REGIONAL FLOOD FREQUENCY ANALYSIS
FOR NEWFOUNDLAND AND LABRADOR
2014 UPDATE

Users' Guide and Electronic Spreadsheet

Submitted to:

Water Resources Management Division
Department of Environment and Conservation
Government of Newfoundland and Labrador

Submitted by:

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Via email to akhan@gov.nl.ca

ATTENTION: Mr. Amir Ali Khan, Ph.D, P.Eng
Manager, Hydrologic Modelling Section

Dear Sir:

RE: Improving Resilience to Climate Change Impacts for the Province of Newfoundland and Labrador
Regional Flood Frequency Analysis – 2014 Update
Final Report

AMEC Environment & Infrastructure, a Division of AMEC Americas Limited (AMEC), is pleased to provide the Users' Guide associated with the above noted project.

We appreciate the opportunity of providing our services to the Water Resources Management Division and trust the information provided herein is fully satisfactory. If you have any questions with regard to this submission, please do not hesitate to contact the undersigned.

Yours truly,

AMEC ENVIRONMENT & INFRASTRUCTURE
a Division of AMEC Americas Limited

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1.0 INTRODUCTION

The Government of Newfoundland and Labrador (the "Province"), through the Office of Climate Change and Energy Efficiency, advocates for better use of climate change data available for the Province and consideration of how climate change will impact infrastructure with regard to both design and performance. The Province has been making, and continues to make, efforts towards maximizing the use of these Provincial datasets to inform better planning and decision-making, ultimately increasing the Province's resilience to the potential impacts of climate change.

Although climate change impact assessments have a view to better understanding future risk, a typical starting point for such an assessment is review of current conditions, capacities and loads. In the case of water resources infrastructure, quantification of existing loads, one aspect represented by streamflow, is a required first step. However, the locations for which streamflow estimates are required typically do not have measured streamflow data. In these cases, a number of alternate means of streamflow estimation are available including statistical approaches whereby regionalized relationships are developed. These regionalized relationships are a means to estimate streamflow magnitudes for ungauged and/or poorly gauged drainage basins and have been developed through a Regional Flood Frequency Analysis (RFFA).

The 2014 RFFA Update, like four (4) previous studies (1971, 1984, 1990, 1999), has derived a set of equations for estimating return period flood flows in ungauged watersheds in the Province.

This Users' Guide and Electronic Spreadsheet (disk in back cover) is a compendium report to the *Regional Flood Frequency Analysis for Newfoundland and Labrador - 2014 Update* (AMEC, 2014). This User's Guide has been designed to assist engineers and analysts in the application of the regional equations and use of the electronic spreadsheet. The electronic spreadsheet automates the application of the regional equations and provides some limited error checking with regard to applicability of the equations to a specific circumstance. It is always advisable to use several methods to estimate design floods and the previous flood frequency analyses (1999) can be used for validation of estimates.

The following table outlines the chronology of the RFFA updates in Newfoundland and Labrador:

Table 1-1: Chronology of RFFA Updates in Newfoundland and Labrador

Year	Authors	Regions included in the Analysis	Regional Equations based on	
			Gauged Watersheds	Regions
2014	AMEC	Newfoundland and Labrador	78 in Newfoundland 12 in Labrador	4 in Newfoundland 1 in Labrador
1999	Rollings	Newfoundland	50	4
1990	Beersing	Newfoundland	39	4
1984	Panu et al	Newfoundland	21	2
1971	Poulin	Newfoundland	17	1

The advantages of calculation on an electronic spreadsheet includes: checking the sensitivity of the estimated flood flow changes in physiographic parameters, avoiding arithmetic and co-efficient selection errors, quick calculation of peak flows and their confidence limits, and printing of results.

The regression equations developed as part of the 2014 update to the Regional Flood Frequency Analysis for Newfoundland and Labrador may be used to estimate frequency flows for ungauged watersheds. The equations are not applicable for all ungauged watersheds, though, as all watersheds with regulated flows and significant urban development have been excluded from the regression equation development process and, therefore, these equations are recommended for use only for unregulated drainage areas with limited urbanization. Application of these equations is also not recommended for ungauged watersheds where the physiographic parameters are outside of the range of the parameters used in regression equation development for their corresponding region. Additional guidance in this regard has been provided in Section 4.2. IT MUST BE NOTED THAT THESE EQUATIONS HAVE LIMITATIONS.

The procedure for application of single station frequency analysis and regional flood frequency analysis for estimating flood flows should be considered as a guideline only. Specific circumstances will warrant professional judgment be used in the application of the regression equations.

A guideline for flood estimation using single station frequency analysis and regional flood frequency analysis is provided herein as well as worked examples. The final section of this report provides documentation on the Microsoft® Excel® spreadsheet RFFA2014.XLS. The RFFA2014 spreadsheet automates the calculation of return period flood flows based on equations developed for the 2014 Regional Flood Frequency Analysis update. The RFFA2014 spreadsheet is provided on disk in the back cover of this Guide. The spreadsheet was developed in Microsoft® Excel® 2007.

Please note, that this User's Guide should be read in conjunction with the main report for the 2014 RFFA Update, which fully documents the development of the regional flood frequency analysis regression equations. The following sections provide excerpts from the main report to provide context and some background for information purposes.

2.0 SINGLE STATION ANALYSIS

2.1 General

Water Survey of Canada (WSC) streamflow gauges, located within the Province of Newfoundland and Labrador, have been identified using the HYDAT database from Environment Canada. The locations of the streamflow gauging stations within the Newfoundland and Labrador have been illustrated on Figures 2-1 and 2-2, respectively.

Water Survey of Canada instantaneous maximum and extreme daily streamflow data for Newfoundland and Labrador have been obtained and screened for use in the analysis. Data summaries have been obtained for all available years to the end of 2012 from the HYDAT database published on April 15, 2014. The HYDAT database identified a total of 205 stations available in Newfoundland and Labrador, of which 111 measure instantaneous maximum, are not regulated, and have greater than 10 years of record, and as such, could support this analysis.

Statistical testing was applied to the available station data, to determine applicability to the RFFA methodology. In total, twenty-one (21) flow gauges were excluded from further analysis.

The data from ninety (90) gauges has been used for this RFFA update (ref. Table 2-1), representing 78 stations in Newfoundland and 12 in Labrador.

2.2 Single Station Frequency Analysis

Single station frequency analysis has been conducted using the U.S. Army Corps of Engineers statistical software package, HEC-SSP, to estimate flows with return periods of 2, 5, 10, 20, 50, 100 and 200 years for each individual streamflow gauge.

HEC-SSP facilitates statistical analyses of hydrologic data. The current version of HEC-SSP can perform flood flow frequency analysis, a generalized frequency analysis on not only flow data but other hydrologic data as well, a volume frequency analysis on high and low flows, a duration analysis, a coincident frequency analysis, and a curve combination analysis. HEC-SSP version 2.0 (USACE, 2010) was used for this component of the analyses.

The theoretical probability distributions generally considered for single site frequency analysis are the Log-Normal (LN) and Three Parameter Log-Normal (3PLN) distributions; the Gumbel (EV-1) and Generalized Extreme Value (GEV). While all of these distributions have been historically recognized as possible flood frequency distributions in Newfoundland, streamflow estimates produced using these distributions typically lie within a narrow band. Further, the 3PLN distribution was selected for the single site frequency analysis completed for the 1999 RFFA update after careful consideration and statistical analysis of results. It would not be anticipated that streamflow data has changed in a manner that would suggest a change to the preferred probability distribution and, as such, the current RFFA update has been completed using the 3PLN distribution. Frequency analysis has been conducted on all 90 gauges in Newfoundland and Labrador and results have been presented in Table 2-2.

The 95% confidence intervals for flows with return period of 2, 20 and 100 years have also been estimated using the 3PLN distribution for each individual flow gauge (ref. Table 2-3). In general, the confidence interval (as represented by a percentage) increases with increasing return period as a reflection of the available station records (i.e., only six (6) stations have greater than 50 years of data). As such, there is a lower confidence in the 100 year flow estimate versus the 2 year flow estimate.

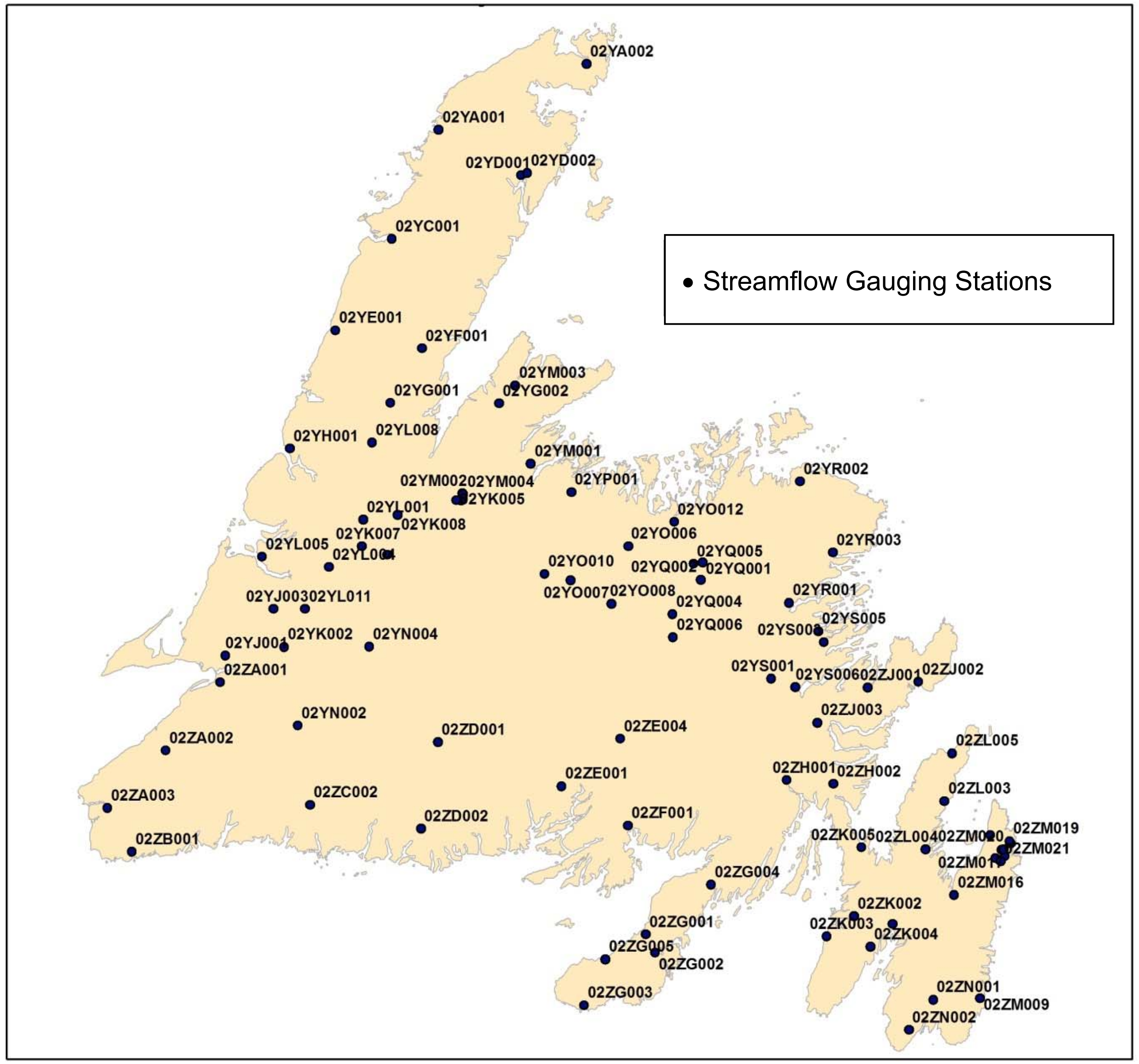

Figure 2-1: Locations of Streamflow Gauging Stations in Newfoundland

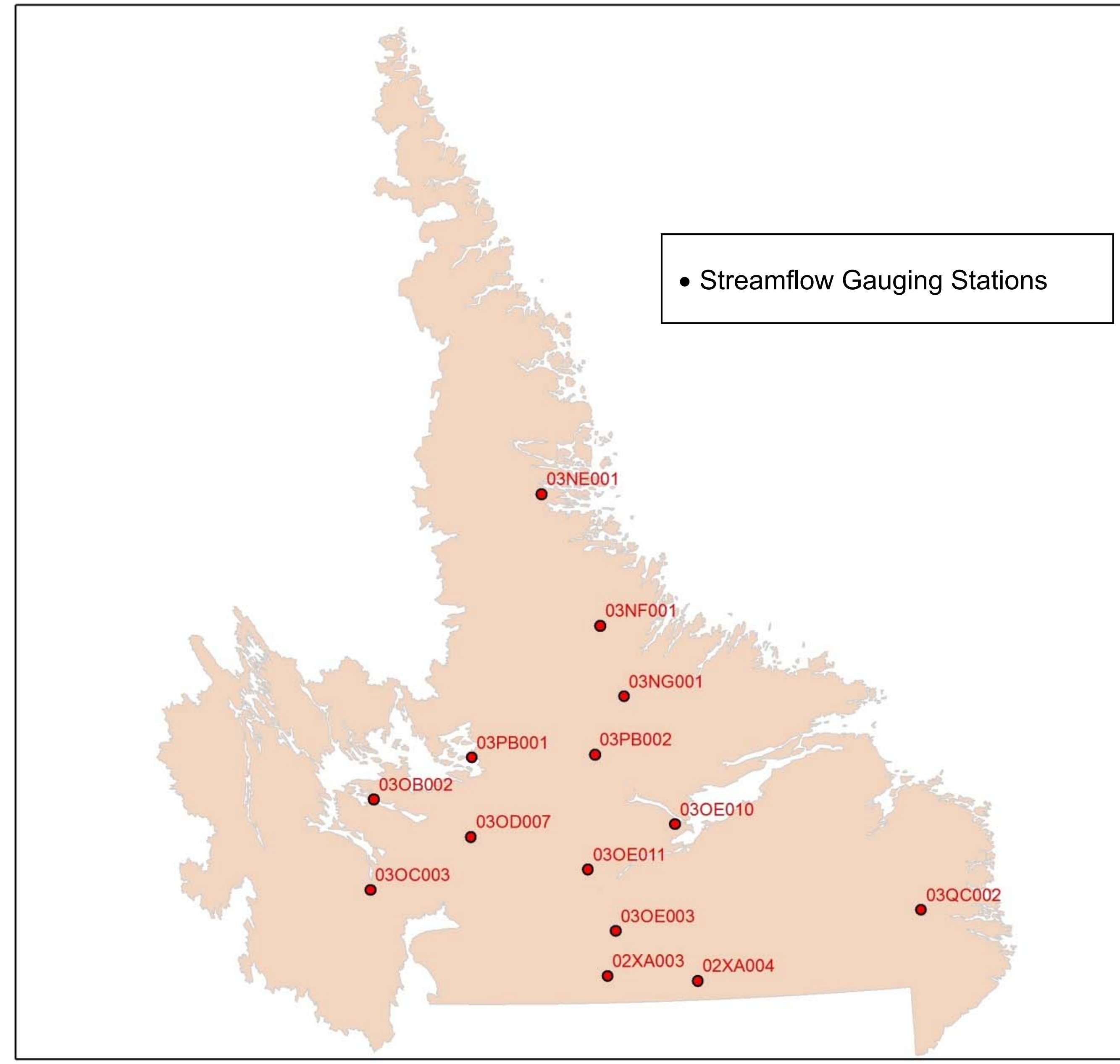

Figure 2-2: Locations of Streamflow Gauging Stations in Labrador

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Table 2-1: Streamflow Gauges Used in Further Analysis

Station	Drainage Area[2] (km^2)		Number of Years with Available Data	Number of Years with Missing Data	Number of Gaps Filled	Regression Correlation Coefficient
	From HYDAT	From GIS				
02XA003	4540	4892.8	27	8	5	0.9952
02XA004	2060	2017.3	12	5	3	0.9839
02YA001	306	305.9	25	3	2	0.9832
02YA002	33.6	32.8	24	3	2	0.9498
02YC001	624	619.7	51	3	2	0.9943
02YD001	237	263.1	19	1	0	-
02YD002	200	197.7	31	2	1	0.9949
02YE001	95.7	100.2	25	4	3	0.7454
02YF001	611	636.9	14	1	0	-
02YG001	627	632.3	24	3	2	0.8915
02YG002	224	222.5	10	1	0	-
02YH001	33.4	31.5	12	2	1	0.9638
02YJ001	640	617.9	40	5	0	-
02YJ003	119	116.4	11	1	0	-
02YK002	470	476.5	49	8	2	0.9935
02YK003	362	365.6	11	1	0	-
02YK004	529	659.6	22	2	1	0.9761
02YK007	112	111.5	11	3	2	0.9861
02YK008	20.4	20.5	26	2	0	-
02YL001	2110	2101.1	83	2	0	-
02YL004	58.5	58.0	27	3	2	0.6741
02YL005	17	17.3	22	6	0	-
02YL008	471	472.7	23	2	1	0.8208
02YL011	12.9	11.6	17	1	0	-
02YM001	974	964.6	40	3	1	0.8717
02YM003	93.2	96.4	30	3	2	0.8238
02YM004	238	242.5	23	0	0	-
02YN002	469	480.5	31	1	0	-
02YN004	276	277.6	12	1	0	-
02YO006	177	177.7	31	1	1	0.9766
02YO007	88.3	86.8	7	6	5	0.8004
02YO008	773	803.4	21	8	8	0.9476
02YO010	61.6	61.5	5	8	7	0.8587
02YO012	58.7	62.9	23	1	1	0.8404
02YP001	63.8	62.8	13	3	2	0.8637
02YQ001	4450	4447.3	63	1	0	-
02YQ004	2200	2207.2	10	6	6	0.9401
02YQ005	80.8	78.8	20	6	6	0.8494
02YR001	275	266.0	49	5	5	0.9975
02YR002	399	394.8	17	4	4	0.9787
02YR003	554	581.2	30	2	2	0.9967
02YS001	1290	1327.2	30	4	1	0.9502
02YS003	36.7	38.6	41	5	3	0.7435
02YS005	2000	2033.8	28	0	0	-
02YS006	663	669.1	16	2	1	0.9984
02ZA001	343	337.3	17	3	1	0.9462
02ZA002	72	70.3	30	1	0	-
02ZA003	139	127.8	14	2	1	0.8412
02ZB001	205	204.3	49	2	1	0.7534
02ZC002	230	251.8	26	5	3	0.6530
02ZD002	1340	4588.3	31	10	4	0.8435
02ZE001	2640	5920.9	16	6	5	0.9980
02ZE004	99.5	99.9	24	0	0	-
02ZF001	1170	1171.9	60	3	1	0.9904
02ZG001	205	210.7	47	8	6	0.9895
02ZG002	166	163.6	19	2	1	0.9956
02ZG003	115	116.4	30	3	2	0.8094
02ZG004	42.7	44.4	29	3	2	0.8346
02ZH001	764	764.7	55	6	4	0.8745
02ZH002	43.3	34.9	39	6	4	0.8569
02ZJ001	67.4	68.5	32	5	4	0.8287
02ZJ002	73.6	78.3	21	9	9	0.7394
02ZJ003	106	99.5	23	4	4	0.7611
02ZK001	301	295.7	59	6	4	0.8293
02ZK003	37.2	37.1	28	2	1	0.6129
02ZK004	104	104.7	29	1	0	-
02ZK005	50.3	47.2	6	6	5	0.8487
02ZL003	10.8	10.8	18	1	0	-
02ZL004	28.9	29.8	27	3	0	-
02ZL005	11.2	11.2	27	1	0	-
02ZM006	3.63	3.7	42	18	0	-
02ZM009	53.6	54.9	33	1	0	-
02ZM010	16.6	17.7	15	1	0	-
02ZM016	17.3	16.6	29	1	0	-
02ZM017	15.3	7.1	15	1	1	0.5310
02ZM018	10.7	12.1	26	3	2	0.5093
02ZM019	5.55	5.4	14	0	0	-
02ZM021	9.21	10.1	13	0	0	-
02ZN001	53.3	90.3	28	3	2	0.6805
02ZN002	15.5	15.7	17	11	10	0.7401
03NE001	75.7	76.1	13	2	1	0.9960
03NF001	7570	7557.6	22	12	11	0.9973
03NG001	8930	8912.0	13	5	4	0.9993
03OC003	15100	15776.1	14	13	3	0.9996
03OD007	1750	894.8	12	3	2	0.9938
03OE003	2330	2336.2	27	6	3	0.9998
03OE010	71.4	70.7	18	1	0	-
03OE011	n/a	781.5	13	2	1	0.9993
03PB002	4480	4609.2	25	9	5	0.9996
03QC002	2310	2318.3	31	4	4	0.9722

NOTES:
1. (shaded) Stations with a drainage area < 50 km^2 (ref. Section 4.1.1.5)
2. Drainage Area based on GIS data

Table 2-2: Single Station Frequency Analysis Results – 3PLN Distribution (m^3/s)

Station	Q2	Q5	Q10	Q20	Q50	Q100	Q200
02XA003	630.7	791.5	891.2	983.0	1097.6	1181.4	1263.6
02XA004	334.4	432.3	494.5	552.5	626.0	680.3	734.1
02YA001	31.6	40.9	46.8	52.3	59.2	64.4	69.5
02YA002	13.9	20.0	24.1	28.3	33.8	38.0	42.3
02YC001	178.4	238.2	277.1	314.0	361.3	396.8	432.3
02YD001	98.9	129.4	149.0	167.3	190.6	207.9	225.2
02YD002	39.8	48.4	53.6	58.3	64.1	68.3	72.3
02YE001	43.4	55.3	62.7	69.6	78.2	84.6	90.9
02YF001	271.5	338.2	379.4	417.2	464.3	498.5	532.1
02YG001	293.4	359.9	400.4	437.3	482.9	515.9	548.1
02YG002	46.1	65.2	78.1	90.7	107.4	120.1	133.1
02YH001	5.2	7.7	9.5	11.2	13.6	15.4	17.3
02YJ001	291.8	397.9	468.0	535.1	622.1	687.9	754.1
02YJ003	29.1	36.7	41.4	45.8	51.3	55.3	59.2
02YK002	117.6	143.9	159.9	174.5	192.5	205.5	218.2
02YK003	61.9	84.3	99.1	113.2	131.5	145.3	159.3
02YK004	91.2	111.8	124.3	135.7	149.8	160.1	170.0
02YK007	23.1	29.7	33.9	37.8	42.8	46.4	50.0
02YK008	9.2	13.7	16.9	20.1	24.4	27.7	31.2
02YL001	577.1	699.7	773.8	840.9	923.4	982.9	1040.6
02YL004	41.6	60.3	73.3	86.0	103.1	116.3	129.8
02YL005	10.1	14.0	16.7	19.2	22.5	25.1	27.6
02YL008	241.2	297.3	331.6	362.9	401.7	429.9	457.4
02YL011	6.6	9.2	11.0	12.7	15.0	16.8	18.5
02YM001	144.0	177.6	198.2	217.0	240.3	257.2	273.7
02YM003	36.5	53.3	65.0	76.6	92.1	104.2	116.6
02YM004	38.2	44.2	47.8	50.9	54.7	57.4	59.9
02YN002	167.0	229.4	270.7	310.4	362.1	401.3	440.8
02YN004	121.7	134.7	142.0	148.4	155.9	161.1	166.0
02YO006	44.9	62.1	73.6	84.6	99.1	110.0	121.1
02YO007	29.8	37.6	42.4	46.9	52.5	56.6	60.7
02YO008	206.1	266.3	304.4	340.0	385.1	418.4	451.4
02YO010	10.9	15.0	17.7	20.3	23.8	26.4	29.0
02YO012	14.9	20.2	23.6	26.9	31.2	34.4	37.7
02YP001	21.2	26.7	30.1	33.2	37.1	40.0	42.8
02YQ001	573.1	729.8	828.1	919.2	1033.8	1118.0	1201.0
02YQ004	619.6	858.3	1017.8	1171.5	1372.5	1525.4	1680.1
02YQ005	36.9	53.6	65.1	76.5	91.7	103.5	115.6
02YR001	28.7	37.7	43.5	48.9	55.8	61.0	66.1
02YR002	67.2	85.6	97.2	107.9	121.3	131.2	141.0
02YR003	58.5	77.0	88.9	100.1	114.4	125.1	135.7
02YS001	169.9	207.8	231.0	252.0	277.9	296.7	315.0
02YS003	13.9	18.7	21.8	24.9	28.7	31.7	34.6
02YS005	214.8	285.3	330.9	374.1	429.4	470.7	512.1
02YS006	115.4	165.4	199.6	233.1	277.7	312.0	347.1
02ZA001	113.6	158.1	187.8	216.5	254.2	282.8	311.9
02ZA002	51.0	74.7	91.2	107.5	129.4	146.4	163.9
02ZA003	148.5	211.2	253.8	295.5	350.6	392.9	436.1

Table 2-2: Single Station Frequency Analysis Results – 3PLN Distribution (m^3/s)

Station	Q2	Q5	Q10	Q20	Q50	Q100	Q200
02ZB001	338.5	502.8	618.3	733.4	888.9	1010.4	1136.1
02ZC002	349.8	470.4	549.1	624.0	720.6	793.1	865.9
02ZD002	867.2	1187.9	1400.2	1603.8	1868.7	2069.2	2271.4
02ZE001	282.0	356.7	403.4	446.6	500.6	540.3	579.3
02ZE004	40.2	52.1	59.7	66.8	75.7	82.3	88.9
02ZF001	196.8	267.7	314.4	359.1	417.0	460.7	504.7
02ZG001	60.1	88.6	108.5	128.3	154.9	175.6	197.0
02ZG002	46.9	65.7	78.5	90.8	107.0	119.4	132.1
02ZG003	65.6	92.6	110.8	128.6	152.0	169.9	188.1
02ZG004	37.0	53.9	65.6	77.2	92.7	104.7	117.0
02ZH001	225.7	331.6	405.4	478.6	577.0	653.5	732.4
02ZH002	31.5	45.7	55.4	65.0	77.8	87.7	97.8
02ZJ001	23.5	35.4	43.8	52.2	63.7	72.7	82.0
02ZJ002	14.5	20.1	23.9	27.5	32.3	35.9	39.6
02ZJ003	35.1	54.8	69.2	83.9	104.2	120.4	137.5
02ZK001	146.0	202.3	239.9	276.1	323.5	359.5	396.0
02ZK003	40.6	60.1	73.9	87.6	106.0	120.5	135.4
02ZK004	81.7	114.7	137.0	158.6	187.1	208.8	230.9
02ZK005	26.2	39.7	49.3	58.9	72.1	82.4	93.2
02ZL003	8.3	12.2	14.9	17.7	21.3	24.2	27.1
02ZL004	14.7	21.6	26.5	31.4	37.9	43.0	48.2
02ZL005	5.4	7.9	9.7	11.5	13.9	15.8	17.7
02ZM006	3.5	4.8	5.7	6.5	7.6	8.4	9.3
02ZM009	28.3	33.8	37.1	40.1	43.8	46.4	48.9
02ZM010	17.2	23.8	28.2	32.4	38.0	42.2	46.4
02ZM016	10.9	14.9	17.6	20.1	23.5	26.0	28.5
02ZM017	12.6	16.5	19.0	21.3	24.2	26.4	28.5
02ZM018	9.1	12.0	13.9	15.6	17.8	19.5	21.1
02ZM019	3.5	4.5	5.2	5.8	6.6	7.2	7.8
02ZM021	10.3	13.6	15.8	17.8	20.4	22.3	24.2
02ZN001	37.1	47.4	53.9	59.9	67.4	73.0	78.5
02ZN002	9.6	13.0	15.3	17.4	20.2	22.3	24.4
03NE001	18.9	23.1	25.7	28.1	31.0	33.1	35.2
03NF001	1128.4	1443.5	1641.9	1826.0	2058.2	2229.1	2397.9
03NG001	1092.3	1426.6	1640.2	1840.6	2095.5	2284.8	2472.9
03OC003	1099.0	1275.3	1378.5	1470.0	1580.2	1658.2	1733.0
03OD007	189.6	244.1	278.6	310.7	351.2	381.2	410.8
03OE003	232.5	295.5	335.0	371.6	417.5	451.3	484.5
03OE010	14.5	17.7	19.6	21.4	23.5	25.1	26.6
03OE011	116.2	151.4	173.8	194.8	221.5	241.4	261.0
03PB002	453.3	564.3	632.7	695.4	773.4	830.3	885.9
03QC002	523.4	644.5	718.6	786.2	869.9	930.6	989.8

Table 2-3: Ninety-five Percent (95%) Confidence Interval as a Percentage of the 3PLN Return Period Flows

Station Number	Sample size	2 Year			20 Year			100 Year		
		Lower Limit	Flow (m^3/s)	Upper Limit	Lower Limit	Flow (m^3/s)	Upper Limit	Lower Limit	Flow (m^3/s)	Upper Limit
02XA003	29	-8.1%	630.7	8.8%	-10.4%	983.0	16.8%	-12.7%	1181.4	22.1%
02XA004	14	-13.2%	334.4	15.2%	-15.8%	552.5	33.4%	-18.9%	680.3	45.5%
02YA001	27	-9.5%	31.6	10.5%	-12.1%	52.3	20.2%	-14.7%	64.4	26.8%
02YA002	26	-13.4%	13.9	15.5%	-17.0%	28.3	30.7%	-20.5%	38.0	41.1%
02YC001	53	-7.6%	178.4	8.2%	-10.2%	314.0	14.7%	-12.4%	396.8	19.2%
02YD001	19	-11.8%	98.9	13.3%	-14.5%	167.3	27.4%	-17.5%	207.9	36.8%
02YD002	32	-6.7%	39.8	7.1%	-8.7%	58.3	13.4%	-10.6%	68.3	17.5%
02YE001	27	-8.9%	43.4	9.8%	-11.4%	69.6	18.9%	-13.8%	84.6	24.9%
02YF001	14	-11.4%	271.5	12.9%	-13.6%	417.2	28.0%	-16.4%	498.5	37.8%
02YG001	26	-7.7%	293.4	8.4%	-9.9%	437.3	16.2%	-12.0%	515.9	21.3%
02YG002	10	-20.7%	46.1	26.1%	-23.4%	90.7	65.8%	-27.8%	120.1	94.2%
02YH001	13	-20.2%	5.2	25.4%	-23.7%	11.2	59.3%	-28.2%	15.4	83.5%
02YJ001	40	-9.3%	291.8	10.2%	-12.2%	535.1	19.0%	-14.9%	687.9	25.0%
02YJ003	11	-13.7%	29.1	15.9%	-15.8%	45.8	36.9%	-18.9%	55.3	50.8%
02YK002	39	-6.2%	117.6	6.7%	-8.2%	174.5	12.2%	-10.1%	205.5	15.9%
02YK003	11	-17.8%	61.9	21.6%	-20.4%	113.2	51.8%	-24.3%	145.3	72.6%
02YK004	23	-8.2%	91.2	8.9%	-10.4%	135.7	17.5%	-12.6%	160.1	23.2%
02YK007	13	-13.5%	23.1	15.6%	-15.9%	37.8	34.8%	-19.1%	46.4	47.6%
02YK008	25	-14.5%	9.2	17.0%	-18.4%	20.1	33.9%	-22.1%	27.7	45.6%
02YL001	83	-4.1%	577.1	4.3%	-5.6%	840.9	7.3%	-7.0%	982.9	9.4%
02YL004	29	-12.9%	41.6	14.8%	-16.5%	86.0	29.0%	-20.0%	116.3	38.7%
02YL005	22	-13.2%	10.1	15.2%	-16.5%	19.2	30.9%	-19.9%	25.1	41.5%
02YL008	24	-8.2%	241.2	9.0%	-10.5%	362.9	17.5%	-12.7%	429.9	23.1%
02YL011	17	-15.5%	6.6	18.3%	-18.8%	12.7	39.3%	-22.6%	16.8	53.6%
02YM001	41	-6.3%	144.0	6.7%	-8.4%	217.0	12.3%	-10.2%	257.2	16.0%
02YM003	32	-12.6%	36.5	14.4%	-16.2%	76.6	27.7%	-19.6%	104.2	36.8%
02YM004	23	-6.0%	38.2	6.4%	-7.6%	50.9	12.4%	-9.3%	57.4	16.3%
02YN002	31	-10.8%	167.0	12.1%	-13.9%	310.4	23.1%	-16.8%	401.3	30.6%
02YN004	12	-5.9%	121.7	6.3%	-7.0%	148.4	13.7%	-8.5%	161.1	18.2%
02YO006	32	-10.8%	44.9	12.1%	-14.0%	84.6	23.2%	-17.0%	110.0	30.7%
02YO007	12	-13.1%	29.8	15.0%	-15.2%	46.9	34.0%	-18.3%	56.6	46.5%
02YO008	29	-9.1%	206.1	10.0%	-11.7%	340.0	19.2%	-14.2%	418.4	25.3%
02YO010	12	-17.6%	10.9	21.3%	-20.4%	20.3	49.8%	-24.4%	26.4	69.5%
02YO012	24	-11.7%	14.9	13.2%	-14.8%	26.9	26.3%	-17.8%	34.4	35.1%
02YP001	14	-11.9%	21.2	13.5%	-14.2%	33.2	29.3%	-17.1%	40.0	39.7%
02YQ001	63	-5.8%	573.1	6.2%	-7.9%	919.2	10.9%	-9.8%	1118.0	14.2%
02YQ004	16	-15.4%	619.6	18.2%	-18.6%	1171.5	39.3%	-22.3%	1525.4	53.8%
02YQ005	26	-13.7%	36.9	15.9%	-17.3%	76.5	31.5%	-20.9%	103.5	42.3%
02YR001	54	-7.1%	28.7	7.6%	-9.5%	48.9	13.6%	-11.6%	61.0	17.7%
02YR002	21	-10.1%	67.2	11.3%	-12.7%	107.9	22.6%	-15.3%	131.2	30.2%
02YR003	32	-9.3%	58.5	10.2%	-12.0%	100.1	19.4%	-14.6%	125.1	25.5%
02YS001	26	-7.6%	169.9	8.3%	-9.8%	252.0	15.9%	-11.9%	296.7	21.0%
02YS003	44	-8.6%	13.9	9.4%	-11.4%	24.9	17.2%	-13.8%	31.7	22.5%
02YS005	28	-10.2%	214.8	11.4%	-13.1%	374.1	22.0%	-15.8%	470.7	29.1%
02YS006	17	-16.3%	115.4	19.5%	-19.8%	233.1	42.0%	-23.7%	312.0	57.5%
02ZA001	18	-14.6%	113.6	17.2%	-17.9%	216.5	36.2%	-21.5%	282.8	49.2%
02ZA002	30	-13.0%	51.0	15.0%	-16.7%	107.5	29.1%	-20.1%	146.4	38.8%
02ZA003	15	-17.0%	148.5	20.5%	-20.4%	295.5	45.5%	-24.4%	392.9	62.8%
02ZB001	50	-10.5%	338.5	11.7%	-14.0%	733.4	21.5%	-17.0%	1010.4	28.2%
02ZC002	22	-12.0%	349.8	13.6%	-15.0%	624.0	27.4%	-18.1%	793.1	36.7%
02ZD002	31	-10.9%	867.2	12.2%	-14.0%	1603.8	23.5%	-16.9%	2069.2	31.1%
02ZE001	16	-11.4%	282.0	12.8%	-13.8%	446.6	27.0%	-16.6%	540.3	36.4%
02ZE004	24	-10.1%	40.2	11.2%	-12.8%	66.8	22.2%	-15.5%	82.3	29.4%
02ZF001	61	-7.5%	196.8	8.1%	-10.1%	359.1	14.4%	-12.4%	460.7	18.7%
02ZG001	53	-10.0%	60.1	11.1%	-13.4%	128.3	20.2%	-16.3%	175.6	26.5%
02ZG002	20	-14.2%	46.9	16.6%	-17.6%	90.8	34.3%	-21.2%	119.4	46.4%
02ZG003	32	-11.4%	65.6	12.9%	-14.8%	128.6	24.8%	-17.9%	169.9	32.9%
02ZG004	31	-12.7%	37.0	14.5%	-16.3%	77.2	28.0%	-19.7%	104.7	37.4%

Table 2-3: Ninety-five Percent (95%) Confidence Interval as a Percentage of the 3PLN Return Period Flows

Station Number	Sample size	2 Year			20 Year			100 Year		
		Lower Limit	Flow (m^3/s)	Upper Limit	Lower Limit	Flow (m^3/s)	Upper Limit	Lower Limit	Flow (m^3/s)	Upper Limit
02ZH001	59	-9.4%	225.7	10.4%	-12.7%	478.6	18.7%	-15.5%	653.5	24.5%
02ZH002	42	-10.7%	31.5	12.0%	-14.1%	65.0	22.3%	-17.1%	87.7	29.4%
02ZJ001	36	-12.7%	23.5	14.5%	-16.5%	52.2	27.6%	-19.9%	72.7	36.7%
02ZJ002	30	-11.3%	14.5	12.7%	-14.5%	27.5	24.6%	-17.6%	35.9	32.6%
02ZJ003	27	-15.8%	35.1	18.8%	-20.1%	83.9	37.7%	-24.1%	120.4	50.9%
02ZK001	63	-7.8%	146.0	8.5%	-10.6%	276.1	15.0%	-12.9%	359.5	19.5%
02ZK003	28	-13.9%	40.6	16.1%	-17.7%	87.6	31.7%	-21.3%	120.5	42.5%
02ZK004	29	-11.9%	81.7	13.5%	-15.2%	158.6	26.2%	-18.4%	208.8	34.8%
02ZK005	11	-23.1%	26.2	30.0%	-26.4%	58.9	74.9%	-31.2%	82.4	107.9%
02ZL003	18	-17.0%	8.3	20.4%	-20.7%	17.7	43.7%	-24.8%	24.2	60.0%
02ZL004	27	-14.0%	14.7	16.2%	-17.7%	31.4	32.1%	-21.4%	43.0	43.1%
02ZL005	27	-14.0%	5.4	16.2%	-17.7%	11.5	32.1%	-21.4%	15.8	43.1%
02ZM006	42	-9.3%	3.5	10.3%	-12.3%	6.5	19.0%	-15.0%	8.4	25.0%
02ZM009	33	-6.0%	28.3	6.4%	-7.9%	40.1	12.0%	-9.6%	46.4	15.6%
02ZM010	15	-15.8%	17.2	18.8%	-18.9%	32.4	41.3%	-22.7%	42.2	56.7%
02ZM016	29	-11.0%	10.9	12.3%	-14.1%	20.1	23.9%	-17.1%	26.0	31.7%
02ZM017	15	-13.2%	12.6	15.2%	-15.8%	21.3	32.8%	-19.0%	26.4	44.5%
02ZM018	26	-10.2%	9.1	11.4%	-13.0%	15.6	22.2%	-15.8%	19.5	29.4%
02ZM019	14	-13.6%	3.5	15.8%	-16.3%	5.8	34.7%	-19.5%	7.2	47.4%
02ZM021	13	-14.8%	10.3	17.4%	-17.5%	17.8	39.2%	-21.0%	22.3	53.9%
02ZN001	30	-8.6%	37.1	9.4%	-11.1%	59.9	17.8%	-13.5%	73.0	23.5%
02ZN002	27	-11.6%	9.6	12.4%	-13.9%	17.4	24.5%	-17.1%	22.3	32.3%
03NE001	14	-10.6%	18.9	11.9%	-12.7%	28.1	25.7%	-15.3%	33.1	34.7%
03NF001	31	-8.5%	1128.4	9.2%	-11.0%	1826.0	17.5%	-13.3%	2229.1	23.1%
03NG001	13	-14.2%	1092.3	16.6%	-16.8%	1840.6	37.2%	-20.1%	2284.8	51.1%
03OC003	14	-7.9%	1099.0	8.6%	-9.5%	1470.0	18.2%	-11.4%	1658.2	24.2%
03OD007	14	-13.0%	189.6	15.0%	-15.5%	310.7	32.7%	-18.6%	381.2	44.6%
03OE003	30	-8.4%	232.5	9.2%	-10.8%	371.6	17.4%	-13.2%	451.3	22.9%
03OE010	18	-9.1%	14.5	10.0%	-11.2%	21.4	20.4%	-13.5%	25.1	27.1%
03OE011	14	-13.6%	116.2	15.7%	-16.2%	194.8	34.5%	-19.4%	241.4	47.1%
03PB002	25	-8.4%	453.3	9.2%	-10.7%	695.4	17.9%	-13.0%	830.3	23.6%
03QC002	35	-6.8%	523.4	7.3%	-8.9%	786.2	13.5%	-10.8%	930.6	17.6%
Median		**-11.1%**		**12.3%**	**-14.0%**		**24.5%**	**-17.0%**		**32.4%**
# of stations < 50%		**0**			**0**			**0**		
# of stations < 40%		**0**			**0**			**0**		
# of stations < 30%		**0**			**0**			**1**		
# of stations < 20%		**3**			**8**			**23**		
# of stations < 10%		**57**			**77**			**85**		
# of stations > 50%				**0**			**4**			**15**
# of stations > 40%				**0**			**9**			**31**
# of stations > 30%				**0**			**31**			**52**
# of stations > 20%				**7**			**60**			**77**
# of stations > 10%				**63**			**89**			**89**

3.0 REGIONAL FLOOD FREQUENCY ANALYSIS

3.1 General

The island of Newfoundland was divided into four hydrologically homogenous regions to support the 1999 RFFA. It was documented in the 1999 RFFA report that these divisions were based on previous studies, the availability of data, regional flood characteristics, regional precipitation characteristics, regional physiographic characteristics and the results of regression analysis on test regions. It was agreed with WRMD that the current study has used the same four hydrological regions in order to be consistent with the 1999 RFFA (ref. Figure 3-1). The analysis has been conducted using the available seventy-eight (78) gauges on the island of Newfoundland which passed all screening procedures.

The analysis for Labrador has been conducted, considering Labrador to be one single homogenous region, using the remaining twelve (12) streamflow gauges.

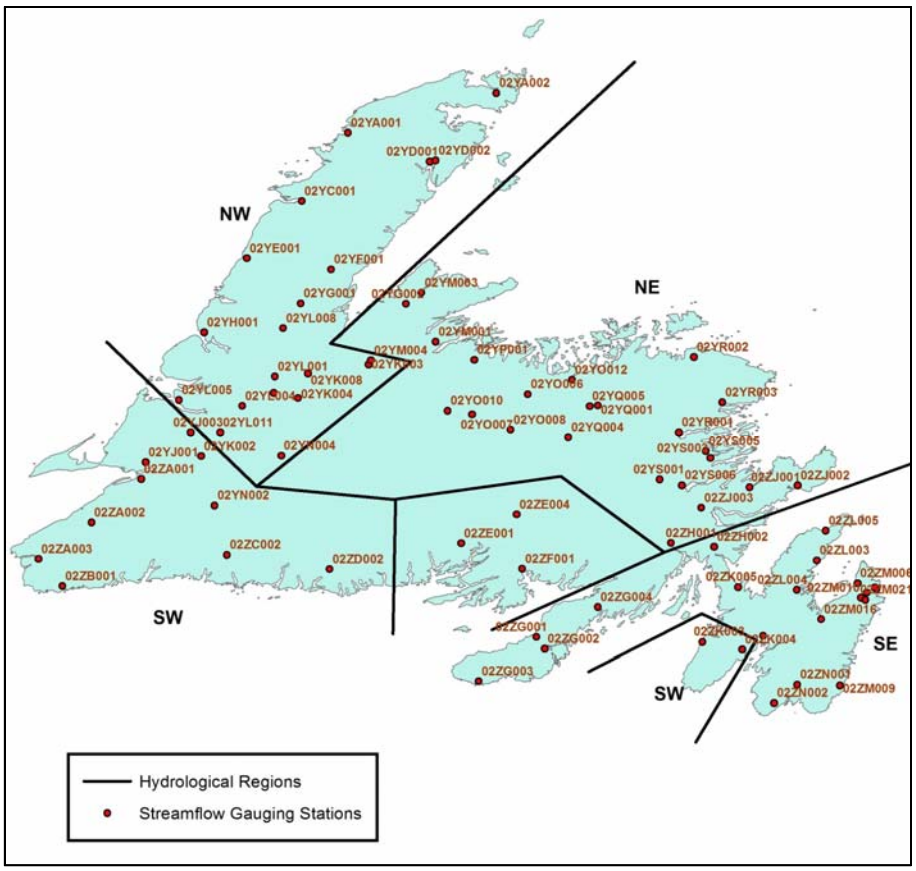

Figure 3-1: Hydrological Regions in Newfoundland

3.2 Linear Multiple Regression Analysis

Linear multiple regression analysis, which is an extension of simple linear regression, correlates more than one independent variables (X) to a single dependent variable (Y). In this form of regression equation, the predicted value of Y is a linear transformation of the X variables such that the sum of squared deviations of the observed and predicted Y is a minimum.

As component of the 1999 RFFA, regression equations were developed, in the form presented below, for each one of the four (4) hydrologically homogenous regions in Newfoundland:

$$Q_T = c \times (var1)^{a1} \times (var2)^{a2} \times (var3)^{a3} \times ... \quad \text{[Eq. 4-1]}$$

where Q_T is the estimated flow with a return period of T
c and a_i (where i = 1, 2, 3,.....) are constant values and
var_i (where i = 1, 2, 3, ...) are the selected physiographic parameters.

Further, in order to facilitate the estimation of these constant values using available statistical software packages, a $\log_{10}$ transformation of both sides of the equation was completed to facilitate the multiple linear regression in the equation form presented below:

$$\log_{10}(Q_T) = \log_{10}(c) + a_1 \times \log_{10}(var_1) + a_2 \times \log_{10}(var_2) + a_3 \times \log_{10}(var_3) + ... \quad \text{[Eq. 4-2]}$$

The same approach has been adopted for the current study in order to maintain consistency with the 1999 RFFA. Using this approach, multiple regression equations have been developed for each of the five regions of Newfoundland and Labrador (the latter as a single region). These regression equations correlate the estimated peak flows from the single station frequency analysis with return periods of 2 to 200 years to physiographic characteristics of the corresponding watersheds, as outlined in the following sections.

The 1999 RFFA identified three primary regression variables upon which the regression equations were founded. These variables are Drainage Area (DA), Lake Attenuation Factor (LAF) and the Lakes and Swamps Factor (LSF) and each is discussed in the main 2014 RFFA Update report. Procedures for estimation of regression and other watershed parameters has been outlined in Appendix A. Values for all variables used for regression equation development for all gauges in Newfoundland and Labrador have been summarized in Table 3-1. The full physiographic database is provided in Appendix B.

3.2.1 Linear Multiple Regression Analysis Results

Linear multiple regression analysis has been conducted using the results from the single station frequency analysis.

Equations for the North-East (NE), North-West (NW) and South-East (SE) regions of Newfoundland and Labrador have been developed based on the DA and LAF variables in a manner consistent with the 1999 RFFA.

Similarly, equations for the South-West (SW) region of Newfoundland have been developed based on the DA and LSF variables, consistent with the 1999 RFFA. Hence, the LSF variable has been defined in Table 4-1 for only those stations located in the south-west region of Newfoundland.

Estimated constant coefficients for all return periods in each of the five regions[1], as well as statistical parameters, namely, the regression correlation coefficient[2] (SMR) and the standard error of the estimate (SEE) for log to base 10 transformed data are presented in Tables 3-2 and 3-3.

The equations developed from the parameters provided in Tables 3-2 and 3-are presented in Tables 3-4 to 3-13. Both one parameter and two parameter equations have been provided for flexibility for situations when the LAF or LSF parameter cannot be estimated.

[1] Labrador plus the NW, NE, SW and SE regions of Newfoundland
[2] Also known as 'multiple R squared'

Table 3-1: Physiographic Parameters Used in 2014 RFFA

Station ID	Region	Area (km^2)	LAF	LSF[1]	Q2 (m^3/s)	Q5 (m^3/s)	Q10 (m^3/s)	Q20 (m^3/s)	Q50 (m^3/s)	Q100 (m^3/s)	Q200 (m^3/s)
02YM001	NE	965	36		144	178	198	217	240	257	274
02YM003	NE	96	50		36	53	65	77	92	104	117
02YO006	NE	178	50		45	62	74	85	99	110	121
02YO008	NE	803	50		206	266	304	340	385	418	451
02YO012	NE	63	128		15	20	24	27	31	34	38
02YP001	NE	63	119		21	27	30	33	37	40	43
02YQ001	NE	4447	277		573	730	828	919	1034	1118	1201
02YQ005	NE	79	50		37	54	65	76	92	104	116
02YR001	NE	266	881		29	38	43	49	56	61	66
02YR002	NE	395	65		67	86	97	108	121	131	141
02YR003	NE	581	307		58	77	89	100	114	125	136
02YS001	NE	1327	138		170	208	231	252	278	297	315
02YS003	NE	39	50		14	19	22	25	29	32	35
02YS005	NE	2034	113		215	285	331	374	429	471	512
02ZH001	NE	765	17		226	332	405	479	577	653	732
02ZJ001	NE	69	89		24	35	44	52	64	73	82
02ZJ002	NE	78	435		14	20	24	28	32	36	40
02YG002	NE	222	299		46	65	78	91	107	120	133
02YO007	NE	87	50		30	38	42	47	53	57	61
02YO010	NE	62	601		11	15	18	20	24	26	29
02YQ004	NE	2207	50		620	858	1018	1172	1373	1525	1680
02YS006	NE	669	12		115	165	200	233	278	312	347
02ZJ003	NE	99	166		35	55	69	84	104	120	137
02YA001	NW	306	1053		32	41	47	52	59	64	69
02YC001	NW	620	175		178	238	277	314	361	397	432
02YD001	NW	263	50		99	129	149	167	191	208	225
02YD002	NW	198	484		40	48	54	58	64	68	72
02YE001	NW	100	134		43	55	63	70	78	85	91
02YF001	NW	637	50		271	338	379	417	464	499	532
02YG001	NW	632	18		293	360	400	437	483	516	548
02YK004	NW	660	666		91	112	124	136	150	160	170
02YK007	NW	112	132		23	30	34	38	43	46	50
02YK008	NW	20	50		9	14	17	20	24	28	31
02YL001	NW	2101	50		577	700	774	841	923	983	1041
02YL004	NW	58	50		42	60	73	86	103	116	130
02YL008	NW	473	50		241	297	332	363	402	430	457
02YM004	NW	243	225		38	44	48	51	55	57	60
02YN004	NW	278	50		122	135	142	148	156	161	166
02YA002	NW	33	652		14	20	24	28	34	38	42
02YH001	NW	31	545		5	8	9	11	14	15	17
02YK003	NW	366	688		62	84	99	113	132	145	159
02YL005	NW	17	50		10	14	17	19	23	25	28
02YL011	NW	12	700		7	9	11	13	15	17	19
02ZG001	SE	211	202		60	89	108	128	155	176	197
02ZG003	SE	116	43		66	93	111	129	152	170	188
02ZG004	SE	44	123		37	54	66	77	93	105	117
02ZH002	SE	35	21		32	46	55	65	78	88	98
02ZK001	SE	296	9		146	202	240	276	324	360	396
02ZL004	SE	30	50		15	22	27	31	38	43	48
02ZL005	SE	11	272		5	8	10	12	14	16	18
02ZM006	SE	4	265		3	5	6	7	8	8	9
02ZM009	SE	55	193		28	34	37	40	44	46	49
02ZM016	SE	17	148		11	15	18	20	23	26	28
02ZM017	SE	7	50		13	16	19	21	24	26	29
02ZM018	SE	12	21		9	12	14	16	18	19	21
02ZM021	SE	10	50		10	14	16	18	20	22	24
02ZN001	SE	90	132		37	47	54	60	67	73	79
02ZN002	SE	16	512		10	13	15	17	20	22	24
02ZG002	SE	164	588		47	66	78	91	107	119	132
02ZK005	SE	47	92		26	40	49	59	72	82	93
02ZL003	SE	11	319		8	12	15	18	21	24	27
02ZM010	SE	18	50		17	24	28	32	38	42	46
02ZM019	SE	5	105		3	5	5	6	7	7	8
02YJ001	SW	618	141	1.67	292	398	468	535	622	688	754
02YJ003	SW	116	290	1.95	29	37	41	46	51	55	59
02YK002	SW	476	274	1.92	118	144	160	174	192	206	218
02YN002	SW	480	371	1.91	167	229	271	310	362	401	441
02ZB001	SW	204	50	1.52	338	503	618	733	889	1010	1136
02ZC002	SW	252	38	1.30	350	470	549	624	721	793	866
02ZD002	SW	4588	50	1.51	867	1188	1400	1604	1869	2069	2271
02ZE001	SW	5921	619	1.92	282	357	403	447	501	540	579
02ZE004	SW	100	50	1.81	40	52	60	67	76	82	89
02ZF001	SW	1172	401	1.84	197	268	314	359	417	461	505
02ZK004	SW	105	116	1.67	82	115	137	159	187	209	231
02ZA001	SW	337	50	1.78	114	158	188	217	254	283	312
02ZA002	SW	70	50	1.39	51	75	91	108	129	146	164
02ZA003	SW	128	131	1.66	149	211	254	295	351	393	436
02ZK003	SW	37	50	1.24	41	60	74	88	106	120	135
02XA003	Labrador	4893	50		631	792	891	983	1098	1181	1264
02XA004	Labrador	2017	50		334	432	494	552	626	680	734
03NE001	Labrador	76	27		19	23	26	28	31	33	35
03NF001	Labrador	7558	50		1128	1444	1642	1826	2058	2229	2398
03NG001	Labrador	8912	50		1092	1427	1640	1841	2095	2285	2473
03OC003	Labrador	15776	90		1099	1275	1378	1470	1580	1658	1733
03OD007	Labrador	895	131		190	244	279	311	351	381	411
03OE003	Labrador	2336	106		233	296	335	372	418	451	485
03OE010	Labrador	71	18		15	18	20	21	24	25	27
03OE011	Labrador	782	226		116	151	174	195	222	241	261
03PB002	Labrador	4609	50		453	564	633	695	773	830	886
03QC002	Labrador	2318	50		523	645	719	786	870	931	990

NOTES:

1. LSF only computed for SW Region

Table 3-2: Regression Coefficients for Newfoundland

NW Region

T	C	DA	LAF	SMR	SEE
Q2	3.959	0.883	-0.408	0.952	0.117
Q5	6.496	0.842	-0.415	0.942	0.125
Q10	8.416	0.820	-0.418	0.934	0.131
Q20	10.421	0.803	-0.421	0.925	0.138
Q50	13.256	0.783	-0.424	0.915	0.145
Q100	15.563	0.770	-0.426	0.906	0.151
Q200	18.024	0.757	-0.428	0.898	0.157
Q2	0.611	0.875		0.778	0.241
Q5	0.974	0.834		0.751	0.248
Q10	1.242	0.812		0.734	0.253
Q20	1.519	0.795		0.718	0.257
Q50	1.905	0.775		0.699	0.262
Q100	2.216	0.761		0.686	0.266
Q200	2.544	0.749		0.673	0.270

n=15

NE Region

T	C	DA	LAF	SMR	SEE
Q2	2.911	0.767	-0.285	0.964	0.102
Q5	4.746	0.745	-0.302	0.954	0.112
Q10	6.128	0.734	-0.310	0.947	0.119
Q20	7.568	0.725	-0.317	0.940	0.126
Q50	9.597	0.715	-0.325	0.931	0.134
Q100	11.243	0.708	-0.330	0.925	0.140
Q200	12.997	0.702	-0.335	0.918	0.145
Q2	0.836	0.755		0.902	0.161
Q5	1.271	0.733		0.882	0.173
Q10	1.582	0.722		0.870	0.181
Q20	1.895	0.712		0.858	0.187
Q50	2.322	0.702		0.844	0.195
Q100	2.658	0.695		0.834	0.200
Q200	3.009	0.688		0.824	0.205

N=17

SW Region

T	C	DA	LSF	SMR	SEE
Q2	90.931	0.523	-4.825	0.887	0.164
Q5	141.407	0.519	-5.060	0.871	0.179
Q10	178.118	0.517	-5.183	0.863	0.188
Q20	215.518	0.516	-5.284	0.855	0.195
Q50	267.085	0.514	-5.399	0.846	0.204
Q100	308.149	0.513	-5.475	0.840	0.210
Q200	351.240	0.512	-5.544	0.835	0.215
Q2	7.864	0.497		0.495	0.327
Q5	10.853	0.492		0.462	0.346
Q10	12.845	0.490		0.444	0.356
Q20	14.762	0.488		0.430	0.365
Q50	17.264	0.485		0.415	0.375
Q100	19.163	0.484		0.405	0.382
Q200	21.084	0.482		0.395	0.388

N=11

SE Region

T	C	DA	LAF	SMR	SEE
Q2	3.820	0.715	-0.180	0.938	0.120
Q5	5.135	0.721	-0.181	0.942	0.117
Q10	5.993	0.725	-0.181	0.941	0.118
Q20	6.809	0.728	-0.181	0.939	0.121
Q50	7.861	0.731	-0.181	0.936	0.125
Q100	8.651	0.733	-0.181	0.932	0.128
Q200	9.443	0.735	-0.181	0.929	0.132
Q2	1.464	0.762		0.901	0.145
Q5	1.966	0.768		0.905	0.143
Q10	2.293	0.772		0.904	0.144
Q20	2.604	0.775		0.903	0.146
Q50	3.005	0.778		0.900	0.149
Q100	3.306	0.780		0.897	0.152
Q200	3.608	0.782		0.894	0.155

N=15

Table 3-3: Regression Coefficients for Labrador

T	C	DA	LAF	SMR	SEE
Q2	0.581	0.845	-0.053	0.969	0.125
Q5	0.685	0.843	-0.034	0.965	0.133
Q10	0.746	0.842	-0.025	0.962	0.138
Q20	0.800	0.842	-0.017	0.960	0.142
Q50	0.866	0.841	-0.008	0.958	0.147
Q100	0.914	0.840	-0.002	0.956	0.150
Q200	0.959	0.840	0.004	0.954	0.153
Q2	0.495	0.837		0.968	0.120
Q5	0.617	0.838		0.965	0.127
Q10	0.692	0.839		0.962	0.131
Q20	0.761	0.839		0.960	0.135
Q50	0.847	0.840		0.958	0.139
Q100	0.909	0.840		0.956	0.142
Q200	0.970	0.840		0.954	0.145

n=12

North-West Region

Table 3-4: North-West Region of Newfoundland - One Parameter Equations		
One Parameter Equations	**SMR**	**SEE**
$Q_2 = 0.611 \times DA^{0.875}$	0.778	0.241
$Q_5 = 0.974 \times DA^{0.834}$	0.751	0.248
$Q_{10} = 1.242 \times DA^{0.812}$	0.734	0.253
$Q_{20} = 1.519 \times DA^{0.795}$	0.718	0.257
$Q_{50} = 1.905 \times DA^{0.775}$	0.699	0.262
$Q_{100} = 2.216 \times DA^{0.761}$	0.686	0.266
$Q_{200} = 2.544 \times DA^{0.749}$	0.673	0.270

Table 3-5: North-West Region of Newfoundland - Two Parameters Equations		
Two Parameters Equations	**SMR**	**SEE**
$Q_2 = 3.959 \times DA^{0.883} \times LAF^{-0.408}$	0.952	0.117
$Q_5 = 6.496 \times DA^{0.842} \times LAF^{-0.415}$	0.942	0.125
$Q_{10} = 8.416 \times DA^{0.820} \times LAF^{-0.418}$	0.934	0.131
$Q_{20} = 10.421 \times DA^{0.803} \times LAF^{-0.421}$	0.925	0.138
$Q_{50} = 13.256 \times DA^{0.783} \times LAF^{-0.424}$	0.915	0.145
$Q_{100} = 15.563 \times DA^{0.770} \times LAF^{-0.426}$	0.906	0.151
$Q_{200} = 18.024 \times DA^{0.757} \times LAF^{-0.428}$	0.898	0.157

North-East Region

Table 3-6: North-East Region of Newfoundland - One Parameter Equations		
One Parameter Equations	**SMR**	**SEE**
$Q_2 = 0.836 \times DA^{0.755}$	0.902	0.161
$Q_5 = 1.271 \times DA^{0.733}$	0.882	0.173
$Q_{10} = 1.582 \times DA^{0.722}$	0.870	0.181
$Q_{20} = 1.895 \times DA^{0.712}$	0.858	0.187
$Q_{50} = 2.322 \times DA^{0.702}$	0.844	0.195
$Q_{100} = 2.658 \times DA^{0.695}$	0.834	0.200
$Q_{200} = 3.009 \times DA^{0.688}$	0.824	0.205

Table 3-7: North-East Region of Newfoundland - Two Parameters Equations		
One Parameters Equations	**SMR**	**SEE**
$Q_2 = 2.911 \times DA^{0.767} \times LAF^{-0.285}$	0.964	0.102
$Q_5 = 4.746 \times DA^{0.745} \times LAF^{-0.302}$	0.954	0.112
$Q_{10} = 6.128 \times DA^{0.734} \times LAF^{-0.310}$	0.947	0.119
$Q_{20} = 7.568 \times DA^{0.725} \times LAF^{-0.317}$	0.940	0.126
$Q_{50} = 9.597 \times DA^{0.715} \times LAF^{-0.325}$	0.931	0.134
$Q_{100} = 11.243 \times DA^{0.708} \times LAF^{-0.330}$	0.925	0.140
$Q_{200} = 12.997 \times DA^{0.702} \times LAF^{-0.335}$	0.918	0.145

South-West Region

Table 3-8: South-West Region of Newfoundland - One Parameter Equations		
One Parameter Equations	**SMR**	**SEE**
$Q_2 = 7.864 \times DA^{0.497}$	0.495	0.327
$Q_5 = 10.853 \times DA^{0.492}$	0.462	0.346
$Q_{10} = 12.845 \times DA^{0.490}$	0.444	0.356
$Q_{20} = 14.762 \times DA^{0.488}$	0.430	0.365
$Q_{50} = 17.264 \times DA^{0.485}$	0.415	0.375
$Q_{100} = 19.163 \times DA^{0.484}$	0.405	0.382
$Q_{200} = 21.084 \times DA^{0.482}$	0.395	0.388

Table 3-9: South-West Region of Newfoundland - Two Parameters Equations		
Two Parameters Equations	**SMR**	**SEE**
$Q_2 = 90.931 \times DA^{0.523} \times LSF^{-4.825}$	0.887	0.164
$Q_5 = 141.407 \times DA^{0.519} \times LSF^{-5.060}$	0.871	0.179
$Q_{10} = 178.118 \times DA^{0.517} \times LSF^{-5.183}$	0.863	0.188
$Q_{20} = 215.518 \times DA^{0.516} \times LSF^{-5.284}$	0.855	0.195
$Q_{50} = 267.085 \times DA^{0.514} \times LSF^{-5.399}$	0.846	0.204
$Q_{100} = 308.149 \times DA^{0.513} \times LSF^{-5.475}$	0.840	0.210
$Q_{200} = 351.240 \times DA^{0.512} \times LSF^{-5.544}$	0.835	0.215

South-East Region

Table 3-10: South-East Region of Newfoundland - One Parameter Equations		
One Parameter Equations	**SMR**	**SEE**
$Q_2 = 1.464 \times DA^{0.762}$	0.901	0.145
$Q_5 = 1.966 \times DA^{0.768}$	0.905	0.143
$Q_{10} = 2.293 \times DA^{0.772}$	0.904	0.144
$Q_{20} = 2.604 \times DA^{0.775}$	0.903	0.146
$Q_{50} = 3.005 \times DA^{0.778}$	0.900	0.149
$Q_{100} = 3.306 \times DA^{0.780}$	0.897	0.152
$Q_{200} = 3.608 \times DA^{0.782}$	0.894	0.155

Table 3-11: South-East Region of Newfoundland - Two Parameters Equations		
Two Parameters Equations	**SMR**	**SEE**
$Q_2 = 3.820 \times DA^{0.715} \times LAF^{-0.180}$	0.938	0.120
$Q_5 = 5.135 \times DA^{0.721} \times LAF^{-0.181}$	0.942	0.117
$Q_{10} = 5.993 \times DA^{0.725} \times LAF^{-0.181}$	0.941	0.118
$Q_{20} = 6.809 \times DA^{0.728} \times LAF^{-0.181}$	0.939	0.121
$Q_{50} = 7.861 \times DA^{0.731} \times LAF^{-0.181}$	0.936	0.125
$Q_{100} = 8.651 \times DA^{0.733} \times LAF^{-0.181}$	0.932	0.128
$Q_{200} = 9.443 \times DA^{0.735} \times LAF^{-0.181}$	0.929	0.132

Labrador

Table 3-12: Labrador - One Parameter Equations		
One Parameter Equations	**SMR**	**SEE**
$Q_2 = 0.495 \times DA^{0.837}$	0.968	0.120
$Q_5 = 0.617 \times DA^{0.838}$	0.965	0.127
$Q_{10} = 0.692 \times DA^{0.839}$	0.962	0.131
$Q_{20} = 0.761 \times DA^{0.839}$	0.960	0.135
$Q_{50} = 0.847 \times DA^{0.840}$	0.958	0.139
$Q_{100} = 0.909 \times DA^{0.840}$	0.956	0.142
$Q_{200} = 0.970 \times DA^{0.840}$	0.954	0.145

Table 3-13: Labrador - Two Parameters Equations		
Two Parameters Equations	**SMR**	**SEE**
$Q_2 = 0.581 \times DA^{0.845} \times LAF^{-0.053}$	0.969	0.125
$Q_5 = 0.685 \times DA^{0.843} \times LAF^{-0.034}$	0.965	0.133
$Q_{10} = 0.746 \times DA^{0.842} \times LAF^{-0.025}$	0.962	0.138
$Q_{20} = 0.800 \times DA^{0.842} \times LAF^{-0.017}$	0.960	0.142
$Q_{50} = 0.866 \times DA^{0.841} \times LAF^{-0.008}$	0.958	0.147
$Q_{100} = 0.914 \times DA^{0.840} \times LAF^{-0.002}$	0.956	0.150
$Q_{200} = 0.959 \times DA^{0.840} \times LAF^{0.004}$	0.954	0.153

4.0 APPLICATIONS

4.1 General

Regional flood frequency analysis correlates a watershed's physiographic characteristics with different anticipated frequency flows and is one of the available methods for estimation of return period floods on ungauged watersheds. Other options available include the application of the regional flood index technique and deterministic hydrological modelling.

The regression equations presented herein may be used to estimate frequency flows for ungauged watersheds in Newfoundland and Labrador using either one physiographic parameter (Drainage Area) or two physiographic parameters (Drainage Area and Lake Attenuation Factor or Drainage Area and Lakes and Swamps Factor). For estimation of frequency flows in Labrador, it is recommended to use the equations with Drainage Area as the independent physiographic parameter.

The Regional Flood Index technique is another technique that may be used to estimate flows with higher return periods for watersheds with few years of available data.

4.2 Allowable Range of Parameters

As mentioned above, the developed regression equations are not applicable to all ungauged watersheds. If an ungauged watershed has physiographic parameters outside of the range provided in Table 4-1, it is not recommended that the regression equations be used as the extrapolation of the results beyond the extremes of the parameters used in regression equation development may reduce the accuracy of estimations significantly.

The 1999 RFFA Users' Guide included the results of a sensitivity analysis of estimated peak flows based on potential errors in estimation of physiographic parameters. The following was noted:

- The anticipated error in peak flow ranged from 1.7% to 3.4% for all regions and return periods when the error in the abstraction of Drainage Area was 3%.
- A 3% error in the estimation of Lakes and Swamps Factor may result in an error as high as 18% in flood estimation for the South-west Region.
- The Lake Attenuation Factor was relatively insensitive to estimation error.

The sensitivity of a regression equation for a specific watershed can be easily assessed by varying the independent variable(s) in the spreadsheet.

Table 4-1: Range of Physiographic Parameters Used for Regression Equation Development

Region	Statistics	DRAINAGE AREA (km^2) HYDAT	DRAINAGE AREA (km^2) GIS	WATERSHED PERIMETER (km)	FTREE	FSWAMP	FLAKE	FLSAR	FBAR'N	FACLS	LSF	LAF	LENGTH MAIN R (km)	ELEV DIFF (m)	SLOPE M1 (%)	SLOPE M2 (%)	DRAINAGE DENSITY (km/km^2)	SHAPE FACTOR
NW	Maximum	2110	2101	416	0.94	0.24	0.22	0.36	0.50	1.00	1.95	1053	118.80	700	2.98	3.09	1.34	3.59
	2nd Highest	627	660	236	0.91	0.22	0.13	0.35	0.44	1.00	1.93	700	49.30	678	2.86	2.88	1.30	2.77
	Median	238	263	139	0.72	0.06	0.08	0.13	0.13	0.95	1.84	134	34.45	295	0.97	0.96	0.78	2.41
	2nd Lowest	17	17	26	0.35	0.01	0.02	0.08	0.00	0.46	1.39	18	10.10	130	0.57	0.32	0.34	1.87
	Minimum	13	12	24	0.33	0.01	0.01	0.02	0.00	0.08	1.06	5	8.20	88	0.23	0.14	0.19	1.73
NE	Maximum	4400	4447	785	0.91	0.48	0.20	0.66	0.40	1.00	1.92	881	133.80	372	1.65	1.11	1.24	3.37
	2nd Highest	2150	2207	533	0.88	0.30	0.18	0.38	0.23	1.00	1.89	601	128.80	360	1.28	1.03	1.11	3.36
	Median	267	266	158	0.75	0.12	0.09	0.20	0.02	0.89	1.77	89	42.25	207	0.57	0.44	0.68	2.61
	2nd Lowest	59	62	61	0.21	0.06	0.03	0.13	0.00	0.44	1.22	12	16.00	107	0.21	0.15	0.35	2.03
	Minimum	37	39	45	0.11	0.06	0.02	0.11	0.00	0.40	1.16	5	11.20	95	0.20	0.12	0.26	2.01
SE	Maximum	301	296	179	0.88	0.17	0.14	0.21	0.79	1.00	1.95	588	45.20	370	2.98	2.43	1.62	3.46
	2nd Highest	205	211	177	0.75	0.08	0.13	0.16	0.73	1.00	1.95	512	44.70	259	2.44	2.42	1.55	3.23
	Median	28	27	41	0.38	0.02	0.08	0.12	0.51	0.92	1.85	123	14.00	133	0.90	0.93	1.10	2.28
	2nd Lowest	6	5	16	0.16	0.00	0.04	0.07	0.04	0.50	1.40	21	7.00	64	0.37	0.34	0.96	1.70
	Minimum	4	4	11	0.09	0.00	0.04	0.04	0.00	0.39	1.36	9	2.60	23	0.22	0.23	0.55	1.62
SW	Maximum	2640	5921	1155	0.86	0.38	0.18	0.46	0.82	1.00	1.95	619	100.40	561	2.26	2.19	1.73	4.20
	2nd Highest	1340	4588	914	0.86	0.34	0.15	0.39	0.78	1.00	1.92	401	68.10	509	1.78	1.77	1.50	3.78
	Median	218	228	150	0.52	0.06	0.07	0.15	0.30	0.82	1.67	124	31.10	296	0.84	0.63	1.12	2.67
	2nd Lowest	72	70	66	0.08	0.01	0.04	0.06	0.01	0.34	1.30	50	16.60	122	0.29	0.30	0.36	2.15
	Minimum	37	37	43	0.04	0.01	0.02	0.05	0.01	0.34	1.24	38	14.60	109	0.12	0.08	0.15	1.98
Labrador	Maximum	15100	15776	1404	n/a	n/a	n/a	n/a	n/a	n/a	n/a	226	n/a	n/a	n/a	n/a	n/a	4.12
	2nd Highest	8930	8912	1303	n/a	n/a	n/a	n/a	n/a	n/a	n/a	131	n/a	n/a	n/a	n/a	n/a	3.86
	Median	2330	2327	520	n/a	n/a	n/a	n/a	n/a	n/a	n/a	50	n/a	n/a	n/a	n/a	n/a	3.08
	2nd Lowest	76	76	83	n/a	n/a	n/a	n/a	n/a	n/a	n/a	27	n/a	n/a	n/a	n/a	n/a	2.75
	Minimum	71	71	68	n/a	n/a	n/a	n/a	n/a	n/a	n/a	18	n/a	n/a	n/a	n/a	n/a	2.17

4.3 Estimating Flood Flows

As previously noted, the procedure for application of single station frequency analysis and regional flood frequency analysis for estimating flood flows should be considered as a guideline only. Specific circumstances will warrant professional judgment be used in the application of the regression equations. Some examples of these situations include:

- Too few data for single station frequency analysis
- Physiographic parameters near or out of range
- Partial urbanization
- Inter-basin transfers of water
- Regulation
- Diversion
- Water withdrawals
- Channelization
- Forestry operations

Single station frequency analysis and regional flood frequency analysis do not preclude other flood estimation techniques which can range from simple lumped event models to complex deterministic watershed simulation.

4.3.1 General Method for Applying the RFFA Regression Equations

The step-wise procedure for applying the RFFA regression equations is as follows:

1. *Locate the site on a map where the flood flow estimate is required.*

   This can be completed using hardcopy maps, such as the 1:50,000 scale National Topographic Series (NTS) map or in a digital environment using a Geographic Information System (GIS) or computer aided drafting software such as AutoCAD®.

2. *Delineate the watershed contributing flow to the point of interest.*

   This can be completed manually or digitally using auto-delineation tools. In either instance, the resultant watershed areas/delineation should be reviewed for consistency with the underlying topography.

3. *Estimate the necessary physiographic parameters.*

   The full suite of possible parameters to be estimated includes:

Variable	Description	Units
DA	Watershed Drainage Area (GIS)	km^2
PERIM	Watershed Perimeter	km
FTREE	Fraction of watershed occupied by forest	-
FSWAMP	Fraction of watershed occupied by wetlands/swamps	-
FLAKE	Fraction of watershed occupied by lakes	-
FLSAR	Fraction of watershed occupied by lakes and wetlands/swamps	-
FBAR*N	Fraction of watershed occupied by barrens	-
FACLS	Fraction of drainage area controlled by lakes and wetlands/swamps	-
LSF	Lakes and Swamps Factor	-
LAF	Lake Attenuation Factor	-
LENGTHMAINR	Length of the main river	km
ELEVDIFF	Elevation Difference	m
SLOPEM1	Slope of the main channel - Method 1	%
SLOPEM2	Slope of the main channel – Method 2	%
DRAIND	Drainage Density	km/km^2
SHAPE	Shape Factor	-

Only DA, LAF and LSF are used in the regional regression equations. However, the other parameters are estimated as a means of comparison to other watersheds in the selected hydrological region. Details are provided in Appendix A. Estimation of some of the physiographic parameters can be complex. Users not familiar with estimation of the watershed parameters noted above should gain experience with watersheds with defined/known physiographic data (ref Table 3-1 and Appendices A and B).

For those watersheds where a LAF is estimated to be zero (0), a default value of 50 should be applied. The need for this transformation has been discussed in detail in the 2014 RFFA Update main report.

4. *Check that the estimated physiographic parameters are in range.*

   The specific physiographic parameters for the watershed of interest should be in the range of the range of physiographic parameters used for regression equation development. This is of particular importance for DA, LAF and LSF since these parameters are used in the regional equations. Extremes of watershed physiography are provided in Table 4-1.

5. *Select the appropriate regression equation.*

   The appropriate regression equation will be based on the geographic region encompassing the specific location for which flood flow estimates are required, and the desired return period. The individual constants and coefficients are outlined in Table 3-2 for Newfoundland and Table 3-3 for Labrador. The same information is presented in equation form in Tables 3-4 to 3-11 for the various regions of Newfoundland and Tables 3-12 and 3-13 for Labrador.

6. *Calculate the flood estimate using the equation selected in Step 5.*

   For cases, where the watershed is near the boundary of the region, calculation of the flood estimate based on another region may be warranted.

7. *Calculate the upper and lower 95% confidence limits on the flood estimate.*

   The upper and lower 95% confidence limits may be calculated using the following method:

   a) multiply the SEE (ref. Tables 3-2 and 3-3 or Tables 3-4 to 3-13) by 1.96,
   b) add the result in step (a) to the $\log_{10}$ of the flood estimate to obtain the upper limit,
   c) subtract the result from step (a) the $\log_{10}$ of the flood estimate to obtain the lower limit
   d) determine the upper and lower limits by computing the inverse log of the results from steps (b) and (c).

4.3.2 Single Station Frequency Analysis

If a streamflow gauging station is located on the same stream of interest, then the results of a single station frequency analysis may provide results that are more reliable.

Table 2-2 provides a listing the streamflow gauging stations for which single station frequency analysis has been completed as a component of the development of the RFFA regression equations.

If a streamflow gauging station coincides with the site where a flood flow estimate is required, then the results of the single station frequency analysis can be used without adjustment if the number of years of record available for analysis is equal to or greater than that specified in Table 4-2. The single station frequency analysis, completed for the 2014 RFFA update, utilized all flood data up to and including 2013. An update of the flood database and the single station frequency analysis, completed for the 2014 RFFA update, may be warranted if the number of floods available for single station frequency analysis is small.

Table 4-2: Minimum Number of Instantaneous Annual Peak Flows Required for Single Station Frequency Analysis

Return Period (yrs)	Number of Instantaneous Annual Peaks Flows Required
2	10+
20	14+
100	18+

Table 4-2 has been replicated from the Users' Guide developed for the 1999 RFFA update (Rollings, 1999). The suggested minimum numbers of instantaneous annual maximum peak flows, outlined in the Table, were derived as part of the 1999 RFFA Update from an analysis of the absolute percentage deviation between the single station frequency estimates and the regional flood frequency estimates (ref. Appendix B).

Adjustment of the single station frequency analysis flood flow estimates for differing physiography may also be necessary. In this case, for locations near a streamflow gauging station, the results of a single station frequency analysis may be used with adjustment if[3]:

a) the number of floods upon which the single station frequency analysis is based is equal to or greater than that specified in Table 4-2, and,

b) the drainage area associated with a streamflow gauging station is no more than 10 to 25% of the drainage area for the site where flood flow estimates are required.

The following equation[1] may be used to adjust the single station frequency analysis flood flow estimate to account for differing physiography at a location:

$$Q_{Ts} = Q_{Tfg} * \frac{Q_{Trs}}{Q_{Trg}}$$

where: Q_{Ts} is the flood of return period 'T' at the desired site 's'

Q_{Tfg} is the flood of return period 'T' from the single station frequency analysis (f) for station 'g' from Table 2-2

Q_{Trs} is the flood of return period 'T' from the regional flood frequency analysis (r) at site 's' (following Steps 1 – 7)

Q_{Trg} is the flood of return period 'T' from the regional flood frequency analysis (r) at station 'g' (following Steps 1 – 7)

4.4 Examples

These examples have been abstracted from the Users' Guide for the 1999 RFFA update and updated to reflect the newly developed data from the 2014 RFFA update.

4.4.1 Southwest Brook at Lewisport (Example #1)

This example involves the estimation of the 20 year return period flood flow (Q_{20}) at an existing bridge on Southwest Brook near the Town of Lewisporte. The bridge is located about 5.7 km upstream from where the Southwest Brook discharges into Lewisporte Harbour as indicated in Figure 4-1. Streamflow gauge 02YO012 is located near the outlet of Southwest Brook and has recorded streamflow data available for the period 1989 to 2012.

1. Figure 4-1 illustrates the location where the flood estimate is required. The watershed is located in the North-east (NE) region of Newfoundland.
2. The drainage divide was delineated on a 1:50,000 NTS map.
3. The parameters summarized in Table 4-3 were determined.

[3] As defined in the 1999 RFFA Update

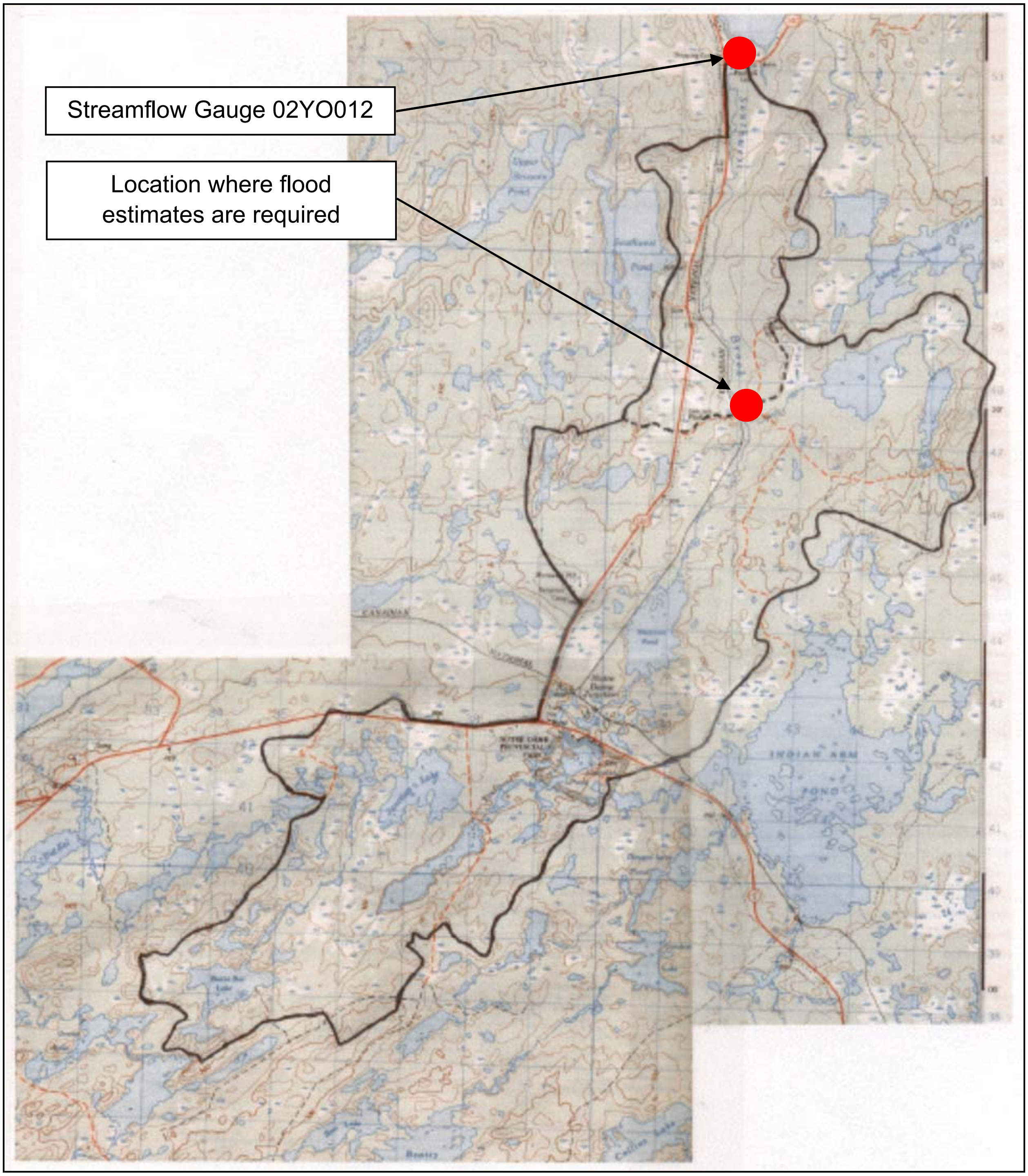

Figure 4-1: Example #1 - Southwest Brook near Lewisporte (source: Rollings, 1999)

Table 4-3: Example #1 – Parameterization and Valid Ranges

Parameter	Estimated Value	Parameter Ranges				
		Maximum	2nd Highest	Median	2nd Lowest	Minimum
DA	49.9	4447	2207	266	62	39
PERIM	59.0	785	533	158	61	45
LAF	222	881	601	89	12	5
LSF	1.44	1.92	1.89	1.77	1.22	1.16
FACLS	0.82	1	1	0.89	0.44	0.40
FLAKE	0.14	0.20	0.18	0.09	0.03	0.02
FSWAMP	0.07	0.48	0.30	0.12	0.06	0.06
FLSAR	0.21	0.66	0.38	0.20	0.13	0.11
FTREE	0.79	0.91	0.88	0.75	0.21	0.11
FBAR'N	0.00	0.40	0.23	0.02	0	0
SLOPEM2	0.48	1.11	1.03	0.44	0.15	0.12
DRAIND	0.66	1.24	1.11	0.68	0.35	0.26
SHAPE	2.34	3.37	3.36	2.61	2.03	2.01

NOTES:

1. The highlighted cells indicate the range applicable for the measured value of the parameters
2. Estimates of parameters SLOPEM1, LENGTHMAINR and ELEVDIFF were not computed for this example.

4. The physiographic parameters of the watershed were verified against the ranges of parameters of the watersheds, for those watersheds associated with gauging stations which were used in the development of the RFFA regression equations for NE region (ref. Tables 4-1 and 4-3).

   As indicated in Table 4-3, DA, PERIM and FBAR'N were near the minimum of the ranges for those parameters. All other parameters were between the 2nd highest and 2nd lowest value of the parameter for the NE region.

5. The appropriate equation was selected from Table 3-7.

   The two parameter regression equation was selected for use as an estimate of the LAF parameter was available for this watershed.

   The following regression equation is applicable to the NE region for estimation of the Q_{20} flood flow:

Equation	SEE
$Q_{20} = 7.568 \times DA^{0.725} \times LAF^{-0.317}$	0.126

6. The flood estimate was calculated using the regression equations identified in Step 5.

Equation	Q_{20}
$Q_{20} = 7.568 \times (49.9)^{0.725} \times (222)^{-0.317}$	23.2 m^3/s

7. The upper and lower confidence limits were calculated.

   Following Step 7, the upper and lower confidence limits of the Q_{20} flood flow estimate were determined.

   - The value of SEE for the Q_{20} estimate is identified in Step 5 as 0.126.
   - Confidence limit offset = 1.96 x 0.126 = 0.247
   - Log(Upper confidence limit) = Log(Q_{20}) + 0.247 = 1.366 + 0.247 = 1.613
   - Log(Lower confidence limit) = Log(Q_{20}) - 0.247 = 1.366 – 0.247 = 1.119
   - Upper 95% confidence limit = $10^{1.613}$ = 41.1 m^3/s
   - Lower 95% confidence limit = $10^{1.119}$ = 13.2 m^3/s

8. As previously noted, the streamflow gauge at Southwest Brook near Lewisporte has been in operation since 1989. The location where the flood estimate is required is about 5.7 km upstream from the gauging station. The drainage area to the point of interest is 49.9 km^2. The drainage area to the gauging station is 59.8 km^2. The difference between the two locations is about 17%; within the range defined as valid for use of a nearby gauging data to support single station frequency analysis.

9. As previously noted, streamflow gauging station 02YO012 has been in operation since 1989 and presently has a period of record of 23 years (ref. Table 2-1). As such, the results of the single station frequency analysis can be used with adjustment as another means of estimation of Q_{20} flood flows at the point of interest.

   Based on the single station frequency analysis for station 02YO012, the Q_{20} flood flow has been estimated as 26.9 m^3/s (ref. Table 2-2). The single station frequency analysis for this station was completed as a component of the 2014 RFFA update.

   As noted previously, the flood flow adjustment for differing physiography between gauging location and point of interest location can be computed as follows:

$$Q_{Ts} = Q_{Tfg} \times \frac{Q_{Trs}}{Q_{Trg}}$$

where:

Q_{Tfg}	26.9 m^3/s
Q_{Trs}	23.2 m^3/s
Q_{Trg}	$Q_{20} = 7.568 \times DA^{0.725} \times LAF^{-0.317}$ $Q_{20} = 7.568 \times (59.8)^{0.725} \times (128)^{-0.317}$ Q_{20} = 31.6 m^3/s
Q_{Ts}	= 26.9 x (23.2 / 31.6) = 19.7 m^3/s

If the computation of the LAF parameter could not be completed, two alternate adjustment methods are available, namely use of the one parameter regression equations and adjustment based on simple area adjustment.

One Parameter Regression Equations

$Q_{20} = 1.895 \times (DA)^{0.712}$	One Parameter Regression Equation		
$Q_{20} = 1.895 \times (49.9)^{0.712}$	30.7 m^3/s	Q_{Trs}	At point of interest
$Q_{20} = 1.895 \times (59.8)^{0.712}$	34.9 m^3/s	Q_{Trg}	At streamflow gauging station

As noted previously, the flood flow adjustment for differing physiography between gauging location and point of interest location can be computed as follows:

$$Q_{Ts} = Q_{Tfg} \times \frac{Q_{Trs}}{Q_{Trg}}$$

where:

Q_{Tfg}	26.9 m^3/s
Q_{Trs}	30.7 m^3/s
Q_{Trg}	34.9 m^3/s
Q_{Ts}	= 26.9 x (30.7 / 34.9) = = 23.6 m^3/s

Simple Area Adjustment

$$Q_{Ts} = Q_{Tfg} \times \frac{DA_{Trs}}{DA_{Trg}}$$

where:

Q_{Tfg}	26.9 m^3/s
DA_{Trs}	49.9 ha
DA_{Trg}	59.8 ha
Q_{Ts}	= 26.9 x (49.9 / 59.8) = = 22.4 m^3/s

The assessment determined a variety of flood flow estimates based on the approaches used. It now falls to the analyst to use their best judgment for making a determination as to which estimate has the best foundation of supporting data.

For this example, the single station flood frequency estimate with adjustment (19.7 m^3/s) might be considered as preferential over the regional flood frequency estimate (23.2 m^3/s) given that the data record for streamflow gauging station 02YO012 meets the minimum criteria as outlined in Table 4-2. The alternate estimation methods yielded estimates of 23.6 m^3/s and 22.4 m^3/s for the one parameter regression equation and simple area adjustment methods respectively. Other criteria, as determined by the analyst, might also be employed to prioritize the estimates.

If the station record of streamflow at the gauging site had not not been sufficient (i.e. < 14 years as outlined in Table 4-2), single station flood frequency estimates might still be used to rectify the estimates computed using other approaches.

The Q_{20} flood flow estimate computed for this example from the 1999 RFFA update (Rollings, 1999) was 19.5 m^3/s, which is comparable to the preferred estimate of 19.7 m^3/s.

4.4.2 Rose Blanche Brook near Rose Blanche (Example #2)

This example involves the calculation of the 1:100 year flood flow estimate (Q_{100}) at an existing bridge on Rose Blanche Brook near Rose Blanche.

1. Figure 4-2 illustrates the location where the flood estimate is required. The watershed is located in the south-west (SW) region of Newfoundland.
2. The drainage divide was delineated on a 1:50,000 NTS map.
3. The parameters summarized in Table 4-4 were determined.

Table 4-4: Example #2 – Parameterization and Valid Ranges

Parameter	Measured Value	Parameter Ranges				
		Maximum	2nd Highest	Median	2nd Lowest	Minimum
DA	83.9	5921	4588	228	70	37
PERIM	67.2	1155	914	150	66	43
LAF	50	619	401	124	50	38
LSF	1.32	1.95	1.92	1.67	1.30	1.24
FACLS	0.37	1.00	1.00	0.82	0.34	0.34
FLAKE	0.04	0.18	0.15	0.07	0.04	0.02
FSWAMP	0	0.38	0.34	0.06	0.01	0.01
FLSAR	0.04	0.46	0.39	0.15	0.06	0.05
FTREE	0.05	0.86	0.86	0.52	0.08	0.04
FBAR'N	0.91	0.82	0.78	0.30	0.01	0.01
SLOPEM2	1.99	2.19	1.77	0.63	0.30	0.08
DRAIND	1.48	1.73	1.50	1.12	0.36	0.15
SHAPE	2.05	4.20	3.78	2.67	2.15	1.98

NOTES:

1. The highlighted cells indicate the range applicable for the measured value of the parameters
2. The hatched cells indicate the measured value of the parameter is outside the parameter range limit

4. The physiographic parameters of the watershed were verified against the ranges of parameters of the watersheds, which were used in the development of the RFFA regression equations for SW region (ref. Tables 4-1 and 4-4).

   As indicated in Table 4-4, many of the physiographic parameters are near to or outside the range of the range of physiographic parameters used for regression equation development. Based on this comparative assessment, the analyst will have to make a decision on the applicability of the regression equations to the watershed under consideration.

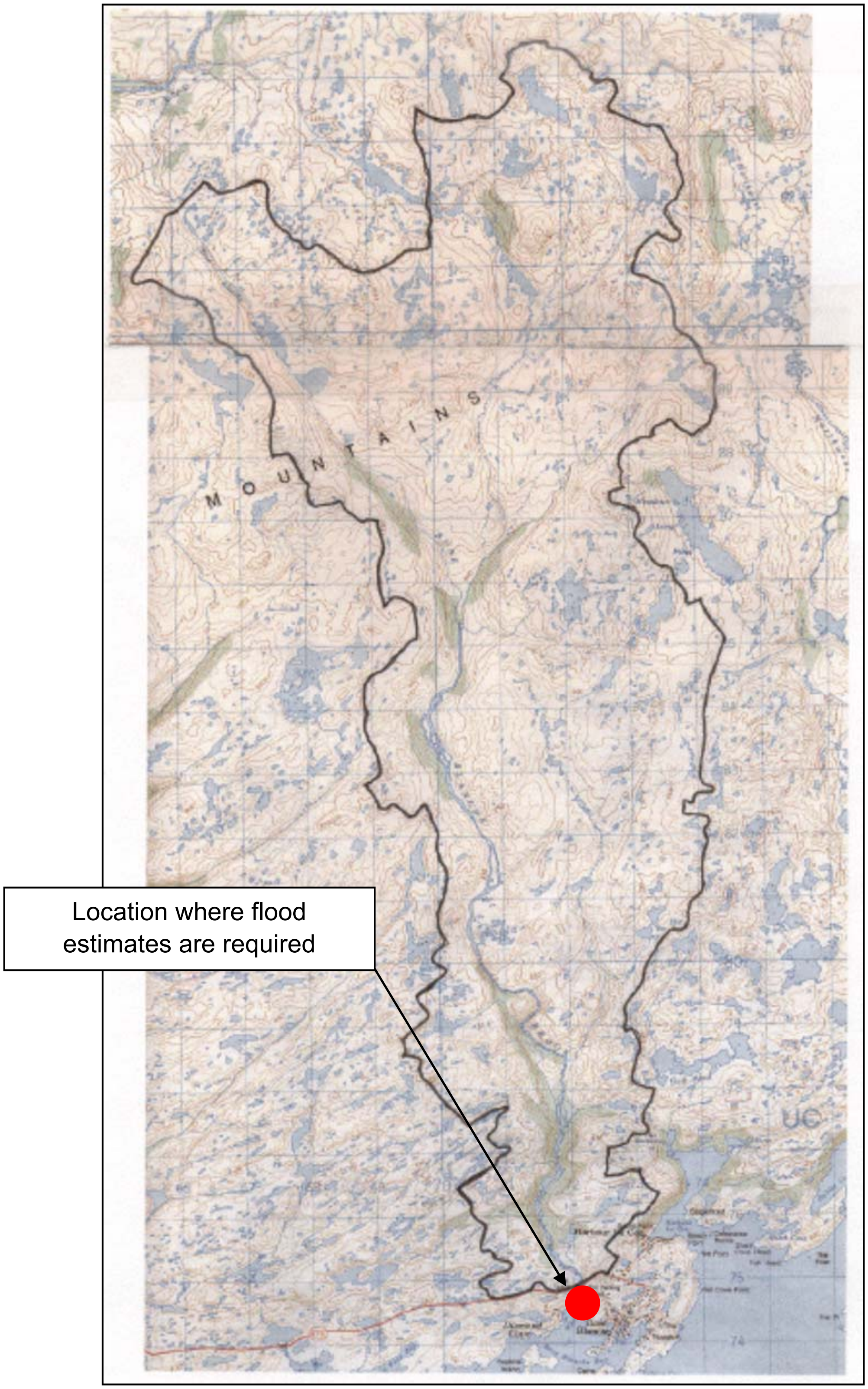

Figure 4-2: Example #2 - Rose Blanche Brook near Rose Blanche (source: Rollings, 1999)

5. The applicable regression equation was selected from Table 3-9.

   The two parameter regression equation was selected for use as an estimate of the LSF parameter was available for this watershed.

   The following regression equation is applicable to the SW region for estimation of the Q_{100} flood flow:

Equation	SEE
$Q_{100} = 308.149 \text{ x } DA^{0.513} \text{ x } LSF^{-5.475}$	0.210

   The following regression equation is applicable to the SW region for estimation of the Q_{100} "upper envelope curve" flood flow:

$$Q_{100} = 19.163 \text{ x } DA^{0.484}$$

6. The flood flow and upper envelope curve estimates were calculated using the regression equations identified in Step 5.

$$Q_{100} = 308.149 \text{ x } (83.9)^{0.513} \text{ x } (1.32)^{-5.475} \quad = 653.9 \text{ m}^3/\text{s}$$

$$Q_{100\text{-Upper}} = 19.163 \text{ x } (83.9)^{0.484} \quad = 163.5 \text{ m}^3/\text{s}$$

   The estimated flood flow appears unrealistic given that the "Upper Envelope Curve" estimate is meant to represent the largest floods in this region.

7. The upper and lower confidence limits were calculated.

   The upper and lower confidence limits of the $Q_{100\text{-Upper}}$ flood flow estimate were determined.

   - Q_{100} as defined by $Q_{100\text{-Upper}}$ = 163.5 m^3/s
   - $Log(Q_{100})$ = 2.214
   - The value of SEE for the Q_{100} estimate is identified in Step 5 as 0.210.
   - Confidence limit offset = 1.96 x 0.210 = 0.247
   - Log(Upper confidence limit) = $Log(Q_{100})$ + 0.247 = 2.214 + 0.247 = 2.461
   - Log(Lower confidence limit) = $Log(Q_{100})$ - 0.247 = 2.214 – 0.247 = 1.967
   - Upper 95% confidence limit = $10^{2.461}$ = 288.7 m^3/s
   - Lower 95% confidence limit = $10^{1.967}$ = 92.6 m^3/s

   Since many of the physiographic parameters point to a higher Q_{100} flood estimate, the upper 95% confidence limit estimate might be considered[4] the most appropriate, namely 288.7 m^3/s.

The estimates for this example from the 1999 RFFA Update, outlined below, show a broader

[4] This decision would be made by the analyst

range of possible peak flow estimates.

- Q_{100} from the two parameter regression equation = 864 m^3/s
- Upper Envelope Curve Q_{100} estimate = 256 m^3/s
- Upper 95% confidence limit = 438 m^3/s
- Lower 95% confidence limit = 150 m^3/s

The availability of additional years of streamflow data to support development of regression equations for the current RFFA update has reduced the range of the upper and lower 95% confidence limits to 196 m^3/s (i.e. 288.7 – 92.6) from 288 m^3/s (i.e. 438 – 150) as computed for the 1999 RFFA update.

The range of flood flow estimates for this example comparing the 1999 and 2014 RFFA updates clearly demonstrates:

- the importance of streamflow gauging particularly for the SW region where watershed response is highly variable
- the importance of understanding of the basis for flood flow estimates and the use of engineering judgment when using flood flow estimates for analysis and design.

5.0 ELECTRONIC SPREADSHEET

The electronic spreadsheet provides a convenient means of quick calculation of return period flows and their confidence limits using the regression equations developed as part of the 2014 RFFA update. In addition, the sensitivity of the flood estimates to errors in the physiographic parameters can be evaluated along with the effect of region selection. The results can also be printed.

It is assumed that the user is familiar with spreadsheet operations such as loading files, entering data and printing. The spreadsheet is provided in Microsoft Excel 2007 format.

A printout of the output for the Southwest Brook near Lewisport example (Example #1 – ref. Section 4.3.2.1) is provided as Figure 5-1. The following data were input:

- Watershed Name
- Region Number
- All available parameter values

The output is listed alongside "Results". "Estimate" represents the flood estimate, L95%L represents the lower 95% confidence limit of the estimate (assuming a normal distribution) and U95%L represents the upper limit.

Input is required for "Region #" and drainage area ("DA"). Optionally, the watershed name can be added for printout purposes. It is recommended that LAF be input for Regions 1, 2 and 3 (NW, NE and SE respectively) and that LSF be input for Region 4 (SW). Region 5 represents Labrador. All other parameters are not used in the calculation of the flood estimates. It is recommended, however, that all physiographic parameters be calculated to ensure (or not) that the watershed under consideration has physiographic parameters which are consistent with the selected region. Error checking within the spreadsheet will advise if the physiographic parameters are "near the range extremes" or if they are "out of range" under the "Remarks:" column. Only input cells will accept data.

Occasionally an "ERR" message will appear. This indicates that either the region was not specified as the number 1,2 3, 4 or 5 or if the drainage area was not specified.

Watershed Name: Southwest Brook near Lewisporte, 5.7 km upstream
Region #: 2
(NW=1, NE=2, SE=3, SW=4 or Labrador=5)

Parameters:	Value	Units	Range in Region: lowest	2nd lowest	2nd highest	highest	Remarks:
DA	49.9	km^2	39.00	62.00	2207.00	4447.00	Parameter near extreme
PERIM	59	km	45.00	61.00	533.00	785.00	Parameter near extreme
LAF	222	(-)	5.00	12.00	601.00	881.00	
LSF	1.44	(-)	1.16	1.22	1.89	1.92	
FACLS	0.82	(-)	0.40	0.44	1.00	1.00	
FLAKE	0.14	(-)	0.02	0.03	0.18	0.20	
FSWAMP	0.07	(-)	0.06	0.06	0.30	0.48	
FLSAR	0.21	(-)	0.11	0.13	0.38	0.66	
FTREE	0.79	(-)	0.11	0.21	0.88	0.91	
FBAR'N	0	(-)	0.00	0.00	0.23	0.40	
SLOPEM2	0.48	(%)	0.12	0.15	1.03	1.11	
DRAIND	0.66	(km/km^2)	0.26	0.35	1.11	1.24	
SHAPE	2.34	(-)	2.01	2.03	3.36	3.37	

Results:		Estimate	L95%L	U95%L
DA+LAF or LSF	Q_2 =	12.52	7.90	19.85
	Q_5 =	17.09	10.31	28.34
	Q_{10} =	20.25	11.83	34.64
	Q_{20} =	23.24	13.16	41.05
	Q_{50} =	27.15	14.83	49.70
	Q_{100} =	30.12	16.01	56.66
	Q_{200} =	33.10	17.21	63.69

Results:		Estimate	L95%L	U95%L
DA only	Q_2 =	16.01	7.74	33.10
	Q_5 =	22.33	10.23	48.75
	Q_{10} =	26.62	11.76	60.26
	Q_{20} =	30.67	13.19	71.31
	Q_{50} =	36.14	14.99	87.12
	Q_{100} =	40.25	16.32	99.25
	Q_{200} =	44.33	17.58	111.82

Regional Flood Frequency Analysis for Newfoundland and Labrador - 2014 Update **Version 2014**

Consult "Regional Flood Frequency Analysis for Newfoundland and Labrador - 2014 Update - User's Guide and Electronic Spreadsheet" for instructions on use.

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Figure 5-1: Electronic Spreadsheet Example #1 - Sample Printout

6.0 REFERENCES

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APPENDIX A

Physiographic Parameters
Description and Estimation Procedures

APPENDIX A

Physiographic Parameters: Description and Estimation Procedures

Definitons and procedures for estimation of a number of physiographic parameters have been outlined below. These parameters support application of the RFFA equations in two ways, namely:

1. For direct use in the RFFA equations (parameters DA, LAF and LSF)
2. For comparison of watershed characteristics related to the selected point of interest to other watersheds in the selected hydrological region as a means of determining physiological similarlity.

The parameters are sumamrized in the Table below. Suggested procedures for estimation of these parameters is provided in the following sections.

Variable	Description	Units
DA	Watershed Drainage Area	km^2
PERIM	Watershed Perimeter	km
FTREE	Fraction of watershed occupied by forest	-
FSWAMP	Fraction of watershed occupied by wetlands/swamps	-
FLAKE	Fraction of watershed occupied by lakes	-
FLSAR	Fraction of watershed occupied by lakes and wetlands/swamps	-
FBAR*N	Fraction of watershed occupied by barrens	-
FACLS	Fraction of drainage area controlled by lakes and wetlands/swamps	-
LSF	Lakes and Swamps Factor	-
LAF	Lake Attenuation Factor	-
LENGTHMAINR	Length of the main river	km
ELEVDIFF	Elevation Difference	m
SLOPEM1	Slope of the main channel - Method 1	%
SLOPEM2	Slope of the main channel – Method 2	%
DRAIND	Drainage Density	km/km^2
SHAPE	Shape Factor	-

Watershed Drainage Area (DA)
Watershed Perimeter (PERIM)
Fraction of watershed occupied by forest (FTREE)
Fraction of watershed occupied by wetlands /swamps (FSWAMP)
Fraction of watershed occupied by lakes (FLAKE)
Fraction of watershed area occupied by lakes and wetlands/swamps (FLSAR)

These parameters can be determined from hardcopy or digital mapping.

If using hardcopy maps, areas can be estimated using planimeter, a digitizer or transparent grid with 0.01 km^2 blocks.

Digital mapping within a GIS or CAD platform offers the opportunity to use the watershed boundary to support estimation of other parameters.

Fraction of watershed occupied by barrens (FBAR*N)

This parameter can be estimated as the Drainage Area (DA) less the area of forests, lakes and swamps.

Fraction of drainage area controlled by lakes and wetlands/swamps (FACLS)

This parameter can be determined from hardcopy or digital mapping. A sub-basin can be considered to be controlled if a lake or wtland/swamp at the outlet of the sub-basin has a surface area greater than 1% of the sub-basin. The "Percentage of Basin Area Controlled by Lake and Swamp" has been previously defined by Poulin (1971) (ref. Figure A-1.

Lakes and Swamps Factor (LSF)

The Lakes and Swamps Factor is a combination of the fraction of watershed area occupied by lakes and swamps and the fraction of watershed area controlled by lakes and swamps and is computed using the following equation;

$$LSF = (1 + FACLS) - \frac{FLSAR}{(1 + FACLS)}$$

where: FACLS is the fraction of watershed area controlled by lakes and swamps
FLSAR is the fraction of watershed area occupied by lakes and swamps

The description of the LSF variable provided in Section 4.2 of the 1999 RFFA report has been replicated below.

"The reasons for the transformation were: (1) When FLSAR and FACLS tend toward 0, log_{10}(LSF) tends towards 0 and at the limit drops out of the regression equation. (2) It is reasonable to assume that as FLSAR increases, the amount of water lost to infiltration decreases and to a slight

extent compensates for the attenuating effects of lakes and swamps. However, the effect is reduced if a larger percentage of the watershed area is controlled by lakes and swamps. The fraction of drainage area occupied by lakes and swamps (FLSAR) ranges from 0.05 to 0.36 (not including the extreme case of Pipers Hole River watershed where FLSAR is 0.66). During this study it was found that combining the term FLSAR with FALCS in the form given improved the predictive capability of the regression equations, especially on watersheds with higher FLSARs."

Lake Attenuation Factor (LAF)

The Lake Attenuation Factor represents the influences of lakes within a watershed in the context of the runoff response and is defined as follows:

$$LAF = \sum_{i=1}^{n}\left[\left(100 \times \frac{LAREAi}{DA}\right) \times \left(100 \times \frac{CAREAi}{DA}\right)\right]$$

where n is the number of lakes in the watershed with surface area greater than 1% of the watershed's drainage area
$LAREAi$ is the area of a lake
DA is the contributing drainage area of the watershed
$CAREAi$ is the drainage area which is controlled by a lake

Values of LAF have been abstracted from the 1999 RFFA study documentation where available. For stations newly added for the current RFFA update, the LAF has been determined manually using available physiographic data.

If a watershed has no significant lakes the LAF value is zero (0). However, this is problematic in the determination of the regression equations as the $\log_{10}(0) = -\infty$. For the 1999 RFFA, the LAF value was defaulted to 50 for stations where the LAF value was calculated to be zero. This assumption has also been adopted for the current study in order to maintain consistency with the 1999 RFFA study.

The LAF is further defined in Figure A-2.

Length of the main river (LENGTHMAINR)

This parameter measures the length of the longest river in the watershed.

Elevation Difference (ELEVDIFF)

This parameter represents the difference in elevation between the outlet of the watershed and the highest elevation on the divide in then vicinity of the main channel.

Slope of the main channel – Method 1 (SLOPEM1)

This parameter is computed as LENGTHMAINR / ELEVDIFF.

Slope of the main channel – Method 2 (SLOPEM2)

This variation of the slope parameter represents the average slope of the curve that joins two points on the main river channel which are located at 10% and 85% of the LENGTHMAINR from the outlet. In effect, the sloep of the main river is calculated over only 75% of its overall length.

Drainage Density (DRAIND)

This parameter is computed as the total length of all streams in a watershed divided by the drainage area (DA).

Shape Factor (SHAPE)

The Shape factor characterizes the physical shape of a watershed and is computed as:

$$SHAPE = 0.28 \times \frac{PERIM}{SQRT\ (DA)}$$

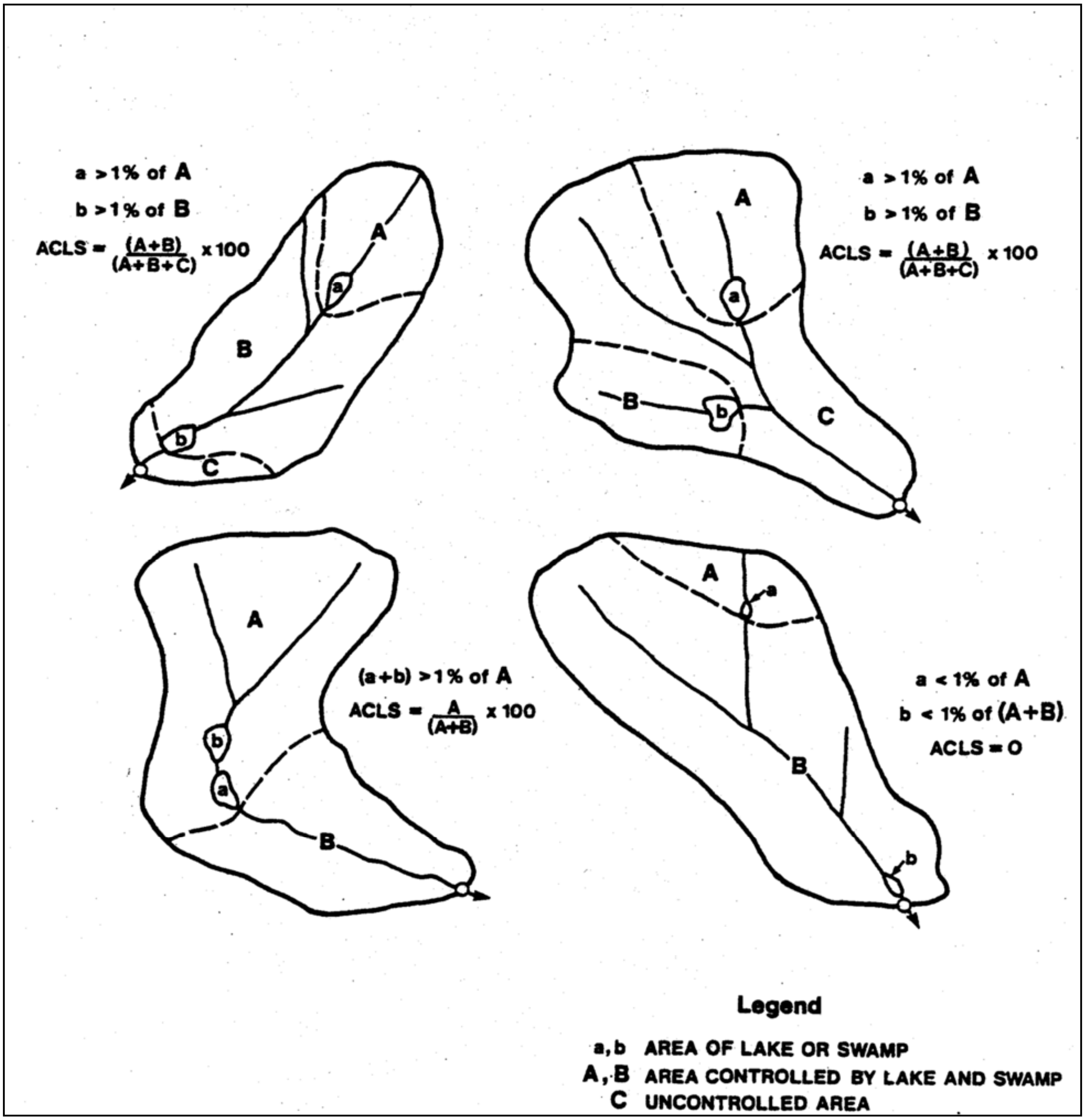
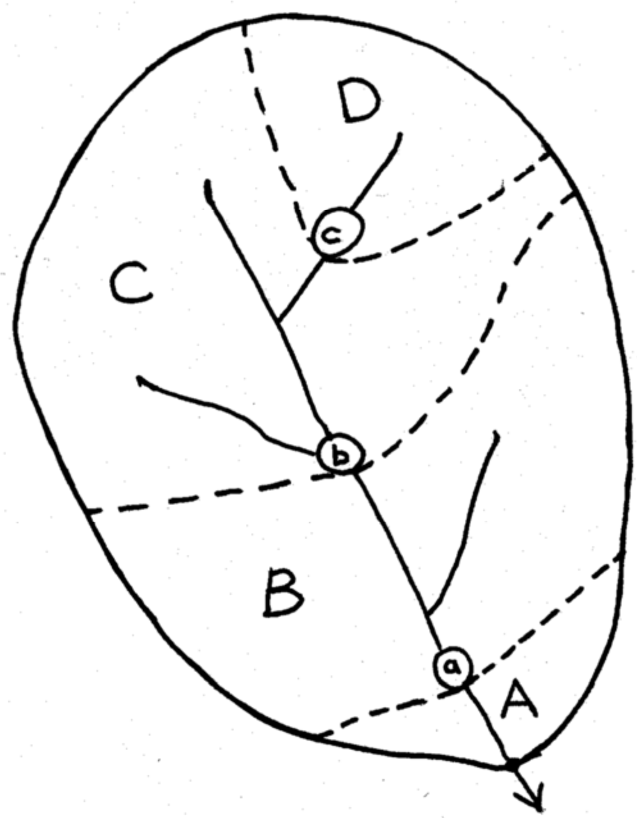


Figure A-1: Percentage of Basin Area Controlled by Lake and Swamp (ACLS) – Definition (source: Rollings, 1999)

$$LAF = \sum_{i=1}^{n} \{(100 \times LAREA_i/DA) \times (100 \times CAREA_i/DA)\}$$

where: n is the number of lakes in the watershed with area greater than 1% of the watershed's drainage area,
$LAREA_i$ is the area of a lake,
DA is the drainage area of the watershed, and
$CAREA_i$ is the drainage area which is controlled by a lake.



If area of lakes a, b, c > 1% of the drainage area (A+B+C+D), then

$$LAF = \{(100 \times a/(A+B+C+D)) \times (100 \times (B+C+D)/(A+B+C+D))\} + \{(100 \times b/(A+B+C+D)) \times (100 \times (C+D)/(A+B+C+D))\} + \{(100 \times c/(A+B+C+D)) \times (100 \times (D)/(A+B+C+D))\}$$

Figure A-2: Lake Attenuation Factor (LAF) - Definition
(source: Rollings, 1999)

APPENDIX B

Physiographic Parameters by Station

ID #	STATION NAME	Location	Hydrometric Region	Period of Record (Years)	LATITUDE DEG	LATITUDE MIN	LATITUDE SEC	LONGITUDE DEG	LONGITUDE MIN	LONGITUDE SEC	DRAINAGE AREA (km^2) HYDAT	DRAINAGE AREA (km^2) GIS	WATERSHED PERIMETER (km)	FTREE	FSWAMP	FLAKE	FLSAR	FBAR'N	FACLS	LSF	LAF	LENGTH MAIN R (km)	ELEV DIFF (m)	SLOPE M1 (%)	SLOPE M2 (%)	DRAINAGE DENSITY (km^{-1})	SHAPE FACTOR
02YA001	STE. GENEVIEVE RIVER NEAR FORESTER'S POINT	Newfoundland	NW	28	51	8	18	56	48	32	306	305.9	139.4	0.64	0.14	0.22	0.35	0	0.96	1.78	1053	38.9	88	0.23	0.14	0.54	2.23
02YA002	BARTLETTS RIVER NEAR ST. ANTHONY	Newfoundland	NW	27	51	27	57	55	38	28	33.6	32.8	50.5	0.4	0.03	0.13	0.16	0.44	0.99	1.91	652	13.2	150	1.14	1.21	0.91	2.47
02YC001	TORRENT RIVER AT BRISTOL'S POOL	Newfoundland	NW	54	50	36	27	57	9	6	624	619.7	208.6	0.33	0.04	0.13	0.17	0.5	0.99	1.91	175	48.3	479	0.99	1.01	0.76	2.35
02YD001	BEAVER BROOK NEAR RODDICKTON	Newfoundland	NW	20	50	55	51	56	9	26	237	263.1	207.9	0.81	0.04	0.05	0.08	0.11	0.73	1.68	50	40.6	328	0.81	0.68	0.34	3.59
02YD002	NORTHEAST BROOK NEAR RODDICKTON	Newfoundland	NW	33	50	55	28	56	7	42	200	197.7	120.9	0.83	0.04	0.13	0.17	0	0.99	1.9	484	38.3	270	0.7	0.47	0.93	2.41
02YE001	GREAVETT BROOK ABOVE PORTLAND CREEK POND	Newfoundland	NW	29	50	10	44	57	35	39	95.7	100.2	85.4	0.49	0.06	0.06	0.12	0.39	0.88	1.82	134	24.5	700	2.86	3.09	0.75	2.39
02YF001	CAT ARM RIVER ABOVE GREAT CAT ARM	Newfoundland	NW	15	50	5	33	56	55	22	611	636.9	235.8	0.69	0.05	0.08	0.13	0.18	1	1.93	50	30.2	250	0.83	0.73	0.58	2.62
02YG001	MAIN RIVER AT PARADISE POOL	Newfoundland	NW	27	49	49	38	57	10	34	627	632.3	223.8	0.78	0.06	0.07	0.13	0.09	0.63	1.55	18.3	31.9	375	1.18	1.11	1.3	2.49
02YG002	MIDDLE ARM BROOK BELOW FLATWATER POND	Newfoundland	NE	11	49	48	22	56	21	33	224	222.5	134.1	0.83	0.06	0.09	0.15	0.02	0.96	1.88	299	26.4	255	0.96	0.75	0.45	2.52
02YH001	BOTTOM CREEK NEAR ROCKY HARBOUR	Newfoundland	NW	14	49	35	6	57	55	34	33.4	31.5	44.2	0.79	0.02	0.11	0.13	0.08	0.93	1.86	545	14.6	163	1.12	0.85	1.13	2.20
02YJ001	HARRYS RIVER BELOW HIGHWAY BRIDGE	Newfoundland	SW	45	48	35	33	58	22	46	640	617.9	236.0	0.79	0.09	0.06	0.14	0.07	0.75	1.67	141	60	509	0.85	0.35	1.12	2.66
02YJ003	PINCHGUT BROOK AT OUTLET OF PINCHGUT LAKE	Newfoundland	SW	12	48	48	21	58	1	56	119	116.4	82.8	0.86	0.05	0.05	0.1	0.04	1	1.95	290	16.6	164	0.99	0.78	1.73	2.15
02YK002	LEWASEECHJEECH BROOK AT LITTLE GRAND LAKE	Newfoundland	SW	57	48	37	19	57	56	59	470	476.5	234.5	0.55	0.06	0.1	0.16	0.29	1	1.92	274	54.9	561	1.02	0.59	0.63	3.01
02YK003	SHEFFIELD RIVER AT SHEFFIELD LAKE	Newfoundland	NW	12	49	20	10	56	38	57	362	365.6	180.7	0.67	0.07	0.11	0.18	0.15	1	1.91	688	37	351	0.95	1.13	0.43	2.65
02YK004	HINDS BROOK NEAR GRAND LAKE	Newfoundland	NW	24	49	4	21	57	11	46	529	659.6	230.5	0.35	0.24	0.12	0.36	0.29	0.95	1.77	666	49.3	320	0.65	0.32	0.64	2.51
02YK005	SHEFFIELD BROOK NEAR TRANS-CANADA HIGHWAY	Newfoundland	NW	41	49	20	18	56	40	4	391	395.8	182.8	0.68	0.08	0.1	0.17	0.15	0.94	1.85	590	38.1	378	0.99	1.07	0.19	2.57
02YK007	GLIDE BROOK BELOW GLIDE LAKE	Newfoundland	NW	14	49	7	50	57	22	9	112	111.5	85.5	0.87	0.09	0.04	0.13	0	0.98	1.91	132	26.8	234	0.88	0.9	1.28	2.27
02YK008	BOOT BROOK AT TRANS-CANADA HIGHWAY	Newfoundland	NW	28	49	16	0	57	6	14	20.4	20.5	30.3	0.75	0.22	0.02	0.24	0.01	0.65	1.5	50	10.1	137	1.35	1.16	1.28	1.87
02YL001	UPPER HUMBER RIVER NEAR REIDVILLE	Newfoundland	NW	85	49	15	35	57	22	37	2110	2101.1	416.3	0.74	0.06	0.05	0.11	0.15	0.75	1.68	50	118.8	678	0.57	0.46	0.79	2.54
02YL004	SOUTH BROOK AT PASEDENA	Newfoundland	NW	30	49	1	44	57	37	41	58.5	58	55.9	0.94	0.01	0.01	0.02	0.05	0.08	1.06	50	13.2	130	0.99	1.04	1.34	2.05
02YL005	RATTLER BROOK NEAR MCIVERS	Newfoundland	NW	28	49	3	30	58	6	19	17	17.3	25.7	0.91	0.08	0.02	0.1	0	0.46	1.39	5	8.2	244	2.98	2.88	1.05	1.73
02YL008	UPPER HUMBER RIVER ABOVE BLACK BROOK	Newfoundland	NW	25	49	37	6	57	18	40	471	472.7	215.0	0.58	0.01	0.07	0.08	0.34	0.99	1.95	50	48.5	393	0.81	0.64	0.57	2.77
02YL011	COPPER POND BROOK NEAR CORNER BROOK LAKE	Newfoundland	NW	18	48	48	24	57	47	2	12.9	11.6	23.7								700						1.94
02YM001	INDIAN BROOK AT INDIAN FALLS	Newfoundland	NE	43	49	31	43	56	7	45	974	964.6	313.3	0.79	0.07	0.09	0.16	0.05	0.88	1.8	36.4	65	290	0.45	0.41	0.45	2.82
02YM003	SOUTH WEST BROOK NEAR BAIE VERTE	Newfoundland	NE	33	49	54	37	56	13	20	93.2	96.4	75.2	0.91	0.07	0.05	0.11	0	0.56	1.49	50	18.6	107	0.58	0.57	0.68	2.14
02YM004	INDIAN BROOK DIVERSION ABOVE BIRCHY LAKE	Newfoundland	NW	23	49	22	2	56	37	55	238	242.5	130.7								225						2.35
02YN002	LLOYD'S RIVER BELOW KING GEORGE IV LAKE	Newfoundland	SW	32	48	14	23	57	50	41	469	480.5	227.2	0.23	0.06	0.12	0.18	0.63	1	1.91	371	57.3	166	0.29	0.3	1.37	2.90
02YN003	STAR BROOK BELOW STAR LAKE	Newfoundland	NE	9	48	35	46	57	14	41	427	425.4	188.8	0.21	0.3	0.09	0.38	0.4	1	1.8	377	42.5	360	0.85	0.74	0.59	2.56
02YN004	STAR BROOK ABOVE STAR LAKE	Newfoundland	NW	13	48	38	38	57	19	41	276	277.6	147.2								50						2.47
02YO006	PETER'S RIVER NEAR BOTWOOD	Newfoundland	NE	32	49	6	14	55	24	48	177	177.7	129.7	0.83	0.13	0.03	0.16	0.02	0.97	1.89	50	42.7	190	0.45	0.45	0.8	2.72
02YO007	LEECH BROOK NEAR GRAND FALLS	Newfoundland	NE	13	48	57	42	55	50	42	88.3	86.8	67.5	0.7	0.24	0.04	0.28	0.02	0.73	1.57	50	23.1	272	1.18	0.88	0.74	2.03
02YO008	GREAT RATTLING BR. ABOVE TOTE R. CONFLUENCE	Newfoundland	NE	29	48	50	36	55	32	43	823	803.4	282.9	0.73	0.19	0.05	0.24	0.03	0.55	1.4	5	69	221	0.32	0.3	0.69	2.79
02YO010	JUNCTION BROOK NEAR BADGER	Newfoundland	NE	13	48	59	34	56	1	4	61.6	61.5	64.7	0.81	0.09	0.1	0.19	0	0.89	1.79	601	18.2	187	1.03	0.62	0.77	2.31
02YO012	SOUTHWEST BROOK AT LEWISPORTE	Newfoundland	NE	24	49	13	58	55	3	7	58.7	62.9	89.5	0.8	0.08	0.12	0.2	0	0.67	1.55	128	22.7	134	0.59	0.42	0.54	3.16
02YP001	SHOAL ARM BROOK NEAR BADGER BAY	Newfoundland	NE	16	49	22	18	55	49	44	63.8	62.8	61.4	0.88	0.07	0.06	0.13	0	0.79	1.72	119	20	113	0.56	0.53	0.88	2.17
02YQ001	GANDER RIVER AT BIG SHUTE	Newfoundland	NE	64	49	1	59	54	51	2	4400	4447.3	785.4	0.76	0.08	0.09	0.17	0.07	0.91	1.82	277	133.8	297	0.22	0.15	0.45	3.30
02YQ004	NORTHWEST GANDER RIVER NEAR GANDER LAKE	Newfoundland	NE	16	48	46	7	55	5	52	2150	2207.2	455.9	0.66	0.25	0.06	0.31	0.03	0.44	1.22	50	104.2	265	0.25	0.17	0.45	2.72
02YQ005	SALMON RIVER NEAR GLENWOOD	Newfoundland	NE	26	49	1	41	54	55	1	80.8	78.8	78.3	0.85	0.11	0.04	0.15	0	0.87	1.79	50	22.5	372	1.65	1.03	1.09	2.47
02YQ006	SOUTHWEST GANDER RIVER BELOW LARSON FALLS	Newfoundland	NE	10	48	39	26	55	5	52	531	536.6	222.6	0.64	0.3	0.04	0.34	0.02	0.4	1.16	50	51.3	299	0.58	0.26	0.4	2.69
02YR001	MIDDLE BROOK NEAR GAMBO	Newfoundland	NE	54	48	48	27	54	13	21	267	266	157.6	0.75	0.07	0.18	0.24	0.01	0.98	1.86	881	49.3	177	0.36	0.32	0.26	2.71
02YR002	RAGGED HARBOUR RIVER NEAR MUSGRAVE HARBOUR	Newfoundland	NE	21	49	24	35	54	6	25	399	394.8	169.2	0.68	0.16	0.17	0.33	0	0.96	1.79	65.1	42	95	0.23	0.21	0.74	2.38
02YR003	INDIAN BAY BROOK NEAR NORTHWEST ARM	Newfoundland	NE	32	49	3	32	53	53	8	554	581.2	230.2	0.7	0.13	0.2	0.33	0	0.97	1.8	307	52.4	136	0.26	0.23	0.68	2.67
02YS001	TERRA NOVA RIVER AT EIGHT MILE BRIDGE	Newfoundland	NE	34	48	27	30	54	22	21	1290	1327.2	438.8	0.55	0.21	0.09	0.3	0.15	0.92	1.76	138	105	207	0.2	0.12	0.73	3.37
02YS003	SOUTHWEST BROOK AT TERRA NOVA NATIONAL PARK	Newfoundland	NE	46	48	36	28	53	59	44	36.7	38.6	44.6	0.84	0.14	0.02	0.16	0	1	1.92	50	11.2	143	1.28	1.11	0.64	2.01
02YS005	TERRA NOVA RIVER AT GLOVERTOWN	Newfoundland	NE	28	48	40	46	54	1	55	2000	2033.8	532.5	0.61	0.23	0.13	0.36	0.03	0.93	1.74	113	128.8	274	0.21	0.16	0.35	3.31
02YS006	NORTHWEST RIVER AT TERRA NOVA NATIONAL PARK	Newfoundland	NE	18	48	24	49	54	12	2	663	669.1	310.4								12						3.36
02ZA001	LITTLE BARACHOIS BROOK NEAR ST. GEORGE'S	Newfoundland	SW	20	48	27	44	58	24	55	343	337.3	219.8	0.6	0.02	0.07	0.09	0.3	0.83	1.78	50	65.5	463	0.72	0.68	1.04	3.35
02ZA002	HIGHLANDS RIVER AT TRANS-CANADA HIGHWAY	Newfoundland	SW	31	48	7	30	58	47	1	72	70.3	66.4	0.82	0.01	0.04	0.05	0.13	0.43	1.39	50	20.4	460	2.26	2.19	1.15	2.22
02ZA003	LITTLE CODROY RIVER NEAR DOYLES	Newfoundland	SW	16	47	49	19	59	12	40	139	127.8	89.8	0.66	0.07	0.04	0.11	0.16	0.73	1.66	131	25.2	450	1.78	1.46	1.46	2.22
02ZB001	ISLE AUX MORTS RIVER BELOW HIGHWAY BRIDGE	Newfoundland	SW	51	47	37	48	59	1	35	205	204.3	154.7	0.08	0.06	0.07	0.13	0.78	0.6	1.52	50	33.3	444	1.33	1.27	0.72	3.03
02ZC002	GRANDY BROOK BELOW TOP POND BROOK	Newfoundland	SW	31	47	51	22	57	44	59	230	251.8	146.1	0.2	0.01	0.05	0.06	0.82	0.34	1.3	38.4	28.9	360	1.24	1.08	0.96	2.58
02ZD002	GREY RIVER NEAR GREY RIVER	Newfoundland	SW	41	47	45	36	56	56	2	1340	4588.3	914.1	0.04	0.16	0.04	0.2	0.75	0.63	1.51	50	60	310	0.52	0.34	0.15	3.78
02ZE001	SALMON RIVER AT LONG POND	Newfoundland	SW	22	47	57	40	55	55	50	2640	5920.9	1154.7	0.35	0.02	0.14	0.16	0.5	1	1.92	619	100.4	122	0.12	0.08	0.36	4.20
02ZE004	CONNE RIVER AT OUTLET OF CONNE RIVER POND	Newfoundland	SW	24	48	10	8	55	29	58	99.7	99.9	92.5	0.6	0.34	0.05	0.39	0.01	1	1.81	50	18.7	109	0.58	0.59	1.38	2.59
02ZF001	BAY DE NORD RIVER AT BIG FALLS	Newfoundland	SW	63	47	45	49	55	26	25	1170	1171.9	391.4	0.32	0.05	0.18	0.24	0.44	0.96	1.84	401	68.1	282	0.41	0.34	0.61	3.20
02ZG001	GARNISH RIVER NEAR GARNISH	Newfoundland	SE	55	47	13	59	55	20	48	205	210.7	179.3	0.26	0.01	0.09	0.1	0.63	0.96	1.91	202	44.7	370	0.83	0.6	0.55	3.46
02ZG002	TIDES BROOK BELOW FRESHWATER POND	Newfoundland	SE	21	47	8	38	55	16	54	166	163.6	115.4	0.37	0.04	0.09	0.13	0.49	0.92	1.85	588	26.7	221	0.83	0.78	1.35	2.53
02ZG003	SALMONIER RIVER NEAR LAMALINE	Newfoundland	SE	33	46	53	40	55	47	34	115	116.4	90.7	0.16	0.06	0.07	0.13	0.73	0.92	1.85	42.8	24.5	136	0.55	0.34	1.55	2.35
02ZG004	RATTLE BROOK NEAR BOAT HARBOUR	Newfoundland	SE	32	47	27	0	54	51	11	42.7	44.4	54.4	0.34	0.03	0.14	0.16	0.46	0.92	1.83	123	10	107	1.07	1.1	1.62	2.29
02ZG005	LITTLE BARASWAY BROOK NEAR MOLLIERS	Newfoundland	SE	10	47	6	0	55	37	15	28.2	27.45	40.8	0.31	0.08	0.07	0.15	0.55	0.5	1.4	132	13	133	1.03	1.19	1.43	2.15
02ZH001	PIPERS HOLE RIVER AT MOTHERS BROOK	Newfoundland	NE	61	47	57	48	54	17	4	764	764.7	258.2	0.11	0.48	0.18	0.66	0.23	0.91	1.57	17.4	50.9	207	0.41	0.38	0.71	2.61
02ZH002	COME BY CHANCE RIVER NEAR GOOBIES	Newfoundland	SE	45	47	55	8	53	57	55	43.3	34.9	48.0	0.4	0.02	0.08	0.1	0.5	0.92	1.87	20.8	17	110	0.65	0.59	1.11	2.28
02ZJ001	SOUTHERN BAY RIVER NEAR SOUTHERN BAY	Newfoundland	NE	37	48	23	50	53	40	26	67.4	68.5	63.6	0.82	0.06	0.1	0.16	0.03	0.86	1.78	89.3	16	128	0.8	0.5	1.24	2.15
02ZJ002	SALMON COVE RIVER NEAR CHAMPNEYS	Newfoundland	NE	30	48	24	45	53	18	6	73.6	78.3	66.0	0.74	0.06	0.13	0.19	0.07	0.82	1.72	435	18	137	0.76	0.55	1.11	2.09
02ZJ003	SHOAL HARBOUR RIVER NEAR CLARENVILLE	Newfoundland	NE	27	48	13	13	54	3	59	106	99.5	85.1	0.65	0.1	0.07	0.17	0.18	0.68	1.58	166	25.1	250	0.99	0.91	0.66	2.39
02ZK001	ROCKY RIVER NEAR COLINET	Newfoundland	SE	65	47	14	38	53	34	7	301	295.7	177.1	0.51	0.02	0.1	0.12	0.37	0.57	1.49	8.79	45.2	165	0.37	0.23	0.96	2.88
02ZK002	NORTHEAST RIVER NEAR PLACENTIA	Newfoundland	SW	34	47	16	26	53	50	19	89.6	92.85	88.3	0.48	0.16	0.15	0.31	0.24	0.81	1.64	278	26.9	200	0.74	0.57	1.11	2.61
02ZK003	LITTLE BARACHOIS (BARASWAY) R NEAR PLACENTIA	Newfoundland	SW	30	47	11	53	54	2	20	37.2	37.1	43.0	0.86	0.11	0.02	0.13	0.01	0.34	1.24	50	14.6	228	1.56	1.77	1.16	1.98
02ZK004	LITTLE SALMONIER RIVER NEAR NORTH HARBOUR	Newfoundland	SW	30	47	7	19	53	44	54	104	104.7	97.7	0.23	0.38	0.08	0.46	0.31	0.91	1.67	116	28.5	236	0.83	0.66	1.5	2.67
02ZK005	TROUT BROOK NEAR BELLEVUE	Newfoundland	SE	12	47	36	21	53	46	53	50.3	47.2	79.2	0.36	0	0.07	0.07	0.57	0.5	1.45	91.6	14.8	137	0.92	0.88	1.18	3.23
02ZL003	SPOUT COVE BROOK NEAR SPOUT COVE	Newfoundland	SE	19	47	49	43	53	9	15	10.8	10.8	21.7	0.42	0.01	0.08	0.09	0.49	1	1.95	319	7	91	1.31	1.25	1.09	1.85
02ZL004	SHEARSTOWN BROOK AT SHEARSTOWN	Newfoundland	SE	30	47	35	59	53	18	29	28.9	29.8	49.7	0.7	0	0.04	0.04	0.27	0.39	1.36	50	13.4	122	0.91	1.03	1.14	2.55
02ZL005	BIG BROOK AT LEAD COVE	Newfoundland	SE	28	48	3	34	53	5	56	11.2	11.2	25.4	0.39	0.03	0.07	0.1	0.51	1	1.95	272	8.7	211	2.43	2.43	1	2.13
02ZM006	NORTHEAST POND RIVER AT NORTHEAST POND	Newfoundland	SE	60	47	38	5	52	50	12	3.9	3.7	11.1	0.75	0.17	0.04	0.21	0.04	1	1.89	265	2.6	64	2.44	2.42	1.04	1.62
02ZM009	SEAL COVE BROOK NEAR CAPPAHAYDEN	Newfoundland	SE	34	46	51	47	52	58	21	53.6	54.9	48.8	0.38	0.01	0.12	0.14	0.51	1	1.93	193	14.9	133	0.89	0.98	1.13	1.84
02ZM010	WATERFORD RIVER AT MOUNT PEARL	Newfoundland	SE	16	47	31	21	52	49	32	16.6	17.7	26.4								50						1.76
02ZM016	SOUTH (MAHERS) RIVER NEAR HOLYROOD	Newfoundland	SE	30	47	21	17	53	7	2	17.3	16.6	29.4	0.22	0.05	0.06	0.11	0.68	0.9	1.84	148	8.7	259	2.98	2.22	1.01	2.02
02ZM017	LEARY BROOK AT ST. JOHN'S	Newfoundland	SE	16	47	34	43	52	46	47	15.3	7.1	16.2								50						1.70
02ZM018	VIRGINIA RIVER AT PLEASANTVILLE	Newfoundland	SE	29	47	35	20	52	41	27	10.7	12.1	25.2								21						2.03
02ZM019	VIRGINIA RIVER AT CARTWRIGHT PLACE	Newfoundland	SE	14	47	36	6	52	42	6	5.55	5.4	20.6								105						2.49
02ZM021	SOUTH BROOK AT PEARL TOWN ROAD	Newfoundland	SE	13	47	30	24	52	46	24	9.21	10.1	20.8								50						1.83
02ZN001	NORTHWEST BROOK AT NORTHWEST POND	Newfoundland	SE	31	46	51	8	53	18	11	53.3	90.3	98.9	0.09	0	0.13	0.13	0.79	1	1.94	132	14.6	93	0.63	0.61	1.09	2.91
02ZN002	ST. SHOTTS RIVER NEAR TREPASSEY	Newfoundland	SE	28	46	43	36	53	29	8	15.5	15.7	32.4	0.88	0	0.12	0.12	0	0.82	1.75	512	10.3	23	0.22	0.43	1.03	2.29
02XA003	LITTLE MECATINA RIVER ABOVE LAC FOURMONT	Labrador	Labrador	35	52	14	47	61	19	1	4540	4892.8	1029.9								50						4.12
02XA004	RIVIERE JOIR NEAR PROVINCIAL BOUNDARY	Labrador	Labrador	17	52	10	50	60	4	34	2060	2017.3	484.8								50						3.02
03NE001	REID BROOK AT OUTLET OF REID POND	Labrador	Labrador	15	56	22	23	62	10	41	75.7	76.1	67.7								27						2.17
03NF001	UGJOKTOK RIVER BELOW HARP LAKE	Labrador	Labrador	34	55	14	3	61	18	6	7570	7557.6	1181.8								50						3.81
03NG001	KANAIRIKTOK RIVER BELOW SNEGAMOOK LAKE	Labrador	Labrador	18	54	37	25	60	59	38	8930	8912	1302.8								50						3.86
03OC003	ATIKONAK RIVER ABOVE PANCHIA LAKE	Labrador	Labrador	27	52	58	6	64	40	42	15100	15776.1	1404.4								90						3.13
03OD007	EAST METCHIN RIVER	Labrador	Labrador	15	53	26	5	63	14	2	1750	894.8	294.1								131						2.75
03OE003	MINIPI RIVER BELOW MINIPI LAKE	Labrador	Labrador	33	52	37	45	61	11	8	2330	2336.2	555.1								106						3.22
03OE010	BIG POND BROOK BELOW BIG POND	Labrador	Labrador	19	53	31	46	60	18	36	71.4	70.7	82.8								18						2.76
03OE011	PINUS RIVER	Labrador	Labrador	15	53	9	51	61	34	31		781.5	331.8								226						3.32
03PB002	NASKAUPI RIVER BELOW NASKAUPI LAKE	Labrador	Labrador	34	54	8	55	61	26	37	4480	4609.2	709.8								50						2.93
03QC002	ALEXIS RIVER NEAR PORT HOPE SIMPSON	Labrador	Labrador	35	52	39	55	56	52	16	2310	2318.3	475.6								50						2.77
										Maximum	15100.00	15776.10	1404.41	0.94	0.48	0.22	0.66	0.82	1.00	1.95	1053.00	133.80	700.00	2.98	3.09	1.73	4.20
										2nd Highest	8930.00	8912.00	1302.75	0.91	0.38	0.20	0.46	0.79	1.00	1.95	881.00	128.80	678.00	2.98	2.88	1.62	4.12
										Median	188.50	197.70	129.67	0.66	0.07	0.08	0.16	0.15	0.91	1.79	105.00	26.85	221.00	0.83	0.65	0.90	2.54
										2nd Lowest	5.55	5.40	16.20	0.08	0.00	0.02	0.04	0.00	0.34	1.16	5.00	7.00	64.00	0.20	0.12	0.19	1.70
										Minimum	3.90	3.70	11.13	0.04	0.00	0.01	0.02	0.00	0.08	1.06	5.00	2.60	23.00	0.12	0.08	0.15	1.62

Abbreviations:

ID #	station identification number
DEG	degrees
MIN	minutes
SEC	seconds
FTREE	fraction of watershed occupied by forests
FSWAMP	fraction of watershed occupied by swamps
FLAKE	fraction of watershed occupied by lakes and swamps
FLSAR	fraction of watershed occupied by lakes and swamps
FBAR'N	fraction of watershed occupied by barren area
FACLS	fraction of watershed controlled by lakes and swamps
LSF	lakes and swamps factor
LAF	lake attenuation factor
LENGTHMAINR	length of main river channel
ELEVDIFF	elevation difference between the outlet and watershed divide
SLOPEM1	slope method 1
SLOPEM2	slope method 2

Legend

	Missing Data