5. HYDROLOGY

5.1 Database

The hydrological data used in this study were extracted from the Hydat CD - ROM of Surface Water Data (Environment Canada, 1994). The primary database consisted of daily streamflow measurements at all active and discontinued hydrometric stations in Labrador. Data from watersheds with regulated flow were included in the database because they could provide some insights into the natural hydrological processes and also because they assisted in the development of mean annual isolines. A listing of all active and discontinued streamflow gauging stations in Labrador is given in Table 5.1. Some of their characteristics are given in Table 5.2.

Streamflow measurements at select hydrometric stations in Quebec were included to characterize the hydrology of Labrador. Quebec data were needed for the following reasons.

1. Streamflow data in Labrador are sparse, whereas data in Quebec are relatively more abundant. There were 35 streamflow records available for Labrador, and 1002 streamflow records available for Quebec. Quebec has nearly 30 times as many streamflow records but has only a little more than 5 times the area.
2. Watersheds in Quebec, which are near the Quebec-Labrador border, can be used to characterize hydrology in Labrador because of their geographical proximity to

Table 5.1 Streamflow Gauging Stations in Labrador

STATION NUMBER	STATION NAME
02XA003	Little Mecatina River above Lac Fourmont
02XA004	Riviere Joir near Provincial Boundary
02XD002	North Brook near Red Bay
03NF001	Ugjoktok River below Harp Lake
03NG001	Kanairiktok River below Snegamook Lake
03OA001	Ashuanipi River at Menihek Rapids
03OA003	McPhadyen River near the Mouth
03OA004	Ashuanipi River below Wightman Lake
030B002	Churchill River at Flour Lake
03OB003	McKenzie River below Andre Lake
03OC002	Atikonak River at Atikonak Rapids
03OC003	Atikonak River above Panchia Lake
03OC004	Atikonak River (West Branch) below Kepimits Lake
03OC005	Atikonak River above Atikonak Lake
030C006	Atikonak River at Gabbro Lake
03OD001	Churchill River near Churchill Falls
03OD002	Unknown (Atikonak) River at Twin Falls
03OD003	Unknown (Atikonak) River at Lake 51
03OD004	Metchin River (East Branch) near Winokapau Lake
03OD005	Churchill River at Churchill Falls Powerhouse
03OD006	Atikonak River at Ossakmanuan Lake Control Structure
03OE001	Churchill River above Upper Muskrat Falls
03OE002	Minipi River near Minipi Lake
03OE003	Minipi River below Minipi Lake
03PB001	Naskaupi River at Fremont Lake
03PB002	Naskaupi River below Naskaupi Lake
03QC001	Eagle River above Falls
03QC002	Alexis River near Port Hope Simpson

the study area. In general, geographical proximity suggests similar physiography, similar climate and similar hydrology.

3. Some inter-provincial rivers are gauged in both Labrador and Quebec. These data can be used to develop methodologies for transferring hydrological information from large gauged watersheds to relatively smaller ungauged watersheds.

Initially, 39 Quebec stations were identified as having streamflows records which

Table 5.2 Characteristics of Streamflow Gauging Stations in Labrador

STATION NUMBER	START YEAR	FINISH YEAR	YEARS OF RECORD	COMPLETE YEARS OF RECORD	FLOW REGIME	DRAINAGE AREA (km^2)
02XA003	1978	1993	16	13	Natural	4,540
02XA004	1980	1993	14	13	Natural	2,060
02XD002	1984	1993	10	0	Natural	35.5
03NF001	1979	1993	15	14	Natural	7,570
03NG001	1979	1993	15	15	Natural	8,930
03OA001	1952	1993	42	30	Regulated	19,000
03OA003	1972	1982	11	2	Natural	3,610
03OA004	1972	1983	12	3	Natural	8,310
030B002	1955	1971	17	15	Natural	33,900
03OB003	1972	1975	4	2	Natural	1,040
03OC002	1955	1957	3	1	Natural	19,900
03OC003	1972	1983	12	5	Natural	15,100
03OC004	1972	1983	12	3	Natural	7,070
03OC005	1972	1983	12	3	Natural	3,680
030C006	1973	1993	21	21	Regulated	21,400
03OD001	1954	1955	2	0	Natural	57,500
03OD002	1962	1976	15	14	Regulated	22,800
03OD003A[1]	1955	1963	9	8	Natural	19,900
03OD003B[1]	1964	1971	8	5	Regulated	19,900
03OD004	1972	1972	1	0	Natural	1,090
03OD005	1972	1993	22	22	Regulated	69,200
03OD006	1977	1993	17	17	Regulated[2]	Unknown
03OE001A[1]	1948	1970	23	17	Natural	78,800
03OE001B[1]	1972	1993	22	21	Regulated	92,500
03OE002	1972	1978	7	0	Natural	2,220
03OE003	1979	1993	15	14	Natural	2,330
03PB001	1955	1970	16	13	Natural	8,990
03PB002	1978	1993	16	15	Natural	4,480
03QC001	1966	1993	28	23	Natural	10,900
03QC002	1978	1993	16	16	Natural	2,310

1. Streamflow records split into 2 parts: natural flows and regulated flows
2. Zero Flow 1977-93

may be useful for modelling hydrology in Labrador. These stations, and some of their characteristics are listed in Appendix H. The primary criterion for selecting Quebec stations was that the station measure streamflow from a watershed which is in or bordering

Table 5.3 Characteristics of Select Streamflow Gauging Stations in Quebec

STATION NUMBER	START YEAR	FINISH YEAR	YEARS OF RECORD	COMPLETE YEARS OF RECORD	FLOW REGIME	DRAINAGE AREA (km^2)
02UC002	1965	1993	29	25	Natural	19,000
02UC003	1965	1982	18	16	Natural	3,390
02VA001	1947	1986	40	32	Natural	684
02VB003	1965	1979	15	13	Natural	7,590
02VB004	1978	1993	16	14	Natural	7,230
02VC001	1956	1993	38	35	Natural	13,000
02VC002	1972	1982	11	10	Natural	6,550
02WA001	1962	1988	27	25	Natural	2,060
02WA002	1962	1982	21	19	Natural	5,590
02WB001	1962	1971	10	9	Natural	16,000
02WB002	1966	1983	18	16	Natural	11,600
02WB003	1980	1993	14	11	Natural	15,600
02WC001	1974	1993	20	18	Natural	2,950
02WC002	1980	1988	9	7	Natural	5,200
02XA006	1965	1980	16	11	Natural	19,100
02XA007	1978	1993	16	11	Natural	12,100
02XB001	1967	1982	16	14	Natural	5,750
02XB002	1980	1993	14	10	Natural	1,060
02XC001	1967	1993	27	22	Natural	6,630
02XD001	1969	1988	20	7	Natural	206
03LA001	1972	1982	11	8	Natural	23,600
03LD004	1972	1993	22	20	Natural	8,990
03LE002	1962	1980	19	17	Natural	50,800
03MB002	1956	1993	38	31	Natural	29,800
03MC001	1972	1993	22	19	Natural	3,680
03MD001	1975	1993	19	15	Natural	24,200
03MD002	1980	1988	9	4	Natural	6,030
03ME002	1957	1979	23	14	Natural	35,200

Labrador. A secondary criterion for selecting Quebec stations was that the station measure streamflow in or near a bordering tertiary watershed. For this study, the listing was reduced to 28 because some of the stations were significantly removed from the study area, or because some of them provided redundant information, or because the length of record was short, or because the data was of poor quality. In addition, naturally flowing rivers were chosen over regulated rivers. The 28 Quebec stations which were used in this study are listed along with their characteristics in Table 5.3.

The watersheds which were used in this study are shown in Plate 5.1. Some of the Labrador watersheds were omitted from Plate 5.1 either because they had short periods of record, or because the streamflow records predate the diversions associated with the Churchill Falls hydro-electric development and thus would create considerable confusion in Plate 5.1. The locations of all streamflow gauging stations are shown in Appendix I.

The "Atikonak River at Ossakmanuan Lake Control Structure" data was discarded from the database because it was regulated and it had zero flow for its 17-year period of record. For the purpose of analysis the "Churchill River above Upper Muskrat Falls" data was split into two parts - natural flows from 1948 to 1970, and regulated flows from 1972 to 1993. In addition, the "Unknown (Atikonak) River at Lake 51" data was split into two parts - natural flows from 1955 to 1963, and regulated flows from 1963 to 1971.

In Labrador, the drainage areas of the 6 watersheds with regulated flow ranged from 19,000 km^2 to 92,500 km^2, with a median size of 22,100 km^2. The drainage areas of the 22 watersheds with natural flow ranged from 35.5 km^2 to 78,800 km^2, with a median size of 5,805 km^2. The drainage areas of gauged watersheds in Labrador are much larger than the drainage areas of gauged watersheds on the island of Newfoundland. The drainage areas of the 107 watersheds on the island of Newfoundland ranged from 2.31 km^2

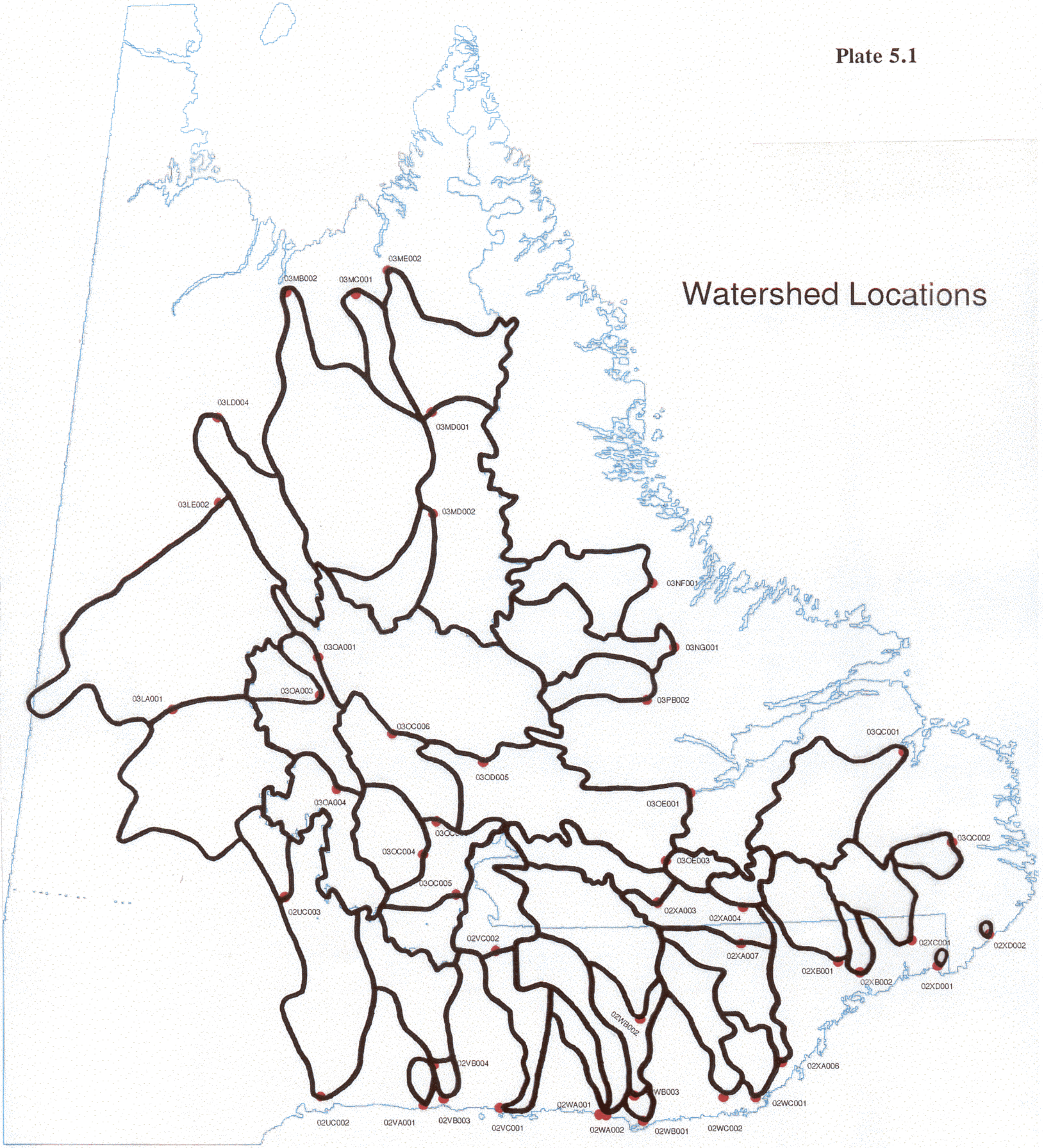
to 8640 km^2, with a median size of 139 km^2 . Streamflow data on small and medium sized watersheds in Labrador are lacking.

The length of record for regulated watersheds ranged from 15 to 42 years, with a median of 21.5 years. The length of record for unregulated watersheds ranged from 1 to 28 years, with a median of 13 years. Seventeen (17) of the 22 unregulated stations had 10 or more years of record. Ten or more years of data are desirable to get reasonable estimates of mean annual runoff.

The current (1994) streamflow gauging network in Labrador consists of 9 watersheds which have natural flows and 5 watersheds which have regulated flows.

In Quebec, the drainage areas of the selected watersheds ranged from 206 km^2 to 50,800 km^2 with a median size of 7410 km^2. The length of record ranged from 9 years to 40 years with a median length of 18.5 years. The drainage areas and lengths of record are comparable with that of Labrador watersheds.

Plate 5.1



Watershed Locations

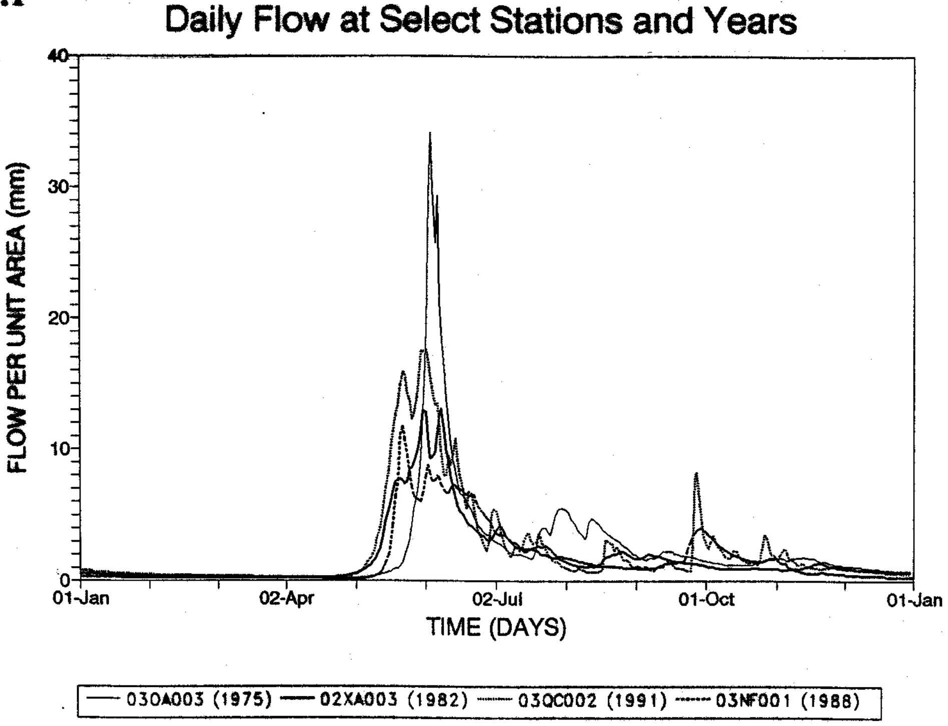
5.2 Streamflows

5.2.1 Examination of Hydrographs

The 416 annual hydrographs of daily streamflows for all stations in Labrador are shown in Appendix J. One hundred (100) of the annual hydrographs had some missing data. Six of the annual hydrographs had errors which were confirmed by Environment Canada. The horizontal sections on the annual hydrographs for station number 03PB001 in 1957 and 1958, and for station number 03OE002 in 1957, represent mean monthly flows and not daily flows. Daily streamflows jumped erratically during 1982 for station numbers 03OA003 and 03OA004, and during 1980 for station number 03OC003. The erratic jumps could not be confirmed on nearby watersheds. These data were contributed by private operators. These annual hydrographs were eliminated from hydrological analysis where warranted.

Naturally flowing rivers in Labrador enter the recession phase when air temperatures drop below zero and a permanent snow cover is established. Typically, the hydrographs are in recession for the winter months of December through until April. Base flow recession sometimes started as early as November and sometimes ended as late as May. The spring flood accounts for a large portion of the total discharge. This is due to the melting of the previous winter's accumulation of snowfall. After the spring flood, a number of rainfall-runoff events are evident, especially on the smaller watersheds. The

Figure 5.1



rainfall-runoff events continue until November or December when streamflows return to base flow recession. Typical annual hydrographs are shown in Figure 5.1. The flow rates have been normalized for drainage area. The watershed names, from left to right on the legend, are: McPhadyen River near the Mouth (03OA003), Little Mecatina River above Lac Fourmont (02XA003), Alexis River near Port Hope Simpson (03QC002), and Ugjoktok River below Harp Lake (03NF001). They represent the western, central, eastern and northern regions. The years were randomly selected. The annual hydrographs of gauged rivers in Labrador are cyclical due to the annual variation in air temperature and smooth due to their large drainage areas.

5.2.2 Annual Runoff

The spatial distribution of annual runoff in Labrador is shown in Plate 5.2. Watersheds which were used to develop the isolines, the values of mean annual runoff, and the coordinates of their centroids (estimated to nearest 0.05°) are listed in Table 5.4. Data from regulated and unregulated stations in Labrador, and data from select stations in Quebec were used to develop the isolines. Isolines outside Labrador are only approximate. One station was derived based on the difference in flows between stations 03OE001B - Churchill River above Upper Muskrat Falls and 03OD005 - Churchill River at Churchill Falls Powerhouse. Outliers were discarded based on visual inspection.

The mean annual runoff in Labrador ranged between 600 mm and 800 mm with the exception of the extreme south-eastern corner of Labrador where it is greater than 1000 mm. The average standard deviation of mean annual runoff for 17 select watersheds in Labrador was 126 mm. The range of standard deviation for the selected watersheds went from a low of 101 mm to a high of 181 mm. It was noted that the range of the mean annual runoff and the standard deviation of the mean annual runoff were quite low.

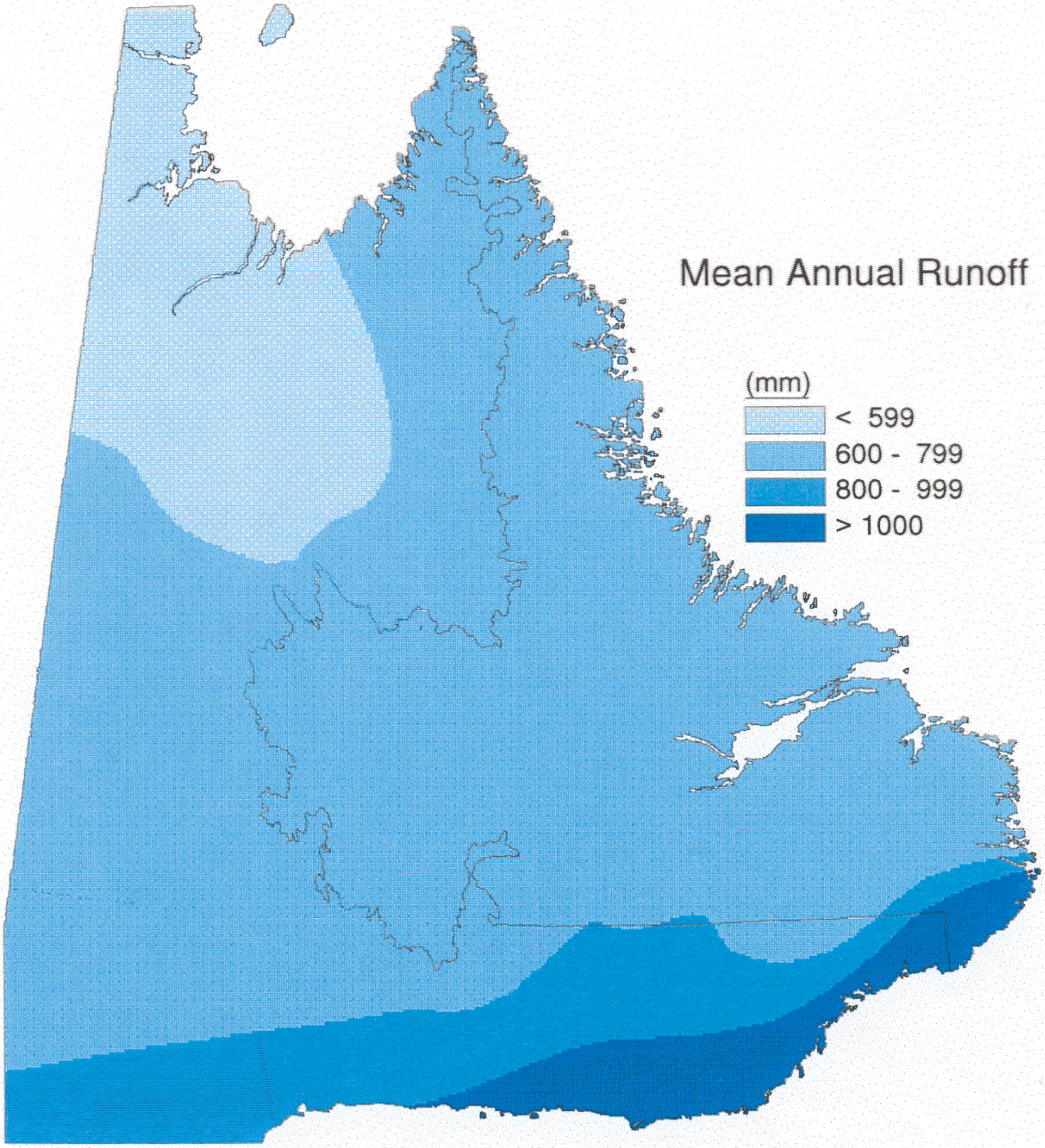
5.2.3 Monthly Runoff

The annual distributions of mean monthly runoff for 16 select Labrador watersheds are shown in Appendix K. These watersheds are unregulated, have few missing data, and

Table 5.4 Mean Annual Runoff of Select Stations

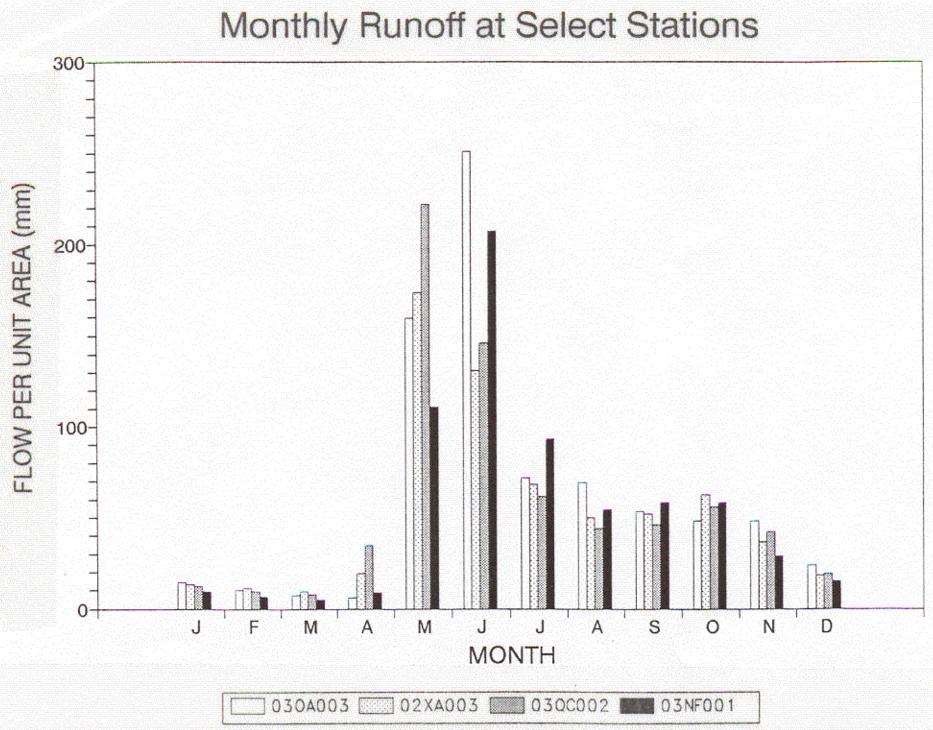
Station Number	Centroid Latitude (ºC)	Centroid Longitude (ºC)	Drainage Area (km^2)	Mean Annual Flow (m^3/s)	Mean Annual Runoff (mm)	Standard Deviation of MAR (mm)
Labrador:						
02AX003	52.60	62.30	4540	92	639	127
02AX004	52.40	60.00	2060	43	665	141
03NF001	55.20	62.30	7570	156	650	125
03NG001	54.70	62.70	8930	190	671	138
03OA001	53.45	66.60	19000	400	664	110
03OA003	54.25	67.20	3610	88	765	
03OA004	52.80	66.35	8310	181	687	
03OB002	53.45	65.80	33900	719	669	142
03OC003	52.60	64.95	15100	360	752	
03OC004	52.80	65.40	7070	159	710	
03OC005	51.95	64.80	3680	94	804	
03OC006	52.85	65.10	21400	489	721	118
03OD002	52.85	65.05	22800	483	669	106
03OD003a	52.85	65.15	19900	401	636	181
03OD003b	52.85	65.15	19900	401	636	
03OD005	53.60	65.45	69200	1420	648	103
03OE001a	53.40	64.90	78800	1620	649	111
03OE001b	53.50	64.75	92500	1830	624	101
03OE003	52.55	61.75	2330	57	769	133
03PB001	54.20	64.00	8990	219	769	123
03PB002	54.30	62.15	4480	90	635	117
03QC001	53.10	58.75	10900	255	738	140
03QC002	52.55	57.20	2310	52	706	119
derived-	53.10	62.55	23300	490	664	
Quebec:						
02UC002	51.70	66.40	19000	432	718	
02UC003	52.60	67.25	3390	76	705	
02VA001	50.55	64.80	684	21	946	
02VB003	51.35	64.95	7590	182	757	
02VB004	51.50	65.00	7230	164	716	
02VC001	51.80	63.65	13000	298	723	
02VC002	52.15	63.80	6550	151	728	
02WA001	50.90	62.50	2060	65	996	
02WA002	51.30	62.50	5590	162	915	
02WB001	51.75	62.15	16000	419	826	
02WB002	52.00	62.30	11600	297	808	
02WB003	51.80	62.20	15600	334	676	
02WC001	50.80	60.05	2950	100	1070	
02WC002	51.20	60.75	5200	156	947	
02XA006	52.05	60.85	19100	495	818	
02XA007	52.35	61.40	12100	278	725	
02XB001	52.15	59.15	5750	178	977	
02XB002	51.80	58.45	1060	27	813	
02XC001	52.25	58.10	6630	145	690	
02XD001	51.60	57.20	206	10	1461	
03LA001	53.25	68.25	23600	541	723	
03LD004	55.75	67.65	8990	165	579	
03LE002	54.70	68.90	50800	1040	646	
03MB002	56.35	66.40	29800	518	549	
03MC001	57.40	65.95	36800	70	602	
03MD001	55.55	64.65	24200	522	681	
03MD002	55.20	65.45	6030	101	529	
03ME002	56.20	64.70	35200	740	663	

Plate 5.2



have record lengths of 14 to 28 years. Typical annual distributions are shown in Figure 5.2. The annual cycle of streamflow is evident. Low flows persist from January until April or May when streamflows increase dramatically. Monthly streamflows peak in May or June and then gradually decline until August or September. Streamflows are uniform for most of the remainder of the year and at a level which is between spring flood flows and winter low flows. A secondary peak of monthly discharge has been observed in October. Monthly discharges decline from October to December and on through until the spring flood.

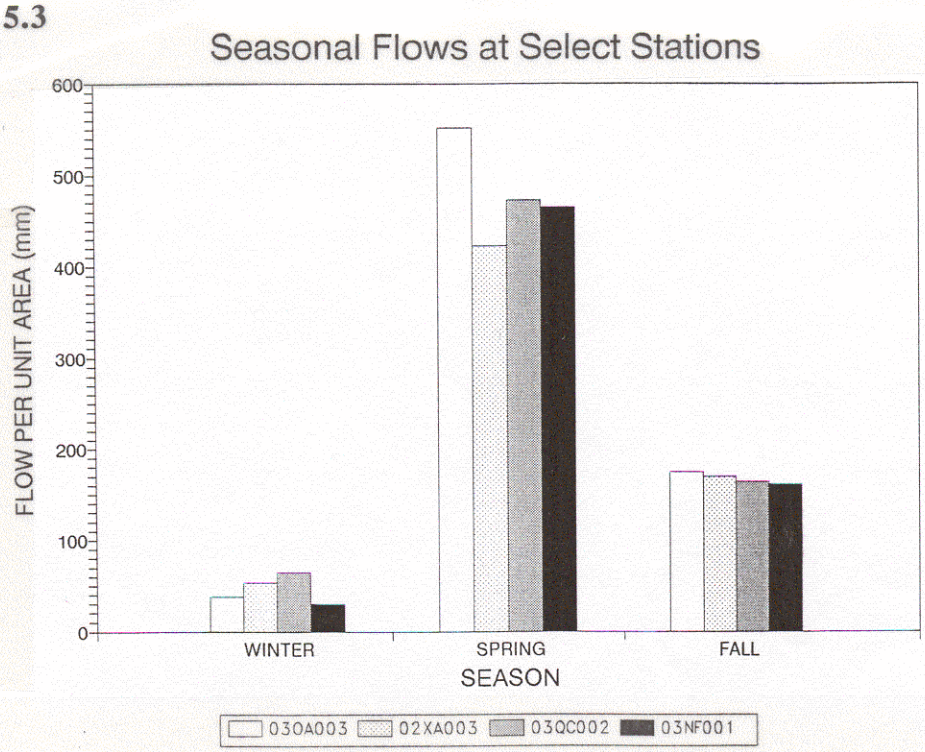
Figure 5.2



5.2.3 Seasonal Runoff

The selection of the start and finish dates of the hydrological seasons and the number of seasons is subjective and approximate due to the stochastic nature of streamflows. A number of seasons were readily apparent which correspond to: the spring flood which can run from April or May to June, July or even August, a period of uniform monthly flows which corresponds to rainfall-runoff events and which can run from July or August to October, November or December, and base flow which can start as early as November and continue until as late as April or May. For ease of computation and comparison it was decided to use three seasons of equal duration which are defined as: **WINTER** - January to April, **SPRING** - May to August, and **FALL** - September to December. The distributions of mean seasonal runoff for select stations are shown in Figure 5.3. The distributions of mean seasonal runoff for the 16 stations which were selected for monthly analysis are shown in Appendix L by region. With the exception of station number 03PB001 - Naskaupi River at Fremont Lake, the **WINTER** runoff for naturally flowing gauged watersheds ranged between 31 mm (03NF001) and 77 mm (03OB002), **SPRING** runoff ranged between 376 mm (03OE001A) and 552 mm (03OA003), and **FALL** runoff ranged between 161 mm (03NF001) and 214 mm (03OB002). Fremont Lake appears to have had a very significant controlling influence on streamflows for Naskaupi River at Fremont Lake. The annual distribution of monthly runoff for Naskaupi River at Fremont Lake is shown in Appendix K.

Figure 5.3



5.3 Timing of Streamflow Extremes

The highest daily discharges are experienced in the spring and are due mostly to snowmelt runoff. The lowest daily discharges are experienced prior to the spring flood when temperatures are below freezing, precipitation is in the form of snowfall, and snow cover is near maximum. The calendar day number of the minimum daily discharge and the calendar day number of the maximum daily discharge were extracted for each annual hydrograph. The time to peak, which is defined as the difference between the day number of the minimum and maximum daily discharges, was calculated for each annual hydrograph. Due to the shortness and incompleteness of records, the time to peak was sometimes calculated as the difference between the mean day number of the minimum discharge and the mean day number of the maximum daily discharges. Results are summarized in Table 5.5 and details are provided in Appendix M. The mean day number of the minimum daily discharge (the start of the spring flood) was day number 105 (April 15). The mean day number of the maximum daily discharge (the peak of the spring flood) was day number 154 (June 3). The mean time to peak was 50 days.

Two hundred and six (206) of the 208 annual minimum daily flows, which were analyzed for timing, occurred between March 6th and May 21st. Two hundred and twenty-two (222) of the 223 annual peak flows, which were analyzed for timing, occurred between April 23rd and July 31st. For the 203 instances where the minimum and maximum flows were available in the same year, the fastest time to peak was 12 days and the slowest time to peak was 106 days.

Table 5.5 Timing of the Spring Flood

Station Number	Mean Day # of Minimum Flow	Mean Day # of Maximum Flow	Mean Days to Peak
02XA003	92	138	47
02XA004	93	140	47
03NF001	114	151	37
03NG001	113	151	38
03OB002	103	168	65
03OC003	113	156	44
03OC004	113	154	42
03OD003a	104	169	67
03OE001a	99	163	64
03OE003	104	152	48
03PB001	115	178	64
03PB002	111	154	42
03QC001	100	153	52
03QC002	92	136	45

5.4 High Flows

5.4.1 Mean Peak Flows

The mean annual peak flow was calculated for stations which had at least 8 years of data. Results are summarized in Table 5.6. Plate 5.3 shows select stations. Details are provided in Appendix N. Outlet control is a subjective evaluation of whether there is a large lake at the outlet of the watershed which attenuates peak flows. Since peak flows are highly correlated with drainage area, mean annual peak flows were normalized for drainage area so that interbasin comparisons could be made. The Churchill River above Upper Muskrat Falls watershed (03OE001) was removed from the sample set because it was suspected that the drainage area of the watersheds was much larger than the area of the meteorological events which cause high flows. The mean annual peak flow per unit area on the 13 selected watersheds was 0.1189 $m^3/s/km^2$. The standard deviation was 0.0509 $m^3/s/km^2$, and the range went from 0.0400 $m^3/s/km^2$ to 0.2238 $m^3/s/km^2$. If peak flows are grouped by outlet control then sample statistics are considerably different. Watersheds which are controlled at the outlet have a lower mean peak flow per unit area of 0.0882 $m^3/s/km^2$, a standard deviation of 0.0310 $m^3/s/km^2$, and a range that went from 0.0400 $m^3/s/km^2$ to 0.1366 $m^3/s/km^2$. Watersheds which are not controlled at the outlet have a higher mean peak flow per unit area of 0.1681 $m^3/s/km^2$, a standard deviation of 0.0342 $m^3/s/km^2$, and a range that went from 0.1403 $m^3/s/km^2$ to 0.2238 $m^3/s/km^2$. In addition, the coefficient of variation dropped from 43% for all watersheds combined, to

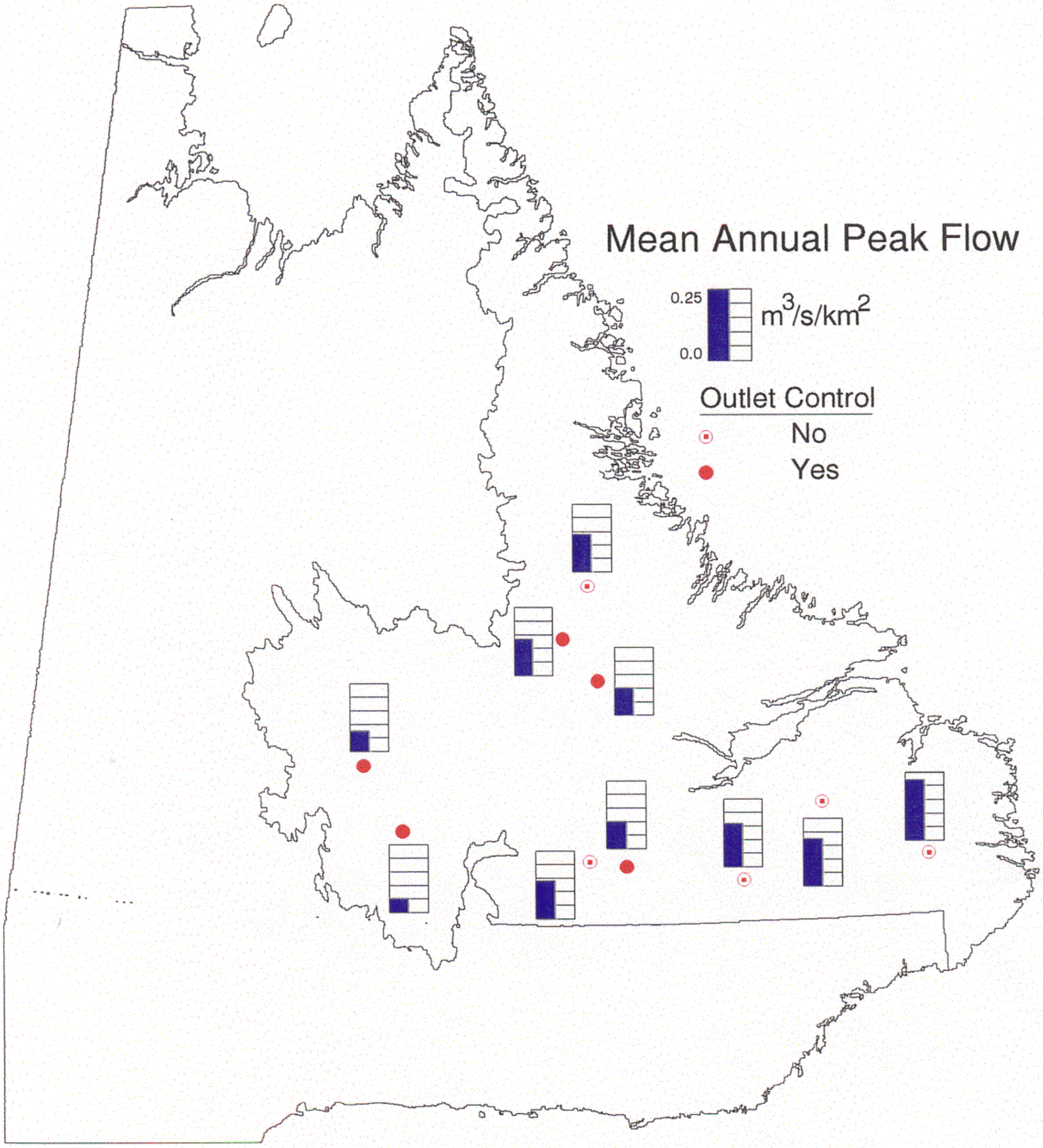
35% for outlet controlled watersheds, and 20% for not outlet controlled watersheds. A comparison of peak flow statistics for outlet controlled and not outlet controlled watersheds indicated that peak flows are substantially attenuated on outlet controlled watersheds.

Table 5.6 Mean Annual Peak Flow

Station Number	Drainage Area (km^2)	Controlled Outlet? (Yes/No)	Mean Annual Peak Flow (m^3/s)	Mean Annual Peak Flow ($m^3/s/km^2$)
02XA003	4540	No	637	0.1403
02XA004	2060	No	331	0.1607
03NF001	7570	No	1070	0.1413
03NG001	8930	Yes	1220	0.1366
03OB002	33900	Yes	2530	0.0746
03OC003	15100	Yes	1470	0.0974
03OC004	7070	Yes	675	0.0955
03OD003a	19900	Yes	1060	0.0533
03OE001a	78800	No	5140	0.0652
03OE003	2330	Yes	242	0.1039
03PB001	8990	Yes	360	0.0400
03PB002	4480	Yes	467	0.1042
03QC001	10900	No	1900	0.1743
03QC002	2310	No	517	0.2238

5.4.2 Frequency Analysis

Missing annual maximum instantaneous discharge records were estimated from the annual maximum daily discharge records where available. At least 10 years of record are desirable for frequency analysis. Eleven stations were selected for analysis. Periods of record ranged from 13 to 25 years.


Mean Annual Peak Flow
0.25
0.0
m³/s/km²
Outlet Control
No
Yes

Annual maximum instantaneous discharge series were tested for independence, trend, general randomness and outliers using Environment Canada's, *CFA88 - Consolidated Frequency Analysis Package*. The tests for independence and trend used the nonparametric Spearman rank order serial correlation coefficient. General randomness was tested using the number of runs above and below the median value. The number of runs is compared to the critical value for the given sample size. Outliers were detected using a modified Grubbs and Beck Test. Details are provided in the *Consolidated Frequency Analysis Package*.

All data sets tested independent at a 1% level of significance. The 02AX003 data set was dependent at a 5% level of significance. The data sets did not exhibit trend at a 1% level of significance except for station 03NG001. The annual maximum instantaneous discharge series at 03NG001 appears to be decreasing with time. Two other stations failed the test for trend at a 5% level of significance: 03PB002 and 03OE003. The 02XA003 and 03QC001 data sets failed the test for randomness at a 5% level of significance. A number of low outliers were detected and removed: 624 m^3/s on 02XA004 in 1983, 204 m^3/s on 03QC002 in 1979, 113 m^3/s on 03OE003 in 1987, and 1370 m^3/s on 03OB002 in 1961. All stations were retained for frequency analysis because: 1.) there were no known environmental or anthropogenic disturbances which might affect peak flows other than the diversions associated with the Churchill Falls hydro-electric development which have been taken into account, 2.) a certain number of test failures can be expected given the number of stations and tests, and 3.) the region has few stations and those stations have short periods of record.

The frequency of annual maximum instantaneous discharges was analyzed using the HYDSTAT program in the CAHH (*Computer-Aided Hydrology and Hydraulics*) software package. HYDSTAT includes four of the most common statistical distributions hydrology: Extreme Value Type I (EVI), Log-Pearson Type III (LP3), Log-Normal (LN) and Normal (N). The LP3 results were discarded because of the assumptions inherent in the generalized map skew coefficient. Goodness-of-fit was assessed using the Chi-Squared Test. Class intervals were selected such that the expected number of points in each interval would be slightly greater than three.

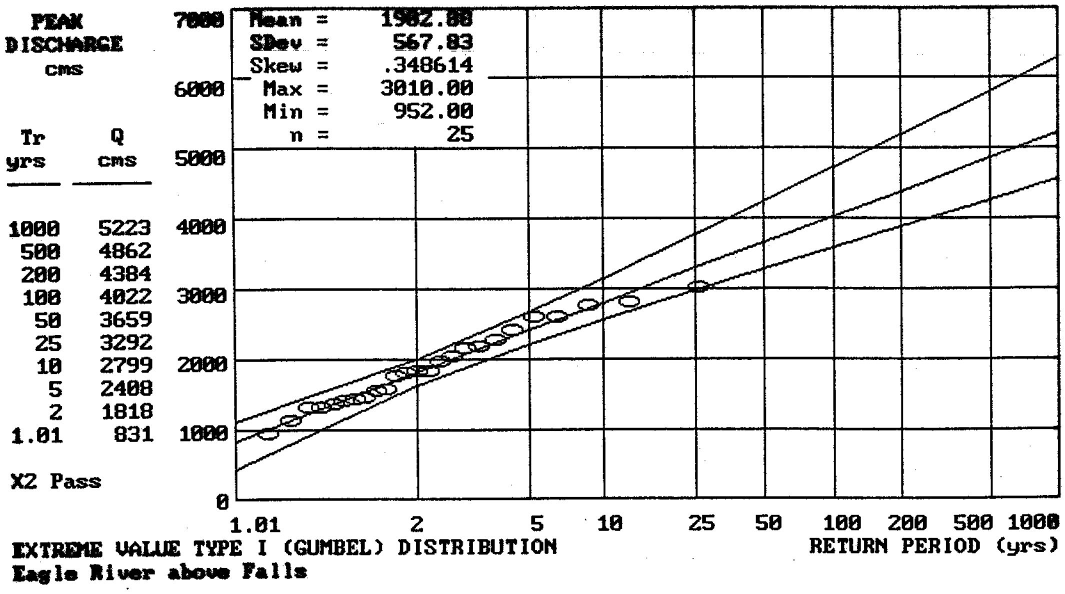
Flood flow estimates for the 1 : 10, 1 : 25, 1 : 50 and 1 : 100 year return periods as well as flow estimates for the upper and lower 90% confidence limits for each station and distribution are shown in Table 5.7. Probability plots for all stations and distributions are shown in Appendix O. The LN distribution was the best or tied for the best fitting distribution on 6 of the 11 watersheds which were tested. The EVI distribution best fitted the data for 3 of the watersheds, and the Normal distribution best fitted the data for 2 of the watersheds. The only distribution which passed the goodness-of-fit test on all watersheds was the Normal distribution. In addition, it was the only distribution which fitted the 03PB002 data set. The EVI distribution is shown for Eagle River above Falls (03QC001) in Figure 5.4. Based on the goodness-of-fit test, it was the distribution which best fitted the Eagle River data.

Table 5.7 Flood Flow Estimates for Select Return Periods

Station Number	Probability Distribution	Lower 90% Limit	1:10 Year Peak Flow	Upper 90% Limit	Lower 90% Limit	1:25 Year Peak Flow	Upper 90% Limit	Lower 90% Limit	1:50 Year Peak Flow	Upper 90% Limit	Lower 90% Limit	1:100 Year Peak Flow	Upper 90% Limit
02XA003	N	760	840	967	823	914	1071	862	962	1138	897	1006	1200
	LN	759	867	1073	842	982	1274	899	1064	1427	953	1143	1582
	EVI*	816	906	1059	935	1053	1269	1021	1162	1426	1105	1271	1584
02XA004	N*	428	502	646	485	581	792	524	639	906	561	696	1023
	LN	429	503	648	488	587	802	530	649	925	570	710	1053
	EVI	480	545	655	566	651	806	627	729	918	688	807	1032
03NF001	N	1271	1395	1588	1372	1514	1750	1435	1590	1857	1490	1659	1953
	LN*	1265	1426	1719	1394	1599	2010	1481	1722	2228	1564	1840	2445
	EVI	1361	1501	1733	1552	1735	2061	1689	1909	2307	1824	2081	2555
03NG001	N*	1497	1663	1916	1636	1826	2136	1723	1931	2280	1800	2025	2411
	LN*	1505	1750	2208	1708	2032	2698	1849	2237	3078	1984	2438	3468
	EVI*	1616	1802	2104	1877	2121	2544	2066	2358	2876	2251	2593	3207
03OB002	N	3041	3301	3700	3258	3557	4045	3395	3722	4271	3516	3871	4477
	LN*	3001	3303	3828	3252	3631	4348	3420	3859	4728	3577	4077	5100
	EVI	3227	3520	3995	3638	4022	4687	3935	4394	5208	4227	4764	5729
03OE001A	N	6045	6541	7289	6472	7041	7956	6741	7365	8394	6980	7656	8791
	LN*	6023	6644	7706	6555	7338	8795	6914	7823	9592	7248	8287	10377
	EVI*	6397	6952	7836	7199	7926	9162	7779	8648	10160	8349	9366	11157
03OE003	N	303	337	391	330	369	435	346	389	463	361	407	489
	LN*	297	339	417	330	383	494	351	414	552	372	444	611
	EVI	327	365	430	377	427	519	413	474	585	449	519	652
03PB001	N*	412	444	492	439	475	533	455	495	561	470	512	585
	LN*	412	452	519	445	494	586	467	523	634	487	551	681
	EVI	435	470	527	484	531	611	520	575	673	555	620	736
03PB002	N*	560	615	700	606	669	773	635	704	821	661	736	864
	LN	- Failed Goodness-of-fit Test -			- Failed Goodness-of-fit Test -			- Failed Goodness-of-fit Test -			- Failed Goodness-of-fit Test -		
	EVI	- Failed Goodness-of-fit Test -			- Failed Goodness-of-fit Test -			- Failed Goodness-of-fit Test -			- Failed Goodness-of-fit Test -		
03QC001	N	2409	2631	2940	2641	2897	3272	2788	3069	3490	2919	3224	3687
	LN	2390	2693	3179	2707	3107	3801	2931	3408	4273	3144	3704	4750
	EVI*	2556	2799	3148	2976	3292	3774	3282	3659	4245	3582	4022	4716
03QC002	N	632	691	782	679	746	858	709	782	908	735	815	954
	LN	623	691	812	677	763	931	714	814	1018	748	862	1103
	EVI*	674	740	850	764	851	1005	829	933	1121	893	1014	1238

* indicates the best or tied for the best fit

Figure 5.4 Probability Distribution of Peak Flows on Eagle River



Mean = 1982.00
SDev = 567.83
Skew = .348614
Max = 3010.00
Min = 952.00
n = 25

Tr yrs	Q cms
1000	5223
500	4862
200	4384
100	4022
50	3659
25	3292
10	2799
5	2408
2	1818
1.01	831

5.5 Low Flows

Two low flow periods occur during the year. The first period of low flows, termed the "Winter Minimum", occurs just prior to the spring flood and is always a lower magnitude than that which occurs in the second period of low flows. The second period of low flows, termed the "Summer Minimum", occurs after the spring flood and before baseflow recession in mid November. The timing of winter minimum flows was indicated in Section 5.3. The earliest date of the winter minimum was March 6th and the latest date of the winter minimum was May 21st. While, the earliest and latest months of the summer minimum were June and November, nearly 75% of the summer minimum flow events occurred during August or September.

5.5.1 Winter Minimum Flows

The average winter minimum flow on 14 select watersheds ranged between 0.00149 $m^3/s/km^2$ and 0.01301 $m^3/s/km^2$ with a mean of 0.00408 $m^3/s/km^2$ and a standard deviation of 0.00286 $m^3/s/km^2$. The average winter minimum flow on 02PB001 (0.01301 $m^3/s/km^2$) appears to be a high outlier. If this watershed is removed, the highest average winter minimum flow would be 0.00563 $m^3/s/km^2$, the mean would be 0.00340 $m^3/s/km^2$ and the standard deviation would be 0.00130 $m^3/s/km^2$. Results are summarized along with the summer minimum flows in Table 5.8 and Plate 5.4. Details can be found in Appendix P.

5.5.2 Summer Minimum Flows

The average summer minimum flow on 20 select watersheds ranged between 0.00554 $m^3/s/km^2$ and 0.02836 $m^3/s/km^2$, with a mean of 0.01400 $m^3/s/km^2$ and a standard deviation of 0.00552 $m^3/s/km^2$. Average summer minimum flows were on average about 4 times higher than the average winter minimum flows. Results are summarized along with the winter minimum flows in Table 5.8 and Plate 5.4. Details can be found in Appendix P.

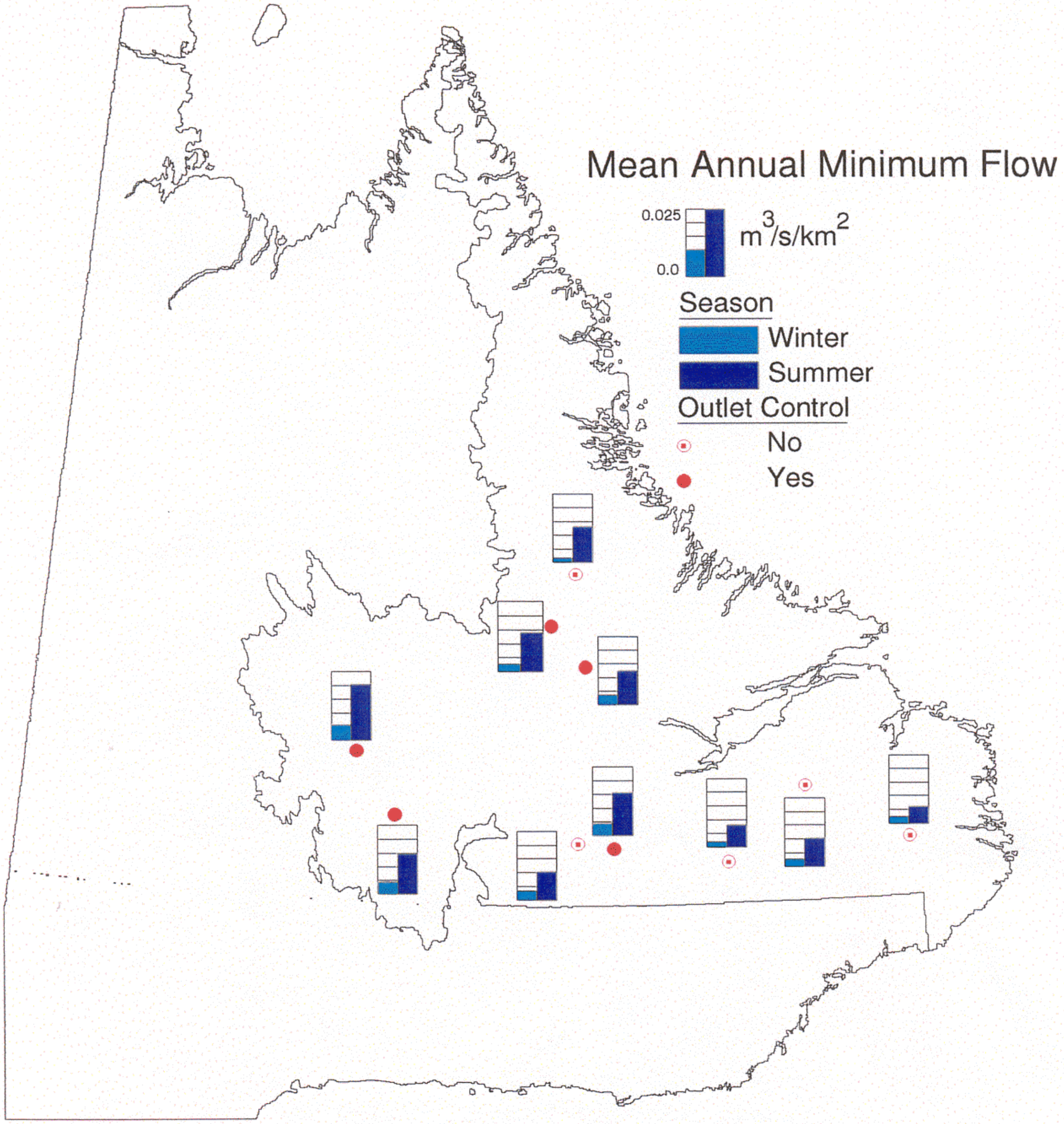
Table 5.8 Mean Annual Minimum Flows

Station Number	Winter Minimum Flow (m^3/s)	Winter Minimum Flow ($m^3/s/km^2$)	Summer Minimum Flow (m^3/s)	Summer Minimum Flow ($m^3/s/km^2$)
02XA003	14.2	0.00313	46.9	0.01033
02XA004	3.74	0.00182	16.2	0.00786
02XD002			0.22	0.00620
03NF001	11.3	0.00149	99.1	0.01309
03NG001	23.4	0.00262	124	0.01389
03OA003			51.4	0.01424
03OA004			148	0.01781
03OB002	190	0.00560	694	0.02047
03OB003			5.76	0.00554
03OC003	47	0.00311	241	0.01596
03OC004	24	0.00339	122	0.01726
03OC005			60	0.01630
03OD003a	86.3	0.00434	290	0.01457
03OE001a	444	0.00563	1480	0.01878
03OE002			34.4	0.01550
03OE003	10.1	0.00433	36.2	0.01554
03PB001	117	0.01301	255	0.02836
03PB002	16.5	0.00368	55.2	0.01232
03QC001	28.7	0.00263	111	0.01018
03QC002	5.42	0.00235	13.6	0.00589

5.5.3 Recession Characteristics

Streamflows in Labrador steadily decrease for about 4 months during the winter. During this period an increase in streamflows due to rainfall or snowmelt is very rare. The date when baseflow recession starts is highly variable, and its abstraction is somewhat subjective. The approximate start dates of baseflow recession were extracted with weekly

Plate 5.4


Mean Annual Minimum Flow
0.025
0.0
$m^3/s/km^2$
Season
Winter
Summer
Outlet Control
No
Yes

precision from the annual hydrographs. The median values are shown in Table 5.9. For individual stations the median start date ranged between November 1st and November 23rd. The median start date of recession for most watersheds was November 15th. Baseflow recession is assumed to end when the minimum annual flow is reached. The mean date of the minimum annual flow was April 15th.

Table 5.9 Recession Characteristics

Station Number	**Median Start Date of Baseflow**	**Mean Finish Date of Baseflow**	**February Daily Recession**	$\frac{\textbf{Flow Mar. 1}}{\textbf{Flow Jan. 1}}$
02XA003	Nov. 15	Apr. 02	0.993	0.637
02XA004	Nov. 15	Apr. 03	0.991	0.554
03NF001	Nov. 01	Apr. 24	0.990	0.501
03NG001	Nov. 07	Apr. 23	0.993	0.613
03OA003			0.990	0.479
03OA004			0.992	0.600
03OB002	Nov. 15	Apr. 13	0.992	0.633
03OB003				0.470
03OC003	Nov. 15	Apr. 23	0.989	0.526
03OC004	Nov. 15	Apr. 23	0.990	0.501
03OC005			0.992	0.609
03OD003a		Apr. 14	0.992	0.555
03OE001a	Nov. 23	Apr. 09	0.994	0.570
03OE003	Nov. 07	Apr. 14	0.991	0.570
03PB001	Nov. 15	Apr. 25	0.995	0.750
03PB002	Nov. 15	Apr. 21	0.994	0.645
03QC001	Nov. 15	Apr. 10	0.991	0.541
03QC002	Nov. 15	Apr. 02	0.991	0.525

The shape of the recession does not follow the classical exponential decay: q_t =

q_0K^t, in that "K" is not a constant. "K" gradually increases with time and approaches 1 as streamflows decrease to the minimum annual flow. This implies a lower limit to discharge based on the availability of groundwater. Two indices have been developed to provide a measure of the recession characteristics. The first is termed the "February Recession Constant". It was calculated as the average of 30 day mean of the daily recession ratios starting on February 1st. This index provides a measure of the daily recession in February. The second index, termed the "March 1st to January 1st Ratio" provides a measure of the total recession during this period. The "February Recession Constant" ranged between 0.989 and 0.995 with a mean of 0.992. The "March 1st to January 1st Ratio" ranged between 0.470 and 0.750 with a mean of 0.571. Results are summarized in Table 5.9. Details are provided in Appendix Q.