REGIONAL FLOOD FREQUENCY ANALYSIS FOR NEWFOUNDLAND AND LABRADOR 2014 UPDATE

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 final report for 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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EXECUTIVE SUMMARY

A Regional Flood Frequency Analysis (RFFA) is a method by which sets of equations for estimating return period flood flows in ungauged watersheds are developed. A RFFA was originally completed for the island of Newfoundland in 1971. Three updates of the RFFA were subsequently completed in 1984, 1990 and 1999. None of these assessments developed equations for Labrador.

The current (2014) update of the RFFA work scope includes elements that stem from recommendations made in the 1999 RFFA update, as well as, new elements requested by the Province of Newfoundland and Labrador (the "Province"). In general this work scope included the following:

- Update of the RFFA regression equations for the island of Newfoundland following the methodology and equation structure adopted for the 1999 RFFA update using up to date hydrologic and topographic data. Within this update effort, the following investigations were also completed:
  - Development of RFFA equations for floods in small watersheds (< 50 km^2)
  - Development of RFFA equations reflective of Newfoundland as one single hydrological homogeneous region (the 1999 RFFA update represented Newfoundland as four (4) regions)
  - Comparison of the equations developed using the approaches noted above to those developed using the 1999 RFFA approach making recommendation to which approach estimates flood frequency flows with more accuracy.
- Development of RFFA regression equations for Labrador
- Development of a user guide and spreadsheet software for use by engineers

The methodology outlined below formed the basis of the current RFFA update:

a) The characteristics of floods have been examined along with the climatic considerations and the physiographic influences. This aspect of the assessment has been fundamentally based on the Flood Risk and Vulnerability Analysis Project (AMEC, 2012).

b) A database of flood flows has been created using the most up to date version of the HYDAT database (April 2014) from Environment Canada, missing data estimated, and the flood series statistically and hydraulically screened. Unregulated streamflow data from 111 stations in the Province, each with 10 or more years of data, has been assessed for applicability to the current RFFA update. The screening process resulted in a dataset of 90 stations (12 in Labrador and 78 in Newfoundland) from which to be the RFFA regression equations.

c) A single station frequency analysis has been conducted on each flood series. The single station frequency analysis provided estimates of frequency flows for the 2, 5, 10, 20, 50, 100

and 200 year return periods. The 3 Parameter Log Normal distribution was used, consistent with the 1999 RFFA.

d) Mathematical equations have been formulated such that return period flood flows can be estimated on ungauged and unregulated watersheds. One parameter and two parameter equations, based on drainage area (DA), lake attenuation factor (LAF) and lakes and swamps factor (LSF) have been developed. Newfoundland was segregated into four (4) hydrologically homogeneous regions, namely North-west (NW), North-east (NE), South-east (SE) and South-west (SW). Equations for the NW, NE and SE regions were based on DA and LAF. The equations for the SW region were based on DA and LSF. Labrador was viewed as a single region with the recommended equations based on DA only.

e) The equations for predicting return period flood flows have been tested using an independent set of station data. Analogous to the 1999 RFFA update, 80% of the screened station data was used for regression equation development and the remaining 20% of the screened station has been used for verification purposes.

f) Verification testing of the equations determined in Step (d) has been completed. The results of this study have been compared to results of the 1999 RFFA.

General conclusions from this RFFA update include:

1. Regression statistical parameters developed as part of the 2014 RFFA have been found to be consistent with the 1999 RFFA, but have shown relatively higher standard error of estimation and lower correlation coefficients compared to previous studies. The 2014 update has used only two physiographic parameters (Drainage Area and Lake Attenuation Factor) while the older studies (1990 and 1984) have used more parameters which may result in lower levels of error for estimation.
2. Regression equations developed for the regions of Newfoundland have regression correlation coefficients of 90% or higher for all return period flows. The exception to this has been the SW region where the regression correlation coefficient has a range of 84%-89%.
3. Comparing the results of the verification of regression equations with independent datasets has indicated that the percentage differences between the frequency flow estimates and regression equation estimates are generally lower in the 2014 study, compared to the results from the 1999 RFFA.
4. The range of the physiographic parameters used for development of regression equations has expanded significantly in the 2014 update, when compared with the parameter envelope from the 1999 RFFA, especially for drainage area. Therefore, the equations are applicable for a greater range of watershed area compared to the 1999 RFFA.
5. Regression equations have also been developed considering Newfoundland to be one hydrologically homogenous region. The regression correlation coefficients have a range of 84%-88% which is equal to or lower than the values developed for any of the four (4) regions in Newfoundland. The standard error of the estimation associated with the one region has also been computed to be greater than the levels observed for any of the four individual

regions. It has been concluded, therefore, that the regression equations developed for the four (4) regions of Newfoundland provide a better estimate for frequency flows.

6. The 1999 RFFA recommended developing a separate set of regression equations for watersheds having a drainage area of less than 50 km^2. Regression equations have therefore been developed using results from the single station frequency analysis for twenty-one (21) watersheds in Newfoundland having this characteristic. The physiographic parameters selected have been drainage area and lake attenuation factor to support development of the regression equations, to be consistent with the 1999 RFFA. Results of the analysis indicate that selection of drainage area as the only independent variable does not result in a good fit and including lake attenuation factor, despite increasing the regression correlation coefficient, does not have a significant impact on the goodness of fit. It has been concluded, therefore, that the regression equations developed for the four (4) regions of Newfoundland provide a better estimate for frequency flows for watersheds having drainage area less than 50 km^2.
7. Similar methodology has been applied to watersheds in Labrador. Single station frequency analysis has been conducted using a 3 Parameter Log Normal distribution. Regression equations have been developed for all return period floods using the frequency flows for all available gauges which have passed the screening process. Drainage area and lake attenuation factor have been selected as independent variables for the regression process, in order to maintain consistency with the methodology used for Newfoundland. Regression statistical parameters indicate that drainage area accounts for 95%-97% of variations in frequency flows, but lake attenuation factor does not have a significant impact on different return period floods.
8. Regional flood indexes have been developed for all regions in Newfoundland and Labrador which may be used for estimation of frequency floods for ungauged watersheds with few years of available data, but their application should be done with caution as the impact of physiographic parameters on frequency flows has not been considered in this method and priority should be given to regional regression equations.

Recommendations:

1. Regression equations have been developed with data from a greater number of gauges in Newfoundland compared to the 1999 RFFA; however, there are still several gauges with only a short period of available data. It is therefore recommended to update the current RFFA in 5 to 10 years to have increased accuracy in results of single station frequency analysis which are the basis for the regression equation development.
2. The SW region in Newfoundland has the highest levels of estimation standard error and lowest levels of regression correlation coefficient. While both drainage area and lake and swamp factor have been found to have significant influence on the frequency flows, it is recommended to investigate if including additional physiographic parameters in the equations for the South-west region may increase the goodness of fit for the regression equations.
3. Equations developed for Labrador have strong regression parameter statistics; however, after the data screening process, only twelve (12) gauges, through the entire Labrador region, were

available for regression equation development which made it impossible to verify the developed equations using independent data. The drainage area variable used in the regression equation development process has a wide range from 4 km^2 to 15776 km^2 and lake attenuation factor has been found to have no significant impact on estimation of frequency flows. It is therefore recommended to increase the number of gauging stations in Labrador to support update the equations in future using a larger number of flow gauges. It is also recommended that the value of adding other physiographic parameters to the equations be evaluated. Until then, it is recommended to use only drainage area as the independent physiographic parameter for Labrador.

4. While dividing Newfoundland into four (4) hydrologically homogeneous regions may not be very desirable, considering the island to be one single region has not resulted in strong goodness of fit for the associated regression equations. Considering the relatively close regression statistical parameters for the three regions of North-west, North-east and South-east, it is recommended to assess the validity of merging these three regions into one single region or some combination of these three regions into two regions. Having fewer regions would simplify the effort for future RFFA updates.

5. Further assessment is required in order to develop regression equations for smaller watersheds with less than 50 km^2 drainage area. It is recommended to investigate other physiographic parameters for these watersheds and develop regression equations using independent parameters which have a higher influence on frequency flows, compared to lake attenuation factor.

6. It has been documented that precipitation patterns in Newfoundland are changing, perhaps as a result of climate change. This RFFA update sought to maximize data availability to support regression equation development by including all station data which passed the various screening tests. This resulted in a temporal mix of data, some that might be generally considered to be “older” (greater than 20 years old) and some “newer” (the past 20 years). Single station frequency analysis may result in a different set of frequency flows if the entire record is used or if only the most recent past 20 years is used. It is recommended that this issue be investigated in a future RFFA update.

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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 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 impacts 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 are developed through a Regional Flood Frequency Analysis (RFFA).

This study, 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.

Regular updates of the Regional Flood Frequency Analysis, on a 5-10 year cycle, have been recommended in previous studies and are justified based on the expanded hydrometric and physiographic databases: more watersheds available for analysis, longer periods of record, and the range of physiographic parameter values may have increased. Technology, such as Geographic Information Systems (GIS), also evolves and additional offers opportunities for more efficient and effective data processing.

The annual cost of flooding to public property in the Province is estimated to be in the hundreds of thousands of dollars. Accurate flood estimation using Regional Flood Frequency Analysis will allow for the effective design of in-stream structures by minimizing capital and flood damage costs. This is particularly relevant since many of the in-stream structures are constructed and repaired by the Province.

1.1 Work Scope

This RFFA update effort is comprised of the following major components:

- Update of the regional equations for Newfoundland, last updated in 1999, using up to date and readily available hydrologic and physiographic data.
- Extend the RFFA to include Labrador, that is, develop regional equations specific to Labrador using the same methodology as applied to Newfoundland.
- Develop a user's guide/manual and spreadsheet software for use by engineers.

1.2 Methodology

The methodology outlined in the 1999 RFFA will form the basis of this updated assessment, as described below. It should be noted that the previous RFFA encompassed the island of Newfoundland only. For the current update, the RFFA will also include Labrador and will also be based on the methodology described below.

a. The characteristics of floods will be examined along with the climatic considerations and the physiographic influences.

b. A database of flood flows will be created, missing data estimated (where possible), and the flood series statistically and hydraulically screened.

c. A single station frequency analysis will be conducted on each flood series.

d. Mathematical equations will be formulated such that return period flood flows can be estimated on ungauged and unregulated watersheds.

e. The equations for predicting return period flood flows will be tested using an independent set of station data.

2.0 REVIEW OF FLOODS IN NEWFOUNDLAND AND LABRADOR

A detailed review of flooding in the Province and related and casual factors was completed in 2012 through the *Flood Risk and Vulnerability Analysis Project* (AMEC, 2012). Portions of the executive summary from the report are replicated below for convenience.

"The Flood Events Inventory is a database of flood events which have occurred in the Province of Newfoundland and Labrador over the period 1950-2011. The database was compiled through a review of existing information contained in the previous Flood Events Inventory and the collection and compilation of new data. The updated inventory now documents 650 flood events and 269 storm events over the period 1950 to 2011.

The Eastern and Western regions have more documented flood producing storm events than the Central region with a total of 148, 91, 29 storm events documented in the inventory, respectively.

The inventory documents flood events at ninety-eight communities in the Province. St. John's has had the most reported floods with seventy-three or about 11% of the documented floods in the inventory. Stephenville, Corner Brook, Deer Lake and Placentia have all reported multiple floods in the Western Region. Flooding in Labrador is extremely rare with only one documented flood event in the current inventory.

Rainfall events result in the greatest number of flood events representing the causal event in 66% of the flood events in the inventory. Flood events associated with coastal events occur most frequently in the fall and winter. Together, flood events resulting from rainfall or coastal processes represent 87% of the events documented in the inventory. Other casual factors include snow melt and ice jams.

Beyond simply documenting location and date/time of a flood or storm, the Inventory also includes damage estimates, and some basic information about impacts (homes flooded, people displaced, etc.). A link to the source information for the data record is also defined.

Two sources of damages data are presently available in the Flood Event Inventory, namely; damage estimates abstracted from the source data and Disaster Financial Assistance Arrangements (DFAA) damage estimates.

Of the 650 flood events in the Flood Events Inventory, only fifty-three flood events have damage estimates [based on source data reports] totalling about $252 million (normalized to 2011 dollars). Damage estimates range from a few thousand dollars to over $100 million associated with Hurricane Igor in 2010. Eighteen flood events in the inventory have documented damages of $1 million or more. The average annual cost is estimated to be about $8.1 million over the period (1962-2011) represented by data records with damage information (i.e., $252M/31) or $4.5 million (i.e., $252M/56) if it is assumed that years with no recorded flood damages are taken into account.

Similarly, eleven flood events have damage estimates (based on DFAA Damage Reports) totalling about $180 million (normalized to 2011 dollars). All DFAA damage estimates are greater than $1 million. The average annual cost is estimated to be about $22.5 million over the period

(2000-2010) represented by data records with damage information (i.e., $180M/8) or $16.3 million (i.e., $180M/11) if it is assumed that years with no recorded flood damages are taken into account.

It is suspected though that average annual damages may be higher as many of the records in the inventory lack damages estimate data."[1]

Other flood related issues discussed in the report included:

Land Use Change[1]

"Across the thirty-nine community flood watersheds accessed only one did not experience a loss of forest cover over the assessment period, namely Hant's Harbour. The other community flood watersheds experienced loss of forest cover in the range of about 4% to almost 28%."

Climate Change[1]

"The particular time frames of interest for the climate change assessment were 2020, 2050 and 2080. Areas of focus for the climate change assessment were projected climate, hurricanes and tropical storms, sea level rise, ocean currents, and some possible worst case scenarios.

Precipitation is anticipated to increase into the future as average temperatures rise across the Province. Summer precipitation on the island remains basically neutral in the first half of the century with mild increases thereafter while Labrador sees a steady rise in summer precipitation. There is a clear steady rise in winter precipitation across all WRMD[2] *regions through the century. The differential change in precipitation across the island's three WRMD regions is very small. The West sees slightly larger winter increases while Labrador shows large steady increases in both summer and winter. This represents an influence towards increased flood risk across the Province, especially in winter for all WRMD regions. Winter thaws and rain events could lead to increases in rain on snow flooding. Winter rains also lead to greater risk of rain on frozen ground events where the ground's ability to absorb liquid is compromised.*

On average, Newfoundland and Labrador is affected, or threatened, by one or two tropical storm systems each year, based on 92 storms tracking across or near Newfoundland and Labrador from 1954 – 2011. A breakdown of tropical system frequency for each of the five regions of Newfoundland and Labrador, based on intensity, is provided in the table below. A post or extra tropical storm is a cyclone which has lost its tropical characteristics and peak wind speeds have diminished, typically when a storm begins interacting with colder water temperatures or has become absorbed within a larger synoptic system.

[1] *Flood Risk and Vulnerability Analysis Project*, Water Resources Management Division, Department of Environment and Conservation, Government of Newfoundland and Labrador, Completed by AMEC Environment & Infrastructure, June 13, 2012

[2] Water Resources Management Division, Department of Environment and Conservation, Government of Newfoundland and Labrador

Table 2-1: Storm System Frequency across Newfoundland				
Storm Type	**Labrador**	**Western**	**Central**	**Eastern**
Post or Extra Tropical Storm	9	10	3	16
Tropical Storm	0	3	0	3
Category 1 Hurricane	0	3	0	4
Category 2 Hurricane	0	0	1	0
Category 3 Hurricane	0	0	0	0

Climate change currently being experienced across much of the globe, including Newfoundland and Labrador, will continue to promote an increase in the frequency of tropical cyclone development over the Tropical Atlantic through the end of the 21st century. Additionally, storms are expected to mature into more intense hurricanes (higher category) and are expected to have an increased ability to survive their track towards Atlantic Canada, arriving with more force as the increasing water temperatures south of Newfoundland will not provide as much resistance to promote weakening as experienced before the 1990's.

Hurricanes, with their combination of abundant rains over wide areas and strong winds producing significant storm surge and waves, have, like Hurricane Igor, caused some of the worst and costliest floods in Newfoundland. With increased frequencies and intensities anticipated in the coming decades, flooding events of the magnitude of Hurricane Igor, a Category 1 storm, are likely to occur more frequently. As Atlantic sea surface temperatures warm, the probability of another Category 2 hurricane making landfall in Newfoundland increases. In addition, it would not be unrealistic to expect a first Category 3 hurricane to make landfall in Newfoundland before 2080, perhaps before 2050.

Sea level is an ocean indicator for climate change. Sea level in the Province has been observed to be rising relative to benchmarks and wharf deck elevations. The rate of global mean sea level rise is presently estimated at about 3 mm/year, yet another confirmation that global warming is already underway. There are regional differences also. For the North Atlantic, a comparable rate of about 2.5 mm/year is estimated. These rates may increase with continued melting of the polar ice caps and warming of the oceans.

Sea level also changes locally in relation to the geological uplift or subsidence of the earth which is in response to the retreat of the ice sheets that covered and depressed the land during the last glaciation, some 10,000 to 20,000 years ago. Though uplift has slowed since the glacial sheet melted, it is still occurring at different rates over the Province. Geophysical modelling indicates uplift rates of 0 to 4 mm/year for Labrador and the Northern Peninsula, and subsidence rates of 0 to 2 mm/year for Newfoundland.

The net long term sea level effect is the sum of global sea level changes and local geological impact. Batterson and Liverman (2010) have prepared projections of sea level rise by 2049 and 2099 relative to 1990 levels for four regions in Newfoundland and Labrador. The 2099 projections are illustrated below.

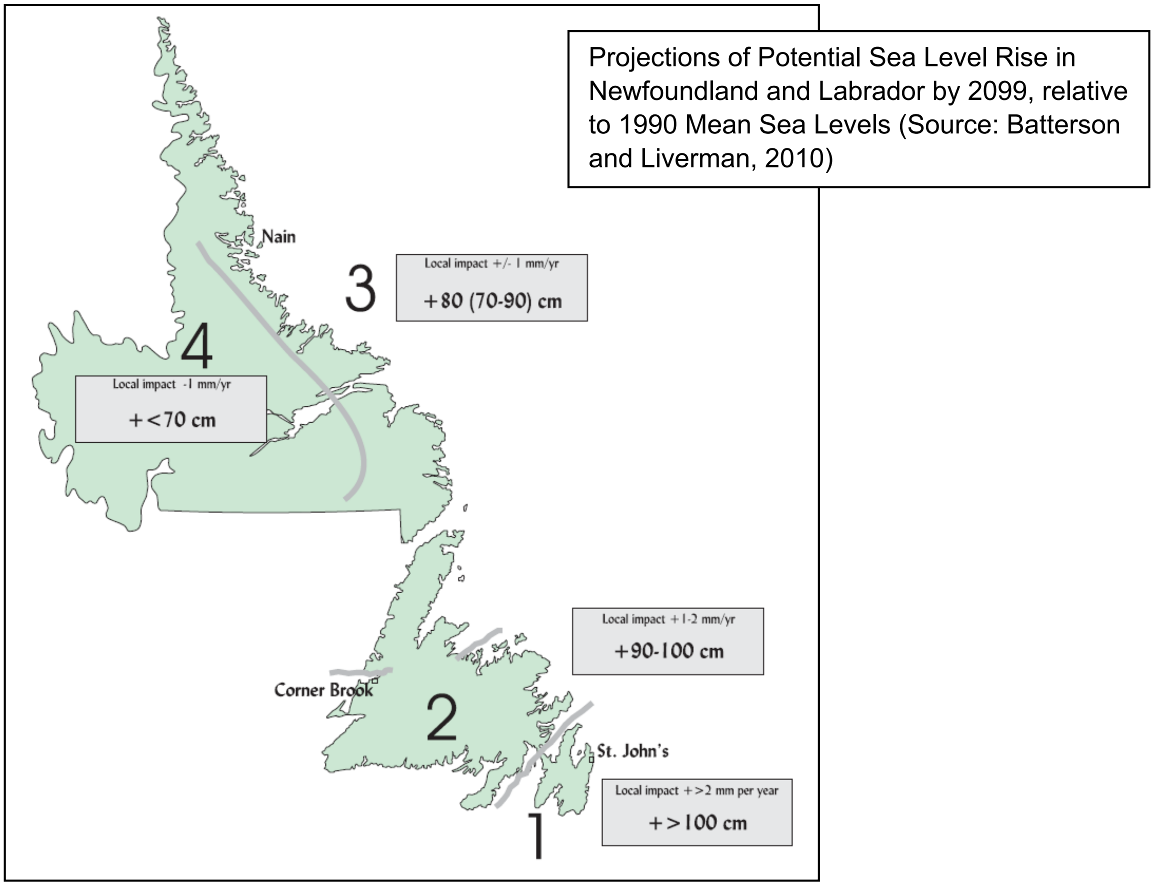

Figure 2-1: Projections of Potential Sea Level Rise in Newfoundland and Labrador

The two major currents that influence the local weather and global climate of Newfoundland are the Labrador Current and the Gulf Stream. The Labrador Current carries cold and relatively fresh water from the Arctic south along the continental shelf and slope of Labrador and Newfoundland. The Gulf Stream brings warm and salty water north from the Gulf of Mexico along the continental slope of North America. It veers to the northeast away from the continent at Cape Hatteras and flows eastward just south of the Grand Banks, occasionally moving north onto their southern edge. The presence of the air masses over the two currents, moist and cold over the Labrador Current, moist and warm over the Gulf Stream, directly affects the temperature, precipitation and formation of fog, especially on the eastern coastal region of the island of Newfoundland.

The ocean currents which exert a major influence on Newfoundland and Labrador climate are not expected to change significantly as a result of global warming over this century. The ocean-atmosphere oscillations that are responsible, to some extent, for the observed decadal (and longer) cycles in warmer and colder periods and periods with greater tropical storm intensity, continue through to the end of this century, if not beyond. Their periodicity and intensity may change somewhat over the coming decades and tracking those may help to predict climate anomalies in particular years or series of years in the future. But because these planetary scale general circulation features are in all likelihood well handled by global climate models, the gradual upward trends in temperature and precipitation seen out to 2050 and 2080 likely capture the long term effects of the small changes in these large ocean currents and oscillations.

Worst case scenarios are intense phenomena that may occur in isolation or in combination with other events or circumstances that could lead to extreme water levels and hence flooding conditions. A preliminary, largely qualitative, assessment of scenarios that could lead to extreme flooding in parts of Newfoundland and Labrador was completed focusing on winter rain, Atlantic bombs, hurricanes and tropical storms, and severe summer weather. While these phenomena are considered rare, most of these events have occurred in the past and are likely to occur again."

3.0 SINGLE STATION ANALYSIS

3.1 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 3-1 and 3-2, respectively. Data has also been statistically screened using the following tests:

- Trend
- Randomness
- Independence
- Homogeneity

Flood records demonstrating significant influences from any of these tests have been rejected from further analysis.

A single station frequency analysis has been completed for each annual maximum daily flood series, with ten (10) or more years of data, whereby a statistical distribution has been fitted to the remaining single station records to estimate frequency flows for each site.

3.2 Data Screening

3.2.1 Record Screening

WSC 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. It was originally proposed to use the January 13, 2014 HYDAT database (as it was the most up to date at the time of writing of the proposal for this project), however a revised HYDAT database was published on April 15, 2014 (in the midst of this project). A comparative review of the station data for the Province, across the two databases, has been completed to confirm that all available WSC data has been included in this RFFA update.

The following comments relate to initial screening of the data to identify those stations which could potential be used to support the RFFA update.

From the January 13, 2014 HYDAT:

- The database identifies 203 streamflow gauges located in the Province with streamflow records to 2012.
- Of the 203 stations, 176 stations have data which includes measurement of maximum daily instantaneous flows.

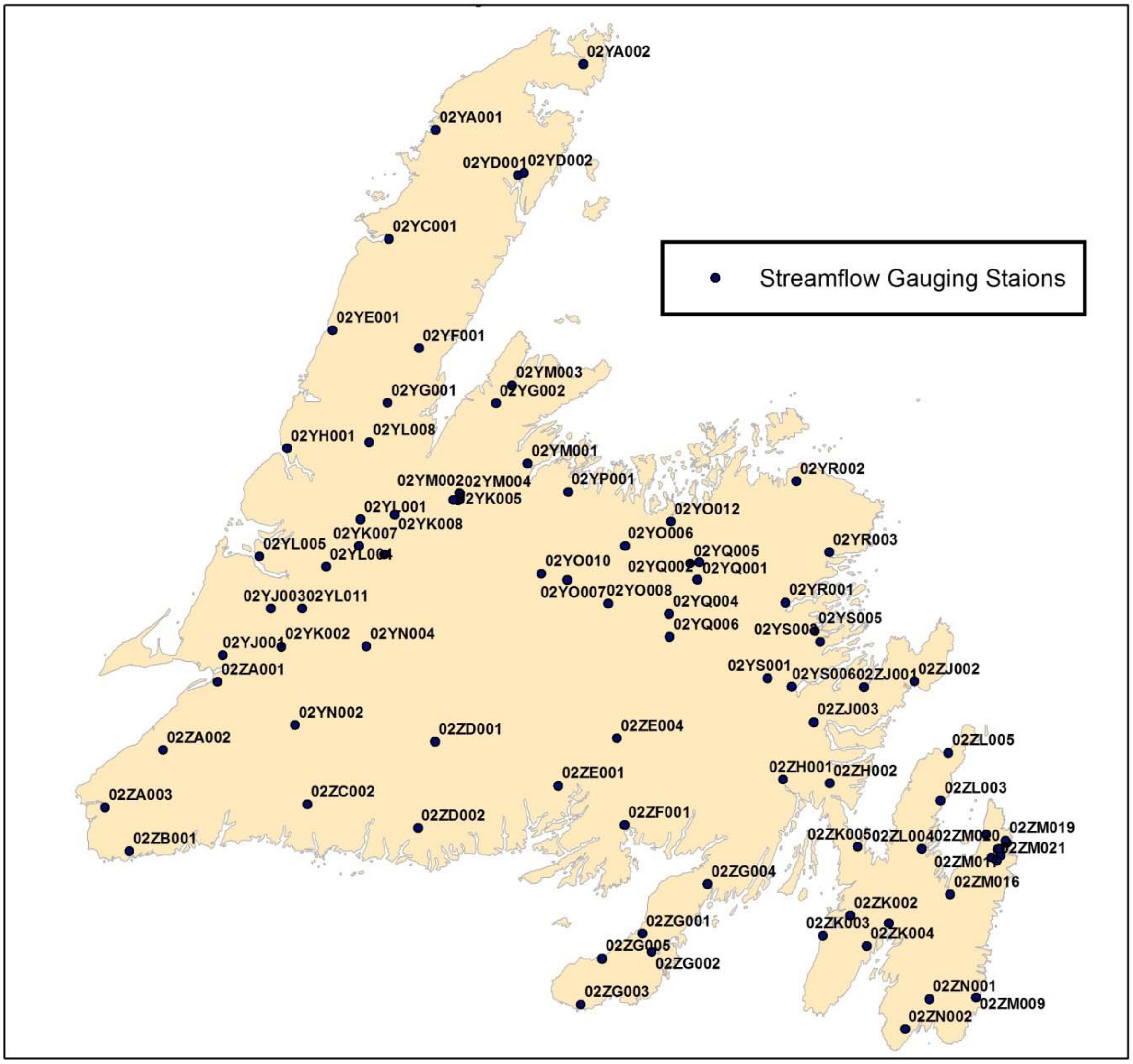

Figure 3-1: Locations of Streamflow Gauging Stations in Newfoundland

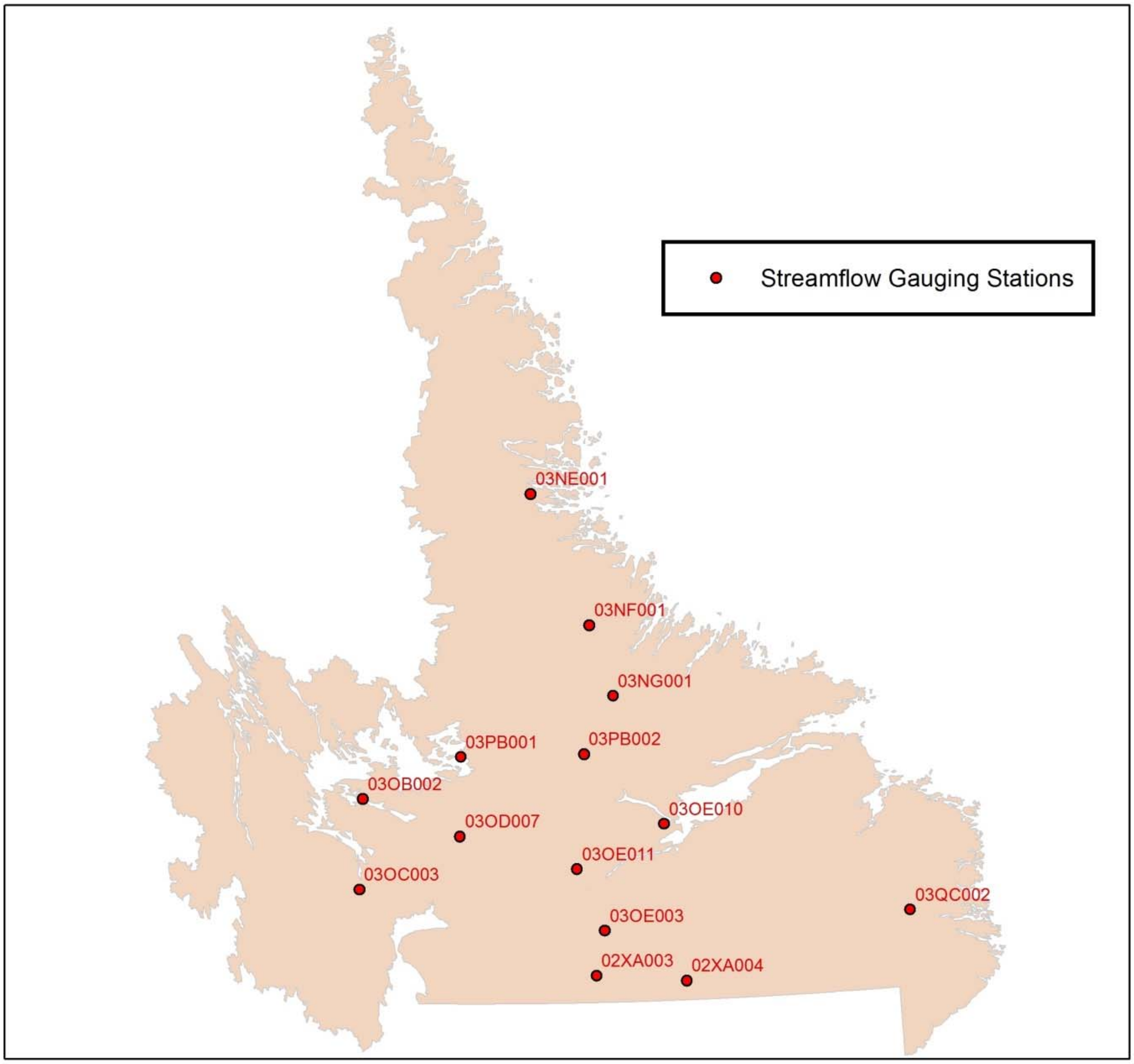

Figure 3-2: Locations of Streamflow Gauging Stations in Labrador

- Of the 176 stations, 31 stations measure regulated flows, 143 stations measure unregulated flows and for 2 stations this metric is noted as "undefined".

  The two "undefined" stations are:

  03OA009 Harrie River at Outlet of Harrie Lake
  03OE009 Peters River Below Lindo Lake

  Both of these stations only has a record length of only 2 years.
- Of the 143 stations, 108 stations have records greater than or equal to 10 years.[3]
- Of the 108 stations, 66 stations are still active and 42 have been discontinued.

[3] The 1999 RFFA used a station record length cut-off of 10 years which was also applied for this RFFA update.

From the April 15, 2014 HYDAT:

- The database identifies 205 streamflow gauges located in the Province with streamflow records to 2012.
  The two stations added to the HYDAT database in the April release are:

02ZM023	Outer Cove Brook at Clovelly Golf Course
02ZM024	Outer Cove Brook below Airport

  These are both new stations having record lengths of only 1 year each.
- Of the 205 stations, 178 stations have data which includes measurement of maximum daily instantaneous flows.
- Of the 178 stations, 31 stations measure regulated flows, 145 stations measure unregulated flows and for 2 stations this metric is noted as "undefined". The two "undefined" stations are:

03OA009	Harrie River at Outlet of Harrie Lake
03OE009	Peters River Below Lindo Lake

- Of the 145 stations, 111 stations have a period of record greater than or equal to 10 years.[2]
- Of the 111 stations, 69 stations are still active and 42 have been discontinued.

  The three additional stations identified using the April 15, 2014 HYDAT database (beyond those included with the January 13, 2014 HYDAT database) not excluded through the general screening process were:

02YR004	Triton Brook above Gambo Pond
03NE011	Reid Brook below Tributary
03NE012	Tributary To Reid Brook

Therefore, in using the April 15, 2014 release of the HYDAT database, the following additional data has been included in this RFFA update:

- Data for stations 02YR004, 03NE011, 03NE012
- 2012 streamflow data for a number of the stations defined in both HYDAT releases

Figure 3-3 illustrates and Table 3-1 provides a summary of the available HYDAT data for the 111 stations. As can be seen from Figure 3-3, a number of stations have missing annual maximum instantaneous flow data. Where missing data have been identified, these values have been estimated from the available annual maximum daily discharge data using regression analysis techniques, where possible, as presented in Table 3-3. A comprehensive review of the datasets to support the single station flood frequency analysis is presented in Appendix A.

Further review of the streamflow data for the stations identified in Table 3-1 has indicated that fourteen (14) of these stations have a period of record of greater than or equal to 10 years but do not have 10 years of recorded data (ref. Table 3-1).

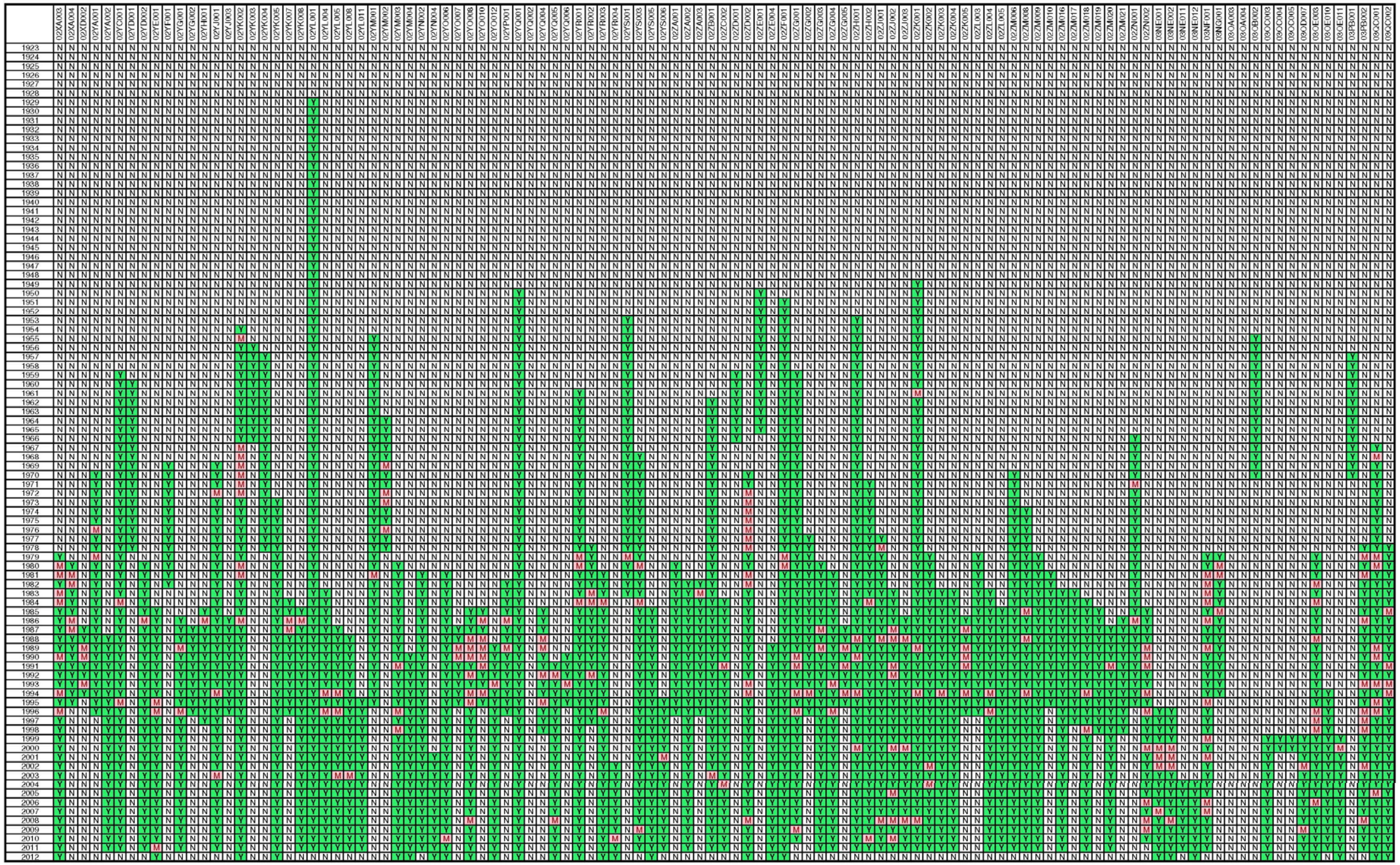

Figure 3-3: Summary of Available Streamflow Data in Newfoundland and Labrador Streamflow Gauges

Table 3-1: Streamflow Gauging Stations Available for Frequency Analysis

Station Number	Station Name	Area (km^2) from HYDAT	Start Year	Finish Year	Period of Record	Number of years with	
						Available data	Missing data
02XA003	Little Mecatina River Above Lac Fourmont	4540	1978	2012	35	27	8
02XA004	Riviere Joir Near Provincial Boundary	2060	1980	1996	17	12	5
02XD002	North Brook Near Red Bay	35.5	1984	1995	12	5	7
02YA001	Ste. Genevieve River Near Forresters Point	306	1969	1996	28	25	3
02YA002	Bartletts River Near St. Anthony	33.6	1986	2012	27	24	3
02YC001	Torrent River At Bristol's Pool	624	1959	2012	54	51	3
02YD001	Beaver Brook Near Roddickton	237	1959	1978	20	19	1
02YD002	Northeast Brook Near Roddickton	200	1980	2012	33	31	2
02YE001	Greavett Brook Above Portland Creek Pond	95.7	1984	2012	29	25	4
02YF001	Cat Arm River Above Great Cat Arm	611	1968	1982	15	14	1
02YG001	Main River At Paradise Pool	627	1986	2012	27	24	3
02YG002	Middle Arm Brook Below Flatwater Pond	224	1987	1997	11	10	1
02YH001	Bottom Creek Near Rocky Harbour	33.4	1985	1998	14	12	2
02YJ001	Harrys River Below Highway Bridge	640	1968	2012	45	40	5
02YJ003	Pinchgut Brook At Outlet Of Pinchgut Lake	119	1986	1997	12	11	1
02YK002	Lewaseechjeech Brook At Little Grand Lake	470	1952	2012	57	49	8
02YK003	Sheffield River At Sheffield Lake	362	1955	1966	12	11	1
02YK004	Hinds Brook Near Grand Lake	529	1956	1979	24	22	2
02YK005	Sheffield Brook Near Trans Canada Highway	391	1972	2012	41	40	1
02YK007	Glide Brook Below Glide Lake	112	1984	1997	14	11	3
02YK008	Boot Brook At Trans-Canada Highway	20.4	1985	2012	28	26	2
02YL001	Upper Humber River Near Reidville	2110	1928	2012	85	83	2
02YL004	South Brook At Pasadena	58.5	1983	2012	30	27	3
02YL005	Rattler Brook Near Mcivers	17	1985	2012	28	22	6
02YL008	Upper Humber River Above Black Brook	471	1988	2012	25	23	2
02YL011	Copper Pond Brook Near Corner Brook Lake	12.9	1995	2012	18	17	1
02YM001	Indian Brook At Indian Falls	974	1954	1996	43	40	3
02YM002	Indian Brook Diversion To Birchy Lake	n/a	1963	1978	16	11	5
02YM003	South West Brook Near Baie Verte	93.2	1980	2012	33	30	3
02YM004	Indian Brook Diversion Above Birchy Lake	238	1990	2012	23	23	0
02YN002	Lloyds River Below King George Iv Lake	469	1981	2012	32	31	1
02YN004	Star Brook Above Star Lake	276	2000	2012	13	12	1
02YO006	Peters River Near Botwood	177	1981	2012	32	31	1
02YO007	Leech Brook Near Grand Falls	88.3	1984	1996	13	7	6
02YO008	Great Rattling Brook Above Tote River	773	1984	2012	29	21	8
02YO010	Junction Brook Near Badger	61.6	1985	1997	13	5	8
02YO012	Southwest Brook At Lewisporte	58.7	1989	2012	24	23	1
02YP001	Shoal Arm Brook Near Badger Bay	63.8	1982	1997	16	13	3
02YQ001	Gander River At Big Chute	4450	1949	2012	64	63	1
02YQ002	Gander River At Outlet Of Gander Lake	4160	1923	1939	17	0	17
02YQ004	Northwest Gander River Near Gander Lake	2200	1983	1998	16	10	6
02YQ005	Salmon River Near Glenwood	80.8	1987	2012	26	20	6
02YQ006	Southwest Gander River Below Larson Falls	531	1987	1996	10	5	5
02YR001	Middle Brook Near Gambo	275	1959	2012	54	49	5
02YR002	Ragged Harbour River Near Musgrave Harbour	399	1977	1997	21	17	4
02YR003	Indian Bay Brook Near Northwest Arm	554	1981	2012	32	30	2
02YR004	Triton Brook Above Gambo Pond	227	2002	2012	10	10	0
02YS001	Terra Nova River At Eight Mile Bridges	1290	1951	1984	34	30	4
02YS003	Southwest Brook At Terra Nova National Park	36.7	1967	2012	46	41	5
02YS005	Terra Nova River At Glovertown	2000	1985	2012	28	28	0
02YS006	Northwest River At Terra Nova National Park	663	1995	2012	18	16	2
02ZA001	Little Barachois Brook Near St. George's	343	1978	1997	20	17	3
02ZA002	Highlands River At Trans-Canada Highway	72	1982	2012	31	30	1
02ZA003	Little Codroy River Near Doyles	139	1982	1997	16	14	2
02ZB001	Isle Aux Morts River Below Highway Bridge	205	1962	2012	51	49	2
02ZC002	Grandy Brook Below Top Pond Brook	230	1982	2012	31	26	5
02ZD001	Grey River Near Pudops Lake	982	1958	1967	10	8	2
02ZD002	Grey River Near Grey River	1340	1969	2012	41	31	10
02ZE001	Salmon River At Long Pond	2640	1944	1965	22	16	6
02ZE004	Conne River At Outlet Of Conne River Pond	99.5	1989	2012	24	24	0
02ZF001	Bay Du Nord River At Big Falls	1170	1950	2012	63	60	3
02ZG001	Garnish River Near Garnish	205	1958	2012	55	47	8
02ZG002	Tides Brook Below Freshwater Pond	166	1977	1997	21	19	2
02ZG003	Salmonier River Near Lamaline	115	1980	2012	33	30	3
02ZG004	Rattle Brook Near Boat Harbour	42.7	1981	2012	32	29	3
02ZG005	Little Barasway Brook Near Molliers	28.2	1987	1996	10	6	4
02ZH001	Pipers Hole River At Mothers Brook	764	1952	2012	61	55	6
02ZH002	Come By Chance River Near Goobies	43.3	1961	2012	45	39	6
02ZJ001	Southern Bay River Near Southern Bay	67.4	1976	2012	37	32	5
02ZJ002	Salmon Cove River Near Champneys	73.6	1983	2012	30	21	9
02ZJ003	Shoal Harbour River Near Clarenville	106	1986	2012	27	23	4
02ZK001	Rocky River Near Colinet	301	1948	2012	65	59	6
02ZK002	Northeast River Near Placentia	89.6	1979	2012	34	31	3
02ZK003	Little Barachois River Near Placentia	37.2	1983	2012	30	28	2
02ZK004	Little Salmonier River Near North Harbour	104	1983	2012	30	29	1
02ZK005	Trout Brook Near Bellevue	50.3	1986	1997	12	6	6
02ZL003	Spout Cove Brook Near Spout Cove	10.8	1979	1997	19	18	1
02ZL004	Shearstown Brook At Shearstown	28.9	1983	2012	30	27	3
02ZL005	Big Brook At Lead Cove	11.2	1985	2012	28	27	1
02ZM006	Northeast Pond River At Northeast Pond	3.63	1953	2012	60	42	18
02ZM008	Waterford River At Kilbride	52.7	1974	2012	39	35	4
02ZM009	Seal Cove Brook Near Cappahayden	53.6	1979	2012	34	33	1
02ZM010	Waterford River At Mount Pearl	16.6	1981	1996	16	15	1
02ZM016	South River Near Holyrood	17.3	1983	2012	30	29	1
02ZM017	Leary Brook At St. John's	15.3	1983	1998	16	15	1
02ZM018	Virginia River At Pleasantville	10.7	1984	2012	29	26	3
02ZM019	Virginia River At Cartwright Place	5.55	1985	1998	14	14	0
02ZM020	Leary Brook At Prince Philip Drive	17.8	1985	2012	28	24	4
02ZM021	South Brook At Pearl Town Road	9.21	1986	1998	13	13	0
02ZN001	Northwest Brook At Northwest Pond	53.3	1966	1996	31	28	3
02ZN002	St. Shotts River Near Trepassey	15.5	1985	2012	28	17	11
03NE001	Reid Brook At Outlet Of Reid Pond	75.7	1995	2012	15	13	2
03NE002	Camp Pond Brook Below Camp Pond	24.3	1995	2012	15	13	2
03NE011	Reid Brook Below Tributary	n/a	2003	2012	10	8	2
03NE012	Tributary To Reid Brook	n/a	2003	2012	10	9	1
03NF001	Ugjoktok River Below Harp Lake	7570	1979	2012	34	22	12
03NG001	Kanairiktok River Below Snegamook Lake	8930	1979	1996	18	13	5
03OA003	Mcphadyen River Near The Mouth	3610	1972	1982	10	0	10
03OA004	Ashuanipi River Below Wightman Lake	8310	1972	1983	12	0	12
03OB002	Churchill River At Flour Lake	33900	1955	1971	17	16	1
03OC003	Atikonak River Above Panchia Lake	15100	1972	2012	27	14	13
03OC004	Kepimits River Below Kepimits Lake	7070	1972	2000	13	2	11
03OC005	Atikonak River Above Atikonak Lake	3680	1972	2000	14	2	12
03OD007	East Metchin River	1750	1998	2012	15	12	3
03OE003	Minipi River Below Minipi Lake	2330	1979	2012	33	27	6
03OE010	Big Pond Brook Below Big Pond	71.4	1994	2012	19	18	1
03OE011	Pinus River	n/a	1998	2012	15	13	2
03PB001	Naskaupi River At Fremont Lake	8990	1955	1970	16	14	2
03PB002	Naskaupi River Below Naskaupi Lake	4480	1978	2012	34	25	9
03QC001	Eagle River Above Falls	10900	1966	2012	47	37	10
03QC002	Alexis River Near Port Hope Simpson	2310	1978	2012	35	31	4

3.2.2 Excessive Regulation Screening

Storage systems within a watershed such as natural lakes or reservoirs can tend to attenuate or reduce flood peaks. The effects of natural lake systems, if any, on the 1:20 year and 1:100 year flood peaks can be accounted for by including the appropriate physiographic parameters in the regional equation. For example, it has been assumed in previous studies that the flood peak attenuation may be a function of the amount of lake surface area in a watershed, and the appropriate parameter can therefore be introduced in the regression equation. Man-made reservoirs which are not operated can also be treated as natural lakes provided structural changes are negligible over the period of record.

On the other hand, those reservoirs which are periodically operated either by stop logs or gates may have a greater effect on flood peaks than the effect of natural lakes. This is because controlled reservoirs may be drawn down prior to the flood creating an artificial storage and affecting the passage of the flood peak. Operation of the reservoir outlet during the passage of the flood can also lead to unnatural fluctuations in the discharge hydrograph.

Several of the WSC hydrometric stations are classified in HYDAT as being under the influence of some degree of regulation. Since the regulation effects are usually unsystematic it was generally not possible to detect the effects of regulation by means of statistical tests similar to those described in the previous section. It is recommended to undertake additional investigations, as a component of a future RFFA update, to establish which of the major reservoirs within the study area can or cannot be treated as natural lakes. This could be accomplished by developing an inventory of reservoirs in the Province including an assessment of their physical characteristics and hydrologic effects on peak flows. It is also suggested that discussions in this context be held with representatives from several agencies, including the WSC and Newfoundland Power and other dam owner/operators to fully understand reservoir operational procedures.

A similar assessment was completed for the RFFA for Nova Scotia (AMEC, 2001) and the main findings were:

- Many existing reservoirs and their operational characteristics, with respect to their influence on flood peaks, are not particularly well documented.
- Hydrologic data such as records of peak inflows and outflows and the effects of the reservoirs on peak flows are almost non-existent.
- Most of the power dams operated by the Nova Scotia Power Corporation are “run of the river” and it can therefore be assumed that these structures would have a negligible effect on peak discharge rates.

Through this process, the streamflow records for a number of additional “regulated” streamflow gauging stations were added to the assessment database for the RFFA for Nova Scotia as part of the 2001 study.

It is recommended that a similar review of “regulated” stations in the Province of Newfoundland and Labrador be completed with the next review/update of the RFFA for the Province with the objective of potentially adding more station data to the overall assessment.

3.2.3 Other Screening

For the purposes of this assessment, drainage area delineations in GIS format have been provided to AMEC by WRMD. The watershed areas represented by these delineations have been abstracted from the GIS data and used for this assessment in place of those drainage areas defined in the HYDAT database as the GIS data is considered to be more accurate. Also, in cases where no drainage area delineation was available in the GIS data for a specific station, drainage area boundaries have been delineated using the available 1:50000 topography data.

Efforts to delineate and abstract watershed areas relevant to stations 03OB002 (data record from 1955 to 1970) and 03PB001 (data record from 1955 to 1971), both in Labrador, identified anomalies in the GIS data (both the elevation and lakes/streams layers) in the area of Michikamau Lake. Upon further investigation it has been determined that Michikamau Lake was absorbed into the Smallwood Reservoir upon the completion of the Churchill Falls Generating Station in 1974. With this in mind, these two stations have been screened from the overall assessment as their respective watersheds, in their present forms, no longer function in the manner represented by the station data available in HYDAT.

3.2.4 Statistical Screening

All datasets which pass screening to this point have been subjected to a number of statistical tests (described briefly below). As noted previously, and consistent with the 1999 RFFA study, all stations with less than 10 years of available data have been excluded from further analysis. The computations for each of these tests have been completed using CFA v3.1 (Environment Canada, 1993). For detailed descriptions of these tests please refer to the CFA v3.1 Reference Manual (Environment Canada, 1993). Initial statistical screening results have been summarized in Table 3-2.

Spearman Test for Independence

Autocorrelations are often calculated for time series data to determine how the correlation between data values varies with the distance or time “lag” between them. This test for data independence determines whether future streamflow peaks are dependent upon last year’s streamflow peaks.

Spearman Test for Trend

This test evaluates whether a general upward or downward trend with time can be determined across a dataset. This type of trend might be demonstrated in watersheds experiencing urban growth or deforestation over the period of record.

Runs Test for General Randomness

The Runs Test is an evaluation of data randomness to determine if the time series has any inherent systematic pattern or if it is a random sequence. Each point in the time series is determined to lie above (+) or below (-) the median. A run is considered to be a string of consecutive streamflow values. Consider a time plot of the data, with a horizontal line indicating the median. A run ends when the line that joins consecutive points crosses the median line. The run length is the number of points in a run. If the series is random, about half of the points above and half below the median are expected; moreover the expected run length will be close to two (2). Based on these characteristics of a random sequence, if fewer runs than expected are observed then the sequence will be seen to exhibit positive serial correlation. If a series tends to oscillate above and below the median, many more runs than expected are observed and such a series will be seen to exhibit negative serial correlation.

Mann-Whitney Split Sample Test for Homogeneity

This test is used to evaluate the distribution functions associated with two data samples taken from the streamflow time series for a station. If the two distribution functions are the same it is an indication that both data samples exhibit the same characteristics and the nature of the flow generating mechanism in the watershed has not changed over the period of the overall time series. Conversely, if the two distribution functions are not the same it is an indication that the data samples exhibit different characteristics and the nature of the flow generating mechanism in the watershed has changed over the period of the overall time series. An example of this might be the introduction of a new dam in the watershed above the streamflow station or a change in land use in the watershed.

CFA v3.1 evaluates the Mann-Whitney test on either a seasonal or time span basis. For the purposes of the current RFFA update this test was evaluated using the time span option (i.e. splitting the overall time series for a gauge into two populations of approximately equal numbers of observations).

Statistical Screening Results

The results of the statistical screening have been summarized in Table 3-2.

3.2.5 Gauges Used in Further Analyses

The data screening process, described in Section 3.2.1, indicated several streamflow gauges with missing annual maximum instantaneous flows (which are required for frequency analysis) within the period of record. In order to maximize data availability, estimates of the missing streamflow values have been determined by relating the annual maximum daily discharge values to the annual maximum instantaneous discharge values through linear regression where annual maximum daily discharge values exist.

Where station streamflow data failed one or more statistical screening tests, data gap filling has been explored as a means of reversing the statistical screening result. This effort has been completed to maximize the stations available for further analysis.

A summary of this gap filling effort has been presented in Table 3-3. As noted, the correlation coefficient varies between 0.51 and 0.99, with an average value of 0.88, suggesting a generally strong correlation between the two parameters increasing the confidence level in the results of the missing data “filling” procedure.

Table 3-2: Statistical Screening Results

Station Number	Sample Size	Independent	Trend	General Randomness	Homogeneous
02XA003	29	PASS	FAIL	PASS	PASS
02XA004	14	PASS	FAIL	PASS	PASS
02YA001	27	PASS	FAIL	PASS	PASS
02YA002	26	PASS	PASS (5%)	PASS	FAIL (5%)
02YC001	53	PASS	PASS (5%)	PASS	FAIL (5%)
02YD001	19	PASS	FAIL	PASS	PASS
02YD002	32	PASS	FAIL	PASS	PASS
02YE001	27	PASS	FAIL	PASS	PASS
02YF001	14	PASS	FAIL	PASS	PASS
02YG001	26	PASS	FAIL	PASS	PASS
02YG002	10	PASS	FAIL	PASS	PASS
02YH001	13	PASS	FAIL	PASS	PASS
02YJ001	40	PASS	FAIL	PASS	PASS
02YJ003	11	PASS	FAIL	PASS	PASS
02YK002	39	PASS	FAIL	PASS	PASS
02YK003	11	PASS	FAIL	PASS	PASS
02YK004	23	PASS	FAIL	PASS	PASS
02YK005	40	FAIL (5%)	PASS (1%)	PASS	FAIL (1%)
02YK007	13	PASS	FAIL	PASS	PASS
02YK008	25	PASS	FAIL	PASS	PASS
02YL001	83	PASS	FAIL	PASS	PASS
02YL004	29	PASS	FAIL	PASS	FAIL (5%)
02YL005	22	PASS	FAIL	PASS	PASS
02YL008	24	PASS	FAIL	PASS	PASS
02YL011	17	PASS	FAIL	PASS	PASS
02YM001	41	PASS	FAIL	PASS	PASS
02YM003	32	PASS	FAIL	PASS	PASS
02YM004	23	FAIL (5%)	FAIL	PASS	PASS
02YN002	31	PASS	FAIL	PASS	PASS
02YN004	12	PASS	FAIL	PASS	PASS
02YO006	32	PASS	FAIL	PASS	PASS
02YO007	12	PASS	FAIL	PASS	PASS
02YO008	29	PASS	PASS (5%)	PASS	PASS
02YO010	12	PASS	FAIL	PASS	FAIL (5%)
02YO012	24	PASS	FAIL	PASS	PASS
02YP001	14	PASS	PASS (5%)	PASS	PASS
02YQ001	63	PASS	FAIL	PASS	PASS
02YQ004	16	PASS	FAIL	PASS	PASS
02YQ005	26	PASS	FAIL	PASS	PASS
02YR001	54	PASS	FAIL	PASS	PASS
02YR002	21	PASS	FAIL	PASS	PASS
02YR003	32	PASS	FAIL	PASS	PASS
02YS001	26	PASS	FAIL	PASS	PASS
02YS003	44	PASS	FAIL	PASS	FAIL (5%)
02YS005	28	PASS	FAIL	PASS	PASS
02YS006	17	PASS	FAIL	PASS	PASS
02ZA001	18	PASS	FAIL	PASS	PASS
02ZA002	30	PASS	FAIL	PASS	PASS
02ZA003	15	PASS	FAIL	PASS	PASS
02ZB001	50	PASS	FAIL	PASS	PASS
02ZC002	22	PASS	FAIL	PASS	PASS

Table 3-2: Statistical Screening Results

Station Number	Sample Size	Independent	Trend	General Randomness	Homogeneous
02ZD002	31	PASS	PASS (5%)	PASS	PASS
02ZE001	16	PASS	FAIL	PASS	PASS
02ZE004	24	PASS	FAIL	PASS	PASS
02ZF001	61	PASS	FAIL	FAIL (5%)	PASS
02ZG001	53	FAIL (5%)	FAIL	PASS	FAIL (5%)
02ZG002	20	PASS	FAIL	PASS	PASS
02ZG003	32	PASS	FAIL	PASS	PASS
02ZG004	31	PASS	FAIL	PASS	PASS
02ZH001	59	PASS	FAIL	PASS	FAIL (5%)
02ZH002	42	PASS	FAIL	PASS	PASS
02ZJ001	36	PASS	FAIL	PASS	PASS
02ZJ002	30	PASS	PASS (5%)	PASS	PASS
02ZJ003	27	PASS	FAIL	PASS	PASS
02ZK001	63	PASS	FAIL	PASS	PASS
02ZK002	33	PASS	FAIL	FAIL	FAIL (5%)
02ZK003	28	PASS	FAIL	PASS	FAIL (5%)
02ZK004	29	PASS	FAIL	PASS	FAIL (5%)
02ZK005	11	PASS	FAIL	PASS	PASS
02ZL003	18	PASS	FAIL	PASS	PASS
02ZL004	27	PASS	FAIL	PASS	PASS
02ZL005	27	PASS	FAIL	PASS	PASS
02ZM006	42	PASS	PASS (5%)	PASS	PASS
02ZM008	35	PASS	PASS (1%)	PASS	FAIL (1%)
02ZM009	33	PASS	PASS (5%)	PASS	PASS
02ZM010	15	PASS	FAIL	PASS	PASS
02ZM016	29	PASS	FAIL	PASS	PASS
02ZM017	15	PASS	FAIL	PASS	PASS
02ZM018	26	PASS	FAIL	PASS	PASS
02ZM019	14	PASS	FAIL	PASS	PASS
02ZM020	24	PASS	PASS (1%)	PASS	FAIL (1%)
02ZM021	13	PASS	FAIL	PASS	PASS
02ZN001	30	PASS	PASS (5%)	PASS	PASS
02ZN002	27	PASS	FAIL	PASS	PASS
03NE001	14	PASS	FAIL	PASS	PASS
03NE002	14	FAIL (5%)	PASS (1%)	FAIL	FAIL (1%)
03NF001	31	PASS	FAIL	PASS	PASS
03NG001	13	PASS	PASS (5%)	PASS	PASS
03OB002	17	PASS	FAIL	PASS	PASS
03OC003	14	PASS	FAIL	PASS	PASS
03OD007	14	PASS	FAIL	PASS	PASS
03OE003	30	PASS	FAIL	PASS	PASS
03OE010	18	PASS	FAIL	PASS	FAIL (5%)
03OE011	14	PASS	FAIL	PASS	FAIL (5%)
03PB001	16	PASS	FAIL	PASS	PASS
03PB002	25	PASS	FAIL	PASS	PASS
03QC001	42	FAIL (5%)	FAIL	FAIL	PASS
03QC002	35	PASS	FAIL	PASS	PASS

Note: FAIL (X%) means FAIL at X% level of significance, PASS (X%) means PASS at X% level of significance

Table 3-3: 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

The statistical screening tests, presented above, have been re-assessed for the final time series of annual maximum instantaneous flows for each station where missing data has been estimated. In some cases, for time series noted in Table 3-2 as failing the statistical screening, complementing the HYDAT time series with estimated data reversed the statistical screening result. However, for the time series from other stations this has not been the case (refer to Appendix A for details).

Table 3-4 summarizes those gauges that have been screened out based on the statistical and other screening results. In total, twenty-one (21) flow gauges have been excluded from further analysis.

The data from ninety (90) gauges has been used for this RFFA update (ref. Table 3-3). Please refer to Figures 3-1 and 3-2 for station locations in Newfoundland and Labrador, respectively.

3.3 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 92 gauges in Newfoundland and Labrador and results have been presented in Table 3-5.

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 3-6). 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.

A comparison of the average 95% confidence intervals for flows with 2, 20 and 100 year return period between the 1999 RFFA and the current study has been completed (ref. Table 3-7). The results indicate that the median and maximum upper limit and lower limit average confidence intervals have been consistently reduced for all selected return periods. Further, the reduction for average maximum percentages are more significant in the 2014 RFFA, compared to the values reported as part of the 1999 study. This can be attributed to the increase in the available data for gauges across the Province as documented by the increase in median sample size per station from 16 years, for the 1999 RFFA, to 26 years for the current RFFA update.

Table 3-4: Streamflow Gauges Screened from the Analysis

Station	Reason for Screening
02XD002 02YM002 02YQ002 02YQ006 02YR004 02ZD001 02ZG005 03OA003 03OA004 03OC004 03OC005	Gauges excluded due to insufficient data.
02YK005	The period of record is 1973 to 2012. There are no missing values, however, the data did not pass the statistical screening and therefore, this gauge has not been retained for frequency analysis.
02ZK002	The period of record is 1979 to 2011 with 2 missing values which have been estimated with confidence. However, this gauge did not pass the statistical screening and therefore has not been retained for frequency analysis.
02ZM008	The period of record is 1974 to 2011 with 3 missing values which could not be estimated with confidence. This gauge did not pass statistical screening and therefore has not been retained for frequency analysis.
02ZM020	The period of record is 1978 to 2011 with 1 missing value which could not be estimated with confidence. An outlier has been identified by HEC-SSP and removed, however this gauge did not pass statistical screening and therefore has not been retained for frequency analysis.
03OB002	Michikamau Lake was absorbed into the Smallwood Reservoir upon the completion of the Churchill Falls Generating Station in 1974. With this in mind, this station has been screened from the overall assessment as the watershed, in its present forms, no longer functions in the manner represented by the station data available in HYDAT.
03NE002	The period of record is 1996 to 2012 with 4 missing values. One value has been estimated with confidence; three could not be (2000, 2001, 2002). This gauge did not pass statistical screening and therefore has not been retained for frequency analysis.
03NE011 03NE012	Gauges excluded due to insufficient data.
03PB001	Michikamau Lake was absorbed into the Smallwood Reservoir upon the completion of the Churchill Falls Generating Station in 1974. With this in mind, this station has been screened from the overall assessment as the watershed, in its present forms, no longer functions in the manner represented by the station data available in HYDAT.
03QC001	The period of record is 1967 to 2012 with 9 missing values. Six have been estimated with confidence; three could not be (1968, 1979, 1980). This gauge did not pass statistical screening and therefore has not been retained for frequency analysis.

Table 3-5: 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 3-5: 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 3-6: 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%
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**

Table 3-7: Comparison of Average 95% Confidence Interval between 1999 and 2014 RFFA Studies								
Statistic	**RFFA Study**	**Median Sample Size per Station**	**2 Year Flow**		**20 Year Flow**		**100 Year Flow**	
			Lower Limit	**Upper Limit**	**Lower Limit**	**Upper Limit**	**Lower Limit**	**Upper Limit**
Median	1999	16	-16%	17%	-23%	31%	-29%	41%
	2014	26	-11.1%	12.3%	-14.0%	24.5%	-17%	32.4%
Maximum	1999	16	-39%	51%	-62%	218%	-75%	365%
	2014	26	-23.1%	30%	-26.4%	74.9%	-31.2%	107.9%

4.0 REGIONAL FLOOD FREQUENCY ANALYSIS

4.1 General

A number of RFFA's have been completed for the island of Newfoundland (1971, 1984, 1990 and 1999) whereby sets of equations for estimating return period flood flows in ungauged watersheds have been developed. The last revision, completed in 1999, made the following recommendations.

i. The regional regression equations developed in this study are recommended for estimating return period flood flows on ungauged watersheds or on watersheds with less than 10 to 20 years of flood data
ii. In the South-west Region, the "Upper Envelope Curve" is recommended where flooding may threaten life or cause severe flood damages
iii. The RFFA be updated in 5 years (or in 2004)
iv. More streamflow gauges are required along the south coast from Isle aux Morts River to Bay du Nord River
v. There is a need for a separate RFFA model for floods on small (< 50 km^2) watersheds

The current study has focused on recommendation (iii) above; which is to update of the 1999 RFFA. As outlined in the RFP work scope, the update effort focuses on the following:

a. Incorporating new hydrologic and physiographic data
b. Extending the RFFA to cover both Newfoundland and Labrador
c. Development of a user guide and spreadsheet software for use by engineers

The island of Newfoundland was divided into four hydrologically homogenous regions to support the 1999 RFFA. It was documented 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. The current study has used the same four hydrological regions in order to be consistent with the 1999 RFFA (ref. Figure 4-1). The analysis has been conducted using the available seventy-eight (78) gauges on the island of Newfoundland which have 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.

The station data for Newfoundland and Labrador has been split into two groups, as follows:

- Consistent with the 1999 RFFA, stations with the lowest ratio of an upper 95% confidence level of the 100 year flow to the 100 year estimated flow (ref. Table 3-6, column 100 Year, Upper Limit) have been retained for the development of the regression equations. Sorted in this manner, 80% of the stations were retained for regression equation development and 20% were utilized for verification purposes.

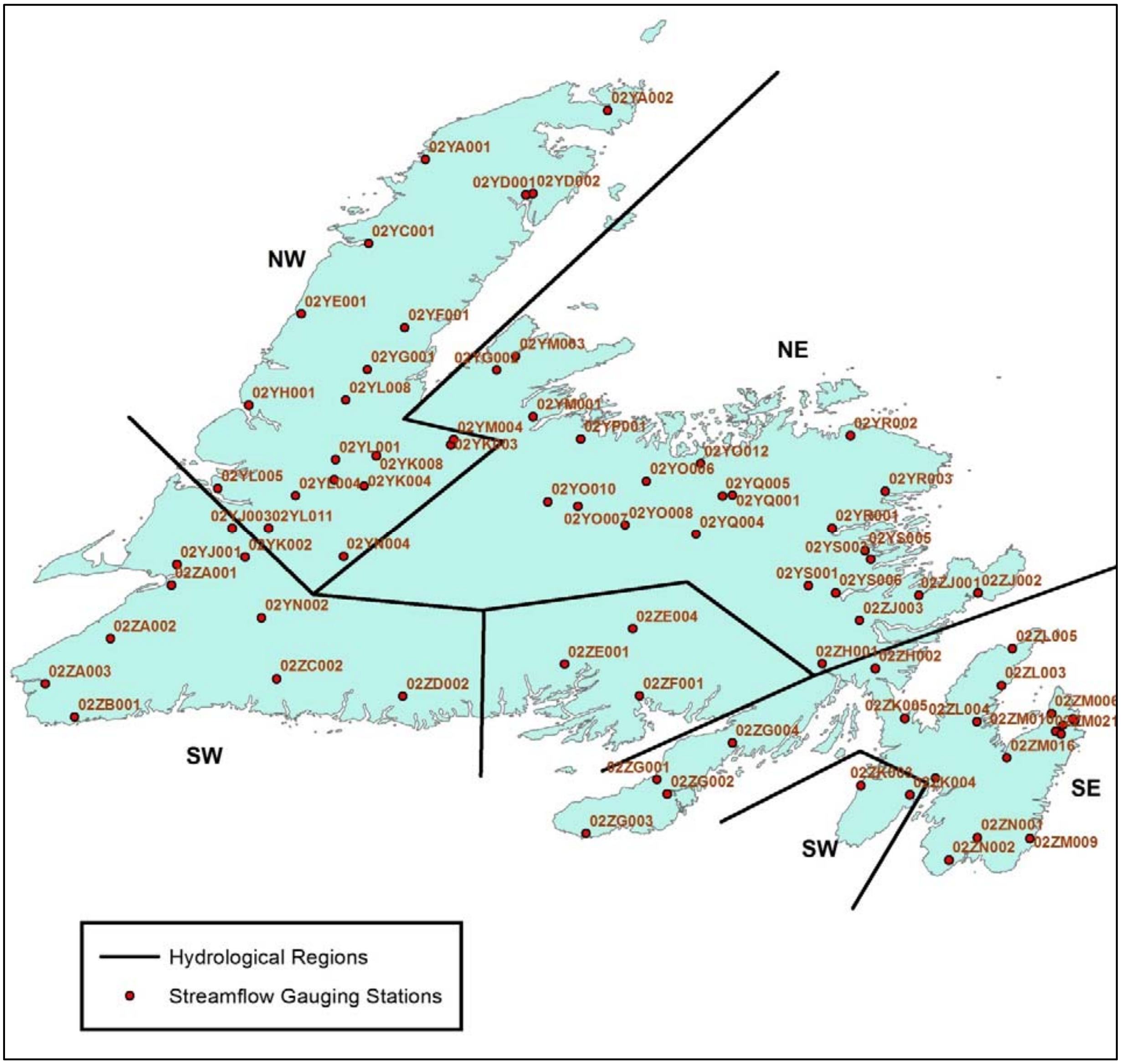

Figure 4-1: Hydrological Regions in Newfoundland

- In order to verify the accuracy of the developed regression equations, not all streamflow gauges have been included in the regression equation development process. Similar to the 1999 RFFA, 75% to 80% of the gauges in each region have been segregated from the regression equation development analysis to support verification. This segregated group of gauges has been used to support verification of the developed regional regression equations.

As discussed previously, the 1999 RFFA regions were based on flood, climatic and physiographic characteristics as well as previous studies, the availability of flood data and the results of regression analysis on test regions. However, more recent efforts (albeit for low flow analysis) suggest the island is one homogeneous region and there is, perhaps, no need for separate regions. An assessment has therefore been conducted to evaluate this hypothesis and determine whether a single set of equations would be sufficient for the whole island of Newfoundland. Results of this assessment have been presented in Section 4.2.4.

A review of the need for a separate set of equations for floods on small (<50 km^2) watersheds, recommendation (v) from the 1999 RFFA, has been conducted to determine if a separate set of equations would better predict flows with different return periods for such, compared with the equations developed based on all flow gauges. Results of this assessment have been presented in Section 4.2.5.

4.2 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:

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

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:

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

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 four 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.

4.2.1 Regression Parameters

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), as detailed below.

Drainage Area (DA)

The drainage area of a watershed represents an area characterized by all surface water runoff being conveyed to the same outlet; in the case of this assessment a streamflow gauging station. As noted previously, drainage area delineations in GIS format have been provided to AMEC by WRMD. The areas represented by these delineations have been abstracted from the GIS data and used for this assessment in place of those drainage areas defined in the HYDAT database as the GIS data is considered to be more accurate. Also, in cases where no drainage area delineation was available in the GIS data for a specific station, drainage area boundaries have been delineated using the available 1:50000 topography data.

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:

$$\text{LAF} = \sum_{i=1}^{n}[\left(100 \times \frac{LAREAi}{DA}\right) \times \left(100 \times \frac{CAREAi}{DA}\right)] \qquad \text{[Eq. 4-3]}$$

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 Equation 4-2 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.

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;

$$\text{LSF} = (1 + \text{FACLS}) - \frac{\text{FLSAR}}{(1 + \text{FACLS})} \qquad \text{[Eq. 4-4]}$$

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."*

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

Summary of Regression Parameters

Values for all variables used for regression equation development for all gauges in Newfoundland and Labrador have been summarized in Table 4-1.

4.2.2 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[4], as well as statistical parameters such as regression correlation coefficient[5] (SMR) and the standard error of the estimate (SEE) for log to base 10 transformed data are presented in Tables 4-2 and 4-3. Statistical results of each regression equation have also been provided in Appendix B.

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

Table 4-1: 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 4-2: 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 4-3: 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

In general, the developed regional equations have relatively high SMRs and low SEEs. The newly developed regression equations for all return periods in the three NW, NE and SE regions of Newfoundland have a value of 90% or higher for SMR and a value of 0.15 or lower for SEE. The newly developed regression equations for all return periods in the SW region of Newfoundland has been observed to have a marginally lower SMR which varies in the range of 84% to 89% and a range of standard error in the range of 0.16 to 0.21.

Drainage area has been, for the current RFFA update assessment, determined to be the most significant parameter with the highest impact on estimation of frequency flows for all regions and all return periods. Results presented in Table 4-2 indicate that the impact of the drainage area has been found to be the most significant in the SE and NE regions where drainage area accounts for 90% and 82% to 90% of the variation in flood flows (log to base 10 units), respectively. The SW region has been found to be the region with the least impact on frequency flow estimation from drainage area where this variable accounts for only 40% to 50% of the variation in frequency flows.

For all the regions in Newfoundland, the addition of a second variable to the regression equations resulted in an increase in the SMR and a reduction in the SEE. In the NW region, SMR increased significantly from a range of 67-78% to 90-95% by including the LAF parameter. As well, the SEE decreased from a range of 0.24-0.27 to 0.12-0.16. The variations in SMR and SEE were found to be smaller in the NE region. SMR increased from a range of 82-90% to 92-96% and the SEE decreased from a range of 0.16-0.20 to 0.10-0.14 when LAF was introduced to the equations. The SE region has been observed to have the least variation in regression statistical parameters when LAF has been introduced to the equations. The SMR increased from a range of 89-90% to 93-94% and the SEE decreased from a range of 0.15-0.16 to 0.12-0.13. The SW region exhibited the greatest variation in regression statistical parameters when a second parameter (LSF) was introduced to the equations. The SMR increased significantly from a range of 40-50% to a range of 84-89% and the SEE has decreased significantly from a range of 0.33-0.39 to 0.15-0.22.

For the purposes of this RFFA update, the entirety of Labrador has been considered to be one homogeneous region. The regression equations developed using the results of the single station frequency analysis have been summarized in Table 4-3. The regression outputs for all return periods for Labrador have also been provided in Appendix B. In order to maintain consistency with the regression equation development process in Newfoundland, the same physiographic parameters of DA and LAF have been used as independent variables. LAF was calculated for all watersheds using the methodology as described under Section 4.2.1 and for watersheds with zero value for LAF, a default value of 50 has been adopted, consistent with the 1999 RFFA, as described previously.

The results for Labrador (ref. Table 4-3) indicate that while the SMR for all return periods is very high, 95% to-97%, and the SEE is relatively low. Almost all variation in the frequency flows estimate is represented by drainage area. The second physiographic parameter included in the regression equations, LAF, does not have a significant impact on computed frequency flows. It is, therefore, recommended to exclude the LAF from the equations for Labrador and consider drainage area as the only independent variable.

4.2.3 Regression Verification Assessment

Verification of the regression equations, developed for Labrador and the four (4) regions of Newfoundland, has been completed by comparison of the frequency flows computed using the regression equations to the actual frequency flow determined using single station frequency analysis across two groups of stations, namely:

- Group 1 - stations used to develop the regression equations, and;
- Group 2 - stations not used in the development of the regression equations.

As such, the regression equations have been verified using both the dataset used to develop them and independent dataset in each region. Results of this verification analysis have been summarized in Tables 4-4 and 4-5.

The results of the comparison between the single station frequency analysis estimates and the regional regression equation estimates in Newfoundland have been presented in Table 4-4. The results indicate that the SE region has the lowest median absolute percentage difference statistics for return period floods with a range of 11%-20%. SW region has the highest median absolute percentage difference statistics for return period floods with a range of 30%-39%. The maximum absolute difference between the frequency analysis estimates and the regression equation estimates has been computed as 90%.

Verification of the regression equations has also been completed using independent datasets which have not been used in the regression equation development process. Results of this assessment have been summarized in Table 4-5. Based on the results presented in Table 4-5, the maximum difference between estimated frequency flows (single station frequency analysis estimate vs. regression equation estimate) has been observed in the SW region, specifically at stations 02ZA002 and 02ZK003. This significant difference may be attributed to the fact that these stations have smaller drainage areas of those used in development of the regression equations in the SW region, namely 70 km^2 and 37 km^2, respectively. The average drainage area used for regression equation development in SW region is 1276 km^2. In addition, the watersheds associated with stations 02ZA002 and 02ZK003 have assumed LAF values of 50 (meaning no lakes are present in these watersheds) however have positive LSF values reflecting the presence of swamps in these watersheds. Further investigation, beyond the scope of the present study, would be needed to better understand the runoff regime in each of these drainage basin to investigate the large difference between the single station frequency analysis flow estimates and the regression equations estimates.

Results for comparison between the single station frequency analysis estimations and regional regression equation estimations in Labrador have been presented, similarly, in Table 4-6. In general, the percentage differences are considered to be reasonable. The median absolute percentage difference between the estimates based on the single station frequency analysis and the regression equation estimates varies in a range of 23%-28% and the maximum absolute difference varies in a range of 46%-89%.

Table 4-4: Results of Comparison between the Single Station Frequency Analysis and Regional Regression Equations for Newfoundland

Station	DA (km^2)	LAF	Region	Frequency Analysis Results							Regression Equation Estimates							Percentage Difference						
				Q2	Q5	Q10	Q20	Q50	Q100	Q200	Q2	Q5	Q10	Q20	Q50	Q100	Q200	Q2	Q5	Q10	Q20	Q50	Q100	Q200
02YA001	305.92	1053	NW	32	41	47	52	59	64	69	36	45	50	55	61	66	70	14.4	9.8	7.5	5.6	3.5	2.2	0.9
02YC001	619.72	175	NW	178	238	277	314	361	397	432	140	171	190	207	228	243	258	-21.4	-28.2	-31.5	-34.1	-36.9	-38.7	-40.4
02YD001	263.08	50	NW	99	129	149	167	191	208	225	110	140	159	176	198	214	230	10.9	8.0	6.5	5.3	4.0	3.1	2.3
02YD002	197.74	484	NW	40	48	54	58	64	68	72	34	43	49	54	61	65	70	-15.2	-11.4	-9.3	-7.6	-5.5	-4.2	-2.9
02YE001	100.22	134	NW	43	55	63	70	78	85	91	31	41	48	54	61	67	73	-27.9	-25.4	-24.1	-22.9	-21.6	-20.8	-20.0
02YF001	636.87	50	NW	271	338	379	417	464	499	532	240	294	328	358	396	423	450	-11.7	-13.0	-13.6	-14.1	-14.7	-15.1	-15.4
02YG001	632.34	18.3	NW	293	360	400	437	483	516	548	359	444	496	544	603	646	688	22.3	23.3	23.9	24.3	24.8	25.2	25.5
02YK004	659.63	666	NW	91	112	124	136	150	160	170	86	104	114	124	136	144	153	-5.8	-7.3	-8.0	-8.7	-9.4	-9.8	-10.2
02YK007	111.54	132	NW	23	30	34	38	43	46	50	35	45	52	59	67	73	79	49.8	52.7	54.2	55.5	56.9	57.9	58.8
02YK008	20.456	50	NW	9	14	17	20	24	28	31	12	16	20	23	27	30	33	24.7	18.5	15.4	12.8	10.1	8.3	6.6
02YL001	2101.1	50	NW	577	700	774	841	923	983	1041	687	804	873	934	1008	1061	1111	19.1	14.9	12.8	11.1	9.2	7.9	6.8
02YL004	58.0	50	NW	42	60	73	86	103	116	130	29	39	46	52	61	67	73	-30.5	-35.1	-37.4	-39.2	-41.1	-42.4	-43.6
02YL008	472.7	50	NW	241	297	332	363	402	430	457	184	229	257	282	314	336	359	-23.7	-23.0	-22.6	-22.3	-22.0	-21.7	-21.5
02YM004	242.5	225	NW	38	44	48	51	55	57	60	55	70	79	88	98	106	114	44.7	58.1	65.6	72.0	79.6	84.8	89.7
02YN004	277.6	50	NW	122	135	142	148	156	161	166	115	146	166	184	207	223	240	-5.4	8.6	16.8	24.0	32.6	38.6	44.4
																	Absolute Median	**21.4**	**18.5**	**16.8**	**22.3**	**21.6**	**20.8**	**20.0**
																	Absolute Maximum	**49.8**	**58.1**	**65.6**	**72.0**	**79.6**	**84.8**	**89.7**
02YM001	964.62	36.4	NE	144	178	198	217	240	257	274	203	269	313	354	406	445	485	40.7	51.6	57.7	62.9	69.0	73.1	77.0
02YM003	96.37	50	NE	36	53	65	77	92	104	117	32	44	52	60	71	78	87	-13.2	-17.6	-19.7	-21.5	-23.4	-24.7	-25.8
02YO006	177.74	50	NE	45	62	74	85	99	110	121	51	69	82	94	109	121	133	12.7	11.7	11.2	10.8	10.4	10.0	9.8
02YO008	803.42	50	NE	206	266	304	340	385	418	451	161	214	248	280	321	352	383	-22.0	-19.8	-18.6	-17.7	-16.5	-15.8	-15.1
02YO012	62.85	128	NE	15	20	24	27	31	34	38	17	24	28	33	38	43	47	16.8	19.2	20.5	21.5	22.7	23.5	24.3
02YP001	62.84	119	NE	21	27	30	33	37	40	43	18	25	29	34	39	44	48	-16.1	-7.8	-3.1	0.9	5.6	8.9	12.0
02YQ001	4447.3	277	NE	573	730	828	919	1034	1118	1201	366	456	512	563	626	673	718	-36.1	-37.5	-38.2	-38.8	-39.4	-39.8	-40.2
02YQ005	78.831	50	NE	37	54	65	76	92	104	116	27	38	45	52	61	68	75	-26.4	-29.4	-30.8	-32.0	-33.4	-34.2	-35.0
02YR001	265.99	881	NE	29	38	43	49	56	61	66	30	39	45	51	57	62	68	5.7	4.5	3.9	3.4	2.8	2.5	2.1
02YR002	394.78	65.1	NE	67	86	97	108	121	131	141	86	116	135	154	177	195	213	28.7	35.6	39.4	42.6	46.3	48.8	51.1
02YR003	581.21	307	NE	58	77	89	100	114	125	136	75	97	111	125	141	154	166	27.9	26.1	25.2	24.4	23.6	23.0	22.5
02YS001	1327.2	138	NE	170	208	231	252	278	297	315	177	229	261	292	331	360	388	4.1	10.0	13.2	15.9	19.0	21.2	23.2
02YS003	38.6	50	NE	14	19	22	25	29	32	35	16	22	27	31	37	41	46	13.2	18.9	22.0	24.6	27.6	29.7	31.6
02YS005	2033.8	113	NE	215	285	331	374	429	471	512	260	334	381	424	479	520	560	20.9	17.0	15.0	13.4	11.6	10.4	9.3
02ZH001	764.7	17	NE	226	332	405	479	577	653	732	209	283	331	377	437	482	527	-7.3	-14.7	-18.3	-21.1	-24.2	-26.2	-28.0
02ZJ001	68.5	89	NE	24	35	44	52	64	73	82	21	29	34	39	46	51	56	-12.3	-19.1	-22.5	-25.2	-28.1	-29.9	-31.6
02ZJ002	78.3	435	NE	14	20	24	28	32	36	40	15	20	23	26	30	33	36	0.4	-2.6	-4.1	-5.3	-6.7	-7.6	-8.4
																	Absolute Median	**16.1**	**18.9**	**19.7**	**21.5**	**23.4**	**23.5**	**24.3**
																	Absolute Maximum	**40.7**	**51.6**	**57.7**	**62.9**	**69.0**	**73.1**	**77.0**

Table 4-4 (cont'd): Results of Comparison between the Single Station Frequency Analysis and Regional Regression Equations for Newfoundland

Station	DA (km^2)	LAF	Region	Frequency Analysis Results							Regression Equation Estimates							Percentage Difference						
				Q2	Q5	Q10	Q20	Q50	Q100	Q200	Q2	Q5	Q10	Q20	Q50	Q100	Q200	Q2	Q5	Q10	Q20	Q50	Q100	Q200
02ZG001	210.7	202	SE	60	89	108	128	155	176	197	67	93	111	128	150	167	184	11.6	5.3	2.2	-0.3	-3.0	-4.8	-6.5
02ZG003	116.4	42.8	SE	66	93	111	129	152	170	188	58	81	96	110	129	143	158	-11.5	-13.0	-13.8	-14.5	-15.2	-15.7	-16.1
02ZG004	44.4	123	SE	37	54	66	77	93	105	117	24	33	39	45	53	58	64	-34.8	-38.4	-40.2	-41.6	-43.2	-44.2	-45.2
02ZH002	34.9	20.8	SE	32	46	55	65	78	88	98	28	39	45	52	61	68	74	-11.3	-15.7	-17.9	-19.7	-21.7	-22.9	-24.1
02ZK001	295.7	8.79	SE	146	202	240	276	324	360	396	150	210	250	288	339	378	417	3.0	3.8	4.2	4.5	4.8	5.1	5.3
02ZL004	29.8	50	SE	15	22	27	31	38	43	48	21	29	35	40	46	51	56	45.5	35.5	30.5	26.5	22.2	19.4	16.9
02ZL005	11.2	272	SE	5	8	10	12	14	16	18	8	11	13	14	17	18	20	45.0	34.1	28.7	24.4	19.8	16.8	14.1
02ZM006	3.7	265	SE	3	5	6	7	8	8	9	4	5	6	6	7	8	9	2.2	0.6	-0.2	-0.9	-1.7	-2.2	-2.7
02ZM009	54.9	193	SE	28	34	37	40	44	46	49	26	36	42	48	57	63	69	-8.5	5.5	13.6	20.8	29.4	35.5	41.3
02ZM016	16.6	148	SE	11	15	18	20	23	26	28	12	16	19	21	25	27	30	5.5	5.6	5.6	5.7	5.7	5.7	5.7
02ZM017	7.1	50	SE	13	16	19	21	24	26	29	8	10	12	14	16	18	20	-39.4	-36.8	-35.4	-34.2	-32.8	-31.9	-31.1
02ZM018	12.1	21	SE	9	12	14	16	18	19	21	13	18	21	24	28	31	34	43.6	49.2	52.2	54.7	57.6	59.6	61.4
02ZM021	10.1	50	SE	10	14	16	18	20	22	24	10	13	16	18	21	23	25	-4.6	-1.6	0.0	1.4	2.9	4.0	4.9
02ZN001	90.3	132	SE	37	47	54	60	67	73	79	40	55	65	75	87	97	107	6.6	15.4	20.3	24.5	29.5	32.8	36.0
02ZN002	15.7	512	SE	10	13	15	17	20	22	24	9	12	14	16	19	21	23	-8.0	-7.2	-6.8	-6.5	-6.1	-5.8	-5.6
																	Absolute Median	**11.3**	**13.0**	**13.8**	**19.7**	**19.8**	**16.8**	**16.1**
		LSF															**Absolute Maximum**	**45.5**	**49.2**	**52.2**	**54.7**	**57.6**	**59.6**	**61.4**
02YJ001	617.9	1.67	SW	292	398	468	535	622	688	754	220	297	347	394	455	501	548	-24.4	-25.4	-25.9	-26.3	-26.8	-27.1	-27.4
02YJ003	116.4	1.95	SW	29	37	41	46	51	55	59	44	57	65	73	84	91	99	50.0	55.2	58.1	60.4	63.1	65.0	66.7
02YK002	476.5	1.92	SW	118	144	160	174	192	206	218	98	128	147	165	188	204	221	-16.5	-11.0	-8.0	-5.5	-2.5	-0.5	1.4
02YN002	480.5	1.91	SW	167	229	271	310	362	401	441	101	132	152	170	194	211	229	-39.5	-42.4	-43.9	-45.1	-46.5	-47.3	-48.1
02ZB001	204.3	1.52	SW	338	503	618	733	889	1010	1136	195	269	319	366	429	476	524	-42.5	-46.5	-48.5	-50.1	-51.8	-52.9	-53.9
02ZC002	251.8	1.3	SW	350	470	549	624	721	793	866	462	661	798	932	1110	1247	1387	32.0	40.6	45.3	49.4	54.0	57.2	60.2
02ZD002	4588.3	1.51	SW	867	1188	1400	1604	1869	2069	2271	1023	1399	1648	1887	2198	2433	2670	17.9	17.8	17.7	17.7	17.6	17.6	17.5
02ZE001	5920.9	1.92	SW	282	357	403	447	501	540	579	367	474	542	605	685	744	803	30.0	32.8	34.2	35.4	36.8	37.7	38.6
02ZE004	99.9	1.81	SW	40	52	60	67	76	82	89	58	77	89	101	116	127	138	43.3	47.1	49.1	50.8	52.7	54.0	55.2
02ZF001	1171.9	1.84	SW	197	268	314	359	417	461	505	193	253	292	329	375	409	444	-1.9	-5.4	-7.1	-8.5	-10.1	-11.1	-12.1
02ZK004	104.7	1.67	SW	82	115	137	159	187	209	231	87	118	138	158	183	202	221	6.7	2.9	1.0	-0.5	-2.2	-3.4	-4.4
																	Absolute Median	**30.0**	**32.8**	**34.2**	**35.4**	**36.8**	**37.7**	**38.6**
																	Absolute Maximum	**50.0**	**55.2**	**58.1**	**60.4**	**63.1**	**65.0**	**66.7**

Table 4-5: Results of the Verification Analysis for Regional Regression Equations in Newfoundland

Station	DA (km^2)	LAF	Region	Frequency Analysis Results							Regression Equation Estimates							Percentage Difference						
				Q2	Q5	Q10	Q20	Q50	Q100	Q200	Q2	Q5	Q10	Q20	Q50	Q100	Q200	Q2	Q5	Q10	Q20	Q50	Q100	Q200
02YA002	32.8	652	NW	14	20	24	28	34	38	42	6	8	10	11	13	14	16	-55.9	-58.2	-59.3	-60.3	-61.3	-62.0	-62.6
02YH001	31.5	545	NW	5	8	9	11	14	15	17	6	9	10	12	14	15	17	22.1	12.8	8.3	4.6	0.7	-1.9	-4.1
02YK003	365.6	688	NW	62	84	99	113	132	145	159	50	62	69	76	84	90	96	-18.7	-26.2	-29.9	-32.7	-35.8	-37.8	-39.6
02YL005	17.3	50	NW	10	14	17	19	23	25	28	10	14	17	20	24	26	29	-1.7	0.7	2.0	3.1	4.4	5.2	6.0
02YL011	11.6	700	NW	7	9	11	13	15	17	19	2	3	4	5	6	6	7	-63.6	-63.1	-62.9	-62.7	-62.4	-62.3	-62.1
																	Absolute Median	**22.1**	**26.2**	**29.9**	**32.7**	**35.8**	**37.8**	**39.6**
																	Absolute Maximum	**63.6**	**63.1**	**62.9**	**62.7**	**62.4**	**62.3**	**62.6**
02YG002	222.5	299	NE	46	65	78	91	107	120	133	36	48	55	63	72	79	86	-22	-27	-29	-31	-33	-35	-36
02YO007	86.8	50	NE	30	38	42	47	53	57	61	29	41	48	56	65	73	80	-2	8.15	13.9	18.9	24.7	28.8	32.6
02YO010	61.5	601	NE	11	15	18	20	24	26	29	11	15	17	20	23	25	27	1.46	-0.8	-1.9	-2.9	-3.9	-4.6	-5.2
02YQ004	2207.2	50	NE	620	858	1018	1172	1373	1525	1680	349	454	520	583	662	721	779	-44	-47	-49	-50	-52	-53	-54
02YS006	669.1	12	NE	115	165	200	233	278	312	347	209	285	335	383	446	493	540	81	72.3	67.9	64.4	60.5	58	55.7
02ZJ003	99.5	166	NE	35	55	69	84	104	120	137	23	31	37	42	49	54	59	-34	-43	-47	-50	-53	-55	-57
																	Absolute Median	**28.1**	**34.7**	**37.9**	**40.4**	**42.5**	**43.6**	**44.7**
																	Absolute Maximum	**81.0**	**72.3**	**67.9**	**64.4**	**60.5**	**58.0**	**56.9**
02ZG002	163.6	588	SE	47	66	78	91	107	119	132	46	64	76	88	103	114	126	-1.5	-2.5	-3.0	-3.4	-3.9	-4.2	-4.5
02ZK005	47.2	92	SE	26	40	49	59	72	82	93	27	37	43	50	58	64	71	1.2	-7.8	-12.2	-15.7	-19.4	-21.8	-24.0
02ZL003	10.8	319	SE	8	12	15	18	21	24	27	7	10	12	14	16	17	19	-10.6	-17.2	-20.4	-23.0	-25.9	-27.7	-29.3
02ZM010	17.7	50	SE	17	24	28	32	38	42	46	15	20	24	27	32	35	38	-14.7	-15.5	-16.0	-16.4	-16.8	-17.0	-17.3
02ZM019	5.4	105	SE	3	5	5	6	7	7	8	6	7	9	10	12	13	14	58.9	65.4	68.9	71.9	75.2	77.5	79.7
																	Absolute Median	**10.6**	**15.5**	**16.0**	**16.4**	**19.4**	**21.8**	**24.0**
																	Absolute Maximum	**58.9**	**65.4**	**68.9**	**71.9**	**75.2**	**77.5**	**79.7**
02ZA001	337.3	1.78*	SW	114	158	188	217	254	283	312	118	157	182	206	236	259	282	3.9	-0.7	-3.0	-4.9	-7.0	-8.3	-9.6
02ZA002	70.3	1.39*	SW	51	75	91	108	129	146	164	171	243	292	339	401	449	498	236.1	225.2	219.6	215.1	210.1	206.8	203.9
02ZA003	127.8	1.66*	SW	149	211	254	295	351	393	436	100	135	158	181	209	231	253	-33.0	-36.1	-37.6	-38.9	-40.3	-41.2	-42.0
02ZK003	37.1	1.24*	SW	41	60	74	88	106	120	135	213	311	379	446	535	605	677	425.3	416.9	412.5	408.9	405.0	402.3	399.9
																	Absolute Median	**134.5**	**130.6**	**128.6**	**127.0**	**125.2**	**124.0**	**122.9**
																	Absolute Maximum	**425.3**	**416.9**	**412.5**	**408.9**	**405.0**	**402.3**	**399.9**

*LSF for South-west Region

Table 4-6: Results of Comparison between the Single Station Frequency Analysis and Regional Regression Equations for Labrador

Station	DA (km^2)	LAF	Frequency Analysis Results							Regression Equation Estimates							Percentage Difference						
			Q2	Q5	Q10	Q20	Q50	Q100	Q200	Q2	Q5	Q10	Q20	Q50	Q100	Q200	Q2	Q5	Q10	Q20	Q50	Q100	Q200
02XA003	4892.8	50	631	792	891	983	1098	1181	1264	618	772	867	955	1064	1143	1221	-2.1	-2.5	-2.7	-2.9	-3.1	-3.2	-3.4
02XA004	2017.3	50	334	432	494	552	626	680	734	292	366	411	453	505	543	580	-12.6	-15.4	-16.9	-18.0	-19.3	-20.2	-21.0
03NE001	76.057	27.1	19	23	26	28	31	33	35	19	24	26	29	32	35	37	0.5	1.9	2.6	3.2	4.0	4.4	4.9
03NF001	7557.6	50	1128	1444	1642	1826	2058	2229	2398	892	1114	1251	1376	1533	1647	1759	-21.0	-22.9	-23.8	-24.6	-25.5	-26.1	-26.6
03NG001	8912	50	1092	1427	1640	1841	2095	2285	2473	1025	1280	1437	1581	1761	1892	2020	-6.1	-10.3	-12.4	-14.1	-16.0	-17.2	-18.3
03OC003	15776	89.7	1099	1275	1378	1470	1580	1658	1733	1610	2030	2291	2532	2833	3054	3271	46.5	59.2	66.2	72.2	79.3	84.2	88.8
03OD007	894.76	131	190	244	279	311	351	381	411	140	178	202	225	253	274	294	-26.3	-27.0	-27.3	-27.6	-28.0	-28.2	-28.4
03OE003	2336.2	106	233	296	335	372	418	451	485	318	403	457	506	568	613	658	36.7	36.4	36.3	36.2	36.0	35.9	35.9
03OE010	70.712	18.4	15	18	20	21	24	25	27	18	22	25	27	30	33	35	25.1	26.8	27.7	28.4	29.2	29.7	30.2
03OE011	781.51	226	116	151	174	195	222	241	261	121	156	178	199	225	244	263	4.2	3.1	2.5	2.0	1.5	1.2	0.8
03PB002	4609.2	50	453	564	633	695	773	830	886	587	734	825	908	1011	1087	1161	29.6	30.1	30.3	30.5	30.8	30.9	31.1
03QC002	2318.3	50	523	645	719	786	870	931	990	329	411	462	509	568	610	652	-37.2	-36.2	-35.7	-35.2	-34.8	-34.4	-34.1
																Absolute Median	**23.0**	**24.8**	**25.6**	**26.1**	**26.7**	**27.1**	**27.5**
																Absolute Maximum	**46.5**	**59.2**	**66.2**	**72.2**	**79.3**	**84.2**	**88.8**

4.2.4 Newfoundland as One Homogeneous Region

A recent thesis[6] study (Zadeh, 2012), focused on establishing regional equations for low flow estimation for the Province of Newfoundland and Labrador, investigated the possibility of hydrological homogeneity across the two primary geographies of the Province, namely Newfoundland and Labrador. It was determined through use of the Hosking and Wallis Homogeneity test (Hosking and Wallis, 1997) that the two primary geographies of the Province could each be considered homogeneous for the purposes of low flow regression equation development.

For this component of the overall RFFA, consideration has also been given to defining Newfoundland as one hydrologically homogeneous region in the context of regression equation development. The Hosking and Wallis Homogeneity test has not been used for this current assessment, opting instead for a simpler approach based on a review of statistical parameters resulting from development a single set of regression equations for the whole of Newfoundland.

As such, one common set of regression equations has been developed for all of Newfoundland. The objective of this analysis has been to determine if the regression equations based on one homogeneous region provide a similar, or better, level of accuracy with regard to frequency flow estimation when compared with estimates from regression equations which have been developed based on Newfoundland represented by four (4) homogeneous regions.

The regression results have been summarized in Table 4-7 and regression outputs have been summarized in Appendix B. Accuracy of the developed equations has also been verified using all of the independent flow gauges not used in regression equation development process. Results of the verification assessment have been presented in Table 4-8.

The results indicate that drainage area accounts for 75%-82% of the variation in frequency flows when Newfoundland is considered to be one homogenous region. Addition of the second physiographic parameter, LAF, increases the SMR and reduces the SEE slightly, but the variation in regression statistical parameters has not been found to be significant. The SMR values have been found to be at the same level as those associated with the regression equations developed for the SW region where the SMR values have been calculated as the lowest of all of the four (4) regions. Further, the SEE values associated with the regression equations for the one homogeneous region have been found to be at the same level or greater than those associated with the SW region equations.

[6] Thesis submitted to the School of Graduate Studies in partial fulfillment of the requirements for the degree of Master of Engineering Faculty of Engineering and Applied Science, Memorial University of Newfoundland.

Table 4-7: Regression Coefficients – Newfoundland Considered One Homogeneous Region

T	C	DA	LAF	SMR	SEE
Q2	6.135	0.721	-0.312	0.881	0.197
Q5	9.246	0.706	-0.323	0.873	0.202
Q10	11.458	0.699	-0.329	0.867	0.205
Q20	13.677	0.692	-0.333	0.860	0.209
Q50	16.694	0.685	-0.338	0.852	0.214
Q100	19.066	0.681	-0.342	0.846	0.218
Q200	21.531	0.676	-0.345	0.840	0.222
Q2	1.588	0.702		0.815	0.244
Q5	2.285	0.686		0.800	0.250
Q10	2.764	0.678		0.791	0.255
Q20	3.235	0.672		0.782	0.259
Q50	3.861	0.664		0.770	0.265
Q100	4.344	0.659		0.762	0.269
Q200	4.840	0.655		0.754	0.273

n=58

Table 4-8: Verification Results for Regression Equations Developed for Newfoundland Considering the Island to be one Single Region

Station	DA (km^2)	LAF	Region	Frequency Analysis Results							Regression Equation Estimates							Percentage Difference						
				Q2	Q5	Q10	Q20	Q50	Q100	Q200	Q2	Q5	Q10	Q20	Q50	Q100	Q200	Q2	Q5	Q10	Q20	Q50	Q100	Q200
02YG002	222.5	299	NE	46	65	78	91	107	120	133	51	67	77	86	98	107	116	10.4	2.34	-1.6	-4.8	-8.3	-10	-12
02YO007	86.83	50	NE	30	38	42	47	53	57	61	45	61	72	82	95	104	114	51.6	62.7	68.9	74.1	80.2	84.4	88.3
02YO010	61.55	601	NE	11	15	18	20	24	26	29	16	21	25	28	32	35	38	49.1	43.4	40.6	38.2	35.7	34	32.4
02YQ004	2207	50	NE	620	858	1018	1172	1373	1525	1680	466	602	688	768	869	944	1019	-25	-30	-32	-34	-37	-38	-39
02YS006	669.1	12	NE	115	165	200	233	278	312	347	306	408	475	537	618	679	739	165	147	138	131	123	118	113
02ZJ003	99.5	166	NE	35	55	69	84	104	120	137	34	46	53	60	69	76	83	-2.2	-17	-23	-28	-34	-37	-40
02YA002	32.77	652	NW	14	20	24	28	34	38	42	10	13	16	18	20	22	24	-28	-33	-35	-37	-40	-41	-42
02YH001	31.49	545	NW	5	8	9	11	14	15	17	10	14	16	18	21	23	25	98.3	79.3	70.1	62.9	55.1	50.1	45.7
02YK003	365.6	688	NW	62	84	99	113	132	145	159	56	72	83	92	104	113	122	-9.2	-14	-17	-18	-21	-22	-23
02YL005	17.28	50	NW	10	14	17	19	23	25	28	14	20	23	27	31	35	38	39.8	39.5	39.3	39.2	39	38.9	38.9
02YL011	11.65	700	NW	7	9	11	13	15	17	19	5	6	7	8	10	11	12	-29	-31	-33	-34	-35	-36	-36
02ZG002	163.6	588	SE	47	66	78	91	107	119	132	33	43	50	56	63	69	75	-30	-34	-37	-39	-41	-42	-43
02ZK005	47.21	92	SE	26	40	49	59	72	82	93	24	33	38	44	51	56	61	-8.2	-18	-22	-26	-30	-32	-34
02ZL003	10.84	319	SE	8	12	15	18	21	24	27	6	8	9	10	12	13	15	-32	-37	-39	-41	-43	-44	-46
02ZM010	17.68	50	SE	17	24	28	32	38	42	46	14	20	24	27	32	35	39	-17	-17	-16	-16	-16	-16	-16
02ZM019	5.422	105	SE	3	5	5	6	7	7	8	5	7	8	9	11	12	14	39.5	49.7	55.2	60	65.5	69.3	72.9
02ZA001	337.3	50	SW	114	158	188	217	254	283	312	120	160	185	209	240	263	286	5.8	0.96	-1.5	-3.4	-5.6	-7	-8.3
02ZA002	70.25	50	SW	51	75	91	108	129	146	164	39	53	62	71	82	90	99	-24	-29	-32	-34	-37	-38	-40
02ZA003	127.8	131	SW	149	211	254	295	351	393	436	44	59	68	77	89	98	106	-70	-72	-73	-74	-75	-75	-76
02ZK003	37.1	50	SW	41	60	74	88	106	120	135	24	34	40	45	53	59	64	-40	-44	-46	-48	-50	-51	-53
																	Absolute Median	**29.2**	**33.6**	**36.1**	**37.8**	**37.9**	**38.6**	**39.7**
																	Absolute Maximum	**165.1**	**146.8**	**137.7**	**130.5**	**122.6**	**117.5**	**112.9**

The relatively close values for SMR associated with the equations for the NW, NE and SE regions suggests that consideration be given to representing these three (3) regions as one single hydrological region. With this approach, development of only two (2) sets of regression equations for regional flood frequency analysis in Newfoundland would be required.

Considering the relatively lower SMR and higher SEE levels associated with the one region equations, compared to the statistical parameters associated with the regression equations for each of the four regions in Newfoundland (despite the increased number of sample size) it is recommended that consideration be given to representing the island as more than one hydrological region, but less than four. It is also recommended that the Hosking and Wallis Homogeneity test (or alternates) be applied to combinations of the four regions to determine which regions might best be suited to amalgamation.

4.2.5 Equations for Small Watersheds

As noted previously, the 1999 RFFA update recommended that there is a need for a separate RFFA model for floods on small (< 50 km^2) watersheds. To investigate this recommendation, regression equations specific to these watersheds have been developed. The objective of this assessment has been to determine if a separate set of equations, specific to this size of watershed, would predict flows with more accuracy, compared to the regression equations developed using data from all flow gauges (regardless of drainage area). The results of this assessment have been summarized in Table 4-9 using frequency flows from the twenty-one (21) flow gauges with drainage area less than 50 km^2 (these gauges have been highlighted in Table 3-4). Regression outputs have also been summarized in Appendix B.

Table 4-9: Regression Coefficients for Small Watersheds (DA<50 km^2) in Newfoundland

T	C	DA	LAF	SMR	SEE
Q2	4.376	0.686	-0.216	0.694	0.175
Q5	5.092	0.731	-0.203	0.708	0.176
Q10	5.512	0.754	-0.196	0.714	0.177
Q20	5.884	0.773	-0.190	0.718	0.178
Q50	6.333	0.795	-0.183	0.722	0.179
Q100	6.652	0.810	-0.179	0.724	0.180
Q200	6.957	0.823	-0.175	0.726	0.182
Q2	1.372	0.736		0.576	0.201
Q5	1.716	0.778		0.610	0.198
Q10	1.929	0.799		0.625	0.197
Q20	2.125	0.817		0.637	0.196
Q50	2.369	0.837		0.648	0.196
Q100	2.547	0.851		0.655	0.196
Q200	2.722	0.863		0.661	0.196

n=21

Results presented in Table 4-9 indicate that the SMR for all frequency flows ranges between 69%-73%. Fourteen (14) of the twenty-one (21) total gauges used for this assessment are located in South-east region which has a SMR value of 93%-94% and the remaining are located in North regions, except for one station which is in the South-west. Regression outputs presented in Appendix B also indicate that the probability for the LAF parameter to have a non-significant impact on frequency flows at the 95% confidence interval is near 5% which rejects the null hypothesis. Given the relatively low SMR levels and the fact that drainage area accounts for only 58%-66% of the variations in frequency flows in small watersheds, it is recommended that further assessment be conducted, as a component of the next RFFA update, to determine if other physiographic parameters can be identified with more significant/ contributory impact on frequency flows which may increase the accuracy of these equations specific to small (< 50 km^2) watersheds.

4.2.6 Comparison of Results with Previous Studies

Regression equations developed as part of the 2014 RFFA update have been compared to the results of previous RFFA results conducted in 1984, 1990 and 1999. The two criteria which have been used for the evaluation of the regression equations have been the goodness of fit (SMR) and the standard error of the estimation (SEE). Results of this assessment have been summarized in Table 4-10.

Based on results presented in Table 4-10, the 1984 and 1990 studies have higher SMRs and relatively lower SEEs when compared with those from the 1999 and 2014 RFFA studies. This can be attributed to the fact that these two earlier studies have used more physiographic parameters (as many as five [5]) for regression equation development when compared with the two (2) parameters used for 1999 and 2014 studies.

Table 4-10: Comparison of Regression Equation Statistical Parameters between Different Studies

Study	Region	Parameters	Range of R^2	Range of SMR	Range of SEE
2014	NW	DA, LAF	0.948 - 0.976	0.898 - 0.952	0.117 - 0.157
	NE	DA, LAF	0.958 - 0.982	0.918 - 0.964	0.102 - 0.145
	SE	DA, LAF	0.964 - 0.968	0.929 - 0.942	0.120 - 0.132
	SW	DA, LSF	0.914 - 0.942	0.835 - 0.887	0.164 - 0.215
1999	NW	DA, LAF	0.980 - 0.982	0.960 - 0.964	0.093 - 0.104
	NE	DA, LAF	0.953 - 0.975	0.909 - 0.950	0.117 - 0.161
	SE	DA, LAF	0.964 - 0.983	0.929 - 0.967	0.088 - 0.129
	SW	DA, LSF	0.910 - 0.961	0.829 - 0.924	0.140 - 0.237
1990	C (NW)	DA, LSF, SLP, DRD	0.93		0.081 - 0.096
	B (NE)	DA, DRD	0.97 - 0.98		0.079 - 0.098
	A (SE)	DA, LSF, DRD	0.96		0.098 - 0.111
	D (SW)	DA, LSF	0.94 - 0.97		0.120 - 0.160
1984	North	DA, MAR, LAT, SHAPE, BAREA,	0.9916 - 0.9998		2.6-19.9%
	South	DA, MAR, ACLS, SHAPE, SLOPE	0.9941 - 0.9982		12.5-24.2%
	Island	DA, MAR, ACLS, SHAPE	0.9883 - 0.9878		19.0-25.6%

Comparison of the regression parameters between the 1999 and 2014 RFFA indicates that the two studies have relatively similar levels for SMR and SEE for all regions; however, comparison between the differences between single station frequency analysis estimates and regression equation estimates for the two studies (ref. Table 4-11), indicates improvements are mixed, compared to the 1999 RFFA. General reductions in absolute maximum differences are evident in the NW, SE and SW regions, particularly for the high return periods. Minor increases in absolute maximum differences are evident in the NE region. Absolute median differences are generally considered to be aligned between the two RFFA updates with the exception of the NW region where the absolute median differences are about double those of the 1999 RFFA update.

A similar comparison has been conducted between the results of the regression equation verification analysis using independent datasets for the 1999 and 2014 RFFA. Results of this assessment have been presented in Table 4-12 and indicate that the absolute maximum percentage difference in all regions have been computed as either similar or significantly improved for the 2014 update, compared to 1999 RFFA. This is especially true for the South-west region. Except for the South-west region, the absolute median of the differences have also improved in the 2014 study for all other regions.

Table 4-11: Comparison between 1999 and 2014 RFFA Differences between Frequency Analysis Estimates and Regression Equation Estimates

Region	Statistical Parameter	RFFA	Q2	Q5	Q10	Q20	Q50	Q100	Q200
NW	Absolute Median	2014	21.4	18.5	16.8	22.3	21.6	20.8	20.0
		1999	8.0	8.8	8.8	8.9	9.5	10.3	11.7
	Absolute Maximum	2014	49.8	58.1	65.6	72.0	79.6	84.8	89.7
		1999	51.9	58.3	67.0	78.0	97.0	111.8	130.0
NE	Absolute Median	2014	16.1	18.9	19.7	21.5	23.4	23.5	24.3
		1999	18.2	21.0	22.6	24.5	20.8	22.9	28.0
	Absolute Maximum	2014	40.7	51.6	57.7	62.9	69.0	73.1	77.0
		1999	53.9	51.5	45.1	41.9	47.8	55.8	65.0
SE	Absolute Median	2014	11.3	13.0	13.8	19.7	19.8	16.8	16.1
		1999	10.6	15.0	15.7	13.1	11.8	9.8	14.3
	Absolute Maximum	2014	45.5	49.2	52.2	54.7	57.6	59.6	61.4
		1999	32.2	34.2	34.8	47.9	66.7	81.4	94.5
SW	Absolute Median	2014	30.0	32.8	34.2	35.4	36.8	37.7	38.6
		1999	20.0	17.4	15.7	19.7	24.2	28.1	30.9
	Absolute Maximum	2014	50.0	55.2	58.1	60.4	63.1	65.0	66.7
		1999	45.4	60.0	69.3	77.9	89.9	97.0	107.7

Table 4-12: Comparison between 1999 and 2014 RFFA Differences between Frequency Analysis Estimates and Regression Equation Estimates for Verification with Independent Datasets

Region	Statistical Parameter	RFFA	Q2	Q5	Q10	Q20	Q50	Q100	Q200
NW	Absolute Median	2014	22.1	26.2	29.9	32.7	35.8	37.8	39.6
		1999	47.5	45.8	45.2	44.5	42.4	43.5	49.2
	Absolute Maximum	2014	63.6	63.1	62.9	62.7	62.4	62.3	62.6
		1999	90.8	105.5	117.5	131.8	153.6	170.1	187.5
NE	Absolute Median	2014	28.1	34.7	37.9	40.4	42.5	43.6	44.7
		1999	20.8	27.8	27.9	28.3	29.2	29.4	26.0
	Absolute Maximum	2014	81.0	72.3	67.9	64.4	60.5	58.0	56.9
		1999	69.9	269.6	273.8	299.8	306.7	322.1	343.4
SE	Absolute Median	2014	10.6	15.5	16.0	16.4	19.4	21.8	24.0
		1999	45.2	39.7	37.3	37.3	35.8	35.7	28.5
	Absolute Maximum	2014	58.9	65.4	68.9	71.9	75.2	77.5	79.7
		1999	136.9	152.1	146.9	134.8	110.4	90.1	67.5
SW	Absolute Median	2014	134.5	130.6	128.6	127.0	125.2	124.0	122.9
		1999	47.4	50.6	48.3	47.7	47.0	45.7	44.4
	Absolute Maximum	2014	425.3	416.9	412.5	408.9	405.0	402.3	399.9
		1999	226.1	264.2	359.8	471.4	653.7	814.8	1007.0

4.2.7 Recommended Regression Equations

The foregoing assessment confirms that development of the regression equations developed for the four regions of Newfoundland, consistent with the 1999 RFFA update, and Labrador (as a whole), presently provide the most accurate means of estimating frequency flows in ungauged watersheds in the Province. As such, the regression equation co-efficients listed in Table 4-2 and 4-3 have been recommended for use in the Province. These co-efficients have been replicated below in equation form (ref. Equation 4-1).

Both one parameter and two parameter equations have been detailed in the Tables below to provide flexibility for situations where the LAF or LSF parameter cannot be estimated.

4.2.7.1 North-West Region

Table 4-13 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 4-14 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

4.2.7.2 North-East Region

Table 4-15 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 4-16 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

4.2.7.3 South-West Region

Table 4-17 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 4-18 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

4.2.7.4 South-East Region

Table 4-19 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 4-20 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

4.2.7.5 Labrador

Table 4-21 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 4-22 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

4.3 Index Flood Method

An index flood technique for regional flood frequency analysis has been developed for the island of Newfoundland by Poulin (1971). This technique uses an average dimensionless flood frequency index for all watersheds in a hydrologically homogeneous region. Based on this method, frequency flows for a watershed may be estimated using the ratio between the different return period flood flows (Q5, Q10, Q20, Q50, Q100 and Q200) and the median flood (Q2). Results of this assessment have been presented in Table 4-23.

Taking into account that the influence of different physiographic parameters on frequency floods has not been considered in this technique, its application is less recommended compared to multiple linear regression between frequency flows and physiographic parameters; however, application of this technique for watersheds with similar hydrological characteristics and few data may provide better estimates for less frequent floods (i.e., with longer return periods), compared to single station frequency analysis.

Table 4-23: Regional Flood Index Results

Region	Statistics	Q5/Q2	Q10/Q2	Q20/Q2	Q50/Q2	Q100/Q2	Q200/Q2	n
NW	Min	1.11	1.17	1.22	1.28	1.32	1.36	15
	Median	1.29	1.47	1.65	1.86	2.02	2.18	
	Max	1.49	1.83	2.18	2.64	3.00	3.38	
NE	Min	1.22	1.36	1.48	1.64	1.75	1.85	17
	Median	1.35	1.59	1.81	2.09	2.31	2.52	
	Max	1.56	1.97	2.39	2.97	3.44	3.92	
SE	Min	1.20	1.31	1.42	1.55	1.64	1.73	15
	Median	1.38	1.64	1.89	2.21	2.46	2.70	
	Max	1.51	1.88	2.25	2.75	3.14	3.55	
SW	Min	1.22	1.36	1.48	1.64	1.75	1.86	11
	Median	1.37	1.61	1.85	2.15	2.39	2.62	
	Max	1.49	1.83	2.17	2.63	2.99	3.36	
Labrador	Min	1.16	1.25	1.34	1.44	1.51	1.58	12
	Median	1.26	1.43	1.58	1.77	1.91	2.04	
	Max	1.31	1.50	1.68	1.92	2.09	2.26	

5.0 APPLICATIONS

5.1 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 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 5.2.

Using the regression equations provided as part of the current study, it is possible 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). 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 may also be used to estimate flows with higher return periods for watersheds with few years of available data, however the application of the Regional Flood Index should be considered as a procedure secondary to the regional regression equations.

5.2 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 5-1, 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.

Table 5-1: Range of Physiographic Parameters Used for Regression Equation Development

Region	Statistics	DA (km^2)	LAF	LSF
NW	Minimum	20	0	
	2nd Lowest	58	18	
	2nd Highest	660	666	
	Maximum	2101	1053	
NE	Minimum	39	0	
	2nd Lowest	63	17	
	2nd Highest	2034	435	
	Maximum	4447	881	
SE	Minimum	4	0	
	2nd Lowest	7	9	
	2nd Highest	211	272	
	Maximum	296	512	
SW	Minimum	100		1.30
	2nd Lowest	105		1.51
	2nd Highest	4588		1.92
	Maximum	5921		1.95
Labrador	Minimum	4	0	
	2nd Lowest	76	18	
	2nd Highest	8912	131	
	Maximum	15776	226	

6.0 SUMMARY AND RECOMMENDATIONS

6.1 SUMMARY

9. Single Station Frequency Analysis has been conducted for all gauges which passed the screening process in Newfoundland and Labrador, using a 3 Parameter Log Normal distribution, consistent with the 1999 RFFA.

10. Regression statistical parameters developed as part of the 2014 RFFA have been found to be consistent with the 1999 RFFA, but have shown relatively higher standard error of estimation and lower correlation coefficients compared to previous studies. The 2014 update has used only two physiographic parameters (Drainage Area and Lake Attenuation Factor) while the older studies (1990 and 1984) have used more parameters which may result in lower levels of error for estimation.

11. The island of Newfoundland has been represented by four (4) hydrologically homogeneous regions consistent with the 1999 RFFA. Regression equations developed for these regions have regression correlation coefficients of 90% or higher for all return period flows. The exception to this has been the South-west region where the regression correlation coefficient has a range of 84%-89%.

12. Comparing the results of the verification of regression equations with independent datasets has indicated that the percentage differences between the frequency flow estimates and regression equation estimates are generally lower in the 2014 study, compared to the results from the 1999 RFFA.

13. The range of the physiographic parameters used for development of regression equations has expanded significantly in the 2014 update, when compared with the parameter envelope from the 1999 RFFA, especially for drainage area. Therefore, the equations are applicable for a greater range of watershed area compared to the 1999 RFFA.

14. Regression equations have been developed considering Newfoundland to be one hydrologically homogenous region. The regression correlation coefficient has a range of 84%-88% which is equal or lower than the values developed for any of the four (4) regions in Newfoundland. The standard error of the estimation associated wit the one region has also been computed to be greater than the levels observed for any of the four individual regions. It has been concluded, therefore, that the regression equations developed for the four (4) regions of Newfoundland provide a better estimate for frequency flows.

15. The 1999 RFFA recommended developing a separate set of regression equations for watersheds having a drainage area of less than 50 km^2. Regression equations have therefore been developed using results from the single station frequency analysis for twenty-one (21) watersheds in Newfoundland having this characteristic. The physiographic parameters selected have been drainage area and lake attenuation factor to support development of the regression equations, to be consistent with the 1999 RFFA. Results of the analysis indicate that selection of drainage area as the only independent variable does not result in a good fit and including lake attenuation factor, despite increasing the regression correlation coefficient, does not have a significant impact on the goodness of fit. It has been concluded, therefore, that the regression equations developed

for the four (4) regions of Newfoundland provide a better estimate for frequency flows for watersheds having drainage area less than 50 km^2.

16. Similar methodology has been applied to watersheds in Labrador. Single station frequency analysis has been conducted using a 3 Parameter Log Normal distribution. Regression equations have been developed for all return period floods using the frequency flows for all available gauges which have passed the screening process. Drainage area and lake attenuation factor have been selected as independent variables for the regression process, in order to maintain consistency with the methodology used for Newfoundland. Regression statistical parameters indicate that drainage area accounts for 95%-97% of variations in frequency flows, but lake attenuation factor does not have a significant impact on different return period floods.

17. Regional flood indexes have been developed for all regions in Newfoundland and Labrador which may be used for estimation of frequency floods for ungauged watersheds with few years of available data, but their application should be done with caution as the impact of physiographic parameters on frequency flows has not been considered in this method and priority should be given to regional regression equations.

6.2 RECOMMENDATIONS

1. Regression equations have been developed with data from a greater number of gauges in Newfoundland compared to the 1999 RFFA; however, there are still several gauges with only a short period of available data. It is therefore recommended to update the current RFFA in 5 to 10 years to have increased accuracy in results of single station frequency analysis which are the basis for the regression equation development.

2. The South-west region in Newfoundland has the highest levels of estimation standard error and lowest levels of regression correlation coefficient. While both drainage area and lake and swamp factor have been found to have significant influence on the frequency flows, it is recommended to investigate if including additional physiographic parameters in the equations for the South-west region may increase the goodness of fit for the regression equations.

3. Equations developed for Labrador have strong regression parameter statistics; however, after the data screening process, only twelve (12) gauges, through the entire Labrador region, were available for regression equation development which made it impossible to verify the developed equations using independent data. The drainage area variable used in the regression equation development process has a wide range from 4 km^2 to 15776 km^2 and lake attenuation factor has been found to have no significant impact on estimation of frequency flows. It is therefore recommended to increase the number of gauging stations in Labrador to support update the equations in future using a larger number of flow gauges. It is also recommended that the value of adding other physiographic parameters to the equations be evaluated. Until then, it is recommended to use only drainage area as the independent physiographic parameter for Labrador.

4. While dividing Newfoundland into four (4) hydrologically homogeneous regions may not be very desirable, considering the island to be one single region has not resulted in strong goodness of fit for the associated regression equations. Considering the relatively close

regression statistical parameters for the three regions of North-west, North-east and South-east, it is recommended to assess the validity of merging these three regions into one single region or some combination of these three regions into two regions. Having fewer regions would simplify the development of future regression equations.

5. Further assessment is required in order to develop regression equations for smaller watersheds with less than 50 km^2 drainage area. It is recommended to investigate other physiographic parameters for these watersheds and develop regression equations using independent parameters which have a higher influence on frequency flows, compared to lake attenuation factor.

6. It has been documented that precipitation patterns in Newfoundland are changing, perhaps as a result of climate change. This RFFA update sought to maximize data availability to support regression equation development by including all station data which passed the various screening tests. This resulted in a temporal mix of data, some that might be generally considered to be "older" (greater than 20 years old) and some "newer" (the past 20 years). Single station frequency analysis may result in a different set of frequency flows if the entire record is used or if only the past 20 years is used. It is recommended that this issue be investigated in a future RFFA update.

7.0 REFERENCES

AMEC, 2001 — Regional Flood Frequency Analysis for Mainland Nova Scotia Streams, Nova Scotia Power Inc., completed by AMEC Engineering &Construction Services Limited. October 2001.

AMEC, 2012 — *Flood Risk and Vulnerability Analysis Project*, Water Resources Management Division, Department of Environment and Conservation, Government of Newfoundland and Labrador, completed by AMEC Environment & Infrastructure, June 13, 2012

Batterson and Liverman, 2010 — *Past and Future Sea Level Change in Newfoundland and Labrador: Guidelines for Policy and Planning*, Martin Batterson (Geochemistry, Geophysics and Terrain Sciences, Memorial University) and David Liverman (Geological Survey of Newfoundland and Labrador), Current Research (2010) Newfoundland and Labrador Department of Natural Resources, Geological Survey, Report 10-1, page 129-141, 2010.

Beersing, 1990 — Beersing, A. K., *Regional Flood Frequency Analysis for the Island of Newfoundland*, Government of Newfoundland and Labrador, Department of Environment and Labour, Water Resources Division, January 1990.

Condie, 1980 — Condie, R., *The Three Parameter Log Normal Distribution Applied to Regional Flood Frequency Analysis by the Index Flood Method*, Technical Workshop Series No. 2, Inland Waters Directorate, Environment Canada, Ottawa, 1980.

Environment Canada, 1993 — *Consolidated Frequency Analysis v3.1, Reference Manual*, Paul J. Pilon and K. David Harvey, Interpretation and Applications Division, Survey and Information Systems Branch, Eco-Systems Sciences and Evaluation Directorate, Environment Canada, March 1993.

Hosking & Wallis 1997 — Hosking, J. R. M., & Wallis, J. R. (1997). *Regional Frequency Analysis: An Approach Based on L-Moments.* Cambridge; New York: Cambridge University Press.

Panu et al, 1984 — Panu, U. S., Smith, D. A., and Ambler D. C., *Regional Flood Frequency Analysis for the Island of Newfoundland*, Canada-Newfoundland Flood Damage Reduction Program, Newfoundland and Labrador Department of Environment and Lands, St. John's; Environment Canada, Dartmouth, 1984.

Poulin, 1971 — Poulin, R. Y., *Flood Frequency Analysis for Newfoundland Streams*, Water Planning and Operations Branch, Department of Environment, Ottawa, 1971.

Rollings, 1999 — Rollings, K. *Regional Flood Frequency Analysis for the Island of Newfoundland*. Government of Newfoundland and Labrador, Department of Environment and Labour, Water Resources Management Division, Hydrologic Modelling Section, December 1999.

USACE, 2010 — *HEC-SSP, Statistical Software Package, User's Manual*, U.S. Army Corps of Engineers, Institute for Water Resources, Hydrologic Engineering Centre, October 2010.

Zadeh, 2012 — Shabnam Mostofi Zadeh, *Low Flow Frequency Study for Newfoundland and Labrador,* Thesis, Faculty of Engineering and Applied Science, Memorial University of Newfoundland, November 2012.

APPENDIX A

Datasets Review and Screening Results

Station Number	Comments
02XA003	The period of record is 1979 to 2012, with 7 missing values. Five values were estimated with confidence; two values could not be (1981, 1983). Values between 1984 and 2012 were retained for frequency analysis.
02XA004	The period of record is 1980 to 1995, with 4 missing values. Three values were estimated with confidence; 1 could not be (1981). Values between 1982 and 1995 were retained for frequency analysis.
02XD002	Gauge excluded due to short period of record.
02YA001	The period of record is 1970 to 1996 with 2 missing values which were estimated with confidence. All values were retained for frequency analysis.
02YA002	The period of record is 1988 to 2011 with 0 missing values. Two additional years were estimated with confidence (1986, 1987). Values between 1986 and 2011 were retained for frequency analysis.
02YC001	The period of record is 1959 to 2011, with 2 missing values which were estimated with confidence. All values were retained for frequency analysis.
02YD001	The period of record is 1960 to 1978. There were no missing values. All values were retained for frequency analysis.
02YD002	The period of record is 1980 to 2011, with 1 missing value which was estimated with confidence. All values were retained for frequency analysis.
02YE001	The period of record is 1985 to 2012, with 3 missing values. Two values were estimated with confidence; one could not be (2011). An additional year was estimated with confidence (1984). Values between 1984 and 2010 were retained for frequency analysis.
02YF001	The period of record is 1969 to 1982. There were no missing values. All values were retained for frequency analysis.
02YG001	The period of record is 1986 to 2011 with 2 missing values which were estimated with confidence. All values were retained for frequency analysis.
02YG002	The period of record is 1987 to 1996. There were no missing values. All values were retained for frequency analysis.
02YH001	The period of record is 1985 to 1997 with 1 missing value which was estimated with confidence. All values were retained for frequency analysis.
02YJ001	The period of record is 1969 to 2011 with 3 missing values which could not be estimated with confidence. All values were retained for frequency analysis.
02YJ003	The period of record is 1986 to 1996. There were no missing values. All values were retained for frequency analysis.
02YK002	The period of record is 1654 to 2012 with 10 missing values. Two values were estimated with confidence; eight could not be. Available values between 1973 and 2012 were retained for frequency analysis.
02YK003	The period of record is 1956 to 1966. There were no missing values. All values were retained for frequency analysis.
02YK004	The period of record is 1957 to 1978 with 0 missing values. One additional year was estimated with confidence (1979). Values between 1957 and 1979 were retained for frequency analysis.
02YK005	The period of record is 1973 to 2012. There were no missing values. This gauge did not pass the statistical screening and therefore was not retained for frequency analysis.
02YK007	The period of record is 1984 to 1996 with 2 missing values which were estimated with confidence. All values were retained for frequency analysis.
02YK008	The period of record is 1985 to 2011 with 1 missing value which could not be estimated with confidence. All values were retained for frequency analysis.
02YL001	The period of record is 1929 to 2011. There were no missing values. All values were retained for frequency analysis.
02YL004	The period of record is 1983 to 2011 with 2 missing values which were estimated with confidence. All values were retained for frequency analysis.
02YL005	The period of record is 1987 to 2011 with 3 missing values which could not be estimated with confidence. All values were retained for frequency analysis.
02YL008	The period of record is 1988 to 2011 with 1 missing value which was estimated with confidence. All values were retained for frequency analysis.
02YL011	The period of record is 1995 to 2011. There were no missing values. All values were retained for frequency analysis.

Station Number	Comments
02YM001	The period of record is 1955 to 1995 with 1 missing value which was estimated with confidence. All values were retained for frequency analysis.
02YM002	The period of record is 1964 to 1978 with 4 missing values which could not be estimated with confidence. This gauge was excluded.
02YM003	The period of record is 1980 to 2012 with 3 missing values. Two values were estimated with confidence; one value could not be (1998). All values were retained for frequency analysis.
02YM004	The period of record is 1990 to 2012. There were no missing values. All values were retained for frequency analysis.
02YN002	The period of record is 1981 to 2011. There were no missing values. All values were retained for frequency analysis.
02YN004	The period of record is 2001 to 2012. There were no missing values. All values were retained for frequency analysis.
02YO006	The period of record is 1981 to 2012 with 1 missing value which was estimated with confidence. All values were retained for frequency analysis.
02YO007	The period of record is 1987 to 1995 with 2 missing values which were estimated with confidence. Three additional years were estimated with confidence (1984, 1985, 1986). All values were retained for frequency analysis.
02YO008	The period of record is 1985 to 2012 with 7 missing values which were estimated with confidence. One additional year was estimated with confidence (1984). All values were retained for frequency analysis.
02YO010	The period of record is 1985 to 1995 with 6 missing values which were estimated with confidence. One additional year was estimated with confidence (1996). All values were retained for frequency analysis.
02YO012	The period of record is 1989 to 2012 with 1 missing value which was estimated with confidence. All values were retained for frequency analysis.
02YP001	The period of record is 1982 to 1996 with 2 missing values which were estimated with confidence. An outlier identified by HEC-SSP was identified and removed (1983). All other values were retained for frequency analysis.
02YQ001	The period of record is 1950 to 2012 with 0 missing values. All values were retained for frequency analysis.
02YQ002	Gauge excluded due to short period of record.
02YQ004	The period of record is 1985 to 1998 with 4 values missing which were estimated with confidence. Two additional years were estimated with confidence (1983, 1984). All values were retained for frequency analysis.
02YQ005	The period of record is 1991 to 2012 with 2 missing values which were estimated with confidence. Four additional years were estimated with confidence (1987-1990). All values were retained for frequency analysis.
02YQ006	Gauge excluded due to short period of record.
02YR001	The period of record is 1961 to 2012 with 3 missing values which were estimated with confidence. Two additional years were estimated with confidence (1959, 1960). All values were retained for frequency analysis.
02YR002	The period of record is 1978 to 1997 with 3 missing values which were estimated with confidence. One additional year was estimated with confidence (1977). All values were retained for frequency analysis.
02YR003	The period of record is 1981 to 2012 with 2 missing values which were estimated with confidence. All values were retained for frequency analysis.
02YR004	The period of record is from 2002 to 2012 with one year missing which could not be estimated with confidence. This gauge was excluded.
02YS001	The period of record is 1953 to 1983 with 1 missing value which could not be estimated (1979). Values between 1953 and 1978 were retained for frequency analysis.
02YS003	The period of record is 1968 to 2011 with 3 missing values which were estimated with confidence. All values were retained for frequency analysis.
02YS005	The period of record is 1985 to 2012 with 0 missing values. All values were retained for frequency analysis.
02YS006	The period of record is 1995 to 2011 with 1 missing value which was estimated with confidence. All values were retained for frequency analysis.
02ZA001	The period of record is 1980 to 1996 with 0 missing values. An additional year was estimated with confidence (1979). All values were retained for frequency analysis.
02ZA002	The period of record is 1982 to 2011 with 0 missing values. All values were retained for frequency analysis.
02ZA003	The period of record is 1982 to 1996 with 1 missing value which was estimated with confidence. All values were retained for frequency analysis.

Station Number	Comments
02ZB001	The period of record is 1962 to 2911 with 1 missing value which was estimated with confidence. All values were retained for frequency analysis.
02ZC002	The period of record is 1984 to 2011 with 2 missing values. One was estimated with confidence; one could not be (2004). Two additional years have been estimated with confidence (1982, 1983). Values from 1984 to 2003 were retained for frequency analysis.
02ZD001	Gauge excluded due to short period of record.
02ZD002	The period of record is 1970 to 2012 with 12 missing values. Four were estimated with confidence, however the rest could not be. Values from 1982 to 2012 were retained for frequency analysis.
02ZE001	The period of record is 1950 to 1965 with 0 missing values. All values were retained for frequency analysis.
02ZE004	The period of record is 1989 to 2012 with 0 missing values. All values were retained for frequency analysis.
02ZF001	The period of record is 1951 to 2012 with 2 missing values. One was estimated with confidence; one could not be (1980). All available values were retained for frequency analysis.
02ZG001	The period of record is 1959 to 2010 with 5 missing values which were estimated with confidence. One additional year was estimated with confidence (2011). All values were retained for frequency analysis.
02ZG002	The period of record is 1977 to 1996 with 1 missing value which was estimated with confidence. All values were retained for frequency analysis.
02ZG003	The period of record is 1980 to 2011 with 2 missing values which were estimated with confidence. All values were retained for frequency analysis.
02ZG004	The period of record is 1981 to 2011 with 2 missing values which were estimated with confidence. All values were retained for frequency analysis.
02ZG005	Gauge excluded due to short period of record.
02ZH001	The period of record is 1953 to 2011 with 4 missing values which were estimated with confidence. All values were retained for frequency analysis.
02ZH002	The period of record is 1971 to 2011 with 2 missing values which were estimated with confidence. An additional year was estimated with confidence (1970). All values were retained for frequency analysis.
02ZJ001	The period of record is 1977 to 2011 with 3 missing values which were estimated with confidence. An additional year was estimated with confidence (2012). All values were retained for frequency analysis.
02ZJ002	The period of record is 1983 to 2011 with 8 missing values which were estimated with confidence. An additional year was estimated with confidence (2012). All values were retained for frequency analysis.
02ZJ003	The period of record is 1986 to 2011 with 3 missing values which were estimated with confidence. An additional year was estimated with confidence (2012). All values were retained for frequency analysis.
02ZK001	The period of record is 1949 to 2011 with 4 missing values which were estimated with confidence. All values were retained for frequency analysis.
02ZK002	The period of record is 1979 to 2011 with 2 missing values which were estimated with confidence. This gauge did not pass the statistical screening and therefore was not retained for frequency analysis.
02ZK003	The period of record is 1983 to 2011 with 1 missing value which was estimated with confidence. All values, with the exception of the estimated value (1994) was retained for frequency analysis.
02ZK004	The period of record is 1983 to 2011 with 0 missing values. All values were retained for frequency analysis.
02ZK005	The period of record is 1986 to1996 with 5 missing values which were estimated with confidence. All values were retained for frequency analysis.
02ZL003	The period of record is 1979 to 1996 with 0 missing values. All values were retained for frequency analysis.
02ZL004	The period of record is 1983 to 2011 with 2 missing values which could not be estimated with confidence. All values were retained for frequency analysis.
02ZL005	The period of record is 1985 to 2011 with 0 missing values. All values were retained for frequency analysis.
02ZM006	The period of record is 1970 to 2011 with 0 missing values. All values were retained for frequency analysis.
02ZM008	The period of record is 1974 to 2011 with 3 missing values which could not be estimated with confidence. This gauge did not pass statistical screening and therefore was not retained for frequency analysis.
02ZM009	The period of record is 1979 to 2011 with 0 missing values. All values were retained for frequency analysis.
02ZM010	The period of record is 1981 to 1995 with 0 missing values. All values were retained for frequency analysis.
02ZM016	The period of record is 1983 to 2011 with 0 missing values. All values were retained for frequency analysis.

Station Number	Comments
02ZM017	The period of record is 1983 to 1997 with 0 missing values. All values were retained for frequency analysis.
02ZM018	The period of record is 1984 to 2011 with 2 missing values which could not be estimated with confidence. All values were retained for frequency analysis.
02ZM019	The period of record is 1985 to 1998 with 0 missing values. All values were retained for frequency analysis.
02ZM020	The period of record is 1978 to 2011 with 1 missing value which could not be estimated with confidence. An outlier was identified by HEC-SSP and removed, however this gauge did not pass statistical screening and therefore was not retained for frequency analysis.
02ZM021	The period of record is 1986 to 1998 with 0 missing values. All values were retained for frequency analysis.
02ZN001	The period of record is 1966 to 1995 with 2 missing values which were estimated with confidence. All values were retained for frequency analysis.
02ZN002	The period of record is 1985 to 2010 with 9 missing values which were estimated with confidence. An additional year was estimated with confidence (2011). All values were retained for frequency analysis.
03NE001	The period of record is 1996 to 2012 with 4 missing values. One value was estimated with confidence; three could not be (2000, 2001, 2002). All values were retained for frequency analysis.
03NE002	The period of record is 1996 to 2012 with 4 missing values. One value was estimated with confidence; three could not be (2000, 2001, 2002). This gauge did not pass statistical screening and therefore was not retained for frequency analysis.
03NE011	The period of record is from 2004 to 2011. This gauge was excluded due to short period of record
03NE012	The period of record is from 2004 to 2012. This gauge was excluded due to short period of record
03NF001	The period of record is 1979 to 2011 with 11 missing values. Ten values were estimated with confidence; one could not be (1981). An additional year was estimated with confidence (2012). Values between 1982 and 2012 were retained for frequency analysis.
03NG001	The period of record is 1979 to 1994 with 3 missing values which were estimated with confidence. All values with the exception of the estimated values (1980, 1981, 1985) were retained for frequency analysis.
03OA003	Gauge excluded due to short period of record.
03OA004	Gauge excluded due to short period of record.
03OB002	The period of record is 1955 to 1971 with 0 missing values. Gauge excluded due to change in watershed characteristics as a result of flooding due to the Churchill Hydro-electric project.
03OC003	The period of record is 1999 to 2012 with 0 missing values. All values were retained for frequency analysis.
03OC004	Gauge excluded due to short period of record.
03OC005	Gauge excluded due to short period of record.
03OD007	The period of record is 1999 to 2012 with 0 missing values. All values were retained for frequency analysis.
03OE003	The period of record is 1979 to 2012 with 7 missing values. Three values were estimated with confidence; four values could not be (1984, 1996, 1997, 1998). All values were retained for frequency analysis.
03OE010	The period of record is 1994 to 2011 with 0 missing values. All values were retained for frequency analysis.
03OE011	The period of record is 1999 to 2012 with 1 missing value which was estimated with confidence. All values were retained for frequency analysis.
03PB001	The period of record is 1957 to 1970 with 0 missing values. Gauge excluded due to change in watershed characteristics as a result of flooding due to the Churchill Hydro-electric project.
03PB002	The period of record is 1978 to 2011 with 9 missing values. Five values were estimated with confidence; four could not be (1981, 1996, 1997, 1998). All values with the exception of the estimated values were retained for frequency analysis.
03QC001	The period of record is 1967 to 2012 with 9 missing values. Six were estimated with confidence; three could not be (1968, 1979, 1980). This gauge did not pass statistical screening and therefore was not retained for frequency analysis.
03QC002	The period of record is 1978 to 2012 with 4 missing values which were estimated with confidence. All values were retained for frequency analysis.

APPENDIX B

Regression Analysis Outputs

NE-Q2

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.981635386
R Square	0.963608031
Adjusted R Square	0.958409178
Standard Error	0.101542101
Observations	17

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	3.822215612	1.911107806	185.3501301	8.45355E-11
Residual	14	0.144351176	0.010310798		
Total	16	3.966566788			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.463977365	0.150908164	3.074567679	0.008238119	0.140311544	0.787643186	0.140311544	0.787643186
DA	0.766694485	0.040616345	18.87650101	2.35111E-11	0.679581088	0.853807882	0.679581088	0.853807882
LAF	-0.285402278	0.058406578	-4.886474908	0.000240291	-0.410671929	-0.160132628	-0.410671929	-0.160132628

NE-Q5

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.976702703
R Square	0.953948169
Adjusted R Square	0.947369336
Standard Error	0.112135001
Observations	17

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	3.646601455	1.823300728	145.0026438	4.39267E-10
Residual	14	0.176039619	0.012574259		
Total	16	3.822641074			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.676312571	0.166650946	4.058258218	0.001174126	0.318881842	1.0337433	0.318881842	1.0337433
DA	0.745466383	0.044853454	16.62004417	1.30089E-10	0.649265293	0.841667474	0.649265293	0.841667474
LAF	-0.301549804	0.064499569	-4.675222038	0.000357572	-0.43988762	-0.163211989	-0.43988762	-0.163211989

NE-Q10

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.973118271
R Square	0.946959169
Adjusted R Square	0.939381907
Standard Error	0.119307538
Observations	17

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	3.557826229	1.778913114	124.973799	1.18106E-09
Residual	14	0.199280039	0.014234289		
Total	16	3.757106268			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.787303631	0.177310508	4.440253661	0.000559775	0.407010415	1.167596846	0.407010415	1.167596846
DA	0.734370431	0.047722433	15.38836933	3.62734E-10	0.632015991	0.83672487	0.632015991	0.83672487
LAF	-0.309990735	0.06862518	-4.517157295	0.000483074	-0.457177108	-0.162804362	-0.457177108	-0.162804362

NE-Q20

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.969612806
R Square	0.940148993
Adjusted R Square	0.931598849
Standard Error	0.125904601
Observations	17

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	3.486072883	1.743036442	109.9570964	2.75106E-09
Residual	14	0.221927561	0.015851969		
Total	16	3.708000444			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.878962093	0.187114823	4.697447696	0.000342841	0.477640714	1.280283473	0.477640714	1.280283473
DA	0.725206912	0.050361227	14.40010419	8.72287E-10	0.617192824	0.833221	0.617192824	0.833221
LAF	-0.316961046	0.072419783	-4.376719085	0.000632547	-0.472286032	-0.16163606	-0.472286032	-0.16163606

NE-Q50

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.9650614
R Square	0.931343506
Adjusted R Square	0.921535436
Standard Error	0.133939359
Observations	17

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	3.407004726	1.703502363	94.95685217	7.1907E-09
Residual	14	0.251156526	0.017939752		
Total	16	3.658161252			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.982123985	0.199055786	4.933913268	0.000219937	0.555191785	1.409056184	0.555191785	1.409056184
DA	0.714893356	0.053575091	13.34376384	2.36784E-09	0.599986215	0.829800496	0.599986215	0.829800496
LAF	-0.324806335	0.077041341	-4.216000545	0.000863277	-0.490043577	-0.159569093	-0.490043577	-0.159569093

NE-Q100

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.961664234
R Square	0.924798099
Adjusted R Square	0.914054971
Standard Error	0.139601994
Observations	17

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	3.355284835	1.677642417	86.08275391	1.3602E-08
Residual	14	0.272842036	0.019488717		
Total	16	3.628126871			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.050899635	0.207471389	5.065274986	0.000172386	0.605917764	1.495881506	0.605917764	1.495881506
DA	0.7080174	0.055840117	12.67936809	4.59847E-09	0.58825226	0.82778254	0.58825226	0.82778254
LAF	-0.330036551	0.080298464	-4.110122819	0.001060954	-0.502259628	-0.157813474	-0.502259628	-0.157813474

NE-Q200

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.958297709
R Square	0.918334498
Adjusted R Square	0.906667998
Standard Error	0.144970761
Observations	17

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	3.308652368	1.654326184	78.71550834	2.42254E-08
Residual	14	0.294231303	0.021016522		
Total	16	3.602883671			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.11384166	0.215450254	5.169832199	0.000142227	0.651746825	1.575936495	0.651746825	1.575936495
DA	0.701725018	0.057987598	12.10129486	8.39603E-09	0.577353991	0.826096046	0.577353991	0.826096046
LAF	-0.334823313	0.083386556	-4.015315295	0.001277124	-0.513669688	-0.155976939	-0.513669688	-0.155976939

NW-Q2

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.975700594
R Square	0.951991648
Adjusted R Square	0.943990256
Standard Error	0.116823066
Observations	15

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	3.247542086	1.623771043	118.9782545	1.22434E-08
Residual	12	0.163771545	0.013647629		
Total	14	3.411313631			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.597568205	0.197921342	3.019220664	0.010678372	0.166334647	1.028801764	0.166334647	1.028801764
DA	0.882854408	0.062755214	14.06822405	8.07343E-09	0.746122543	1.019586273	0.746122543	1.019586273
LAF	-0.408306567	0.06187134	-6.599284334	2.5404E-05	-0.543112637	-0.273500497	-0.543112637	-0.273500497

NW-Q5

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.970413129
R Square	0.941701641
Adjusted R Square	0.931985248
Standard Error	0.124878849
Observations	15

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	3.02284595	1.511422975	96.91884885	3.92589E-08
Residual	12	0.187136722	0.015594727		
Total	14	3.209982673			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.812652352	0.211569429	3.841067004	0.002347914	0.351682167	1.273622537	0.351682167	1.273622537
DA	0.841893728	0.067082633	12.55009963	2.9303E-08	0.695733226	0.988054229	0.695733226	0.988054229
LAF	-0.414666868	0.06613781	-6.269739915	4.1304E-05	-0.558768778	-0.270564959	-0.558768778	-0.270564959

NW-Q10

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.966246955
R Square	0.933633178
Adjusted R Square	0.922572041
Standard Error	0.131297211
Observations	15

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	2.910164234	1.455082117	84.40661892	8.54488E-08
Residual	12	0.20686749	0.017238958		
Total	14	3.117031724			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.925080312	0.222443401	4.158722208	0.001325811	0.440417777	1.409742848	0.440417777	1.409742848
DA	0.82048273	0.07053046	11.63302684	6.83021E-08	0.666810059	0.9741554	0.666810059	0.9741554
LAF	-0.417991147	0.069537076	-6.011054409	6.11223E-05	-0.56949942	-0.266482874	-0.56949942	-0.266482874

NW-Q20

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.962015702
R Square	0.925474212
Adjusted R Square	0.913053247
Standard Error	0.137553849
Observations	15

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	2.819580388	1.409790194	74.50904426	1.71332E-07
Residual	12	0.227052736	0.018921061		
Total	14	3.046633124			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.017926748	0.233043382	4.367971066	0.000915446	0.510168839	1.525684657	0.510168839	1.525684657
DA	0.802800952	0.073891411	10.86460442	1.45165E-07	0.641805398	0.963796507	0.641805398	0.963796507
LAF	-0.420736902	0.07285069	-5.775331716	8.80663E-05	-0.579464921	-0.262008884	-0.579464921	-0.262008884

NW-Q50

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.956351129
R Square	0.914607482
Adjusted R Square	0.900375395
Standard Error	0.145482421
Observations	15

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	2.720302582	1.360151291	64.26376676	3.87721E-07
Residual	12	0.253981619	0.021165135		
Total	14	2.974284201			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.122423827	0.246475949	4.553887842	0.0006617	0.585398868	1.659448787	0.585398868	1.659448787
DA	0.782900479	0.078150495	10.01785692	3.51294E-07	0.612625178	0.953175781	0.612625178	0.953175781
LAF	-0.423827019	0.077049788	-5.500690308	0.000136105	-0.591704085	-0.255949954	-0.591704085	-0.255949954

NW-Q100

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.952022893
R Square	0.906347589
Adjusted R Square	0.890738854
Standard Error	0.151220293
Observations	15

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	2.655689025	1.327844512	58.06669014	6.74705E-07
Residual	12	0.274410925	0.022867577		
Total	14	2.930099949			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.192088514	0.256197037	4.653014441	0.000557548	0.633883123	1.750293904	0.633883123	1.750293904
DA	0.769633453	0.081232775	9.474420299	6.39732E-07	0.592642441	0.946624466	0.592642441	0.946624466
LAF	-0.425886842	0.080088655	-5.317692519	0.000182983	-0.600385031	-0.251388653	-0.600385031	-0.251388653

NW-Q200

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.947663321
R Square	0.89806577
Adjusted R Square	0.881076732
Standard Error	0.156749576
Observations	15

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	2.597658727	1.298829363	52.8614836	1.12181E-06
Residual	12	0.294845156	0.02457043		
Total	14	2.892503882			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.255845072	0.265564734	4.728960248	0.000489412	0.677229223	1.834460922	0.677229223	1.834460922
DA	0.757491682	0.084203005	8.996017236	1.10926E-06	0.574029095	0.940954269	0.574029095	0.940954269
LAF	-0.427772107	0.083017051	-5.152822265	0.000239863	-0.608650722	-0.246893492	-0.608650722	-0.246893492

SE-Q2

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.968539729
R Square	0.938069206
Adjusted R Square	0.927747407
Standard Error	0.119558392
Observations	15

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	2.598182232	1.299091116	90.88233677	5.64209E-08
Residual	12	0.171530508	0.014294209		
Total	14	2.76971274			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.582090175	0.179648597	3.24015987	0.007084537	0.190669507	0.973510843	0.190669507	0.973510843
DA	0.714611372	0.060227904	11.86512101	5.48446E-08	0.583386042	0.845836703	0.583386042	0.845836703
LAF	-0.180480558	0.067187054	-2.686240078	0.019807087	-0.326868574	-0.034092542	-0.326868574	-0.034092542

SE-Q5

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.970406853
R Square	0.94168946
Adjusted R Square	0.931971037
Standard Error	0.116768368
Observations	15

ANOVA

	df	SS	MS	F	Significance F
Regression	2	2.642361977	1.321180989	96.89734938	3.93081E-08
Residual	12	0.16361822	0.013634852		
Total	14	2.805980198			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	0.710503541	0.175456304	4.049461472	0.001611887	0.328217097	1.092789986	0.328217097	1.092789986
DA	0.721246011	0.058822421	12.26141317	3.80223E-08	0.593082965	0.849409057	0.593082965	0.849409057
LAF	-0.180660624	0.065619172	-2.753168304	0.017499265	-0.323632518	-0.037688731	-0.323632518	-0.037688731

SE-Q10

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.970028567
R Square	0.940955421
Adjusted R Square	0.931114658
Standard Error	0.118062876
Observations	15

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	2.665612279	1.33280614	95.61813514	4.23721E-08
Residual	12	0.167266112	0.013938843		
Total	14	2.832878391			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.77762722	0.177401433	4.383432569	0.000890918	0.391102702	1.164151738	0.391102702	1.164151738
DA	0.724714499	0.059474534	12.18529099	4.07617E-08	0.595130622	0.854298376	0.595130622	0.854298376
LAF	-0.180755046	0.066346634	-2.724404165	0.018456718	-0.325311943	-0.036198149	-0.325311943	-0.036198149

SE-Q20

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.969039184
R Square	0.939036941
Adjusted R Square	0.928876431
Standard Error	0.120521613
Observations	15

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	2.684893382	1.342446691	92.42025823	5.13335E-08
Residual	12	0.174305511	0.014525459		
Total	14	2.859198893			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.833062169	0.181095935	4.600115232	0.000610809	0.438488023	1.227636315	0.438488023	1.227636315
DA	0.727578445	0.06071313	11.98387308	4.90893E-08	0.595295898	0.859860991	0.595295898	0.859860991
LAF	-0.180834418	0.067728346	-2.669996058	0.020410902	-0.328401808	-0.033267028	-0.328401808	-0.033267028

SE-Q50

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.967217386
R Square	0.935509471
Adjusted R Square	0.92476105
Standard Error	0.124695546
Observations	15

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	2.706670434	1.353335217	87.03691711	7.19409E-08
Residual	12	0.186587751	0.015548979		
Total	14	2.893258185			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.89545209	0.187367692	4.77911682	0.000449234	0.487212959	1.303691222	0.487212959	1.303691222
DA	0.730801198	0.062815762	11.63404183	6.82361E-08	0.593937411	0.867664985	0.593937411	0.867664985
LAF	-0.180921885	0.070073931	-2.581871513	0.024014832	-0.333599864	-0.028243906	-0.333599864	-0.028243906

SE-Q100

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.965600861
R Square	0.932385022
Adjusted R Square	0.921115859
Standard Error	0.128238126
Observations	15

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	2.721246925	1.360623462	82.73773498	9.55559E-08
Residual	12	0.197340205	0.016445017		
Total	14	2.918587129			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.937045112	0.192690778	4.86294737	0.000389602	0.517207973	1.356882251	0.517207973	1.356882251
DA	0.732950619	0.064600347	11.34592385	9.00702E-08	0.592198554	0.873702684	0.592198554	0.873702684
LAF	-0.180980856	0.07206472	-2.511365577	0.027339199	-0.337996391	-0.023965321	-0.337996391	-0.023965321

SE-Q200

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.963849426
R Square	0.929005715
Adjusted R Square	0.917173335
Standard Error	0.131965476
Observations	15

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	2.734619483	1.367309741	78.51384549	1.28038E-07
Residual	12	0.208978643	0.017414887		
Total	14	2.943598126			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.975109285	0.198291499	4.917554661	0.000355266	0.543069223	1.407149346	0.543069223	1.407149346
DA	0.734917714	0.066478011	11.05504968	1.19935E-07	0.590074571	0.879760858	0.590074571	0.879760858
LAF	-0.181033848	0.074159342	-2.441146907	0.031092564	-0.342613173	-0.019454523	-0.342613173	-0.019454523

SW-Q2

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.941796677
R Square	0.88698098
Adjusted R Square	0.858726225
Standard Error	0.163950408
Observations	11

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	1.687632045	0.843816022	31.39227303	0.000163157
Residual	8	0.215037891	0.026879736		
Total	10	1.902669935			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.958710257	0.306178145	6.397289586	0.000209738	1.25266219	2.664758325	1.25266219	2.664758325
DA	0.522847398	0.084124593	6.215155118	0.000255183	0.328855738	0.716839058	0.328855738	0.716839058
LSF	-4.824796395	0.916106604	-5.266632045	0.000758382	-6.937342009	-2.712250781	-6.937342009	-2.712250781

SW-Q5

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.933451722
R Square	0.871332118
Adjusted R Square	0.839165147
Standard Error	0.179392227
Observations	11

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	1.743455229	0.871727614	27.08778918	0.000274082
Residual	8	0.257452569	0.032181571		
Total	10	2.000907798			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	2.150470469	0.335015813	6.419011836	0.000204943	1.377922619	2.923018318	1.377922619	2.923018318
DA	0.519160559	0.092047945	5.640110247	0.00048698	0.306897617	0.731423501	0.306897617	0.731423501
LSF	-5.059929234	1.002390941	-5.0478601	0.000991887	-7.371446886	-2.748411581	-7.371446886	-2.748411581

SW-Q10

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.928728141
R Square	0.86253596
Adjusted R Square	0.828169951
Standard Error	0.187997534
Observations	11

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	1.77411758	0.88705879	25.09851924	0.000357073
Residual	8	0.282744582	0.035343073		
Total	10	2.056862161			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	2.250706976	0.351086263	6.410695075	0.000206764	1.441100603	3.06031335	1.441100603	3.06031335
DA	0.517233279	0.096463414	5.361963228	0.00067608	0.294788247	0.73967831	0.294788247	0.73967831
LSF	-5.182836004	1.05047486	-4.933802988	0.001143949	-7.605235373	-2.760436634	-7.605235373	-2.760436634

SW-Q20

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.924673465
R Square	0.855021017
Adjusted R Square	0.818776271
Standard Error	0.19533516
Observations	11

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	1.800207526	0.900103763	23.59020595	0.000441794
Residual	8	0.305246598	0.038155825		
Total	10	2.105454123			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	2.333484047	0.364789314	6.396799356	0.000209847	1.492278382	3.174689712	1.492278382	3.174689712
DA	0.515641773	0.100228423	5.144666107	0.000880071	0.284514614	0.746768931	0.284514614	0.746768931
LSF	-5.284335764	1.091475355	-4.841461368	0.001285737	-7.801282443	-2.767389084	-7.801282443	-2.767389084

SW-Q50

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.919968259
R Square	0.846341597
Adjusted R Square	0.807926996
Standard Error	0.203813792
Observations	11

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	1.830402063	0.915201032	22.03176862	0.000557475
Residual	8	0.332320495	0.041540062		
Total	10	2.162722558			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	2.426649509	0.380623199	6.375464022	0.00021468	1.548930839	3.304368178	1.548930839	3.304368178
DA	0.513850464	0.104578894	4.913519764	0.001173565	0.272691102	0.755009827	0.272691102	0.755009827
LSF	-5.398573106	1.138851455	-4.740366343	0.001463266	-8.024769268	-2.772376944	-8.024769268	-2.772376944

SW-Q100

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.916760008
R Square	0.840448912
Adjusted R Square	0.80056114
Standard Error	0.209582441
Observations	11

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	1.851020904	0.925510452	21.07033982	0.000648036
Residual	8	0.351398396	0.0439248		
Total	10	2.2024193			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	2.488760098	0.391396177	6.358672483	0.000218571	1.586198897	3.391321299	1.586198897	3.391321299
DA	0.512656313	0.107538846	4.767173291	0.001413727	0.26467129	0.760641335	0.26467129	0.760641335
LSF	-5.474731839	1.171084965	-4.67492283	0.001592321	-8.175258608	-2.774205069	-8.175258608	-2.774205069

SW-Q200

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.913780837
R Square	0.834995417
Adjusted R Square	0.793744272
Standard Error	0.214935893
Observations	11

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	1.870234076	0.935117038	20.24175094	0.000741283
Residual	8	0.369579506	0.046197438		
Total	10	2.239813582			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	2.545603437	0.401393774	6.341910621	0.000222532	1.619987735	3.471219138	1.619987735	3.471219138
DA	0.511563456	0.110285756	4.63852701	0.001669409	0.257244048	0.765882864	0.257244048	0.765882864
LSF	-5.544432304	1.200998481	-4.616518999	0.001717984	-8.313939765	-2.774924844	-8.313939765	-2.774924844

Labrador-Q2

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.984187523
R Square	0.968625081
Adjusted R Square	0.961652877
Standard Error	0.125378323
Observations	12

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	4.367777667	2.183888833	138.9266654	1.71641E-07
Residual	9	0.141477516	0.015719724		
Total	11	4.509255183			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-0.235573237	0.246028314	-0.957504576	0.36332524	-0.792127948	0.320981475	-0.792127948	0.320981475
Drainage Area	0.844730866	0.053983188	15.64803594	7.80882E-08	0.722612411	0.966849321	0.722612411	0.966849321
LAF	-0.053128715	0.137623834	-0.386042981	0.70843214	-0.364455456	0.258198026	-0.364455456	0.258198026

Labrador-Q5

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.982217877
R Square	0.964751959
Adjusted R Square	0.956919061
Standard Error	0.133304764
Observations	12

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	4.37738281	2.188691405	123.166668	2.89806E-07
Residual	9	0.159931441	0.01777016		
Total	11	4.537314251			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-0.164554246	0.261582269	-0.629072629	0.544935698	-0.756294447	0.427185956	-0.756294447	0.427185956
Drainage Area	0.843103996	0.057396015	14.68924274	1.35286E-07	0.71326519	0.972942802	0.71326519	0.972942802
LAF	-0.034493503	0.146324438	-0.235733031	0.818916643	-0.365502378	0.296515371	-0.365502378	0.296515371

Labrador-Q10

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.981012439
R Square	0.962385405
Adjusted R Square	0.954026606
Standard Error	0.137958993
Observations	12

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	4.38263372	2.19131686	115.1344132	3.88243E-07
Residual	9	0.171294153	0.019032684		
Total	11	4.553927872			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-0.127428546	0.270715203	-0.47071071	0.649046542	-0.739828881	0.48497179	-0.739828881	0.48497179
Drainage Area	0.84225327	0.059399951	14.17935975	1.83711E-07	0.707881246	0.976625294	0.707881246	0.976625294
LAF	-0.024753422	0.151433238	-0.163460959	0.873767241	-0.367319206	0.317812361	-0.367319206	0.317812361

Labrador-Q20

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.979927651
R Square	0.960258201
Adjusted R Square	0.95142669
Standard Error	0.142035528
Observations	12

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	4.387094455	2.193547227	108.7309072	4.97295E-07
Residual	9	0.18156682	0.020174091		
Total	11	4.568661275			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-0.096771155	0.278714537	-0.347205265	0.736418031	-0.72726724	0.533724931	-0.72726724	0.533724931
Drainage Area	0.841550935	0.061155153	13.76091612	2.3797E-07	0.703208367	0.979893503	0.703208367	0.979893503
LAF	-0.016709413	0.155907922	-0.107174878	0.91700133	-0.369397635	0.335978809	-0.369397635	0.335978809

Labrador-Q50

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.978611645
R Square	0.957680752
Adjusted R Square	0.948276475
Standard Error	0.146852343
Observations	12

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	4.392250387	2.196125194	101.8345931	6.59813E-07
Residual	9	0.194090497	0.021565611		
Total	11	4.586340884			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-0.062268602	0.288166514	-0.216085488	0.833739202	-0.714146545	0.589609341	-0.714146545	0.589609341
Drainage Area	0.840760729	0.063229093	13.29705506	3.19766E-07	0.697726584	0.983794874	0.697726584	0.983794874
LAF	-0.007655214	0.161195189	-0.04749034	0.963159566	-0.372304065	0.356993636	-0.372304065	0.356993636

Labrador-Q100

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.977679188
R Square	0.955856594
Adjusted R Square	0.946046948
Standard Error	0.150187026
Observations	12

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	4.39576275	2.197881375	97.44047986	7.97804E-07
Residual	9	0.203005285	0.022556143		
Total	11	4.598768035			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-0.039265262	0.29471012	-0.133233502	0.896940194	-0.70594587	0.627415347	-0.70594587	0.627415347
Drainage Area	0.840233766	0.064664882	12.99366431	3.89927E-07	0.693951641	0.986515891	0.693951641	0.986515891
LAF	-0.001619523	0.164855565	-0.009823889	0.992376113	-0.374548719	0.371309674	-0.374548719	0.371309674

Labrador-Q200

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.976787693
R Square	0.954114198
Adjusted R Square	0.943917353
Standard Error	0.153319082
Observations	12

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	4.399030359	2.19951518	93.56955056	9.49626E-07
Residual	9	0.211560668	0.023506741		
Total	11	4.610591027			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-0.018212016	0.300856115	-0.060533974	0.953053266	-0.698795829	0.662371797	-0.698795829	0.662371797
Drainage Area	0.839751416	0.066013427	12.72091834	4.67742E-07	0.690418669	0.989084163	0.690418669	0.989084163
LAF	0.00390408	0.168293524	0.023198038	0.981998497	-0.376802321	0.38461048	-0.376802321	0.38461048

Newfoundland – Single Region-Q2

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.938870429
R Square	0.881477682
Adjusted R Square	0.87716778
Standard Error	0.19721489
Observations	58

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	15.9093809	7.954690452	204.5238121	3.38457E-26
Residual	55	2.139154216	0.038893713		
Total	57	18.04853512			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.787813352	0.135699944	5.805553981	3.30913E-07	0.515864589	1.059762116	0.515864589	1.059762116
DA	0.721130125	0.03623981	19.89883834	8.47333E-27	0.648503923	0.793756328	0.648503923	0.793756328
LAF	-0.312411473	0.056422314	-5.537019885	8.8901E-07	-0.425484315	-0.19933863	-0.425484315	-0.19933863

Newfoundland – Single Region-Q5

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.934318345
R Square	0.872950771
Adjusted R Square	0.868330799
Standard Error	0.201574407
Observations	58

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	15.35504842	7.677524211	188.9515292	2.28681E-25
Residual	55	2.234773295	0.040632242		
Total	57	17.58982172			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.965966764	0.138699648	6.964450006	4.31338E-09	0.68800646	1.243927068	0.68800646	1.243927068
DA	0.706444182	0.037040906	19.07200048	6.5416E-26	0.632212548	0.780675817	0.632212548	0.780675817
LAF	-0.323059124	0.057669552	-5.601901032	7.00819E-07	-0.438631489	-0.20748676	-0.438631489	-0.20748676

Newfoundland – Single Region-Q10

SUMMARY
OUTPUT

Regression Statistics	
Multiple R	0.93090292
R Square	0.866580246
Adjusted R Square	0.861728619
Standard Error	0.205404471
Observations	58

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	15.07200835	7.536004175	178.6164054	8.7812E-25
Residual	55	2.32050482	0.042190997		
Total	57	17.39251317			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.059090342	0.141335044	7.493473021	5.86296E-10	0.775848586	1.342332099	0.775848586	1.342332099
DA	0.69876778	0.037744711	18.51299852	2.70489E-25	0.623125689	0.774409871	0.623125689	0.774409871
LAF	-0.328624899	0.058765317	-5.592157377	7.26334E-07	-0.446393224	-0.21085657	-0.446393224	-0.210856574

Newfoundland – Single Region-Q20

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.927531042
R Square	0.860313834
Adjusted R Square	0.855234337
Standard Error	0.209319362
Observations	58

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	14.84174618	7.420873091	169.3698884	3.10255E-24
Residual	55	2.409802733	0.043814595		
Total	57	17.25154892			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.135994198	0.144028809	7.887270663	1.33162E-10	0.847354017	1.424634378	0.847354017	1.424634378
DA	0.692428506	0.038464103	18.00194061	1.01797E-24	0.615344721	0.769512291	0.615344721	0.769512291
LAF	-0.333221662	0.05988535	-5.564326898	8.04382E-07	-0.453234584	-0.21320874	-0.453234584	-0.21320874

Newfoundland – Single Region-Q50

SUMMARY
OUTPUT

Regression Statistics	
Multiple R	0.923131269
R Square	0.852171341
Adjusted R Square	0.846795753
Standard Error	0.214490189
Observations	58

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	14.58632339	7.293161693	158.5261746	1.47354E-23
Residual	55	2.530332256	0.046006041		
Total	57	17.11665564			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.222549302	0.14758676	8.283597412	3.01593E-11	0.926778828	1.518319776	0.926778828	1.518319776
DA	0.685293208	0.039414284	17.38692513	5.20115E-24	0.606305218	0.764281198	0.606305218	0.764281198
LAF	-0.338394728	0.061364701	-5.514485113	9.65432E-07	-0.461372335	-0.21541712	-0.461372335	-0.21541712

Newfoundland – Single Region-Q100

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.919840323
R Square	0.846106219
Adjusted R Square	0.840510082
Standard Error	0.218360093
Observations	58

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	14.41826654	7.209133271	151.1946805	4.45225E-23
Residual	55	2.622462171	0.04768113		
Total	57	17.04072871			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.280252629	0.15024957	8.520840544	1.24531E-11	0.979145764	1.581359495	0.979145764	1.581359495
DA	0.680536658	0.04012541	16.96024183	1.65165E-23	0.60012354	0.760949776	0.60012354	0.760949776
LAF	-0.341843638	0.062471863	-5.471961611	1.12775E-06	-0.467040048	-0.21664723	-0.467040048	-0.216647227

Newfoundland – Single Region-Q200

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.91657702
R Square	0.840113433
Adjusted R Square	0.834299376
Standard Error	0.222180996
Observations	58

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	14.26600791	7.133003957	144.4969385	1.273E-22
Residual	55	2.715041728	0.049364395		
Total	57	16.98104964			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.33306212	0.152878663	8.719739509	5.95042E-12	1.026686435	1.639437805	1.026686435	1.639437805
DA	0.676183417	0.040827531	16.56194711	4.94565E-23	0.594363216	0.758003617	0.594363216	0.758003617
LAF	-0.344999837	0.063565007	-5.427511998	1.32625E-06	-0.472386956	-0.21761272	-0.472386956	-0.217612718

Newfoundland – Small Watersheds – Q2

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.833301582
R Square	0.694391526
Adjusted R Square	0.660435029
Standard Error	0.175282803
Observations	21

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	1.256580005	0.628290003	20.44944518	2.32535E-05
Residual	18	0.553033099	0.030724061		
Total	20	1.809613104			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.641125837	0.2500904	2.563576362	0.019536825	0.115705405	1.166546269	0.115705405	1.166546269
Area (km2)	0.686473882	0.127791369	5.371832915	4.18166E-05	0.417994179	0.954953585	0.417994179	0.954953585
LAF	-0.216073728	0.081819831	-2.640847881	0.01660685	-0.387970814	-0.044176641	-0.387970814	-0.044176641

Newfoundland – Small Watersheds – Q5

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.841713183
R Square	0.708481082
Adjusted R Square	0.676090091
Standard Error	0.17575418
Observations	21

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	1.351279993	0.675639996	21.87278202	1.52055E-05
Residual	18	0.556011573	0.030889532		
Total	20	1.907291565			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.706899008	0.250762952	2.818993005	0.011364287	0.180065596	1.23373242	0.180065596	1.23373242
Area (km2)	0.73098955	0.12813503	5.70483769	2.07427E-05	0.461787841	1.000191259	0.461787841	1.000191259
LAF	-0.202607927	0.082039864	-2.469627783	0.023759034	-0.374967286	-0.030248569	-0.374967286	-0.030248569

Newfoundland – Small Watersheds – Q10

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.845185586
R Square	0.714338675
Adjusted R Square	0.682598528
Standard Error	0.176617084
Observations	21

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	1.404076084	0.702038042	22.50583999	1.26667E-05
Residual	18	0.561484697	0.031193594		
Total	20	1.965560781			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.74128022	0.251994128	2.941656721	0.008722928	0.211860203	1.270700236	0.211860203	1.270700236
Area (km2)	0.754259755	0.128764137	5.857684993	1.51032E-05	0.483736341	1.024783168	0.483736341	1.024783168
LAF	-0.195570438	0.082442657	-2.372199611	0.029034266	-0.368776033	-0.022364844	-0.368776033	-0.022364844

Newfoundland – Small Watersheds – Q20

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.847607672
R Square	0.718438765
Adjusted R Square	0.687154184
Standard Error	0.177642019
Observations	21

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	1.44937513	0.724687565	22.96462757	1.11213E-05
Residual	18	0.568020366	0.031556687		
Total	20	2.017395496			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.769672161	0.253456488	3.036703334	0.007095197	0.237179841	1.302164481	0.237179841	1.302164481
Area (km2)	0.773476425	0.129511375	5.97226634	1.19292E-05	0.501383124	1.045569727	0.501383124	1.045569727
LAF	- 0.189757951	0.082921084	-2.288416188	0.034425158	-0.363968683	- 0.015547218	- 0.363968683	- 0.015547218

Newfoundland – Small Watersheds – Q50

SUMMARY
OUTPUT

Regression Statistics	
Multiple R	0.849877413
R Square	0.722291617
Adjusted R Square	0.69143513
Standard Error	0.179128489
Observations	21

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	1.502191897	0.751095949	23.40809626	9.82428E-06
Residual	18	0.57756628	0.032087016		
Total	20	2.079758177			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.801632398	0.255577356	3.13655486	0.005704015	0.264684299	1.338580498	0.264684299	1.338580498
Area (km2)	0.795101607	0.130595098	6.088295962	9.41039E-06	0.520731488	1.069471726	0.520731488	1.069471726
LAF	-0.183216562	0.083614949	-2.191193843	0.041835822	-0.358885052	-0.007548073	-0.358885052	-0.007548073

Newfoundland – Small Watersheds – Q100

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.851138165
R Square	0.724436177
Adjusted R Square	0.693817974
Standard Error	0.180311162
Observations	21

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	1.538493473	0.769246736	23.66031039	9.1622E-06
Residual	18	0.585218073	0.032512115		
Total	20	2.123711546			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.822936668	0.257264773	3.19879266	0.004975678	0.282443437	1.363429899	0.282443437	1.363429899
Area (km2)	0.809520594	0.131457335	6.158048097	8.16681E-06	0.533338981	1.085702207	0.533338981	1.085702207
LAF	-0.178855637	0.084167006	-2.12500889	0.04769024	-0.355683956	-0.002027318	-0.355683956	-0.002027318

Newfoundland – Small Watersheds – Q200

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.852123623
R Square	0.726114669
Adjusted R Square	0.695682965
Standard Error	0.18152554
Observations	21

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	1.572477422	0.786238711	23.86046738	8.67199E-06
Residual	18	0.593127392	0.032951522		
Total	20	2.165604815			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.842430984	0.258997427	3.252661599	0.004419419	0.298297583	1.386564385	0.298297583	1.386564385
Area (km2)	0.82271779	0.132342688	6.21657156	7.25471E-06	0.54467612	1.100759459	0.54467612	1.100759459
LAF	- 0.174863668	0.084733863	-2.063681052	0.053771719	-0.352882908	0.003155573	- 0.352882908	0.003155573