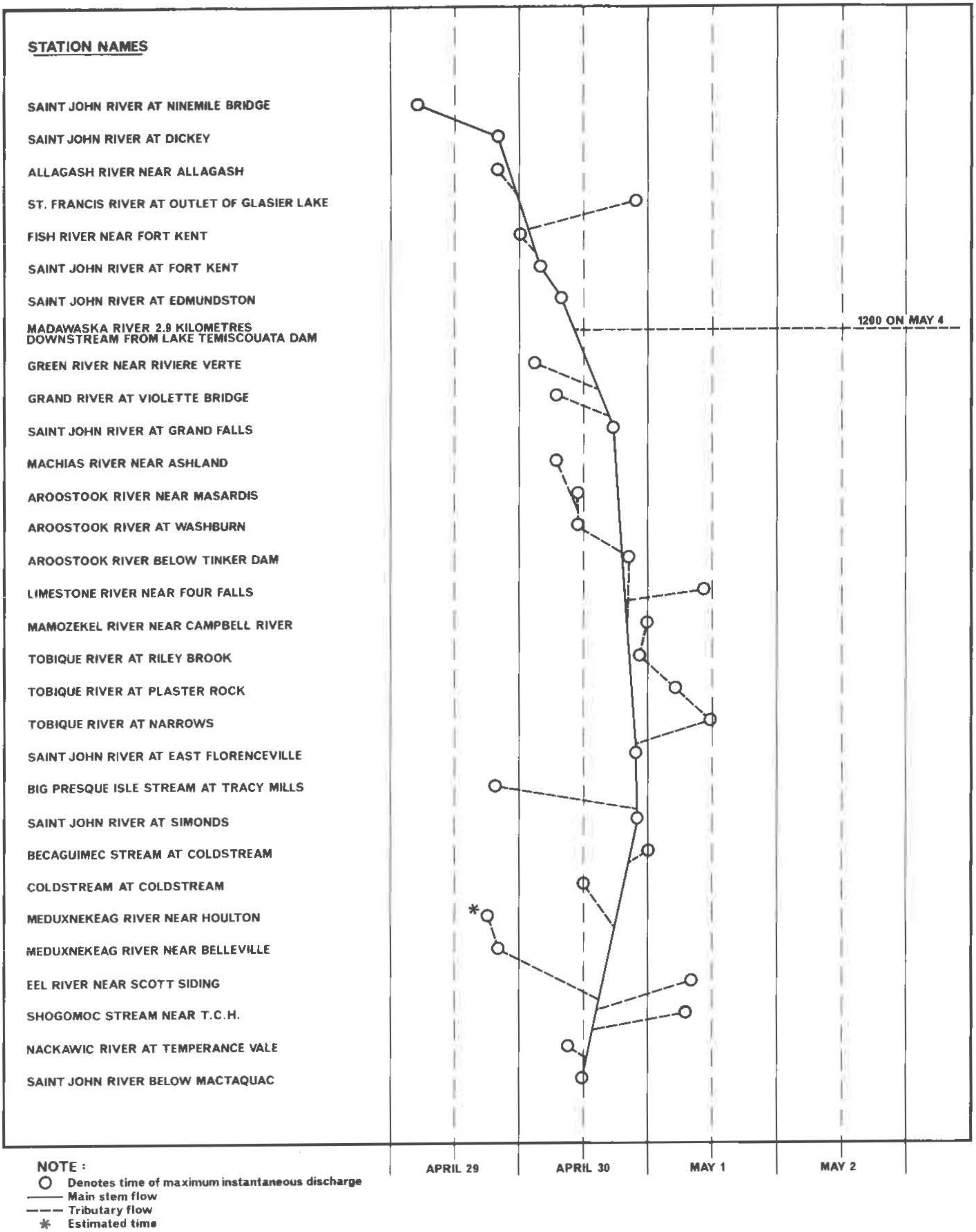


FIGURE 3-5 TIME-ORIENTED SCHEMATIC OF RECORDED PEAK DISCHARGES FOR STATIONS ABOVE FREDERICTON

following the storm movement and from upstream to downstream as channel routing allowed.

The peak discharges along the main stem of the Saint John River progressed in a downstream direction to the Mactaquac head pond. The maximum instantaneous discharge at the Mactaquac hydrometric station located just downstream of the Mactaquac Dam occurred 11 hours in advance of the peak discharge recorded at East Florenceville due to regulation of the outflow from the dam in advance of the inflow to the head pond.

The maximum instantaneous discharge at the St. Francis River gauge was somewhat delayed due to lake storage, while that at the Madawaska River gauge flow did not peak until May 4 because of regulation of storage reservoirs. The recorded peak on the Limestone River occurred on May 1 apparently due to localized rain late in the day on April 30. Due to the timing of the precipitation, the recorded peaks on the Tobique River Basin occurred later than those on the Aroostook River Basin.

The tributaries to the Saint John River between East Florenceville and Mactaquac did not contribute as significantly to the main stem discharge as did the upstream contribution. The peak discharges at these tributary stations were only about 40% - 50% of those recorded during the March 26, 1979 event.

3.2.1 Saint John River below Mactaquac Dam

The hydraulic characteristics of this lower reach of the Saint John River are described in detail in the publication "New Brunswick Flood, April - May 1973" (Ref. 6)

The physical characteristic of this part of the river are unique. A narrow gorge at the mouth of the river restricts outflow and causes a buildup of water upstream. Under normal summer flow conditions and low water in Saint John harbour, the direction of flow through the gorge is outwards. However, at high water there is an inward flow through the gorge. Thus the gorge is named "Reversing Falls". During extended periods of low flow, water elevations are frequently as low as 0.3 metres above mean sea level just upstream of the Falls and 0.9 metres above mean sea level at Fredericton. In contrast, the maximum levels reached during the 1973 flood were 5.3 metres above the Falls and 8.6 metres at Fredericton.

Flooding characteristics of the Saint John River downstream of the Mactaquac Dam are complicated by the large bodies of water along and adjacent to the river (see Figure 3.6). As flood waters are backed up by the Reversing Falls, they are stored not only in the main channel but also in Kennebecasis Bay, Belleisle Bay, Washademoak Lake, the Grand Lake system and the Oromocto River Valley. Thus, a relationship between river flow and stage is difficult to define. Water levels reached during a particular flood are a function of runoff volume as well as antecedent water levels of the main channel and of the large bodies of water adjacent to the river. A given volume of runoff from the Basin may, therefore, produce varying water levels.

The relationship which exists between Grand Lake and the Saint John River further complicates the flood problem for the lower portion of the river. Under normal conditions the flow between Grand Lake and the Saint John River fluctuates back and forth through the Jemseg River depending on the difference in elevation between the two systems. As the Saint John River rises during flood periods, water continually flows in a reverse direction through the Jemseg River into Grand Lake. On a year round basis, however, there is a net outflow from Grand Lake.

The flood plain to the north of the Saint John River in the Portobello Creek and French Lake areas is at a low elevation (about 3 metres above mean sea level). The Trans-Canada Highway, built on a natural levee on the north bank of the river, serves as a dyke for this area at medium stages by preventing the natural overflow of the Saint John onto its flood plain. As the river rises and increases the stage in Grand Lake, this area begins to flood by backflow from Grand Lake into French Lake and up Portobello Creek. However, when the river rises above the elevation of the Trans-Canada Highway, as happens about one in every two years, flood waters enter the flood plain area directly from the river and flow downstream into Grand Lake. At the peak of the 1973 flood several feet of water covered the Trans-Canada Highway. Flow was taking place across the highway onto the flood plain in the Maugerville area and, further downstream, back into the Saint John through the Jemseg River as well as directly across the highway.

3.2.2. Tributary Streamflows

The runoff from the tributary basins downstream of the Mactaquac Dam was

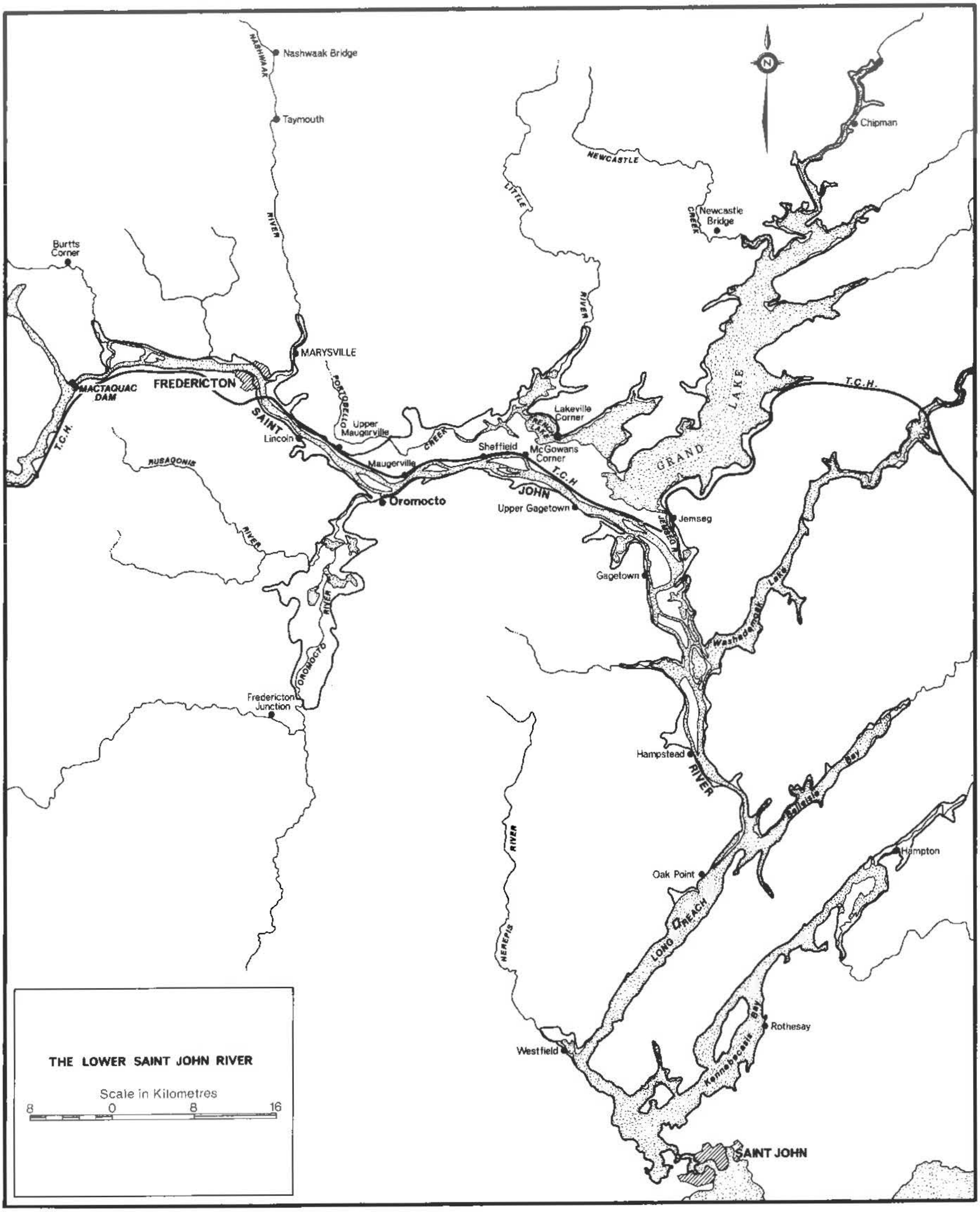


FIGURE 3-6 THE LOWER SAINT JOHN RIVER

not particularly high during the April 30 flood event. On April 15 the snow surveys indicated that much of the snowpack in this area, with the exception of the Nashwaak River Basin, contained less than 50 mm of water-equivalent. The peak for the year at all of these tributaries occurred either in January or March.

The recorded streamflow at five hydrometric stations on tributaries below the Mactaquac Dam are shown on Figure 3.7 for the period April 10 - May 15. All hydrographs have a small peak on April 10 - 11 resulting from the rain experienced over these basins on April 9 and 10. At all of these stations, with the exception of the Nashwaak River station, the peak discharge of April 10 - 11 is higher than that produced by the rains accompanying the April 30 event. The peak discharge on the Nashwaak River during the April 30 event was 620 m^3/s compared with the maximum instantaneous discharge for the year of 818 m^3/s on March 26, 1979.

3.2.3 Water Levels on the Saint John River Below Mactaquac Dam

The progress of the flood from April 10 to May 15 in the lower reach of the Saint John River is indicated on the water level hydrographs on Figure 3.8. The location of the gauges are shown on Figure 4.1.

The effect of the Bay of Fundy on the Saint John River discharge is described in the publication "New Brunswick Flood, April - May, 1973" (Ref. 6).

The influence of tides in the Bay of Fundy is immediately apparent on the hydrographs for the gauges at Indiantown and Oak Point. When the stage immediately upstream of the Reversing Falls is below about 3.7 metres above mean sea level, flow takes place in both directions across the Falls, depending on the fluctuation in the tide in Saint John Harbour. Above this elevation the flow is continuously outward through the Falls. However, this is considerably more discharge at low water than at high water causing a cyclical pattern of increase and lowering of water levels several kilometres upstream.

As the water level at the Mactaquac gauging station began to increase on April 21, water level fluctuations between 0.2 and 0.3 metres were recorded at Indiantown. This may be compared with the summer low fluctuations of about 0.6 metres. The fluctuations were gradually dampened as the estuary water levels began to rise. At the peak stage at Indiantown the fluctuation was about 0.1 metres. The tidal fluctuations were less evident at Oak Point and

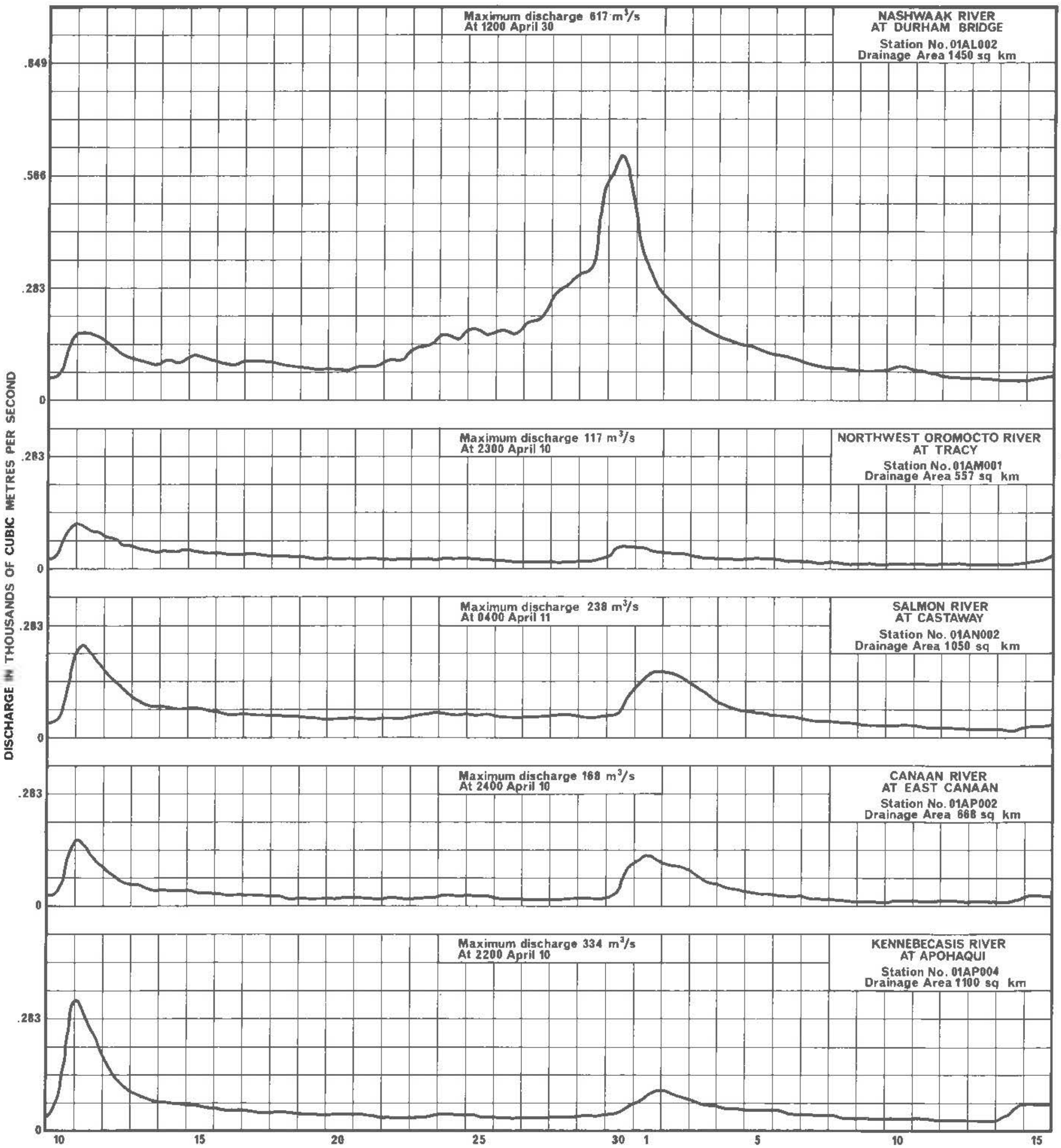


FIGURE 3-7 HYDROGRAPHS OF STREAMFLOW FOR TRIBUTARIES OF SAINT JOHN RIVER BELOW FREDERICTON

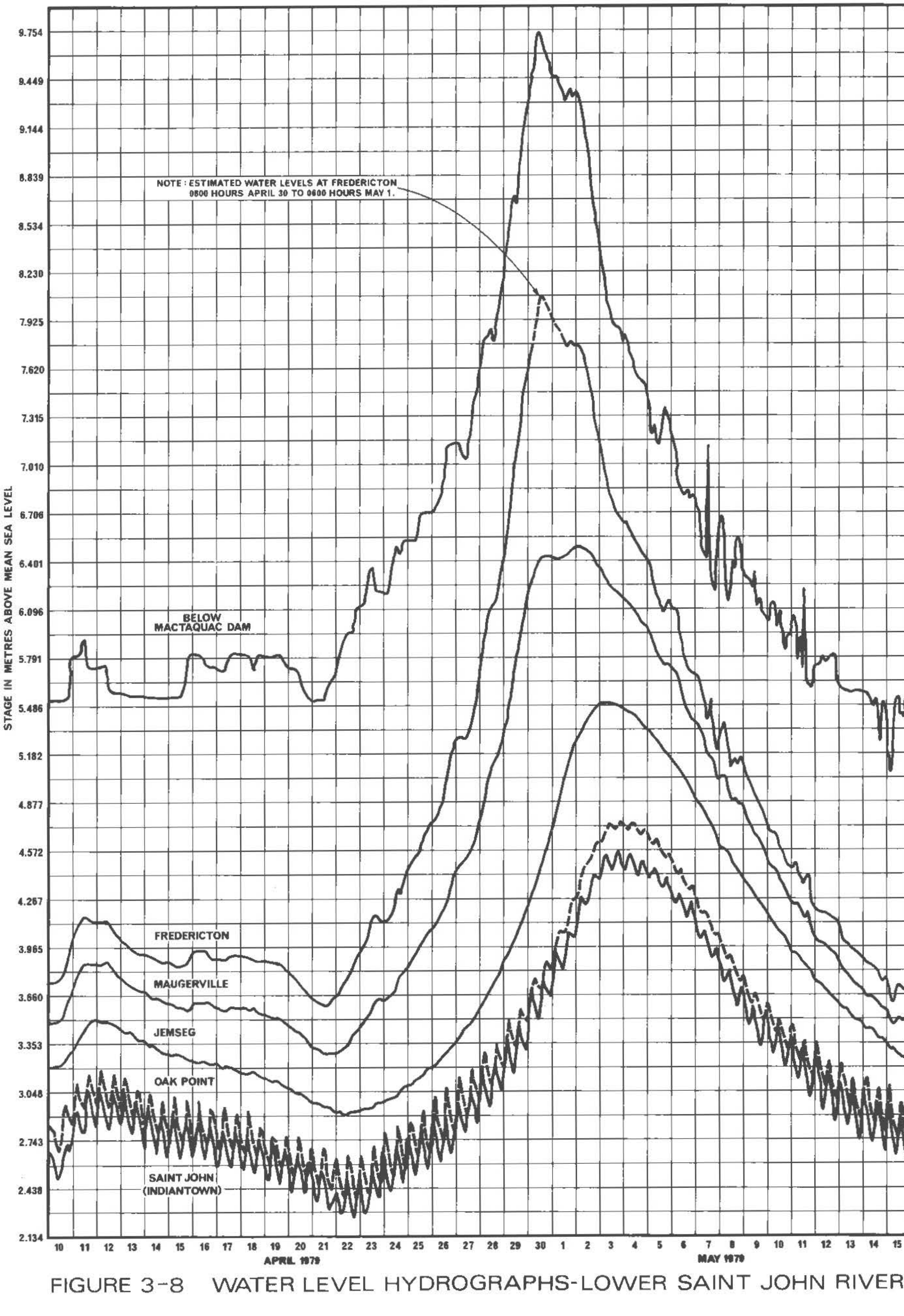


FIGURE 3-8 WATER LEVEL HYDROGRAPHS-LOWER SAINT JOHN RIVER

not evident at Jemseg between April 25 and May 14.

As can be noted on Figure 3.8, the stage at Mactaquac between April 10 and April 21 remained relatively stable. This is illustrated in the water level hydrographs recorded at the downstream stations, although the more abrupt changes are dampened at the more downstream sections. When the water level at the Mactaquac gauge began to rise on April 21 as a result of increased discharges from the Mactaquac Dam, the stage at the various water level stations downstream to Saint John responded accordingly. The releases from the dam were increased significantly on April 27 with the commencement of rain. The rate of rise at the Mactaquac station increased substantially, peaking on April 30.

The peak water levels recorded at stations on the Saint John River downstream of the Mactaquac Dam followed the peak at the Mactaquac gauging station except for the Fredericton gauge which peaked on April 30. The maximum water level at Maugerville actually occurred early on May 2, reflecting the secondary peak which occurred at Mactaquac late on May 1. The water levels recorded at the stations downstream of Maugerville, lagging the Maugerville peak in time, occurred on May 3.

Shown on Figure 3.9 are the profiles of water levels of the Saint John River downstream of the Mactaquac Dam recorded at midnight on the days before and after the flood crest.

These profiles indicate how the water surface slope for each day changed as the volume of water stored in the Saint John River Estuary increased during the flood. The hypothetical profile of the maximum instantaneous stage recorded at each station is also shown.

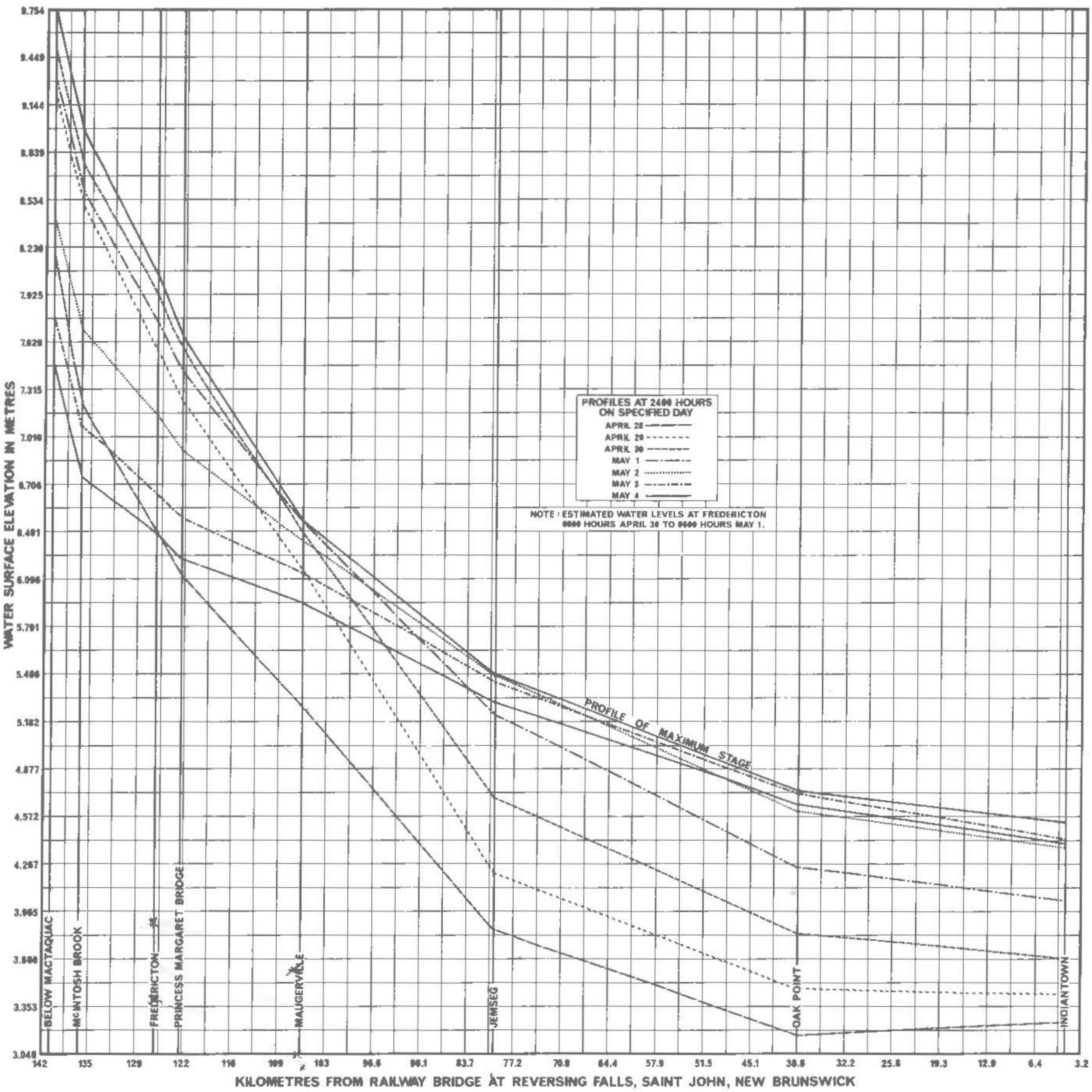


FIGURE 3-9 WATER SURFACE PROFILES-LOWER SAINT JOHN RIVER

CHAPTER 4

FLOOD MAGNITUDES

There are many factors to consider in evaluating the magnitude of a flood. Historically, a significant amount of research has centered around the statistical analysis of peak streamflows. For many rivers such as the Saint John, however, a number of other factors like the volume and timing of runoff and antecedent conditions of in-channel and off-channel storage also play a role in the duration and magnitude of flooding. Many of these factors can be integrated and expressed in terms of flood elevation for which there exists a substantial data base along the lower reach of the river. There are certain problems in assigning probabilities to water levels. Factors such as changing morphological and ice regimes cause the data to exhibit non-stationarity making it virtually impossible to apply standard statistical techniques.

The following discussion concentrates on defining the magnitude of the 1979 flood on the basis of peak streamflows; however, flows, water levels and flood volume are also compared with previous floods. The impact of upstream reservoir storage is also assessed. Finally, the components of the 1979 flood hydrograph are assessed at selected stations.

4.1 Peak Discharges

A map showing the locations of all hydrometric gauging stations operating within the Basin is shown as Figure 4.1. Maximum daily mean and instantaneous discharges during the spring of 1979 are given in Table 4.1 for all streamflow gauging stations in New Brunswick, Quebec and Maine which lie within the Saint John River Basin. The maximum daily mean discharge for the period of record at each gauging station prior to 1979 is included in the table for comparative purposes.

It will be noted that the 1979 maxima of record were exceeded at four of the five hydrometric stations on the main stem of the Saint John River above and including the gauge at Grand Falls and at hydro-

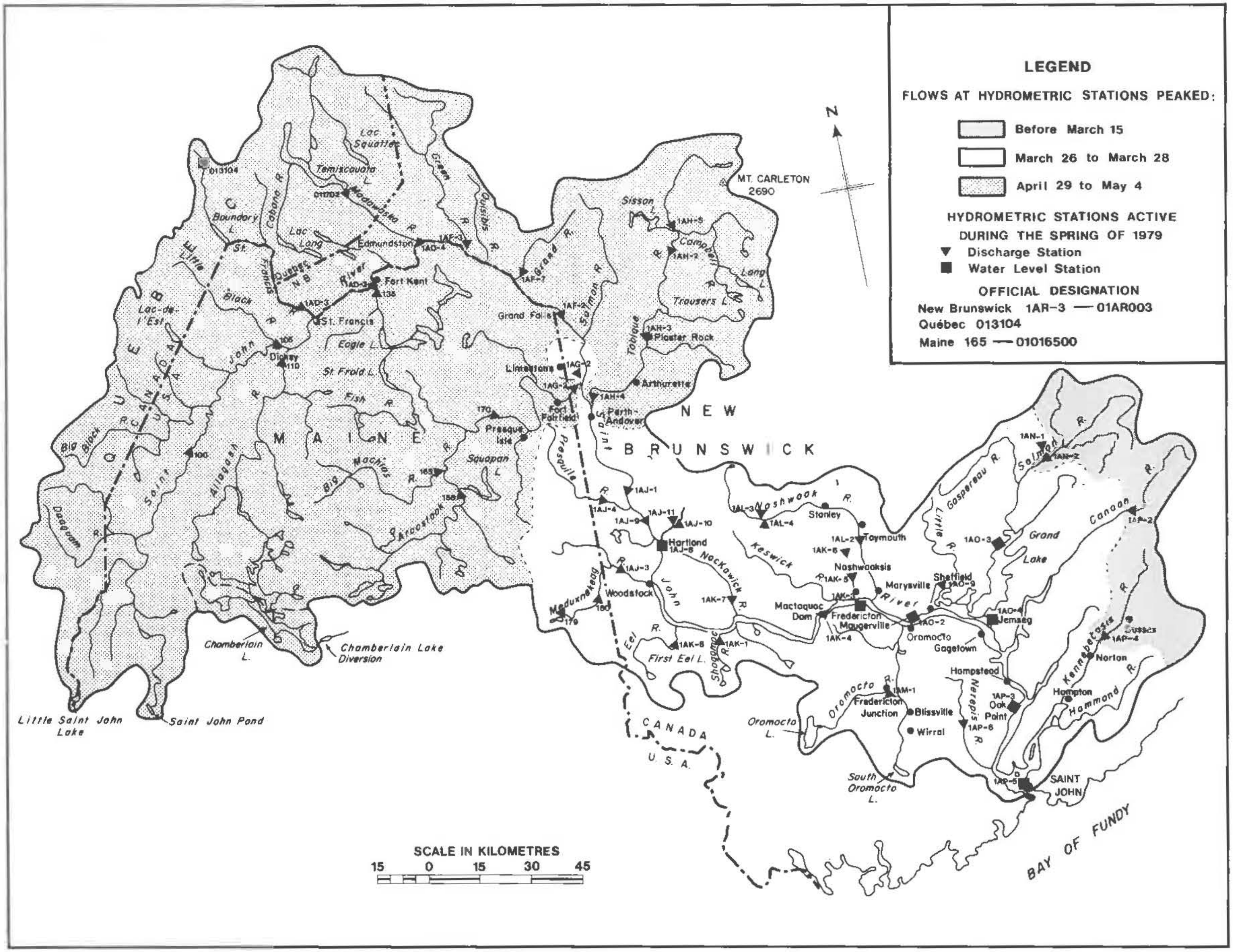


FIGURE 4-1 LOCATION OF HYDROMETRIC STATIONS AND TIMING OF PEAK FLOWS SPRING OF 1979 - SAINT JOHN RIVER BASIN

TABLE 4.1- SUMMARY OF PEAK DISCHARGES AT STREAM GAUGING STATIONS IN NEW BRUNSWICK, QUEBEC AND MAINE

SAINT JOHN RIVER BASIN

Station Number	Station Name	Drainage Area (km^2)	Period of Record	Maximum Daily Mean Discharge prior to 1979		Maximum Daily Mean Discharge During 1979		Maximum Instantanueous Discharge 1979			
				Date	Discharge (m^3/s)	Date	Discharge (m^3/s)	Date	Time Ast	Discharge (m^3/s)	Unit Discharge ($m^3/s/km^2$)
01010000	Saint John River at Ninemile Bridge	3340	1950-79	May 1, 1974	1090	Apr 29	968	Apr 29	600	983	.294
01010500	Saint John River at Dickey	6990	1946-79	May 10, 1969	2020	Apr 29	2400*	Apr 29	2100	2590*	.371
01011000	Allagash River near Allagash	3240	1931-79	May 17, 1961	793	Apr 29	756	Apr 29	1400	804	.248
01AD003	St. Francis River at outlet of Glasier Lake	1350	1951-79	May 12, 1969	362	Apr 30	411*	Apr 30	2151*	425*	.315
01013500	Fish River near Fort Kent	2260	1929-79	Apr 30, 1973	442	Apr 30	360	Apr 30	0200	371	.164
01AD002	Saint John River at Fort Kent	14700	1926-79	May 16, 1961 Apr 30, 1973	3680	Apr 30	4130*	Apr 30	0315	4300*	.293
011702	Madawaska River 1.9 mi. down-stream from Lake Temiscouata Dam	2720	1919-79	May 19, 1974	442	May 4	383	May 4	1200	385	.142
01AD004	Saint John River at Edmundston	15500	1967-79	Apr 30, 1973	3740	Apr 30	4190*	Apr 30	1109	4250*	.274
01AF003	Green River near Riviere Verte	1150	1962-79	May 11, 1969	442	Apr 30	481*	Apr 30	0303	507*	.441
01AF007	Grand River at Violette Bridge	339	1977-79	May 11, 1978	71.4	Apr 30	115*	Apr 30	0600	126*	.372
01AF002	Saint John River at Grand Falls	21900	1930-79	Apr 30, 1973	5540	Apr 30	6260*	Apr 30	1741	6400*	.292
01015800	Aroostook River near Masardis	2300	1957-79	Apr 25, 1958	606	Apr 30	572	Apr 30	1100	578	.251

* new historic extreme discharge

TABLE 4.1- Continued

Station Number	Station Name	Drainage Area (km^2)	Period of Record	Maximum Daily Mean Discharge prior to 1979 Date	Discharge (m^3/s)	Maximum Daily Mean Discharge During 1979 Date	Discharge (m^3/s)	Maximum Instantaneous Discharge 1979 Date	Time Ast	Discharge (m^3/s)	Unit Discharge ($m^3/s/km^2$)
01016500	Machias River near Ashland	855	1951-79	June 29, 1954	374	Apr 30	292	Apr 30	0600	297	.294
01017000	Aroostook River at Washburn	4280	1930-79	Apr 30, 1973	1200	Apr 30	1050	Apr 30	1100	1070	.250
01AG003	Aroostook River below Tinker Dam	6060	1975-79	Apr 4, 1976	1280	Apr 30	1530*	Apr 30	2050	1610*	.266
01AG002	Limestone River at Four Falls	199	1967-79	Apr 29, 1973	69.9	Mar 26	45.9	Mar 26	1040	51.0	.256
01AH005	Mamozekel River near Campbell River	230	1972-79	Apr 29, 1973	92.0	May 1	59.6	Apr 30	2400	77.9	.339
01AH002	Tobique River at Riley Brook	2230	1954-79	May 28, 1961	606	May 1	442	Apr 30	2241	467	.209
01AHoo3	Tobique River at Plaster Rock	3130	1954-79	May 28, 1961	974	May 1	612	May 1	0358	637	.204
01AH004	Tobique River at Narrows	4330	1954-79	Apr 29, 1973	1220	May 1	847	-	-	-	-
01AJ001	Saint John River at East Florenceville	34200	1951-79	Apr 30, 1973	9170	Apr 30	9060	Apr 30	2142	9510*	.278
01AJ004	Big Presque Isle Stream at Tracey Mills	484	1967-79	Apr 29, 1973	220	Mar 26	204	Mar 26	1942	248	.512
01AJ009	Saint John River at Simonds	35000	1974-79	May 3, 1974	7530	May 1	8830*	Apr 30	2200	9150*	.261
01AJ010	Becaguimec Stream at Coldstream	350	1973-79	May 2, 1974	180	Mar 26	116	Mar 26	2101	168	.480
01AJ011	Cold Stream at Coldstream	156	1973-79	Apr 3, 1976	52.4	Mar 26	88.6*	Mar 26	1514	118*	.756

* new historic extreme discharge

TABLE 4.1- Continued

Station Number	Station Name	Drainage Area (km^2)	Period of Record	Maximum Daily Mean Discharge prior to 1979: Date	Maximum Daily Mean Discharge prior to 1979: Discharge (m^3/s)	Maximum Daily Mean Discharge During 1979: Date	Maximum Daily Mean Discharge During 1979: Discharge (m^3/s)	Maximum Instantaneous Discharge 1979: Date	Time Ast	Discharge (m^3/s)	Unit Discharge ($m^3/s/km^2$)
01017900	Marley Brook near Ludlow	3.8	1964-79	Apr 15, 1964	1.64	Mar 26	2.61*	Mar 26	0415	3.99	1.05
01018000	Meduxnekeag River near Houlton	453	1940-79	Apr 29, 1973	160	Mar 27	154	Mar 27	0100	174	.384
01AJ003	Meduxnekeag River near Belleville	1210	1967-79	Apr 29, 1973	510	Mar 26	402	Mar 26	2041	549	.454
01AK008	Eel River near Scott Siding	531	1974-79	Apr 5, 1976	114	Mar 28	108	Mar 27	2140	111	.209
01AK001	Shogomoc Stream near T.C.H.	234	1918-79	Apr 30, 1923	117	Mar 27	64.8	Mar 27	1147	66.3	.283
01AK007	Nackawic River at Temperance Vale	240	1967-79	Apr 29, 1973	113	Mar 26	87.8	Mar 26	2250	115	.479
01AK004	Saint John River below Mactaquac	39900	1967-79	Apr 30, 1973	11100	Apr 30	10100	Apr 30	1129	10700	.268
01AK006	North Nashwaaksis Stream at Sandwith's Farm	5.7	1966-79	Apr 29, 1973	2.14	Mar 26	1.77B	-	-	-	-
01AK005	North Nashwaaksis Stream near Royal Road	26.9	1965-79	Apr 29, 1973	14.2	Mar 26	11.3	Mar 26	1129	15.4	.572
01AL003	Hayden Brook near Narrows Mountain	6.7	1970-79	Apr 29, 1973	7.76	Mar 26	3.68E	-	-	-	-
01AL004	Narrows Mountain Brook near Narrows Mountain	3.9	1971-79	Apr 29, 1973	3.54	Mar 26	2.60B	-	-	-	-

* - new historic extreme discharge
A - manual reading
B - backwater condition existed
E - estimated flow

TABLE 4.1 - Continued

Station Number	Station Name	Drainage Area (km^2)	Period of Record	Maximum Daily Mean Discharge prior to 1979: Date	Maximum Daily Mean Discharge prior to 1979: Discharge (m^3/s)	Maximum Daily Mean Discharge During 1979: Date	Maximum Daily Mean Discharge During 1979: Discharge (m^3/s)	Maximum Instantaneous Discharge 1979: Date	Maximum Instantaneous Discharge 1979: Time AST	Maximum Instantaneous Discharge 1979: Discharge (m^3/s)	Maximum Instantaneous Discharge 1979: Unit Discharge ($m^3/s/km^2$)
01AL002	Nashwaak River at Durham Bridge	1450	1962-79	Feb 4, 1970	827	Mar 27	623	Mar 26	2138	818	.564
01AM001	Northwest Oromocto River at Tracey	557	1962-79	Feb 4, 1970	456	Mar 26	343A	-	-	-	-
01AN001	Castaway Brook near Castaway	34.4	1971-79	Dec 10, 1974	18.1	Mar 9	12.5B	-	-	-	-
01AN002	Salmon River at Castaway	1050	1974-79	Dec 10, 1974	289	Jan 4	227	Jan 3	1968	317	.302
01AQ009	Burpee Millstream near Fernmount	93.2	1976-79	Apr 21, 1978	18.5	Mar 26	59.7	Mar 26	1420	84.1	.902
01AP002	Canaan River at East Canaan	668	1925-41 1962-79	May 5, 1972	236	Jan 30 Mar 15	170B	-	-	-	-
01AP006	Nerepis River near Fowler's Corner	293	1976-79	Oct 2, 1977	64.6	Mar 26	172	Mar 26	1138	281	.959
01AP004	Kennebecacis River at Apohaqui	1100	1961-79	Apr 2, 1962	515	Jan 3	303	Jan 3	1940	464	.422

* - new historic extreme discharge
A - manual reading
B - backwater condition existed
E - estimated flow

metric stations on a number of tributaries to the Saint John River above the Beechwood Dam, including the St. Francis, Green, Grand and Aroostook rivers. Below the Beechwood Dam, streamflow on tributaries to the Saint John River peaked prior to the end of March. Despite this, streamflow as recorded at hydrometric stations on the main stem of the Saint John River below the Beechwood Dam peaked on April 30. Figure 4.1 provides an illustration of the timing of peak flows recorded during 1979 at hydrometric stations located within the Saint John River Basin.

In order to indicate the contribution of runoff from the tributaries to the main stem below the Beechwood Dam during the peak flooding period of April 29th to May 4th, the maximum daily mean and maximum instantaneous streamflow values and corresponding maximum instantaneous unit (area) discharges are listed in Table 4.2.

4.2 Flood Frequencies

The most widely accepted measure of the magnitude of a flood is its frequency expressed by a recurrence interval (or return period) in years. In order to estimate the recurrence intervals of the April-May 1979 flood, single station frequency analyses were carried out on streamflow data for all hydrometric stations in the Basin, including contributing areas in Quebec and Maine, with periods of record of at least ten years. It was not the objective of this study to present a regional flood frequency analysis since such analyses have already been carried out in recent years for the area under consideration (Ref. 7,8,9).

The frequency analyses were calculated using annual maximum daily mean flows in the computer program FDRPFFA (Ref. 9). Program FDRPFFA, developed by the Inland Waters Directorate, Environment Canada, provides flood frequency analyses for four distributions: Gumbel I, Log-Normal, Three Parameter Log-Normal and Log-Pearson Type III. Parameters are estimated using maximum likelihood theory; however, if the maximum likelihood method fails to give true solutions, a moment fit is employed. The data sets were checked for low outliers employing a test recommended by the United States Water Resources Council (Ref. 10). Where it was evident that the exclusion of a low outlier improved the fit of the distribution, this data point was removed from the set.

TABLE 4.2

SUMMARY OF MAXIMUM DISCHARGES FOR THE PERIOD APRIL 29-MAY 4 AT GAUGING STATIONS IN THE SAINT JOHN RIVER BASIN AT WHICH THE 1979 SPRING RUNOFF PEAK DISCHARGES OCCURRED PRIOR TO APRIL 29

				Maximum Daily Mean Discharge April 29-May 4		Maximum Instantaneous Discharge April 29-May 4			
Station Number	Station Name	Drainage Area (km^2)	Period of Record	Date	Discharge (m^3/s)	Date	Time AST	Discharge (m^3/s)	Discharge ($m^3/s/km^2$)
01AG002	Limestone River at Four Falls	199	1967-1979	May 1	20.2	May 1	0220	22.8	0.11
01AJ004	Big Presque Isle Stream at Tracey Mills	484	1967-1979	April 29	114	April 29	1934	132	0.27
01AJ010	Becaguimec Stream at Coldstream	350	1973-1979	April 30	68.8	April 30	2400	73.1	0.21
01AJ011	Cold Stream at Cold-stream	156	1973-1979	April 30	16.4	April 30	1200	17.3	0.11
01017900	Marley Brook near Ludlow	3.8	1964-1979	April 29	1.59	April 29	0615	2.44	0.64
01018000	Meduxnekeag River near Houlton	453	1940-1979	April 29	109E	April 29	-	125E	0.28
01AJ003	Meduxnekeag River near Belleville	1210	1967-1979	April 29	292	April 29	2010	394	0.33
01AL008	Eel River near Scott Siding	531	1974-1979	May 1	51.8	May 1	0817	52.1	0.10
01AK001	Shogomoc Stream near T. C. H.	234	1918-1979	May 1	26.6	May 1	0706	27.4	0.12
01AK007	Nackawic River at Temperance Vale	240	1967-1979	April 30	52.1	April 30	0914	56.4	0.23
01AK006	North Nashwaaksis Stream at Sandwith's Farm	5.7	1966-1979	April 30	0.79E	-	-	-	-
01AK005	North Nashwaaksis Stream near Royal Road	26.9	1965-1979	April 30	4.45	April 30	0756	5.47	0.20

TABLE 4.2 - Continued

01AL003	Hayden Brook near Narrows Mountain	6.7	1970-1979	April 29	3.11	April 29	1606	4.42	0.66
01AL004	Narrows Mountain Brook near Narrows Mountain	3.9	1971-1979	April 30	0.73	April 30	1116	0.90	0.23
01AL002	Nashwaak River at Durham Bridge	1450	1962-1979	April 30	578	April 30	1421	620	0.43
01AM001	Northwest Oromocto River at Tracey	557	1962-1979	April 30	49.0	April 30	1500	57.5	0.10
01AN001	Castaway Brook near Castaway	34.4	1971-1979	May 1	5.32	May 1	0945	5.72	0.17
01AN002	Salmon River at Castaway	1050	1974-1979	May 2	157	May 1	1742	170	0.16
01AØ009	Burpee Millstream near Fernmount	93.2	1976-1979	April 30	15.9E	-	-	-	-
01AP002	Canaan River at East Canaan	668	1925-1941 1962-1979	May 1	119	May 1	1445	129	0.19
01AP006	Nerepis River near Fowler's Corner	293	1976-1979	April 30	21.9	April 30	1220	24.6	0.08
01AP004	Kennebecasis River at Apohaqui	1100	1961-1979	May 2	92.0	May 1	2350	101	0.09

E - estimated flow

The frequency analyses indicated that the data sets for all but three stations displayed characteristics which yielded a superior fit using the Three Parameter Log-Normal frequency distribution; namely, that the coefficients of skew and kurtosis of the transformed data were close to 0.0 and 3.0 respectively. The three exceptions were the following hydrometric station records:

01AK005 North Nashwaaksis Stream near Royal Road
01AK006 North Nashwaaksis Stream at Sandwith's Farm
01AK007 Nackawic River at Temperance Vale

The data for these stations, which had only 12 to 14 years of record, were found to fit the Gumbel I distribution best. This was due to the highly positive skewness exhibited by the data.

Samples of the resulting flood frequency curves for selected hydrometric stations are shown in Figures 4.2 to 4.8. The analysis for the hydrometric station on the Saint John River below Mactaquac, station 01AK004 (Figure 4.8), was based upon the combined record of this station for the period 1967-1979 and the pro-rated record for the discontinued hydrometric station 01AK002 at Pokiok for the period 1919-1966. The maximum daily mean flow recorded during 1965 at the Pokiok gauge was eliminated from the analyses as it was found to be a low outlier.

Figures 4.2 to 4.8 also contain the 95 percent confidence bands. These bands indicate the possible error in the estimated discharge associated with a particular return period.

Based upon these single station flood frequency curves, the return period of the 1979 flood, for the period April 29 - May 4, was determined at selected hydrometric stations as shown on Table 4.3. All estimated return periods presented in Table 4.3 are based on the Three Parameter Log-Normal distribution.

For hydrometric stations located on the main stem of the Saint John River, the estimated return period of the maximum daily mean discharges recorded between April 29 and May 4 (actually all maxima on the main stem occurred on either April 29th or April 30th) increased rapidly

01AD003 ST. FRANCIS R. AT OUTLET OF GLASIER LAKE

THREE PARAMETER LOG-NORMAL DISTRIBUTION-WITH 95 PCT CL

PARAMETERS ESTIMATED BY MAXIMUM LIKELIHOOD

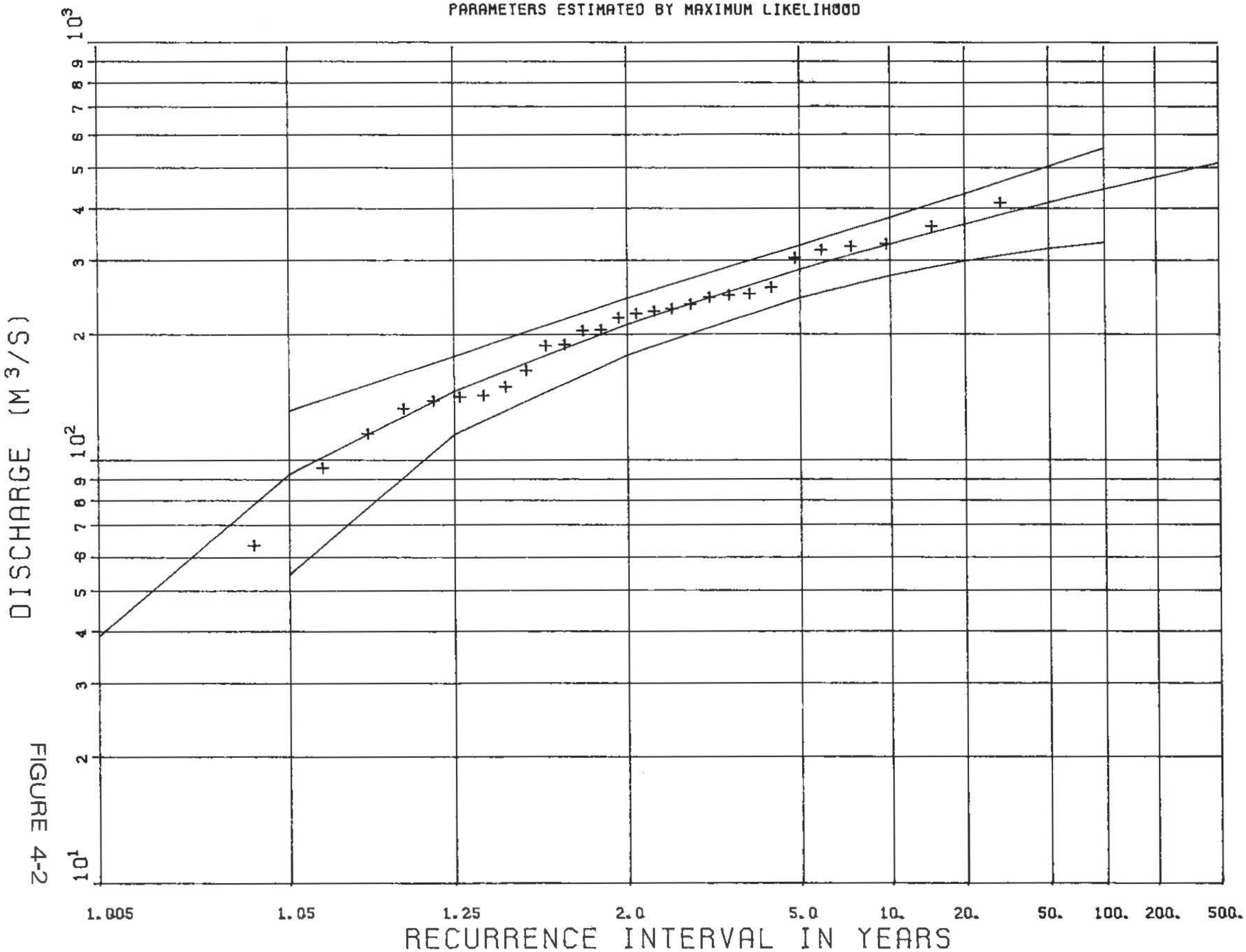


FIGURE 4-2

01AD002 SAINT JOHN RIVER AT FORT KENT

THREE PARAMETER LOG-NORMAL DISTRIBUTION-WITH 95 PCT CL

PARAMETERS ESTIMATED BY MAXIMUM LIKELIHOOD

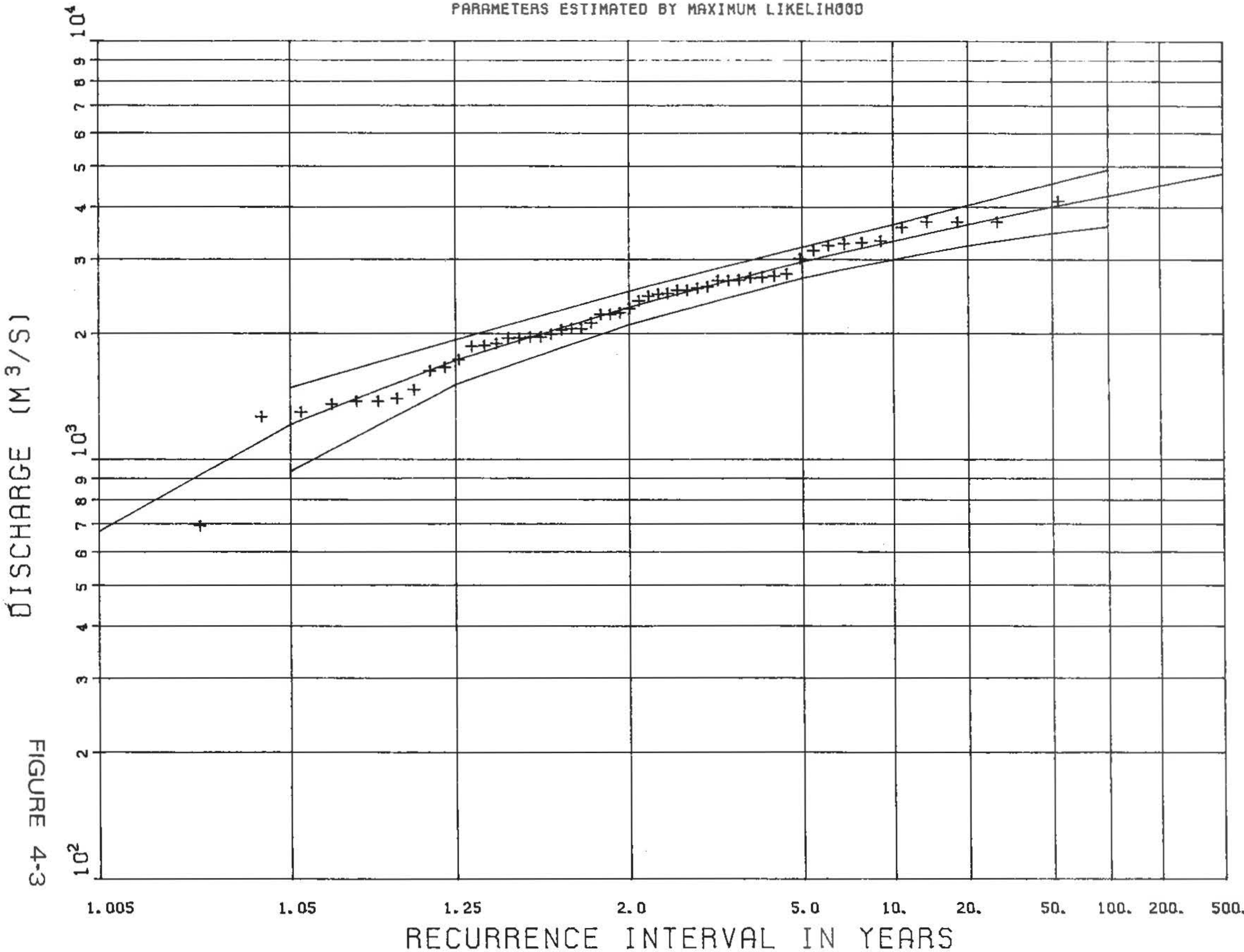


FIGURE 4-3

1011000 ALLAGASH RIVER NEAR ALLAGASH

THREE PARAMETER LOG-NORMAL DISTRIBUTION-WITH 95 PCT CL

PARAMETERS ESTIMATED BY MAXIMUM LIKELIHOOD

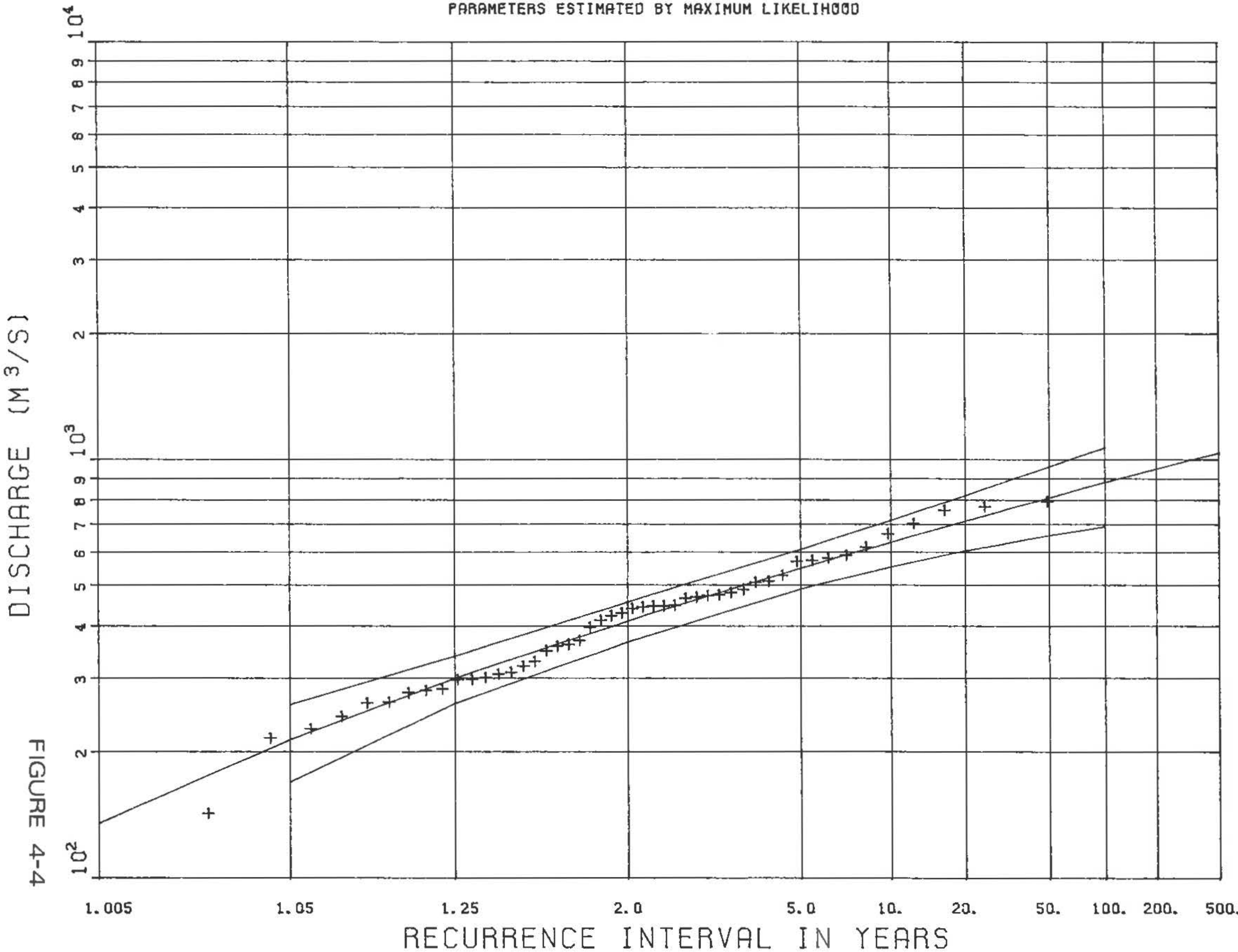
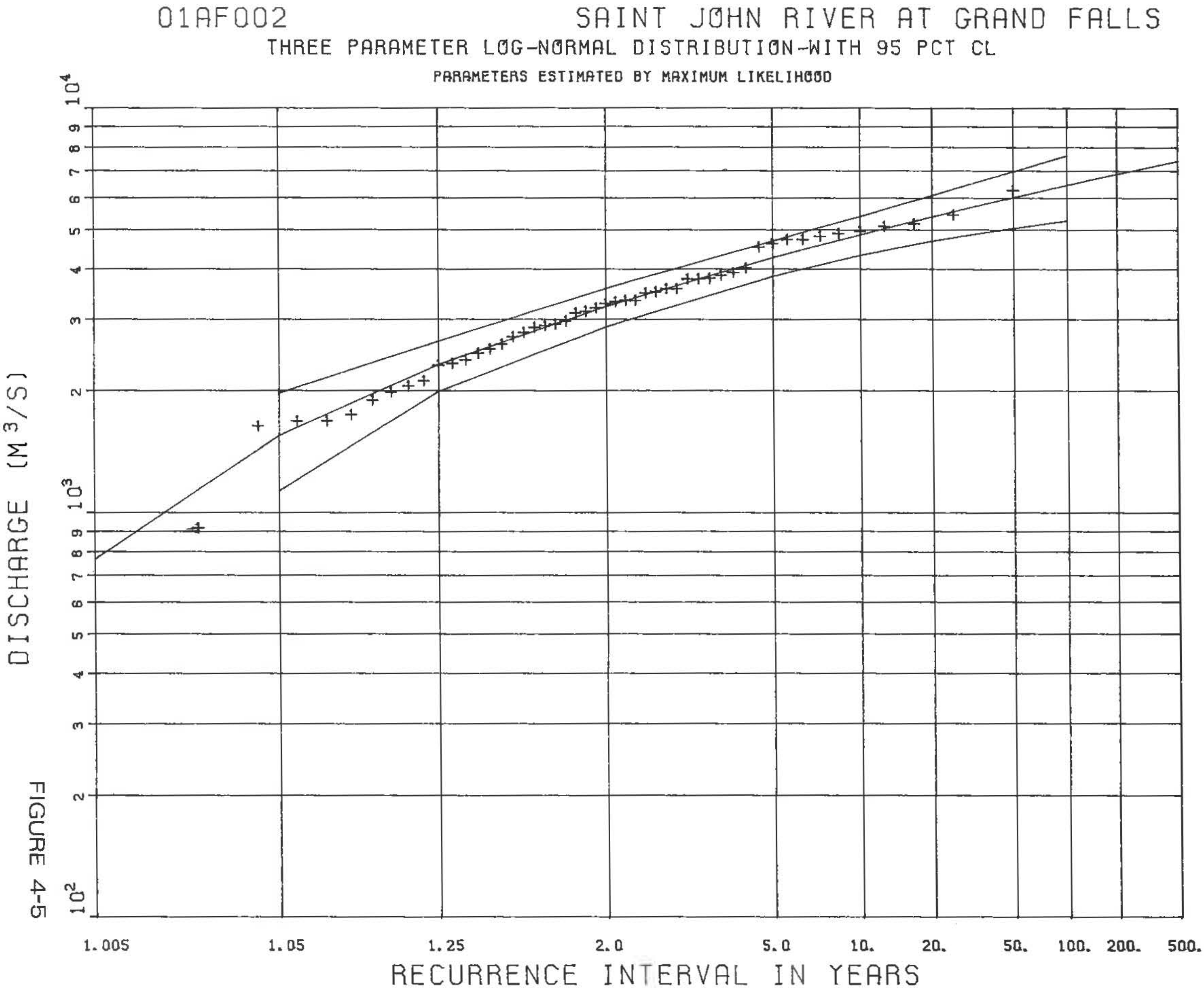


FIGURE 4-4



01AF002
SAINT JOHN RIVER AT GRAND FALLS
THREE PARAMETER LOG-NORMAL DISTRIBUTION-WITH 95 PCT CL
PARAMETERS ESTIMATED BY MAXIMUM LIKELIHOOD
DISCHARGE (M 3/S)
RECURRENCE INTERVAL IN YEARS
1.005
1.05
1.25
2.0
5.0
10.
20.
50.
100.
200.
500.

FIGURE 4-5

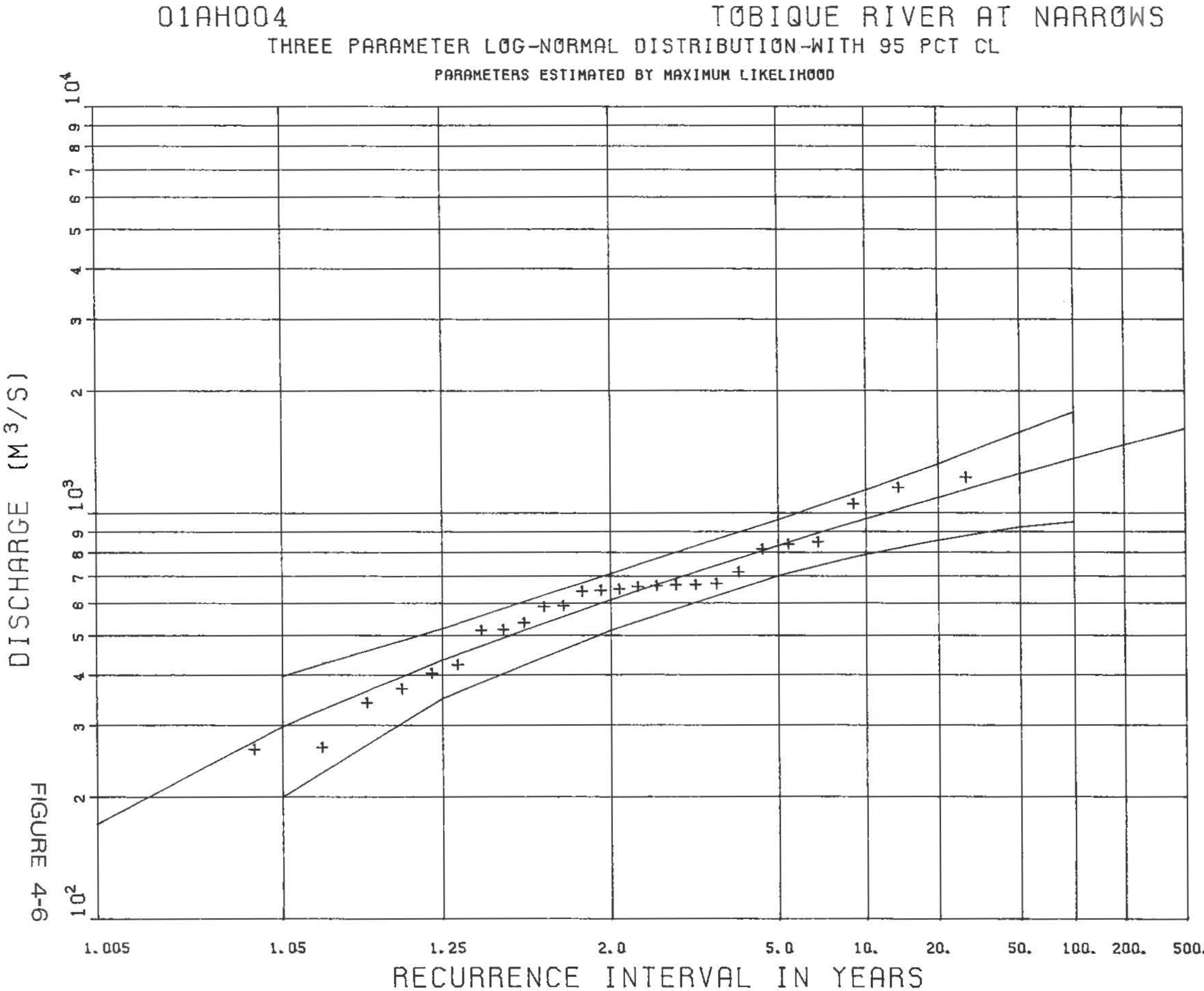
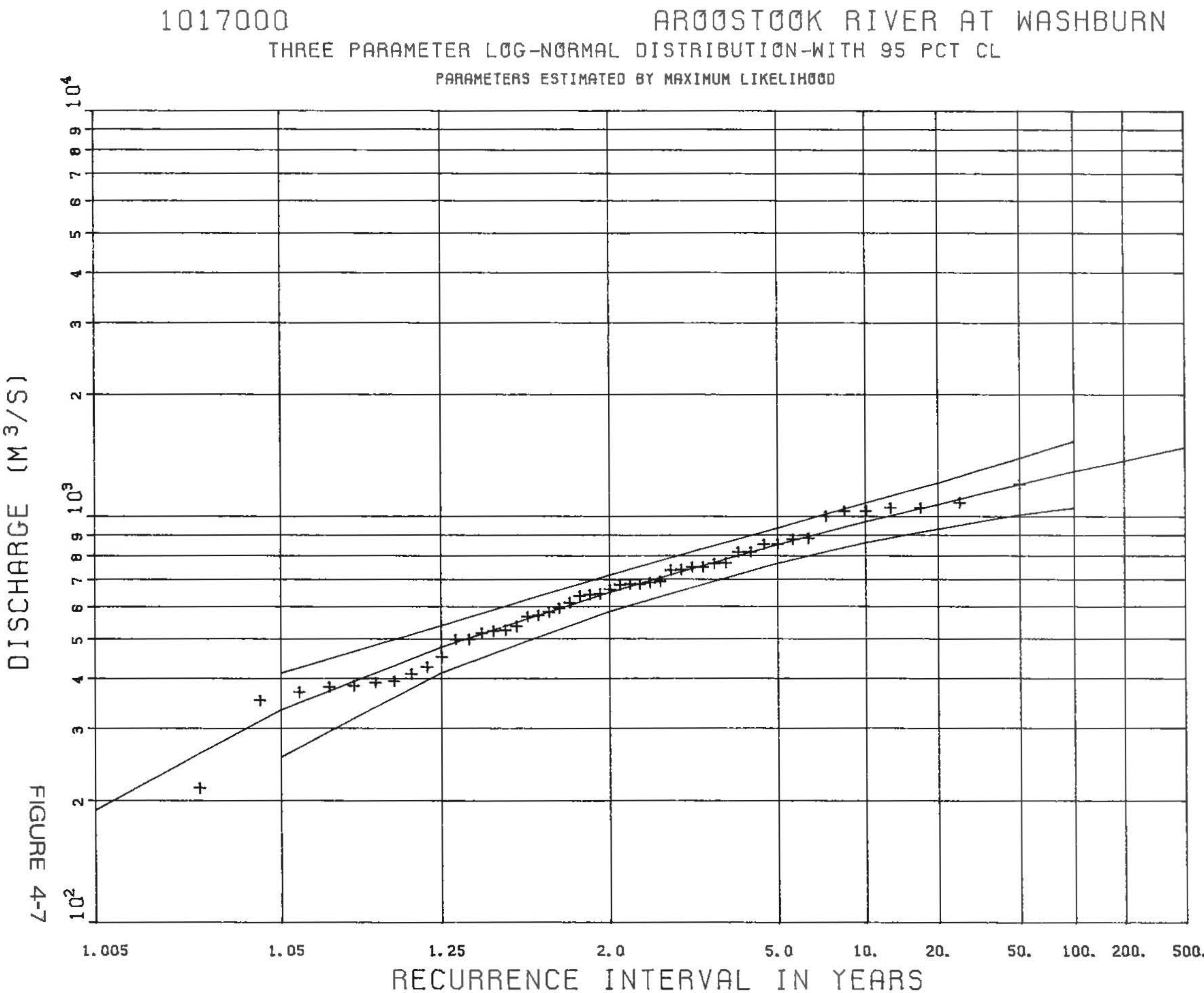

01AH004
TOBIQUE RIVER AT NARROWS
THREE PARAMETER LOG-NORMAL DISTRIBUTION-WITH 95 PCT CL
PARAMETERS ESTIMATED BY MAXIMUM LIKELIHOOD
DISCHARGE (M 3/S)
10^4
9
8
7
6
5
4
3
2
10^3
9
8
7
6
5
4
3
2
10^2
1.005
1.05
1.25
2.0
5.0
10.
20.
50.
100.
200.
500.
RECURRENCE INTERVAL IN YEARS

FIGURE 4-6



1017000
AROOSTOOK RIVER AT WASHBURN
THREE PARAMETER LOG-NORMAL DISTRIBUTION-WITH 95 PCT CL
PARAMETERS ESTIMATED BY MAXIMUM LIKELIHOOD
DISCHARGE (M 3/S)
10^4
9
8
7
6
5
4
3
2
10^3
10^2
1.005
1.05
1.25
2.0
5.0
10.
20.
50.
100.
200.
500.
RECURRENCE INTERVAL IN YEARS

FIGURE 4-7

01AK004 SAINT JOHN RIVER BELOW MACTAQUAC*

THREE PARAMETER LOG-NORMAL DISTRIBUTION-WITH 95 PCT CL

PARAMETERS ESTIMATED BY MAXIMUM LIKELIHOOD

DISCHARGE (M 3/S)

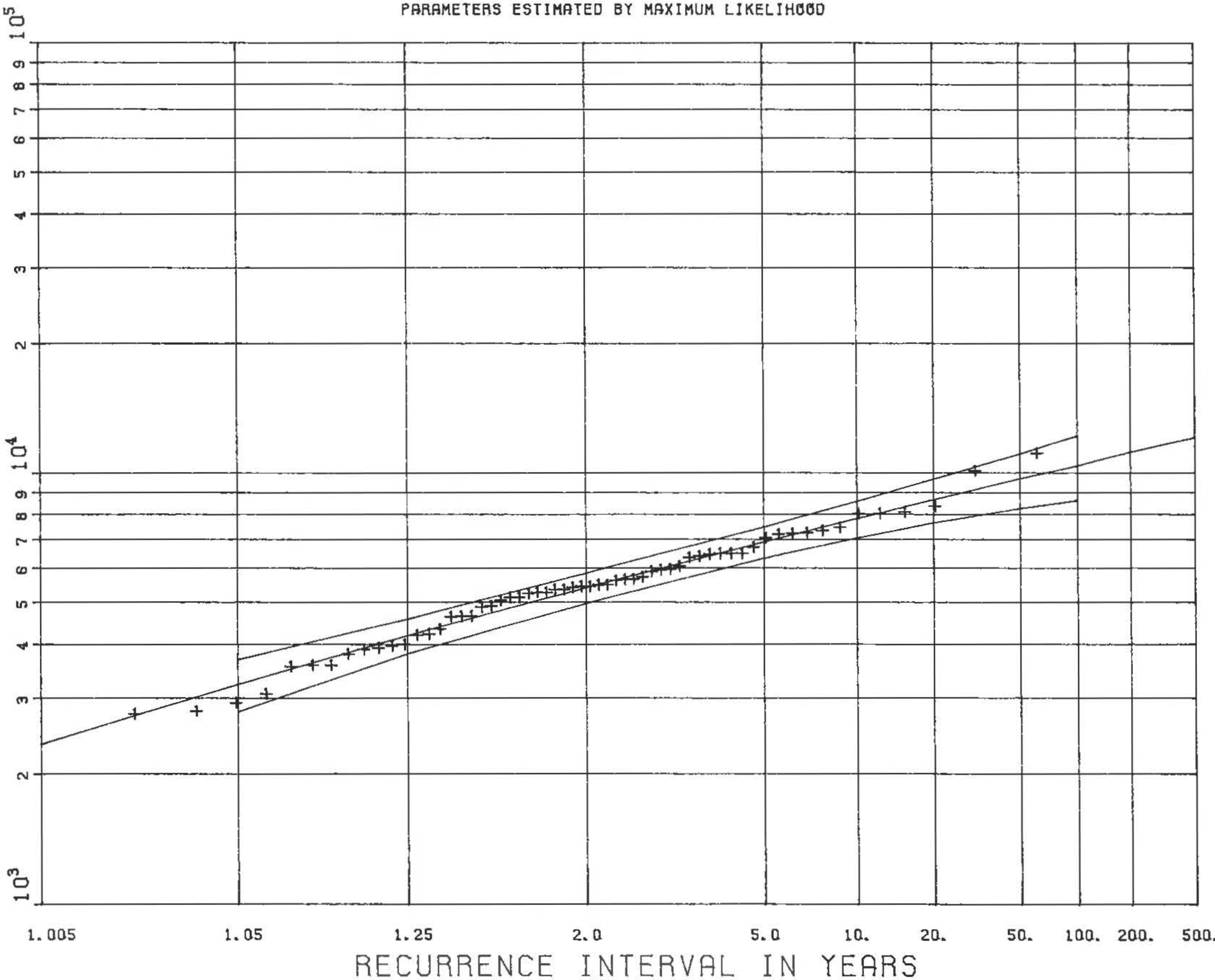


FIGURE 4-8

* INCLUDES DATA FOR DISCONTINUED STATION 01AK002 AT POKIOK (1919 - 1966)
DATA POINT FOR 1965 WAS CONSIDERED A LOW OUTLIER AND THEREFORE WAS ELIMINATED

TABLE 4.3

FLOOD FREQUENCY ANALYSIS FOR SELECTED HYDROMETRIC STATIONS IN NEW BRUNSWICK, QUEBEC AND MAINE

SAINT JOHN RIVER BASIN

Station Number		Period of Record Analysed	Maximum Daily Mean Flood Discharges (m^3/s) Q_{20}	Maximum Daily Mean Flood Discharges (m^3/s) Q_{100}	Maximum Daily Mean Discharge April 29-May 4 Discharge (m^3/s)	Maximum Daily Mean Discharge April 29-May 4 Return Period (years)
01010000	Saint John River at Ninemile Bridge	1951-1979	1000	1180	968	16
01010500	Saint John River at Dickey	1947-1979	2180	2630	2400	44
01011000	Allagash River near Allagash	1932-1979	713	882	756	32
01AD003	St. Francis River at Outlet of Glasier Lake	1952-1979	366	444	411	50
01013500	Fish River near Fort Kent	1930-1979	363	421	360	20
01AD002	Saint John River at Fort Kent	1927-1979	3640	4260	4130	70
011702	Madawaska River 1.9 mi. downstream from Lake Temiscouata Dam	1923-1979	388	462	383	20
01AF002	Saint John River at Grand Falls	1931-1979	5400	6460	6260	70
01015800	Aroostook River near Masardis	1958-1979	624	730	572	10+
01016500	Machias River near Ashland	1952-1979	332	425	292	12
01017000	Aroostook River at Washburn	1931-1979	1070	1290	1050	17
01AH002	Tobique River at Riley Brook	1955-1979	512	684	442	10
01AH003	Tobique River at Plaster Rock	1955-1979	804	1080	612	7
01AH004	Tobique River at Narrows	1955-1979	1090	1258	847	5
01AK004	Saint John River below Mactaquac#	1919-1979	8660	10400	10100	80+

- Includes adjusted values from Pokiok for period 1919-1966

+ - Excluding low outlier

from 16 years at Ninemile Bridge in the headwaters to 70 years at Fort Kent and Grand Falls and to 80 years at the station below Mactaquac.

The estimated return periods of the maximum daily mean discharges for the same period on the tributaries varied from 50 years on the St. Francis River in the northern part of the headwaters to 70 years at Fort Kent and Grand Falls and to 80 years at the station below Mactaquac.

The estimated return periods of the maximum daily mean discharges for the same period on the tributaries varied from 50 years on the St. Francis River in the northern part of the headwaters and 32 years on the Allagash River in the southern portion of the headwaters, from 10 to 17 years (upstream to downstream) on the Aroostook River and from 10 to 5 years (upstream to downstream) on the Tobique River, and finally to roughly the mean annual flood (return period equals 2 years) on the tributaries downstream of the Beechwood Dam. An exception was in the headwaters of the Nashwaak River which had an estimated return period of 9 years.

Estimated 1:20 and 1:100 year recurrence interval daily mean flood flows resulting from the single station frequency analyses are also presented in Table 4.3.

4.3 Frequency of Flood Stages on the Lower Saint John River Downstream of the Mactaquac Dam

The Saint John River from just downstream of the Mactaquac Dam to the City of Saint John (140 km) exhibits a very gentle gradient (less than 0.04 m/km). This reach of the river contains an enormous amount of storage in the river, on the lower portion of the tributary streams, on the vast floodplain north of the Trans-Canada Highway from Fredericton to Jemseg and in several lakes located within and adjacent to this floodplain. During the peak of the historic flood of record which occurred in 1973 (Ref. 6), an estimated 2.8 billion cubic metres of water was in storage. Floodwaters accumulate in this reach due to the gentle gradient; the large low-lying storage areas and the restricting action of the "Reversing Falls" located in the City of Saint John, as explained in Chapter 3.

Records of stage have been kept over the years for a number of locations on the lower reach of the river (Ref. 11, 12). Stages have been recorded for 58 years at Fredericton (1922 to 1979), 32 years at Oromocto (1918-1949), 15 years at Maugerville (1965-1979), 57 years at Oak Point (1923-1979), 14 years at Saint John (1966-1979), 14 years at Jemseg on the Jemseg River (1966-1979) and 15 years on Grand Lake at Newcastle Creek (1965-1979). Stage data have been and are being collected by various agencies to varying standards over the years. It was not until the 1960's, when the Water Survey of Canada became involved, that uniform standards were employed.

Ideally, it would be desirable to analyze the data for these locations along and adjacent to the Saint John River in order to estimate the return period of flood stages of a specific magnitude or alternatively the magnitude of the flood stage with a specified return period. However, it is not accepted practice in hydrotechnical engineering to utilize stage data for the purposes of flood frequency analysis. This is due to the fact that river stages are affected by such things as changes in river morphology, ice jams, tides and backwater conditions and man-made structures such as the Trans-Canada Highway. An examination of Table 4.4, more specifically columns 3 and 5, support this contention. Of the 20 floods considered in Table 4.4, there were only three events (those occuring in 1934, 1942 and 1973) which have the same magnitude ranking on the basis of flow and water level.

Accepted practice for defining flood stages with a particular recurrence interval is to define the hydrologic inputs (streamflows) with the specified recurrence interval and to route these through a calibrated and verified hydraulic mathematical model. The flood stages so defined are applicable, therefore, only for the conditions which existed during the events used for calibration and may or may not take local ice jam effects into consideration. One such analysis, performed by MacLaren Atlantic Limited under the Canada-New Brunswick Flood Damage Reduction Program (Ref. 14), provides estimated 1:20 and 1:100 year flood profiles from the Mactaquac Dam down to Lower Jemseg and up some of the larger tributary streams.

TABLE 4.4

SPRING FLOOD VOLUMES-SAINT JOHN RIVER BELOW MACTAQUAC

Year	Max. Daily Mean Discharge m^3/s	Rank	Max. Daily Mean Water Level at Fredericton metres	Rank	Period of Flood Wave days	Flood Wave** Volume $m^3 \times 10^{-6}$	Rank	No. of Days to Major Peak days	Flood Wave** Volume to 1 day after Major Peak $m^3 \times 10^{-6}$	Rank	No. of Peaks During Period of Flood Wave	Sequence of major Peak
1973	11100	1	8.53	1	56	27,070	1	16	9,518	2	2	2nd
1979	10000	2	7.89	3	23	8,164	19	10	4,576	14	1	-
1923	8350	3	8.05	2	48	11,177	15	14	3,797	16	1	-
1974	8100	4	7.38	7	61	15,540	7	22	5,179	12	3	1st
1947	8040	5	6.74	11	90	19,847	3	34	7,639	7	3	2nd
1958	8040	6	7.59	4	77	13,083	13	33	5,793	9	3	2nd
1941	7450	7	6.74	12	54	11,163	16	13	4,641	15	2	1st
1934	7330	8	7.38	8	60	16,262	6	21	6,131	9	3	1st
1939	7250	9	6.58	13	66	13,101	17	23	7,665	6	2	1st
1961	7220	10	7.41	6	62	18,383	5	40	13,571	1	2	2nd
1977	7190	11	7.01	9	65	14,751	9	28	5,759	11	3	2nd
1976	7050	12	6.89	10	48	19,729	4	14	9,252	3	4	2nd
1936	6710	13	7.56*	5	87	19,911	2	10	3,695	17	3	1st
1942	6480	14	6.55	14	47	11,868	14	23	7,893	5	1	-
1950	6480	15	6.31	16	53	8,999	18	18	3,034	20	1	-
1954	6480	16	6.03	17	70	14,372	11	18	4,906	13	3	1st
1933	6460	17	5.73	18	64	13,332	12	30	7,002	8	4	3rd
1922	6400	18	5.28	20	35	7,046	20	13	3,644	19	1	-
1969	6340	19	6.40	15	60	14,661	10	31	8,184	4	4	3rd
1953	6060	20	5.59	19	67	15,522	8	10	13,692	18	4	1st

* Adjusted to remove the effects on an ice jam

** Baseflow was not subtracted in determining flood volumes.

TABLE 4.5

MAXIMUM HISTORICAL WATER LEVELS AT FREDERICTON

Rank	Event	Maximum Instantaneous Water Level (metres)	Ice Jam Event	Source
1	1936	8.900	Yes	Fredericton Pumping Station
2	1973	8.608	No	Environment Canada
3	1831	8.2E*	Yes	Newspaper
4	1887	8.17	No	Newspaper
5	1923	8.047D	Unknown	Fredericton Pumping Station
6	1979	8.062	No	Environment Canada
7	1854	8.05E	No	Newspaper

* - newspaper reports place level of this event, which occurred either in 1831 or 1832, as being higher than that reached in 1887

D - mean daily value

E - estimated based on newspaper reports comparing floods

Source: References 8 and 14

Historic stage data are; however, interesting to review. For example, river stages at Fredericton from 1922 to 1960 were recorded once a day at the City of Fredericton Pumping Station. From 1961 to date, the Inland Waters Directorate has maintained a continuously recording gauge at this location. In addition, newspaper articles can be used to provide rough estimates of flood stage in Fredericton back to as early as 1768. From these sources estimates of the seven extreme high water levels which have occurred at Fredericton have been compiled and are presented in Table 4.5 (Ref. 11, 13).

It can be seen from Table 4.5 that the highest recorded stage, and one or possibly two others of the seven, were caused in part by ice jams. Since the construction of the Mactaquac Dam, located about 10 km upstream of Fredericton, ice jams have not and are not expected to occur in the Saint John River below the dam. Therefore, the type of ice jam events of 1936 and 1831 can be reasonably assumed to have an extremely low possibility of re-occurring.

The streamflows associated with the 1936 event were much lower than those for the events of 1973 and 1979. No streamflow records are available for the 1800's; however, reported flooding at points upstream and downstream of the 1831 ice jam were not as severe as those for other years. It can therefore be concluded from the data in Table 4.5 that the maximum water level at Fredericton resulting from the 1979 flood was the third or fourth highest non-ice jam event in 212 years.

In an effort to determine whether any relationship exists between the volume of the flood wave and the corresponding flood peak stages along the lower reach of the Saint John River, an analysis was undertaken of the 20 annual flood events with the highest recorded daily mean discharges.

Since there is no standard procedure for determining flood volumes, two different methods were employed. The first method was a simple summation of all discharge volumes commencing at the point where the discharge record begins to display a steady rise and terminating where the recession curve returns to that same discharge. The second method starts at the same point on the hydrograph as the first, but terminates one day after the major peak (in the event that more than one peak occurred). Baseflow was not subtracted from the discharges in either method.

An examination of Table 4.4 indicates that it is difficult to see any relationship between peak discharge, water level and/or volume of a flood at Fredericton. The problem is complicated by the complexity of the Basin, the spatial and temporal distribution of inputs (including the number of minor peaks prior to the major peak) and, most importantly, the storage in the Lower Basin prior to the peak.

This argument can be reinforced by referring to the report entitled, "Hydrotechnical Study of the Saint John River from McKinley Ferry to Lower Jemseg" (Ref. 14). The subject report shows that two hydrographs with different volumes and shapes produced virtually identical peak stages at Fredericton when routed through a mathematical, hydraulic model. Peak stages downstream at Jemseg, however, were significantly different.

The result of this analysis concludes that no simple relationship can be deduced between the levels, volume or discharge at Fredericton.

It is interesting to note, however, that for 18 of the 20 maximum annual events analysed the average initial flow was 630 cubic metres per second, with a range of 330 to 700 cubic metres per second; whereas, the record 1973 and 1979 floods had initial flows of 1200 and 1600 m^3/s respectively.

4.4 Effects of Upstream Storage Reservoirs

It is important to consider the effects of storage reservoirs in discussing the magnitude of floods on the Saint John River. The general location of each major storage reservoir in the Basin and its nominal live storage capacity are given in Table 4.6. This table also presents the quantity of storage in each major reservoir at intervals throughout the spring runoff period. These data were prepared from information supplied by The New Brunswick Electric Power Commission.

About half of the 462 million cubic metres of nominal live storage capacity in the Upper Saint John River Basin is located in the Tobique River Basin. The other half is divided between the Aroostook and the Madawaska River basins.

TABLE 4.6

SUMMARY OF STORAGE DATA FOR RESERVOIRS IN THE SAINT JOHN RIVER BASIN

MARCH 13 TO MAY 3, 1979

Reservoir	Stream	Nominal Live Storage (millions of cubic metres)	Maximum Live Storage in 1979 (millions of cubic metres)	Date	Live Storage in 1979 (millions of cubic metres) Mar 13	Mar 31	Apr 9	Apr 17	Apr 23	Apr 30	May 1	May 3
Saint John Basin												
Temiscouata Lake*	Madawaska River	129.5	235.1	May 4	39.2	102.1	103.2	80.8	82.8	193.1	211.9	232.9
Millinocket Lake*	Aroostook River	28.5	31.9	June 2	14.4	16.6	18.2	18.8	20.8	31.4	31.2	31.1
Squa Pan Lake	Aroostook River	72.3	81.3	May 1	38.2	55.1	60.9	66.2	69.8	80.5	81.3	80.5
Trousers Lake	Tobique River	45.1	60.9	May 2	17.7	33.6	37.2	40.9	43.3	55.1	60.9	57.2
Long Lake	Tobique River	34.9	40.1	May 1	11.5	9.9	22.0	24.4	25.8	33.6	33.6	35.8
Sisson Reservoir	Tobique River	119.6	124.6	June 6	18.5	54.0	64.8	74.1	80.1	110.6	113.4	117.2
Serpentine Lake	Tobique River	31.6	35.4	June 4	6.3	13.3	14.3	16.0	17.0	25.5	25.5	28.0
Total for Saint John River Basin		461.5	609.3		145.8	294.6	320.6	321.2	339.6	529.8	557.8	582.7
Percent of Nominal Live Storage					32	64	69	70	74	115	121	126

* Reservoir consists of natural lake with stoplog controlled outlet

The Temiscouata and Millinocket lakes storages, which have a combined nominal live storage capacity of 158 million cubic metres are controlled by the installation of stoplogs after the flood peak has passed. Thus, these reservoirs do not retain water in addition to that which would go into natural lake storage. They influence only the rate of release of water from the lakes after the flood peak has passed.

It is noted from Table 4.6 that 74 percent of the combined nominal live storage of the Basin was filled by April 23, increasing to 121 percent by May 1. This average increase amounted to about 27 million cubic metres per day, equivalent to a decrease in flow of about 312 m^3/s per day, or about 6% of the average mean daily flow for the same period as recorded at the East Florenceville gauging station. If the uncontrolled Temiscouata and Millinocket lakes are excluded, the average increase in storage amounted to about 10 million cubic metres per day, equivalent to a decrease in flow of about 116 m^3/s per day, or about 2% of the average mean daily flow recorded at the East Florenceville gauging station, and is therefore not very significant.

On those tributaries of the Saint John River which have storage reservoirs, streamflows were reduced by a greater extent than on the main stem. The combined storage effect of the four reservoirs in the Tobique River Basin reduced the volume of water flowing past the Plaster Rock gauge (01AH003) by 20 percent during the period April 23 through May 1. This is in the same proportion to the drainage area controlled by these reservoirs. In effect the reservoirs in the Tobique Basin contained all of the flow from their drainage areas until after the peak.

Not included in Table 4.6 are the headponds of hydroelectric plants in the Saint John River Basin. There are six power developments in the Basin but two of these (Tinker Falls on the Aroostook River and the City of Edmunston's development on the Green River) have very little storage. The live storage capacities of the remaining four developments are listed as follows:

Mactaquac	$456 \times 10^6 m^3$
Beechwood	$42 \times 10^6 m^3$
Grand Falls	$26 \times 10^6 m^3$
Tobique Narrows	$12 \times 10^6 m^3$

It is presently not possible to estimate with reliability the effect of these long narrow storages on flood discharges and volumes without obtaining additional field data and developing models. During extreme flood conditions there are considerable slopes in the water surface elevations of these headponds. Thus, although the water level at the power dam is drawn down considerably from its maximum, the water level in the upper part of the headpond can be as high or higher than the maximum static headpond level due to the natural slope of the river. In this situation estimates of storage volumes based on elevations at the dam are not representative of the true storage.

Notwithstanding the fact that storage volumes cannot be determined accurately, a few generalities can be drawn from the magnitude of the live storage in the headponds and the way in which they were operated during the 1979 flood.

Considering the three smaller headponds at the Beechwood, Grand Falls and Tobique Narrows plants, the combined live storage capacity at low flows is about 80 million cubic metres. This corresponds to 2.3 mm of runoff on the drainage area above the Beechwood Dam - an insignificant amount when compared with flood runoff. Thus, even if the headponds were drawn down to their minimum levels in advance of the flood, they could not have influenced the volume of water passing downstream to a measurable extent.

The Mactaquac headpond is considerably larger, with a live storage capacity at low flows of 456 million cubic metres. At high flows, this can be reduced to about 250 million cubic metres due to the large slope on the headpond. This volume could have been filled three times by the flow which passed through the gates on April 30.

During spring runoff, the New Brunswick Electric Power Commission operates the Mactaquac Dam in such a manner that the headpond is drawn to a low elevation in advance of the spring flood and is then gradually raised after the peak has occurred. This is done to reduce the effects on the upstream communities of Woodstock and Hartland while not augmenting the flows down to Fredericton. In other words, the intention is to operate the dam in such a manner as not to impose any worse conditions either upstream or downstream of the empoundment that would have occurred under natural conditions.

On April 23, the headpond was approximately one metre below the normal operating level. By April 26, the April 30 flood peak was initially forecast by the Flood Forecast Centre as a major event. The New Brunswick Electric Power Commission began to accelerate the drawdown without creating an abrupt increase in flow downstream. By April 30 the Mactaquac headpond had been lowered to 32 metres above sea level in time for the peak flow which passed at noon that day. On May 1, the Power Commission began closing the gates, raising the headpond elevation back to normal operating level.

The regulation of the Mactaquac Dam probably caused an increase in the volume of the flow downstream between April 23 and April 30 just prior to the flood crest, a minimal effect during the peak and a significant decrease in flow from May 1 through May 6 as the headpond was refilled. The storage period probably reduced the duration of the high peak water levels in the lower basin.

4.5 Precipitation and Runoff Volumes

In order to examine the relationship between rainfall, snowmelt and the associated runoff, estimates were made of the magnitude of each of these three parameters from selected drainage areas in the Saint John River Basin. The drainage areas above the following three hydrometric stations were selected for this purpose:

a) Saint John River at Grand Falls (01AF002)
b) Saint John River near East Florenceville (01AJ001)
c) Saint John River below Mactaquac (01AK004)

In computing the snowmelt and rainfall on these drainage areas two periods were considered, April 24 to April 26 and April 27 to May 6. These periods were selected so that the snowmelt and rainfall/snowmelt events could be artificially separated.

The amount of rainfall computed from the isohyetal map for April 27 to May 3, as shown on Figure 2.6, was used to estimate the rainfall for each drainage area.

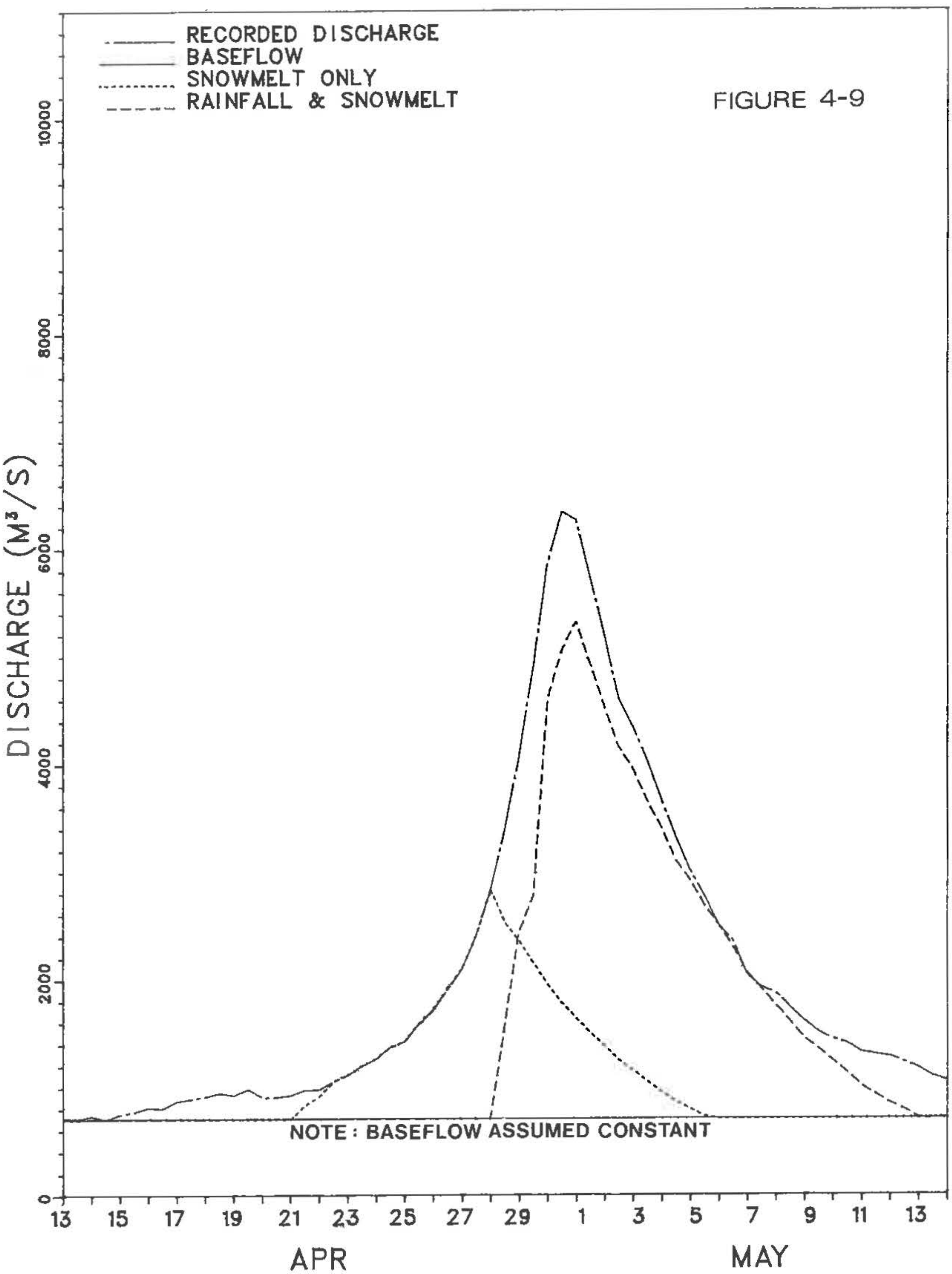
Snowmelt volumes were estimated with the aid of the April 25th snow survey map provided by the Flood Forecasting Centre (this gave the areal concentrations of potential meltwater from snow remaining in the Basin) and the estimated average potential snowmelt rates for the days April 24 through May 7. The potential snowmelt rates estimated by the Energy Budget Method were used to deplete the snow cover and to determine the average snowmelt for each drainage area.

Discharge hydrographs from the data for the three selected hydrometric stations were plotted on semi-logarithmic paper. The recession segment of the plots of the data from Grand Falls and East Florenceville appeared to follow the linear approximation as described by Linsley (Ref. 15) and the data were fitted with a straight line. The hydrograph for the hydrometric station below Mactaquac was less regular due to regulation of the dam; however, a straight line was fitted by eye. The recession segment, so determined for the station below Mactaquac, demonstrated a slope similar to the recession curves of the two other hydrographs. Since the error involved was considered small in comparison to the flood discharge it was assumed, for simplicity, that the baseflow would be a constant value taken as the lowest discharge prior to the event.

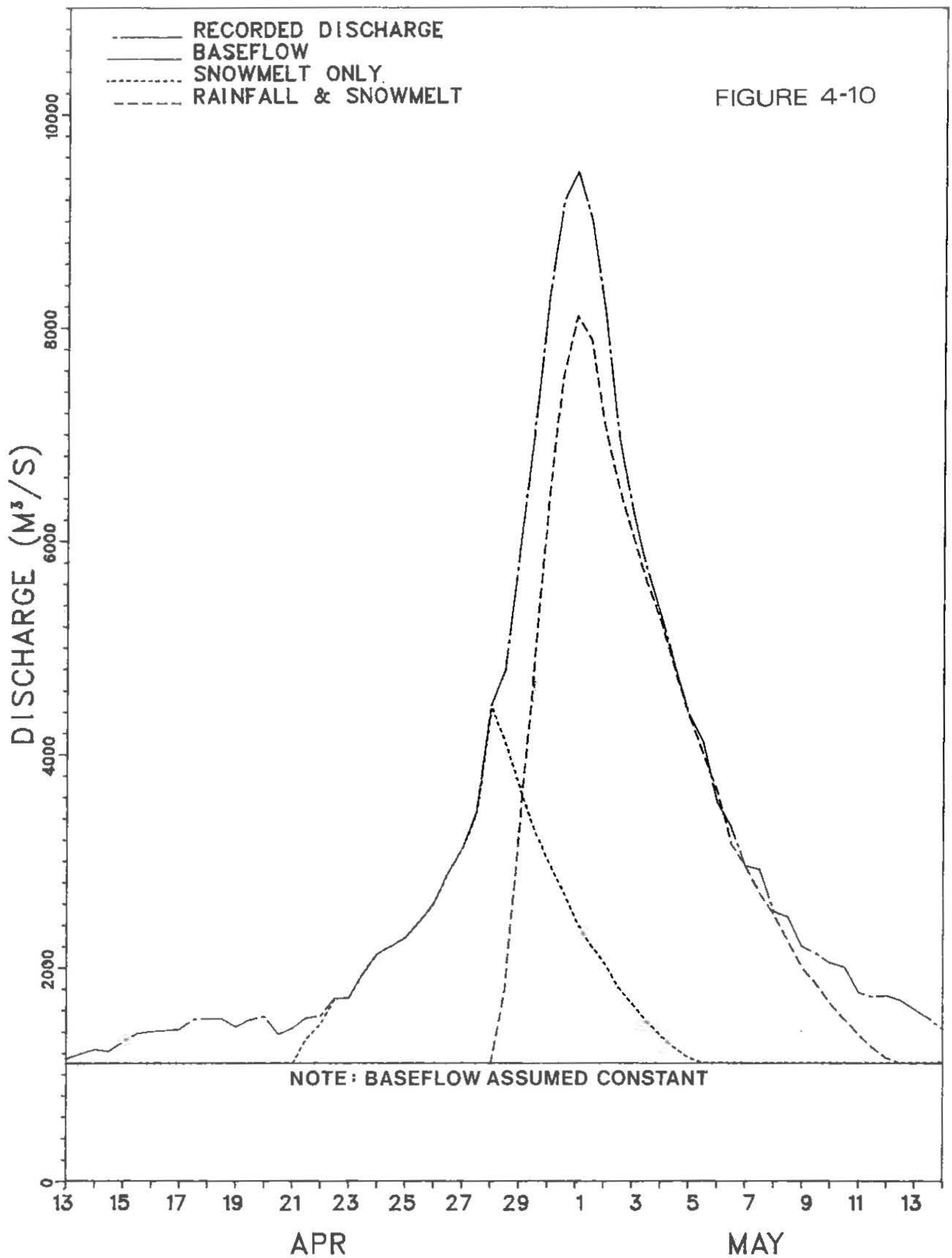
To isolate the runoff from the April 24 to April 27 and the April 28 to May 1 "events", the slope of the computed recession line was carried back individually to April 27 and to April 21. Some trace precipitation and snowmelt occurred between April 14 and April 27 but this was determined to have had a negligible effect on the main events being considered. The component hydrographs are shown in Figures 4.9 to 4.11.

Comparison of the runoff volumes determined from the component hydrographs with the volumes of snowmelt and rainfall are shown in

COMPONENTS OF THE HYDROGRAPH FOR THE HYDROMETRIC STATION ON THE SAINT JOHN RIVER AT GRAND FALLS (01AF002)



COMPONENTS OF THE HYDROGRAPH FOR THE HYDROMETRIC STATION ON THE SAINT JOHN RIVER AT EAST FLORENCEVILLE (01AJ001)



COMPONENTS OF THE HYDROGRAPH
FOR THE HYDROMETRIC STATION ON THE
SAINT JOHN RIVER BELOW MACTAQUAC (01AK004)

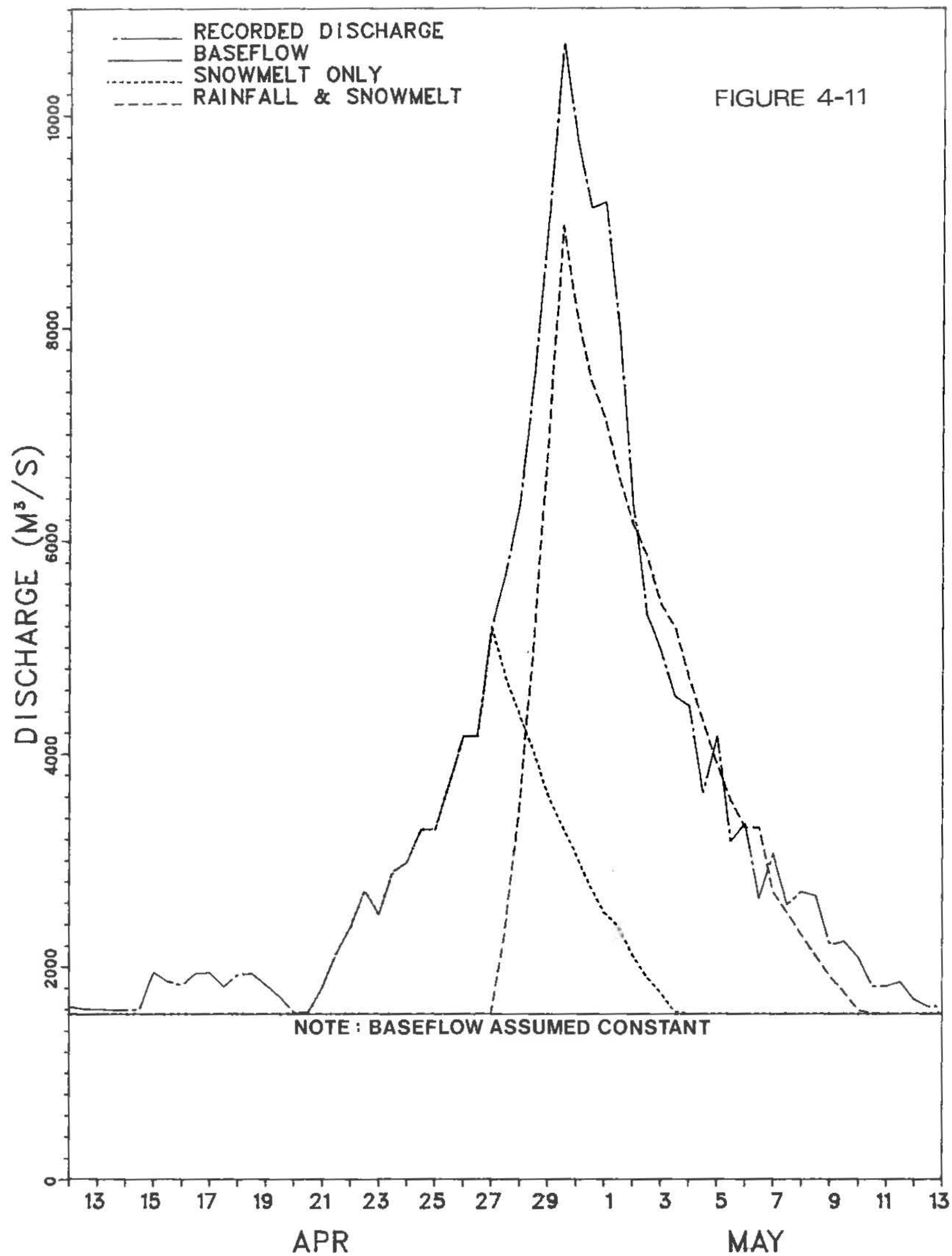


Table 4.7. Ratios of runoff to snowmelt and rainfall are also provided. The ratios for the first period are lower than the ratios for the second period for the Grand Falls and East Florenceville stations. This is most likely due to the retention of the meltwater in the snowpack during the initial melt. This would partially account for the higher ratios for the second period for these two stations. Mactaquac ratios show the opposite effect. This can be attributed mainly to the accelerated drawdown starting on April 26 and the increased storage starting on May 1. The drawdown created a higher than natural discharge at the April 27 separation point whereas the storage would reduce the cutoff discharge for the May 1 recession curve.

Thus, it appears certain that the lack of snow in the lower portion of the Basin (the snowmelt for the lower portion of the Basin having occurred in March) reduced the runoff considerably and consequently the severity of the flooding in the lower part of the Basin.

TABLE 4.7

RUNOFF-PRECIPITATION RATIOS

Station	Period	Rainfall (mm)	Snowmelt (mm)	Total (mm)	Runoff (mm)	Ratio Runoff to Rainfall & Snowmelt
Saint John River at	April 24-27	-	62.5	62.5	46.3	.74
Grand Falls	April 28-May 1	42.9	63.8	106.7	109.5	1.03
Saint John River at	April 24-27	-	52.8	52.8	44.4	.84
East Florenceville	April 28-May 1	48.5	53.9	102.4	101.6	.99
Saint John River	April 24-27	-	48.0	48.0	42.0	.88
Below Mactaquac	April 28-May 1	50.0	47.3	97.3	82.7	.85

CHAPTER 5

FORECASTING

5.1 Development of the Forecast System

The ability to accurately predict the magnitude of floods and to act quickly in evacuating potential victims and move or protect property is of utmost importance in reducing the damaging effects of floods. Flood forecasting and emergency measures systems were operational during the 1979 Flood in the Saint John River Basin, the most severely affected area of the Province.

Flood forecasting has been undertaken in the Saint John River Basin for several years with varying degrees of sophistication. In the early 1960's, the New Brunswick Electric Power Commission attempted to utilize a computerized forecasting system. The results were unsatisfactory and the system proved cumbersome because processing was undertaken on a computer in Niagara Falls, Ontario. For several years following this unsuccessful attempt, intuition and manual methods were used to forecast floods by staff of the New Brunswick Electric Power Commission. In later years assistance was received from the New Brunswick Department of Fisheries and Environment.

Towards the end of 1972, renewed interest arose in the development of a system of flood forecasting using modern computerized techniques. The New Brunswick Department of Fisheries and Environment joined the New Brunswick Electric Power Commission in a search for operational forecasting programs. A computerized flood forecasting program developed by the North Pacific Division of the United States Army Corps of Engineers was selected.

The selected forecasting program, known as the Streamflow Synthesis and Reservoir Regulation Model (SSARR), is a mathematical-hydrologic model of a river basin system which synthesizes streamflow by evaluating snowmelt and rainfall runoff. The river basin is divided into a number of sub-basins for which the basic snowmelt and rainfall runoff relations are established. River flows are computed by routing runoff from upstream to downstream points through channel and reservoir storage. When used as a predictive tool, the model relies on meteorological forecasts of temperature and precipitation as input data. Flood forecasts can be continuously updated as recorded streamflow and precipitation data are reported. The model also has provision for handling backwater conditions such as those which exist on the Saint John River below the Mactaquac dam.

When the Canada-New Brunswick Agreement Respecting Flood Forecasting was signed in August 1977, a Director was appointed on a part-time basis to manage the Flood Forecast Centre (FFC). A full time forecast technician was engaged shortly thereafter and an hydrologic engineer (full-time) and a meteorological technician (part-time) were provided by NBDOE. The FFC staff is augmented on a continuing basis during the spring runoff period and at other times as required by staff from IWD and NBEPC. This provides the necessary backup and makes occasional round-the-clock operation possible.

In mid 1978 another model, referred to as DWOPER (an acronym for Dynamic Wave Operational Model) was applied to the Saint John River from McKinley Ferry to Lower Jemseg. The DWOPER was still under testing during the 1979 flood.

5.2 Model Calibration

The Corps of Engineers SSARR Model was obtained in early February 1973 and the task of applying this model to the Saint John River began immediately.

The first task in model calibration consisted of making numerous computer runs for each of 34 sub-basins of the Saint John watershed using a fall rainstorm which occurred in September-October 1969. These runs provided the initial model parameters for simulation of runoff from the sub-basins and river routing in the main channel. The second task consisted of model calibration for snowmelt conditions. For this, the spring runoff of 1961 was used to obtain the parameters required for snowmelt computations.

The model was operational for flood forecasting in the Saint John River on March 26, 1973 and after a two week trial period for final adjustment of parameters and initial conditions the model was successfully put into operation. Since the 1973 flood, a refinement to the calibrations have been carried out, particularly on sub-basins in the upper portion of the Saint John River Basin.

5.3 Meteorological Forecasts

The ability of the flood forecasting model to predict floods in advance is to a great extent dependent upon the accuracy of meteorological forecasts which are used as model input. The following is a brief description of the forecasts provided by the Atmospheric Environment Service, Environment Canada, to the Saint John River Flood Forecasting Centre.

Twice daily, the Canadian Meteorological Centre in Montreal prepares forecasts of maximum and minimum temperatures and precipitation amounts based on 0000 GMT and 1200 GMT surface and upper air data. These forecasts are sent by teletype and facsimile network to weather offices throughout Canada. After appraisal and tailoring by local meteorologists, the information is disseminated to the public.

The Canadian Meteorological Centre's temperature forecasts are based upon regression equations, applicable to individual cities. They are completely computer produced and have a valid period of either two or three days, depending on the time of issue. The quantitative precipitation forecasts are also computer produced and list expected precipitation values at a number of points in a grid system encompassing most of North America. The forecast precipitation for each grid point represents the average amount expected to fall in a square with sides of 381 kilometres in length surrounding the point. The valid period for the quantitative precipitation forecasts extends 42 hours from the time of collection of the basic data.

For the purpose of flood forecasting, special arrangements were made with the Atmospheric Environment Service to obtain subjective forecasts of temperature and precipitation beyond the period of the computer forecasts produced at the Canadian Meteorological Centre. These subjective forecasts were prepared by meteorologists at the Maritimes Weather Office in Bedford, N.S., and transmitted along with the computer produced forecasts to the Fredericton Weather Office. Temperature forecasts used in flood forecasting were the computer predictions for Saint John and Fredericton augmented by subjective estimates up to day five. The precipitation forecasts provided by the Maritimes Weather Office were those produced by computer for day one and day two at the three grid points nearest the Saint John River Basin together with subjective extensions to days three, four and five for the same points. The subjective predictions indicated only expected occurrence or non-occurrence of precipitation for each day without attempting to quantify precipitation amounts.

5.4 Hydrologic Data Networks

The accuracy of the model in forecasting streamflows is dependent on accurate up-to-date information on actual temperatures, recorded precipitation, snow accumulation and streamflow. The networks of stations used in compiling information for the model is shown on Table 5.1. The network consists of 80 temperature and precipitation stations, 37 stream gauging stations and 81 snow course stations. Data for precipitation, temperature and streamflow are compiled each morning and, during the critical flood period, each afternoon as well. Snow course data are received at two week intervals from co-operating agencies, with periodic checks being made more frequently at some locations during the critical period.

5.5 Forecasts during the Flood

As already mentioned, the objectives of the flood forecasting program include the provision of information consistent with the needs of citizens of low-lying areas along the Saint John River, as well as the

TABLE 5.1

HYDROLOGIC DATA NETWORK USED IN FLOOD FORECASTING

Type of Station	Location	Number of Stations
Temperature and Precipitation	New Brunswick	42
	Quebec	18
	Maine	20
Stream Gauging	New Brunswick	29
	Quebec	1
	Maine	7
Snow Courses	New Brunswick	40
	Quebec	13
	Maine	28

Co-operating Agencies

New Brunswick Electric Power Commission
New Brunswick Department of the Environment
New Brunswick Department of Natural Resources
Quebec Natural Resources
Atmospheric Environment Service, Environment Canada
Water Survey of Canada, Environment Canada
Maine Public Service
Maine Forest Service
National Weather Service
United States Geological Service
Great Northern Paper Company

New Brunswick Electric Power Commission's requirements for information to assist in regulation of hydro-electric developments on the river. To meet these objectives a Saint John River Flood Forecast Unit was established.

The flood forecasting program is run each morning during the spring to predict streamflows for a five-day period at various points along the river. During the critical flood period additional runs are carried out based on an updated weather forecast received each day from the Maritimes Weather Office. As each new run is made, the previous forecast is updated to correct for changes in input forecast data and antecedent conditions in the Basin.

The areal distribution of precipitation and temperature data has been greatly improved with the development of square grid techniques. In addition, the transfer of data from the Maritimes Weather Office to the Flood Forecast Centre is now done using a direct computer to computer link over telephone lines.

5.6 Daily Forecast Service

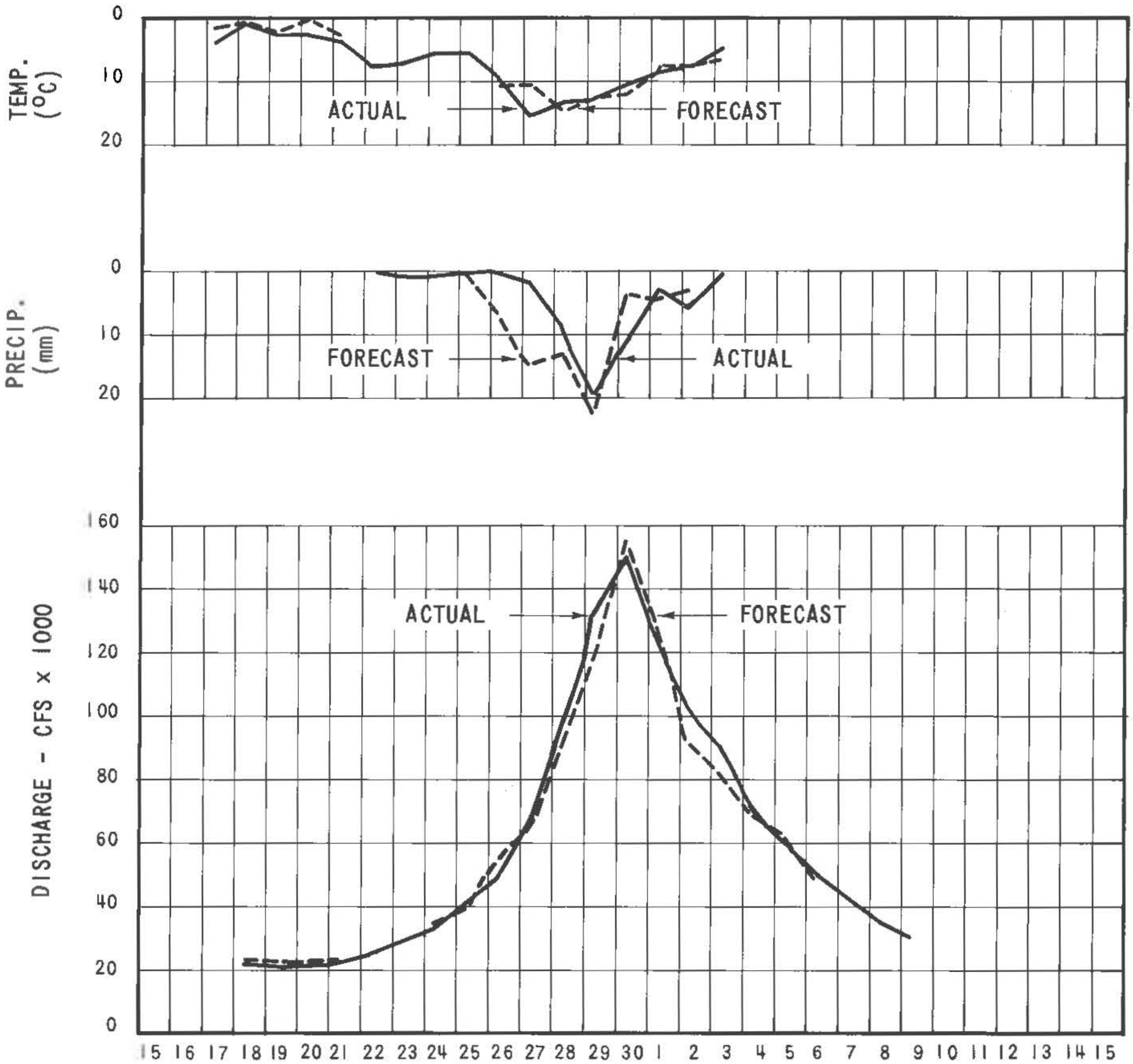
For a complete description of the forecast system the reader is referred to Technical Bulletin No. 81. "The New Brunswick Flood", April - May 1973 by Environment Canada, Inland Waters Directorate, Atlantic Region, Halifax, Nova Scotia, 1974.

A comparison of the actual and forecast streamflow, temperatures and precipitation for 1979 is presented in Figures 5.1 to 5.12 for the Saint John River at Fort Kent, Grand Falls and Mactaquac.

5.6.1 Fort Kent

The 1 to 4-day forecasts for Fort Kent are shown in Figures 5.1 to 5.4 respectively. Generally the one-day forecasts of flow show satisfactory results. Day 2 maintains an acceptable value for the mag-

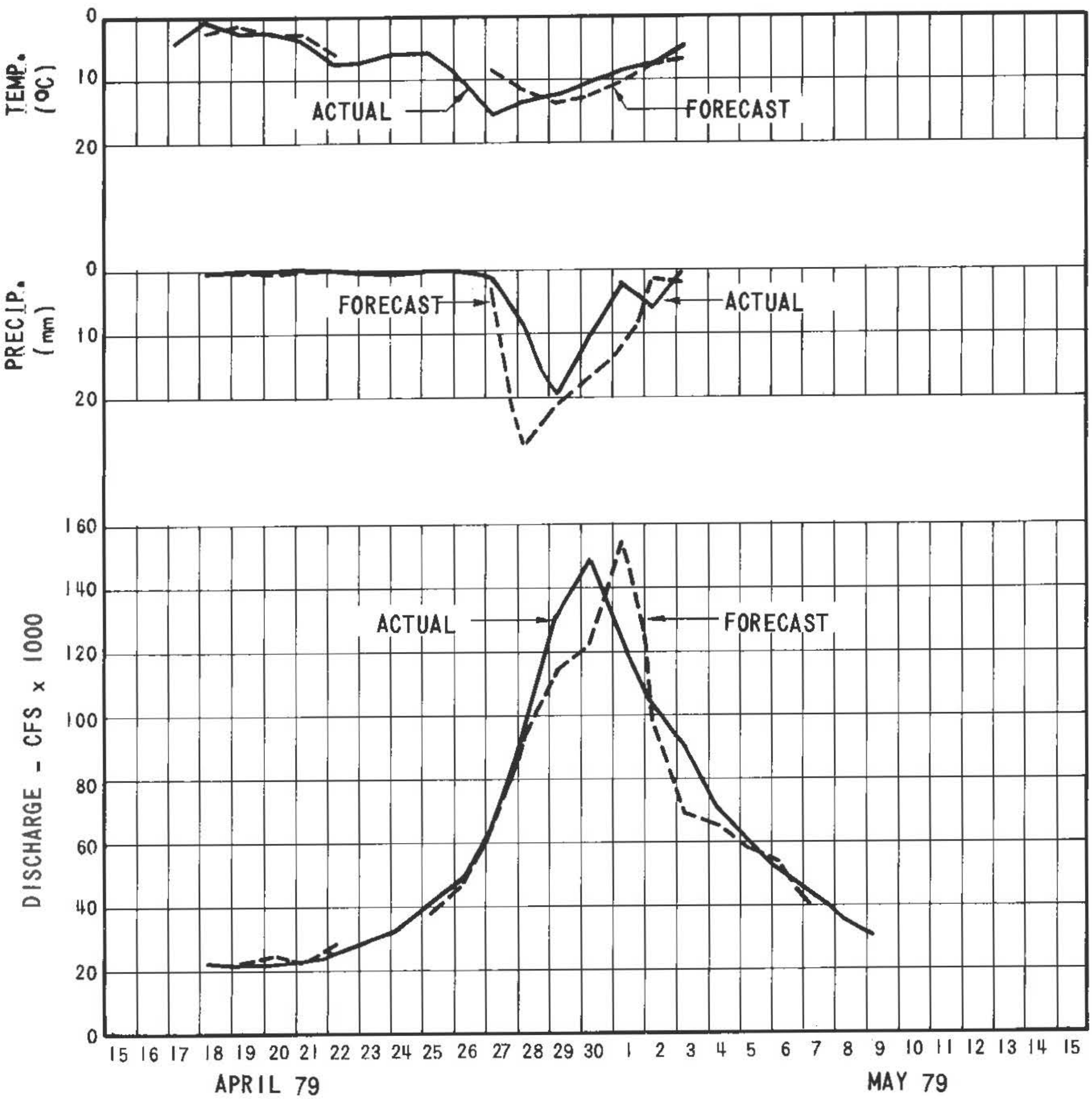
FIGURE 5-1



COMPARISON OF ACTUAL AND FORECAST STREAMFLOW, PRECIPITATION AND TEMPREATURE

FORT KENT - DAY 1

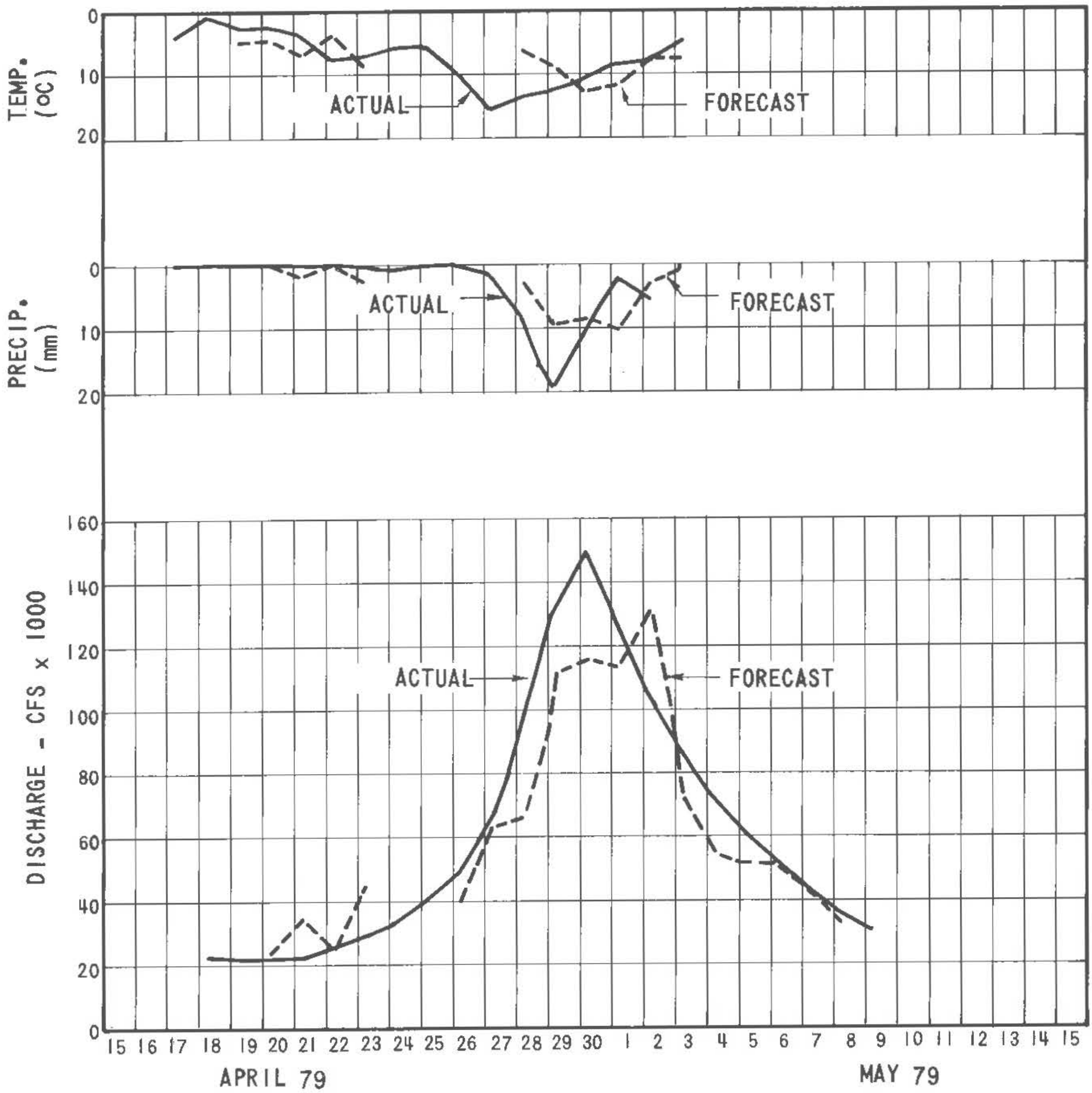
FIGURE 5-2



COMPARISON OF ACTUAL AND FORECAST STREAMFLOW, PRECIPITATION AND TEMPERATURE

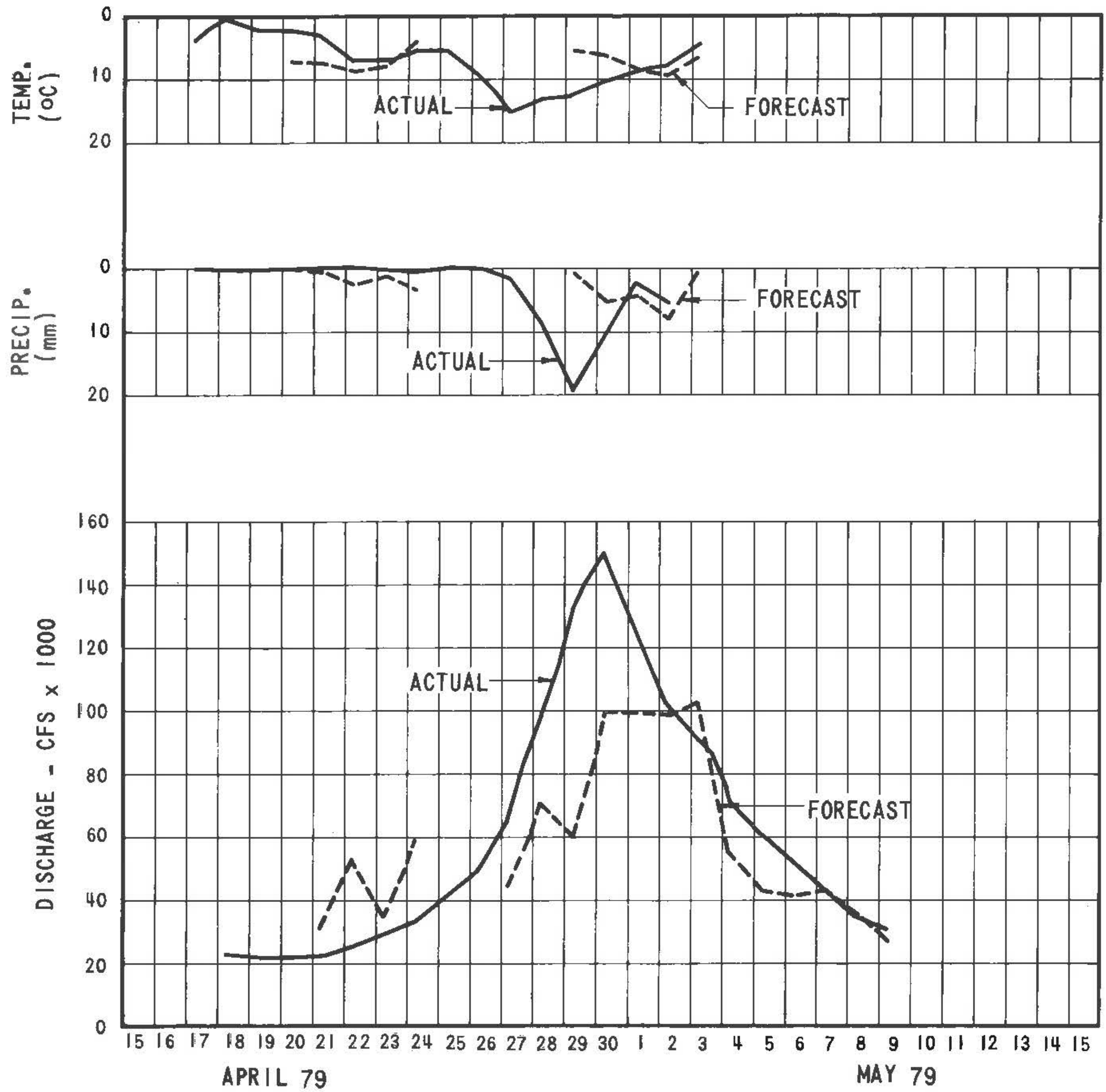
FORT KENT - DAY 2

FIGURE 5-3



COMPARISON OF ACTUAL AND FORECAST STREAMFLOW, PRECIPITATION AND TEMPERATURE
FORT KENT - DAY 3

FIGURE 5-4



COMPARISON OF ACTUAL AND FORECAST STREAMFLOW, PRECIPITATION AND TEMPERATURE

FORT KENT - DAY 4

nitude of peak, however, a 1-day lag is observed in the timing of the peak. Days 3 and 4 indicate decreasing accuracy. This indicates the sensitivity of the model to temperature and precipitation forecasts.

5.6.2 Grand Falls

The 1-to 4-day forecasts for Grand Falls are shown in figures 5.5 to 5.8 respectively. Again the 1-day forecasts give acceptable results both in magnitude and timing of the peak flow. Day 2 forecast flows are generally within acceptable limits with some deterioration in the timing of the peak. Day 3 and day 4 forecast flows are suspectible to precipitation and temperature forecasts and do not give acceptable results.

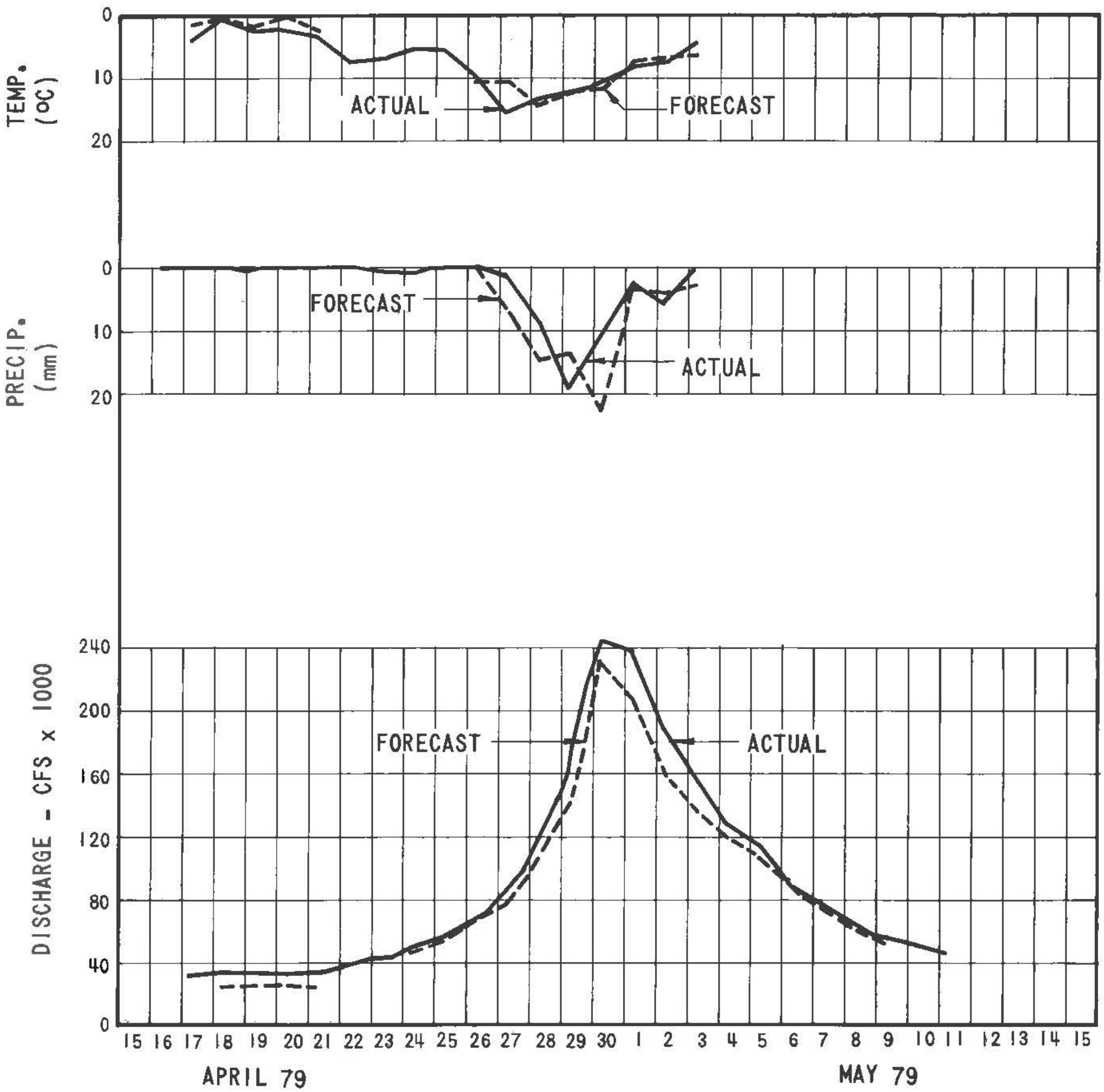
5.6.3 Mactaquac

The 1-to 4-day forecasts for Mactaquac are shown in Figures 5.9 to 5.12 respectively. The 1-day forecasts are within acceptable limits for the magnitude of the peak, the timing of the forecast peak lags the actual by approximately 1 day. This is also prevalent on the rising limb. The day 2 forecasts show the same trend and are within reasonable limits. Day 3 and day 4 flow forecasts are sensitive to temperature and precipitation forecasts; however, day 3 gives a good trend indicator with day 4 being less accurate. Part of the timing problem can be attributed to the operating regulation of the Mactaquac Dam. The actual streamflows are regulated flows and the forecast streamflows are natural inflows with no regulation effects included. This situation can be expected to improve now that the New Brunswick Electric Power Commission is calibrating a dynamic model for regulating the reservoir.

5.7 Summary of Results

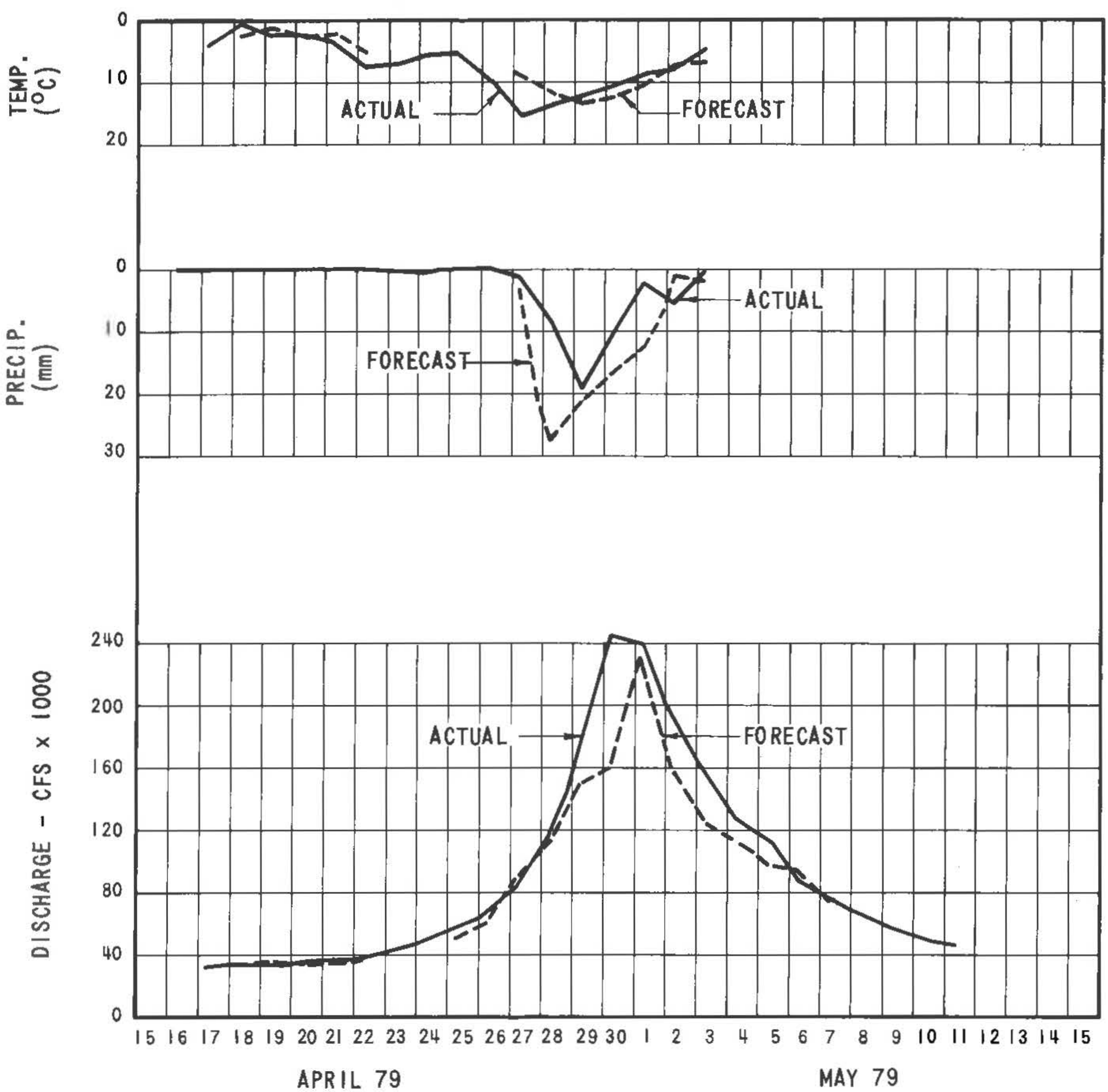
In an overview of the accuracy and performance of the flood forecast for 1979, the following comments are submitted. The 1-day

FIGURE 5-5



COMPARISON OF ACTUAL AND FORECAST STREAMFLOW, PRECIPITATION AND TEMPERATURE
GRAND FALLS - DAY 1

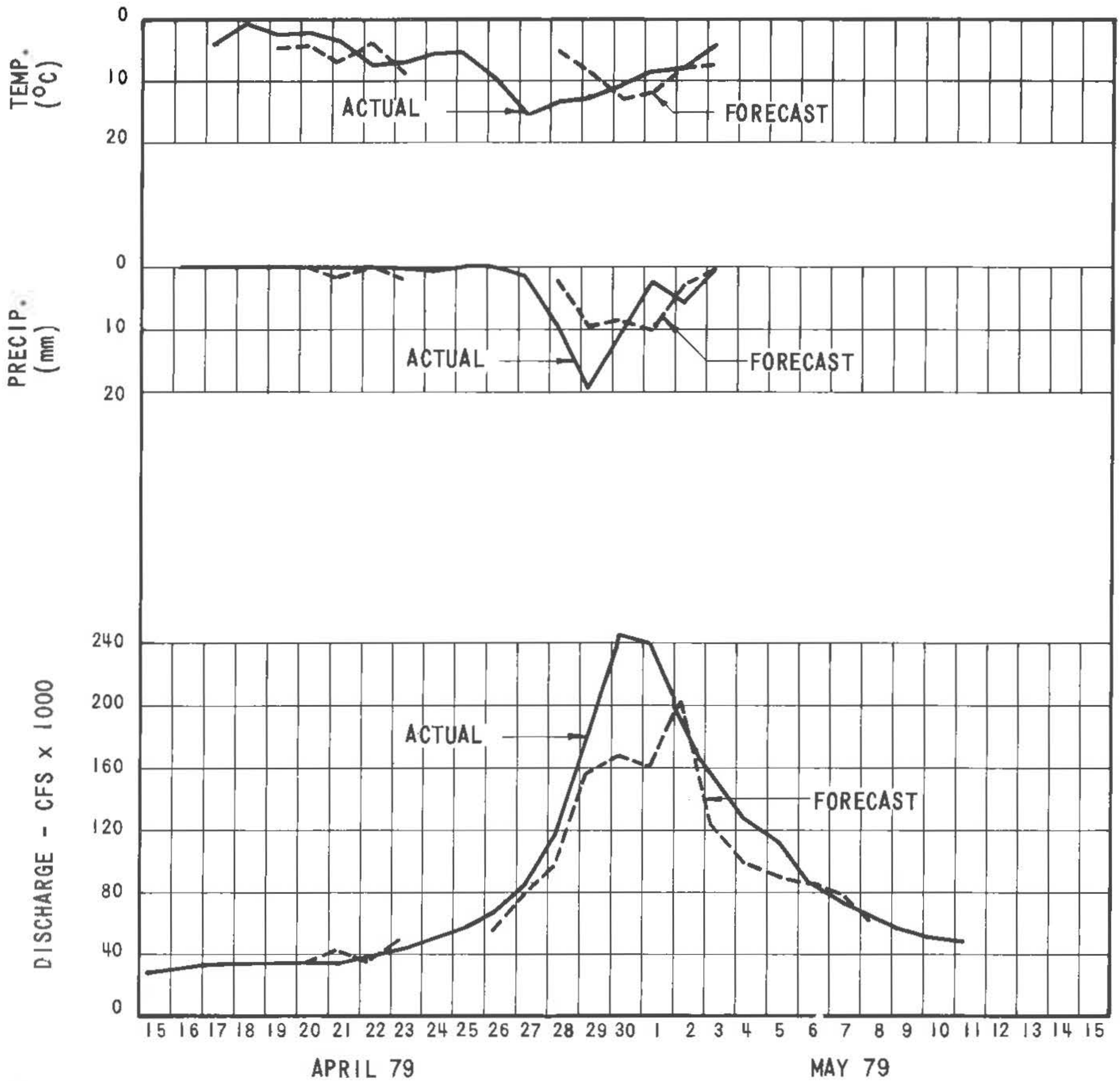
FIGURE 5-6



COMPARISON OF ACTUAL AND FORECAST STREAMFLOW, PRECIPITATION AND TEMPERATURE

GRAND FALLS - DAY 2

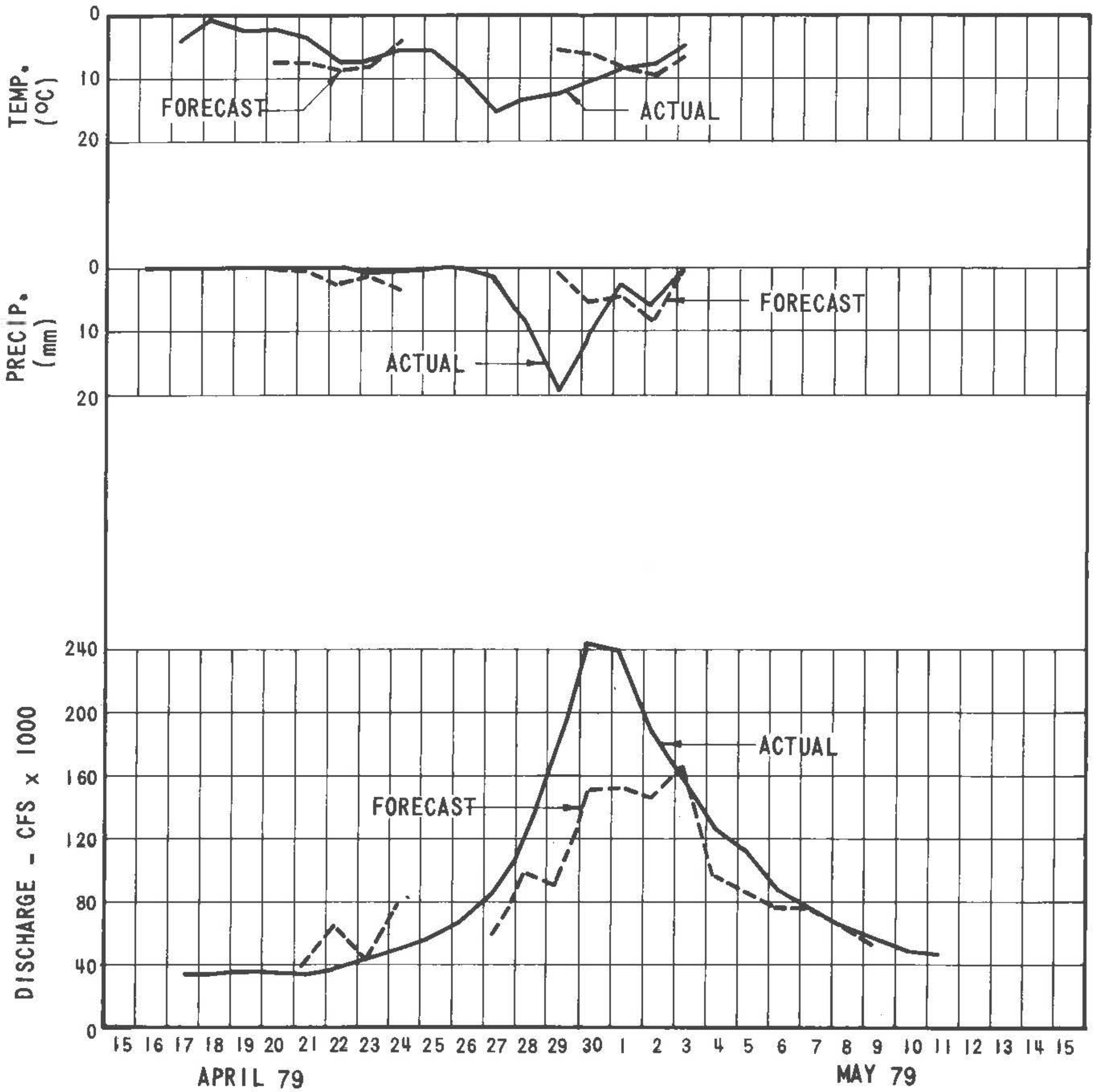
FIGURE 5-7



COMPARISON OF ACTUAL AND FORECAST STREAMFLOW, PRECIPITATION AND TEMPERATURE

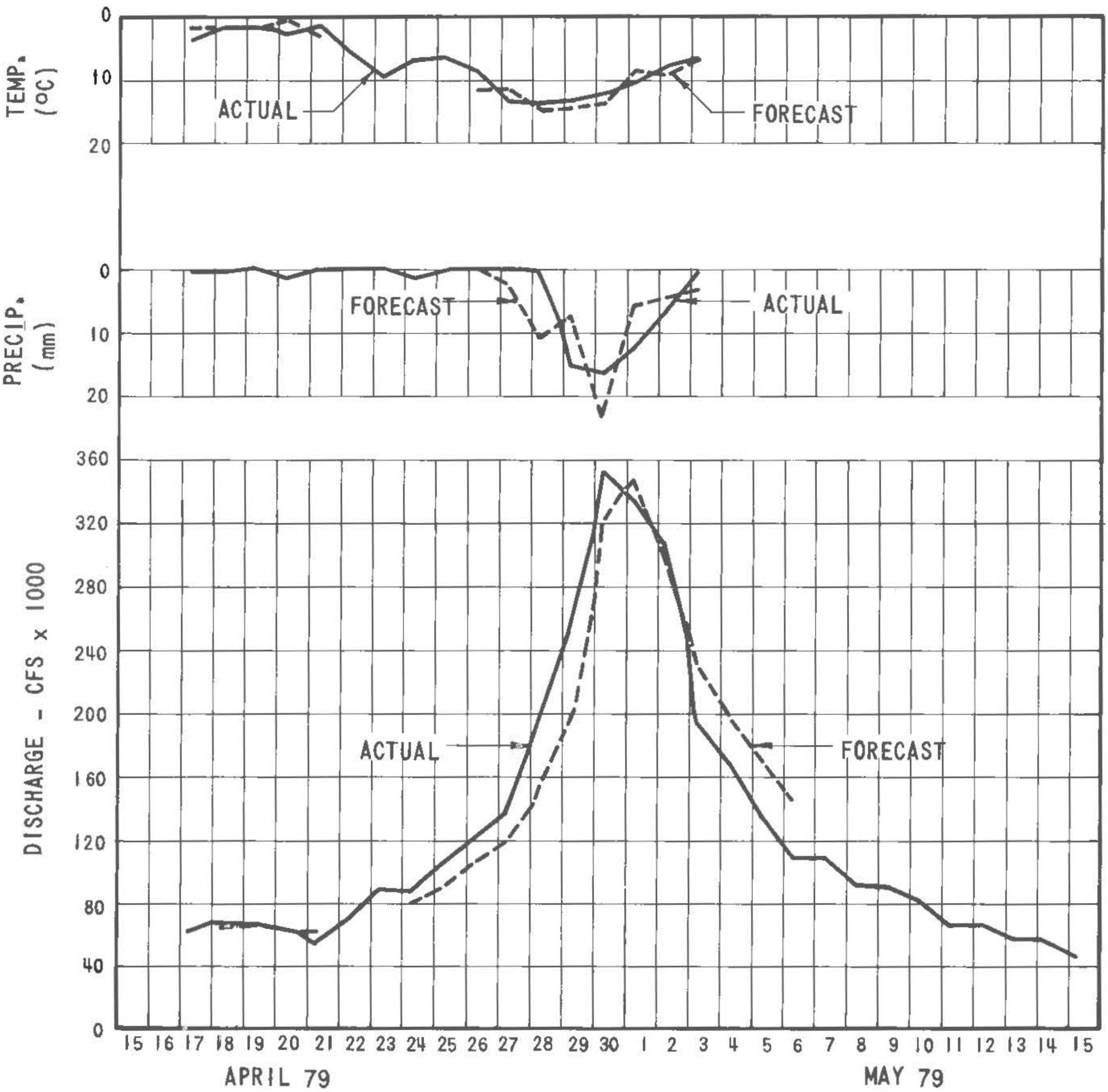
GRAND FALLS - DAY 3

FIGURE 5-8



COMPARISON OF ACTUAL AND FORECAST STREAMFLOW, PRECIPITATION AND TEMPERATURE
GRAND FALLS - DAY 4

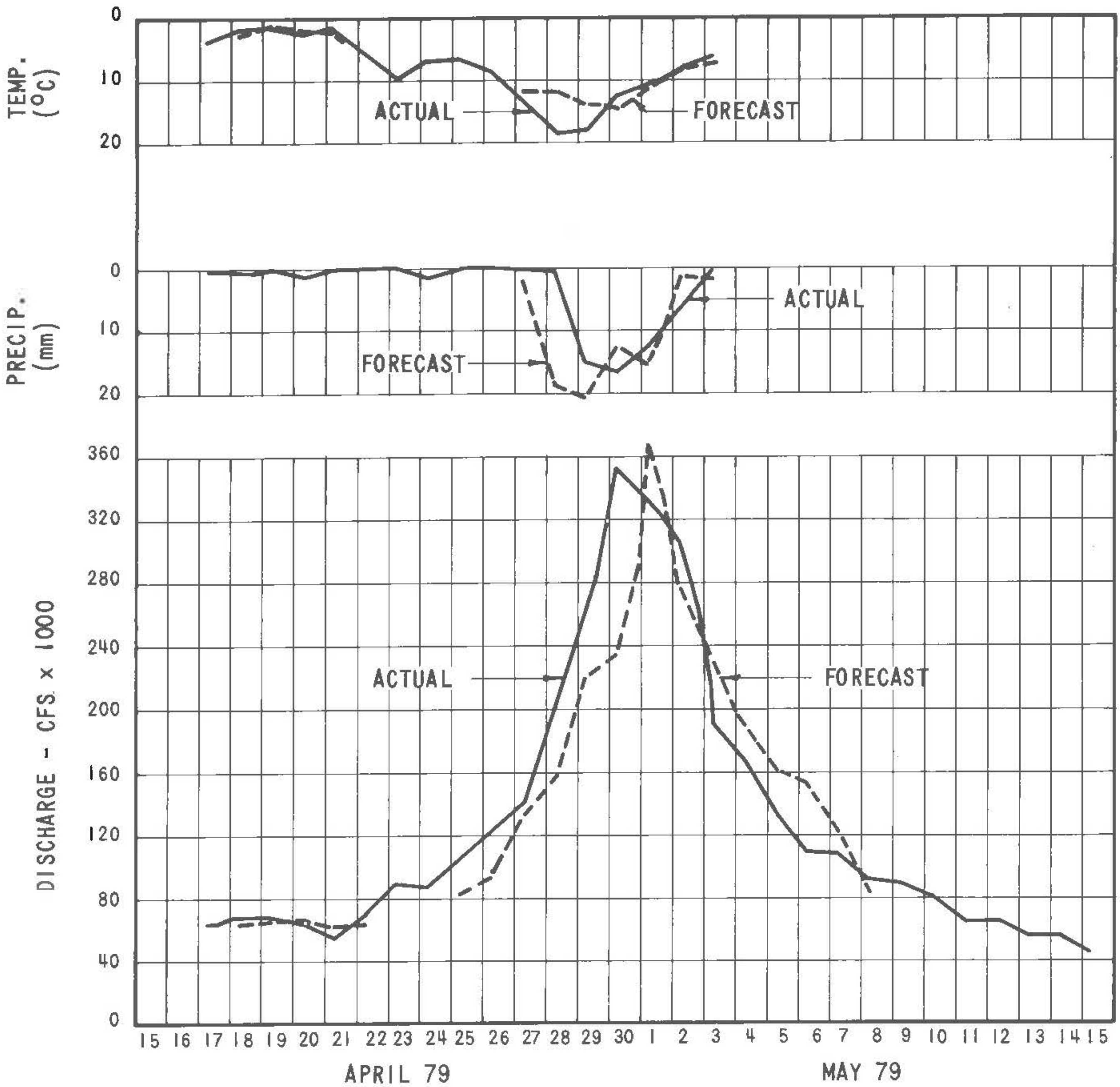
FIGURE 5-9



COMPARISON OF ACTUAL AND FORECAST STREAMFLOW, PRECIPITATION AND TEMPERATURE

MACTAQUAC - DAY 1

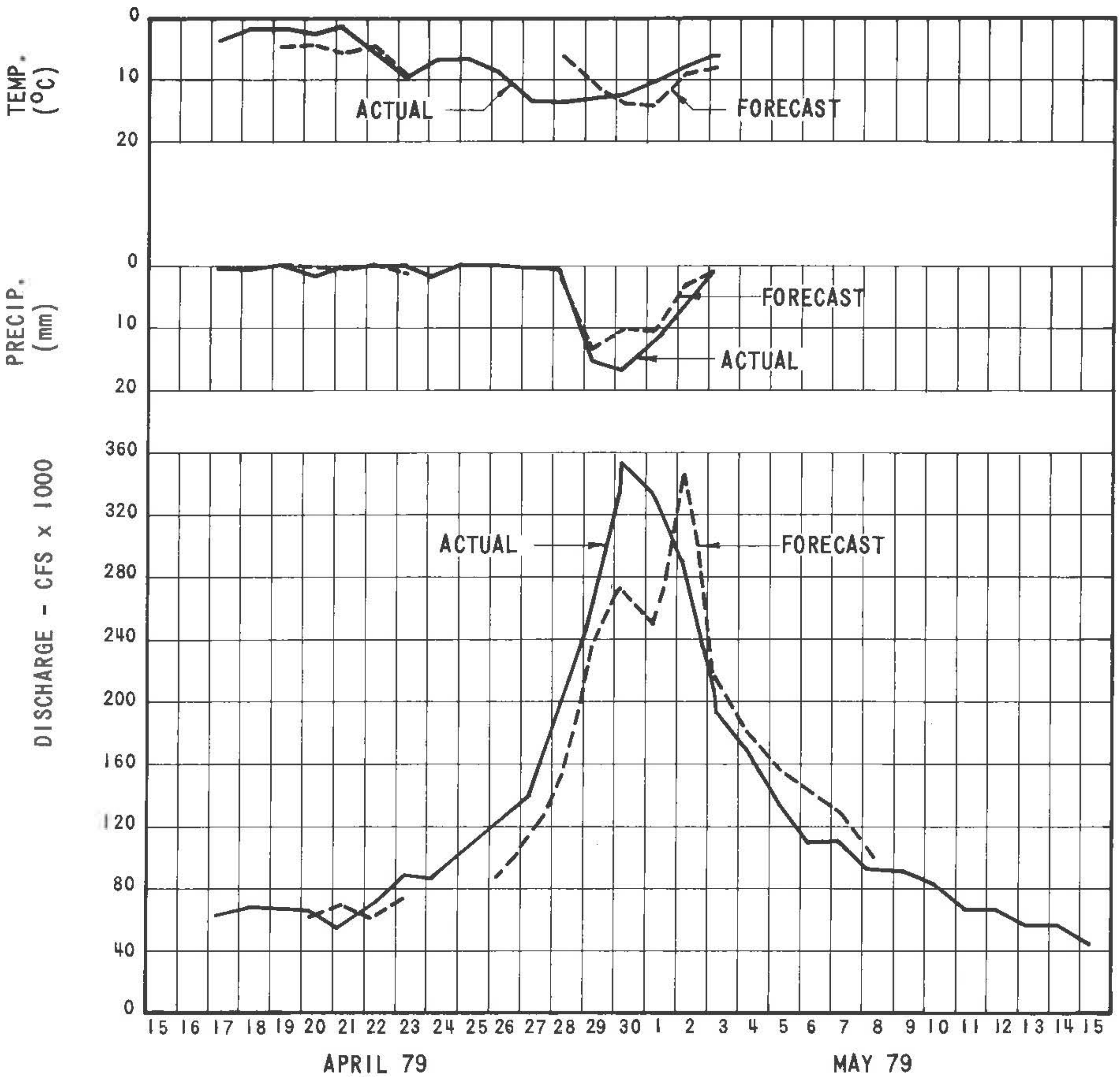
FIGURE 5-10



COMPARISON OF ACTUAL AND FORECAST STREAMFLOW, PRECIPITATION AND TEMPERATURE

MACTAQUAC - DAY 2

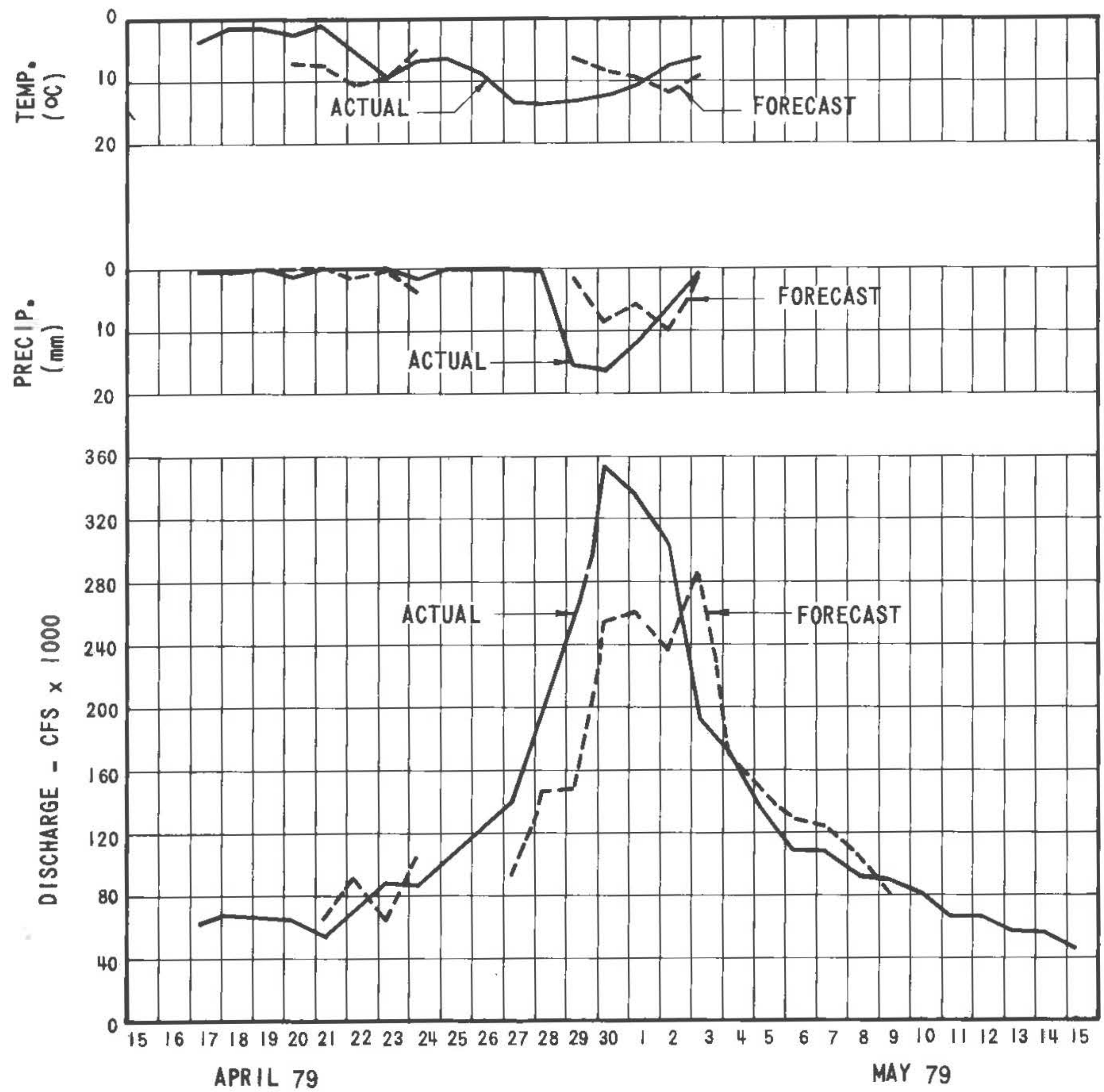
FIGURE 5-11



COMPARISON OF ACTUAL AND FORECAST STREAMFLOW, PRECIPITATION AND TEMPERATURE

MACTAQUAC - DAY 3

FIGURE 5-12



COMPARISON OF ACTUAL AND FORECAST STREAMFLOW, PRECIPITATION AND TEMPERATURE

MACTAQUAC - DAY 4

forecasts are generally quite satisfactory both for providing a warning and for hydro-plant reservoir regulation.

Day 2 forecasts are also acceptable for providing advanced warning with some decline in accuracy for hydro-plant regulation, but the trend is quite acceptable.

Day 3 forecasts are generally satisfactory as a trend analysis to provide advance warning, but do not provide the desired accuracy for accurate hydro-plant reservoir regulation.

Day 4 and day 5 forecasts are at best a trend indication and require some judgement in their use.

Also as indicated on the Figures there are forecast data gaps occurring where there was no forecast made for that particular day or days. It is also noted that the flows at Fort Kent and Grand Falls exceeded the highest flows previously recorded, yet the SSARR program performance was very good under these extreme conditions.

CHAPTER 6

FLOOD DAMAGES

Damaging floods in the Province of New Brunswick are not an uncommon phenomenon. Generally most of the flood damages in the province occur in the Saint John River Basin. This can be seen from Table 6.1 where 86 percent of compensation paid for damages occurred within the Basin during the 1979 flood.

Although the true economic costs of previous floods can only be approximated, the available information suggests that there have been several floods causing damages in excess of one million dollars each since the turn of the century. The floods of 1923 and 1973 were by far the most destructive from the point of view of dollar costs. The latter (1973) flood was in many respects the largest and most widespread since records have been kept, but the damages were fairly small relative to the severity of the event, as explained in the Abstract of this report. The 1979 flood was the second largest in the Saint John River Basin in terms of peak discharge at the Mactaquac (Pokiok) gauging station and fourth largest in terms of stage at Fredericton.

The total economic cost of the 1979 flood in the Basin is estimated to be approximately $6,500,000, towards which about $3,600,000 was paid out in response to compensation claims. Table 6.1 lists total compensation costs by sector and counties included in the Basin.

Summary information on the economic cost of the 1979 flood for the New Brunswick Department of Natural Resources and the New Brunswick Department of Transportation are presented in Tables 6.2 and 6.3 respectively. Detailed compensation costs by counties within the Basin is tabled in Appendix I.

TABLE 6.1

TOTAL COMPENSATION COSTS OF THE 1979 FLOOD

County	Compensation Costs of Different Sectors (Dollars)						Total Cost (Dollars)
	Agriculture	Public	Fisheries	Municipal	Natural Resources	Transportation	
Restigouch	5,615	35,355		66,495		37,822	146,287
Gloucester		255					255
Northumberland	6,980	4,678				49,681	61,339
Westmorland	2,338	1,300	2,755			64,550	70,943
Albert	970	12,576					13,546
[Saint John]	1,615	3,389	383		see		5,387
Charlotte	760	6,582	4,390		Table 19	194,775	206,507
[King-Queens]	52,764	19,060	729			1,058,800	1,131,353
[York-Sunbury*]	10,183	17,937	10,940	10,000			49,060
[York-Sunbury**]	237,737	257,468	700	16.594		717,835	1,230,334
[Carleton]	3,780	24,205		41,488			69,473
[Victoria]	10,919	56,732		16,000		10,100	93,751
[Madawaska]	22,668	193,825		21,972		208,234	446,699
Total	357,329	633,362	19,897	172,549		2,341,797	3,524,934

* Excluding Fredericton, Sheffield, Maugerville Area.
** Fredericton, Sheffield, Maugerville Area.

NOTE: Counties between brackets comprise major portions of the Saint John River Basin.

TABLE 6.2

ECONOMIC COST OF THE 1979 FLOOD

DEPARTMENT OF NATURAL RESOURCES

SUMMARY

Region		Restoration Cost
Region No. 1*	(Northern New Brunswick)	$ 5,500.00
Region No. 4	(Middle Saint John River)	291,759.73
Region No. 5	(Greater Fredericton)	70,948.00
	TOTAL:	$ 368,207.73

* Outside Saint John River Basin

TABLE 6.3

ECONOMIC COST OF THE 1979 FLOOD

DEPARTMENT OF TRANSPORTATION

SUMMARY

AREA		RESTORATION COST HIGHWAYS	RESTORATION COST BRIDGES
District No. 1*	Restigouche County	$ 33,212.00	$ 4,610.00
District No. 2*	Northumberland County	19,681.79	30,000.00
District No. 3*	Westmorland County	64,550.00	-
District No. 5	Queens and Sunbury Counties	1,058,800.00	-
District No. 6	York and Sunbury Counties	550,835.00	167,000.00
District No. 8	Charlotte County	137,983.00	56,792.00
District No. 10	Madawaska County	34,620.00	173,614.00
District No. 11	Victoria County	5,100.00	5,000.00
	SUB-TOTAL	$1,904,781.79	$437,016.00
	TOTAL	$2,341,797.79	

* Outside Saint John River Basin

CHAPTER 7

COMPARISON WITH HISTORIC FLOODS

In comparing the flood of 1979 with past floods, it must be noted that records of stage and discharge exist for only a very short period of time relative to the history of the province.

On the main stem of the Saint John River, records of stage are available since about 1920 at Fredericton, Oromocto and Oak Point. The 1979 peak stage at Fredericton was exceeded only three times since 1922. Those were, in descending order, the flood levels in 1936, 1973, and 1923. The 1936 flood was caused by an ice jam resulting in a peak stage of 8.900 metres at Fredericton; about 1 metre higher than that which occurred in 1979. The next highest stage since 1922 occurred in 1973 and was only 0.643 metres higher than the maximum stage during the 1979 flood. Other major floods in the lower portion of the Basin occurred in 1934, 1958, and 1961. The water level elevations in those years are given in Table 7.1.

TABLE 7.1

Maximum Daily Mean Stage, Lower Saint John River

Year	Stage in Metres above Mean Sea Level		
	Fredericton	Oromocto	Oak Point
1923	8.047	6.645	5.639
1934	7.376	6.431	5.456
1936	8.900 (ice jam)	6.888	4.877
1958	7.590	not available	4.877
1961	7.413	not available	4.694
1973	8.540	7.224	5.639
1979	7.897	6.435	4.690

Prior to the beginning of stage records there is very little information on flood levels, but newspaper reports give some indication that major floods occurred on the Saint John River in 1831, 1854 and 1887. A high water mark chiselled into the corner stone of a fence post at the rear of the old Normal School in Fredericton shows a mark corresponding to the 1887 flood level at an elevation of 8.17 m above mean sea level. Comparative descriptions in newspaper reports suggest the peak stage in 1887 was a few inches higher than that reached in 1854, but lower than the 1831 level. It is likely that the maximum stage in 1831 was only about 0.1 m above that reached in 1979 at Fredericton.

Discharge records in the Basin date back to 1918 at the former main stem Pokiok gauging station, about 40 km above the Mactaquac Dam, and on Shogomoc Stream. At both these stations, the maximum discharge prior to 1979 occurred in 1923 and 1973. On the Shogomoc, the maximum daily discharge in 1923 was 117 m^3/s, considerably higher than the maximum daily means of 78.4 m^3/s recorded in 1973 and 64.8 m^3/s recorded in 1979. At the Pokiok gauging station, the maximum was 8160 m^3/s in 1923, compared with the daily mean discharge of 11,100 m^3/s during 1973 below Mactaquac and 10,000 m^3/s during 1979 below Mactaquac. The drainage area at Pokiok is only three percent less than that below the Mactaquac Dam. The years with other significant floods at Pokiok are shown below in descending order of flow magnitude.

Year	Maximum Daily Mean Discharge (m^3/s)
1958	7840
1947	7840
1941	7280
1934	7160
1939	7080
1961	7050

The 1979 flood could also be compared with previous floods on the basis of damages. This is rather difficult because very little basic information is available on the economic costs of previous floods, with the exception of the 1973 flood. For the Saint John River Basin, an attempt was made to estimate the costs of previous floods during studies for the Saint John River Basin Board. The estimates were developed mainly from newspaper reports with a limited amount of concrete data on physical damages. These estimated, adjusted according to the national annual averages of the consumer price index, indicate that damages exceeded four million dollars, based on 1979 price levels, in six previous years of this century. The estimated damages are listed below:

1922	$ 4,940,000
1923	24,240,000
1936	12,790,000
1961	7,920,000
1970	6,380,000
1973	18,330,000

Comparison of these values with the estimated 1979 cost in the Saint John River Basin of approximately $6,500,000 indicates that the 1979 flood damages were relatively modest considering the magnitude of the flood. This observation reflects the importance of flood forecasts and flood warnings. It also reflects the response of the public to such flood warnings.

CHAPTER 8

LESSONS FOR THE FUTURE

This review of the conditions associated with the 1979 flood in the Saint John River Basin has led to some conclusions which should be of use to government agencies and others employed in developing programs to reduce the magnitude of future flood damages.

As explained in Chapter 2, there were six contributing causes to the 1979 flood. None of these individually were of great significance, but in combination were sufficient to create the flood.

It is this combination of the six contributing causes that is important. The storm system, which moved into Maine, Quebec and western New Brunswick in the period April 27 to May 3, is estimated to have dropped an average of about 43 mm of rain over the Basin in the period April 27 to 29 that directly contributed to peak discharge; with an additional 7 mm to May 3 which contributed to peak stages in the lower Basin. These amounts were fairly modest, with a return period of about two years. The arrival of this precipitation was critical, however, the remaining late season snow pack, thought to be a little below normal in water content, was extremely "ripe". This pack, estimated to have a Basin average of 92 mm, was quite variable in aerial distribution and content, with greatest concentrations of water content across the northern and north-western regions of the Basin. The rapid rise in daily temperatures that accompanied the storm caused accelerated rates of snowmelt

The antecedent conditions in the Basin were particularly susceptible to this precipitation and snowmelt contribution. The watershed was highly saturated from the previous recharges which had occurred during the winter months at about 2-week intervals. The relatively large late March recharge accompanying break-up was followed by rains on April 9 - 10 ranging from 19 - 50 mm over much of the Basin excepting the northern areas. Base flows were very high in most streams and natural ground and surface water storages were already near their nominal capacities immediately prior to the flood.

Most floods that have occurred in the Basin involved some combination of rainfall and snowmelt, although some exceptions exist. The floods of late June, 1922 and late May, 1961 resulted from heavy rainfall without accompanying snowmelt. Flooding may result from snowmelt with little or no accompanying rainfall, but weather records would have to be checked to verify if this has actually occurred.

Current technology in the field of precipitation and temperature prediction limits accurate flood warnings to only two or three days in the Saint John River Basin. Improvement in advancing predictions beyond this present capability is unlikely to occur in the near future.

The first use of a forecasting model for the Basin occurred coincident with the 1973 spring flood when the SSARR-based model was introduced. At that time, the model did not have the capability to predict flood stages in the most flood prone reach of the Basin, from Fredericton downstream. Since 1973, the capabilities of the model have been improved by additional testing and calibration. During the 1979 flood this model's backwater component was used to predict flood stages at several locations from just below the Mactaquac Dam to Saint John. At the time of the writing of this report another more sophisticated hydraulic model (DWOPER) was also in operation for this purpose. Both models are under continuous testing and/or calibration to improve their efficiency.

The magnitude of losses and personal hardships associated with flooding warrant full consideration of all possible ways to minimize these effects in the future. Most of these losses occur on the flood plain of the river in the reach from Fredericton downstream through the Maugerville-Sheffield region, where extensive areas of the flood plain have been developed for commercial, residential and agricultural purposes, frequently without sufficient concern for the potential hazards.

In the Maugerville-Sheffield area much of this susceptible development has resulted from the area's high agricultural productivity. This activity should continue, with consideration given to ways of limiting damages to farm homes and buildings. Of greater concern are the other developments that are not related to agriculture which are taking place in the area.

This whole problem of development can be assisted by adjuncts of the Flood Damage Reduction Program which is now nearing completion for this and other flood prone areas of the Basin. Flood risk maps have been or are being produced as a part of this program, under the Canada-New Brunswick Agreement Respecting Flood Risk Mapping and are now available from the N.B. Department of the Environment or the N.B. Department of Natural Resources.

The Flood Risk Mapping Agreement provides for the designation of flood risk areas. Once an area is designated, the Federal and Provincial department or agencies agree to follow certain policies regarding development of floodplain lands (Ref. 16).

Another means to prevent and/or control developments in flood prone areas is the Flood Risk Area By-Law, Sections 41.1 and 41.2 of the amended Community Planning Act, assented to June 14, 1979.

The ammended Act, Section 41.1, permits a municipality to request, and the Minister of the Environment to designate, any area within the municipality a flood risk area. This designation shall be effected by the production of a map of the designated area showing the various elevations along the line delineating the flood risk area.

Section 41.2 permits a municipal council to enact a flood risk area by-law, and sets forth the provisions the by-law may enact, such as floodway maintenance, flood-water storage capacity conservation and protection of new development. It further permits the prescription of engineering standards, designs and techniques to be followed in all development, and goes on to define what constitutes "development", and for what reasons it may be prohibited. The section also permits the payment of an amount of money to the municipality to provide for equivalent flood water storage capacity where the developer establishes that he is unable to provide this capacity displaced by the development.

Planning and regulation of the use of flood prone land is the most obvious approach to minimizing future flood damages. If such planning and regulation is not undertaken, the potential for future damages will continue to increase because floods will continue to occur in the Basin.

There is also a need to consider methods of reducing future damage to existing structures already located on the flood plains. Flood proofing some of the larger existing government and privately owned buildings in Fredericton may prove to be cost effective. In the case of new structures, it has been shown (Ref. 17) that when flood proofing is incorporated in the design the costs may be relatively small for a large structure, but significant for a smaller building.

The existing forecasting and emergency measures program has been shown to be effective in reducing some potential damage. Efforts should continue towards improving the capabilities of the hydraulic models and forecast predictions, seasoned by appropriate amounts of "seat-of-the-pants" hydrology. The latter is necessary for proper application of the tools being used and in judging the quality of the results obtained.

A discussion of other methods of reducing flood damages, such as the construction of flood control reservoirs, dykes or drainage improvement works is beyond the scope of this report.

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APPENDIX I

DETAILED COSTS OF THE 1979 FLOOD

	COUNTY	NO. OF CLAIMS	LAND	CROP	BUILDINGS	CONTENTS	MISC.	TOTAL
	SAINT JOHN							
AGR.		2					1,615 00	1,615 00
P.S.		6			841 00		2,548 00	3,389 00
FIS.		1						383 00
MUN.								
D.N.R.								
D.O.T.								
					841 00		$4,163 00	
							GRAND TOTAL	$5,387 00

	COUNTY	NO. OF CLAIMS	LAND	CROP	BUILDINGS	CONTENTS	MISC.	TOTAL
	KING - QUEENS'							
AGR.		27	$21,129 95	$720 00	$1,680 00	NIL	$22,234 45	$52,764 40
P.S.		25			13,017 00	2,393 00	3,650 72	19,060 72
FIS.		1						729 00
MUN.								
D.N.R.								
D.O.T.		1		D.O.T. districts are laid out so that this must be shown as Queen & Sunbury.				1,058,800 00
		54	$21,129 95	$720 00	$14,697 00	2,393 00	$25,885 17	
							GRAND TOTAL	$1,131,354 12

	COUNTY	NO. OF CLAIMS	LAND	CROP	BUILDINGS	CONTENTS	MISC.	TOTAL
Excluding Fredericton	YORK-SUNBURY Sheffield, Maugerville Area							
AGR.		4	$7,352 00	$300 00			$2,531 00	$10,183 00
P.S.		18			$13,003 00	$4,087 00	847 47	17,937 47
FIS.		5						10,940 00
MUN.		1						10,000 00
D.N.R.								
D.O.T.								
		28	$7,352 00	$300 00	$13,003 00	$4,087 00	$3,378 47	
							GRAND TOTAL	$49,060 47

	COUNTY	NO. OF CLAIMS	LAND	CROP	BUILDINGS	CONTENTS	MISC.	TOTAL
Fredericton Sheffield, Maugerville Area	YORK-SUNBURY							
AGR.		48	$81,253 00	$87,815 65	$8,903 00	$245 00	$59,520 54	$237,737 19
P.S.		225	6,446 00		189,105 00	37,626 00	24,271 63	257,468 63
FIS.		1						700 00
MUN.								16,594 00
D.N.R.								
D.O.T.		1						717,835 00
		280	$87,719 00	$87,815 65	$198,008 00	$37,871 00	$83,792 17	
							GRAND TOTAL	$1,230,334 82

	COUNTY	NO. OF CLAIMS	LAND	CROP	BUILDINGS	CONTENTS	MISC.	TOTAL
	CARLETON							
AGR.		2	1,550 00	350 00	200 00		1,680 00	3,780 00
P.S.		24	3,759 00		15,749 16	505 00	4,192 00	24,205 16
FIS.								
MUN.		3						41,488 00
D.N.R.								
D.O.T.								
		29	$5,309 00	$350 00	$15,949 16	$505 00	$5,872 00	
							GRANDTOTAL	$69,473 16

	COUNTY	NO. OF CLAIMS	LAND	CROP	BUILDINGS	CONTENTS	MISC.	TOTAL
	VICTORIA							
AGR.		3	$1,868 25	$7,500 00	500 00		$1,051 00	$10,919 25
P.S.		17	34,955 00		11,095 21	2,315 00	8,367 00	56,732 21
FIS.								
MUN.		1						16,000 00
D.N.R.								
D.O.T.		1						10,100 00
		22	$36,823 25	$7,500 00	$11,595 21	$2,315 00	$9,418 00	
							GRAND TOTAL	$93,751 46

	COUNTY	NO. OF CLAIMS	LAND	CROP	BUILDINGS	CONTENTS	MISC.	TOTAL
	MADAWASKA							
AGR.		10	19,675 00	20 00			2,973 00	22,668 00
P.S.		97	19,369 50		103,595 87	48,914 52	21,945 00	193,825 33
FIS.								
MUN.		4						21,972 39
D.N.R.								
D.O.T.		1						208,234 00
		112	$39,044 50	$20 00	$103,595 87	$48,914 52	$24,918 00	
							GRAND TOTAL	$446,699 72

APPENDIX II

SELECTED PHOTOGRAPHS

Fredericton Pumping Station, approximately at peak, Monday, April 30, 1979, at 5:00 p.m.

Parking lot near Pumping Station at Fredericton, Monday, April 30, 1979, at 5:00 p.m.

Campbell Street behind Library, Water Level 26.00 ft., April 30, 1979, at 3:45 p.m.

Intersection of Brunswick and Carleton Streets, Water Level 25.53 ft., Monday, April 30, 1979, at 9:50 a.m.

Intersection of Brunswick and Carleton Streets,
Monday, April 30, 1979, at 3:45 p.m.

Intersection of Brunswick and Carleton Streets,
Water Level 25.83 ft., Monday, April 30, 1979, at 4:00 p.m.

Queen's Square, Fredericton, Monday, April 30, 1979, at 3:05 p.m.

Centennial Building, Fredericton, Monday, April 30, 1979, at 3:30 p.m.

Fredericton Green from Art Gallery Patio, Looking Downstream to Railway Bridge, Monday, April 30, 1979, at 3:15 p.m.

Intersection of University Avenue and Shore Street, Water Level 25.36 ft., Monday, April 30, 1979, at 12:05 p.m.

Waterloo Row at Ball Park, Water Level 25.60 ft., Monday, April 30, 1979, at 11:30 a.m.

Lincoln Road at Corbett Brook, Monday, April 30, 1979, at 11:00 a.m.

A house on the north side of T.C.H. about 4.7 miles from Princess Margaret Bridge, April 30, 1979, at 10:10 a.m.

At Doug Ryan's mail box about 5.6 miles from Princess Margaret Bridge, looking downstream, April 30, 1979, at 10:15 a.m.

Looking downstream on the north side of the Saint John River just below Burton Bridge, April 30, 1979, at 11:08 a.m.

Debris on T.C.H., looking downstream about 1.0 mile below Burton Bridge, April 30, 1979, at 11:30 a.m.

Picture of Water Mark (N7) about 4.5 miles downstream from Burton Bridge, April 30, 1979, at 11:44 a.m.

Picture of Water Mark at McGowans Corner (N9), April 30, 1979, at 12:30 p.m.

A moose escaping high waters on Highway 690, April 30, 1979, at 12:55 p.m.

Doug's Appliance Service on the north side of T.C.H., April 30, 1979, at 2:47 p.m.

At Doug's Appliance Service, showing a washed-away dyke
and a broken fence, April 30, 1979, at 2:48 p.m.

Looking downstream and showing the north side of T.C.H.,
April 30, 1979, at 3:00 p.m.

T.C.H. near Fresh Meat Market, looking downstream, April 30, 1979, at 3:23 p.m.

Just below Burton Bridge, looking upstream, April 30, 1979, at 3:30 p.m.

Showing water level above basement windows about 6.2 miles from Princess Margaret Bridge, May 1, 1979, at 8:05 a.m.

Dutch Drive-in Restaurant, and debris on T.C.H., looking downstream, May 1, 1979, at 8:25 a.m.

Maugerville Gauging Station, just before Burton Bridge, May 1, 1979, at 8:42 a.m.

T.C.H., looking upstream, about 5.0 miles below Burton Bridge, May 1, 1979, at 9:20 a.m.

T.C.H., looking upstream, showing church and graveyard, about 5.5 miles below Burton Bridge, May 1, 1979, at 9:28 a.m.

At S and F Green Houses, about 7.0 miles below Burton Bridge, looking upstream, May 1, 1979, at 9:42 a.m.

Lakeville Corner Bridges, water level is almost at bridge deck, May 1, 1979, at 10:40 a.m.

Devon Underpass on the north side of the Saint John River at Fredericton, May 1, 1979, at 1:00 p.m.