Estimation of Low Flows for the Province of Newfoundland and Labrador

A User's Guide

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Newfoundland Labrador

Government of Newfoundland and Labrador
Department of Municipal Affairs and Environment
Water Resources Management Division
St. John's, NL, Canada

SUMMARY

The objective of this Guide is to provide users with a spreadsheet-based method of estimating 1-day and 7-day low stream flows with return period of 2, 10, 20, 50 and 100 years for the province of Newfoundland and Labrador. The spreadsheet can be used for both gauged and ungauged watersheds on either the the Island or for Labrador. The Guide also includes a walk-through example.

An overview of the study on which the estimation technique is based is also included.

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1 INTRODUCTION

The characteristics and estimation of low flows are important for several water resources engineering and management applications such as estimating available water supply for municipal and industrial uses, determining the waste-water effluent dilution potential of a receiving stream, predicting the impact of stream diversions on the minimum flow requirements for spawning and migrating fish and generally, for environmental impact assessment studies.

An annual low flow condition is defined as a period during which the average streamflow is a minimum for the year. The duration of the low flow is usually measured in days and is expressed as an N-day low flow period. The magnitude of the low flow is expressed as the average daily flow (in m^3/s or L/s) over the continuous N-day period. For design purposes, low flows are usually expressed in terms of return periods in years. For example, a low flow with duration N-day, magnitude x m^3/s and return period T years is the average flow over N continuous days that one expects to be at or below x m^3/s on the average, at least once every T years. The particular combination of duration and return period chosen for characterizing a low flow is primarily a function of the intended water management or engineering application.

A M.Eng. thesis entitled "Low Flow Frequency Study for Newfoundland and Labrador", completed in November 2012, describes the methodology and results of a frequency analysis of low flows at 60 (sixty) gauging stations on streams in the island of Newfoundland and 12 (twelve) gauging stations on streams in Labrador. A series of regression equations for estimating low flows of several durations and return periods at ungauged sections of streams were derived from the result of the analysis.

2 DATA ON GAUGED WATERSHEDS

The analysis of low flows was based on unregulated daily stream flows from 60 gauging stations in the island of Newfoundland and 12 gauging stations in Labrador. Figure 2.1 and 2.2 show the location of the gauging stations. Table 2.1 and 2.2 list these watersheds together with the locations of the gauges, the watersheds' drainage areas, and the record length available for each station. A database listing the physiographic parameters of the gauged watersheds with natural flows is presented in Table 2.3.

Figure 2.1 - Locations of Gauging Stations in Newfoundland

Figure 2.2 -Locations of Gauging Stations in Labrador

Table 2.1 - Selected Hydrometric Stations in Newfoundland (HYDAT database)

ID	Station Num.	Station Name	Start Year	End Year	Drainage Area (km^2)
1	02YA001	STE. GENEVIEVE RIVER NEAR FORRESTERS POINT	1969	1996	306
2	02YA002	BARTLETTS RIVER NEAR ST. ANTHONY	1986	2010	33.6
3	02YC001	TORRENT RIVER AT BRISTOL'S POOL	1960	2010	624
4	02YD002	NORTHEAST BROOK NEAR RODDICKTON	1980	2010	200
5	02YE001	GREAVETT BROOK ABOVE PORTLAND CREEK	1984	2010	95.7
6	O2YG001	MAIN RIVER AT PARADISE POOL	1986	2010	627
7	O2YJ001	HARRYS RIVER BELOW HIGHWAY BRIDGE	1968	2010	640
8	O2YK002	LEWASEECHJEECH BROOK AT LITTLE GRAND	1952	2010	470
9	02YK004	HINDS BROOK NEAR GRAND LAKE	1956	1979	529
10	02YK005	SHEFFIELD BROOK NEAR TRANS CANADA	1973	2010	391
11	02YK008	BOOT BROOK AT TRANS-CANADA HIGHWAY	1986	2010	20.4
12	02YL001	UPPER HUMBER RIVER NEAR REIDVILLE	1928	2010	2110
13	02YL004	SOUTH BROOK AT PASADENA	1983	2010	58.5
14	02YL005	RATTLER BROOK NEAR MCIVERS	1985	2010	17
15	02YL008	UPPER HUMBER RIVER ABOVE BLACK BROOK	1988	2010	471
16	02YM001	INDIAN BROOK AT INDIAN FALLS	1956	1979	974
17	02YM003	SOUTH WEST BROOK NEAR BAIE VERTE	1980	2010	93.2
18	02YM004	INDIAN BROOK DIVERSION ABOVE BIRCHY LAKE	1990	2010	238
19	02YN002	LLOYDS RIVER BELOW KING GEORGE IV LAKE	1981	2010	469
20	02YO006	PETERS RIVER NEAR BOTWOOD	1981	2010	177
21	02YO008	GREAT RATTLING BROOK ABOVE TOTE RIVER	1984	2010	773
22	02YO012	SOUTHWEST BROOK AT LEWISPORTE	1989	2010	58.7
23	02YQ001	GANDER RIVER AT BIG CHUTE	1950	2010	4450
24	02YQ005	SALMON RIVER NEAR GLENWOOD	1987	2010	80.8
25	02YR001	MIDDLE BROOK NEAR GAMBO	1959	2010	275
26	02YR002	RAGGED HARBOUR RIVER NEAR MUSGRAVE	1978	1997	399
27	02YR003	INDIAN BAY BROOK NEAR NORTHWEST ARM	1981	2010	554
28	02YS001	TERRA NOVA RIVER AT EIGHT MILE BRIDGES	1951	1984	1290
29	02YS003	SOUTHWEST BROOK AT TERRA NOVA PARK	1968	2009	36.7
30	02YS005	TERRA NOVA RIVER AT GLOVERTOWN	1985	2010	2000

Table 2.1 (continued) Selected Hydrometric Stations in Newfoundland (HYDAT database)

ID	Station Num.	Station Name	Start Year	End Year	Drainage Area (km^2)
31	02ZA002	HIGHLANDS RIVER AT TRANS-CANADA	1982	2010	72
32	02ZB001	ISLE AUX MORTS RIVER BELOW HIGHWAY	1963	2010	205
33	02ZC002	GRANDY BROOK BELOW TOP POND BROOK	1982	2010	230
34	02ZD002	GREY RIVER NEAR GREY RIVER	1969	2010	1340
35	02ZE001	SALMON RIVER AT LONG POND	1944	1965	2640
36	02ZE004	CONNE RIVER AT OUTLET OF CONNE POND	1990	2010	99.5
37	02ZF001	BAY DU NORD RIVER AT BIG FALLS	1950	2010	1170
38	02ZG001	GARNISH RIVER NEAR GARNISH	1959	2009	205
39	02ZG002	TIDES BROOK BELOW FRESHWATER POND	1978	1996	166
40	02ZG003	SALMONIER RIVER NEAR LAMALINE	1980	2009	115
41	02ZG004	RATTLE BROOK NEAR BOAT HARBOUR	1981	2009	42.7
42	02ZH001	PIPERS HOLE RIVER AT MOTHERS BROOK	1953	2009	764
43	02ZH002	COME BY CHANCE RIVER NEAR GOOBIES	1961	2009	43.3
44	02ZJ001	SOUTHERN BAY RIVER NEAR SOUTHERN BAY	1977	2009	67.4
45	02ZJ002	SALMON COVE RIVER NEAR CHAMPNEYS	1983	2009	73.6
46	02ZJ003	SHOAL HARBOUR RIVER NEAR CLARENVILLE	1986	2009	106
47	02ZK001	ROCKY RIVER NEAR COLINET	1948	2009	301
48	02ZK002	NORTHEAST RIVER NEAR PLACENTIA	1979	2009	89.6
49	02ZK003	LITTLE BARACHOIS RIVER NEAR PLACENTIA	1983	2009	37.2
50	02ZK004	LITTLE SALMONIER RIVER NEAR NORTH HARB	1983	2009	104
51	02ZL004	SHEARSTOWN BROOK AT SHEARSTOWN	1983	2009	28.9
52	02ZL005	BIG BROOK AT LEAD COVE	1985	2009	11.2
53	02ZM006	NORTHEAST POND RIVER AT NORTHEAST POND	1954	2009	3.63
54	02ZM008	WATERFORD RIVER AT KILBRIDE	1974	2009	52.7
55	02ZM009	SEAL COVE BROOK NEAR CAPPAHAYDEN	1980	2009	53.6
56	02ZM016	SOUTH RIVER NEAR HOLYROOD	1983	2009	17.3
57	02ZM018	VIRGINIA RIVER AT PLEASANTVILLE	1984	2009	10.7
58	02ZM020	LEARY BROOK AT PRINCE PHILIP DRIVE	1986	2009	17.8
59	02ZN001	NORTHWEST BROOK AT NORTHWEST POND	1966	1996	53.3
60	02ZN002	ST. SHOTTS RIVER NEAR TREPASSEY	1985	2009	15.5

Table 2.2 - Selected Hydrometric Stations in Labrador (HYDAT database)

ID	Station Num.	Station Name	Start Year	End Year	Drainage Area (km^2)
1	02XA003	LITTLE MECATINA RIVER ABOVE LAC FOURMONT	1978	2010	4540
2	03NF001	UGJOKTOK RIVER BELOW HARP LAKE	1979	2010	7570
3	03OC003	ATIKONAK RIVER ABOVE PANCHIA LAKE	1972	2010	15100
4	03OE003	MINIPI RIVER BELOW MINIPI LAKE	1979	2010	2330
5	03PB002	NASKAUPI RIVER BELOW NASKAUPI LAKE	1978	2010	4480
6	03QC001	EAGLE RIVER ABOVE FALLS	1966	2010	10900
7	03QC002	ALEXIS RIVER NEAR PORT HOPE SIMPSON	1978	2010	2310
8	02XA004	RIVIERE JOIR NEAR PROVINCIAL BOUNDARY	1980	1996	2060
9	03NG001	KANAIRIKTOK RIVER BELOW SNEGAMOOK LAKE	1979	1996	8930
10	03OB002	CHURCHILL RIVER AT FLOUR LAKE	1955	1971	33900
11	03OE010	BIG POND BROOK BELOW BIG POND	1994	2010	71.4
12*	03OE001	CHURCHILL RIVER ABOVE UPPER MUSKRAT FALLS	1948	2010	92500

Table 2.3 - Physiographic Database

ID	Station Number	DA	FA	SW	FL	L+S	AB	ACLS	LSF	LAF	Length Main R	ELEV DIFF	Slope	DD	SF
		Km^2	-	-	-	-	-	-	-	-	(Km)	(m)	%	(km^{-1})	-
1	02YA001	306	0.64	0.14	0.22	0.35	0.01	0.96	1.78	1053	38.9	88	0.23	0.54	1.48
2	02YA002	33.6	0.4	0.03	0.13	0.16	0.44	0.99	1.91	652	13.2	150	1.14	0.91	1.64
3	02YC001	624	0.33	0.04	0.13	0.17	0.5	0.99	1.91	175	48.3	479	0.99	0.76	1.45
4	02YD002	200	0.83	0.04	0.13	0.17	0.01	0.99	1.9	484	38.3	270	0.7	0.93	1.65
5	02YE001	95.7	0.49	0.06	0.06	0.12	0.39	0.88	1.82	134	24.5	700	2.86	0.75	1.64
6	02YG001	627	0.78	0.06	0.07	0.13	0.09	0.63	1.55	18.3	31.9	375	1.18	1.3	1.83
7	02YJ001	640	0.79	0.09	0.06	0.14	0.07	0.75	1.67	141	60	509	0.85	1.12	1.81
8	02YK002	470	0.55	0.06	0.1	0.16	0.29	1	1.92	274	54.9	561	1.02	0.63	2.32
9	02YK004	529	0.35	0.24	0.12	0.36	0.29	0.95	1.77	666	49.3	320	0.65	0.64	1.78
10	02YK005	391	0.68	0.08	0.1	0.17	0.15	0.94	1.85	590	38.1	378	0.99	0.19	1.98
11	02YK008	20.4	0.75	0.22	0.02	0.24	0.01	0.65	1.5	0	10.1	137	1.35	1.28	1.47
12	02YL001	2110	0.74	0.06	0.05	0.11	0.15	0.75	1.68	50	118.8	678	0.57	0.79	1.56
13	02YL004	58.5	0.94	0.01	0.01	0.02	0.05	0.08	1.06	0	13.2	130	0.99	1.34	1.54
14	02YL005	17	0.91	0.08	0.02	0.1	0	0.46	1.39	0	8.2	244	2.98	1.05	1.1
15	02YL008	471	0.58	0.01	0.07	0.08	0.34	0.99	1.95	0	48.5	393	0.81	0.57	1.9
16	02YM001	974	0.79	0.07	0.09	0.16	0.05	0.88	1.8	36.4	65	290	0.45	0.45	1.88
17	02YM003	93.2	0.91	0.07	0.05	0.11	0	0.56	1.49	0	18.6	107	0.58	0.68	1.67
18	02YM004	243.8	0.48	0.093	0.134	0.227	0.294	0.918	1.80	218.1	23.66	116	0.490	0.472	7.469
19	02YN002	469	0.23	0.06	0.12	0.18	0.63	1	1.91	371	57.3	166	0.29	1.37	2.15
20	02YO006	177	0.83	0.13	0.03	0.16	0.02	0.97	1.89	0	42.7	190	0.45	0.8	1.93
21	02YO008	823	0.73	0.19	0.05	0.24	0.03	0.55	1.4	0	69	221	0.32	0.69	1.8
22	02YO012	58.7	0.8	0.08	0.12	0.2	0	0.67	1.55	128	22.7	134	0.59	0.54	1.87
23	02YQ001	4400	0.76	0.08	0.09	0.17	0.07	0.91	1.82	277	133.8	297	0.22	0.45	2.08
24	02YQ005	80.8	0.85	0.11	0.04	0.15	0	0.87	1.79	0	22.5	372	1.65	1.09	1.78
25	02YR001	267	0.75	0.07	0.18	0.24	0.01	0.98	1.83	881	49.3	177	0.36	0.26	1.93
26	02YR002	399	0.68	0.16	0.17	0.33	0	0.96	1.79	65.1	42	95	0.23	0.74	1.68
27	02YR003	554	0.7	0.13	0.2	0.33	0	0.9	1.8	307	52.4	136	0.26	0.68	1.72
28	02YS001	1290	0.55	0.21	0.09	0.3	0.15	0.92	1.76	138	105	207	0.2	0.73	2.35
29	02YS003	36.7	0.84	0.14	0.02	0.16	0	1	1.92	0	11.2	143	1.28	0.64	1.43
30	02YS005	2000	0.61	0.23	0.13	0.36	0.03	0.93	1.74	113	128.8	274	0.21	0.35	2.12
31	02ZA002	72	0.82	0.01	0.04	0.05	0.13	0.43	1.39	0	20.4	460	2.26	1.15	1.72
32	02ZB001	205	0.08	0.06	0.07	0.13	0.78	0.6	1.52	0	33.3	444	1.33	0.72	2.09
33	02ZC002	230	0.2	0.01	0.05	0.06	0.82	0.34	1.3	38.4	28.9	360	1.24	0.96	1.84
34	02ZD002	1340	0.04	0.16	0.04	0.2	0.75	0.63	1.51	0	60	310	0.52	0.15	5.31
35	02ZE001	2640	0.35	0.02	0.14	0.16	0.5	1	1.92	619	100.4	122	0.12	0.36	1.75
36	02ZE004	99.7	0.6	0.34	0.05	0.39	0.01	1	1.81	0	18.7	109	0.58	1.38	1.52

Table 2.3 (continued) - Physiographic Database

ID	Station Number	DA	FA	SW	FL	L+S	AB	ACLS	LSF	LAF	Length Main R	ELEV DIFF	Slope	DD	SF
		Km^2	-	-	-	-	-	-	-	-	(Km)	(m)	%	(km^{-1})	-
37	02ZF001	1170	0.32	0.05	0.18	0.24	0.44	0.96	1.84	401	68.1	282	0.41	0.61	2.15
38	02ZG001	205	0.26	0.01	0.09	0.1	0.63	0.96	1.91	202	44.7	370	0.83	0.55	2.45
39	02ZG002	166	0.37	0.04	0.09	0.13	0.49	0.92	1.82	588	26.7	221	0.83	1.35	1.84
40	02ZG003	115	0.16	0.06	0.07	0.13	0.73	0.92	1.85	42.8	24.5	136	0.55	1.55	1.62
41	02ZG004	42.7	0.34	0.03	0.14	0.16	0.46	0.92	1.83	123	10	107	1.07	1.62	1.53
42	02ZH001	764	0.11	0.48	0.18	0.66	0.23	0.91	1.57	17.4	50.9	207	0.41	0.71	1.67
43	02ZH002	43.3	0.4	0.02	0.08	0.1	0.5	0.92	1.87	20.8	17	110	0.65	1.11	1.66
44	02ZJ001	67.4	0.82	0.06	0.1	0.16	0.03	0.86	1.78	89.3	16	128	0.8	1.24	1.64
45	02ZJ002	73.6	0.74	0.06	0.13	0.19	0.07	0.82	1.72	436	18	137	0.76	1.11	1.33
46	02ZJ003	106	0.65	0.1	0.07	0.17	0.18	0.68	1.58	166	25.1	250	0.99	0.66	1.66
47	02ZK001	301	0.51	0.02	0.1	0.12	0.37	0.58	1.49	8.79	45.2	165	0.37	0.96	1.95
48	02ZK002	89.6	0.48	0.16	0.15	0.31	0.24	0.81	1.64	278	26.9	200	0.74	1.11	1.91
49	02ZK003	37.2	0.86	0.11	0.02	0.13	0.01	0.34	1.24	0	14.6	228	1.56	1.16	1.48
50	02ZK004	104	0.23	0.38	0.08	0.46	0.31	0.91	1.67	116	28.5	236	0.83	1.5	1.85
51	02ZL004	28.9	0.7	0	0.04	0.04	0.27	0.39	1.36	0	13.4	122	0.91	1.14	1.73
52	02ZL005	11.2	0.39	0.03	0.07	0.1	0.51	1	1.95	272	8.7	211	2.43	1	1.52
53	02ZM006	3.9	0.75	0.17	0.04	0.21	0.04	1	1.89	265	2.6	64	2.44	1.04	1.24
54	02ZM008	52.6	0.53	0.012	0.007	0.019	0.447	0.023	1.0	0	11.15	152	1.363	0.779	2.455
55	02ZM009	53.6	0.38	0.01	0.12	0.14	0.51	1	1.93	193	14.9	133	0.89	1.13	1.37
56	02ZM016	17.3	0.22	0.05	0.06	0.11	0.68	0.9	1.84	148	8.7	259	2.98	1.01	1.4
57	02ZM018	14.82	0.34	0.042	0.025	0.067	0.598	0.179	1.12	11.98	6.94	165	2.378	0.735	0.950
58	02ZM020	19.02	0.73	0.010	0.003	0.012	0.258	0.032	1.02	0	5.4	139	2.574	0.941	1.222
59	02ZN001	53.3	0.09	0	0.13	0.13	0.79	1	1.94	132	14.6	93	0.63	1.09	2.06
60	02ZN002	15.5	0.88	0	0.12	0.12	0	0.82	1.75	512	10.3	23	0.22	1.03	1.53
61	02XA003	4478	0.89	0.016	0.064	0.080	0.029	0.602	1.55	0	274.6	329	0.120	0.436	2.680
62	02XA004	2056.6	0.81	0.096	0.059	0.155	0.031	0.578	1.48	0	96.8	162	0.167	0.420	1.818
63	03NF001	7307.3	0.46	0.005	0.103	0.108	0.432	0.829	1.77	0	193.2	452	0.234	0.386	2.272
64	03NG001	8926.0	0.69	0.042	0.089	0.131	0.177	0.987	1.92	0	280.1	393	0.140	0.406	2.196
65	03OC003	15884.5	0.70	0.130	0.147	0.277	0.026	1.000	1.86	270	291.2	259	0.089	0.320	2.063
66	03OE003	2219.0	0.84	0.026	0.126	0.152	0.000	1.000	1.92	366	106.5	151	0.142	0.314	1.921
67	03OE010	70.7	0.93	0.006	0.064	0.070	0.000	0.994	1.96	115	27.5	128	0.466	0.663	1.791
68	03PB002	4540.9	0.81	0.023	0.147	0.170	0.019	0.974	1.89	0	174.1	298	0.171	0.398	1.939
69	03QC001	10705.0	0.73	0.088	0.084	0.173	0.093	0.849	1.76	0	252.8	428	0.169	0.425	1.989
70	03QC002	2312.0	0.88	0.050	0.030	0.080	0.037	0.304	1.24	0	81.0	437	0.539	0.541	1.624

Table 2.3 (continued) - Physiographic Database

ID	Station Number	DA	FA	SW	FL	L+S	AB	ACLS	LSF	LAF	Length Main R	ELEV DIFF	Slope	DD	SF
		Km^2	-	-	-	-	-	-	-	-	(Km)	(m)	%	(km^{-1})	-
71	02YD001*	237	0.81	0.04	0.05	0.08	0.11	0.73	1.68	0	40.6	328	0.81	0.34	2.23
72	02YF001*	611	0.69	0.05	0.08	0.13	0.18	1	1.93	0	30.2	250	0.83	0.58	1.86
73	02YG002*	224	0.83	0.06	0.09	0.15	0.02	0.96	1.88	299	26.4	255	0.96	0.45	1.84
74	02YJ003*	119	0.86	0.05	0.05	0.1	0.04	1	1.95	290	16.6	164	0.99	1.73	1.54
75	02YK003*	362	0.67	0.07	0.11	0.18	0.15	1	1.91	688	37	351	0.95	0.43	1.85
76	02YK007*	112	0.87	0.09	0.04	0.13	0	0.98	1.91	132	26.8	234	0.88	1.28	1.61
77	02YO007*	88.3	0.7	0.24	0.04	0.28	0.02	0.73	1.57	0	23.1	272	1.18	0.74	1.52
78	02YP001*	63.8	0.88	0.07	0.06	0.13	0	0.79	1.72	119	20	113	0.56	0.88	1.62
79	02YQ004*	2150	0.66	0.25	0.06	0.31	0.03	0.44	1.22	0	104.2	265	0.25	0.45	1.63
80	02ZA003*	139	0.66	0.07	0.04	0.11	0.16	0.73	1.66	131	25.2	450	1.78	1.46	1.68
81	03NE001*	75.5	0.09	0	0.137	0.137	0.769	1.000	1.93	310	17.7	412	2.332	0.380	1.330
82	03OD007*	1776.0	0.70	0.066	0.157	0.223	0.080	0.937	1.82	126	145.2	366	0.252	0.401	2.036
83	03OE011*	800.2	0.63	0.139	0.143	0.282	0.087	0.946	1.80	122	93.0	105	0.113	0.372	1.910
84	03NE002*	24.9	0.73	0	0.126	0.126	0.142	0.897	1.83	333	9.8	60	0.615	0.430	1.385

* Used only for the verification of results.
DA= Drainage area; FA=fraction of forest area, SW= fraction of swamp area; FL= fraction of lake area; AB=fraction of barren area, L+S=fraction of lake and swamp area; ACLS= fraction of area controlled by lakes and swamps; LSF=lake and swamp factor; LAF=lake attenuation factor, DD=drainage density; SF= shape factor

Glossary of Table 2.3

DA = Drainage area

FA = Fraction of area controlled by lakes and swamps

SW = Fraction of swamp area

FL = Fraction of lake area

AB = Fraction of barren area

L+S = Fraction of lake and swamp area

ACLS = Fraction of area controlled by lake and swamps

LSF = Lake and swamp factor

LAF = Lake attenuation factor

DD =Drainage density

SF = Shape factor

3 REGIONAL LOW FLOW FREQUENCY ANALYSIS

Annual minimum low flows of 1-day and 7-day durations from the Environment Canada HYDAT database were used as input data into the Low Flow Frequency Analysis (LFA) computer program to obtain estimates of low flows with various return periods. The Province of Newfoundland and Labrador has been divided into two homogeneous regions – 1) Island of Newfoundland and 2) Labrador. Five candidate probability distributions, such as Generalized Logistic Distributuin, Generalized Extreme Value Distribution, Lognormal Distribution, Pearson Type III Distribution, and Generalized Pareto Distribution have been examined to select a suitable probability distribution for the regions. Three parameter - lognomal distribution has been identified as the most suitable probability distribution for 1-day and 7-day LFA for both the regions. Frequency distribution of all sites in a homogeneous region is identical, except for site-specific physiographic factors. Using the physiographic factor, drainage area, a number of regression equations have been developed to determine the 1-day and 7-day low flows for gauged and ungauged watersheds in a homogeneous region for different return period. Mean annual minimum flow prediction equations and minimum low flow prediction equations for 1-day and 7-day are presented in Table 3.1 and 3.2.

Table 3.1 - Mean annual minimum flow prediction equations

Region	Equation	R^2
Newfoundland (1-day)	$Q_{mean} = 0.0021\ A^{1.1067}$	0.91
Newfoundland (7-day)	$Q_{mean} = 0.0027\ A^{1.0848}$	0.92
Labrador (1-day)	$Q_{mean} = 0.0011\ A^{1.1225}$	0.97
Labrador (7-day)	$Q_{mean} = 0.0013\ A^{1.1075}$	0.97

Table 3.2 - Minimum low flow prediction equations

Region	Equation
Newfoundland (1-day)	$0.0021\ \times \Phi^{-1}\left\{\frac{(0.1876)^{-1}Ln[1+0.1876(T^{-1}-0.9581)]}{0.4433}\right\} \times A^{1.1067}$
Newfoundland (7-day)	$0.0027\ \times \Phi^{-1}\left\{\frac{(0.1849)^{-1}Ln[1+0.1849(T^{-1}-0.9594)]}{0.4451}\right\} \times A^{1.0848}$
Labrador (1-day)	$0.0011\ \times \Phi^{-1}\left\{\frac{(0.2083)^{-1}Ln[1+0.2083(T^{-1}-0.9696)]}{0.2888}\right\} \times A^{1.1225}$
Labrador (7-day)	$0.0013\ \times \Phi^{-1}\left\{\frac{(0.2189)^{-1}Ln[1+0.2189(T^{-1}-0.9676)]}{0.2926}\right\} \times A^{1.1075}$

Note:
$\boldsymbol{\varphi}$ is the cumulative distribution function of the standard normal distribution
$\boldsymbol{A}$ is the area of the watershed
$\boldsymbol{T}$ is the return period

4 ILLUSTRATED EXAMPLE

The following instructions are to show how to use the Newfoundland and Labrador Low Flows Calculation sheet:

The complete sheet which will be seen when opening the calculator as shown below (Figure 4.1). The left section with the tables is where drainage areas are entered and low flow values are received. The text on the right explains how to use the calculation sheet and what the return values mean.

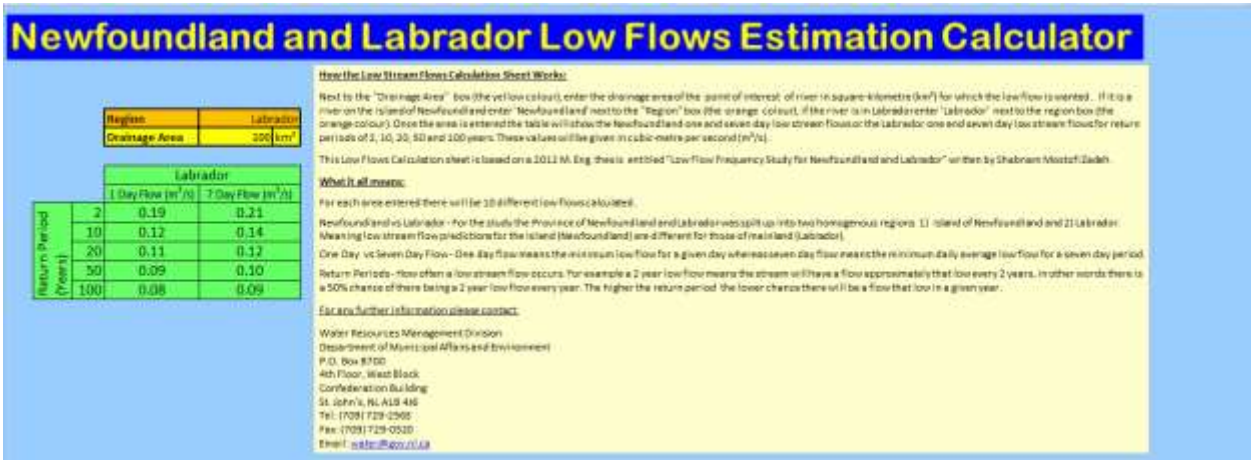


Figure 4.1 – The Complete Estimation Sheet

The location of the river will be entered in the location cell (orange). If low flow is wanted of a stream on the island of Newfoundland enter Newfoundland (see Figure 4.2). If it is in Labrador enter Labrador (see Figure 4.3).

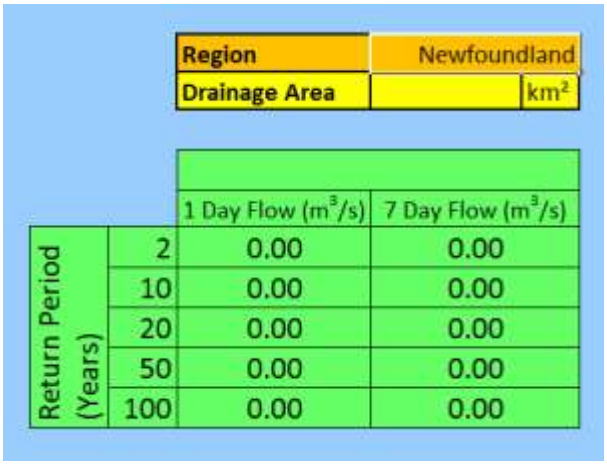


Figure 4.2 – Newfoundland being entered into the location cell

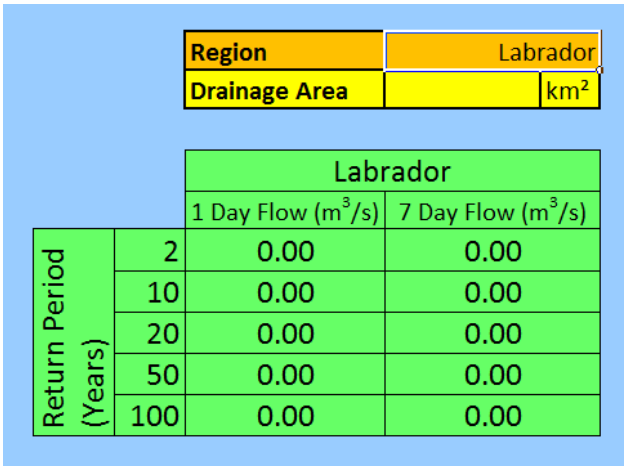
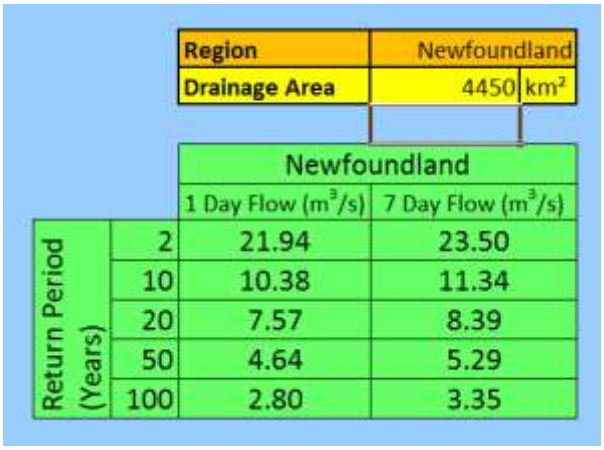


Figure 4.3 - Labrador being entered into the location cell

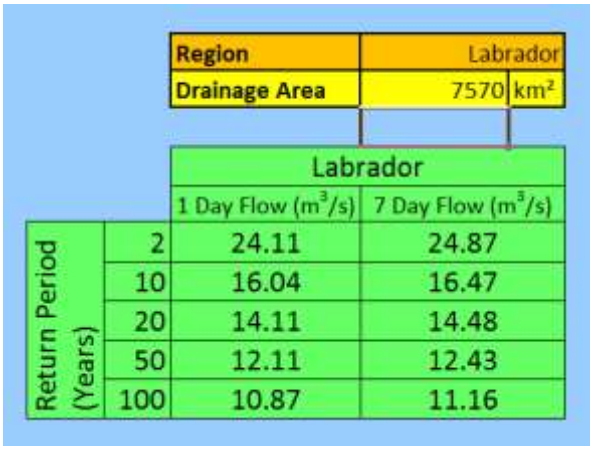
Once the location is entered, the drainage area of the point of interest will be entered in the Drainage Area cell (yellow). Once the area is entered the low flow values will appear in the table. The drainage area for the Gander River, in Newfoundland, is shown being entered into the calculator in Figure 4.4. The drainage area of the Ugjoktok River, in Labrador, is shown in Figure 4.5 being entered into the calculator.



Region	Newfoundland	
Drainage Area	4450 km²	

		Newfoundland	
		1 Day Flow (m^3/s)	7 Day Flow (m^3/s)
Return Period (Years)	2	21.94	23.50
	10	10.38	11.34
	20	7.57	8.39
	50	4.64	5.29
	100	2.80	3.35

Figure 4.4 – The Gander River drainage area being entered into the drainage area cell



Region	Labrador	
Drainage Area	7570 km²	

		Labrador	
		1 Day Flow (m^3/s)	7 Day Flow (m^3/s)
Return Period (Years)	2	24.11	24.87
	10	16.04	16.47
	20	14.11	14.48
	50	12.11	12.43
	100	10.87	11.16

Figure 4.5 – The Ugjoktok River drainage area being entered into the drainage area cell

5 REFERENCES

- Zadeh, S. M. (2012). *Low Flow Frequency Study for Newfoundland and Labrador. M.Eng. Thesis,* Memorial University of Newfoundland, St. John's, NL.