Hydrologic Overview of the

North and South Slave Regions

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On the cover: Slave River at Fitzgerald, looking downstream from gauge
(Photo: Water Survey of Canada (WSC), Yellowknife, NT).

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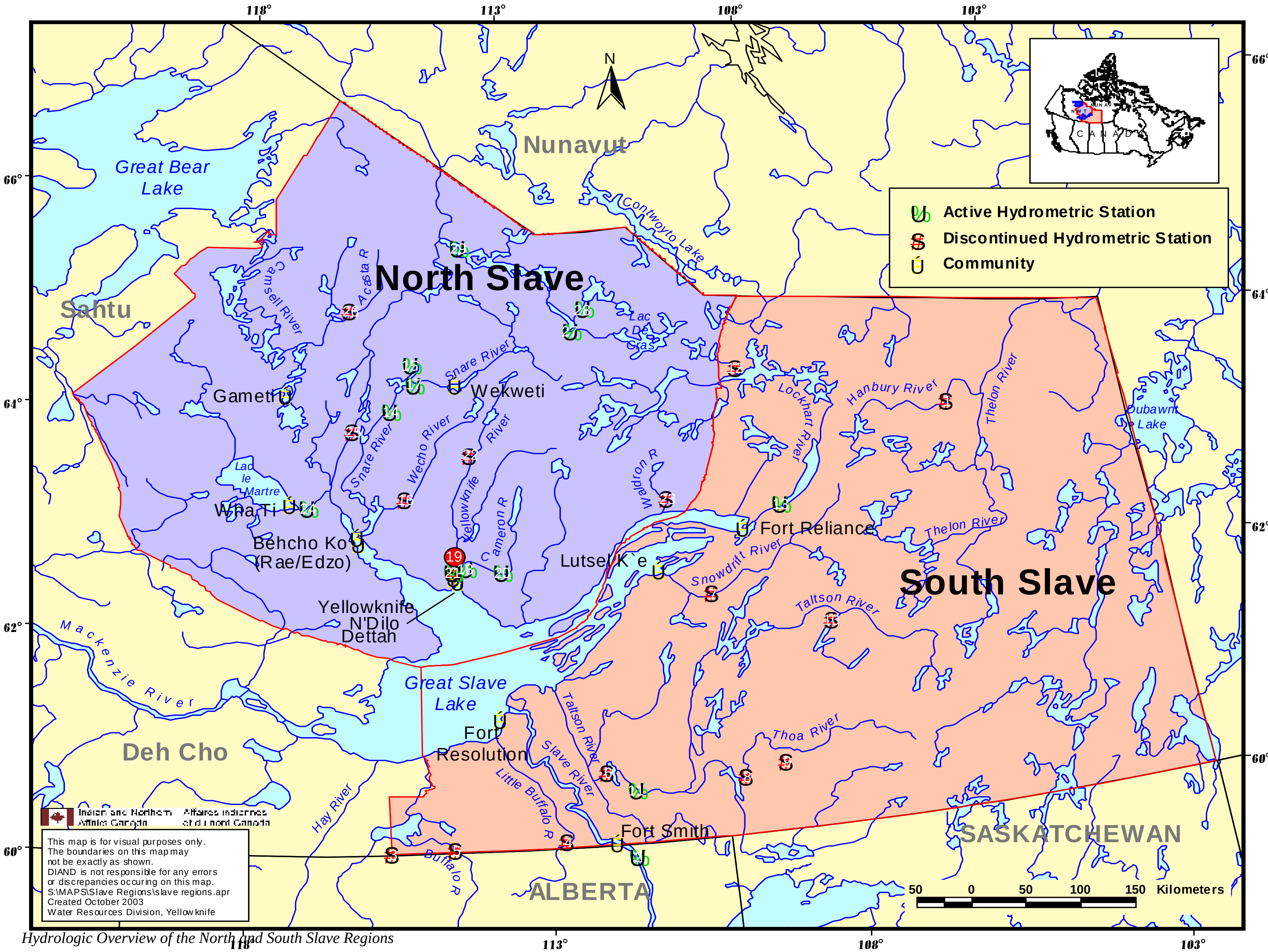
Introduction

The purpose of this report is to provide a general overview of water quantity data collected in the North and South Slave regions of the Northwest Territories (NWT). In the report, these regions are as defined by unofficial administrative boundaries. Beginning in 1921, Environment Canada's Water Survey Division has operated hydrometric stations on streams within these regions and there are currently 13 stations operational (Figure 1). In this report, hydrometric data from 29 stations are presented using mean annual hydrographs, extreme-year hydrographs and basic statistics. Water levels on Great Slave Lake are also briefly examined. Flood frequency analyses using the Pearson theoretical distribution were completed for rivers with twenty or more years of data. A brief comparison of basin yield values between the Slave regions and the Mackenzie Mountain tributaries is also included.

Figure 1. Hydrometric stations in the North and South Slave regions, NWT



Map ID Number	**Station Description (operating stations in bold)**
1	Hanbury River above Hoare Lake
2	**Slave River at Fitzgerald**
3	Whitesand River near Alta/NWT boundary
4	Little Buffalo River below Highway 5
5	Buffalo River near Alta/NWT boundary
6	Taltson River at outlet Tsu Lake
7	Snowdrift River at outlet of Siltaza Lake
8	Thoa River near inlet to Hill Island Lake
9	Marten River above Thoa River
10	Porter Lake outflow
11	**Taltson River below hydro dam**
12	Thonokied River near the mouth
13	**Lockhart River at outlet of Artillery Lake**
14	**Snare River below Ghost River**
15	**Indin River above Chalco Lake**
16	Wecho River at outlet of Inglis Lake
17	**Snare River above Indin Lake**
18	**Yellowknife River at outlet of Prosperous Lake**
19	Baker Creek near Yellowknife
20	**Cameron River below Reid Lake**
21	**Baker Creek at outlet of Lower Martin Lake**
22	Yellowknife River at outlet of Lower Carp Lake
23	Waldron River near the mouth
24	**La Martre River below outlet of Lac La Martre**
25	Emile River at outlet of Basler Lake
26	Acasta River above Little Crapeau Lake
27	**Coppermine River below Desteffany Lake**
28	**Yamba River below Daring Lake**
29	**Coppermine River at outlet of Point Lake**

North and South Slave Regions

Geographic Boundaries

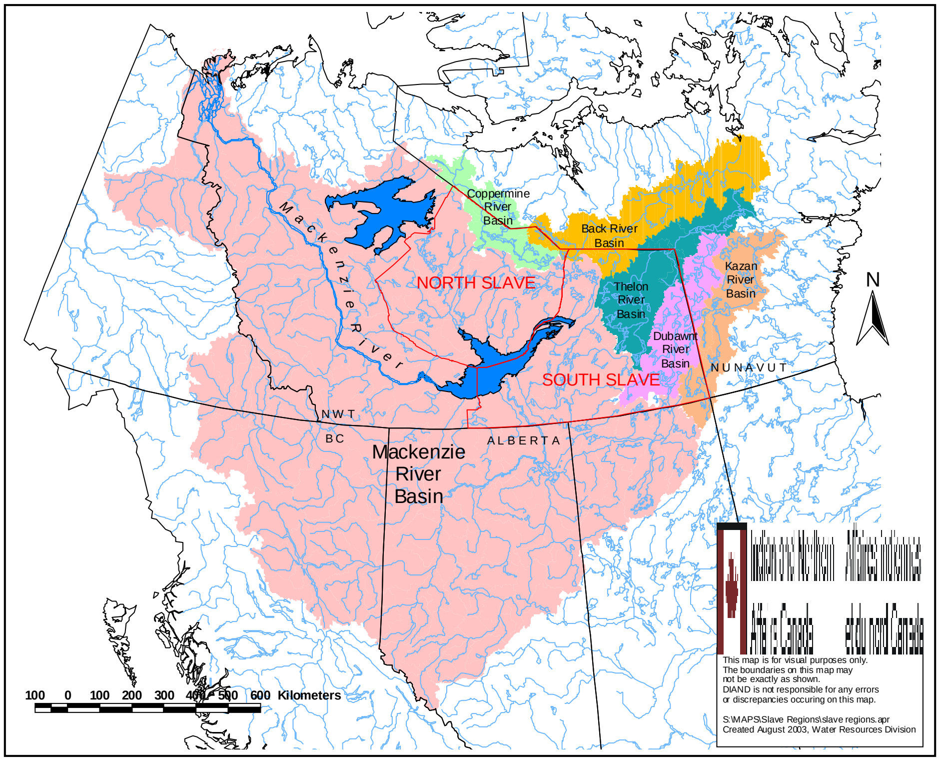
The majority of streams flowing within the North and South Slave regions are nested within the Mackenzie River basin (Figure 2). Covering approximately 1.7 million km^2, the Mackenzie River system is the largest in Canada, flowing over 4000 km from tributaries in the Rocky Mountains in British Columbia to its Delta in the NWT, where it empties into the Beaufort Sea. From its outflow from Great Slave Lake, the Mackenzie River flows northward about 1750 km, with a mean annual discharge of approximately 9000 m^3/s, second in Canada only to the St. Lawrence River.

There are five other river basins within the North and South Slave regions (Figure 2). The headwaters of the Coppermine River basin are situated in the northeastern portion of the North Slave region. The river flows northwest through the NWT and then Nunavut, where it drains into Coronation Gulf. The Hanbury River is part of the headwaters of the Thelon River basin, located in the northeast corner of the South Slave region. Beyond its basin boundaries in the NWT, the Thelon River flows eastward through the Thelon Game Preserve before eventually draining into Hudson Bay via Baker Lake and Chesterfield Inlet in Nunavut.

The headwaters of the Back, Dubawnt and Kazan rivers are located in the northern or eastern areas of the South Slave region, and each river subsequently flows through Nunavut. While the Back River flows northward to Chantrey Inlet east of Adelaide Peninsula, the Dubawnt River drains into the Thelon River at Beverly Lake and the Kazan River flows northward into Baker Lake. Given that the hydrometric gauges on these three rivers are located within Nunavut, they are not discussed further in this report. *Hydrologic Overview of Nunavut* will soon be available (Richea and Kokelj, in progress).

With the exception of the Coppermine, Acasta and Hanbury rivers, all of the streams discussed in this report flow into Great Slave Lake. The Acasta River drains into the northward flowing Camsell River, which subsequently drains into Great Bear Lake (Figure 1) while, as mentioned above, the Coppermine drains into Coronation Gulf and the Hanbury River flows into the Thelon River.

Figure 2. River basins of the North and South Slave regions, NWT



As a result of ongoing land claim negotiations, the boundaries of the North and South Slave regions are not finalized. Boundaries indicated in Figures 1, 2 and 3 are approximate, and are only used to define the general areas discussed within this report. They are not intended to represent political or land settlement boundaries.

In total, the Slave regions cover a vast geographical expanse, ranging from approximately 66°44'N in the north to 60°00'N in the south and between 102°00'W and 121°20'W from east to west. The approximate size of the two regions combined is 482,274 km^2.

Communities within the North Slave region include Yellowknife, Dettah, N'Dilo, Behcho Ko (Rae-Edzo), Wha Ti (Lac LaMartre), Gameti (Rae Lakes) and Wekweti

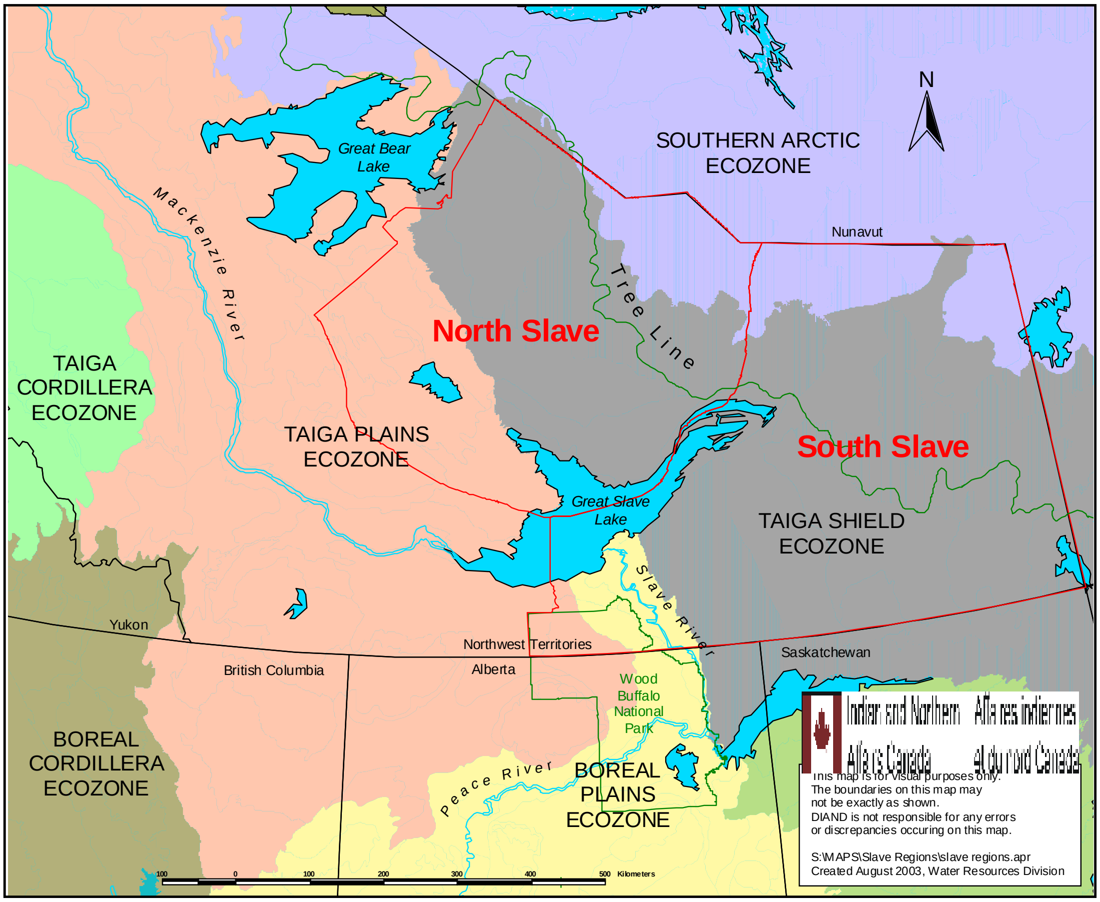
(Snare Lake). Fort Smith, Fort Resolution, Lutsel K'e and Fort Reliance are all within the South Slave region (Figure 1).

Hydrologic Regimes

Many factors combine to determine a hydrologic regime including geology, topography, elevation, climate, permafrost, drainage area and vegetation cover. In the NWT, the amount of available surface storage in lakes and wetlands plays a large role in characterizing hydrologic regimes (Wedel *et al*., 1992). Within the North Slave region, the majority of streams flow southward, draining into Great Slave Lake, while in the western portion of the South Slave region, most streams flow northward into the lake. The majority of river basins in the eastern portion of the South Slave region empty eventually into Hudson Bay.

The primary terrestrial ecozone in both regions is the Taiga Shield featuring Precambrian bedrock of the Canadian Shield (Figure 3). As a result of glacial scouring, the region is characterized by countless lakes and streams and soils are generally shallow and coarse (Environment Canada, 2001a). Along the western edge of both regions, there is an area that falls within the Taiga Plains ecozone, which features broad lowlands, wetlands and plateaus (Environment Canada, 2001a). In the east and north of the North and South Slave regions, respectively, lies a small area of Southern Arctic ecozone characterized by continuous permafrost, shrublands, meadows, eskers and numerous lakes and ponds (Environment Canada, 2001a). A narrow arm of the Boreal Plains ecozone reaches northward along the Slave River valley to the southern shore of Great Slave Lake. Such low-lying river valleys run through gently rolling plains while in the NWT, the valley is bordered to the east by the Taiga Shield. The Slave River terminates in a broad delta (8300 km^2) that originates near Fort Smith and that has aggraded approximately 20.7 m/year from 8070 BP to the present (Vanderburgh and Smith, 1988). The modern delta covers approximately 640 km^2.

Figure 3. Terrestrial ecozones of the North and South Slave regions, NWT



The North and South Slave regions fall primarily within the zone of discontinuous permafrost. Permafrost affects the hydrological cycle in many ways. For example, when ice-rich, it can act as a barrier to water infiltration, leaving more water available on the surface for various processes, such as evaporation, plant uptake or surface runoff to streams. This can result in extensive slope runoff (Woo, 1986) and rapid rises in stream water levels. Vegetation within the regions is characterized primarily by open, stunted forests, with a small portion of boreal forest in the Slave River valley and arctic tundra to the north and east.

Limited research has been completed within the Taiga Shield ecozone regarding hydrologic runoff ratios. Direct runoff has been defined as "…that part of runoff which enters the stream promptly after the rainfall or snow melting" (Chow, 1964), therefore the runoff ratio can be described as the ratio of direct runoff to the total volume of precipitation received. In the past, it was thought that areas with extensive exposed bedrock had high runoff ratios as the bedrock was assumed to be relatively impervious to infiltration (Spence and Woo, 2002). Recent research indicates, however, that runoff ratios in the Shield are highly variable as a result of several physiographic and climatic factors, such as amount of soil cover, bedrock fracture width, rainfall intensity and evaporation, all of which directly control storage and infiltration, and as a result, indirectly control runoff (Spence and Woo, 2002). Spence and Woo (2002) measured runoff ratios on experimental plots between 0 and 0.68.

Photo 1. Bedrock at Cameron River, NWT (Photo: D.L. Bicknell, INAC)

The climate of the Slave regions is primarily subarctic, meaning the mean temperature of the warmest month is above 10°C but no more than four months have a mean temperature exceeding 10°C (Krauss, 1996). A small portion of both regions falls within the arctic climatic zone, where the mean monthly temperature of the warmest month is less than 10°C (Bone, 1992). The climate is characterized by cool summers and dry conditions, with mean temperatures in Yellowknife of –27.9°C in January, 16.5°C in July and 267 mm of precipitation (Environment Canada, 2001b). Fort Smith experiences a mean temperature of –25.4°C in January, 16.3°C in July and 353 mm of precipitation, while Fort Reliance has a mean January temperature of –28.8°C, 14.2° in July and 273 mm of precipitation (Environment Canada, 2001b). A large proportion of the annual precipitation is stored for several months in the form of snow and therefore snowmelt runoff in spring is a dominant feature of most regional stream hydrographs.

Hydrometric Overview

Hydrometric Stations

A network of hydrometric stations with stream gauges quantifies the surface hydrology of the regions. There are currently 13 hydrometric gauges in operation on rivers (Table 1). In addition, there are data from 16 other stations that are no longer operational. Stream flow data used in this report include up to 2002 from the Environment Canada HYDAT database (Environment Canada, 2003a; 2003b).

Photo 2. Hydrometric gauge at Baker Creek at outlet of Lower Martin Lake
(Photo: Water Survey of Canada (WSC), Yellowknife NT)

There are eight closed and one open station within the Slave regions that are not discussed in this report. The majority of these were operated for relatively brief periods of time at hydro-power dam locations. As a result, the data represent a strongly-regulated flow regime and are not representative of naturally-occurring conditions within the basin. However, a few of the stations included in the analysis do measure flow downstream of hydro-electric dams. It was felt that flow data at these stations were still influenced by natural environmental factors even though the relative influence of natural factors will likely have been reduced by the dams. Gauges situated downstream of flow-regulating infrastructure are indicated in Table 1.

Table 1. Hydrometric stations with geographic coordinates and operating periods
(stations in bold are active; those with flow regulatory infrastructure are noted by an asterisk *)

Station Description	Station ID	Latitude	Longitude	Basin Area (km^2)	Operating Period†
Hanbury R above Hoare Lake	06JB001	63°35’29”	105°09’13”	5770	1971-2002
Slave R at Fitzgerald *	**07NB001**	**59°52’20”**	**111°35’0”**	**606000**	**1921-2002**
Whitesand R near Alta/NWT boundary	07PA002	60°0’17”	115°34’44”	3410	1986-1994
Little Buffalo R below Highway 5	07PB002	60°03’01”	112°41’52”	3330	1965-1994
Buffalo R near Alta/NWT boundary	07PC001	60°00’49”	114°31’32”	4350	1987-1994
Taltson R at outlet Tsu Lake *	07QA001	60°38’59”	111°56’49	58700	1952-1997
Snowdrift R at outlet of Siltaza Lake	07QB002	62°10’21”	109°51’39”	9110	1976-1991
Thoa R near inlet to Hill Island Lake	07QC003	60°30’18”	109°38’56”	8830	1968-1995
Marten R above Thoa River	07QC004	60°36’14”	108°58’43	738	1977-1990
Porter Lake outflow	07QD006	61°48’57”	107°52’11”	2050	1983-1990
Taltson R below hydro dam *	**07QD007**	**60°28’01”**	**111°30’46”**	**unavailable**	**1994-2002**
Thonokied R near the mouth	07RC001	64°08’49”	108°55’02”	1780	1980-1990
Lockhart R at outlet of Artillery Lake	**07RD001**	**62°53’41”**	**108°28’03”**	**26600**	**1944-2002**
Snare R below Ghost R	**07SA002**	**63°58’27”**	**115°26’00**	**13300**	**1947-2002**
Indin R above Chalco Lake	**07SA004**	**64°23’16”**	**115°01’19”**	**1520**	**1977-2002**
Wecho R at outlet Inglis Lake	07SA005	63°10’43”	115°11’53”	3400	1983-1995
Snare R above Indin Lake	**07SA008**	**64°12’01”**	**114°58’02**	**7880**	**1999-2002**
Yellowknife R at outlet of Prosperous Lake *	**07SB002**	**62°32’44”**	**114°09’50”**	**16300**	**1937-2002**
Baker Creek near Yellowknife	07SB009	62°30’30”	114°21’38”	126	1968-1982
Cameron R below Reid Lake	**07SB010**	**62°29’27”**	**113°31’23”**	**3630**	**1975-2002**
Baker Cr at outlet of Lower Martin Lake	**07SB013**	**62°30’48”**	**114°24’34”**	**121**	**1983-2002**
Yellowknife R at outlet of Lower Carp Lake	07SB019	63°33’21”	113°58’39”	4800 E	1999-2001
Waldron R near the mouth	07SC002	63°02’46”	110°28’41”	1830	1979-1994
La Martre R below outlet of Lac La Martre	**07TA001**	**63°06’29**	**116°58’26**	**13900**	**1975-2002**
Emile R at outlet Basler Lake	07TB001	63°47’44”	116°07’16”	4850	1978-1997
Acasta R above Little Crapeau Lake	10JA004	64°52’32”	116°08’30”	2280	1980-1994
Coppermine R below Desteffany Lake	**10PA001**	**64°36’57”**	**111°57’17”**	**6110 E**	**1994-2002**
Yamba R below Daring Lake	**10PA002**	**64°48’24”**	**111°40’41”**	**3100 E**	**2000-2002**
Coppermine R at outlet Point Lake	**10PB001**	**65°24’52”**	**114°00’29”**	**19300 E**	**1965-2002**

†Not always a continuous operating period; E – estimated.

Hydrometric Data

Basic hydrological statistics were calculated from daily flow data and are presented in Table 2. For each station, the total annual flow was determined for each year with a complete data record and mean total annual flow was calculated (Table 2). Annual basin yield was obtained by dividing the drainage area of the basin above the station gauge into the total annual flow at the gauge. The basin yield is the annual stream flow expressed as depth of water per unit area of the basin (mm/year). All basin areas used in this report are based on the drainage area above the stream gauging site. The discharge, area and yield of a basin are useful summary statistics for comparison and classification of basins. With just a few years of data, mean annual hydrographs can clearly show patterns in yearly high and low flows. With 20 or more years of data, the annual high flow values can be extracted from these hydrographs and used in a frequency analysis of extremes (flood events).

Annual hydrographs are included in the report as they are an effective way to illustrate the hydrology of a river basin. The area under a complete hydrograph gives the total annual flow or discharge volume. While the volume of flow can vary significantly between rivers (scale of the y-axis), the shape of the curve illustrates the major influences on river flow and can serve to characterize the flow regime.

A review of hydrometric data was completed for each of the stations in the North and South Slave regions. Streams were primarily compared on the basis of terrestrial ecozone. One or two stations with representative hydrographs were chosen and mean annual flows were graphed. Two annual hydrographs, representing the years with the highest (max) and lowest (min) recorded peaks, were also included. In addition, certain anomalous years were graphed and briefly discussed. Hydrographs for the remaining stations are included in Appendix A.

Table 2. Summary flow statistics
(stations with flow regulatory infrastructure are noted by an asterisk *)

Station Description	Years of Record†	Mean Annual Flow (m^3/s)	Mean Total Annual Flow ($10^6 m^3/yr$)	Basin Area (km^2)	Basin Yield (mm/yr)
Hanbury R above Hoare Lake -including 1991 *-not including 1991*	17 *16*	30.2 *28.9*	953 *911*	5770	165 *158*
Slave R at Fitzgerald * (post-dam filling 1972-2002)	31	3410.7	107560	606000	177
Whitesand R near Alta/NWT boundary	6	21.0	661	3410	194
Little Buffalo R below Highway 5	5	3.4	107	3330	32
Buffalo R near Alta/NWT boundary	4	21.1	665	4350	153
Taltson R at outlet of Tsu Lake * (post-dam construction 1966-1997)	29	185.8	5858	58700	100
Snowdrift R at outlet of Siltaza Lake	13	416	1313	9110	144
Thoa R near inlet to Hill Island Lake	24	43.5	1371	8830	155
Marten R above Thoa River	11	5.1	160	738	217
Porter Lake outflow	8	10.2	322	2050	157
Taltson R below hydro dam *	7	199.4	6287	unavailable	-
Thonokied R near the mouth	5	9.4	295	1780	166
Lockhart R at outlet of Artillery Lake	38	123.3	3887	26600	146
Snare R below Ghost R	19	60.1	1895	13300	142
Indin R above Chalco Lake	25	8.0	253	1520	166
Wecho R at outlet Inglis Lake	11	9.7	306	3400	90
Snare R above Indin Lake	4	39.6	1250	7880	159
Yellowknife R at outlet of Prosperous Lake *	15	40.8	1285	16300	79
Baker Cr near Yellowknife	11	0.2	5	126	37
Cameron R below Reid Lake	26	6.2	194	3630	54
Baker Cr at outlet of Lower Martin Lake	18	0.2	8	121	63
Yellowknife R at outlet of Lower Carp Lake	1	insufficient data	insufficient data	4800 E	insufficient data
Waldron R near the mouth	16	6.4	202	1830	111
La Martre R below outlet of Lac La Martre	26	31.7	1000	13900	72
Emile R at outlet Basler Lake	18	15.9	500	4850	103
Acasta R above Little Crapeau Lake	14	11.7	370	2280	162
Coppermine R below Desteffany Lake	4	31.7	999	6110 E	163
Yamba R below Daring Lake	2	19.4	612	3100 E	197
Coppermine R at outlet Point Lake	34	109.5	3454	19300 E	179

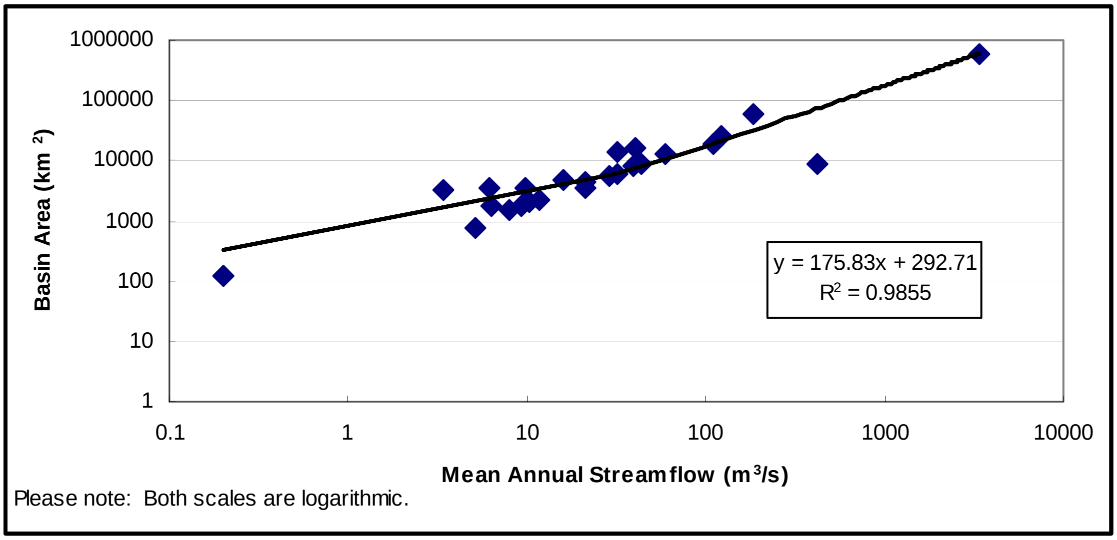
† Number of years with a complete data record E – Estimated value

For most stations, the shape of the mean annual hydrograph is characteristic of a subarctic nival regime (Church, 1974): the lowest production of runoff from drainage basins occurs in late winter, just before spring melt; the largest contribution to annual discharge comes from the melting of the winter snow pack during spring; and a transfer of in-stream water from discharge to ice storage occurs during freeze-up. For basins in the northeastern area of the Slave regions, traditional “spring” thaw may not occur until July, given the arctic climatic conditions. Peak discharge may also occur at any time from late April to early September, depending largely on annual variability in precipitation (snow and rain). The response of a basin to rain events varies according to a number of factors, including basin topography, storage capacity, climate and antecedent moisture conditions (conditions prior to the rain event). In general, streams flowing north to Great Slave Lake in the South Slave region experience spring freshet peak flows around late May while peaks in southward flowing streams in the North Slave region do not usually occur until late June. Rivers in the Coppermine basin generally attain freshet peak flows anywhere from mid-June to mid-July.

In general, it can be anticipated that basins with larger amounts of precipitation and lower amounts of storage have higher basin yield values. There is more moisture available for runoff and less storage volume to retain it. The presence of ice-rich permafrost near the surface can serve to increase basin yields as it limits the capacity for infiltration, enhancing runoff to streams (Church, 1974). Although there is considerable variability in the yield values for the streams studied (ranging from 32 to 217 mm/year; median value 153 mm/yr), the values all fall well below the mean value determined for gauged Mackenzie Mountain tributaries to the Mackenzie River (316 mm/year) which flow from the Taiga Cordillera ecozone (Kokelj, 2001). In general, streams within the Slave regions have higher storage capacity, higher evaporative losses from storage areas and lower amounts of precipitation than those found in the Taiga Cordillera.

It is difficult to make comparisons of the yield values from within the North and South Slave ecozones (Taiga Shield, Taiga Plains, Boreal Plains, Southern Arctic) as not each zone is well represented. In addition, there is significant inter-basin variability within each ecozone. The location of a station gauge within a basin can also influence yield values because, as previously discussed, large amounts of storage upstream can serve to decrease yields. A good relationship does exist between mean annual streamflow at hydrometric gauge sites within the Slave regions and their respective basin areas, with a regression coefficient value of .986 (Figure 4).

Figure 4. Basin area vs. mean annual streamflow for streams in the Slave regions



Taiga Shield

The Indin River is part of the Snare River basin, however the hydrometric station is upstream of hydro-development. To date, the gauge, located above Chalco Lake, has provided 25 full and one partial year of record. Given the relatively small lake storage upstream, flow peaks attained in mid-June during spring freshet decline quite rapidly (Figure 5). The 1996 hydrograph demonstrates that rainfall events later in the year can result in significant increases in flow volumes. Precipitation amounts received between August 18 (Julian Day 231) and September 28 (Day 272), 1996 at two North Slave region rain gauges are shown in Figure 6. During this time, 101 mm of rain fell at Pocket Lake (62°30'N 114°24'W) while 69 mm fell at Salmita (64°03'N 111°11'W). The eight-year mean precipitation values for the same period are 57 mm and 54 mm, respectively. The relatively large amounts of precipitation received during autumn 1996 are also reflected in the hydrographs of other North Slave rivers (e.g., Snare River, Emile River; see Appendix A).

Figure 5. Hydrographs for Indin River above Chalco Lake (1977-2002)

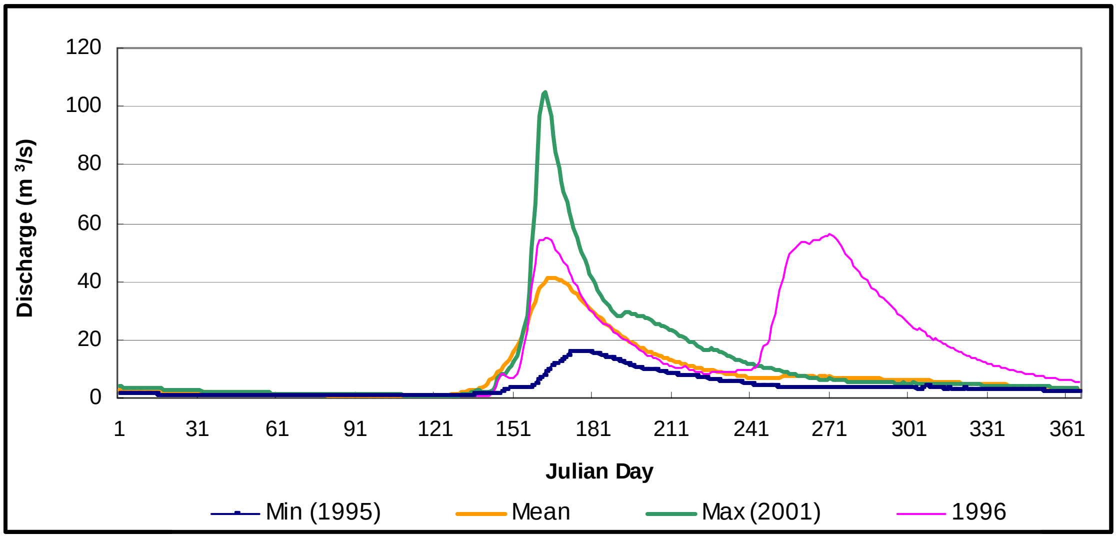


Figure 6. Precipitation at Pocket Lake and Salmita, August 18 – September 28, 1996

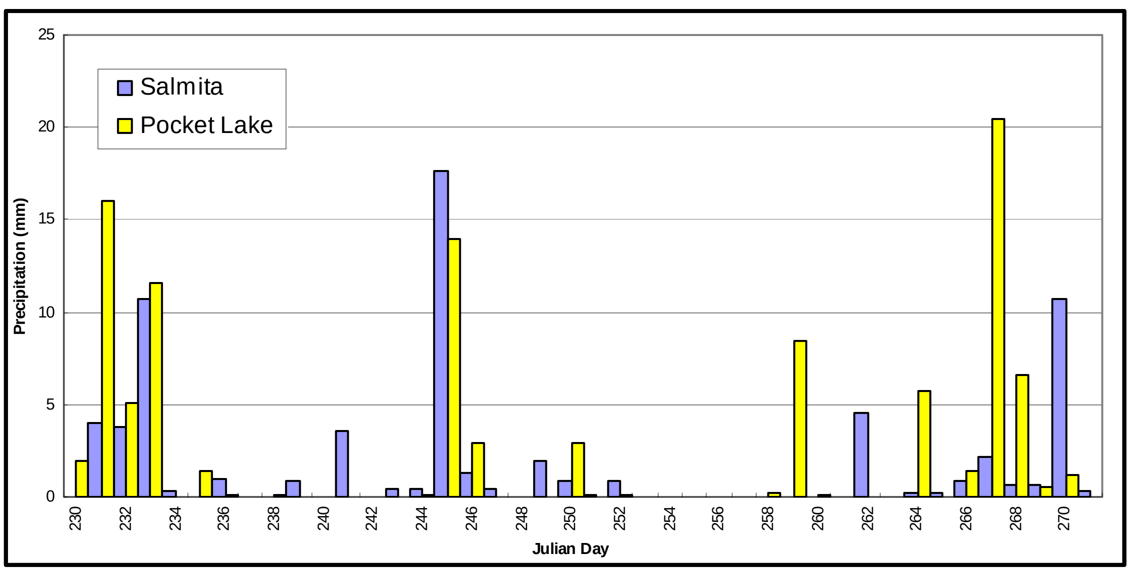
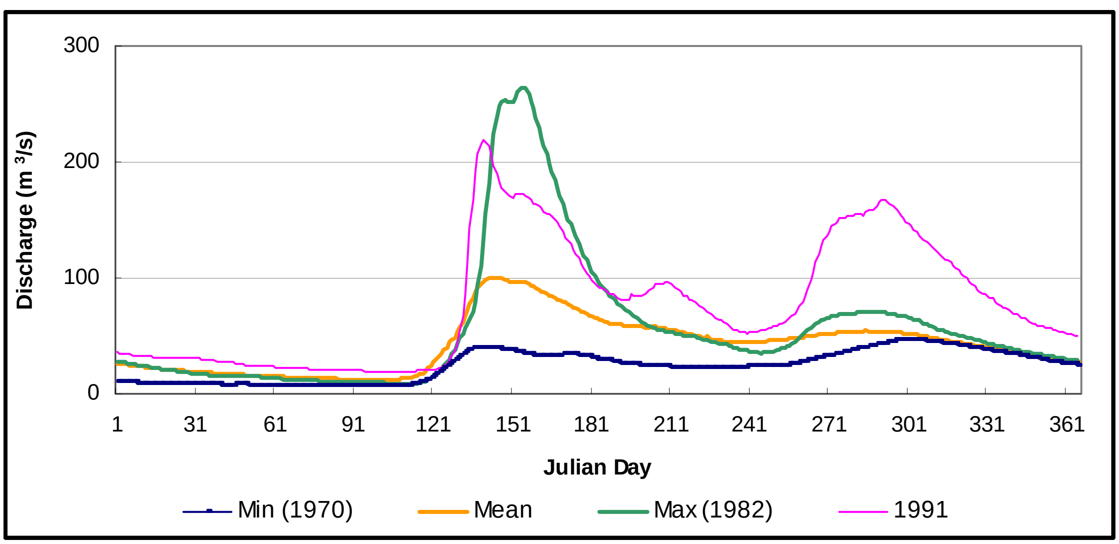


Photo 3. Gauge at Indin River above Chalco Lake, November 2002 (Photo: WSC, Yellowknife, NT)

The gauge that operated on the Thoa River produced 24 complete and four partial years of record. It was installed to evaluate operation of the Taltson River hydroelectricity plant. Spring freshet peak usually occurs in late May and is marked by a rapid increase and more gradual decrease in water volumes (Figure 7). Although the primary source of flow is derived from snowmelt, it is evident by observing the mean annual hydrograph and the hydrograph for 1991 that rain events can result in secondary peaks much later in the year.

Figure 7. Hydrographs for Thoa River near inlet to Hill Island Lake (1968-1995)



Taiga Plains

The gauge on La Martre River is below the outlet of Lac La Martre, just northwest of the North Arm of Great Slave Lake. It was originally installed to assess hydroelectrical potential and has produced 26 complete and two partial years of record (Figure 8). The gauge's location near the outlet of a large lake is evident when examining the mean and annual hydrographs. Except for very small fluctuations, the general trends in increasing and decreasing flows are quite slow and steady with peaks usually occurring in spring. As noted with the Indin River, the late peak in the 1996 hydrograph indicates that there was a significant amount of precipitation received in the basin during the autumn of that year.

Figure 8. Hydrographs for La Martre River below outlet of Lac La Martre (1975-2000)

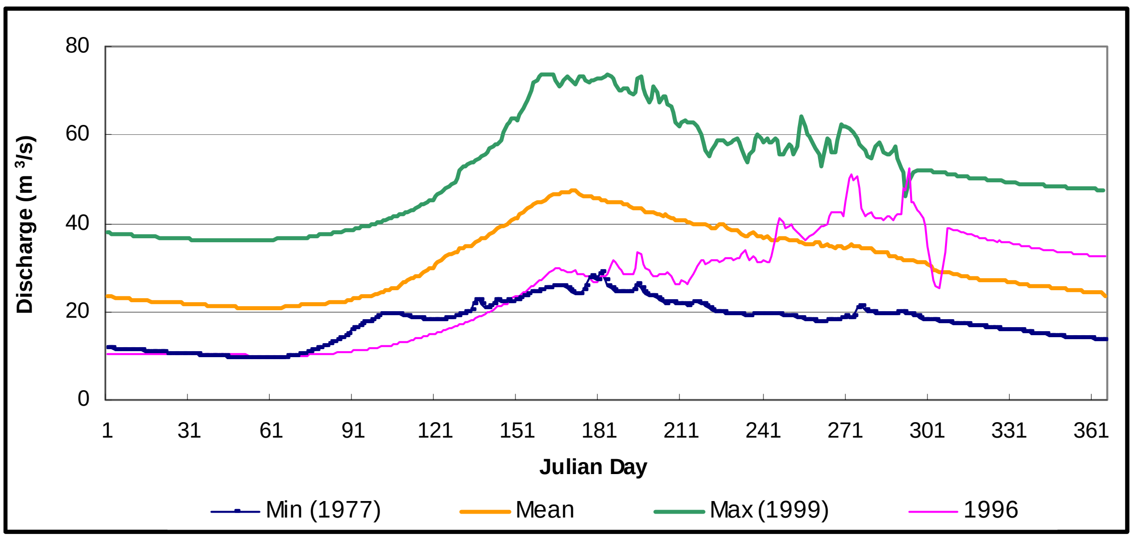
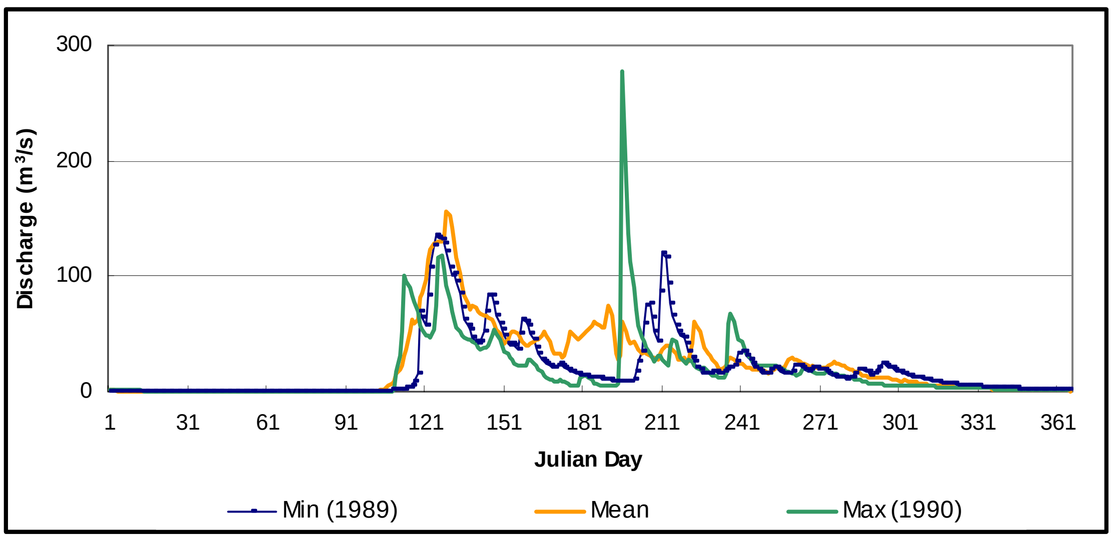


Photo 4. La Martre River – Falls, April 2001 (Photo: WSC, Yellowknife, NT)

The gauge on the Whitesand River is located near where this northward flowing river crosses the Alberta/NWT boundary. This medium-sized basin (3410 km^2) originates from the Caribou Mountains in northern Alberta and does not contain any large lakes. This lack of storage within the basin is evidenced by the annual hydrographs that indicate several relatively abrupt peaks as a result of both spring snowmelt and rain events over the summer (Figure 9). These peaks are also reflected in the mean annual hydrograph, where annual events are usually somewhat smoothed out. This is also a result of the fact that there are only six full and three partial years of data for this location, therefore the mean annual hydrograph is composed of only a small number of years.

Figure 9. Hydrographs for Whitesand River near Alberta/NWT boundary (1986-1994)



Boreal Plains

The Slave River is the primary flow contributor to Great Slave Lake, with a massive basin area of 606,000 km^2 at the site of the gauge at Fitzgerald, Alberta and a mean annual flow volume of almost 108 billion m^3. The river flows approximately 430 km from the Peace-Athabasca Delta until it empties into Great Slave Lake, depositing sediments that form the Slave River Delta, covering about 640 km^2 (Government of Alberta, 2001). Although the hydrometric station itself is situated within the province of Alberta, the river's importance necessitates its inclusion within this report.

Photo 5. Slave River at Fitzgerald – looking upstream from gauge (Photo: WSC, Yellowknife, NT)

The Slave River contributes over 75% of the inflow to Great Slave Lake. One of the primary tributaries to the Slave River is the Peace River, on which construction of the WAC Bennett Dam in British Columbia was completed in 1967. Filling of the dam between 1968 and 1971 created the Williston Reservoir, covering 177,300 hectares. Although research is ongoing to determine some of the effects specific to this basin, dams for hydro power generally attenuate high flows and increase low flows downstream (Figures 10 and 11). Since construction and filling of the Bennett Dam were completed in 1971, the average annual peak flow has decreased approximately 18%, while average annual low flow has increased about 92% (Figure 10). In total, there are 43 full and 11 partial years of data, however only data after 1971 were included in data analyses (i.e., Table 2). As a result, the hydrographs in Figure 12 only include values as of 1972.

Figure 10. A comparison of annual maximum and minimum flows on the Slave River before and after construction of the WAC Bennett Dam (Values from 1968-1971 not included.)

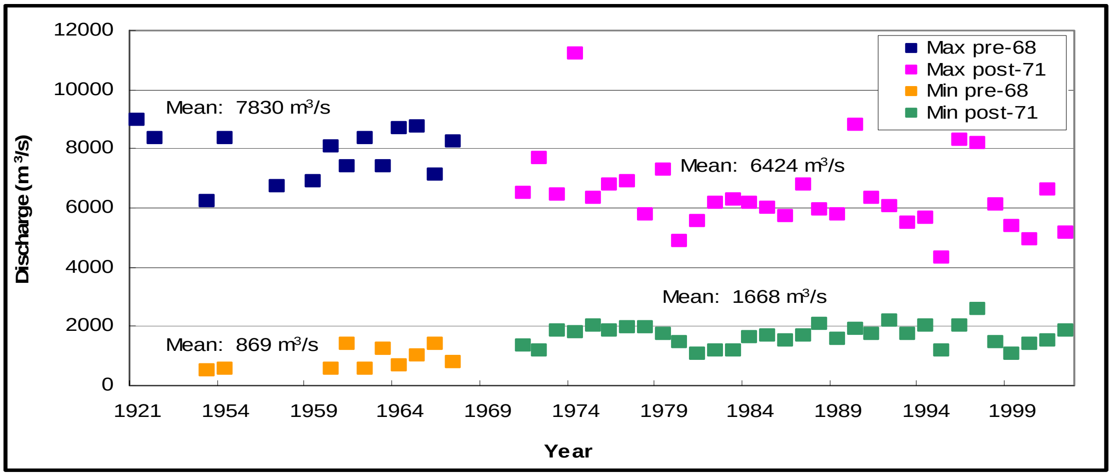


Figure 11. A comparison of daily mean flows on the Slave River before and after construction of the WAC Bennett Dam

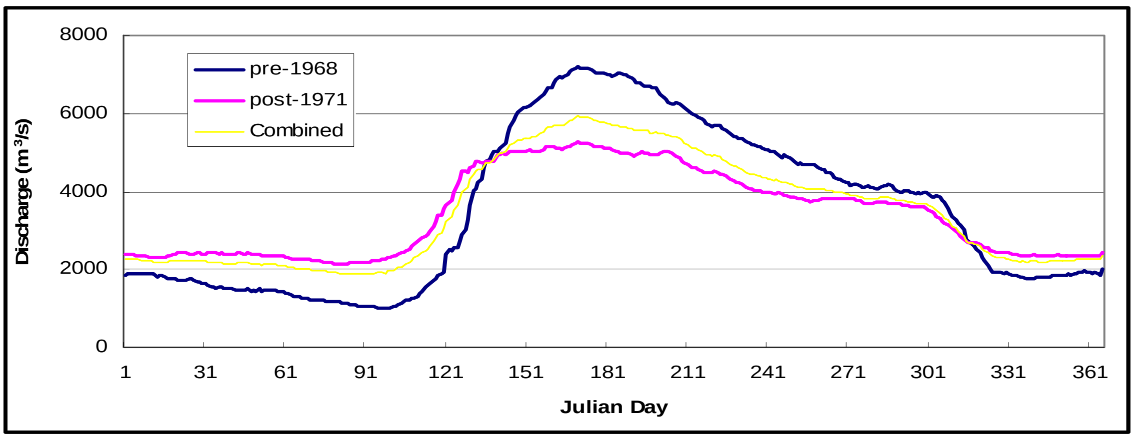
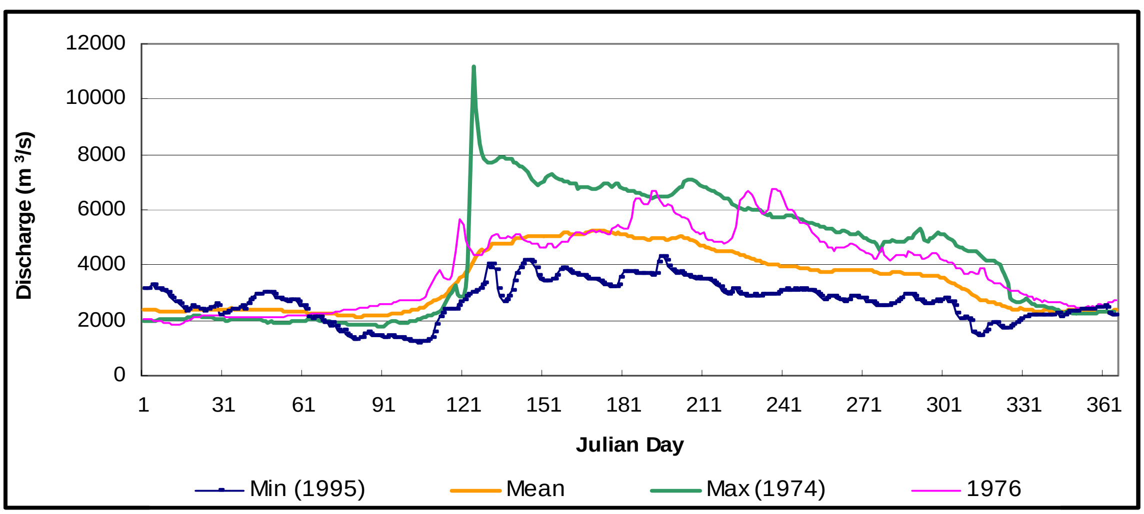
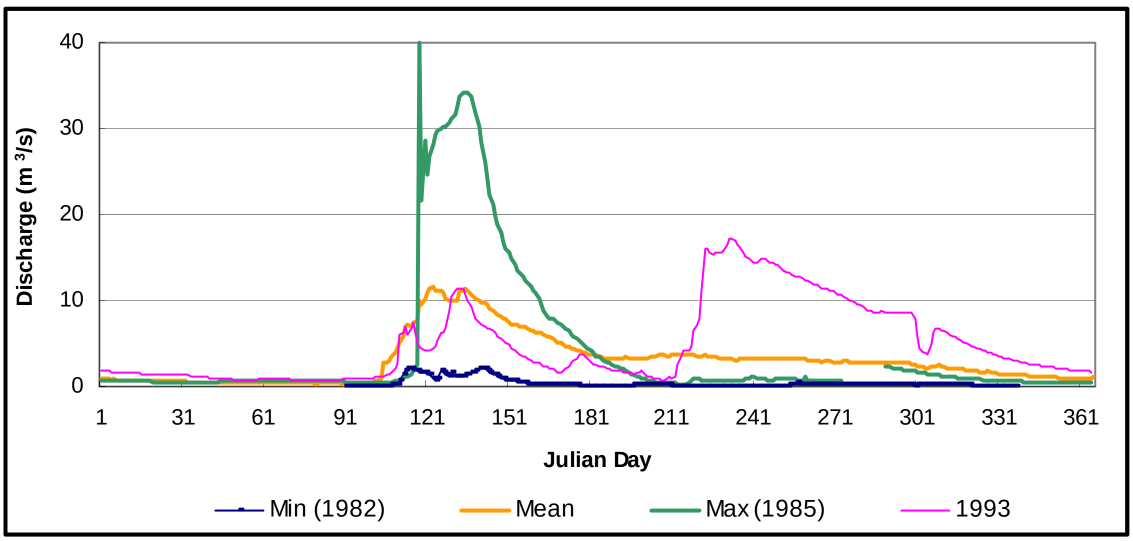


Figure 12. Hydrographs for Slave River at Fitzgerald (1972-2002)



The basin area of the Little Buffalo River is less than 1% of that of the Slave River. The headwaters of the river are in Alberta within the boundaries of Wood Buffalo National Park. The area is characterized by low topography, poor drainage, meandering streams, shallow lakes and bogs (Parks Canada, 2001). Downstream, the river marks the northeast border of the Park. For the Little Buffalo River gauge, initially established in 1965 to evaluate highway crossing design, there are five full and 25 partial years of data (Figure 13). Spring freshet generally occurs in mid-May. It is during this time that peak flows are usually obtained, although significant rainfall events later in the year can sometimes result in annual high flows (e.g., 1993). During both snowmelt and rainfall events, the rising limb of the peak is generally very steep, while the falling limb indicates a more gradual decline in flow volumes.

Figure 13. Hydrographs for Little Buffalo River below Highway 5 (1965-1994)

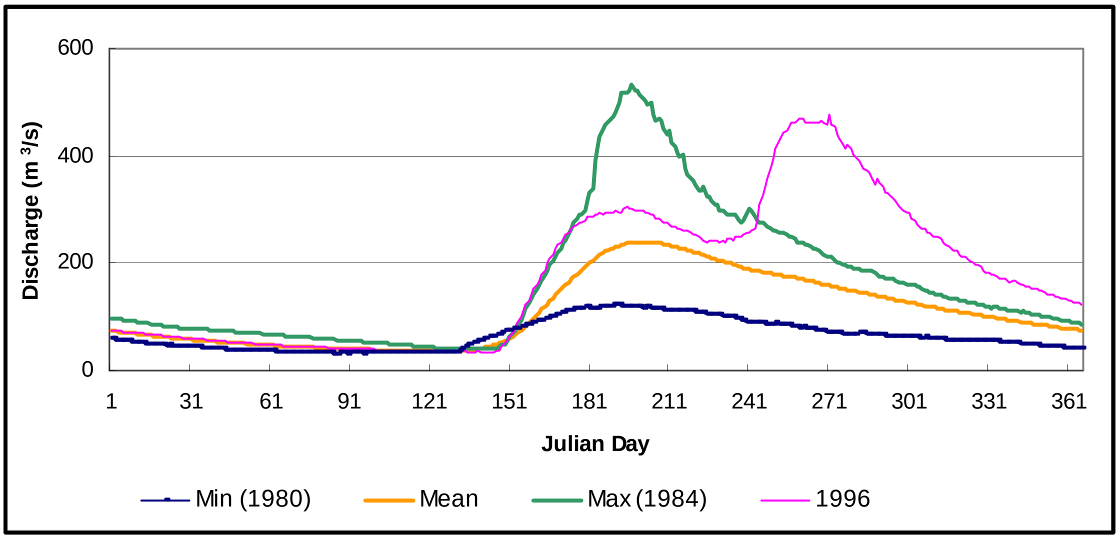


Southern Arctic

There are currently three stations operating on streams within the Southern Arctic ecozone section of the Slave regions, all within the Coppermine River basin. Given the transboundary nature of the Coppermine River, as well as current and potential development within the basin, a separate overview report was written which should be referred to for greater detail: "Overview of the Hydrology and Water Quality of the Coppermine River" (Coulombe-Pontbriand, 1998).

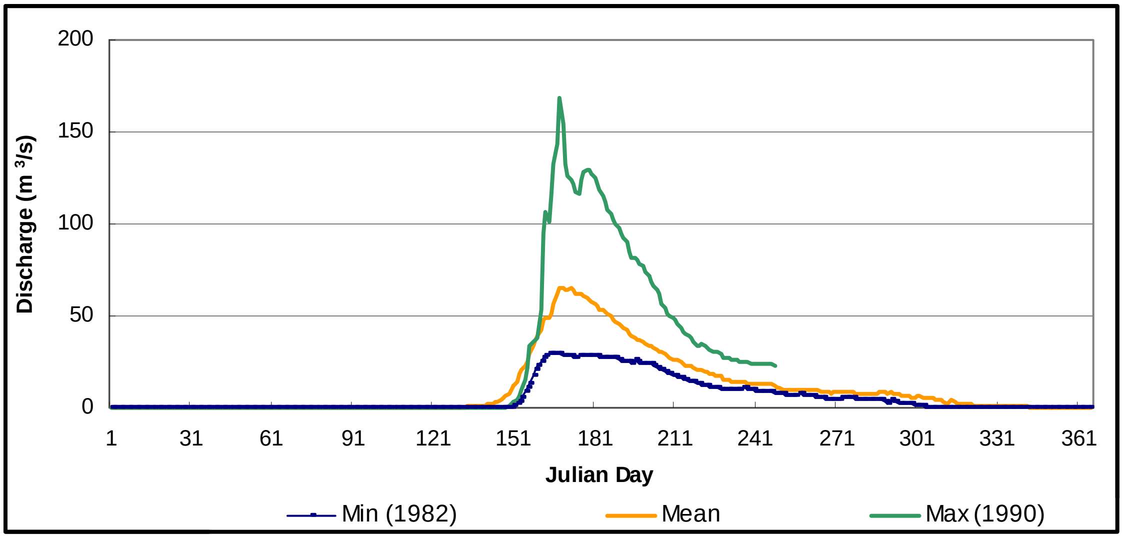
The hydrometric station located on the Coppermine River at the outlet of Point Lake was established in 1965 as part of the National Water Quantity Inventory and currently monitors transboundary flows between the NWT and Nunavut. There are 34 full and four partial years of data for the site (Figure 14). The river typically peaks in July with the late thaw of snow and ice. The gauge is located directly downstream of a large lake and the resultant flow recession is generally very gradual due to the lake's storage capacity. Minimum flows usually occur in late May, just before the onset of spring melt. Rapid changes in river flow due to precipitation events are not common due to the moderating effect of Point Lake. However, similar to some other North Slave rivers (see discussion on the Indin River), the 1996 hydrograph indicates the effect of large amounts of precipitation received in late summer/early autumn in the region.

Figure 14. Hydrographs for Coppermine River at outlet of Point Lake (1965-2002)



The Thonokied River gauge near the mouth was located just upstream of Aylmer Lake, part of the Lockhart basin. It operated for 11 years during which time five full and six partial years of data were collected (Figure 15). Peak flow generally occurred in mid- to late June as a result of snowmelt, after which time there was a relatively gradual recession towards winter low flows. Data from the gauge were judged to be of relatively poor quality however, given that the site was severely affected by ice and bench marks were unstable (Wedel, 1991).

Figure 15. Hydrographs for Thonokied River near the mouth (1980-1990)



Although the gauge for the Lockhart River is within the Taiga Shield ecozone, much of the basin lies above tree line within a region of tundra and tundra/forest transition. Established to assess hydro-power potential, the river has one of the longest data records in the north, with 38 full and nine partial years. The majority of the basin is located northeast of Great Slave Lake, draining in an almost clockwise direction towards the most easterly tip of the lake. Its mean annual hydrograph is similar in appearance to that of individual year hydrographs (Figure 16). This is primarily a result of the gauge's location downstream of several large lakes, including Artillery Lake. The large amount of storage directly upstream and the large size of the basin (26,600 km^2) serve to attenuate flows year-round, resulting in gently sloping and consistent hydrographs from one year to the next. The majority of precipitation events have insufficient impact on flow to be visible on annual hydrographs.

Figure 16. Hydrographs for Lockhart River at outlet of Artillery Lake (1944-2002)

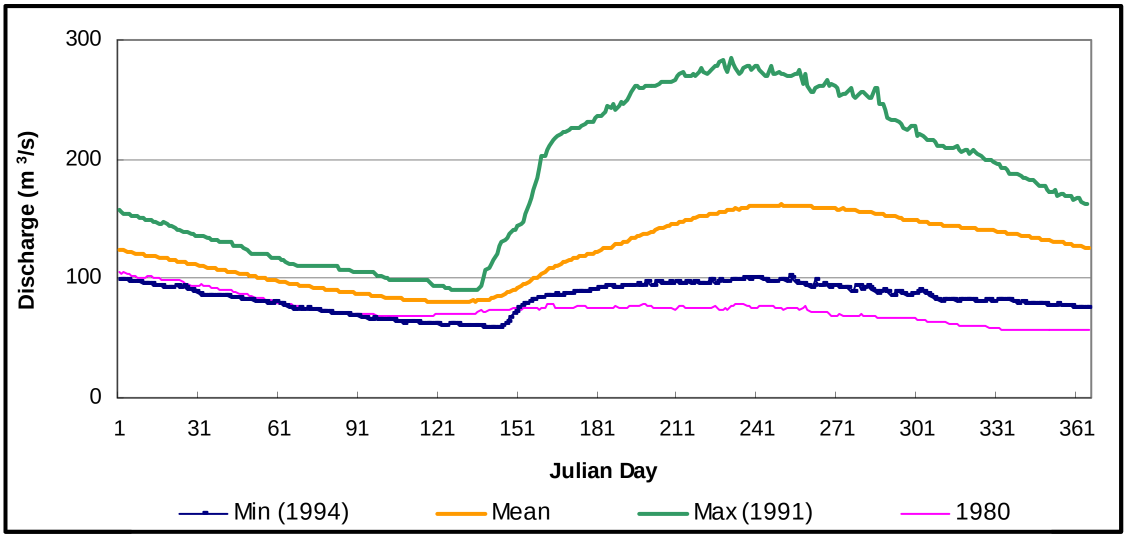
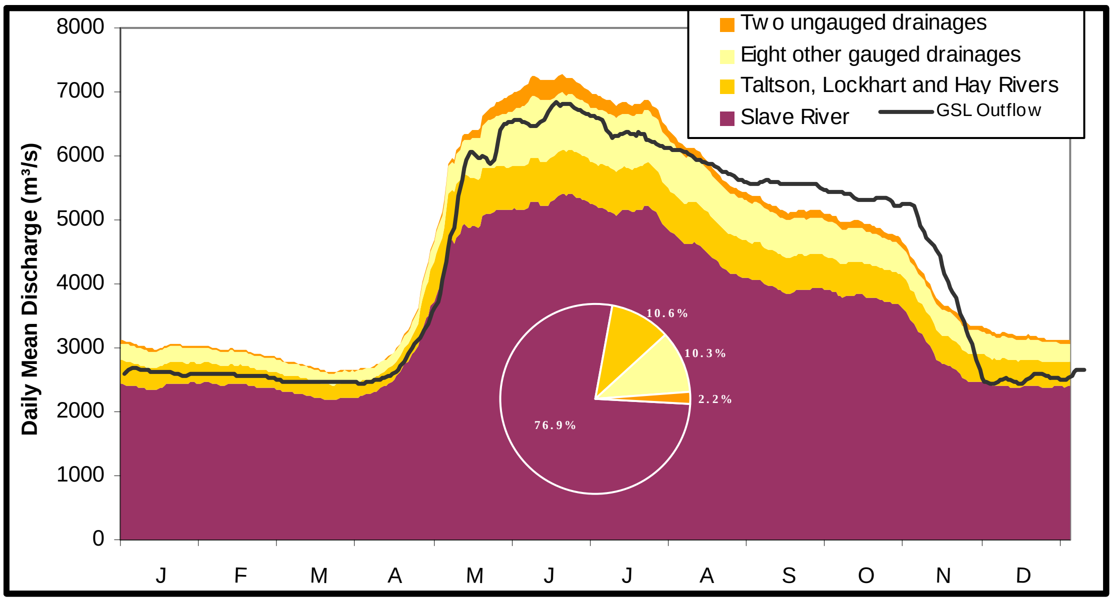


Photo 6. Lockhart River – view of gauge and control, June 2002 (Photo: WSC, Yellowknife, NT)

Great Slave Lake

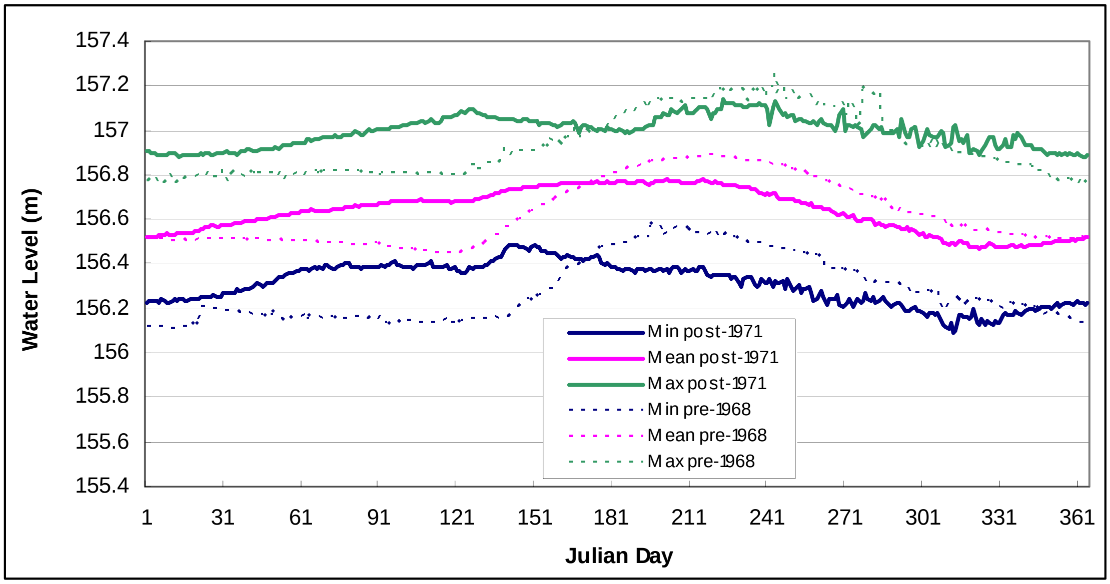
Great Slave Lake is the fifth largest lake in North America covering an area of 28,568 km^2. It is the deepest lake in North America, with an average depth of 73 m and a maximum depth of 614 m. As previously mentioned, the Slave River is the dominant inflow to Great Slave Lake, accounting for approximately 77% of total inflows (Figure 17). The Taltson, Lockhart and Hay rivers together contribute approximately 11% of inflows, while the remaining 12% is provided by 10 other drainage areas. The lake's massive area attenuates the outflow of the Mackenzie River, as gauged at Strong Point, relative to the peaks and lows of inflowing streams (Figure 17).

Figure 17. Area plot of mean annual hydrograph of total inflows to Great Slave Lake and line plot of lake outflow. Area plot shows % contributions of Slave River and groupings of 13 other drainages (Figure and data analysis completed by D. Faria)



The Slave River's majority inflow contribution to the lake means that management of the Williston Reservoir upstream on the Peace River and precipitation received in northern Alberta and British Columbia can potentially influence water levels on Great Slave Lake. In addition, precipitation received in most of the North and South Slave regions has relatively little impact on Great Slave Lake water levels. While the mean annual and mean minimum water levels have only marginally increased, 2 cm and 3 cm respectively, the mean maximum water level has decreased by 7 cm when comparing levels from before 1968 to after 1971 when Bennett Dam construction and filling were completed (Figure 18). As would be expected, the hydrographs of lake levels have become flatter in appearance as input volumes from the Slave River have been attenuated (Figure 11). As mentioned previously, research efforts are ongoing in hope of ascertaining the magnitude of downstream impacts of the Bennett Dam, including water levels on the Slave River and Great Slave Lake.

Figure 18. Comparison of water levels on Great Slave Lake at Yellowknife Bay before and after construction and filling of WAC Bennett Dam



Frequency Analysis of Extremes

Management of water resources often requires a frequency analysis of extreme hydrological events. The accuracy of such an analysis increases with the length of the data record, and the accepted guideline for effective analysis is a minimum of 30 years of flow data from a gauged station. Operating periods of the stations examined in this report vary considerably, from three to 82 years (Table 1), reflecting changes in the cost of logistics, priorities and budgets over the years. Given that so few stations provide 30 or more years of flow data, the minimum acceptable time line for the purposes of frequency analysis was lowered to 20 years. Only years with a complete data record during the break-up and subsequent open water period were used in the frequency analysis to be certain that the maximum annual flow was recorded. The analysis has been applied to ten station data sets (Table 3).

Table 3. Results of flood frequency analyses using Pearson Theoretical Distribution (stations with ≥ 20 years of data)

Station Description	Basin yield (mm/yr)	Number of high-flow data years	10-year high flow (m^3/s)	25-year high flow (m^3/s)	50-year high flow (m^3/s)	100-year high flow (m^3/s)	Highest flow on record (m^3/s)
Hanbury R above Hoare Lake -including 1991	165	21	287	421	537	662	660
-not including 1991	*158*	*20*	*193*	*213*	*225*	*236*	*239* (*1992*)
Slave R at Fitzgerald (post-dam filling 1972-2002)	177	31	8152	9281	10132	10985	11200 (*1974*)
Taltson R at outlet of Tsu Lake (post-dam construction 1966-1997)	100	30	452	522	571	617	543 (*1988*)
Thoa R near inlet to Hill Island Lake	155	24	208	248	276	303	264 (*1982*)
Lockhart R at outlet of Artillery Lake	146	43	230	255	271	287	285 (*1991*)
Indin R above Chalco Lake	166	25	78	92	102	111	105 (*2001*)
Cameron R below Reid Lake	54	27	34	45	53	61	57 (*1991*)
Baker Creek (combined)*	52	32	5	6	8	9	8 (*1991*)
La Martre R below outlet of Lac La Martre	72	26	68	74	78	81	74 (*1999*)
Coppermine R at outlet of Point Lake	179	36	389	464	519	573	533 (*1984*)

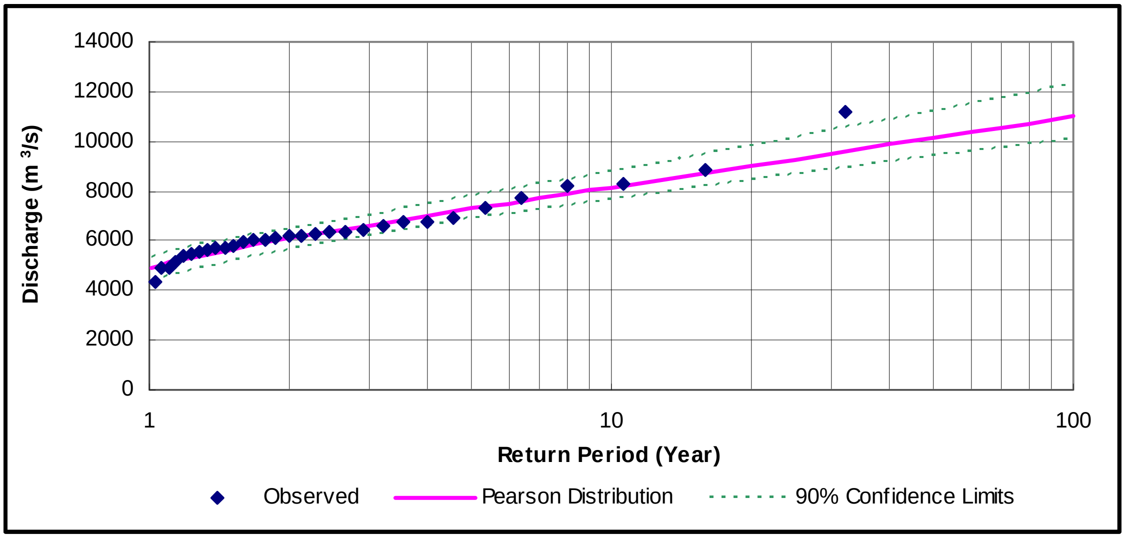
*Data for two stations on Baker Creek (07SB009 1968-1982, 07SB013 1983-2002) were combined given their proximity to each other and similarity of flow records.

Extremes of high flow (flood) events can have significant impact on ecosystem and human activities. Historical records of annual extremes can be used to predict the likelihood or probability of similar events by the technique of frequency analysis. The probability of a given flow magnitude is expressed as a return period, which is the time interval that a given flow magnitude should be exceeded one time. Given that the length of data records is relatively brief, a theoretical distribution was used to calculate flood probabilities. Theoretical distribution techniques use the mean, standard deviation and skewness of the observed annual maximum flow to evaluate the return period of annual maximum flows. The theoretical distribution and the 90% confidence limits were calculated using the Pearson theoretical distribution, widely used in hydrology as a statistical model to describe extreme events (Chow, 1964; Maidment, 1993).

Though estimates of return period can be useful in planning activities and developments near streams, one limitation in the application of the technique is worth noting. The magnitudes of the annual extremes and their corresponding return periods generally follow a characteristic distribution for each stream, but two events of equal magnitude with a given return period can and do occur within less time than expected. In general, as more data are received, the fit between observed data and theoretical distribution should improve.

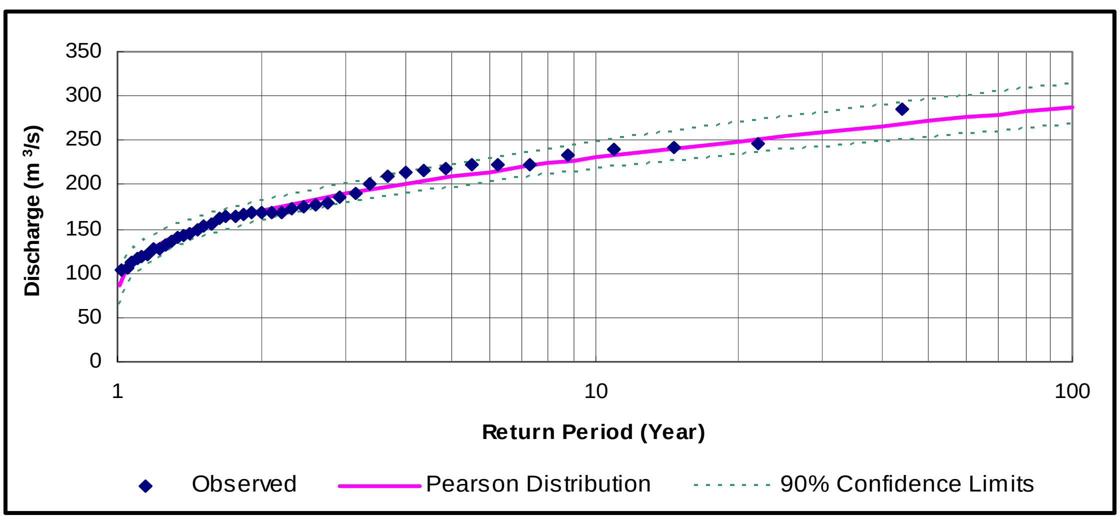
Overall, the Pearson Theoretical Distribution fits the distribution of observed values better near the small and medium-sized observed flows than at high flows (Figures 19 and 20, Appendix B). Nevertheless, there are only a very small number (<20) of observed values which fall outside the range of the 90% confidence limits for all ten of the data sets examined. Not including the Hanbury River values which are discussed below, the station on the Slave River is the only one where the highest flow on record exceeds the predicted 100-year flow (Table 3). The theoretical distribution predicts a return period of approximately 119 years for a flow magnitude of 11,200 m^3/s, whereas it was observed within the 31-year data set (Figure 19). It likely occurred as a result of an ice jam release (discussed at greater length below in relation to the Hanbury River). Given that the value was recorded after completion of the WAC Bennett Dam upstream, it is possible that the peak is related to human-induced, rather than natural, conditions. The large discrepancy between the predicted and observed return periods should decrease over time as the observed data set becomes larger.

Figure 19. Flood frequency distribution for Slave River at Fitzgerald (1972-2002)



The 43-year data set for the Lockhart River provides a very good fit between theoretical and observed return frequency values as all observed values fall within the 90% confidence limits of the analysis (Figure 20). This may be partially explained by the fact that the gauge is situated downstream of a series of large lakes which serve to attenuate flow values (see Figure 16). The large volume of storage available in the basin makes it less likely that there will be extremes of high (or low) flow, potentially increasing the accuracy of prediction of flows with higher return periods.

Figure 20. Flood frequency distribution for Lockhart River at outlet of Artillery Lake (1946-1948, 1963-2002)



It is important to be familiar with the data when using frequency distribution analysis to predict the return period of a given river discharge as demonstrated by Figures 21a and b of the Hanbury River above Hoare Lake, situated in the northern part of the South Slave region. The highest discharge recorded to date at the station occurred in 1991 (660 m^3/s) and is well over twice the next highest recorded value (239 m^3/s) in 1992. An ice jam which was holding back water upstream of the gauge eventually broke, resulting in a very rapid and large rise in water levels at the gauge. This peak is not necessarily indicative of an extremely high meltwater volume in the basin in 1991, but of a short-lived pulse which passed by the gauge as a result of a mechanical break-up. Including the 1991 peak flow value in the flood frequency analysis for the Hanbury River greatly increases the predicted high flow figures (Table 3; Figures 21a and 21b). While the 1991 peak flow may be an exaggerated view of the overall basin conditions that year, it is nevertheless a snapshot of water levels at a particular point in time, at a specific location. It is important to consider the potential for flows of this magnitude, regardless of their origin. This dramatic shift in predicted values as a result of one observed event highlights the importance of having a larger set of observed values.

Figure 21a. Flood frequency distribution for Hanbury River above Hoare Lake (1977-2002), including 1991

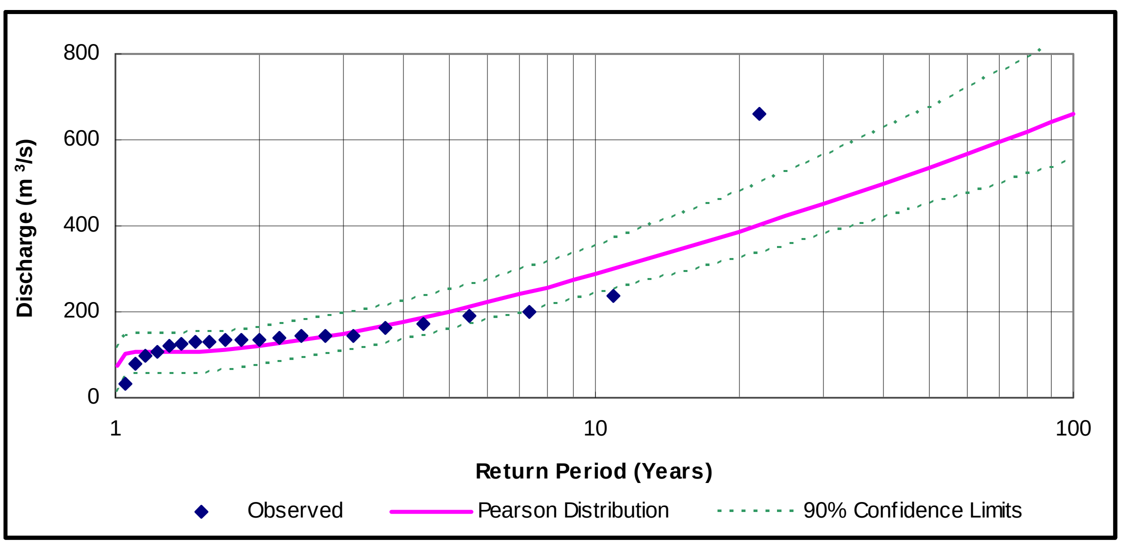
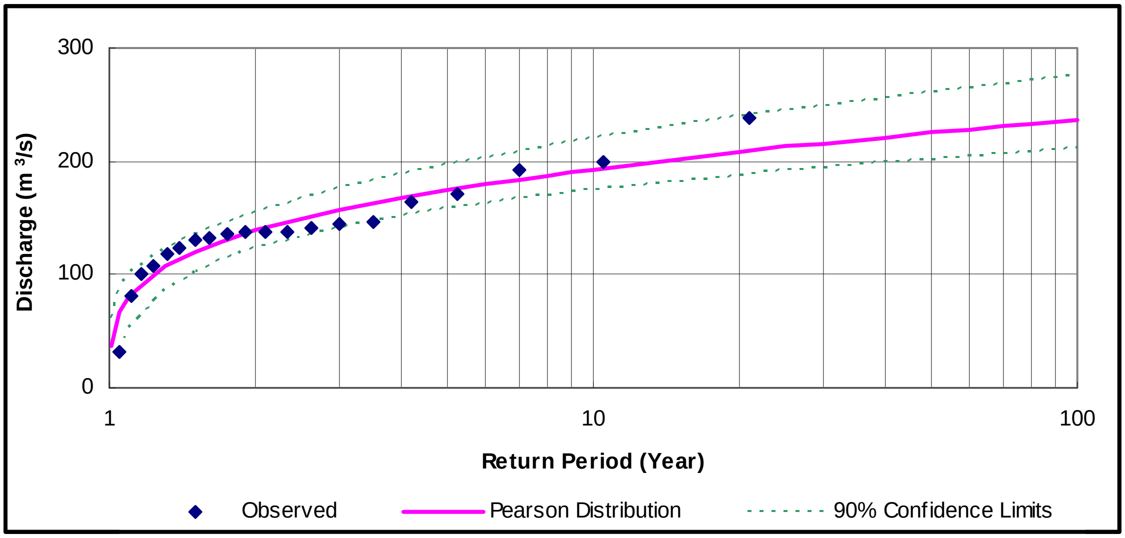


Figure 21b. Flood frequency distribution for Hanbury River above Hoare Lake (1977-2002), not including 1991



Conclusion

The information in this report is based on data recorded at 29 hydrometric stations located across the North and South Slave regions. The operating period of the gauges ranges from three to 82 years. With the exception of the Coppermine, Acasta and Hanbury rivers, the streams discussed in this report flow into Great Slave Lake. The Acasta River drains into the northward flowing Camsell River, the Coppermine drains into Coronation Gulf and the Hanbury River flows into the Thelon River. The primary terrestrial ecozone in both regions is the Taiga Shield. Recent research indicates that runoff ratios in the Shield are highly variable as a result of several physiographic and climatic factors that directly control storage and infiltration, and as a result, indirectly control runoff (Spence and Woo, 2002). The climate of the Slave regions is primarily subarctic and the majority of the areas fall within the zone of discontinuous permafrost. The majority of streams are characterized by a subarctic nival flow regime. This means that the spring snowmelt is the primary source of water, generally resulting in springtime peak flows. Flow peaks can occur at any time between April to early September, however, depending largely on annual variability in precipitation (snow and rain).

Although there is considerable variability in the yield values for the streams studied (ranging from 32 to 217 mm/year), the values all fall well below the mean value for gauged Mackenzie River tributaries flowing from the Mackenzie Mountains. In general, streams within the Slave regions have a higher storage capacity, higher evaporative losses from storage areas and lower amounts of precipitation than those found in the Cordillera.

The Slave River has a massive basin area (606,000 km^2) and a mean annual flow volume of almost 108 billion m^3. One of the primary tributaries to the Slave River is the Peace River, on which construction and filling of the Bennett Dam were completed by 1971. Although research is ongoing to determine some of the effects specific to this basin, the average annual peak flow on the Slave River has decreased approximately 18%, while average annual low flow has increased about 92% since 1971.

Great Slave Lake is the deepest and fifth largest lake in North America. The lake's massive area attenuates the outflow of the Mackenzie River, as gauged at Strong Point, relative to the peaks and lows of inflowing streams. The Slave River's majority inflow contribution to the lake (77%) means that: management of the Williston Reservoir upstream on the Peace River and precipitation received in northern Alberta and British Columbia can potentially influence water levels on Great Slave Lake; and precipitation received in most of the North and South Slave regions has little impact on Great Slave Lake water levels. As would be expected, the hydrographs of lake levels have become flatter in appearance as input volumes from the Slave River have been attenuated.

A flood frequency analysis was performed for rivers having a minimum of 20 years of continuous record during break-up and open water conditions. Overall, the Pearson Theoretical Distribution curve calculated for each stream fits the observed data well, with only a small number of observed values falling outside the range of the 90% confidence limits. The performance of the Distribution curve would improve with an increased period of record.

Acknowledgements

The author would like to acknowledge the assistance of Bob Reid and Derek Faria during the writing of this report. Bob also provided precipitation data for Pocket Lake and Salmita, while Derek contributed Great Slave Lake input values and the corresponding figure. The digital maps were completed by Denise Bicknell, who also obtained all of the photos for the report. The assistance of members of Environment Canada's Water Survey Division (Yellowknife) with data clarifications was essential to the completion of this report. In particular, the author would like to thank Murray Jones for sharing his knowledge of rivers in the Slave regions. Gratitude is also extended to Water Survey Division for the use of their photographs.

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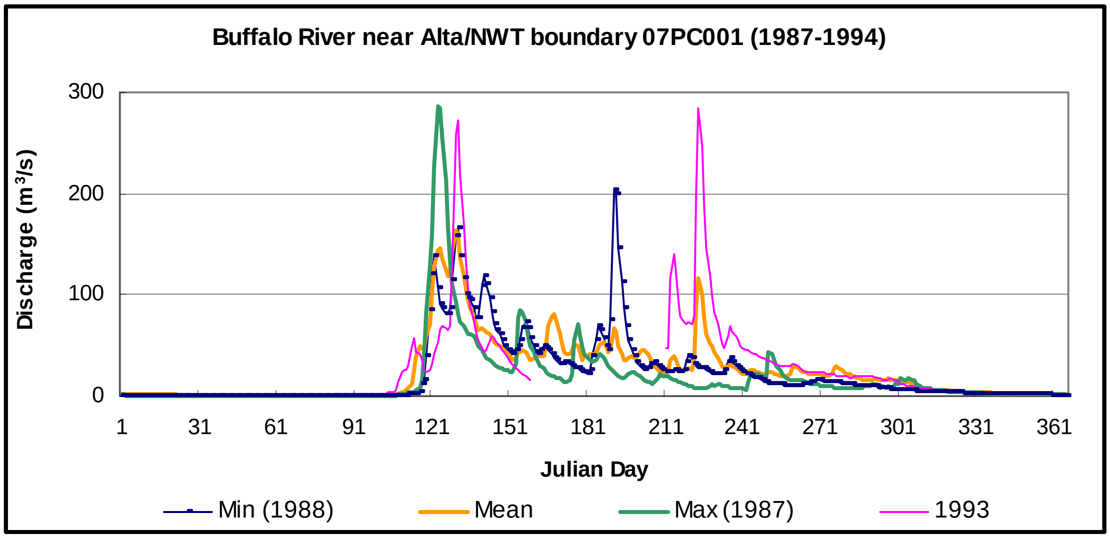
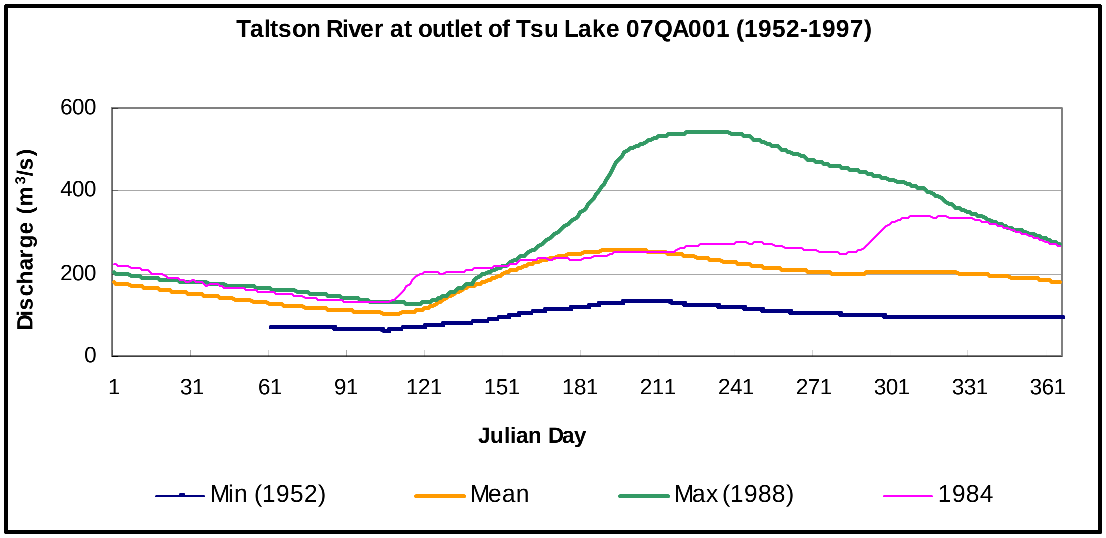
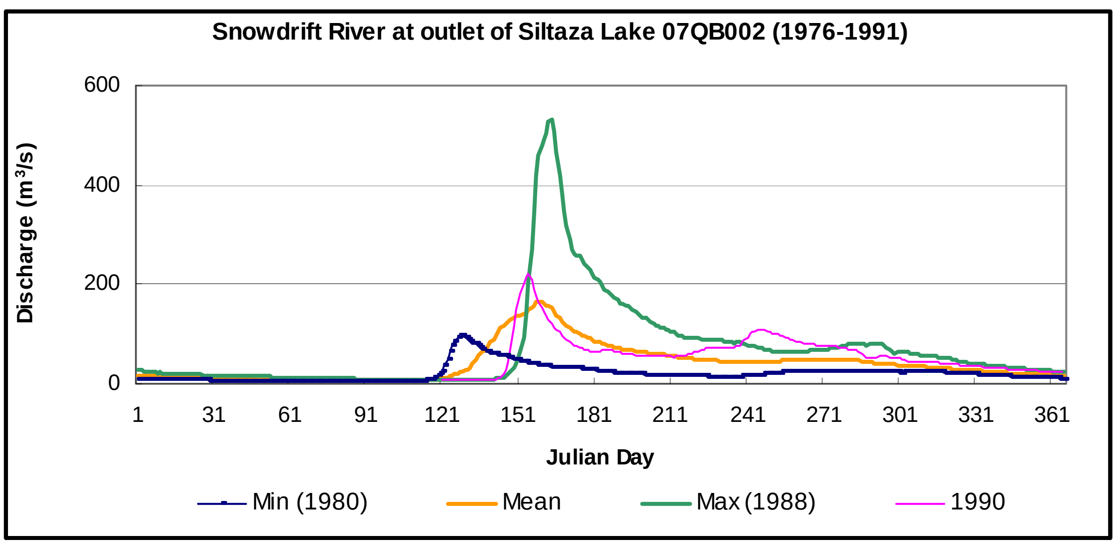
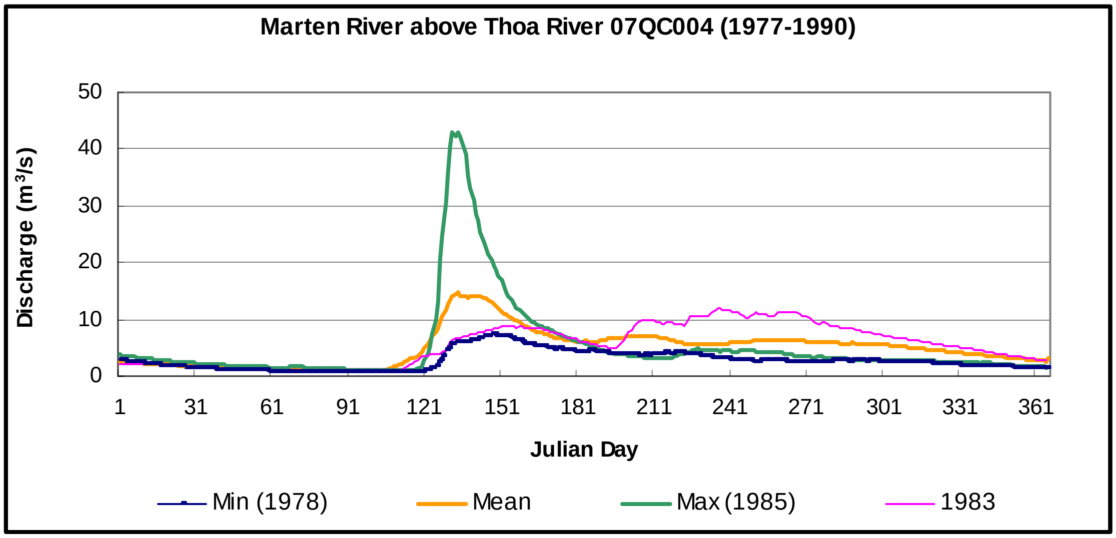
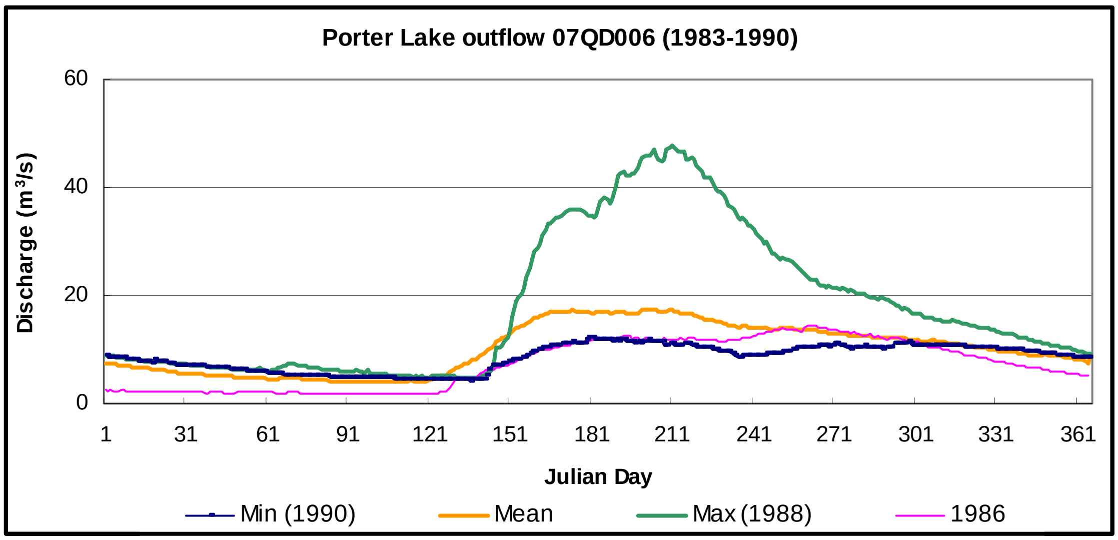
Appendix A. Hydrometric Station Hydrographs

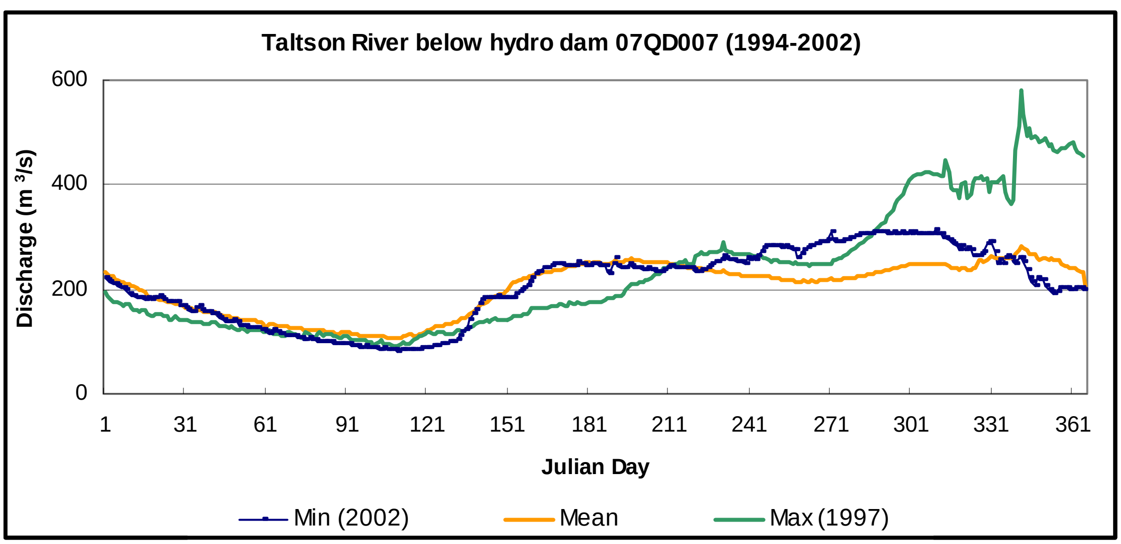


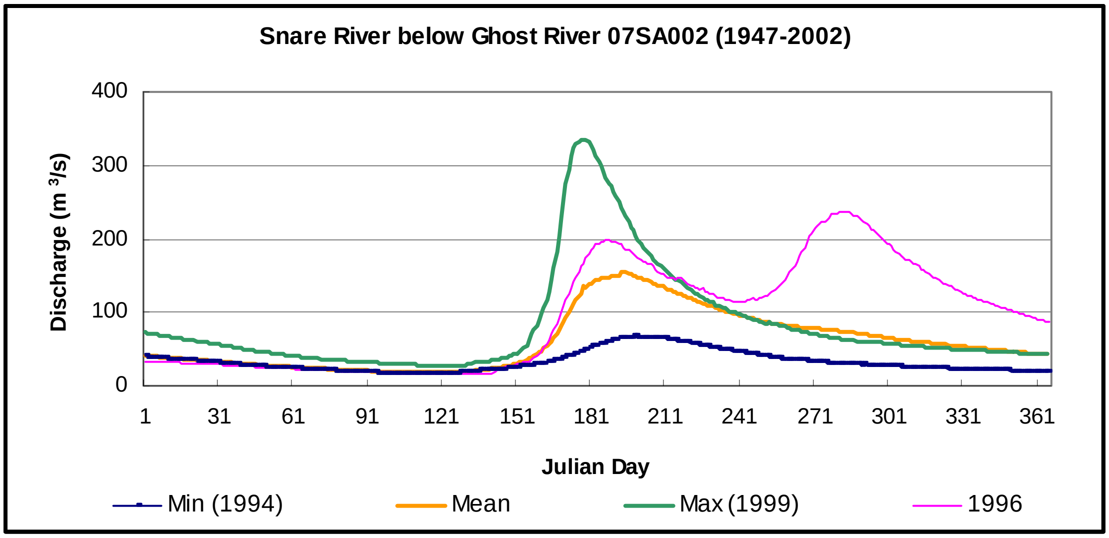


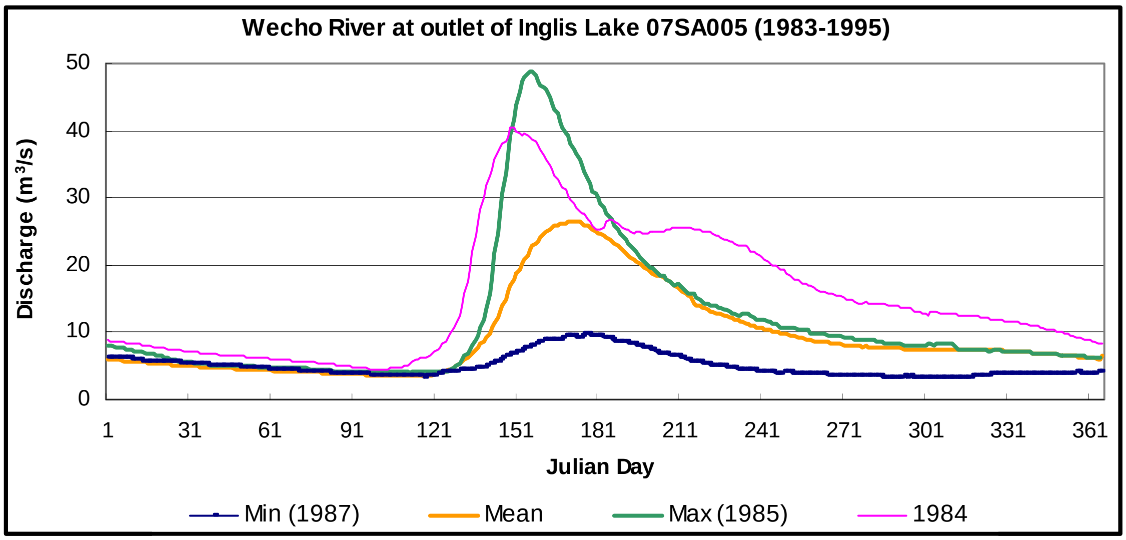


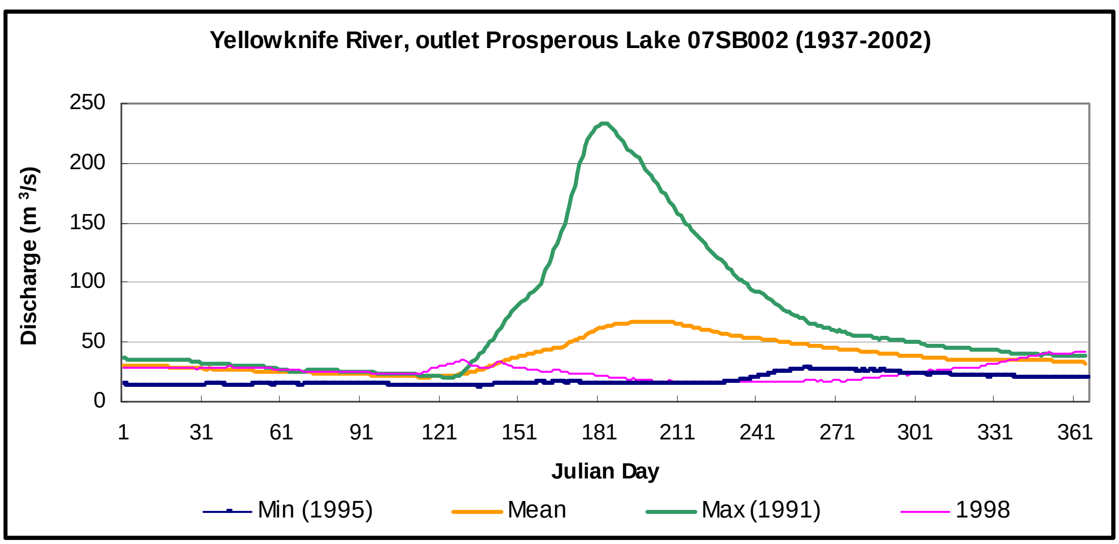

Marten River above Thoa River 07QC004 (1977-1990)
Discharge (m³/s)
0
10
20
30
40
50
1
31
61
91
121
151
181
211
241
271
301
331
361
Julian Day
Min (1978)
Mean
Max (1985)
1983


Porter Lake outflow 07QD006 (1983-1990)
Discharge (m³/s)
0
20
40
60
1
31
61
91
121
151
181
211
241
271
301
331
361
Julian Day
Min (1990)
Mean
Max (1988)
1986


Taltson River below hydro dam 07QD007 (1994-2002)
Discharge (m ³/s)
0
200
400
600
1
31
61
91
121
151
181
211
241
271
301
331
361
Julian Day
Min (2002)
Mean
Max (1997)


Snare River below Ghost River 07SA002 (1947-2002)
Discharge (m 3/s)
400
300
200
100
0
1
31
61
91
121
151
181
211
241
271
301
331
361
Julian Day
Min (1994)
Mean
Max (1999)
1996


Wecho River at outlet of Inglis Lake 07SA005 (1983-1995)
Discharge (m3/s)
50
40
30
20
10
0
1
31
61
91
121
151
181
211
241
271
301
331
361
Julian Day
Min (1987)
Mean
Max (1985)
1984


Yellowknife River, outlet Prosperous Lake 07SB002 (1937-2002)
Discharge (m 3/s)
250
200
150
100
50
0
1
31
61
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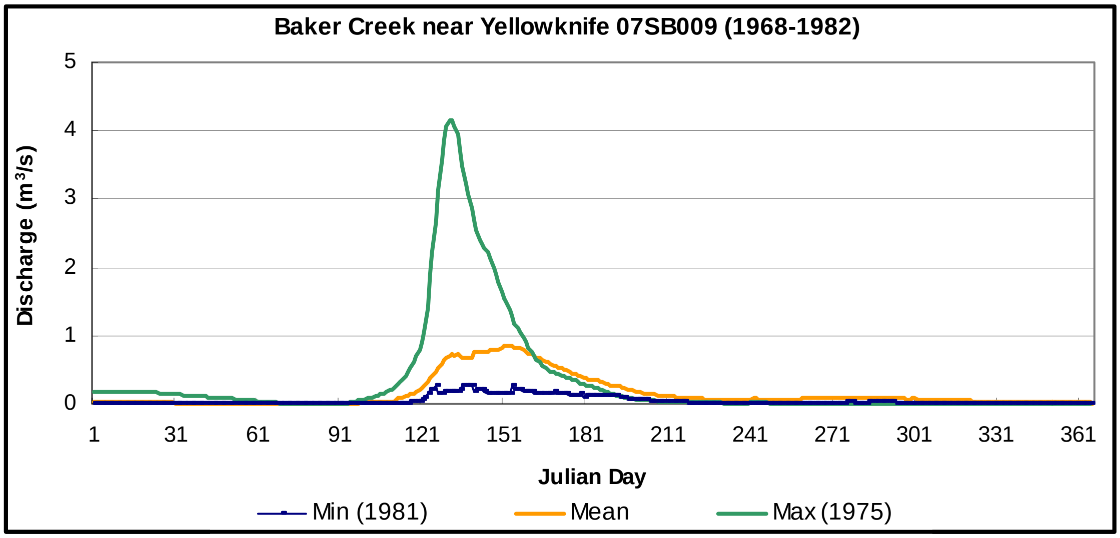
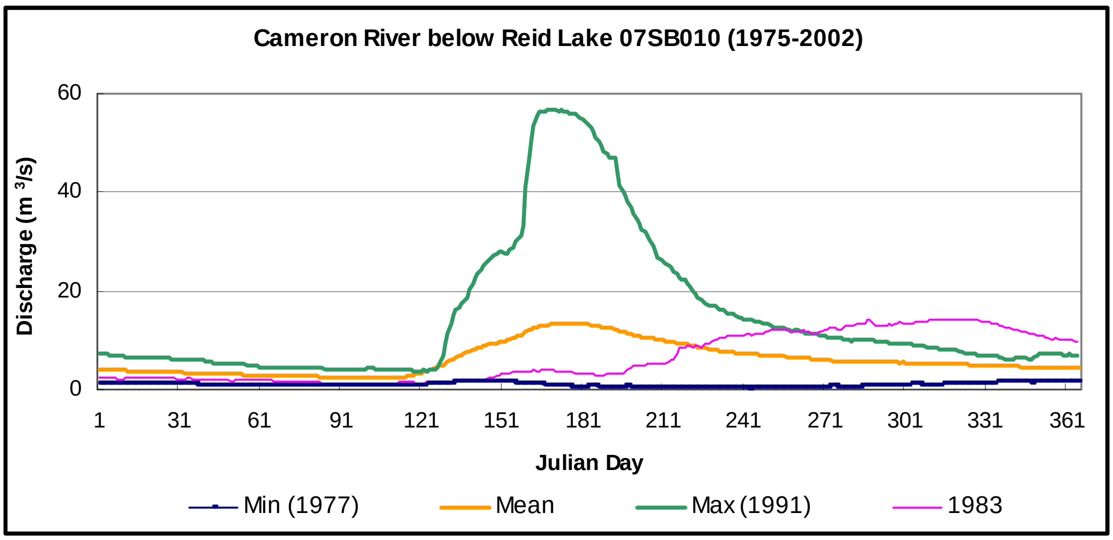
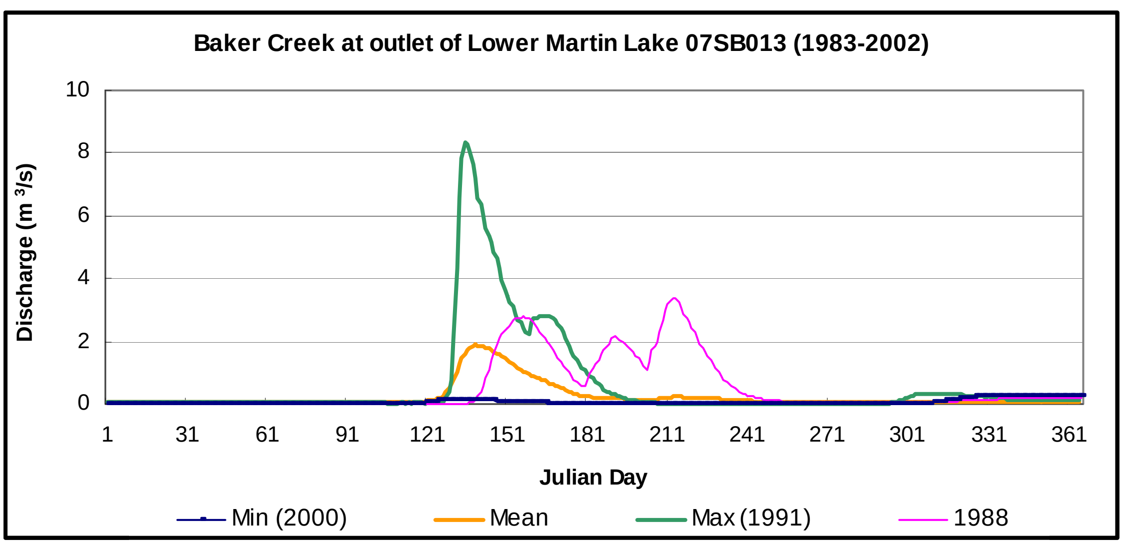
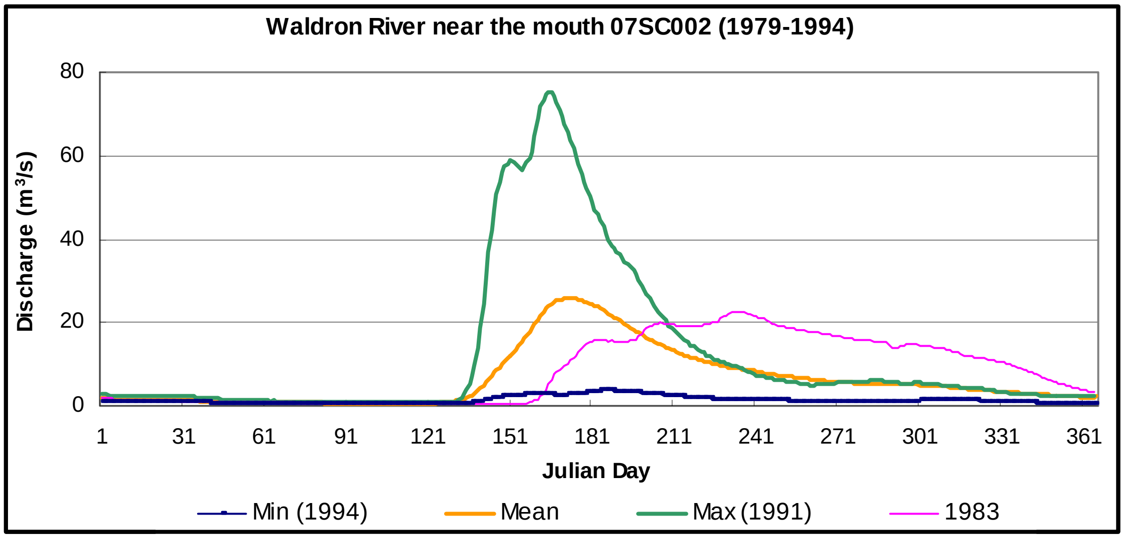
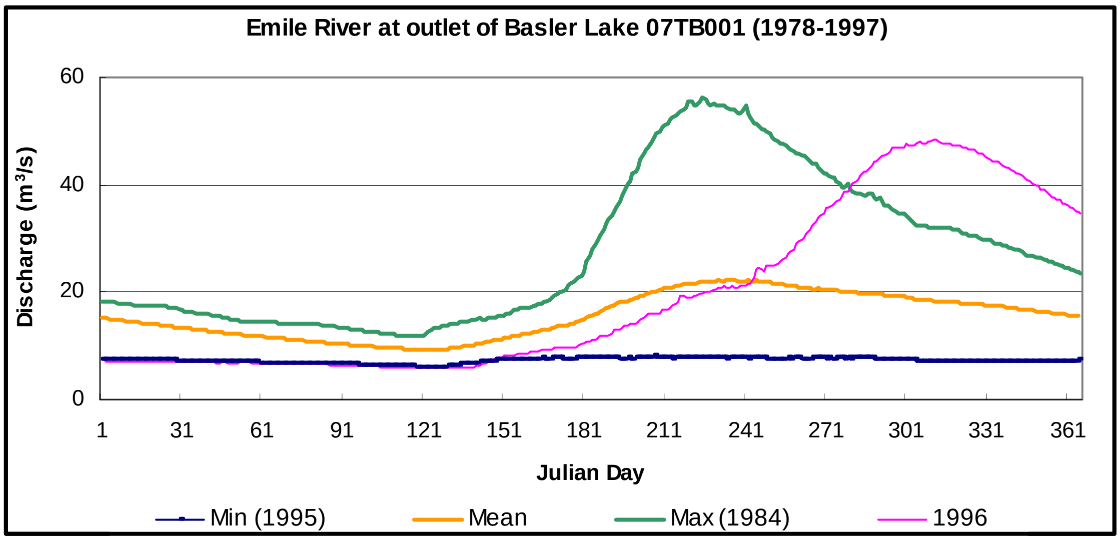
301
331
361
Julian Day
Min (1995)
Mean
Max (1991)
1998

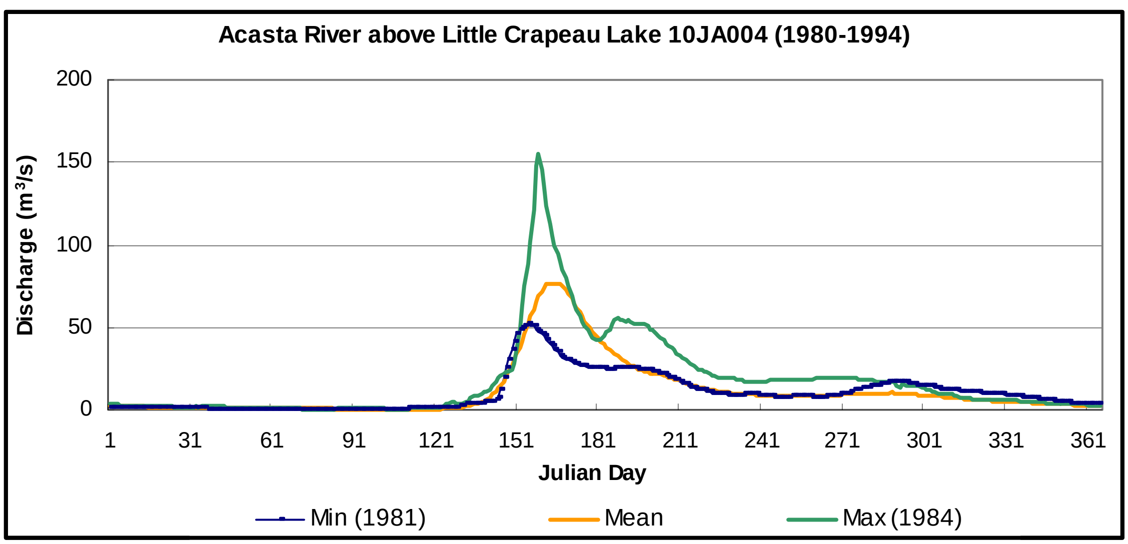

Baker Creek near Yellowknife 07SB009 (1968-1982)
Discharge (m³/s)
0
1
2
3
4
5
1
31
61
91
121
151
181
211
241
271
301
331
361
Julian Day
Min (1981)
Mean
Max (1975)


Cameron River below Reid Lake 07SB010 (1975-2002)
Discharge (m ³/s)
0
20
40
60
1
31
61
91
121
151
181
211
241
271
301
331
361
Julian Day
Min (1977)
Mean
Max (1991)
1983

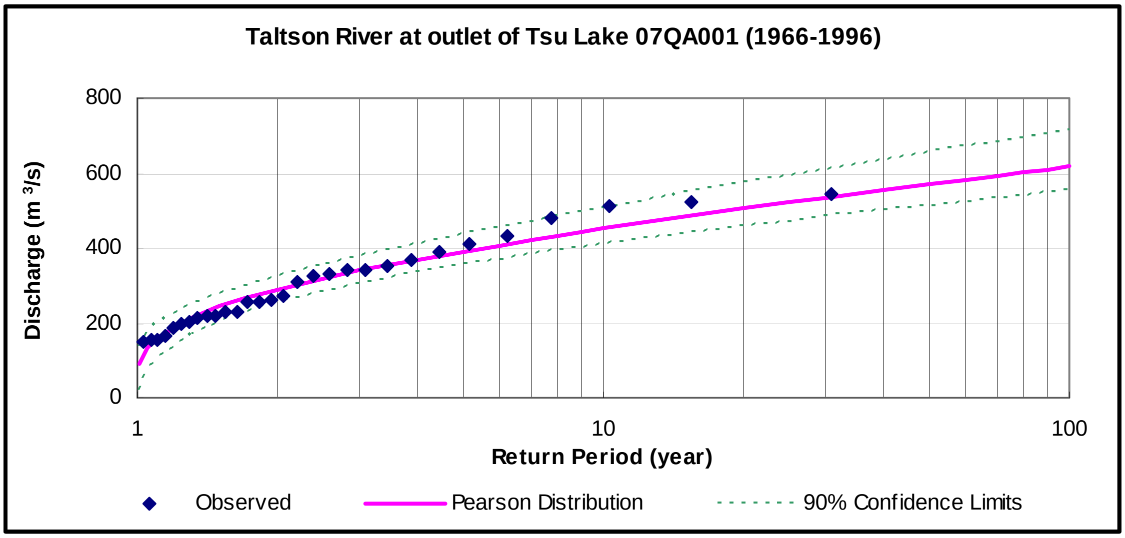

Baker Creek at outlet of Lower Martin Lake 07SB013 (1983-2002)
Discharge (m ³/s)
0
2
4
6
8
10
1
31
61
91
121
151
181
211
241
271
301
331
361
Julian Day
Min (2000)
Mean
Max (1991)
1988

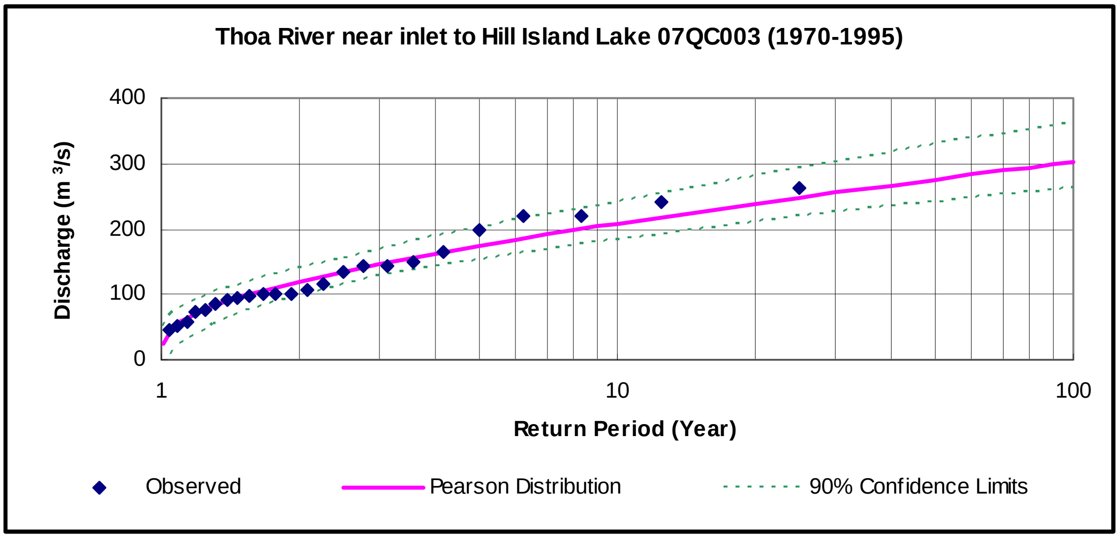

Waldron River near the mouth 07SC002 (1979-1994)
Discharge (m³/s)
80
60
40
20
0
1
31
61
91
121
151
181
211
241
271
301
331
361
Julian Day
Min (1994)
Mean
Max (1991)
1983

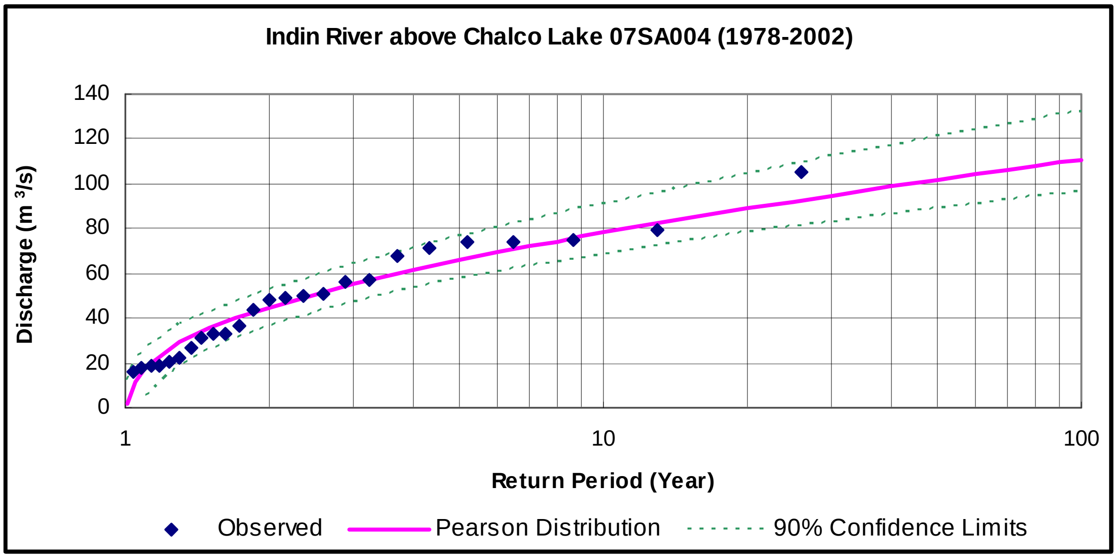

Emile River at outlet of Basler Lake 07TB001 (1978-1997)
Discharge (m³/s)
60
40
20
0
1
31
61
91
121
151
181
211
241
271
301
331
361
Julian Day
Min (1995)
Mean
Max (1984)
1996

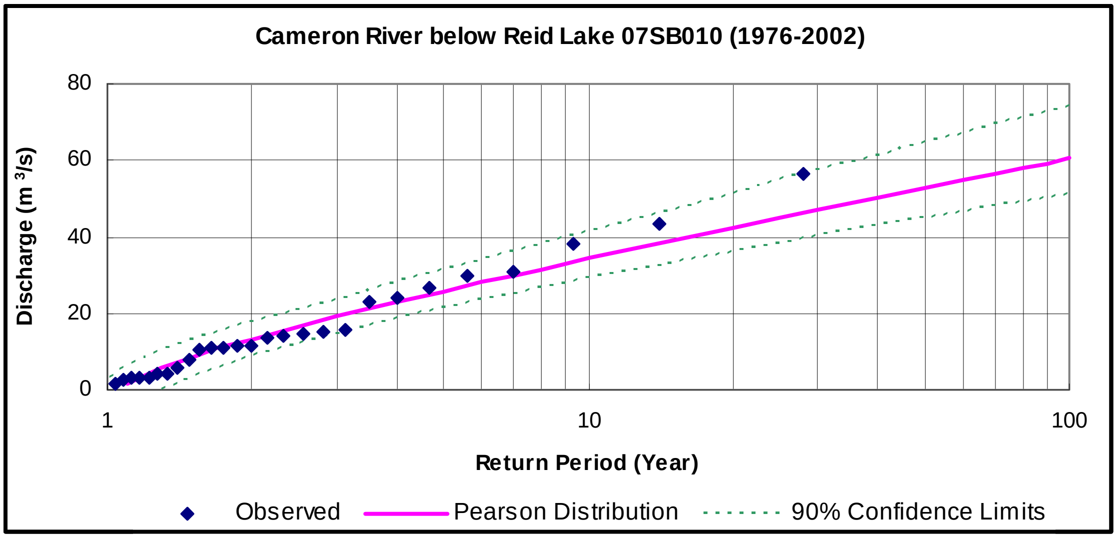

Acasta River above Little Crapeau Lake 10JA004 (1980-1994)
Discharge (m³/s)
200
150
100
50
0
1
31
61
91
121
151
181
211
241
271
301
331
361
Julian Day
Min (1981)
Mean
Max (1984)

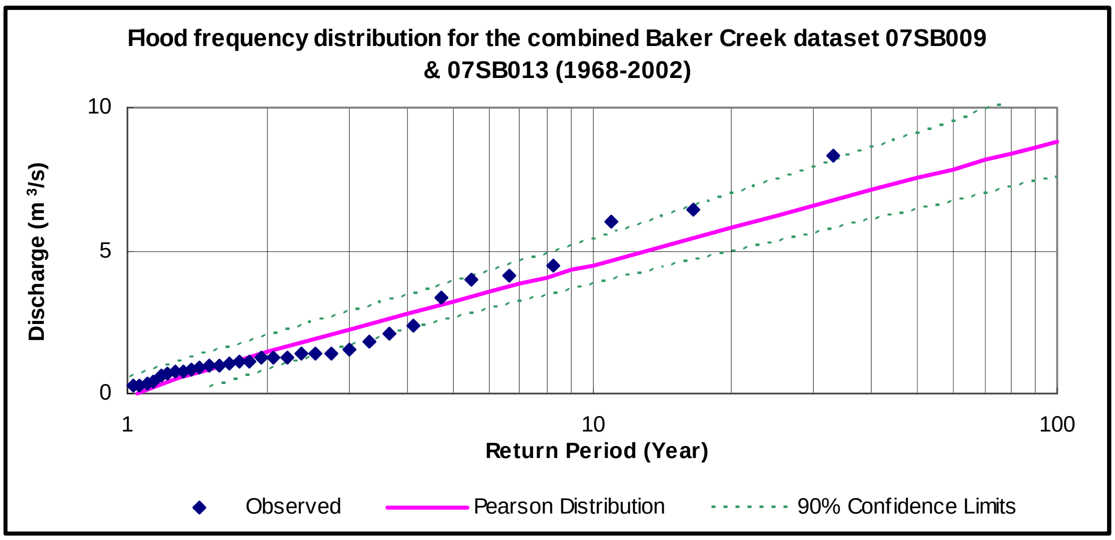
Appendix B. Flood Frequency Graphs

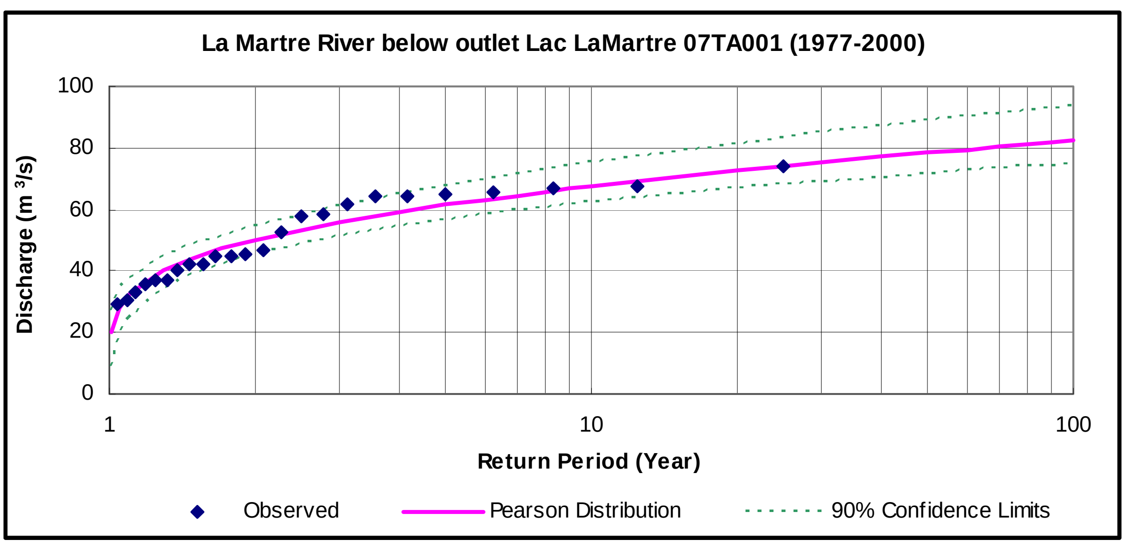


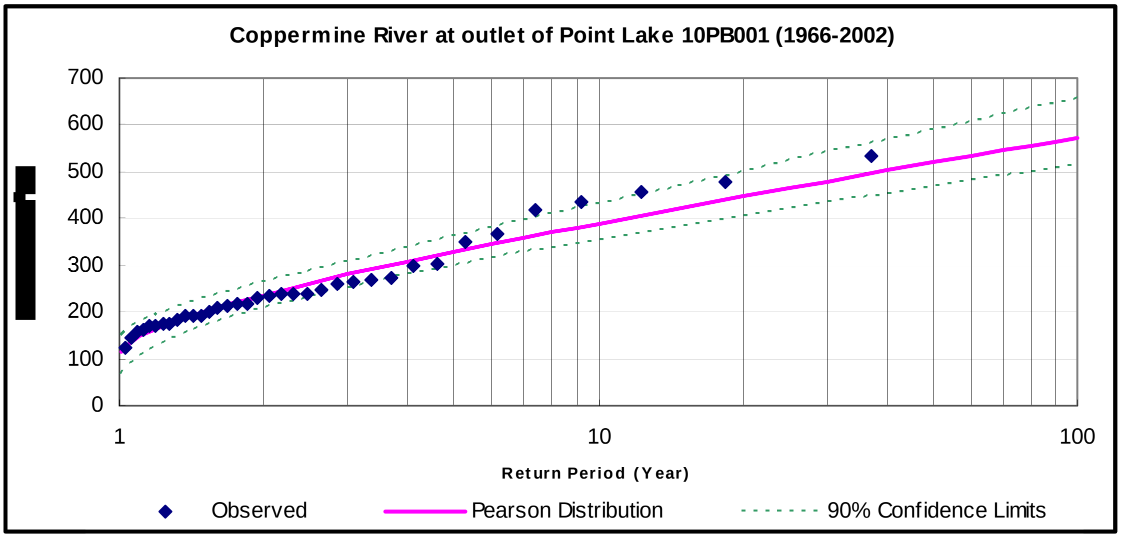





Cameron River below Reid Lake 07SB010 (1976-2002)
Discharge (m ³/s)
80
60
40
20
0
1
10
100
Return Period (Year)
Observed
Pearson Distribution
90% Confidence Limits


Flood frequency distribution for the combined Baker Creek dataset 07SB009 & 07SB013 (1968-2002)
Discharge (m ³/s)
10
5
0
1
10
100
Return Period (Year)
Observed
Pearson Distribution
90% Confidence Limits


La Martre River below outlet Lac LaMartre 07TA001 (1977-2000)
Discharge (m ³/s)
100
80
60
40
20
0
1
10
100
Return Period (Year)
Observed
Pearson Distribution
90% Confidence Limits


Coppermine River at outlet of Point Lake 10PB001 (1966-2002)
700
600
500
400
300
200
100
0
1
10
100
Return Period (Year)
Observed
Pearson Distribution
90% Confidence Limits