BC Environment

Stawamus River Hydrology Data Summary and Analysis

Water Management
Hydrology Branch

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Table of Contents

Stawamus River Hydrology

1. Introduction

This report, which is an appendix to the Stawamus-Mashiter Integrated Watershed Management Plan report, provides a summary and analysis of streamflow and climate data for the Stawamus River watershed. Included is a summary of water utilization by the District of Squamish (DoS) which diverts water from Stawamus River for its community water supply. This information is used to estimate hydrologic characteristics for the Stawamus River watershed, and can be used as input to water supply assessment, resource use impact assessment, and for the development of guidelines and prescriptions for various resource use proposals for the watershed.

Figure 1 shows the location of the watershed and hydrometeorological stations in the vicinity, while Figure 2 shows the watershed boundary.

2. Precipitation

This section describes historical trends in annual and seasonal precipitation, as well as information on rainfall intensity and snowpack. Climate stations and snow courses in the vicinity are shown in Figure 1 with the periods of record shown in Figure 3.

2.1 Annual Precipitation

The long term trends in precipitation are best indicated by data at Squamish, Squamish FMC , and Squamish STP which are at elevation 2 to 6 m. Combining the data at these sites provides a 1960-92 period (Table 1).

Highest annual amounts occurred in 1968 and 1990 with 1970 and 1978 being the driest years since 1960. The extremes are 25 - 30 % from the mean annual amount.

Based on water year (October - September) data for the 1968-92 period (to allow better comparison with streamflow data in Section 3), 1976 and 1991 are the 2 wettest years while very low annual precipitation occurred in 1970 and 1979 (Figure 4). As occurred in 1976 and 1977, it is possible to have precipitation amounts vary from one extreme to the other in consecutive years.

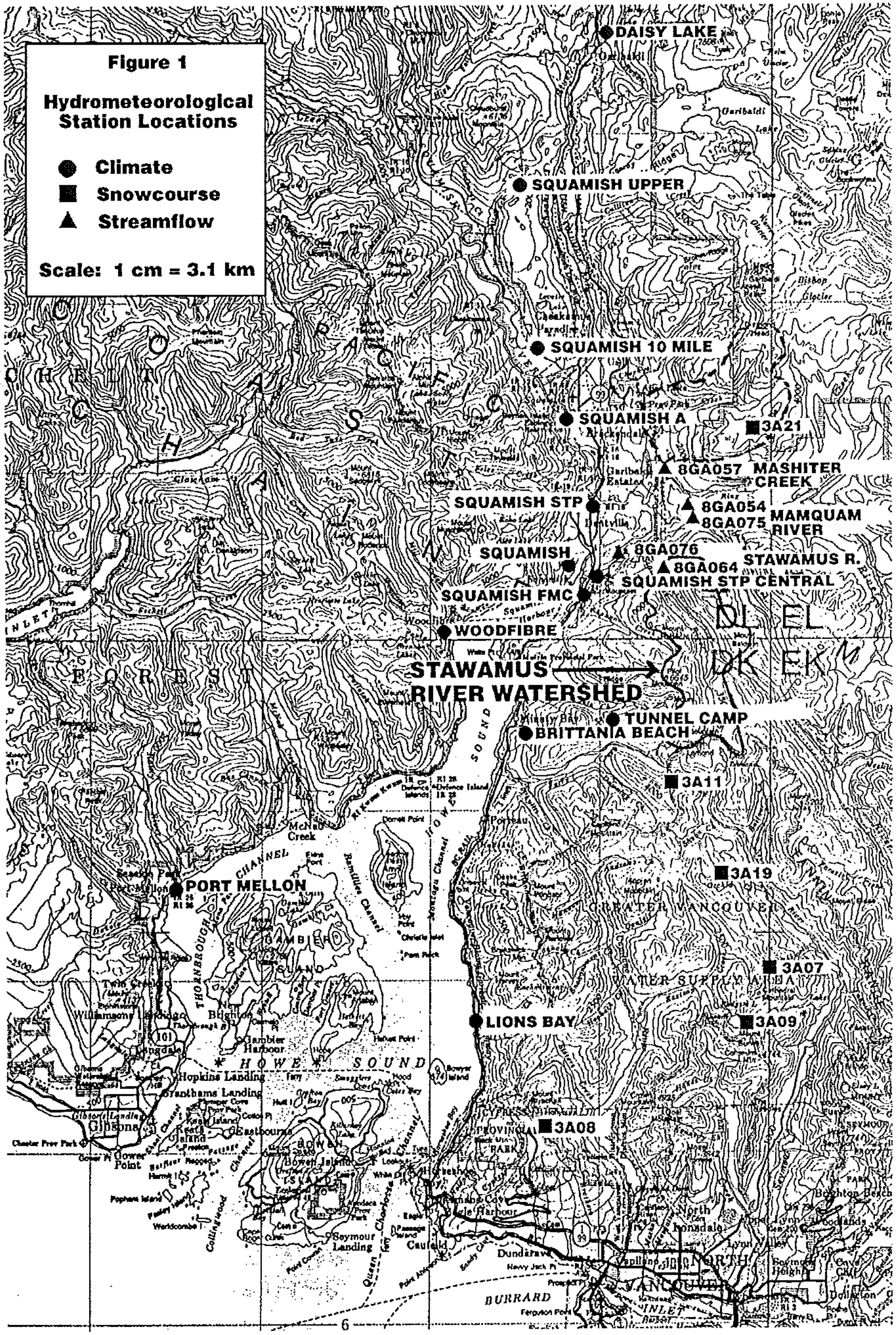


Figure 1
Hydrometeorological Station Locations
Climate
Snowcourse
Streamflow
Scale: 1 cm = 3.1 km
DAISY LAKE
SQUAMISH UPPER
SQUAMISH 10 MILE
SQUAMISH A
3A21
8GA057 MASHITER CREEK
SQUAMISH STP
8GA054
8GA075
MAMQUAM RIVER
SQUAMISH
8GA076
8GA064
STAWAMUS R.
SQUAMISH STP CENTRAL
SQUAMISH FMC
WOODFIBRE
STAWAMUS RIVER WATERSHED
TUNNEL CAMP
BRITTANIA BEACH
3A11
PORT MELLON
3A19
3A07
3A09
LIONS BAY
HOWE SOUND
3A08
BURRARD INLET

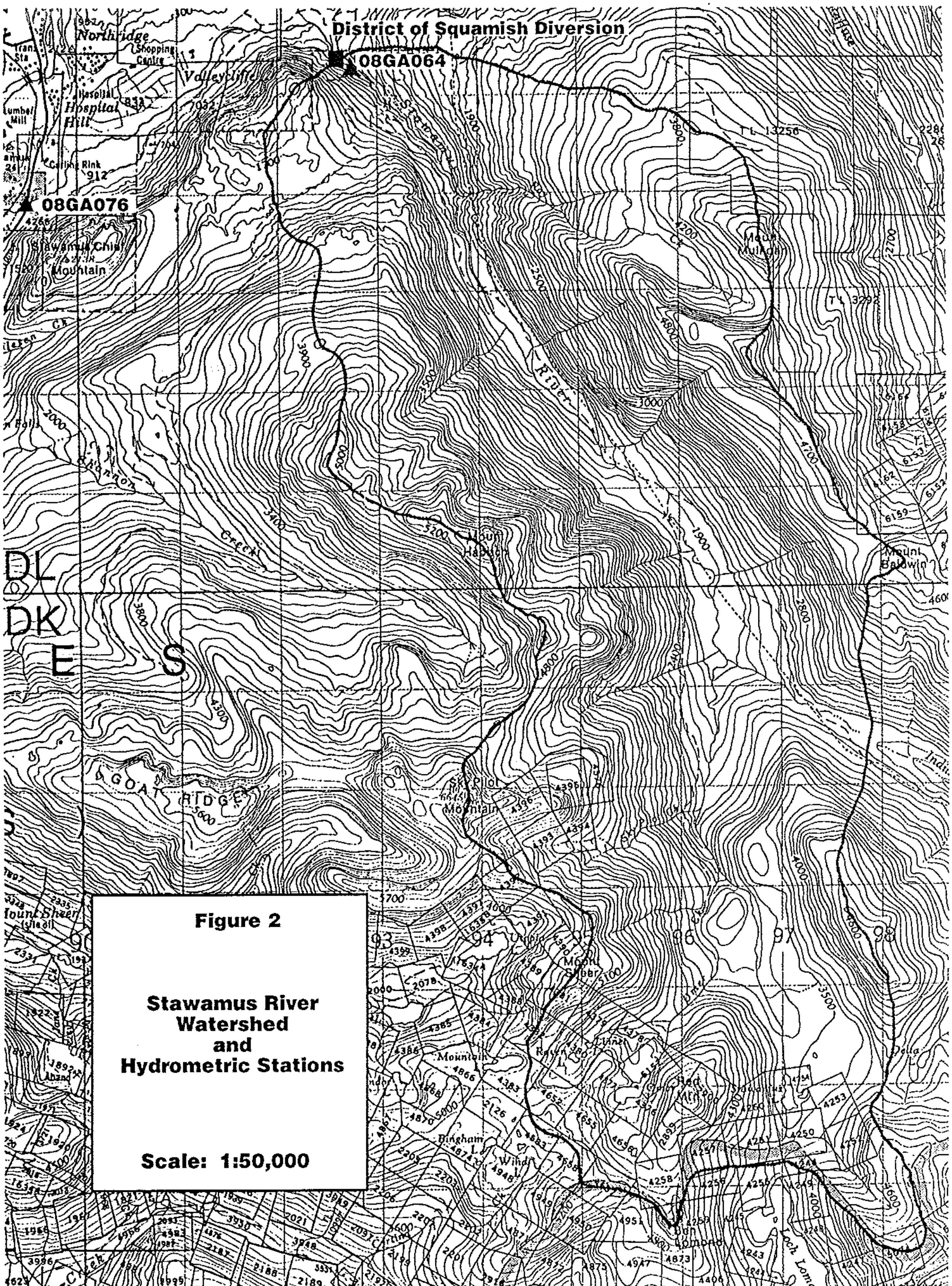


Figure 2

Stawamus River Watershed and Hydrometric Stations

Scale: 1:50,000

Fig. 3 Hydrometeorological Stations
Period of Record

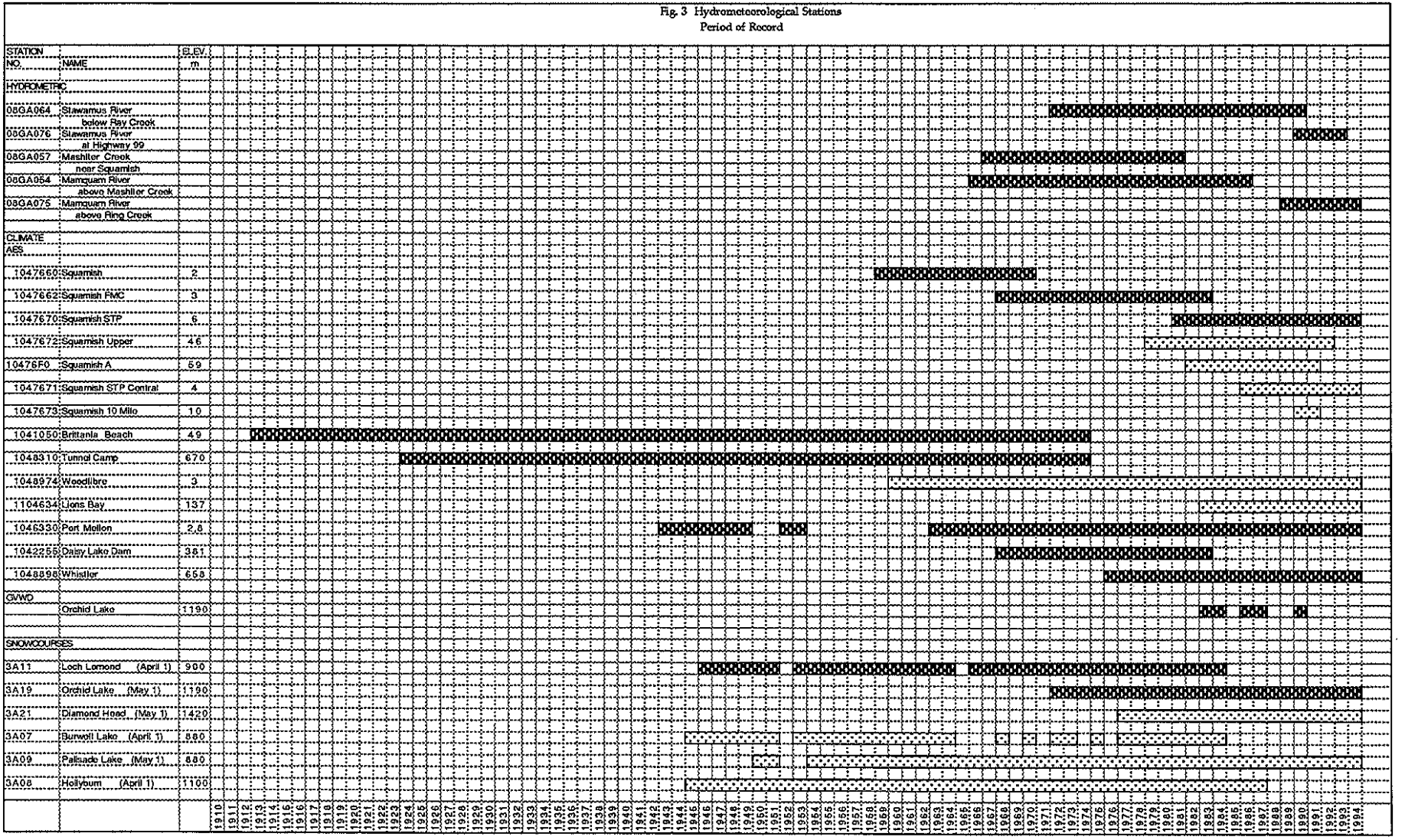


Table 1
Squamish Monthly Precipitation [mm] 1960-92

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1960	203.2	196.3	182.6	240.8	177.8	40.4	0.5	97.3	97.8	312.7	261.1	233.2	2043.7
1961	505.2	447.3	222.5	106.2	96.0	47.5	17.3	115.6	110.7	298.2	258.6	316.5	2541.5
1962	261.6	78.7	111.8	222.5	45.5	88.1	31.0	147.1	123.7	278.1	422.9	457.5	2268.5
1963	53.8	306.6	160.5	116.6	69.9	34.3	124.7	21.3	60.7	413.3	430.3	405.6	2197.6
1964	406.7	160.0	220.0	137.4	128.0	98.3	123.2	106.2	186.2	161.0	238.3	243.6	2208.8
1965	243.6	320.0	53.8	90.7	94.5	24.6	17.0	71.4	21.1	455.4	288.3	397.3	2077.7
1966	407.9	134.9	247.1	64.0	74.9	113.5	39.1	44.7	93.0	319.5	345.2	578.4	2462.3
1967	465.8	323.6	198.4	63.0	48.8	19.8	37.8	14.2	135.9	544.1	164.8	337.8	2354.1
1968	474.2	208.8	292.4	160.3	63.5	138.9	72.4	56.1	139.7	439.4	321.3	373.1	2740.2
1969	236.0	169.9	207.5	208.5	72.9	26.9	66.0	71.9	307.1	187.7	235.0	261.6	2051.1
1970	186.2	85.1	113.3	232.2	61.2	38.1	35.1	22.1	143.5	174.0	249.9	325.6	1666.2
1971	391.4	265.4	275.6	95.0	48.5	98.0	27.2	85.6	138.2	281.4	320.0	145.5	2172.0
1972	153.9	313.7	345.9	197.4	39.9	68.1	126.0	42.2	171.7	41.9	253.7	467.4	2221.7
1973	412.0	178.3	106.7	50.0	122.9	107.7	37.8	34.0	56.4	310.6	303.5	426.2	2146.3
1974	423.4	354.8	368.0	141.2	199.9	68.6	101.9	8.9	66.3	98.0	356.6	376.2	2563.9
1975	241.6	175.3	182.1	63.2	93.5	57.9	33.3	166.1	4.8	547.9	489.5	388.4	2443.5
1976	284.2	305.3	248.4	99.3	149.9	77.7	77.5	110.7	133.9	162.1	128.5	288.0	2065.5
1977	129.7	213.1	191.5	110.9	139.2	54.9	70.9	59.0	149.4	257.7	314.3	221.1	1911.7
1978	155.5	134.8	182.7	85.0	111.0	66.8	24.0	166.2	205.6	91.8	161.8	213.5	1598.7
1979	77.9	332.1	110.7	123.7	93.5	75.7	71.8	52.5	203.2	204.2	108.6	484.3	1938.2
1980	146.7	307.5	172.7	181.4	75.3	85.4	59.4	60.5	174.3	98.0	505.1	319.6	2185.9
1981	140.5	221.7	173.5	262.3	144.2	144.3	33.3	55.8	181.0	403.9	287.7	171.3	2219.5
1982	233.0	400.5	99.0	153.2	38.2	37.8	64.6	59.2	91.4	473.3	192.1	291.4	2133.7
1983	378.7	464.0	289.5	59.4	51.3	151.5	132.2	39.6	85.0	232.4	552.0	154.6	2590.2
1984	363.6	300.4	180.2	188.6	186.2	120.0	17.4	50.4	145.6	390.8	445.4	254.9	2643.5
1985	425.0	149.4	117.6	200.2	72.2	48.2	0.0	42.2	75.2	482.6	106.2	96.2	1815.0
1986	406.0	257.0	334.8	105.2	225.4	64.8	67.2	4.0	73.2	107.4	400.3	330.4	2375.7
1987	368.4	131.0	267.0	189.0	204.8	67.2	86.8	1.2	48.8	58.4	322.0	275.0	2019.6
1988	192.0	239.1	289.5	189.0	182.0	75.0	51.2	29.2	114.8	226.0	388.6	212.0	2188.4
1989	347.4	74.2	186.8	112.8	75.8	80.6	41.0	42.0	13.6	308.2	446.7	181.4	1910.5
1990	375.7	331.2	137.0	75.8	65.8	117.2	44.6	48.4	32.2	362.8	726.7	346.5	2663.9
1991	248.4	331.0	117.4	191.4	84.4	71.8	64.2	277.4	4.4	28.2	393.4	313.2	2125.2
1992	566.8	170.8	49.0	241.0	31.8	74.2	55.8	64.8	98.2	308.8	231.2	144.8	2037.2
Mean Monthly	300.2	244.9	195.0	144.2	102.1	75.3	56.1	68.7	111.7	274.5	322.7	304.0	2199.4
Std Deviation	132.7	103.2	82.1	62.2	54.6	34.7	35.6	56.7	66.8	147.1	135.6	111.8	278.2
Max [mm]	566.8	464.0	368.0	262.3	225.4	151.5	132.2	277.4	307.1	547.9	726.7	578.4	2740.2
Min [mm]	53.8	74.2	49.0	50.0	31.8	19.8	0.0	1.2	4.4	28.2	106.2	96.2	1598.7
For 1967 - 1992 Common Period													
Mean Monthly	300.9	247.6	201.4	145.3	103.2	78.4	57.7	64.0	115.1	262.4	323.3	284.6	2183.9
Std Deviation	130.2	98.2	85.4	62.3	58.0	34.6	31.1	59.6	70.9	157.5	148.3	102.7	299.3
Max [mm]	566.8	464.0	368.0	262.3	225.4	151.5	132.2	277.4	307.1	547.9	726.7	484.3	2740.2
Min [mm]	77.9	74.2	49.0	50.0	31.8	19.8	0.0	1.2	4.4	28.2	106.2	96.2	1598.7

"Notes: Squamish(1960 - 1969), Squamish FMC(1970 - 1983), Squamish STP (1984-1992)"

Figure 4
Squamish Annual Precipitation
1968-92
Percent Departure from Mean.

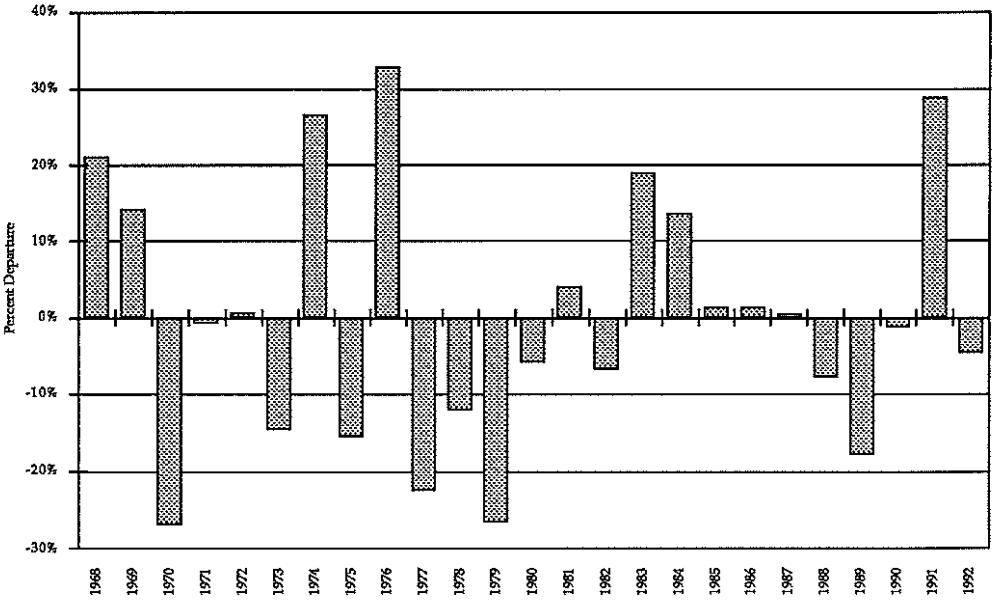
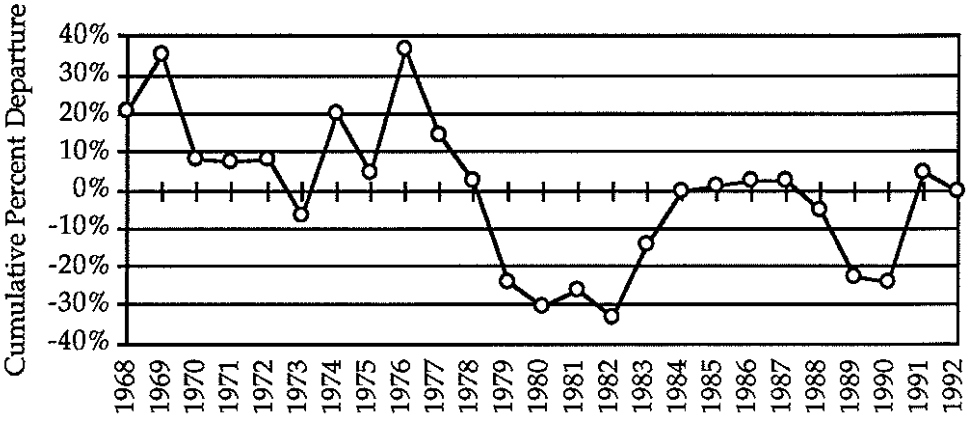


Figure 5 shows the series of dry years from 1977 to 1980 and the five years of above normal annual precipitation from 1983 to 1987.

Figure 5
Squamish Annual Precipitation
1968-92
Cumulative Percent Departure
from Mean.



Using data from a number of climate stations and snow courses in the area an attempt was made to define the spatial variation of annual precipitation for the Stawamus River watershed. Elevation should account for much of the variation in annual precipitation but reliable high elevation data are lacking (Figure 6). The Orchid Lake data point is based on only 4 years of data adjusted to the 1967-92 period.

Danard[1] annual precipitation estimates give a basin average of 2600 mm.

Based on the mean annual runoff (Section 3.1) of 2900 mm for the watershed and the equation P - ET = RO, basin average (i.e., at the median elevation of 1090 m) precipitation would have to be more than 2900 mm. Annual potential evapotranspiration is estimated at 460 mm which would result in an estimate of 3360 mm for mean annual precipitation.

Using all this information the curve shown is judged to be the best precipitation - elevation relationship for the watershed. Annual precipitation ranges from 2200 mm at the mouth, to 2350 mm at the intake to about 3400 mm at the highest elevation (2000 m). Basin average precipitation is roughly 3150 mm.

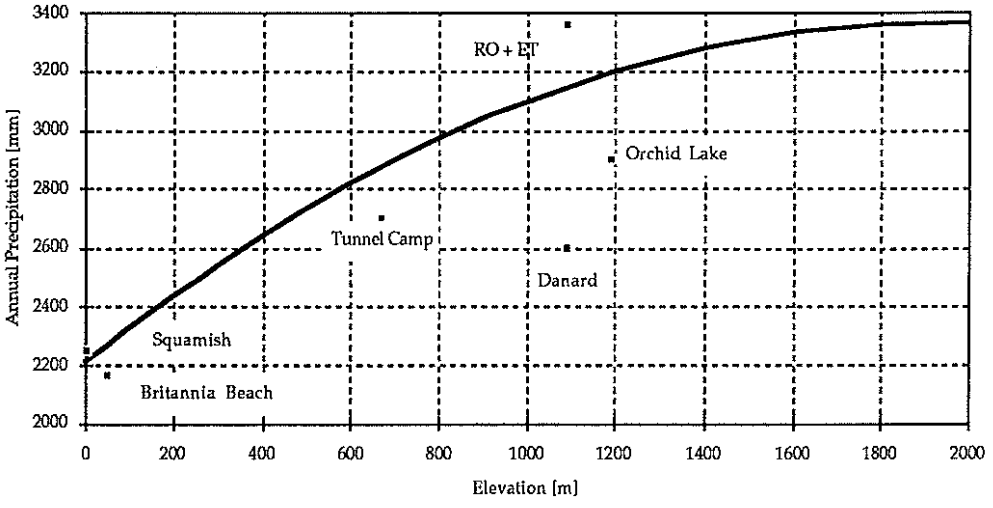


Figure 6
Stawamus River Watershed Precipitation - Elevation Relationship.

Two nearby snow courses 3A11 Loch Lomond (elevation 900 m) and 3A19 Orchid Lake (elevation 1190 m) indicate that mean snowpack accumulations could range from 1200 mm snow water equivalent at 900 m to 2200 mm at 1190 m with snow depths in the order of 300 to 400 cm. These data only provide an indication of what snowpack conditions could occur in the Stawamus River watershed as they are point data and located outside the watershed.

[1] Danard, M., 1980. Mean Annual Precipitation (1941-70) over B.C., Report No. 24, Water Investigations Branch, Water Resources Service, Province of British Columbia.

2.2 Monthly Precipitation

The monthly pattern of precipitation is indicated by Squamish data (Table 2 and Figure 7). The wettest months are usually November through January with 62 % of annual precipitation occurring in the November - March winter season. July and August are the driest months. Precipitation for a particular month can vary considerably (Figure 8), especially in August when the maximum recorded is close to the normal amounts for December and February and the minimum is almost zero.

Table 2
Squamish Monthly Precipitation 1968-92
Mean, Max. and Min. (mm)

	Rainfall	Snowfall(cm)	Total Precip	Max	Min
Jan	294.2	66.8	300.9	566.8	77.9
Feb	244.4	32.3	247.6	464.0	74.2
Mar	197.0	43.8	201.4	368.0	49.0
Apr	145.3	0	145.3	262.3	50.0
May	103.2	0	103.2	225.4	31.8
Jun	78.4	0	78.4	151.5	19.8
July	57.7	0	57.7	132.2	0.0
Aug	64.0	0	64.0	277.4	1.2
Sept	115.1	0	115.1	307.1	4.4
Oct	262.4	0	262.4	547.9	28.2
Nov	322.2	11.3	323.3	726.7	106.2
Dec	282.6	20.4	284.6	484.3	96.2
Total	2166.5	174.6	2183.9		

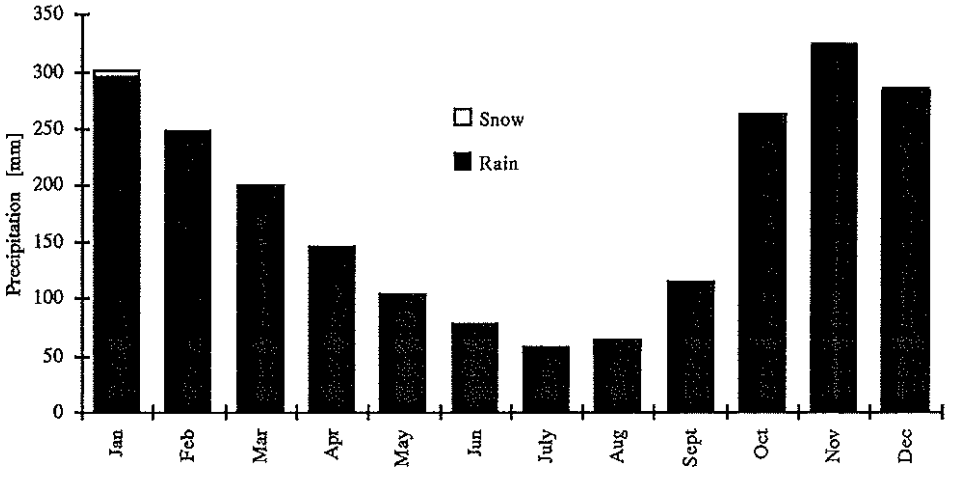
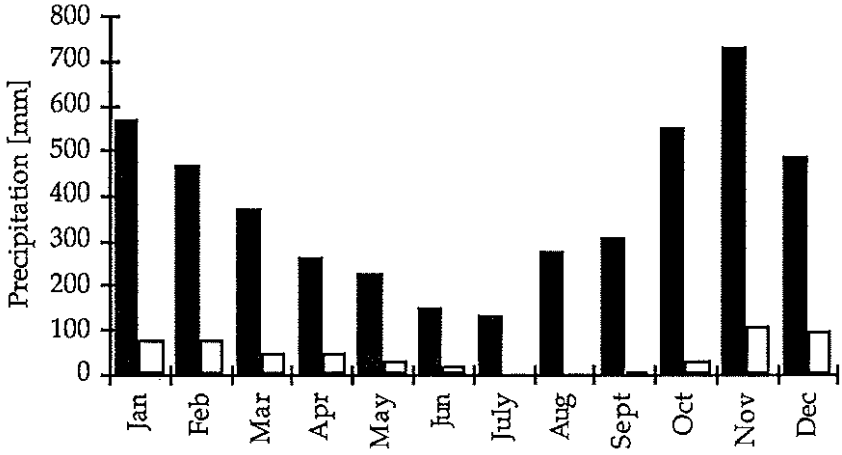


Figure 7
Squamish Monthly Mean Precipitation 1968-92.

At Tunnel Camp (elevation 690 m) the monthly distribution is similar to Squamish, but snowfall accounts for 19% of the annual precipitation as compared to 8% at Squamish.

Figure 8
Squamish Monthly Precipitation
1968-92
Max. and Min.



2.3 Short-Duration Rainfall

There are no recording precipitation gauges in the Stawamus River watershed. However regionalized intensity-duration-frequency (IDF) estimates shown on isohyetal maps for BC have been prepared as part of another study[2]. These maps give the estimates in Table 3 for the Stawamus River watershed. Estimates were made for only the 50 and 100 year return periods and five selected durations (10 min., 30 min., 2 hr., 6 hr. and 24 hr.). To estimate amounts for the 10 and 25 year return periods and the missing standard durations, data for the three closest AES stations with IDF data (Port Mellon, Daisy Lake Dam and Whistler) were used to extend the data available from the maps. Although rainfall intensities can increase with elevation, these IDF estimates should be considered valid for any location in the watershed.

[2] Davies, J., Reksten, D., 1994. Guide for Drainage Design in Small Watersheds, (in preparation), Hydrology Branch, BC Environment.

Table 3
Stawamus River Watershed
Rainfall Intensity-Duration-Frequency Estimates

	Amount (mm)				Intensity (mm/hr)			
	Return Period (years)				Return Period (years)			
	10	25	50	100	10	25	50	100
Duration								
5 min.	5	6	6	7	64	71	77	82
10 min.	7	8	8	9	41	46	49	52
15 min.	8	9	10	11	34	37	40	43
30 min.	11	12	13	14	23	25	26	28
1 hr.	21	23	25	26	21	23	25	26
2 hr.	27	32	36	40	14	16	18	20
6 hr.	56	63	72	77	9	10	12	13
12 hr.	95	105	115	122	8	9	10	10
24 hr.	144	163	178	193	6	7	7	8

3. Streamflow

This section describes some hydrologic characteristics of the Stawamus River watershed. Hydrometric data have been collected by Water Survey of Canada at 08GA064 Stawamus River below Ray Creek from May 1972 to December 1989 and at 08GA076 Stawamus River at Highway 99 from January 1991 to present. The latter station is below the intake used by the District of Squamish for domestic water supply, thus the flow data are "regulated". Data are missing for a number of months including all of 1980 and most of 1981. Estimates were made using correlations with data for 08GA054 Mamquam River above Mashiter Creek. 1981 data are also missing for 08GA054 Mamquam River and these monthly flows were estimated from a correlation with Clowhom Lake inflow allowing Stawamus River 1981 data to be estimated. The record for 08GA064 Stawamus River was extended to 1992 by adding the DoS metered monthly diversion amounts to data for 08GA076 located downstream near the mouth and then adjusting for the drainage area difference.

3.1 Annual Runoff

Using the above estimating methods it was possible to estimate missing data and tabulate monthly flows for the period 1967 to 1992 (Table 4). Figure 9 shows the annual variation (on a water year basis to better compare with precipitation amounts, Section 2).

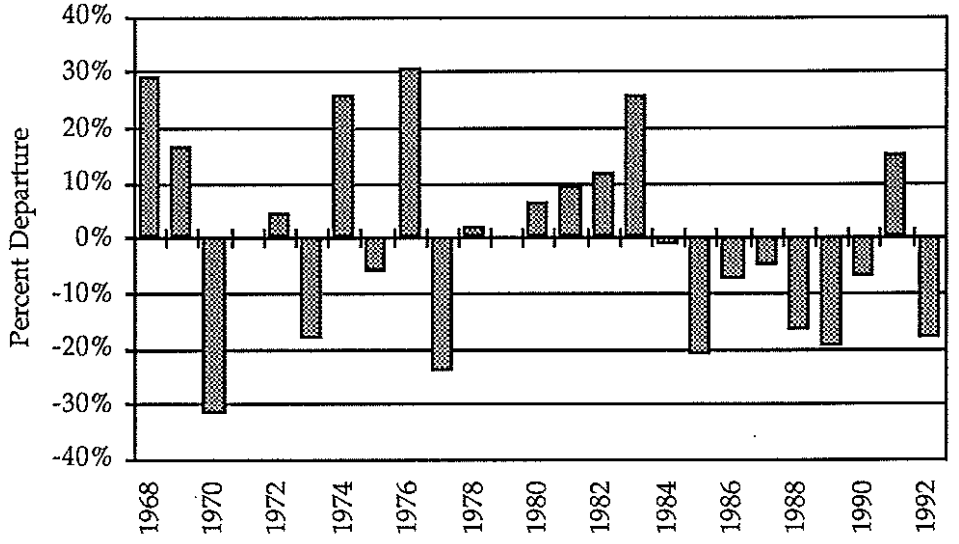


Figure 9
Stawamus River
Annual Runoff
Percent Departure from Mean.

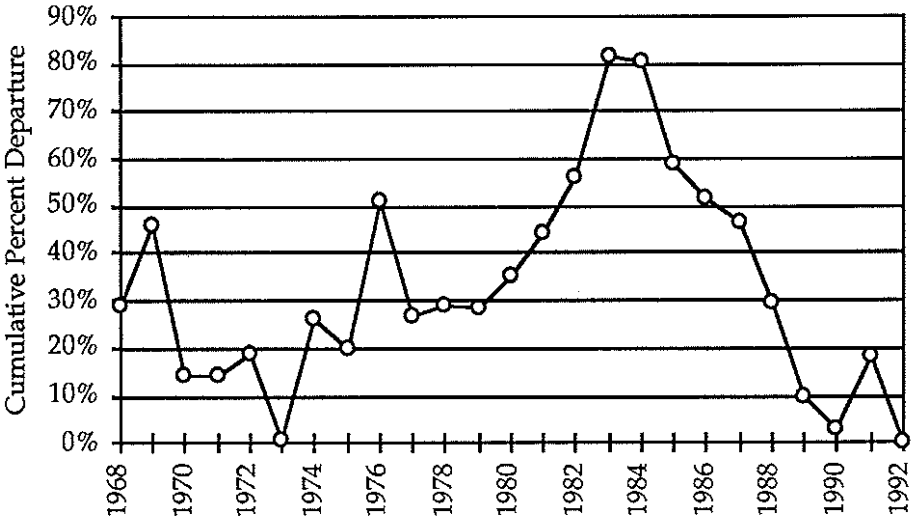
Mean annual runoff at the DoS intake is 3.69 m^3/s or 2900 mm. Annual runoff can range from 1760 to 3690 mm. Figure 10 indicates the above average runoff conditions from 1979 to 1983 and the persistently below average runoff from 1984 to 1990. The most recent "high" runoff year is 1983. 1985 was a very low runoff year but still significantly greater than 1970 which experienced the lowest runoff since 1967.

Table 4
08GA064 Stawamus River below Ray Creek (1967-1992) Monthly Flows (m3/s)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Mean	mm
1967	**2.99**	**2.37**	**2.23**	**2.56**	**5.86**	**9.83**	**4.98**	**2.89**	**1.50**	**8.89**	**4.06**	**2.99**	4.28	3357
1968	**7.00**	**4.13**	**4.78**	**2.94**	**5.87**	**7.65**	**5.16**	**1.91**	**1.62**	**6.56**	**5.10**	**3.07**	4.66	3655
1969	**1.64**	**1.48**	**1.93**	**4.47**	**8.72**	**9.16**	**3.98**	**1.60**	**3.87**	**3.58**	**3.05**	**2.98**	3.88	3043
1970	**1.64**	**1.80**	**1.60**	**3.07**	**4.04**	**6.51**	**1.62**	**0.15**	**0.25**	**1.48**	**2.85**	**1.91**	2.24	1757
1971	**2.58**	**3.80**	**2.01**	**3.37**	**7.44**	**7.83**	**6.82**	**2.49**	**1.82**	**2.89**	**3.01**	**1.17**	3.77	2958
1972	**1.15**	**2.12**	**7.04**	**4.05**	8.30	7.41	5.94	0.95	2.15	0.58	3.68	4.79	4.02	3156
1973	3.19	2.04	1.45	1.88	7.36	6.10	3.15	0.98	1.05	3.82	3.29	4.44	3.24	2544
1974	3.89	1.18	4.11	3.65	6.22	10.20	8.98	3.92	1.66	1.15	4.32	3.71	4.44	3483
1975	0.97	0.61	2.08	2.14	7.82	8.60	5.26	3.54	1.16	7.48	9.00	4.79	4.48	3515
1976	1.43	1.18	1.23	2.75	8.35	7.40	7.80	4.14	2.26	2.25	2.42	3.32	3.72	2924
1977	2.00	3.35	1.57	4.39	4.72	4.74	1.71	1.05	2.24	5.50	4.37	3.52	3.26	2556
1978	1.66	2.62	3.91	2.84	5.28	5.99	2.15	2.54	4.78	**1.87**	**1.87**	**0.68**	3.01	2363
1979	**0.47**	**2.13**	5.68	4.51	10.70	5.91	3.09	0.84	6.37	6.36	1.33	8.68	4.70	3686
1980	**1.59**	**4.72**	**1.94**	**4.57**	**5.39**	**5.67**	**3.02**	**1.21**	**2.69**	1.20	9.77	8.67	4.18	3286
1981	**3.80**	**3.70**	**1.81**	**4.49**	5.21	4.74	**2.32**	**0.65**	2.14	**9.33**	**5.29**	**3.73**	3.93	3088
1982	1.14	3.10	1.76	2.41	6.65	9.61	4.04	1.30	1.13	6.74	2.66	3.47	3.67	2880
1983	4.54	7.26	4.43	3.51	7.10	6.80	5.63	1.78	1.87	2.09	6.14	1.15	4.33	3401
1984	4.16	3.48	3.38	2.53	5.31	7.37	4.83	1.42	1.96	6.45	3.84	1.02	3.81	2994
1985	0.97	0.63	0.74	4.86	6.93	6.02	1.90	0.55	0.87	5.17	1.64	1.07	2.62	2058
1986	4.47	4.48	5.43	2.22	7.81	4.99	2.28	**0.76**	**0.61**	**1.26**	2.42	3.01	3.31	2598
1987	4.06	2.90	6.39	3.88	7.88	6.21	2.64	0.66	0.58	**0.53**	3.19	3.39	3.53	2772
1988	1.41	1.46	1.88	4.92	7.83	6.51	3.56	0.92	1.26	2.21	6.82	2.33	3.42	2685
1989	1.91	0.87	1.97	4.53	5.36	5.63	2.70	0.91	**0.26**	**5.29**	5.68	2.85	3.17	2491
1990	**1.30**	**0.80**	**1.56**	**5.24**	**4.80**	**6.92**	**3.35**	**2.02**	**1.36**	**3.84**	**10.51**	**3.03**	3.73	2927
1991	**2.12**	**8.38**	**1.86**	**4.64**	**4.64**	**4.14**	**2.22**	**5.13**	**1.15**	**0.17**	**4.18**	**3.22**	3.44	2704
1992	**6.87**	**3.99**	**2.81**	**6.06**	**3.31**	**2.97**	**1.37**	**0.56**	**0.82**	**4.15**	**3.22**	**1.09**	3.10	2430
MEAN	2.65	2.87	2.91	3.71	6.50	6.73	3.87	1.72	1.82	3.88	4.37	3.23	3.69	2897
Std Deviation	1.75	1.92	1.74	1.11	1.70	1.78	1.99	1.28	1.38	2.68	2.41	1.98	0.61	481
Max	7.00	8.38	7.04	6.06	10.70	10.20	8.98	5.13	6.37	9.33	10.51	8.68	4.70	3686
Min	0.47	0.61	0.74	1.88	3.31	2.97	1.37	0.15	0.25	0.17	1.33	0.68	2.24	1757

Bold = Estimated Monthly Flows
Note: 1991 & 1992 adjusted 08GA076 for District of Squamish water use.

Figure 10
Stawamus River
Annual Runoff
Cumulative Percent Departure
from Mean.



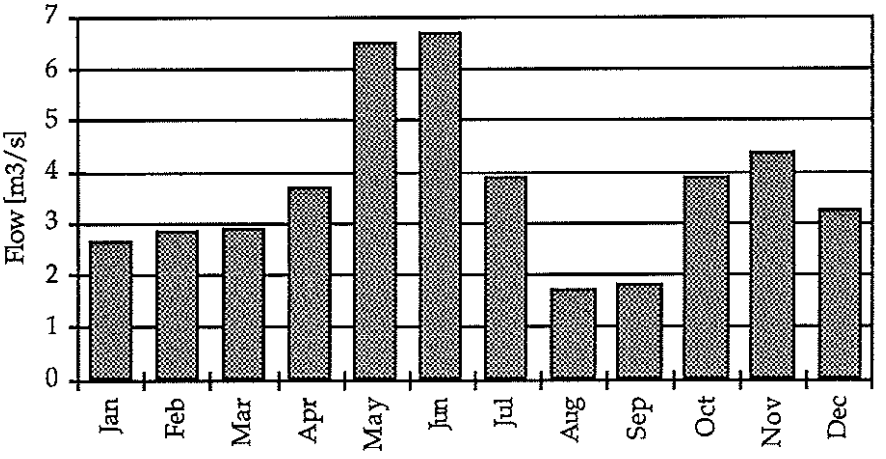
3.2 Monthly Runoff

Stawamus River mean monthly runoff data (Oct. 1967 - Sept. 1992) are shown in Table 5 and Figure 11.

Table 5
Stawamus River at Intake Monthly Flow 1968-92
Mean, Max. and Min.

Month	Mean Runoff [mm]	Discharge [m3/s] Mean	Max	Min
January	177	2.65	7.00	0.47
February	173	2.87	8.38	0.61
March	194	2.91	7.04	0.74
April	239	3.71	6.06	1.88
May	433	6.50	10.70	3.31
June	434	6.73	10.20	2.97
July	259	3.87	8.98	1.37
August	115	1.72	5.13	0.15
September	118	1.82	6.37	0.25
October	258	3.88	9.33	0.17
November	282	4.37	10.51	1.33
December	215	3.23	8.68	0.68
		Mean	Max	Min
Annual	2897	3.69	10.70	0.15

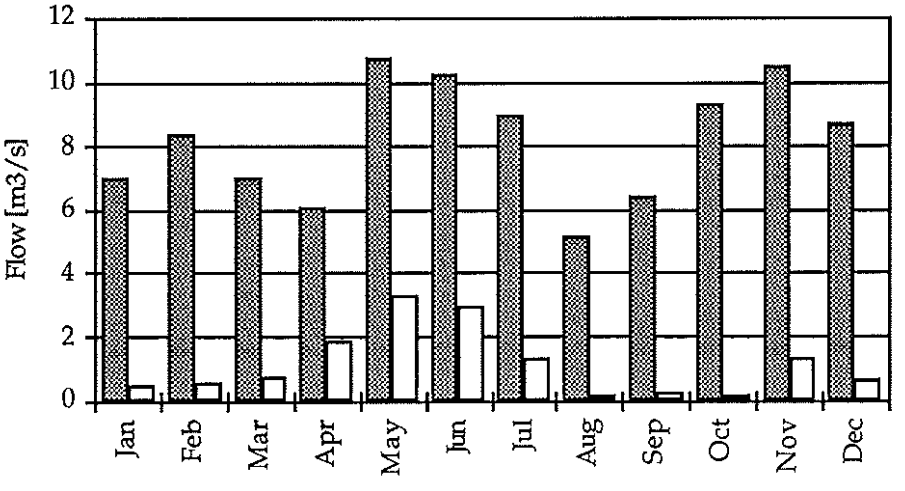
Figure 11
Stawamus River at Intake
Flow 1968-92
Mean Monthly.



April - September snowmelt runoff comprises 55% of the annual total volume. Highest monthly flows occur in May and June reflecting the significant snowmelt contribution to runoff. During the 26 years of record, 65% of the annual maximum monthly runoffs occurred in May and June, while 35% occurred in the October - February winter period. The lowest flows on average occur in August and September.

Extremes of monthly runoff cover a wide range (Figure 12). The highest monthly runoff occurred in May 1979 and the lowest in August 1970 (estimated flow). In recent years (since 1989) the lowest monthly flow occurred in October 1991 (almost as low as August 1970) with the highest runoff occurring in November 1990. The largest range in monthly runoff can be expected in October.

Figure 12
Stawamus River at Intake
Monthly Flow 1968-92
Max. and Min.



3.3 Peak Flows

Annual daily and instantaneous peak flows for 08GA064 (at the intake) and 08GA076 are given in Table 6.

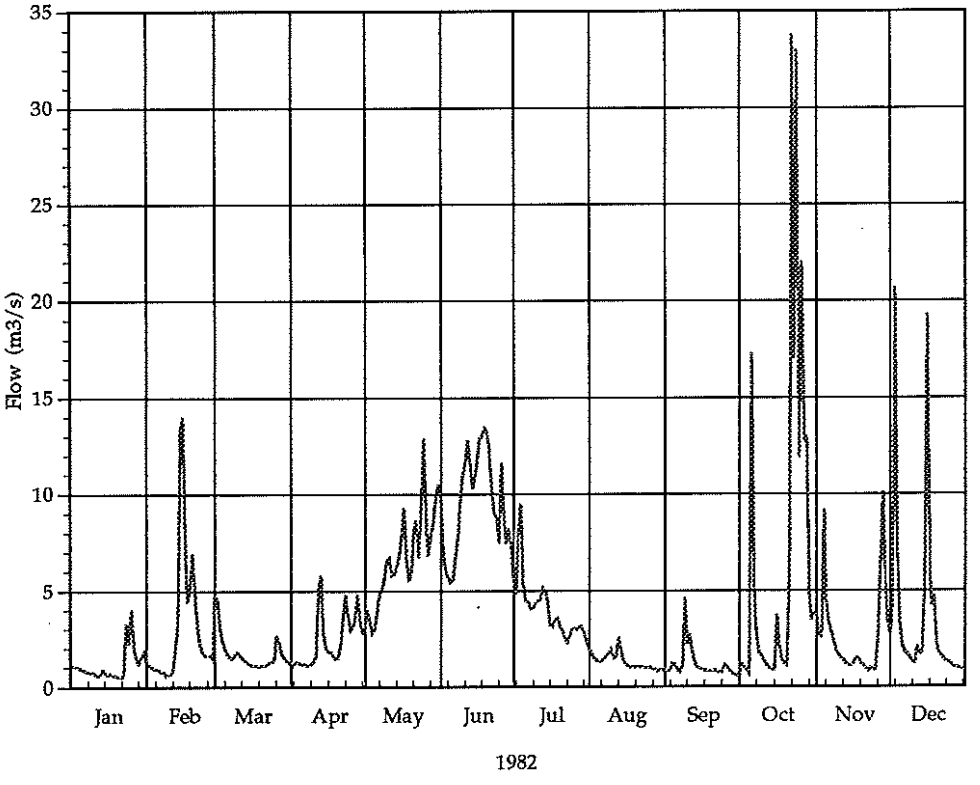
Table 6
08GA064 and 08GA076 Stawamus River
Annual Maximum Discharge

Year	Instantaneous Discharge m3/s	Date	Daily Discharge m3/s	Date
08GA064				
1972	41.9	19-Dec	31.1	12-Jul
1973	41.6	24-May	28.6	15-Jan
1974	39.1	24-Nov	29.2	24-Nov
1975	87.8	3-Nov	53.2	3-Nov
1976	30.9	17-Nov	15.1	8-Jul
1977	79.0	1-Nov	25.9	29-Oct
1978	49.8	7-Nov	22.3	7-Nov
1979	112	24-Oct	61.4	25-Oct
1980	113	26-Dec	64.4	26-Dec
1981	83.4	31-Oct	48.4	31-Oct
1982	53.4	22-Oct	33.8	22-Oct
1983	49.6	15-Nov	33.7	15-Nov
1984	57.9	8-Oct	41.2	8-Oct
1985	51.0	19-Oct	28.7	19-Oct
1986	63.9	24-Feb	40.9	24-Feb
1987	57.4	4-Mar	42.9	4-Mar
1988	67.8	5-Nov	44.0	2-Nov
1989	84.9	9-Nov	53.7	9-Nov
08GA076				
1993	79.2	10-Dec	36.4	10-Dec
Mean	65.4		38.7	

Annual peak flows occur most frequently in the winter period but have also been observed in May and July. The largest recorded peak flow occurred on December 26, 1980.

Daily discharge hydrographs for 1982 (an above average annual runoff year) and 1985 (a below average year) (Figure 13) show typical patterns of daily flow during the year. There can be a number of peak flow events during the year due to rainfall and rain on snow events with the peak flow during the April - June snowmelt season usually being much less in magnitude.

Figure 13
08GA064
Stawamus River
1982 and 1985 Daily Flow.



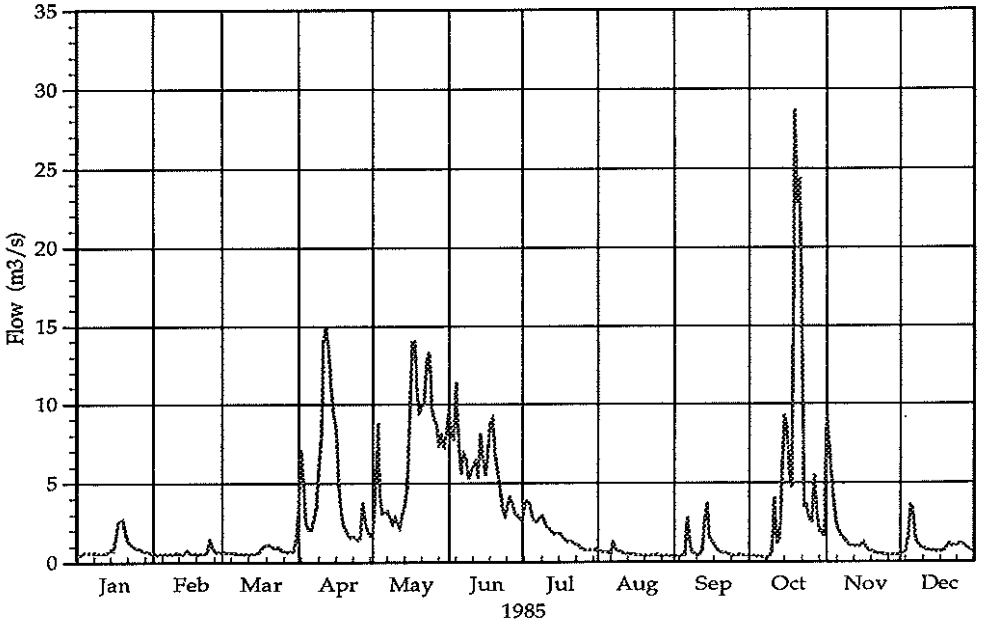


Table 7 contains the results of the frequency analysis of annual daily and instantaneous peak flows. These data indicate that the 50 and 100 year instantaneous peak flows are 2.0 and 2.2 times the mean peak flow. Instantaneous peak flows are on average 1.7 times the daily value.

Table 7
Stawamus River at Intake (1972-88)
Return Period Peak Flows

		RETRUN PERIOD (years)							
		Mean	2	5	10	25	50	100	200
DAILY	m3/s	38.7	37.6	49.6	56.6	64.4	69.7	74.6	79.2
	l/s/km2	904	879	1159	1322	1505	1629	1743	1850
	Ratio to mean		0.97	1.28	1.46	1.66	1.80	1.93	2.05
INSTANTANEOUS	m3/s	65.5	61.3	83.3	98.1	117	131	145	159.5
	l/s/km2	1530	1432	1946	2292	2734	3061	3388	3727
	Ratio to mean		0.94	1.27	1.50	1.79	2.00	2.21	2.44
I/D		1.69	1.63	1.68	1.73	1.82	1.88	1.94	2.01

A peak flow analysis for small (less than 30 km^2), steep watersheds in the Squamish area indicates the variation of 50 and 100 yr rp instantaneous peak flow with drainage area shown in Figure 14. To this has been added the frequency analysis results for 08GA064 Stawamus River. There is good agreement indicating that these relationships can be applied to subbasins in the watershed.

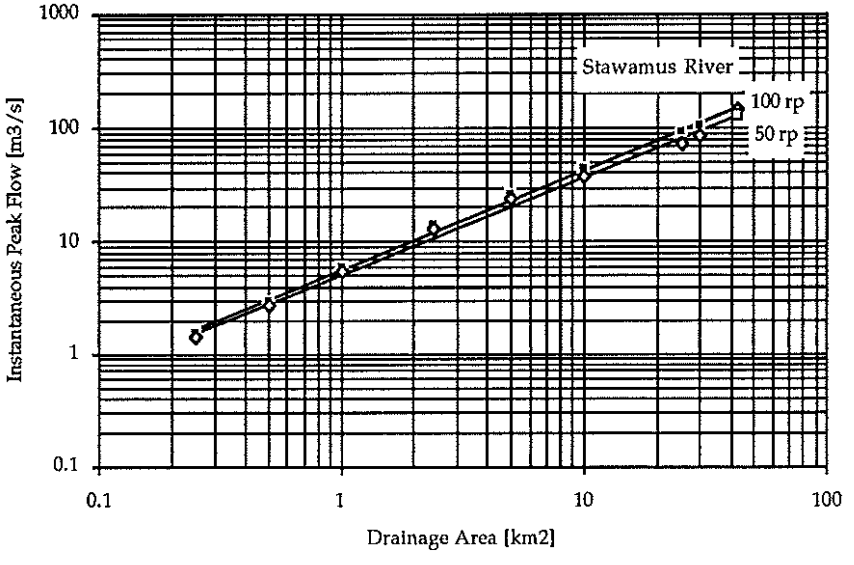


Figure 14
Stawamus River Watershed
50 & 100 year Return Period
Instantaneous Peak Flow
and Drainage Area.

3.4 Low Flows

Based on data from the hydrometric station 08GA064 Stawamus River below Ray Creek (1972-1990) and 08GA076 Stawamus River at Highway 99 (1990-present), low flow data for 1, 7, and 30 day durations are extracted for the years shown in Table 8 for the October - September water year and the June - September summer season. (Dates are the start of the period). For the water year the lowest flows usually occur from October to February with ice conditions being involved in about half the events. During the summer season, lowest flows occur in August and September.

Table 8
Stawamus River at Intake
Annual Minimum Flow (m^3/s)
Note: 1991 and 1992 amounts are adjusted for diversion

	1 - DAY		7 - DAY		30 - DAY	
OCTOBER - SEPTEMBER						
YEAR	DATE	FLOW	DATE	FLOW	DATE	FLOW
1972						
1973	17-Oct-72	0.39	16-Oct-72	0.43	16-Oct-72	0.55
1974	6-Jan-74	0.43	8-Jan-74	0.47	22-Feb-74	0.95
1975	12-Feb-75	0.17	13-Feb-75	0.21	8-Feb-75	0.58
1976	21-Dec-75	0.43	18-Dec-75	0.54	1-Mar-76	0.97
1977	23-Oct-76	0.41	20-Oct-76	0.56	7-Aug-77	0.97
1978	4-Jan-78	0.77	3-Jan-78	0.81	8-Aug-78	1.16
1979						
1980						
1981						
1982						
1983	1-Oct-82	0.57	27-Sep-83	0.77	16-Aug-83	1.75
1984	16-Oct-83	0.40	13-Oct-83	0.43	20-Aug-84	1.21
1985	1-Sep-85	0.35	31-Aug-85	0.38	21-Aug-85	0.50
1986						
1987	21-Oct-86	0.29	27-Sep-87	0.43	29-Aug-87	0.52
1988	22-Oct-87	0.25	5-Jan-88	0.38	29-Dec-87	0.48
1989	16-Feb-89	0.29	16-Feb-89	0.30	15-Feb-89	0.87
1990						
1991						
1992	19-Sep-92	0.28	18-Sep-92	0.30	8-Sep-92	0.38

Table 8 (con't)
Stawamus River at Intake
Annual Minimum Flow (m^3/s)
Note: 1991 and 1992 amounts are adjusted for diversion

	1 - DAY		7 - DAY		30 - DAY	
JUNE - SEPTEMBER						
YEAR	DATE	FLOW	DATE	FLOW	DATE	FLOW
1972	31-Aug-72	0.33	29-Aug-72	0.43	2-Sep-72	0.65
1973	17-Sep-73	0.50	15-Sep-73	0.57	4-Sep-73	0.67
1974	30-Sep-74	0.65	27-Sep-74	0.85	15-Sep-74	1.66
1975	27-Sep-75	0.85	27-Sep-75	0.87	15-Sep-75	1.16
1976	11-Sep-76	0.45	10-Sep-76	1.22	15-Sep-76	2.26
1977	22-Aug-77	0.75	15-Sep-77	0.79	7-Aug-77	0.97
1978	8-Aug-78	0.77	7-Aug-78	0.83	8-Aug-78	1.16
1979	12-Aug-79	0.67	11-Aug-79	0.68	6-Aug-79	0.84
1980						
1981	15-Sep-81	0.42	15-Sep-81	0.44	5-Sep-81	0.56
1982	30-Sep-82	0.59	21-Sep-82	0.79	24-Aug-82	1.12
1983	30-Sep-83	0.63	27-Sep-83	0.77	16-Aug-83	1.75
1984	30-Sep-84	0.70	1-Sep-84	0.83	20-Aug-84	1.21
1985	1-Sep-85	0.35	31-Aug-85	0.38	21-Aug-85	0.50
1986						
1987	30-Sep-87	0.36	27-Sep-87	0.43	29-Aug-87	0.52
1988	12-Sep-88	0.44	13-Sep-88	0.45	2-Sep-88	0.57
1989	31-Aug-89	0.43	10-Aug-89	0.62	16-Aug-89	0.89
1990						
1991	30-Sep-91	0.60	27-Sep-91	0.63	16-Sep-91	1.15
1992	19-Sep-92	0.28	18-Sep-92	0.30	8-Sep-92	0.38

Correlations with corresponding data for 08GA054 Mamquam River were tested to determine the possibility of extending the period of record, but no reasonable correlations were obtained. Years for which a number of days were missing were reviewed and for 1981 it was possible to make reliable estimates by comparing daily discharge hydrographs for Stawamus River and Mamquam River. Flows at 08GA076 are affected by diversion of licensed water use at the DoS intake. Records of daily water use amounts were obtained and the "regulated" flow data adjusted to obtain estimated natural flows.

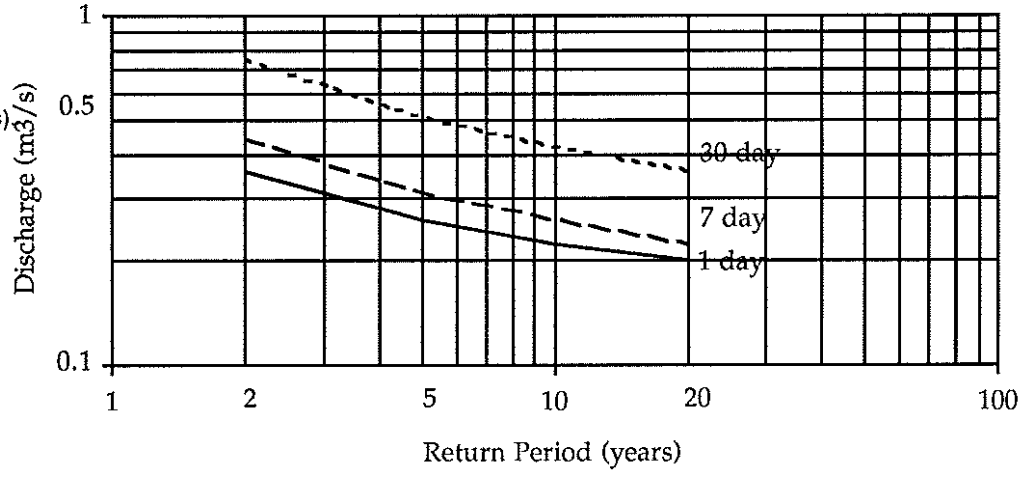
Return period low flow estimates are shown in Table 9 and Figure 15.

Table 9
Stawamus River at Intake
Return Period Low Flows (m^3/s)

	OCTOBER - SEPTEMBER			JUNE - SEPTEMBER		
	1-Day	7-Day	30-Day	1-Day	7-Day	30-Day
Return Period						
Mean	0.39	0.47	0.84	0.54	0.66	1.00
2 yrs.	0.36	0.44	0.75	0.53	0.64	0.89
5 yrs.	0.26	0.31	0.51	0.40	0.46	0.58
10 yrs.	0.22	0.26	0.42	0.33	0.38	0.47
20 yrs.	0.20	0.22	0.36	0.28	0.32	0.39

The estimates in Table 9 are considered the best to use for assessing water availability for domestic water use and fisheries requirements.

Figure 15
Stawamus River at Intake
October - September
Return Period Low Flows (m^3/s)



4. Watershed Hydrology

Sections 2 and 3 present information related to precipitation and flow measured at specific locations near and in the Stawamus River watershed. This section summarizes this information to describe watershed hydrologic characteristics.

The watershed area above the intake (and station 08GA064) is 42.8 km^2 and ranges in elevation from 130 m to 2020 m (Figure 16). Thirty-eight percent of the area lies above 1200 m, the elevation above which runoff contribution is

mainly from snowmelt. Fifty eight percent lies between 400 and 1200 m which is the elevation band generally considered to be subject to rain on snow events. The median elevation is 1090 m.

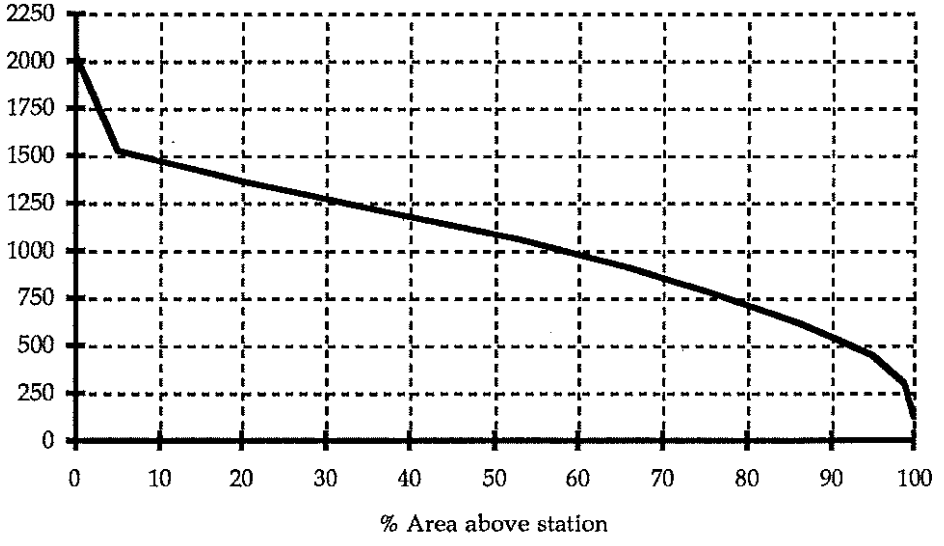


Figure 16
Stawamus River Watershed above Intake
Area - Elevation Relationship.

The average basin slope (as indexed by the elevation difference between the most remote point of the basin and the downstream point divided by the mainstem length) is 11%. The length of the mainstem above the intake is 12 km. with an average channel gradient of 7%. Tributary streams have steep gradients ranging from 16 to 86% (Figure 17).

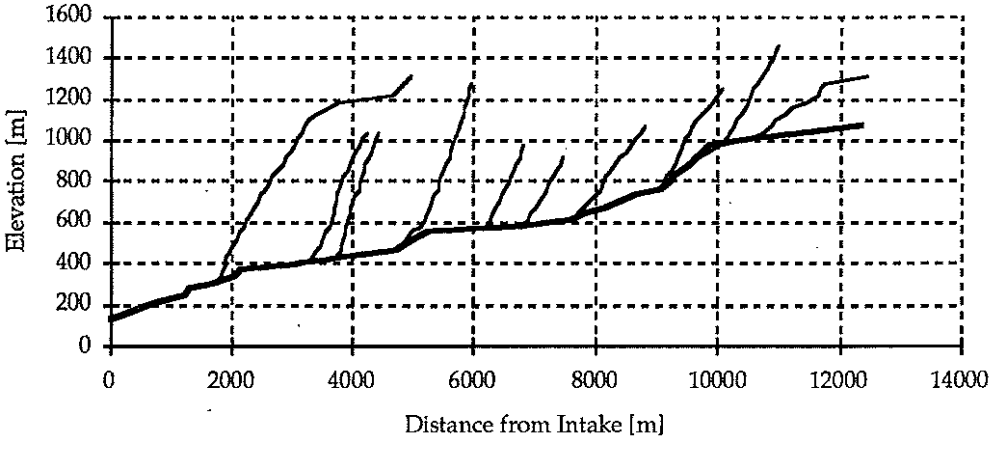


Figure 17
Stawamus River above Intake
Channel Profile.

Elevation is an important factor affecting precipitation amounts (and thus runoff amounts) and the form of precipitation (rain, snow). Basin average annual precipitation is 3150 mm. From the intake to the highest elevation in the watershed annual precipitation increases by 50%. The proportion falling as snow varies from 10% at the intake to 65% at 2000 m. On average, snowfall occurs between November and March at low elevations and at least from October to May at high elevations.

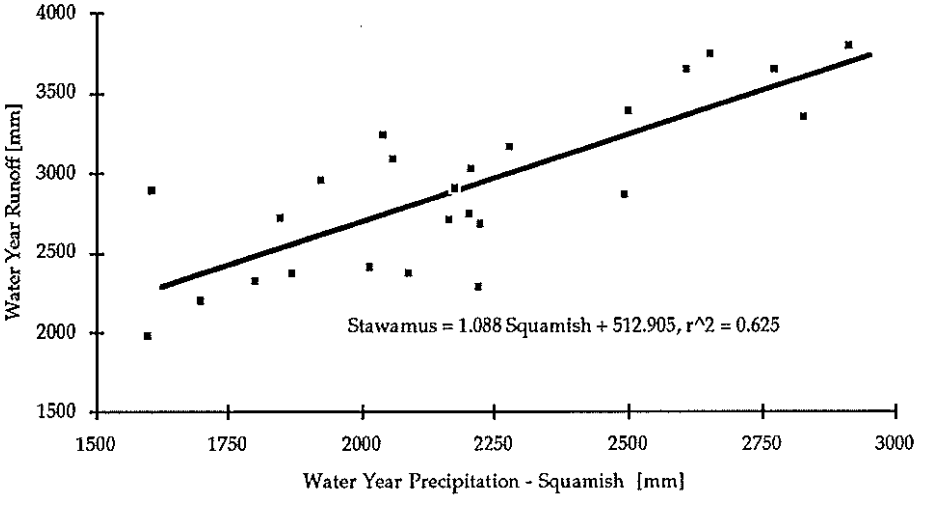
At low elevations 62% of annual precipitation occurs in the November - March season while at elevations above 1200 m it comprises at least 80%.

The highest intensity short duration (eg, 24 hour) precipitation events occur in November and December. Elevation and freezing levels will determine the form of precipitation falling at any point in the watershed.

Extremely dry conditions are most likely to occur from July to September.

About 90% of annual precipitation appears as flow at the intake, thus there is a fairly strong relationship between runoff and precipitation on an annual basis (Figure 18).

Figure 18
Annual Runoff
Precipitation Relationship.



Annual runoff amounts cover a wide range depending on sub-basin elevation, varying from 1600 mm at elevation 200 m to 3000 mm at elevation 2000 m.

In general, May and June are the months of highest monthly flow as a result of the melting of the accumulated winter snowpack in the watershed. August and September are usually the lowest flow months but extremely low monthly flows can also occur in October, January and February depending on the severity of winter temperatures and the extent of freezeup.

Due to the amounts and intensity of fall and winter rainstorms, the larger instantaneous peak flows occur in the October - December period. 70% of annual peak flows occur in October or November.

Annual 7-day average low flows usually occur in the winter (October - February) period and occasionally in the August - September period. The 20 year return period 7-day average low flow at the intake is 0.22 m^3/s. This is equal to that recorded in February 1975. The low flow recorded in September 1992 of 0.30 m^3/s has a return period of 5 years.

5. Design Peak Flows

For the design of bridges, culverts and ditches in the watershed the "Guide for Drainage Design in Small Watersheds in the Squamish Forest District" can be used. As pointed out in Section 3.3 the return period peak flows for Stawamus River agree with those derived from the Guide as far as a relationship with drainage area assuming a steep watershed slope.

6. District of Squamish Water Use

The maximum daily licensed withdrawl at the DoS intake is 0.132 m^3/s. Since 1986 DoS has metered the amount of water diverted from Stawamus River for delivery to consumers. Figure 19 shows the mean monthly consumption for the 1986-92 period.

Mean monthly consumption is compared to the minimum monthly flow in the 1986-92 period (Figure 20). In September consumption can be 70% of the flow. On average, though, consumption during the July-September period averages less than 10% of the mean flow at the intake.

Figure 19
District of Squamish
Mean Monthly Water
Consumption 1986-92.

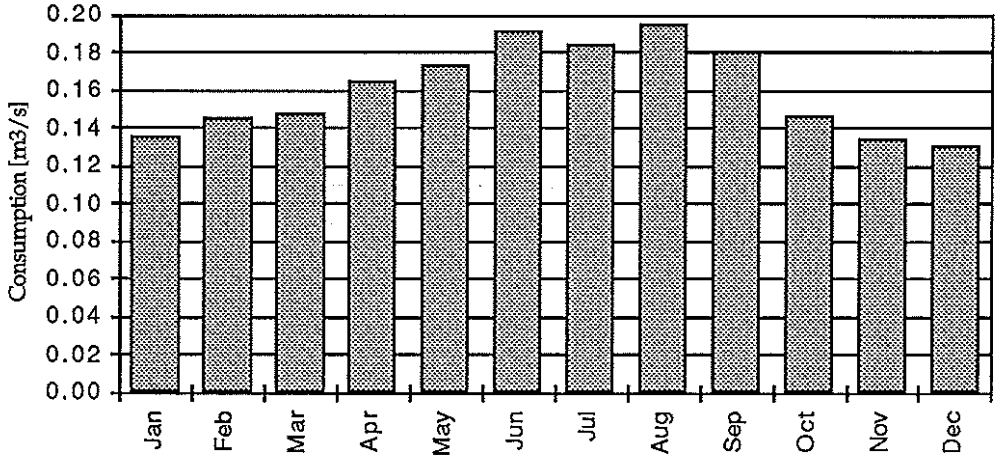
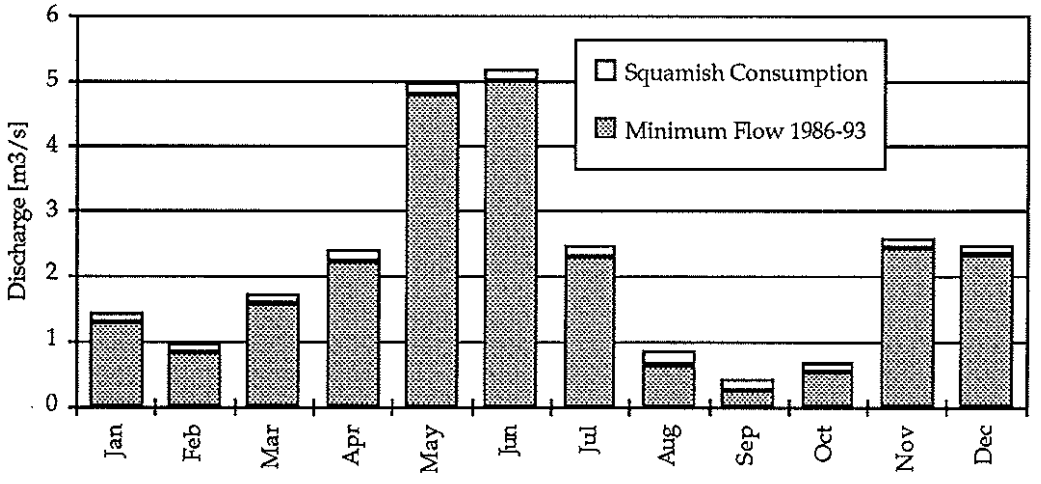


Figure 20
Mean Monthly Water
Consumption and
Min. Monthly Flow 1986-92.



7. Conclusions

This report presents information that can be used as input to stream inventories for fisheries, watershed assessment for cumulative impacts, water supply assessment, development guidelines and prescriptions, and the design of water crossing and drainage structures.

The magnitude of rainfall intensities and peak flow rates, the steep terrain and high gradient tributary channels, the wide range in elevation of the watershed and the large portion of the watershed in the "transient snow zone" all point toward the need for extreme care in managing the watershed for water supply purposes. The need for proper design of the road drainage system cannot be overemphasized.