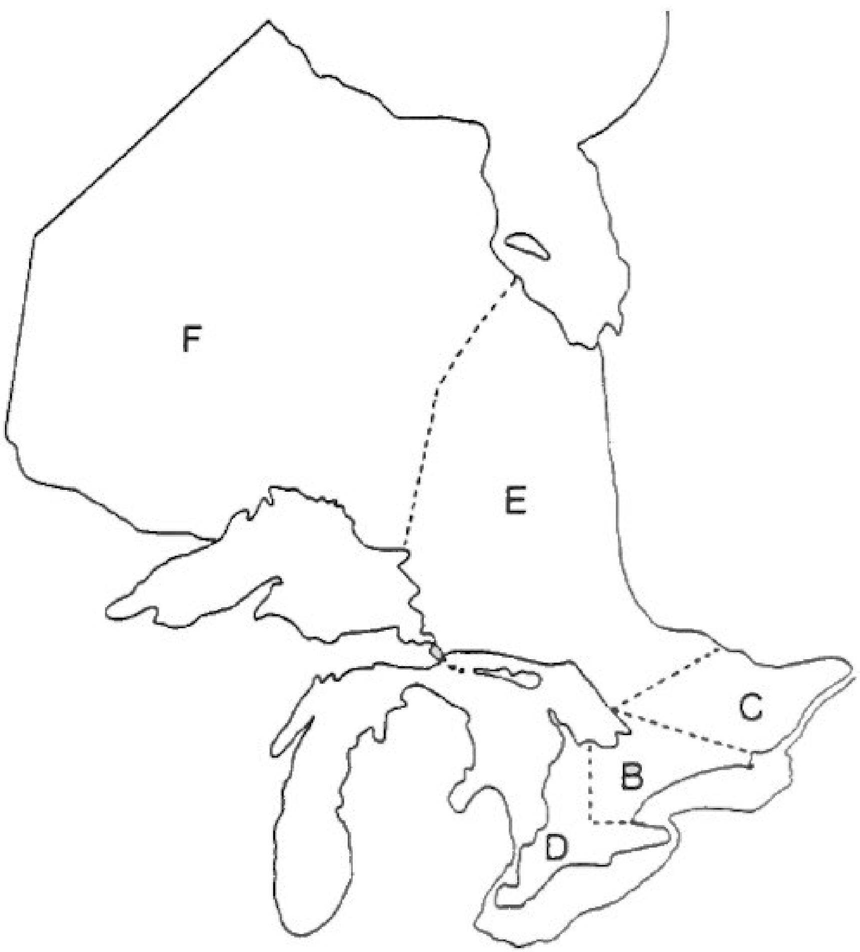
Ministry
of the
Environment
Ontario

A REPORT ON

LOW FLOW CHARACTERISTICS IN ONTARIO



Main Report

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LOW FLOW CHARACTERISTICS IN ONTARIO

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Dr. L. Logan	River Systems Section, Water Resources Branch, Ministry of Environment
Mr. B. Whitehead	River Systems Section, Water Resources Branch, Ministry of Environment
Mr. P. Pilon	Hydrology Division, Water Resources Branch, Inland Waters Directorate
Mr. D. Anderson	Water Survey of Canada Division, Inland Waters Directorate

The background information presented in this report was obtained mainly from the Water Survey of Canada and the Ministry of Environment, Water Resources Branch.

We would also like to express our appreciation for the time and effort of all others who contributed to this project by way of information, discussions and otherwise.

LOW FLOW CHARACTERISTICS IN ONTARIO

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1.0 INTRODUCTION

1.1 General

The knowledge of the hydrologic conditions which exist during low flow periods can be of primary importance in undertaking a variety of water resources investigations. When analysing water quality conditions, the low flow characteristics within the watercourse are a major concern to both the user and the Ontario Ministry of the Environment. Some uses of low flow information include the following:

i) The analysis of municipal and industrial effluent discharges to streams
ii) Instream pollutant analyses (point and non-point sources including mixing zones)
iii) Reservoir design (low flow augmentation)
iv) Environmental approvals
v) Feasibility of small hydro developments
vi) Water supply and evaluation for water taking permits
vii) Base flow/groundwater recharge and/or contamination analysis
viii) Stream fisheries assessments
ix) Analyse effects of changes In watershed on low flows (e.g. deforestation, urbanization)
x) Agricultural
xi) Other

The identification of low flow characteristics within a watercourse is most easily accomplished using continuous hydrometric data recorded for the stream. Available data were previously analysed and published as a series of "Low Flow Characteristics" maps which were published several years ago (more than 10 years In most cases) by the Ministry of the Environment (Ministry of the Environment, 1973-1978). Additional data (both temporally and spatially) are now available and it was, therefore, considered appropriate to update the available data base describing low flow characteristics across the Province of Ontario.

1.2 Study Objectives and Scope

The overall objective of the proposed investigation was to carry out an analysis describing the low flow characteristics at suitable Water Survey of Canada streamflow locations in Ontario. The following points summarize the scope of the investigations:

1. Update statistical low flow analyses for each of the following administrative regions:
   - Central
   - Southeastern
   - Southwestern and West Central
   - Northeastern
   - Northwestern

2. Undertake data base screening analyses to identify constraints on the data base

3. Produce extreme value analyses for suitable stream gauging locations (1, 3, 7, 15, 30-day durations) with greater than 10 years of data

4. Produce annual flow duration analyses, using daily data for suitable stream gauging locations

5. Produce monthly low flow analyses

2.0 METHODOLOGY

2.1 General

The available streamflow data base was obtained for all relevant Water Survey of Canada monitoring locations (see discussion in Section 2.2). Data analyses and screening were then undertaken in order to assess the usefulness of the data at each location prior to undertaking statistical analyses (see Section 2.3). Extreme values for selected low flow durations were then calculated for various recurrence intervals for both annual and monthly series using the techniques discussed in Section 2.4. Flow duration analyses were also undertaken utilizing the daily data base on both an annual and a monthly basis (see Sections 2.5 and 2.6). In most cases the extreme value analysis results should be used for low flow characteristic analysis. However, under certain conditions flow duration results of heavily regulated stations may give more conservative results. Computer drawn maps depicting low flow characteristics were then produced in order to summarize selected low flow statistics on a regional basis (see Section 2.7).

2.2 Data Base

The entire Water Survey of Canada daily streamflow data base for the Province of Ontario for the period of record to the end of 1986 was obtained in computer tape format.

Stations with a minimum of ten years of record were considered to have an appropriate record length for the purpose of this investigation. Stations inactive prior to 1981 were not considered in the analysis.

Several data management programs developed by Cumming Cockburn Limited were then used for extraction and analysis of data from the computer archives. First a program was written and executed to check and screen the available data base at each station for missing data. A second program was then run to utilize this analysis to compute running averages for various durations and to pick the corresponding minimum annual low flow.

A third program sorted and analysed the available data to determine low flow values on a monthly basis. Average flows were determined and extracted for the annual consecutive low 1, 3, 7, 15 and 30 day durations and are available as part of the background files. Another program was used to compute flow duration curves as discussed in Section 2.5.

2.3 Data Analysis and Screening

The data were manually screened to remove station records which contained a significant number of zero low flow occurrences for all durations. These stations are listed in Table 1 and the screening results are discussed in Section 3.2.

The initial version of the Low Flow Frequency Analysis program was obtained from Environment Canada for use in the investigation (Pilon and Jackson, 1988). This program contains a set of data analysis and checking modules suitable for data screening and analysis (Pilon *et al*, 1985). At present there is some question concerning the reliability of the methodology for checking Independence for low flow data series (personal communication, P. Pilon, Water Resources Branch, Environment Canada).

The data screening process was undertaken to test the assumption that the data are reliable measurements and are mutually exclusive and represent independent random events which are free from trend. The non-parametric tests applied include the Spearman Rank Order Correlation Coefficient for Independence; the Spearman Rank Order Correlation Coefficient for Trend; and a general randomness test. The statistical tests were applied at the 1% and 5% levels of significance.(See Appendix A.3 for more details on the statistical tests.)

TABLE 1. Stations with Unacceptable Low Flow Data Set.*

Appendix	Station	Station Name	Reason for Removal
F	02AD009	Ogoki River Diversion to Lake Nipigon	>30% Number of Occurrence of 0.0 Low Flow
E	02CA001	St. Mary's River at Sault Ste. Marie	Very large flows Aug - 1741 cm
E	02CB001	Mississagi River Below Aubry Falls	>30% Number of Occurrence of 0.0 Low Flow
E	02CC007	Mississagi River at Rayner Generating Station	>30% Number of Occurrence of 0.0 Low Flow
E	02CC009	Mississagi River at Red Rock Falls	>30% Number of Occurrence of 0.0 Low Flow
E	02C0004	Serpent River Below Quirke Lake	Only removed from the seasonal analysis
E	02DC007	Temagami River at Cross Lake Dam	Only removed from the seasonal analysis
E	02DD010	French River at Dry Pine Bay	Only removed from the seasonal analysis
E	02DD014	Chippawa Creek at North Bay	Arithmetic overflow
E	02DD017	French River at Chaudiere Dam	Only removed from the seasonal analysis
E	02DD018	Little French River at Freeflowing Channel	Only 2 years of record - deleted
E	020D019	Little French River at Little Chaudiere Dam	Only 2 years of record - deleted
B	02EB012	Muskoka River at Highway No. 69	Only removed from the seasonal analysis
B	02EC005	Severn River at Washago	Only removed from the seasonal analysis
B	02EC007	Severn River at Little Falls	Only removed from the seasonal analysis
	02EC016	Trent Canal Lock 42 near Washago	>30% Number of Occurrence of 0.0 Low Flow
B	02EC101	Uxbridge Brook at Uxbridge	Only removed from the seasonal analysis
D	02FF004	South Parkhill Creek near Parkhill	>30% Number of Occurrence of 0.0 Low Flow
D	02HA003	Niagara River at Queenston	Only 1 day duration could be extracted
D	02HB016	Bronte Creek at Progreston	Arithmetic overflow
B	02HC023	Cold Creek near Bolton	Only removed from the seasonal analysis
B	02HC027	Black Creek near Weston	Arithmetic overflow
B	02HC038	West Duffins Creek above Green River	Arithmetic overflow
B	02HD007	Soper Creek at Bowmanville	Arithmetic overflow
B	02HF004	Bob Creek near Minden	>30% Number of Occurrence of 0.0 Low Flow
E	02JD009	Montreal River at Mountain Chutes	Only removed from the seasonal analysis
E	02JD010	Montreal River at Lower Notch G.S.	>30% Number of Occurrence of 0.0 Low Flow
E	02JD011	Lady Evelyn River at Lady Evelyn Lake	>30% Number of Occurrence of 0.0 Low Flow
E	02JE012	Ottawa River at La Cave Rapids	>30% Number of Occurrence of 0.0 Low Flow
E	02JE021	Matabitchuan River at Rabbit Lake Dam	>30% Number of Occurrence of 0.0 Low Flow

* Program modifications were subsequently made and results are addended in the appropriate Appendices.

TABLE 1 (cont'd)

Appendix	Station	Station Name	Reason for Removal
C	02KA006	Perch Lake Inlet No.3 near Chalk River	>30% Number of Occurrence of 0.0 Low Flow
C	02KA007	Perch Lake Inlet No. 4 near Chalk River	>30% Number of Occurrence of 0.0 Low Flow
C	02KA008	Perch Lake Inlet No.5 near Chalk River	>30% Number of Occurrence of 0.0 Low Flow
C	02KD007	Madawaska River at Bark Lake	Only removed from the seasonal analysis
C	02KF014	Fall River near Fallbrook	Only removed from the seasonal analysis
C	02MB005	St. Lawrence River at Iroquois	Very large flows Aug = 5790 cm
C	02MC002	St. Lawrence River at Cornwall	Very large flows Aug = 5655 cm
F	04CA002	Severn River at Outlet of Muskrat Dam Lake	>30% Number of Occurrence of 0.0 Low Flow
F	04CA004	Severn River below Outlet of Deer Lake	>30% Number of Occurrence of 0.0 Low Flow
F	04CD002	Sachigo River below Outlet of Sachigo Lake	Only removed from the seasonal analysis
F	04DC001	Winisk River below Asheweig River Tributary	Arithmetic overflow
F	04DC002	Shamattawa River at Outlet of Shamattawa Lake	Only removed from the seasonal analysis
F	04GA001	Lake St. Joseph Outflow to Albany River	>30% Number of Occurrence of 0.0 Low Flow
F	04GA002	Cat River below Wesleyan Lake	Arithmetic overflow
F	04GB004	Ogoki River above Whiteclay Lake	Arithmetic overflow
F	04JD003	Long Lake Diversion to Lake Superior	>30% Number of Occurrence of 0.0 Low Flow
F	04JF001	Little Current River at Percy Lake	Arithmetic overflow
E	04LA002	Mattagami River near Timmins	Arithmetic overflow
E	04LG003	Mattagami River at Little Long Rapids	Arithmetic overflow
E	04MB003	Watabeag River at Watabeag Lake Dam	>30% Number of Occurrence of 0.0 Low Flow
E	04MC001	Abitibi River at Iroquois Falls	>30% Number of Occurrence of 0.0 Low Flow
E	04MC002	Abitibi River at Thin Falls	Arithmetic overflow
E	04ME003	Abitibi River at Onakamana	Arithmetic overflow
F	05PB009	Seine River at Sturgeon Falls G.S.	>30% Number of Occurrence of 0.0 Low Flow
F	05PE006	Lake of the Woods E. Outlet at Kenora P. House	Only removed from the seasonal analysis
F	05PE010	Winnipeg River at Whitedog Falls P.House	Arithmetic overflow
F	05QB006	Lake St. Joseph Diversion at Root Portage	>30% Number of Occurrence of 0.0 Low Flow
F	05QE005	English River at Caribou Falls	Arithmetic overflow
F	05QE007	English River at Manitou Falls	>30% Number of Occurrence of 0.0 Low Flow

* Program modifications were subsequently made and results are addended in the appropriate Appendices.

It must also be expected that a certain number of stations which are tested will randomly "fail" any given statistical test. Therefore, the binomial distribution was used to calculate the number of expected random failures over the entire data base for each region in order to assess the suitability of the low flow data on a regional basis. A tabulation of theoretical and actual "failure" results is summarized and discussed in Appendix A.3.4.

The effect of regulation was examined by further subdivision of the data base according to regulated and non-regulated stations. These results are tabulated in Appendices B to F and discussed in Section 3.2.

2.4 Extreme Value Analysis

An extreme value analysis was undertaken for each of the 1, 3, 7, 15 and 30-day durations for each of the stations.

For example, the minimum annual consecutive 7 day average low flow was determined for each year for the station record being analysed (see Section 2.2). The corresponding set of consecutive 7 day average low flows, therefore, represents an extreme value series to which a theoretical extreme value distribution can be fit for the purpose of determining the low flows corresponding to various recurrence intervals. For example, the 7020 low flow is often of interest for water quality investigation (i.e. the consecutive 7 day average low flow with an average recurrence interval of once in 20 years).

Previous investigations have found that the Gumbel III distribution has resulted in the best fit for extreme value analysis of low flows on most Canadian rivers. However, for samples with large negative skewness, the 3-Parameter Log Normal Distribution has proven to give adequate results and was adopted for these stations (Condie, 1983). A technical discussion of the fitting procedure is given in the users manual and briefly in Appendix A.

Parameter estimation for fitting cf distributions proceeded in order of maximum likelihood, smallest observed drought and moments. The procedure utilized for analysis of each station record was identified on summary tables together with the results of the analyses (see Section 3.3. and Appendices B-F).

2.5 Flow Duration Analysis

The daily discharge data was extracted for each station and sorted by computer in order to derive empirical flow duration curves. The flow duration curves were summarized both numerically and graphically for each station (See Section 3.4 and Appendices B-F). The tabular summary presents the results cf the flow duration computer output at 1% intervals across the flow duration curve.

2.6 Seasonal Analysis

In addition to annual computations referred to above, the flow duration curves and extreme value analyses were undertaken on a monthly basis to provide an information base for seasonal water resources investigations.

In order to reduce the amount of data tabulation, it was decided that only the results of the $7Q_{20}$ values would be summarized from the extreme value output. The results from the other 7-day duration recurrence intervals are available as part of the background files.

Flow duration curves were also tabulated on a monthly basis for comparison to the annual curves. A direct comparison with the plotted annual flow duration curve is, therefore, possible by using the numerical tabular summary. Typical results are discussed in Section 3.4.

2.7 Maps

Computer plotting was utilized as a cost-effective way of graphically summarizing selected flow characteristics. Base maps were digitized for each region. Data overlays were then prepared in order to produce two maps for each region, the first map summarizing selected low flow characteristics at each station, and the second map providing a corresponding discharge rate per unit area.

The resulting maps are discussed briefly in Section 3.5 and specific maps for each region accompany Appendices B to F.

3.0 STUDY RESULTS

3.1 General

This section summarizes general study findings and refers to specific results given in separate appendices for each of the five regions. (Appendices B to F).

3.2 Data Base Screening

3.2.1 Data Bases

For all regions, a total of 389 stations were found to have 10 years of record with the station being active within the last 5 years.

Other characteristics of the data base were also tabulated in Section 2 of Appendices B to F including, a brief station description, the period of record at each location, whether stream flows in the watershed are considered to be regulated or natural, and the drainage area of the watershed.

All of this information was extracted from the Water Survey of Canada HYDEX computerized data file maintained by Environment Canada. Statistical analyses were undertaken over the period of available record for both natural and regulated stations. However, subsequent to the data testing and extreme value analyses it was found that eleven data series classed as "regulated" included a portion of natural flow data. These stations were re-analysed with results addended in each Appendix as appropriate. Additional research indicated that three stations not recorded as mixed (natural and regulated flows recorded for the station) in the HYDEX file did consist of mixed periods. An analysis of these stations; 02GB001, Grand River below Brantford, 02GA003 Grand River at Galt. and, 02GA015 Speed River below Guelph, were re-analysed using only the regulated period of data. The period used was from 1945 (the year after the Shand Dam was built) to the present for the Grand River Stations and 1975 to present for the Speed River data series (subsequent to the Guelph Dam construction). The results for the mixed $7Q_2$, $7Q_{10}$ and $7Q_{20}$ compared to the regulated period only are summarized as follows:

Station	Mixed Data			Regulated Data		
	$7Q_2$ m^3/s	$7Q_{10}$ m^3/s	$7Q_{20}$ m^3/s	$7Q_2$ m^3/s	$7Q_{10}$ m^3/s	$7Q_{20}$ m^3/s
02GB001	13.308	7.037	5.495	14.980	9.275	7.713
02GA003	5.822	2.176	1.679	9.186	5.120	4.156
02GA015	1.080	0.595	0.488	1.399	0.885	0.775

The results indicate an increase in the low flow values when using the regulated period only, compared to the analysis of the mixed record period. This may indicate low flow augmentation, or trend in the data series.

Users referring to analysis results for other regulated stations should investigate this aspect in more detail and analyses for all regulated stations used with care.

3.2.2 Screening Results

i) Zero Flows

Prior to undertaking the extreme value analyses a total of 23 data sets containing a significant number (*) of zero low flows for all durations were identified and removed from the data base (see Table 1). For example, for those stations where 30% or more of the available extreme flow data set was comprised of zero flow, it was arbitrarily assumed that use of this data base would result in a biased extreme value analysis. In addition, for short data sets (i.e. 10 years), reduction by 3 years results in insufficient data (7 years) with which to accurately fit the extreme value distribution.

A few stations which originally appeared to have 10 years of records were found to have a significant number of missing years in the detailed screening process. Those stations with minimal data were removed from the analysis (refer to Table 1).

ii) Arithmetic Overflow

Initial application of the LFA program encountered an arithmetic overflow for a number of stations, which are identified in Table 1. The program was subsequently modified and the analysis results are included as addendums to Appendices B to F where appropriate.

iii) High Outliers

Initially the analysis of several stations with very large low flows (greater than 1000 m^3/s) could not be completed. These stations are identified in Table 1. Additional research was undertaken and the LFA program was subsequently modified to permit fitting of the extreme value distribution. These results are addended where appropriate to Appendices B - F (see Table 1).

iv) Statistical Tests

Statistical data analysis tests were undertaken as outlined in Section 2.3 and described in more detail in Appendix A.3. The available test statistics were recently made available as part of the LFA (Pilon, 1988) low flow analysis program. Previous application of these testing procedures to low flow series has been limited to date.

In general, it was found that a significant number of stations failed the non-parametric tests. Therefore, taken over the entire data base, application of these tests has indicated that the available data base of extreme low flows may exhibit some trend with some possibility of non-random characteristics.

The data were further analysed by subdivision of the available data set according to length of record (i.e. >20 years and <20 years) and according to regulation code. However, it was found that neither the length of record, nor the possible effects of regulation could account for the conclusions of the test results. One explanation could be that the available record lengths are too short to permit reasonable application and interpretation of these non-parametric test results. A stronger possibility is that the available low flow data sets do exhibit trend and non random characteristics, which could possibly be attributed to slow cyclic change in groundwater levels or to climatic trends.

Additional testing was beyond the scope of the current investigations. However, further studies are recommended since these results may call into question the basic assumptions underlying application of the extreme value analysis technique for analysis of low flow characteristics.

v) Data Base

Extreme value analyses were undertaken on an annual basis for 344 stations and on a monthly basis for 330 stations. Further analysis was completed on the remaining stations with the revised program or by manual fitting on the annual data series.

Fourteen stations were assigned to more than one region since they may be representative of either region. The fourteen stations which appear in more than one region are:

Station I.D.	Central	South Eastern	Southwestern West Central	North Eastern	North Western
02HB011	✓		✓		
02HB012	✓		✓		
02HB013	✓		✓		
02HB016	✓		✓		
02HK002	✓	✓			
02HK003	✓	✓			
02HK004	✓	✓			
02HK005	✓	✓			
02HK006	✓	✓			
04HA001				✓	✓
04JA002				✓	✓
04JC002				✓	✓
04JC003				✓	✓
04JG001				✓	✓

TABLE 2. Summary of Statistics for Data Used in the Extreme Value Analysis.

Region	No. of * Stations	Day Duration	Mean m^3/s	Standard Deviatian m^3/s	Skew	Coefficient of Variation	Minimum Flow m^3/s	No. of Years
All	344	1	10.89	3.97	0.82	0.71	4.07	28
	344	3	12.50	4.02	0.78	0.66	5.78	29
	344	7	13.80	4.06	0.75	0.62	6.61	28
	344	15	14.32	4.01	0.78	0.59	7.27	29
	341	30	N/A	3.44	0.84	0.57	N/A	28
Northwestern	67	1	22.05	9.26	0.78	0.76	7.48	31
	67	3	24.35	9.46	0.72	0.72	8.79	31
	67	7	26.78	9.58	0.57	0.58	9.47	31
	67	15	27.97	9.82	0.65	0.65	9.47	31
	67	30	29.35	10.05	0.55	0.57	11.01	31
Northeastern	65	1	13.16	5.60	0.79	0.70	3.94	31
	65	3	16.06	6.02	0.78	0.64	6.25	31
	65	7	17.95	5.62	0.62	0.58	7.68	31
	65	15	19.12	5.67	0.53	0.53	8.87	31
	65	30	20.64	6.05	0.59	0.48	10.49	31
Southwestern	101	1	1.98	0.49	0.77	0.67	1.24	26
& West	101	3	2.27	0.44	0.74	0.62	1.58	26
Central	101	7	2.44	0.44	0.77	0.58	1.75	26
	101	15	2.61	0.49	0.85	0.56	1.88	26
	101	30	2.80	0.58	1.03	0.57	1.97	26
Central	76	1	1.45	0.65	0.39	0.45	0.52	24
	76	3	1.65	0.66	0.42	0.42	0.63	24
	76	7	1.89	0.67	0.44	0.40	0.81	24
	76	15	2.14	0.73	0.51	0.41	1.01	24
	76	30	2.53	0.91	0.61	0.40	1.18	24
Southeastern	49	1	27.36	7.36	1.62	1.05	12.22	28
	49	3	30.86	6.99	1.50	0.96	18.58	28
	49	7	33.53	7.69	1.48	0.93	20.97	28
	49	15	33.53	6.68	1.45	0.89	22.51	28
	49	30	N/A	1.51	1.57	0.90	N/A	28

* Some stations appear in more than one region.

The SPSS (Statistical Package Social Science, Norusis, 1986) was used to produce general statistics of the data base including the mean, standard deviation and coefficient of skew of the available low flow samples for different durations. These general statistics are summarized in Table 2.

With reference to Table 2, it is evident that the average of the mean low flow increases as the duration of low flow increases. The standard deviation decreases as a percentage of the mean as the duration increases. The mean skewness of the data decreases with the increase in duration.

Flow duration analyses were subsequently undertaken both on an annual and monthly basis. The flow duration results are summarized in Section 3.4, and the results tabulated on a regional basis in Appendices B to F.

3.3 Extreme Value Analysis

3.3.1 General

Tables summarizing the results of the extreme value analysis for each region are given in Appendices B to F for various recurrence intervals for each duration. An example of the presentation format is given as Table 3. The stations are identified by the Water Survey of Canada station number. The fitting method for the extreme value distribution is identified by a 3 letter code, MAX, MOM, SOD, PLN which stand for; method of maximum likelihood, method of moments, method of smallest observed drought, and the three-parameter log normal distribution respectively.(See also Appendix A.1 for additional information on the fitting procedures.)

The next three parameters appearing in the summary table are general statistics of the data sample including the mean n-day duration flow (m^3/s), Standard deviation, Skew (G), and the coefficient of variation of record (C). The next two columns of the tables give the number of years of record available and the minimum observed average low flow for the particular duration for the available data set. Finally, the estimated flow for the various recurrence intervals are listed for each station.

TABLE 3. Example Of Extreme Value Tabular Format Extreme Value Low Flow Analysis For 7 Day Duration Values.

STN	Method	Mean	Standard Deviation	G	C	Rec (Yrs)	MIN (m^3/s)	RECURRENCE INTERVAL										
								1.005	1.010	1.111	1.250	2.0	5.0	10	20	50	100	200
02HE001	MAX	0.012	0.007	1.291	0.617	17	0.003	0.042	0.030	0.022	0.017	0.010	0.006	0.004	0.004	0.003	0.003	0.003
02HE002	SOD	0.003	0.004	1.276	1.210	17	0.000	0.021	0.018	0.008	0.005	0.002	0.000	0.000	0.000	0.000	0.000	0.000
02HK002	MAX	16.989	5.063	0.393	0.298	37	0.027	38.529	29.241	23.700	21.300	16.780	12.480	10.467	0.975	7.532	6.726	6.099
02HK003	MAX	1.774	0.692	0.522	0.390	27	0.661	3.930	3.686	2.713	2.330	1.680	1.162	0.956	0.023	0.712	0.659	0.622
02HK004	MAX	20.634	7.479	1.565	0.362	23	10.629	46.439	43.126	30.642	26.131	19.127	14.311	12.672	11.726	11.030	10.735	10.553
02HK005	MAX	0.904	0.522	0.388	0.570	10	0.148	2.711	2.488	1.631	1.312	0.803	0.436	0.305	0.226	0.165	0.139	0.122
02HK006	SOD	0.224	0.216	2.679	0.964	13	0.026	1.158	1.000	0.507	0.355	0.157	0.057	0.032	0.021	0.014	0.012	0.011
02HL001	SOD	1.941	1.476	3.763	0.760	71	0.534	0.411	7.352	3.858	2.613	1.477	0.014	0.653	0.582	0.541	0.529	0.523
02HL003	MAX	0.536	0.370	0.420	0.687	31	0.011	1.948	1.764	1.075	0.029	0.450	0.195	0.109	0.061	0.026	0.011	0.002
02HL004	MAX	0.423	0.304	1.457	0.720	29	0.021	1.507	1.365	0.835	0.646	0.357	0.164	0.100	0.064	0.036	0.027	0.021
02HL005	SOD	0.059	0.866	2.240	1.123	21	0.007	0.370	0.319	0.139	0.091	0.036	0.013	0.009	0.007	0.006	0.006	0.006
02HM002	MAX	0.372	0.262	1.195	0.705	30	0.000	1.267	1.156	0.731	0.573	0.322	0.141	0.077	0.039	0.009	0.000	0.000
02HM003	SOD	0.329	0.504	3.044	1.532	20	0.034	3.085	2.465	0.826	0.473	0.145	0.051	0.030	0.034	0.033	0.033	0.033
02HM004	SOD	0.032	0.023	0.762	0.720	21	0.006	0.119	0.107	0.063	0.048	0.026	0.013	0.000	0.006	0.005	0.004	0.004
02HM005	SOD	0.058	0.889	1.625	1.553	17	0.000	0.526	0.429	0.153	0.009	0.025	0.004	0.001	0.000	0.000	0.000	0.000
02HM006	MAX	0.113	0.067	1.123	0.593	16	0.033	0.382	0.344	0.206	0.160	0.095	0.056	0.045	0.039	0.035	0.034	0.033
02HM007	MAX	1.183	0.552	0.196	0.467	13	0.221	2.620	2.482	1.889	1.634	1.159	0.713	0.506	0.355	0.211	0.131	0.070
02KA002	MAX	423.644	65.688	0.044	0.202	36	246.700	641.884	621.782	534.359	495.910	422.320	350.559	315.804	289.624	263.748	248.934	237.197
02KA003	SOD	0.002	0.003	2.441	1.599	20	0.000	0.020	0.017	0.006	0.003	0.001	0.000	0.000	0.000	0.000	0.000	0.000
02KA004	SOD	0.000	0.000	2.796	2.995	19	0.000	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
02KA005	SOD	0.000	0.001	2.924	2.975	16	0.000	0.005	0.004	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
02KB001	MAX	12.485	4.524	0.663	0.386	71	5.000	31.203	28.682	19.404	16.159	11.292	0.132	7.119	6.560	6.167	6.009	5.916
02KC009	MAX	4.934	1.485	0.681	0.301	61	2.300	9.443	8.951	6.953	6.151	4.762	3.614	3.143	2.830	2.561	2.427	2.333
02KC014	SOD	0.530	0.215	0.614	0.406	16	0.202	1.326	1.219	0.025	0.687	0.481	0.347	0.304	0.280	0.263	0.258	0.252
02KD002	MAX	3.020	1.471	0.985	0.487	71	0.009	7.328	6.882	5.027	4.259	2.886	1.687	1.168	0.808	0.484	0.315	0.191
02KD004	MAX	16.862	4.474	0.264	0.265	57	6.671	28.527	27.463	22.806	20.741	16.751	12.800	10.657	9.376	7.094	7.035	6.346
02KD007	SOD	1.282	2.261	1.663	1.779	44	0.000	13.932	11.030	3.451	1.877	0.454	0.066	0.017	0.004	0.000	0.000	0.000
02KE005	MAX	13.646	8.500	1.440	0.614	38	1.963	42.947	39.275	25.324	20.224	12.209	6.586	4.631	3.466	2.626	2.259	2.028
02KF001	SOD	6.365	3.405	1.447	0.535	7	3.240	20.209	18.138	10.938	8.617	5.412	3.604	3.103	2.855	2.700	2.645	2.616
02KF005	MAX	550.569	126.545	0.613	0.236	26	363.700	979.003	926.702	724.724	649.162	527.558	436.725	406.546	387.104	372.033	365.304	360.975
02KF006	MAX	7.368	2.113	1.252	0.257	88	4.611	15.503	14.393	10.335	8.930	0.643	5.511	5.091	4.563	4.705	4.642	4.605
02KF002	MAX	546.194	111.943	0.270	0.205	71	370.600	900.643	668.659	700.536	637.549	530.656	445.329	411.502	389.023	371.346	382.534	356.488
02KF010	SOD	0.391	0.361	1.995	0.923	15	0.064	1.974	1.714	0.859	0.003	0.277	0.115	0.076	0.059	0.049	0.046	0.044
02KF011	SOD	0.091	0.096	1.179	1.055	15	0.011	0.535	0.457	0.211	0.142	0.059	0.021	0.013	0.010	0.000	0.006	0.007
02KF012	MAX	0.289	0.000	0.493	0.278	15	0.167	0.539	0.510	0.396	0.352	0.278	0.219	0.196	0.101	0.169	0.164	0.160
02KF013	SOD	0.162	0.136	0.966	0.757	15	0.024	0.691	0.622	0.370	0.282	0.150	0.064	0.037	0.021	0.011	0.005	0.004
02KF014	SOD	0.237	0 353	2.409	1.490	12	0.002	2.062	1.690	0.628	0.373	0.109	0.018	0.063	0.000	0.000	0.000	0.000
02LA004	MAX	5.634	1.831	0 270	0.314	36	2.391	10.953	10.435	0.264	7.355	5.705	4.232	3.578	3.110	2.695	2.471	2.304
02LA006	SOD	0.168	0.304	2.192	1.622	17	0.009	1.848	1.479	0.490	0.277	0.076	0.010	0.010	0.008	0.007	0.007	0.007
02LA007	SOD	0.165	0.220	1.673	1.332	17	0.013	1.290	1.065	0.414	0.254	0.086	0.026	0.015	0.012	0.011	0.010	0.010
02LE005	MAX	1.333	1.044	1.516	0.763	56	0.000	5.166	4.604	2.746	2.091	1.100	0.440	0.236	0.118	0.034	0.000	0.000
02LE006	MAX	0.216	0.106	0.011	0.465	19	0.074	0.592	0.544	0.362	0.297	0.195	0.126	0.102	0.009	0.079	0.075	0.072
02LE007	SOD	0.053	0 104	2.994	1.950	37	0.000	0.644	0.501	0.144	0.075	0.016	0.002	0.000	0.000	0.000	0.000	0.000

3.3.2 Annual

Extreme value frequency curves were plotted for each location and are available in Appendices B to F. An example graph is given in Figure 1 which summarizes the actual data and the fitted curve for the 1, 3, 7, 15 and 30 day durations for the Trent River at Glen Ross, Water Survey of Canada Station Number 02HK004.

A statistical summary of average unit area low flow characteristics was also undertaken and is summarized in Table 4. Area average low flow rates (litres/second/kilometre^2) together with standard deviation for the 5 durations were tabulated for all the regions for the 2 to 50 year recurrence intervals.

It is interesting to note that in most cases, the standard deviations are approximately equal to or greater than the corresponding mean flows. Low flows are consistently higher than the Provincial average in Northwestern, Northeastern and Central Region and consistently lower in the Southwestern and West Central/Southeastern Regions. However, it should be recognized that this finding may be due to the effects of the drainage area. For example, gauged watersheds in Northern Ontario tend to be larger than watersheds in Southern Ontario. Therefore, if the relationship between watershed area and low flow is non-linear the corresponding statistics may be biased.

TABLE 4. Unit Area Average Low Flows.

Region	Day Duration	2: Mean	2: (Std. Deviation) L/s/km²	5: Mean	5: (Std. Deviation) L/s/km²	10: Mean	10: (Std. Deviation L/s/km²	20: Mean	20: (Std. Deviation) L/s/km²	50: Mean	50: (Std. Deviation) L/s/km²
		Recurrence Interval (Yr)									
All	1	1.59	(1.40)	1.10	(1.12)	0.89	(1.00)	0.75	(0.92)	0.52	(0.25)
	3	1.74	(1.54)	1.24	(1.25)	1.02	(1.12)	0.87	(1.02)	0.73	(0.93)
	7	1.91	(1.90)	1.38	(1.39)	1.15	(1.24	0.99	(1.14)	0.84	(1.00)
	15	2.08	(1.79)	1.52	(1.49)	1.29	(1.34)	1.12	(1.24)	0.97	(1.13)
	30	2.31	(1.88)	1.68	(1.57)	1.43	(1.43)	1.25	(1.32)	1.09	(1.22)
Northwestern	1	1.76	(1.17)	1.24	(0.92)	1.02	(0.80)	0.85	(0.73)	0.70	(0.63)
	3	1.86	(1.30)	1.33	(1.01)	1.09	(0.87)	0.92	(0.78	0.77	(0.71)
	7	1.98	(1.53)	1.43	(1.20	1.18	(1.03)	1.00	(0.91)	0.82	(3.79)
	15	2.08	(1.60)	1.50	(1.26)	1.24	(1.08)	1.05	(0.94)	0.87	(0.82)
	30	2.20	(1.66)	1.60	(1.32)	1.33	(1.14)	1.13	(1.00)	0.94	(0.87)
Northeastern	1	1.93	(1.14)	1.24	(0.80)	0.96	(0.68)	0.77	(0.61)	0.60	(0.57)
	3	2.21	(1.37)	1.49	(1.01)	1.19	(0.86)	0.97	(0.76)	0.78	(0.70)
	7	2.48	(1.63)	1.72	(1.24)	1.40	(1.06)	1.16	(0.94)	0.95	(0.83)
	15	2.71	(1.73)	1.92	(1.36)	1.58	(1.19)	1.35	(1.07)	1.14	(0.97)
	30	3.08	(1.79)	2.18	(1.46)	1.81	(1.31)	1.55	(1.20)	1.31	(1.12)
Southwestern	1	1.14	(1.17)	0.76	(0.96)	0.67	(0.88)	0.52	(0.83)	0.44	(0.78)
West	3	1.24	(1.24)	0.85	(1.03)	0.70	(0.95)	0.61	(0.89)	0.52	(0.83)
Central	7	1.37	(1.34)	0.97	(1.12)	0.81	(1.03)	0.70	(0.96	0.61	(0.91)
	15	1.54	(1.43)	1.11	(1.22)	0.94	(1.13)	0.84	(1.06)	0.74	(1.01)
	30	1.81	(1.59)	1.30	(1.36)	1.12	(1.26)	1.00	(1.19)	0.90	(1.13)
Central	1	2.18	(1.70)	1.63	(1.44)	1.38	(1.32)	1.19	(1.23)	1.00	(1.14)
	3	2.35	(1.83)	1.80	(1.56)	1.54	(1.42)	1.34	(1.30)	1.14	(1.17)
	7	2.53	(1.92	1.97	(1.67)	1.70	(1.53)	1.50	(1.42)	1.30	(1.29)
	15	2.76	(2.02)	2.16	(1.78)	1.88	(1.65)	1.68	(1.54)	1.48	(1.42)
	30	3.14	(2.17)	2.44	(1.93)	2.13	(1.80)	1.91	(1.70)	1.70	(1.59)
Southeastern	1	0.97	(1.31)	0.64	(1.02)	0.51	(0.89)	0.43	(0.80)	0.37	(0.72)
	3	1.08	(1.49)	0.74	(1.22)	0.62	(1.10)	0.54	(1.02)	0.48	(0.95)
	7	1.21	(1.61)	0.84	(1.33)	0.71	(1.21)	0.63	(1.13)	0.55	(1.05)
	15	1.32	(1.65)	0.92	(1.38)	0.78	(1.27)	0.70	(1.18)	0.53	(1.11)
	30	1.13	(1.05)	0.72	(0.80)	0.59	(0.70)	0.51	(0.64)	0.45	(0.50)

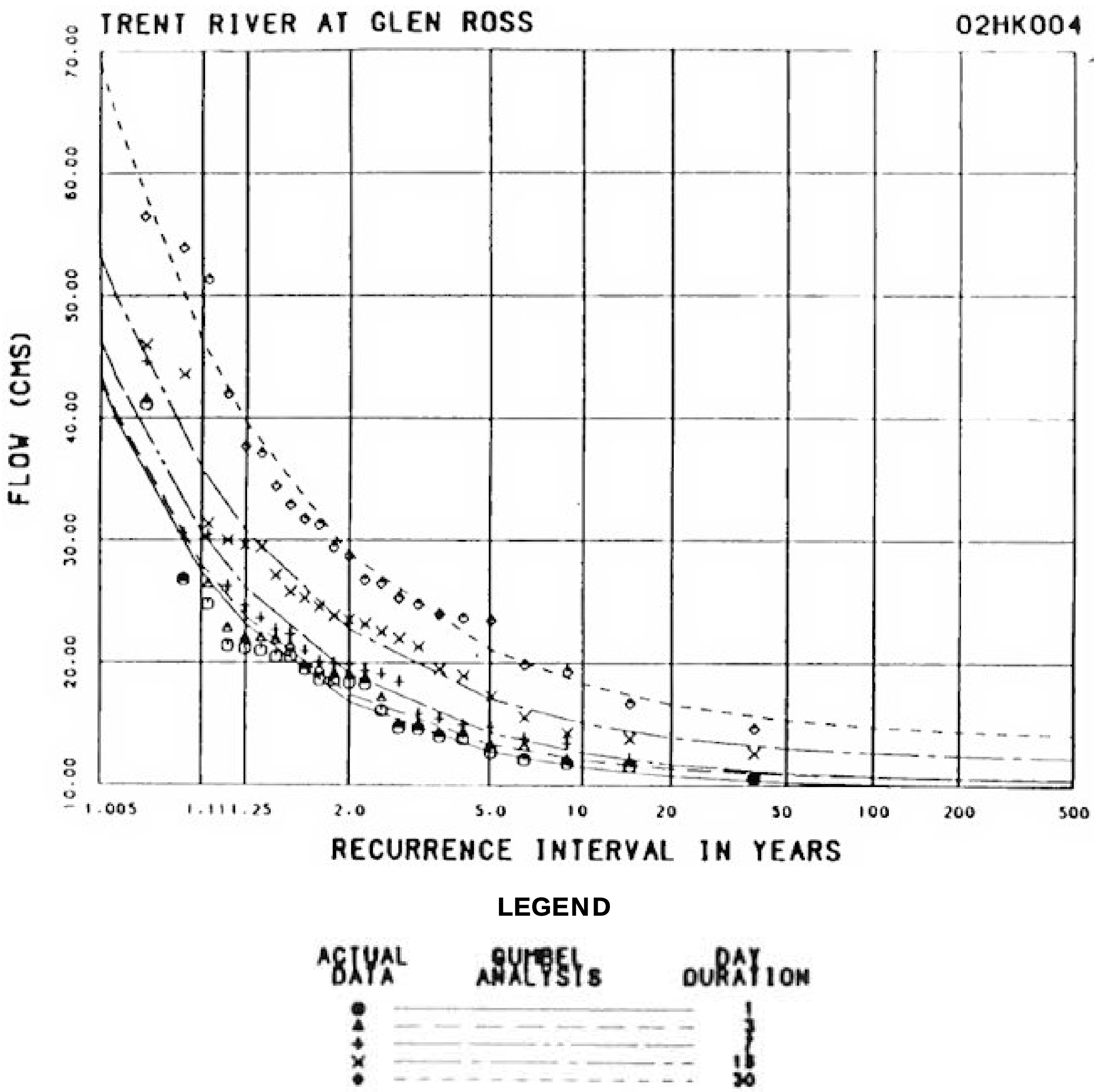


Figure 1. Example Of Low Flow Frequency Curves.

3.3.3 Seasonal

The $7Q_{20}$ values were also determined for each month. The resulting analyses are summarized in Appendices B-F. It is evident from the summary tables that many of the lowest of the $7Q_{20}$ generally take place in the summer months.

3.4 Flow Duration

3.4.1 Annual

Flow duration tables and curves were produced to summarize the percentage of time the flow was greater than or equal to the given value. Flow duration curves for all stations are given in Appendices B to F. An example table is given in Table 5. The first column "Per" refers to the percentage of the period of record that the tabulated flow was equalled or exceeded (all flows are in m^3/s). The annual flow duration curve values are listed in column 2 for the percentage summarized in column 1. Therefore, the largest daily flow recorded for this station up to 1986 is 702 m^3/s, found in the 1st row at 0 percent. More significantly for this study are the low flows summarized in the later section of the table which have been exceeded 90, 95 and 100 percent of the time for the period of record.

The 50 percent value (114 m^3/s) refers to the median daily flow for the period of record of the flow series and can be compared to the mean value 145 m^3/s summarized in the last row of the table. The annual flow duration curve is graphically depicted in Figure 2, which corresponds to the numerical values summarized in columns 1 and 2.

TABLE 5. Example Summary Of Flow Duration Analysis.

SUMMARY TABLE FROM FLOW DURATION ANALYSIS 02HK004 YEARS 0F RECORD:23
STATION AREA:12000 km^2 TRENT RIVER AT GLEN ROSS

Per	Annual	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
0	702.0	425.0	861.0	637.0	702.0	515.0	326.0	391.0	196.0	340.0	385.0	425.0	439.0
1	518.0	383.0	400.0	549.0	854.0	490.0	273.0	374.0	183.0	264.0	378.0	413.0	425.0
2	489.0	385.0	344.0	530.0	818.0	473.0	255.0	289.0	128.0	240.0	337.0	399.0	381.0
3	459.0	340.0	337.0	515.0	584.0	464.0	225.0	183.0	110.0	225.0	323.0	351.0	375.0
4	435.0	319.0	323.0	501.0	558.0	459.0	220.0	171.0	106.0	198.0	309.0	337.0	384.0
5	416.0	294.0	270.0	491.0	550.0	439.0	213.0	184.0	99.10	189.0	272.0	335.0	337.0
8	396.0	270.0	253.0	477.0	534.0	434.0	205.0	181.0	96.30	187.0	213.0	311.0	315.0
7	379.0	288.0	244.0	458.0	526.0	431.0	198.0	156.0	93.40	150.0	203.0	279.0	306.0
8	357.0	259.0	234.0	442.0	521.0	427.0	191.0	152.0	90.80	135.0	197.0	281.0	300.0
9	337.0	253.0	230.0	425.0	518.0	418.0	187.0	148.0	87.30	129.0	189.0	252.0	289.0
10	328.0	250.0	229.0	419.0	513.0	408.0	183.0	138.0	84.80	126.0	181.0	249.0	279.0
11	308.0	248.0	226.0	410.0	510.0	399.0	181.0	127.0	81.30	117.0	175.0	248.0	274.0
12	290.0	243.0	222.0	406.0	504.0	382.0	179.0	121.0	77.50	105.0	187.0	241.0	272.0
13	272.0	240.0	217.0	397.0	499.0	378.0	174.0	112.0	74.20	93.40	159.0	238.0	270.0
14	263.0	238.0	213.0	388.0	496.0	387.0	171.0	108.0	70.70	91.20	154.0	233.0	268.0
15	255.0	234.0	209.0	374.0	496.0	354.0	166.0	103.0	88.50	88.80	148.0	229.0	266.0
16	247.0	233.0	207.0	357.0	490.0	340.0	164.0	99.10	86.00	86.40	146.0	223.0	265.0
17	237.0	232.0	203.0	351.0	487.0	334.0	181.0	96.30	64.00	83.50	140.0	219.0	262.0
18	230.0	228.0	202.0	347.0	481.0	328.0	158.0	92.00	81.80	81.00	135.0	215.0	2650.0
19	224.0	227.0	198.0	341.0	475.0	323.0	153.0	87.00	80.90	78.20	133.0	211.0	258.0
20	219.0	224.0	195.00	331.0	470.0	300.0	149.0	81.80	59.70	75.90	130.0	208.0	254.0
21	213.0	222.0	190.0	321.0	467.0	292.0	142.0	78.20	58.00	74.80	127.0	205.0	252.0
22	208.0	221.0	187.0	318.0	487.0	283.0	136.0	75.30	58.90	73.80	124.0	201.0	248.0
23	202.0	218.0	184.0	311.0	464.0	270.0	133.0	73.00	55.40	72.30	121.0	196.0	237.0
24	196.0	218.0	183.0	303.0	460.0	264.0	130.0	70.39	53.80	89.70	119.0	193.0	227.0
25	193.0	211.0	181.0	297.0	458.0	260.0	126.0	69.40	52.80	87.10	115.0	189.0	223.0
28	187.0	208.0	180.0	289.0	458.0	250.0	120.0	85.70	50.70	84.90	113.0	187.0	221.0
27	183.0	204.0	178.0	283.0	453.0	242.0	118.0	61.70	50.00	63.40	111.0	184.0	217.0
28	180.0	201.0	175.0	273.0	450.0	235.0	112.0	59.40	47.60	61.20	109.0	181.0	215.0
29	177.0	198.0	174.0	268.0	447.0	228.0	111.0	58.00	47.00	58.90	108.0	179.0	213.0
30	173.0	193.0	171.0	265.0	445.0	224.0	109.0	58.90	48.40	58.90	104.0	178.0	212.0
31	169.0	189.0	170.0	262.0	439.0	221.0	108.0	54.90	45.80	57.50	102.0	177.0	206.0
32	165.0	188.0	169.0	258.0	436.0	217.0	104.0	53.80	44.50	58.90	101.0	174.0	204.0
33	162.0	183.0	166.0	247.0	430.0	215.0	102.0	52.40	44.10	58.80	99.80	172.0	202.0
34	159.0	182.0	185.0	237.0	429.0	213.0	99.10	50.70	43.00	55.20	98.50	170.0	200.0
35	155.0	178.0	183.0	230.0	422.0	210.0	95.70	49.90	42.50	54.40	97.40	168.0	199.0
38	152.0	177.0	182.0	227.0	421.0	208.0	91.80	48.10	42.00	54.10	96.30	166.0	194.0
37	149.0	174.0	180.0	225.0	417.0	207.0	90.00	48.40	41.80	53.50	94.00	163.0	192.0
38	146.0	172.0	159.0	219.0	411.0	204.0	88.10	45.40	40.00	53.00	91.20	159.0	190.0
39	143.0	170.0	157.0	212.0	408.0	201.0	87.20	44.50	39.40	51.80	88.20	157.0	189.0
40	139.0	168.0	158.0	208.0	405.0	197.0	85.00	43.800	38.80	51.50	86.90	154.0	186.0
41	138.0	168.0	153.0	203.0	396.0	195.0	84.00	43.200	38.20	51.00	85.00	152.0	183.0
42	133.0	163.0	150.0	199.0	396.0	193.0	81.80	42.200	37.20	50.10	84.10	150.0	182.0
43	130.0	161.0	148.0	193.0	391.0	189.0	80.50	41.300	36.80	49.80	83.50	147.0	I80.0
44	128.0	159.0	147.0	189.0	388.0	184.0	79.40	40.500	36.30	49.20	82.40	146.0	178.0
45	126.0	155.0	144.0	186.0	383.0	181.0	77.80	39.800	35.70	48.70	81.70	143.0	177.0
48	123.0	153.0	144.0	183.0	381.0	178.0	77.30	39.100	35.40	47.70	80.40	142.0	175.0
47	121.0	151.0	142.0	179.0	377.0	173.0	78.20	38.200	34.80	46.40	79.30	137.0	173.0
48	118.0	149.0	140.0	189.0	372.0	171.0	74.30	37.700	34.30	45.70	78.20	132.0	170.0
49	116.0	148.0	139.0	165.0	365.0	170.0	73.10	37.100	33.70	44.30	75.90	127.0	165.0

TABLE 5: (cont'd)

SUMMARY TABLE FROM FLOW DURATION ANALYSIS 02HK004 YEARS OF RECORD:23

STATI0N AREA:12000km^2 TRENT RIVER AT GLEN ROSS

Per	Annual	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
50	114.0	146.0	138.0	162.0	357.0	187.0	71.30	36.00	33.10	44.10	74.50	128.0	163.0
51	111.0	143.0	135.0	158.0	349.0	164.0	88.80	35.30	32.70	43.30	73.80	123.0	162.0
82	109.0	141.0	134.0	154.0	345.0	162.0	88.00	34.50	32.30	43.00	71.40	121.0	161.0
53	106.0	140.0	133.0	152.0	340.0	180.0	85.70	33.70	32.30	42.50	69.30	118.0	157.0
84	104.0	139.0	132.0	145.0	337.0	158.0	64.00	33.10	31.90	41.90	67.10	116.0	155.0
55	103.0	138.0	131.0	142.0	331.0	158.0	62.30	32.80	31.70	41.30	68.00	115.0	153.0
58	100.0	138.0	130.0	137.0	326.0	154.0	80.90	32.30	31.10	41.10	65.10	114.0	152.0
57	97.70	133.0	129.0	136.0	315.0	151.0	59.70	32.00	31.10	40.50	63.10	111.0	151.0
58	95.70	133.0	126.0	135.0	306.0	149.0	57.20	31.70	30.60	39.90	81.70	109.0	149.0
59	93.00	131.0	127.0	132.0	303.0	148.0	55.50	31.10	30.60	38.50	60.30	107.0	147.0
60	90.80	130.0	128.0	131.0	301.0	148.0	54.70	30.90	30.30	37.90	59.50	107.0	145.0
81	87.50	129.0	125.0	130.0	294.0	145.0	53.80	30.30	29.90	37.40	58.70	104.0	144.0
62	85.00	127.0	125.0	128.0	289.0	144.0	53.40	30.00	29.40	38.70	57.80	103.0	142.0
63	82.70	127.0	123.0	128.0	283.0	141.0	51.60	29.50	29.40	38.50	57.20	99.10	139.0
84	80.10	125.0	122.0	127.0	273.0	140.0	51.00	29.00	29.20	38.20	58.00	97.10	138.0
65	77.90	125.0	120.0	126.0	265.0	137.0	50.40	28.90	28.80	35.70	55.50	94.80	135.0
66	75.30	123.0	120.0	125.0	262.0	137.0	49.30	28.50	28.30	35.40	54.60	92.80	133.0
67	72.80	122.0	119.0	123.0	255.0	134.0	47.80	28.10	28.00	35.00	53.50	90.90	131.0
63	89.40	120.0	118.0	121.0	248.0	133.0	47.00	27.60	27.60	34.50	52.70	89.20	129.0
69	85.90	120.0	117.0	120.0	245.0	129.0	46.40	27.00	27.20	34.30	52.10	88.10	126.0
70	82.90	119.0	116.0	118.0	238.0	126.0	45.30	28.50	27.00	34.30	51.50	83.30	125.0
71	59.70	119.0	114.0	117.0	233.0	123.0	44.50	28.20	28.70	33.70	50.70	82.10	123.0
72	57.50	118.0	113.0	116.0	227.0	121.0	43.20	25.90	26.10	33.40	50.10	79.30	121.0
73	55.50	118.0	112.0	114.0	223.0	120.0	41.90	25.40	25.70	32.80	49.90	78.30	119.0
74	53.50	118.0	110.0	114.0	219.0	115.0	41.10	25.20	25.50	32.30	48.10	73.80	117.0
75	51.70	115.0	108.0	112.0	212.0	111.0	40.20	24.90	25.50	32.20	46.90	72.30	113.0
78	50.40	114.0	107.0	111.0	204.0	109.0	39.80	24.50	25.10	31.70	46.30	69.80	115.0
77	48.40	112.0	105.0	108.0	198.0	106.0	38.40	24.00	24.80	31.30	48.00	87.10	114.0
78	48.40	110.0	105.0	108.0	193.0	103.0	37.40	23.40	24.40	31.10	43.60	86.00	112.0
79	44.50	108.0	103.0	108.0	184.0	102.0	36.80	22.50	24.00	30.90	42.20	62.50	111.0
80	43.00	107.0	101.0	105.0	182.0	98.80	36.00	21.40	24.00	30.80	40.80	59.40	110.0
81	41.10	106.0	99.70	104.0	178.0	95.10	35.10	21.00	24.00	29.70	39.40	57.10	108.0
82	39.40	105.0	98.50	103.0	174.0	92.00	34.50	20.10	23.70	29.40	37.90	55.50	108.0
83	37.70	104.0	97.00	102.0	168.0	88.20	33.40	19.90	23.40	28.60	37.40	53.20	103.0
84	38.30	103.0	96.80	99.50	161.0	88.40	32.30	19.70	23.20	28.00	38.50	51.80	103.0
85	34.80	102.0	95.20	97.40	157.0	83.50	31.10	19.50	22.50	27.40	33.70	50.10	101.0
86	33.60	99.10	94.60	96.30	155.0	80.10	30.30	19.30	22.40	28.70	33.10	48.70	100.0
87	32.30	97.50	93.40	98.30	151.0	78.10	28.60	19.00	22.10	26.20	32.60	45.00	98.30
88	31.10	95.80	92.10	92.93	148.0	75.90	27.90	18.50	21.60	25.70	30.90	43.80	96.30
89	30.30	92.00	90.80	89.50	142.0	74.20	26.70	17.80	20.50	25.10	30.30	42.50	94.50
90	29.20	91.70	87.80	88.40	129.0	69.70	25.40	17.50	19.80	24.50	29.70	40.50	93.40
91	28.20	85.00	85.00	85.10	121.0	68.20	24.50	17.20	19.10	24.40	29.70	38.90	90.90
92	27.00	83.30	83.30	84.10	112.0	64.80	23.40	16.70	18.00	24.10	29.40	35.40	35.90
93	25.70	83.00	82.40	81.30	108.0	61.40	21.40	15.90	16.40	23.40	29.20	33.70	32.40
94	24.50	79.30	77.90	79.30	103.0	59.70	19.40	15.70	15.50	23.00	28.80	29.20	79.00
95	23.50	79.33	72.50	76.20	95.40	57.50	18.40	15.20	15.20	22.90	28.20	27.70	73.30
98	22.21	75.30	54.10	69.40	85.20	48.20	17.80	14.30	14.70	22.50	27.70	24.50	68.50
97	19.70	71.40	51.90	54.10	81.00	41.10	16.70	14.40	13.50	21.70	28.90	23.30	39.50
96	17.50	66.30	50.00	51.00	82.80	32.00	16.00	13.70	12.50	21.20	25.20	11.50	37.10
99	15.00	54.10	47.80	49.40	58.90	25.10	14.80	12.30	10.70	19.10	21.70	11.00	33.70
100	10.80	47.93	20.80	28.80	46.40	21.30	13.10	11.40	10.80	18.20	15.00	10.50	31.70
Mean	148.07	164.60	154.39	213.76	339.23	200.33	89.65	59.53	43.90	51.89	95.10	141.93	179.01

3.4.2 Seasonal

The flow duration values were also determined and tabulated for monthly flows. Appropriate summaries for all stations are given in Appendices B to F. This is also shown in Table 5 in the example for Station 02HK004, Trent River at Glen Ross.

The seasonal duration curves were not graphically produced for each station. However an example plot for Station 02HK004 demonstrates how the tabulated values could be used to plot monthly curves and provide a comparison to the annual curve (see Figures 3, 4 and 5).

3.5 Maps

Selected low flow characteristics were summarized on maps for each region. The stations are located at the point of discharge measurement and the selected data is summarized in an information box, the format of which is depicted in Figure 6.

The stations are identified by the 7 digit Water Survey Station Number and this is followed by a regulation code. A code "R" indicates that data collected at the station is affected by regulation; the code "N" means the station data are natural or non-regulated. The symbols 702, etc. refer to the average minimum consecutive 7-day flow (m^3/s) with a recurrence interval of 2, 5, 10 and 20 years, followed by the minimum one day flow and the period of record for the station. The values shown on the right are the flows (m^3/s) equalled or exceeded for the available period of record 5, 50, 75, 95, and 99 percent of the time. The symbol AREA refers to the station drainage area in km^2.

Station names are listed along with the station numbers for identification purposes, on the map for each region.

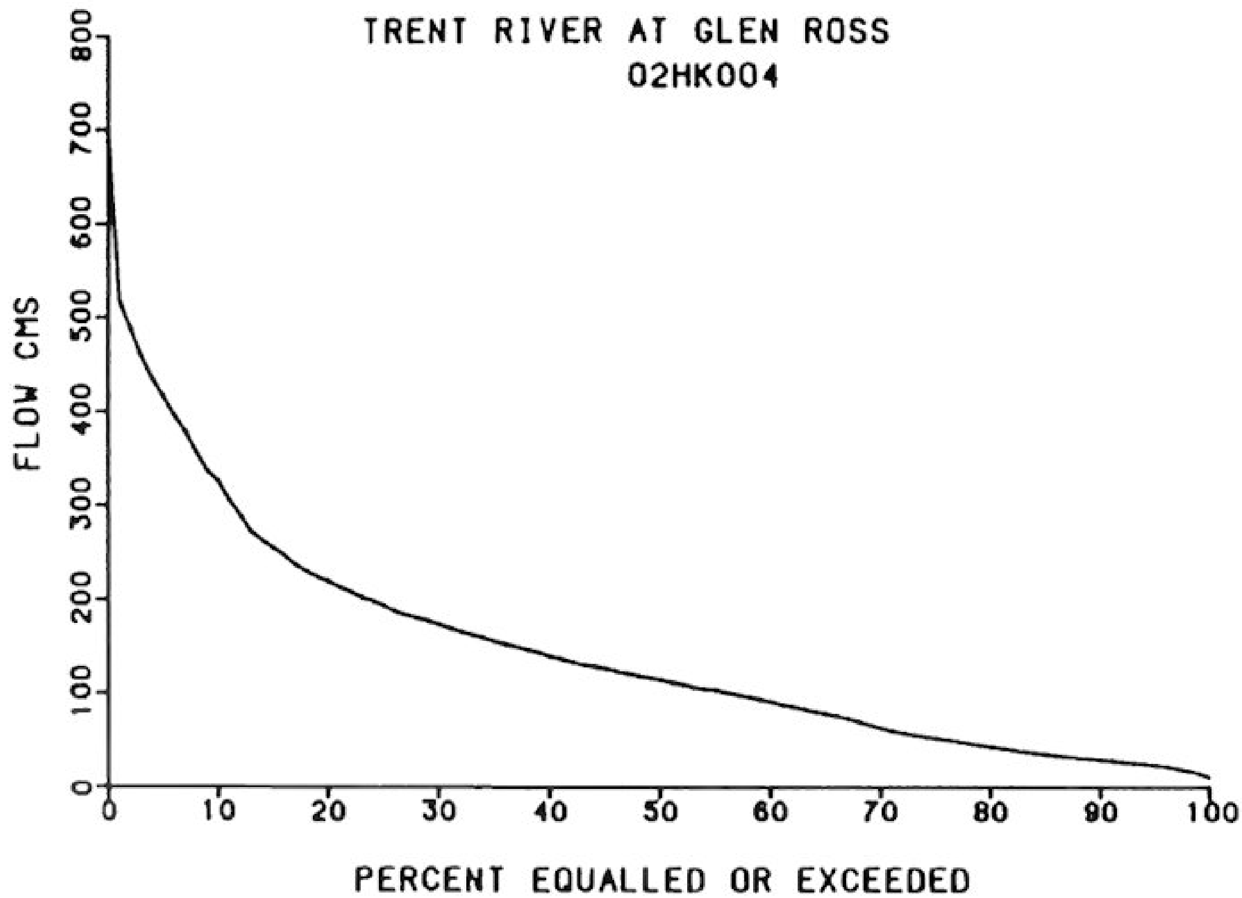


FIGURE 2. Example Of Annual Flow Duration Curve.

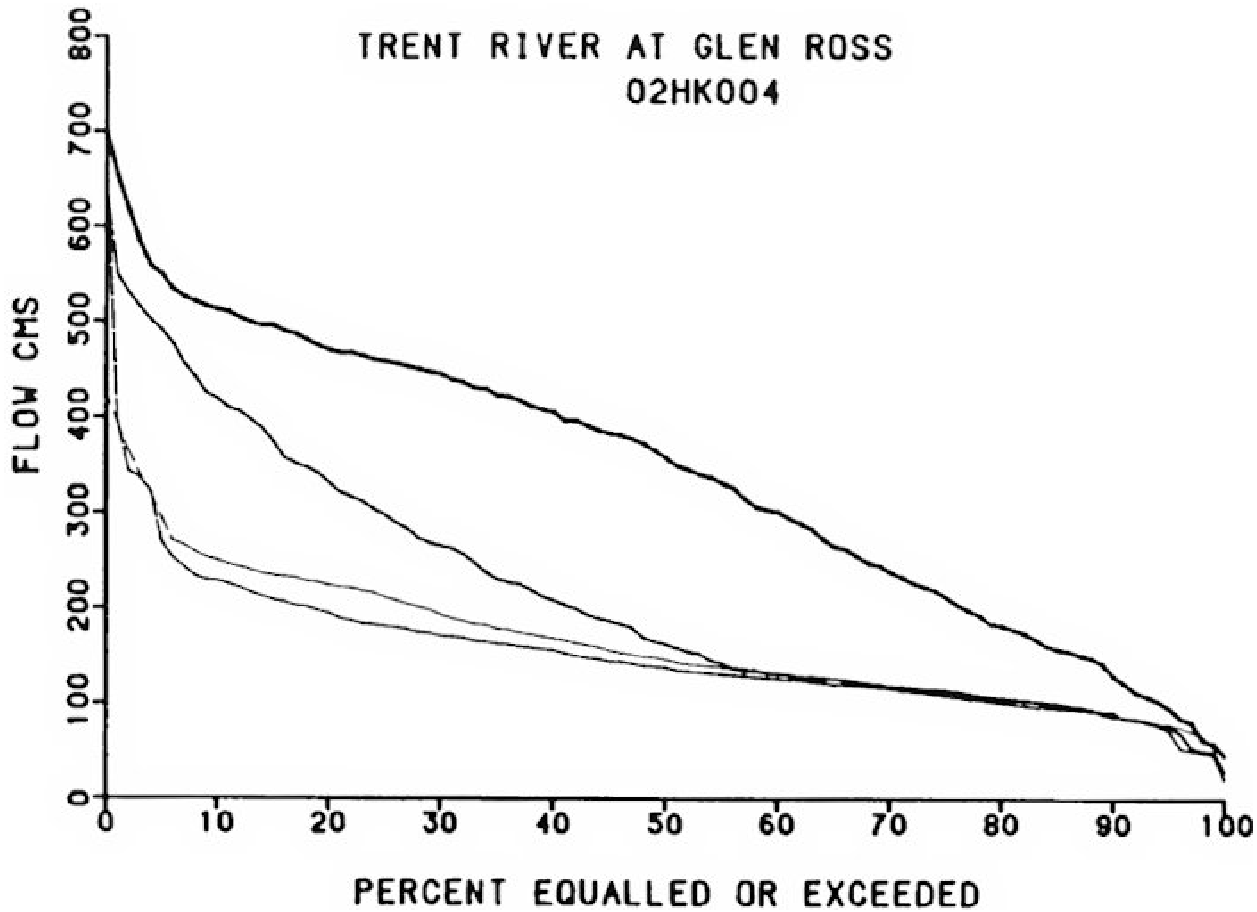


FIGURE 3. Example Of Seasonal Flow Duration Curve.

LEGEND

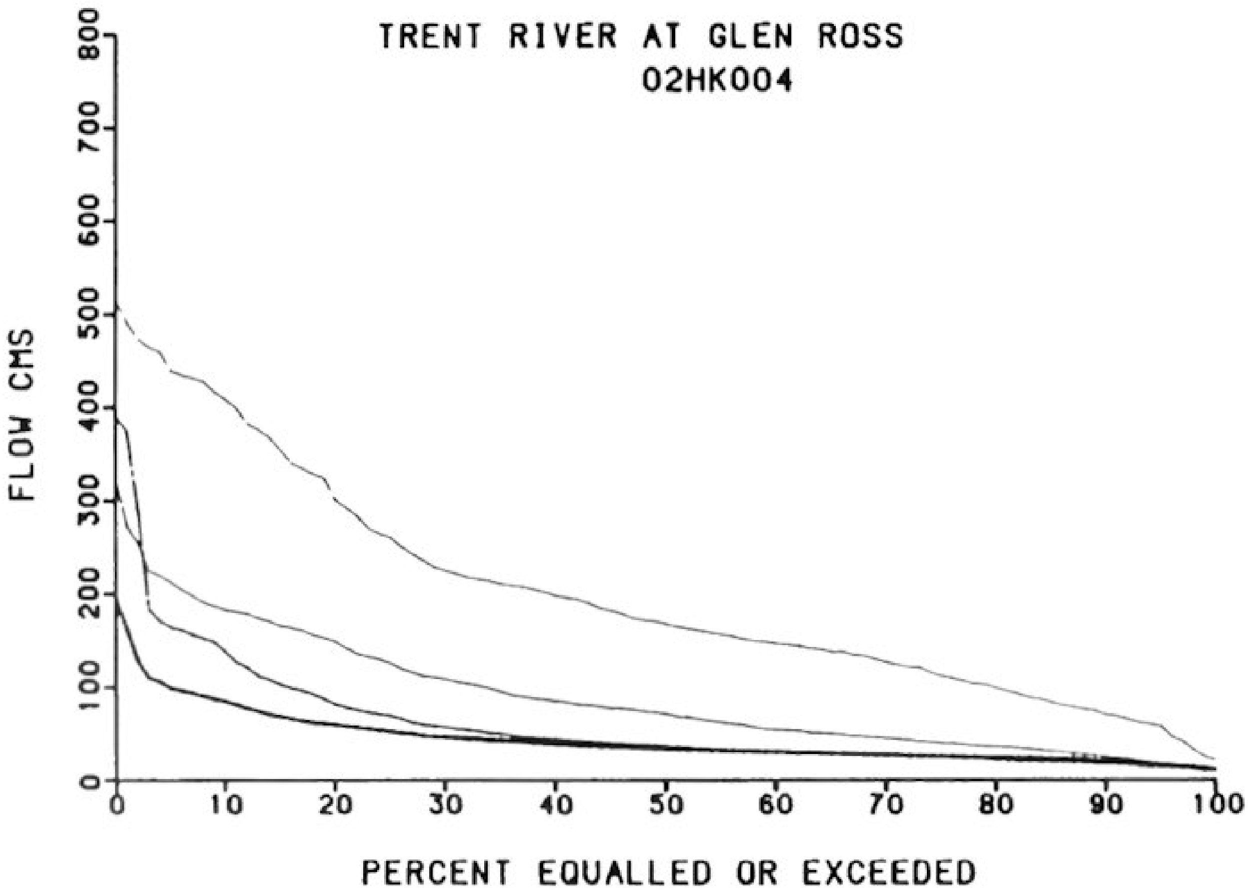
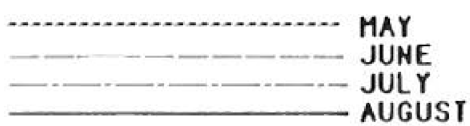


Figure 4. Example Of Seasonal Flow Duration Curve.

LEGEND



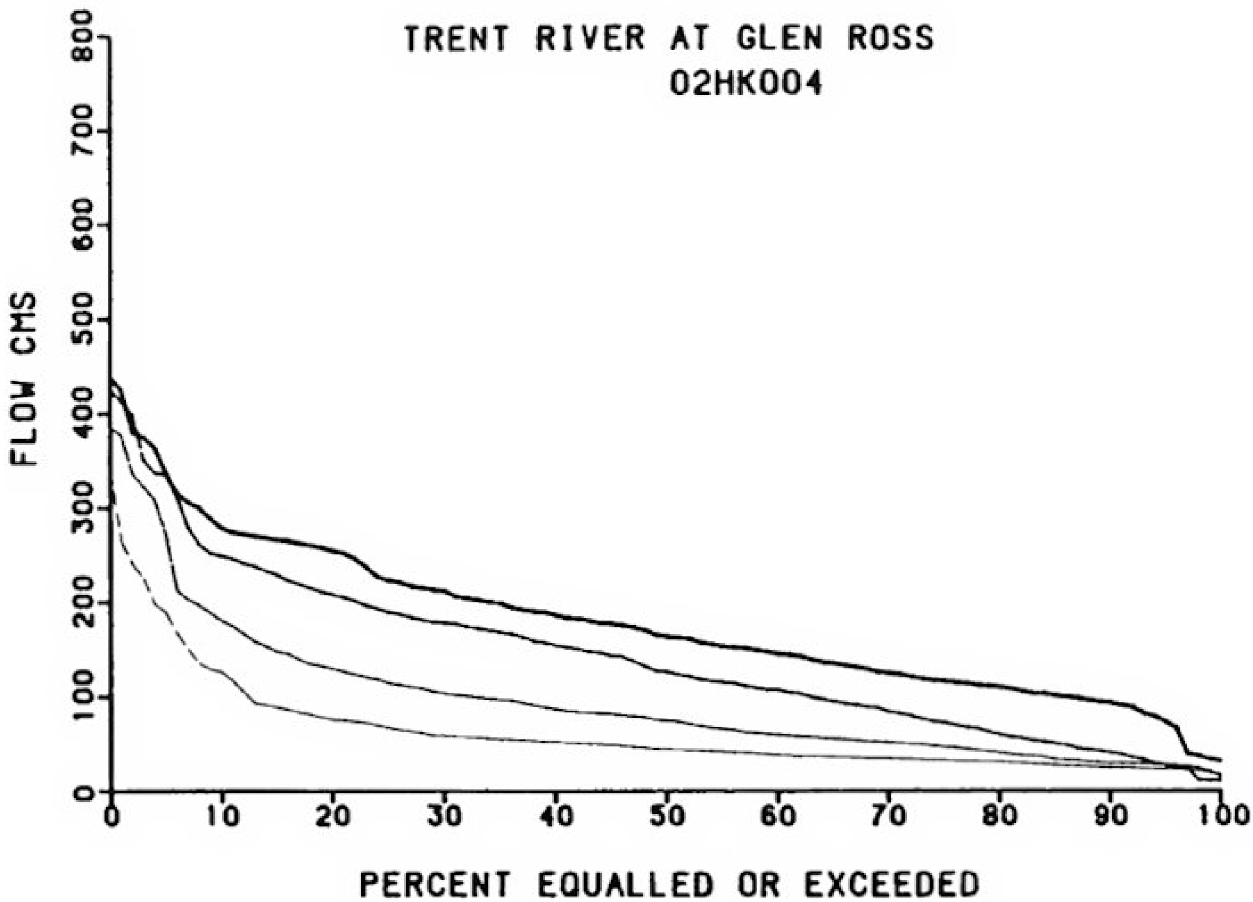


Figure 5. Example Of Seasonal Flow Duration Curve.

LEGEND

7Q2	5% DUR
7Q5	50% DUR
7Q10	75% DUR
7Q20	95% DUR
MIN DAY	99% DUR
PERIOD	AREA
STATION	# RC

7Q20	7-Day Average Low-flow With Recurrence Of 20 Years (m^3/s)
95% DUR	Flow Exceeded 95% Of Record (m^3/s)
PERIOD	Period Of Record (years)
AREA	Drainage Area (km^2)
MIN DAY	Lowest 1 Day Average Flow (m^3/s)
STATION #	WSC Station Identification
RC	Regulation Code

FIGURE 6. Station Information Legend.

A second map summarizes the above noted low flow characteristics expressed as L/s/km^2. It may be possible to refer to watersheds with similar unit runoff rates as a means of providing preliminary low flow estimates for ungauged watersheds. However, the limitations of area proration should be recognized. For example, a preliminary Low Flow Regionalization Study for Southwestern and West Central Ontario Region (Cumming Cockburn Limited, 1988) has found that other significant watershed parameters enter into the determination of low flows. Additional investigations are required in order to refine estimating techniques for ungauged watersheds.

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

1. The analysis of non-parametric test results indicate that the available data base of extreme low flows may exhibit some trend and dependence with some possibility of non-random characteristics. Therefore, some degree of caution should be used when applying the results of this study.

2. The Gumbel Extreme Value Distribution was found to adequately fit the majority of available low flow series for various low flow durations. However, for a number of samples with large negative skewness, the 3 PLN Distribution was adopted.

3. Flow duration analyses were successfully undertaken both on an annual and monthly basis.

4. Extreme value analysis were undertaken on an annual basis for 344 stations and on a monthly basis for 330 stations using the LFA program. Graphical analyses were undertaken for the remainder of the stations.

5. It was found that area average low flows are consistently higher than the Provincial average in the Northwestern, Northeastern and Central Regions and consistently lower in the Southwestern/West Central and Southeastern Regions.

6. A map summarizing the following low flow characteristics was produced for each region:

    - 7 day average extreme values for the 2, 5, 10 and 20 year recurrence intervals
    - flow duration values which were equalled or exceeded over the available period 5, 50, 75, 95 and 99 percent of the time. A second map was also

produced for each region which summarized the above low flow characteristics expressed as L/s/km^2.

7. Users referring to the analysis results for regulated stations should investigate the effects of regulation on low flows in more detail.

4.2 Recommendations

1. Further investigation should be undertaken to confirm the applicability of available non-parametric tests for low flow series.

2. The possibility of effects of cyclic changes in groundwater regime or climatic changes on low flows should be examined in future investigations.

3. Additional investigations are required in order to refine low flow estimating techniques for ungauged watersheds for each region.

4. Maps summarizing monthly $7Q_{20}$ low flow characteristics should be produced for each region. This would be useful when undertaking seasonal low flow analyses to facilitate seasonal analyses.

5. Discharge data are collected continuously by the Water Survey of Canada at each station. Data analysis and management technique are now available which would allow efficient updating of the present analyses on a frequent basis. In our opinion, the low flow analyses should be updated every three years in order to provide reasonably accurate information for investigations requiring low flow information.

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APPENDIX A.1
EXTREME VALUE ANALYSIS

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APPENDIX A
GENERAL APPENDICES

LOW FLOW CHARACTERISTICS IN ONTARIO

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Water Resources Branch

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APPENDIX A

LOW FLOW CHARACTERISTICS IN ONTARIO

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APPENDIX A.1
EXTREME VALUE ANALYSIS

Introduction

Statistical distributions allow estimates of probability of exceedence of events to be made by analytical techniques. Various methods are available, and a good discussion is given by McMahon and Mein (ref 9).

At a gauged location, average low flows can be determined for selected durations of time for each year of record. For example, the corresponding minimum average consecutive 15-day low flow can be determined for each annual record. The series of 15-day average annual low flows can then be ranked lowest to highest and an extreme value analysis undertaken using a theoretical distribution.

The Gumbel Extreme Value Distribution is commonly used for fitting low flow frequency curves to the available data.

The Gumbel Type III Distribution

This is a variation of Fisher and Tippett's third asymnptotic distribution of extreme values and is sometimes referred to as the Weibull distribution. In view of his many contributions it is often referred to in hydrology as the Gumbell II. The probability density function is:

$$\phi(x) = a/(u - e)\ [(x - e) / (u - e)]^{a-1} \exp\{-[(x - e) / (u - e)]^{a}\} \qquad (1)$$

where e is the lower bound parameter
u is the characteristic drought
and a is the shape parameter

Various methods are available for determining the distribution parameters for a particular data set. See references 2 and 6 for example.

The Probability Function

The density function is integrable and gives the distribution function

$$F(x) = 1- \exp \{- [(x - e) / (u - e)]^{a}\} \qquad (2)$$

which gives the probability of non-exceedence of x.
Since it is more common to require x for a given probability of non-exceedence, a simple re-arrangement gives

$$x = e + (u - e) \{- \ln [1- F(x)]^{1/a} \} \qquad (3)$$

There are occasions when the sample series of low flows can have a large negative coefficient of skewness, and since the Gumbel Type III distribution cannot have a skewness of less than -1.14, then the distribution cannot be fitted.

There are insufficient natural samples available with such low skewness to make a firm choice of an alternative treatment, but from the few available, it was found that the negatively skewed three-parameter log-normal distribution provided an acceptable alternative.

If y = ln (a-x) is normally distributed, then the probability density function of x is given by

$$\phi(x) = 1/ [(a - x) \sigma \sqrt{2\pi}] \exp \{ -1 /2 \sigma^{2} [\ln (a - x) - m]^{2} \} \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; 4$$

where m and a are respectively the mean and standard deviation of the series ln (a-x) and a is an lower boundary parameter.

This form of the distribution can only have negative skewness. The equation in the form ln (x-a) is for distributions with positive skewness.

Taking moments, re-arranging and replacing them by their sample estimates gives:

$$k^3 + 3k - g_1 = 0 \qquad (36a) \quad (5)$$

and after solving for k

$$\hat{a} = x - s/k \qquad (37a) \quad (6)$$

$$\hat{m} = \ln(-s/k) - \tfrac{1}{2} \ln(k^2 + 1) \qquad (38a) \quad (7)$$

$$\sigma^2 = \ln(k^2 + 1) \qquad (39a) \quad (8)$$

Thus, the distribution is completely defined and the T-year low flows can be computed from:

$$Q_T = \hat{a} - \exp(\hat{m}\ \sigma\ t) \qquad (9)$$

Additional details are discussed in the user's manual.

Source: Condie, R., L. C. Cheng. "Low Flow Frequency Analysis - Program LOFLOW", Water Resources Branch, Inland Waters Directorate Environment Canada, Ottawa, 1987.

APPENDIX A.2

FLOW DURATION ANALYSIS

APPENDIX A.2
FLOW DURATION ANALYSIS

A flow duration curve is a plot of the flow of a stream against the percent of time the indicated flow was equalled or exceeded during the period covered by the available flow data. This curve is extremely useful for hydro power studies and for characterizing the local streamflow regime.

An empirical procedure was used to analyse each sample discharge record. Flow duration curves are derived by rearranging the available daily or monthly flow data in order of magnitude. The total time period represents 100% of the time. Therefore, by definition of the procedure used here, the largest value is exceeded 0 percent of the time and the smallest value is exceeded 100% of the time.

The flow duration curve represents the percent of time that a specific discharge occurs at that location. However, the curve does not indicate the period of time in the year when the flow is less than or equal to the selected value. Therefore, in some instances, it is also useful to develop flow duration curves on a monthly basis, that is, all data for the month of January over the entire period of record is analysed independently to produce a flow duration curve representative of flow conditions in January.

Single station flow duration analyses and corresponding monthly flow duration curves have been determined at all relevant stream and flow locations across the Province.

APPENDIX A.3

NON-PARAMETRIC TESTS FOR INDEPENDENCE, TREND AND RANDOMNESS

APPENDIX A.3

NONPARAMETRIC TESTS FOR INDEPENDENCE, TREND AND RANDOMNESS

A.3.1 Test Description

This appendix briefly summarizes the functions evaluated in the package and gives the methods used to determine their statistical significance. Statistical tables are provided for ease of reference.

A.3.1.1 Introduction

Any statistical test of significance will generally be made using the following steps:

a) State the null hypothesis, H_O. For instance in split sample tests, the null hypothesis may be that there is no difference between the sample means.

b) Choose a significance level, a.

c) Choose an appropriate statistical test. In this program all tests are nonparametric.

d) Compute the test statistic.

e) The sampling distribution of the test statistic is known and has been tabulated, and the chosen significance level then defines the region of rejection.

f) If the computed test statistic lies in the region of rejection, then the null hypothesis is rejected.

Consider now the four tests in this program.

A.3.1.2 The Spearman Rank Order Serial Correlation Coefficient for Independence

If the series with i ranging from 1 to N is put in chronological order, two time series are formed and their respective ranks computed:

Q_1, Q_2 .... Q_{N-1} by x_i, the rank of Q_i ; i=1; N-1
and Q_2, Q_3 .... Q_N by y_i, the rank of Q_i ; i=2, N

then Spearman rank order serial correlation coefficient is

$$S_1 = \tfrac{1}{2} (\Sigma x_i^2 + \Sigma y_i^2 - \Sigma d_i^2) (\Sigma x_i^2 \, \Sigma y_i^2)^{-\frac{1}{2}} \qquad (1)$$

where $\Sigma x_i^2 = (m^3 - m)/12 - \Sigma T_x$
$\Sigma y_i^2 = (m^3 - m)/12 - \Sigma T_y$
d_i = difference in rank between x_i and y_i
m = N-1

and the summations are over the m pairs of x_i, y_i.

Ignoring for the moment the terms in T and putting them at zero, equation (a) becomes

$$S_1 = 1-(6\, \Sigma d_i^2)\, (m^3-m) \qquad (2)$$

the more familiar form of the Spearman rank correlation coefficient.

The terms in T adjust for tied ranks and are computed as follows. If for instance three observations in the x series were tied for ranks 17, 18, and 19 then each observation is given the rank 18; if two were tied for ranks 24 and 25, then each is ranked 24.5.

For each tied set, T is computed from

$$T_x = (J^3 - J)/12$$

where J is the number of observations tied at a give rank. ΣT_x and ΣT_y are defined by the extension of the foregoing. When N is 10 or greater, then the function

$$t = S_1 [(m-2)/(_1-Si^{2})]^{½} \tag{3}$$

is distributed like Student's t with m-2 degrees of freedom. A one-tail test must be used.

A.3.1.3 The Spearman Rank Order Correlation Coefficient Test for Trend

If the series Q_1 with i ranging from 1 to N is put in chronological order, ranks assigned and denoting the series

Q_1, Q_2 .... Q_N by y_i, the rank of Q_i
and 1, 2, ... N by x_i, the sequential order of Q_i

then the Spearman rank order correlation coefficient r_s is calculated as in equation 1, except that m = N, $T_x = 0$, and the summations are taken over the N pairs of x_i, y_i.

For N = 10 or greater, then the function

$$t = r_s [(N-2)/(1-r_s^2)] \tag{4}$$

is distributed like Student's t with N-2 degrees of freedom. The null hypothesis is that there is no trend, either upward or downward with time, and so a two-tail test is used.

A.3.1.4 Runs Above and Below the Median for General Randomness

This randomness test is based on the order or sequence in which the individual scores or observations were obtained. Actually, the test is based on the number of runs which a sample exhibits.

A run is defined as a succession of identical symbols which are followed and preceded by different symbols or by no symbols at all.

The total number of runs in a simple of any given size gives an indication of whether or not the sample is random. If very few runs occur, a time trend or some bunching due to lack of independence is suggested. If a great many runs occur, systematic short-period cyclical fluctuations seem to be influencing the sample.

For example, once the median of the sample has been determined, each observation can be labelled as being above and equal to or below and equal to the median. If "A" represents above and equal to the median and "B" represents below and equal to the median, then a sample may be ordered as

AABBBABBBBAABA

(A run represents a succession of identical symbols). For our example, each run is underscored and numbered consecutively:

AA	BBB	A	BBBB	AA	B	A
1	2	3	4	5	6	7

This sample begins with 2 observations above or equal to the median, followed by a run of 3 observations below or equal to the median, etc.

Seven runs are observed in all: that is, the total number of runs above and below the median RUNAB, is 7. If nl represents the number of events of type A, then $n_1 = 6$. If n_2 denotes the number below the median, type B, then $n_2 = 8$. Thus, the number of observations is equal to $(n_1 + n_2)$.

In order to apply this run test, one must determine n_1, n_2 and RUNAB.

The null hypothesis, H_o, is that the A's and B's occur in random order. The alternate hypothesis, H_i, is that the order of the A's and B's deviates from randomness.

When either n_1 or n_2 is greater than 20, the sampling distribution of RUNAB tends to normality with

$$z = \frac{| \text{RUNAB} - [(2n_1\ n_2)/(n_1+n_2)+1] |}{(2n_1\ n_2\ (2n_1\ n_2 - n_1 - n_2)/[(n_1+n_2)^2\ (n_1+n_2-1)]^{1/2}} \qquad (5)$$

where z is an N(0,1) variate as described in Table A.4. This package uses a region of rejection defined by

z greater than 1.96 for $\alpha = 0.05$

z greater than 2.575 for $\alpha = 0.01$

A.3.2 <u>Example of Tests</u>

The non-parametric test referred to in Section 2.3 were performed on all extreme value data sets. The data for the 7-day duration for Station 028D002 which "failed" the non-parametric tests is tabulated in Table 1 and comparatively the data for Station 02AB009 which passed all the non-parametric tests is given in Table 2. The results of the tests for independence, trend and randomness for both stations are given in Tables 3 and 4 respectively.

Source: Pilon, P.J., R. Condie, K. D. Harvey. "Consolidated Frequency Analysis Program - CFA", July 1985 Water Resources Branch, Inland Waters Directorate, Environment Canada - Ottawa, 1985.

TABLE 1. 7 Day Duration Flows Used For Extreme Value Analysis.
Shebandowan River At Sunshine 02A8009
7 Day Low Flow Mean Disch. In Period Jan 01 - Dec 31

Starting Month	Year	7day Mean Flow (cm)	Ascending order (cm)	Rank	Cumulat. Probabil (%)	Return Period (Years)
8	1958	5.2310	2.0900	1	2.05	48.67
1	1959	9.3610	2.2740	2	5.48	18.25
8	1960	2.8910	2.5940	3	8.90	11.23
8	1961	3.7160	2.6590	4	12.33	8.11
10	1962	9.7990	2.8640	5	15.75	6.35
10	1963	3.5100	2.8910	6	19.18	5.21
1	1964	2.2740	3.2360	7	22.60	4.42
8	1965	4.1800	3.3830	3	26.03	3.84
7	1966	2.5940	3.5100	9	29.45	3.40
10	1967	3.6090	3.6090	10	32.88	3.04
1	1968	5.4610	3.7160	11	36.30	2.75
9	1969	4.6560	4.0070	12	39.73	2.52
8	1970	2.8640	4.1800	13	43.15	2.32
3	1971	5.8960	4.6560	14	46.58	2.15
9	1972	5.9010	5.2310	15	50.00	2.00
1	1973	6.1360	5.4270	16	53.42	1.87
8	1974	6.1490	5.4610	17	56.85	1.76
11	1975	6.5970	5.9010	18	60.27	1.66
12	1976	2.0900	5.9570	19	63.70	1.57
2	1977	2.6590	5.9960	20	67.12	1.49
12	1978	7.7360	6.1360	21	70.55	1.42
9	1979	4.0070	6 1490	22	73.97	1.35
6	1980	3.3830	6.5970	23	77.40	1.29
9	1981	3.2360	6.7060	24	80.82	1.24
2	1982	5.4270	7.7360	25	84.25	1.19
4	1983	10.8860	8.2340	26	87.67	1.14
10	1984	6.7060	9.3610	27	91.10	1.10
1	1985	8.2340	9.7990	28	94.52	1.06
12	1986	5.9570	10.8860	29	97.95	1.02

TABLE 2. 7 Day Duration Flows Used For Extreme Value Analysis.

Michipicoten River At High Falls 029ED02

7 Day Low Flow Mean Disch In Period Jan 01 Dec 31

Starting Month	Year	7 Day Mean Flow (cm)	Ascending Order (cm)	Rank	Cumulat Probabil. (%)	Return Period (Years)
10	1924	17.000	5.386	1	1.01	98.67
9	1925	20.971	9.609	2	2.70	37.00
4	1926	19.014	15.271	3	4.39	22.77
9	1927	25.643	15.971	4	6.08	16.44
3	1928	29.700	17.000	5	7.77	12.87
9	1933	15.271	19.014	6	9.46	10.57
1	1934	21.314	20.643	7	11.15	6.97
9	1935	27.371	20.971	8	12.84	7.79
12	1936	25.314	21.157	9	14.53	6.98
4	1937	23.100	21.214	10	16.22	6.17
10	1938	23.057	21.314	11	17.91	5.58
8	1939	25.186	22.771	12	19.59	5.10
3	1940	25.800	23.057	13	21.28	4.70
8	1941	24.243	23.100	14	22.97	4.35
7	1942	27.557	23.500	15	24.66	4.05
12	1943	25.943	23.886	16	26.35	3.79
1	1944	23.886	24.243	17	28.04	3.57
3	1945	24.543	24.543	18	29.73	3.36
10	1946	26.157	25.186	19	31.42	3.18
12	1947	21.157	25.314	20	33.11	3.02
10	1948	20.643	25.643	21	34.80	2.87
12	1949	23.500	25.800	22	36.49	2.74
2	1950	31.171	25.943	23	38.18	2.62
9	1951	50.086	26.157	24	39.86	2.51
11	1952	44.057	26.700	25	41.55	2.41
10	1953	31.100	27.200	26	43.24	2.31
11	1954	36.214	27.371	27	44 93	2.23
9	1955	21.214	27.557	28	46.62	2.14
4	1956	32.229	27.700	29	48.31	2.07
7	1957	39.371	29.700	30	50.00	2.00
8	1958	31.800	30.443	31	51.69	1.93
6	1959	42.400	30.871	32	53.38	1.87
10	1960	30.443	31.100	33	55.07	1.82
7	1961	41.000	31.171	34	56.76	1.76
8	1962	42.186	31.800	35	58.45	1.71
11	1963	38.229	32.229	36	60.14	1.66
6	1964	30.871	32.457	37	61.82	1.62
9	1965	61.014	34.900	38	63.51	1.57
10	1966	36.629	36.214	39	65.20	1.13
12	1967	48.743	36.629	40	66.89	1.49
3	1968	32.457	38.229	41	68.58	1.46
9	1969	5.386	39.371	42	70.27	1.42
12	1970	51.043	39.643	43	71.96	1.39
11	1971	34.900	39.757	44	73.65	1.36
5	1972	45.186	41.000	45	75.34	1.33
12	1973	58.300	41.471	46	77.03	1.30
5	1974	39.757	42.186	47	78.72	1.27
11	1975	15.971	42.400	48	80.41	1.24
10	1976	22.771	44.057	49	82.09	1.22
1	1977	9.609	45.186	50	83.78	1.19
10	1978	41.471	46.471	51	85.47	1.17
9	1979	53.143	48.743	52	87.16	1.15
6	1980	39.643	50.086	53	88.85	1.13
3	1981	27.700	50.229	54	90.54	1.10
5	1982	26.700	51.043	55	92.23	1.06
9	1903	55.143	53.143	56	93.92	1.06
10	1984	50.290	55.143	57	95.61	1.35
1	1985	46.471	58.300	58	97.30	1.03
8	1986	27.200	61.014	59	98.99	1.01

TABLE 3. Results Of Statistical Tests For Station 02A6009.

--- SPEARMAN TEST FOR INDEPENDENCE ---
02AB00913007 SHEBANDOWAN RIVER AT SUNSHINE
ANNUAL MINIMUM DAILY FLOW SERIES 58 TO 86 DRAINAGE AREA = 2800.000

SPEARMAN RANK ORDER SERIAL CORRELATION COEFF = 0.068 D F =26
CORRESPONDS TO STUDENTS T = 0.347
CRITICAL T VALUE AT 5% LEVEL = 1.706 NOT SIGNIFICANT
" " " " 1% " = 2.479 NOT SIGNIFICANT

Interpretation. The null hypothesis is that the serial (lag-one) correlation is zero

At the 5% level of significance, the correlation is not significantly different From zero. That is, the data do not display significant serial dependence.

--- SPEARMAN TEST FOR TREND ---
02AB00913007 SHEBANDOWAN RIVER AT SUNSHINE
ANNUAL MINIMUM DAILY FLOW SERIES 58 TO 86 DRAINAGE AREA = 2800.000

SPEARMAN RANK ORDER CORRELATION COEFF = -0.227 D.F.=27
CORRESPONDS TO STUDENTS T = -1.209
CRITICAL T VALUE AT 5% LEVEL = -2.052 NOT SIGNIFICANT
" " " " 1% " = 2.771 NOT SIGNIFICANT

Interpretation: The null hypothesis is that the serial (lag-one) correlation is zero.

At the 5% level of significance, the correlation is not significantly different from zero. That is, the data do not display significant trend.

--- RUN TEST FOR GENERAL RANDOMNESS ---
02AB00913007 SHEBANDOWAN RIVER AT SUNSHINE
ANNUAL MINIMUM DAILY FLOW SERIES 58 TO 86 DRAINAGE AREA = 2800.000
THE NUMBER OF RUNS ABOVE AND BELOW THE MEDIAN (RUNAB) = 11
THE NUMBER OF OBSERVATIONS ABOVE THE MEDIAN (M1) = 14
THE NUMBER OF OBSERVATIONS BELOW THE MEDIAN (M2) = 14
Range at 5% level of significance: 10 to 20. NOT SIGNIFICANT

Interpretation: The null hypothesis is that the data are random.

At the 5% level of significance, the null hypothesis cannot be rejected. That is, the sample is significantly random.

TABLE 4. Results Of Statistical Tests For Station 02AB009.

--- SPEARMAN TEST FOR INDEPENDENCE ---
02BD00213007 MICHIPICOTEN RIVER AT HIGH FALLS
ANNUAL MINIMUM DAILY FLOW SERIES 24 TO 86 DRAINAGE AREA = 5130.000
SPEARMAN RANK ORDER SERIAL CORRELATION COEFF = 0.456 D F.=56
CORRESPONDS TO STUDENTS T = 3.839
CRITICAL T VALUE AT 5% LEVEL = 1.674 SIGNIFICANT
" " " " 1% " = 2.392 SIGNIFICANT

Interpretation: The null hypothesis is that the serial(lag-one) correlation is zero.

At the 1% level of significance, the correlation is significantly different from zero. That is, the data display highly significant serial dependence.

--- SPEARMAN TEST FOR TREND ---
02BD00213007 MICHIPICOTEN RIVER AT HIGH FALLS
ANNUAL MINIMUM DAILY FLOW SERIES 24 TO 86 DRAINAGE AREA = 5130.000
SPEARMAN RANK ORDER CORRELATION COEFF = -0.528 D.F. =57
CORRESPONDS TO STUDENTS T = -4.693
CRITICAL T VALUE AT 5% LEVEL = -2.003 SIGNIFICANT
" " " " 1% " = -2.667 SIGNIFICANT

Interpretation: The mull hypothesis is that the serial(lag-one) correlation is zero.

At the 1% level of significance, the correlation is significantly different Iron zero. That is, the data display highly significant trend.

--- RUN TEST FOR GENERAL RANDOMNESS ---
02BD002213007 MICHIPICOTEN RIVER AT HIGH FALLS
ANNUAL MINIMUM DAILY FLOW SERIES 24 TO 86 DRAINAGE AREA = 5130.000
THE NUMBER OF RUNS ABOVE AND BELOW THE MEDIAN (RUNAB) = 11
THE NUMBER OF OBSERVATIONS ABOVE THE MEDIAN (M1) = 29
THE NUMBER OF OBSERVATIONS BELOW THE MEDIAN (M2) = 29
(NOTE: 2 IS THE STANDARD NORMAL VARIATE.)

For this test, Z = 5.034
Critical Z value at the 5% level = 1.960 SIGNIFICANT
Critical Z value at the 1% level = 2.575 SIGNIFICANT
Interpretation The mull hypothesis is that the data are random
At the 1% level of significance, the null hypothesis can be rejected That is, the sample is mot significantly random.

A.3.3 Graphical Representation

Graphical procedures are available within the LFA (Pilon, Jackson, 1987) program which visually depict some of the results of the non-parametric tests as shown in figures 1 to 6.

Figures 1 and 2 show that there is an apparent trend for Station 02BD002 when compared with the rank versus time graph of Figure 2. These results correspond to the statistical test results. The increase in low flows as a function of time is very apparent for the data for Station 02BD002 (see Figure 3) when compared to the data from Station 02AB009 shown in Figure 4. Figures 5 and 6 graphically depict the probability density function by displaying a histogram of the number of occurrences of between ranges of low flows. It can be seen that both stations are positively skewed for the 7-day duration data.

A.3.4 Summary of Tests Results

Test results are summarized by region for significant levels of 1% and 5% in appendices B to F, Section 2.0.It can be seen from the summary tables (Tables 2 to 6) that the data for stations in the Central Region are random at the 1% level (refer to Table 2).

All other test results indicate that a large number of the data sets "fail" the non-parametric test. This could indicate some dependence, trend and non-randomness. Hence, some degree of caution should be used when applying the results of this study.

To examine effects of length of record and regulation, the analysis was completed using criteria of ≥20 years of record, <20 years of record and regulated vs. non-regulated station data.

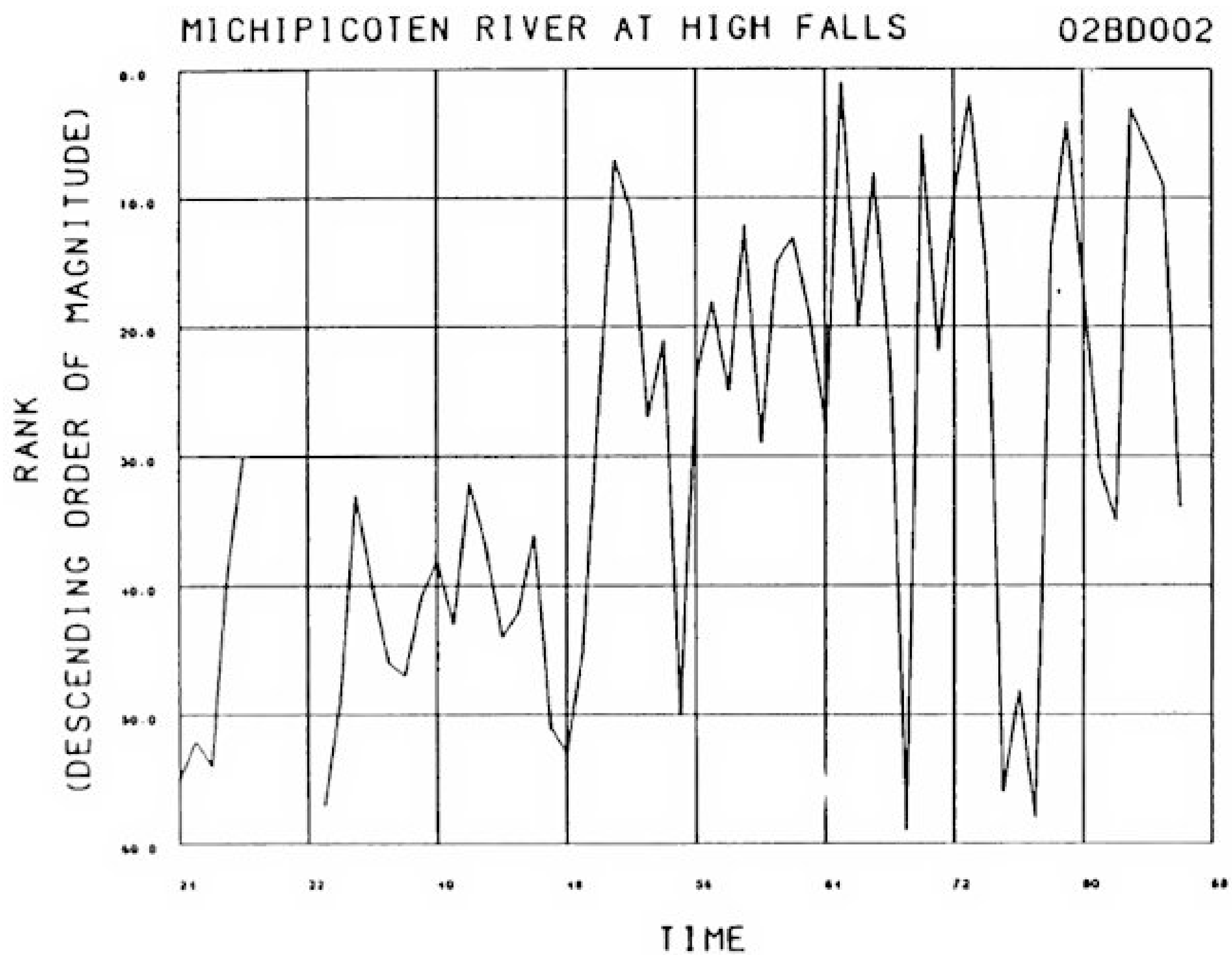

Figure 1. RANK VERSUS TIME: 1924 - 1986.

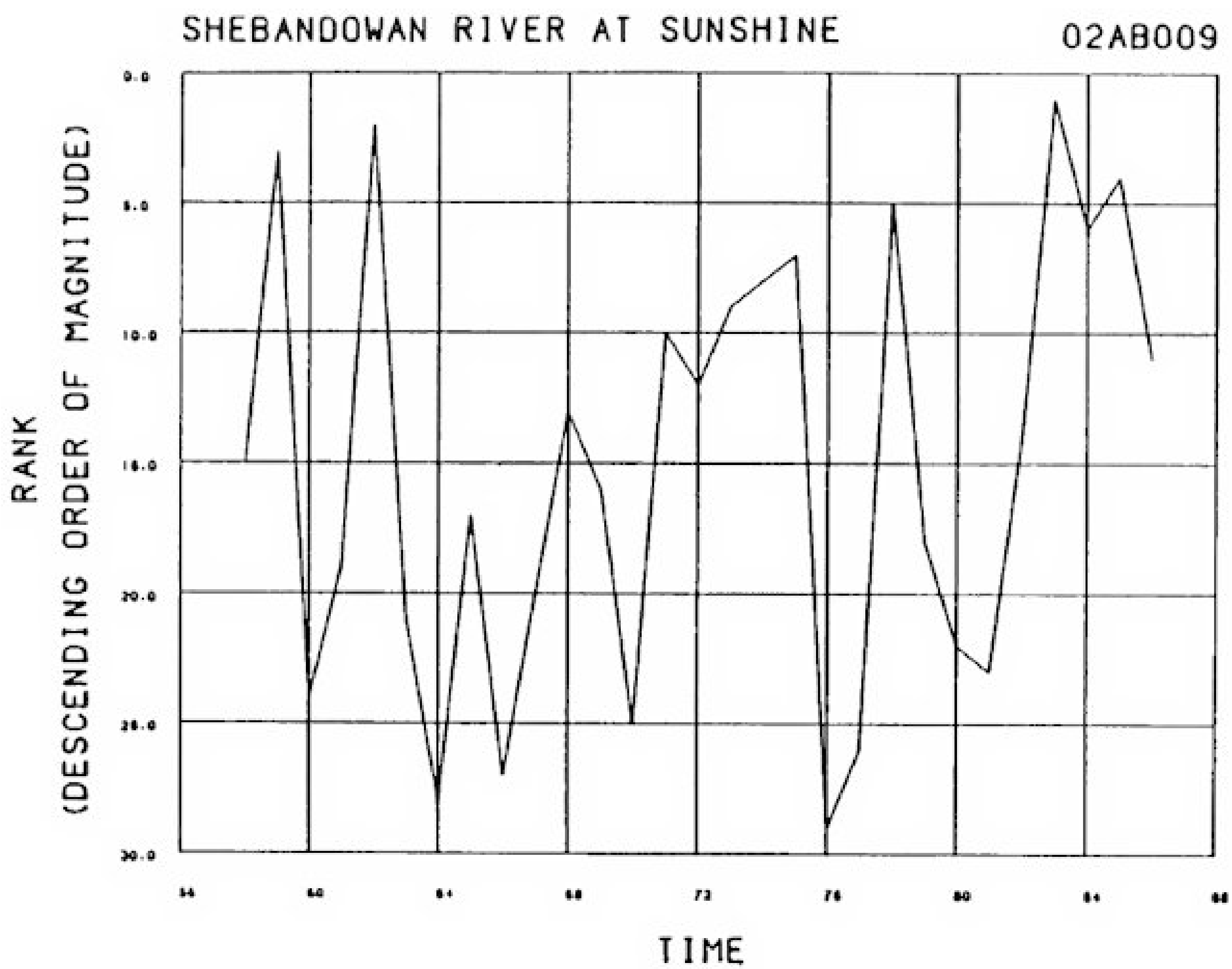

Figure 2. Rank Versus Time: 1958 - 1986.

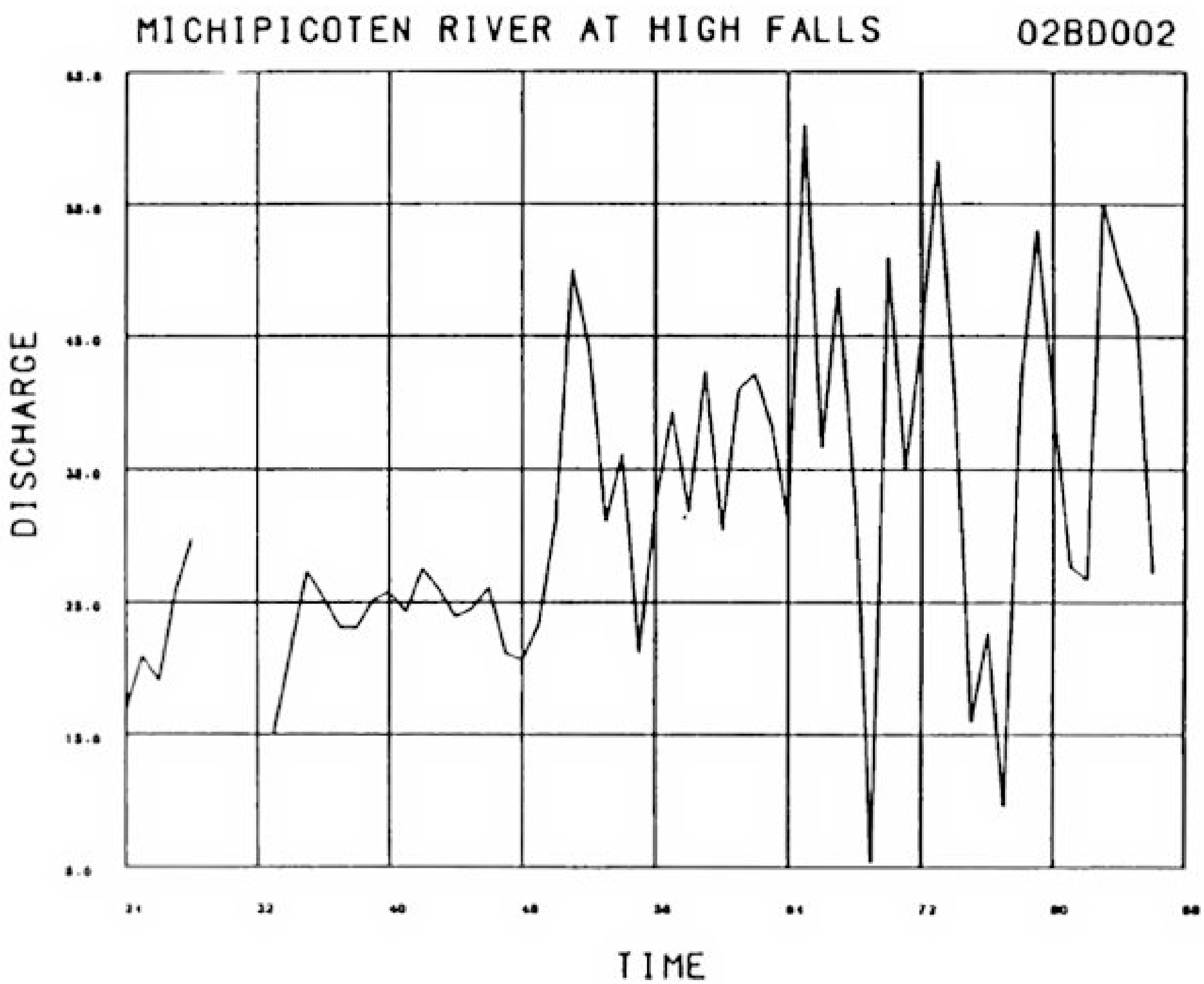

Figure 3. Discharge Versus Time: 1924 - 1986.

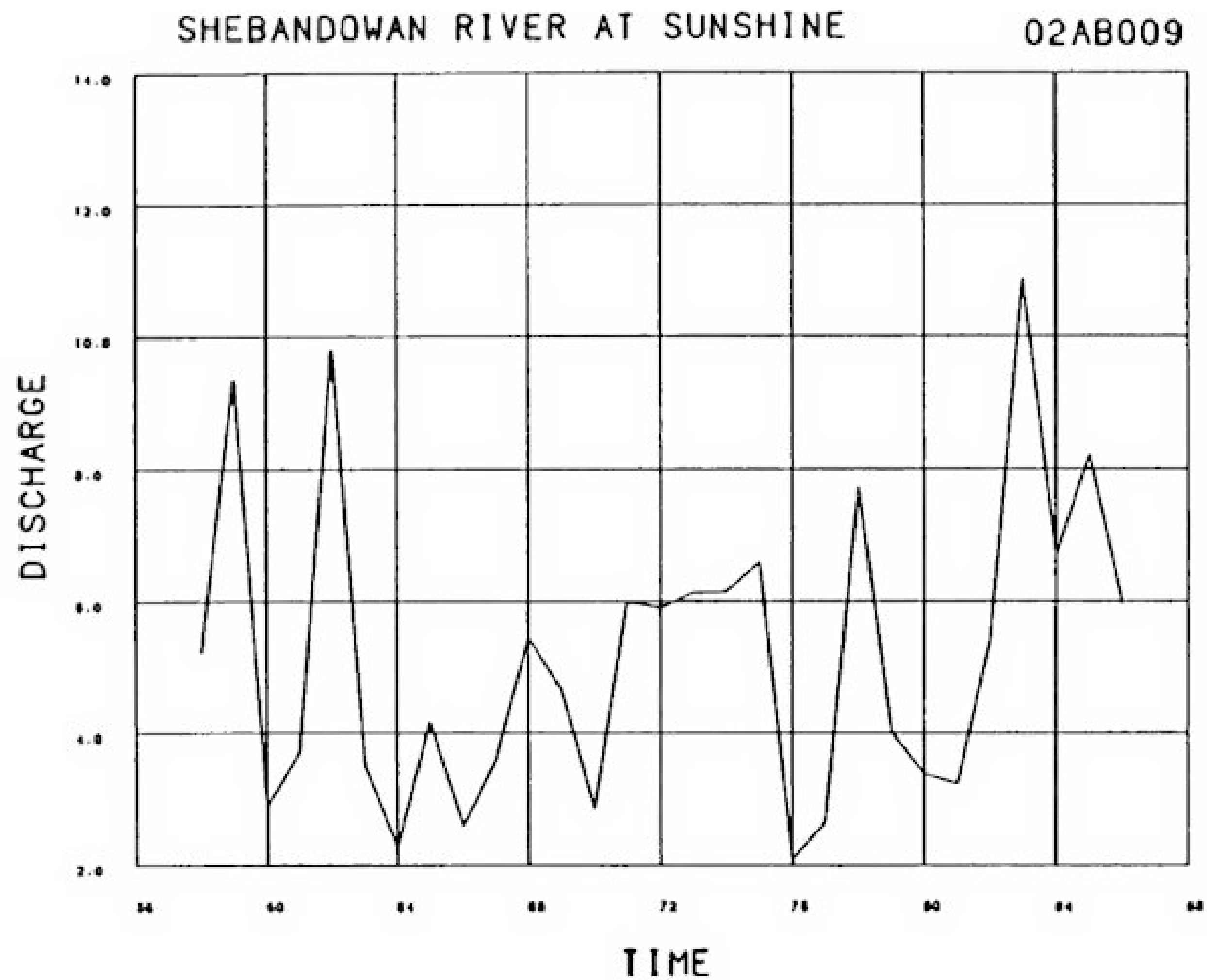

Figure 4. Discharge Versus Time: 1958 - 1986.

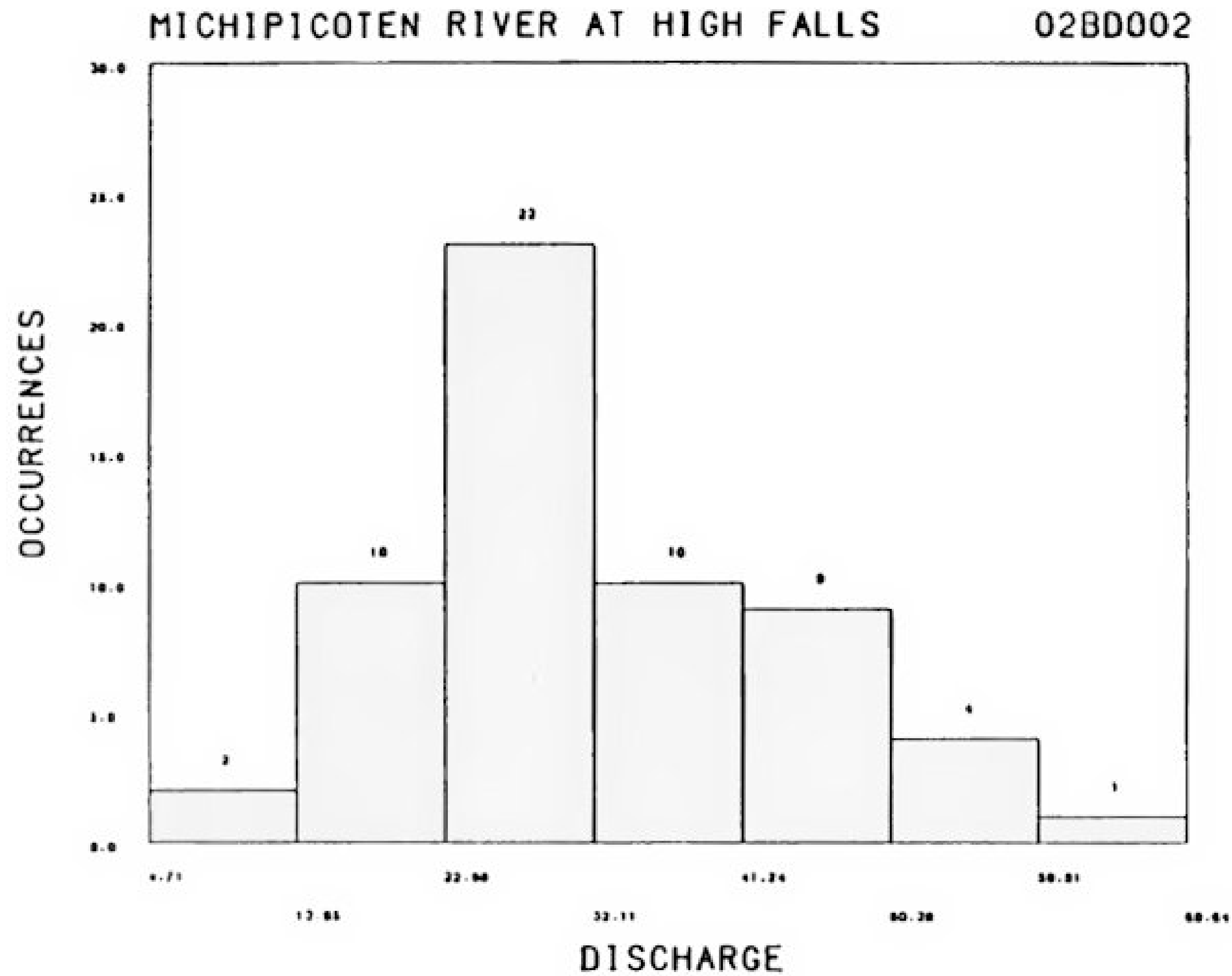

Figure 5. Histogram For Discharge: 1924 - 1986 (59 Observations).

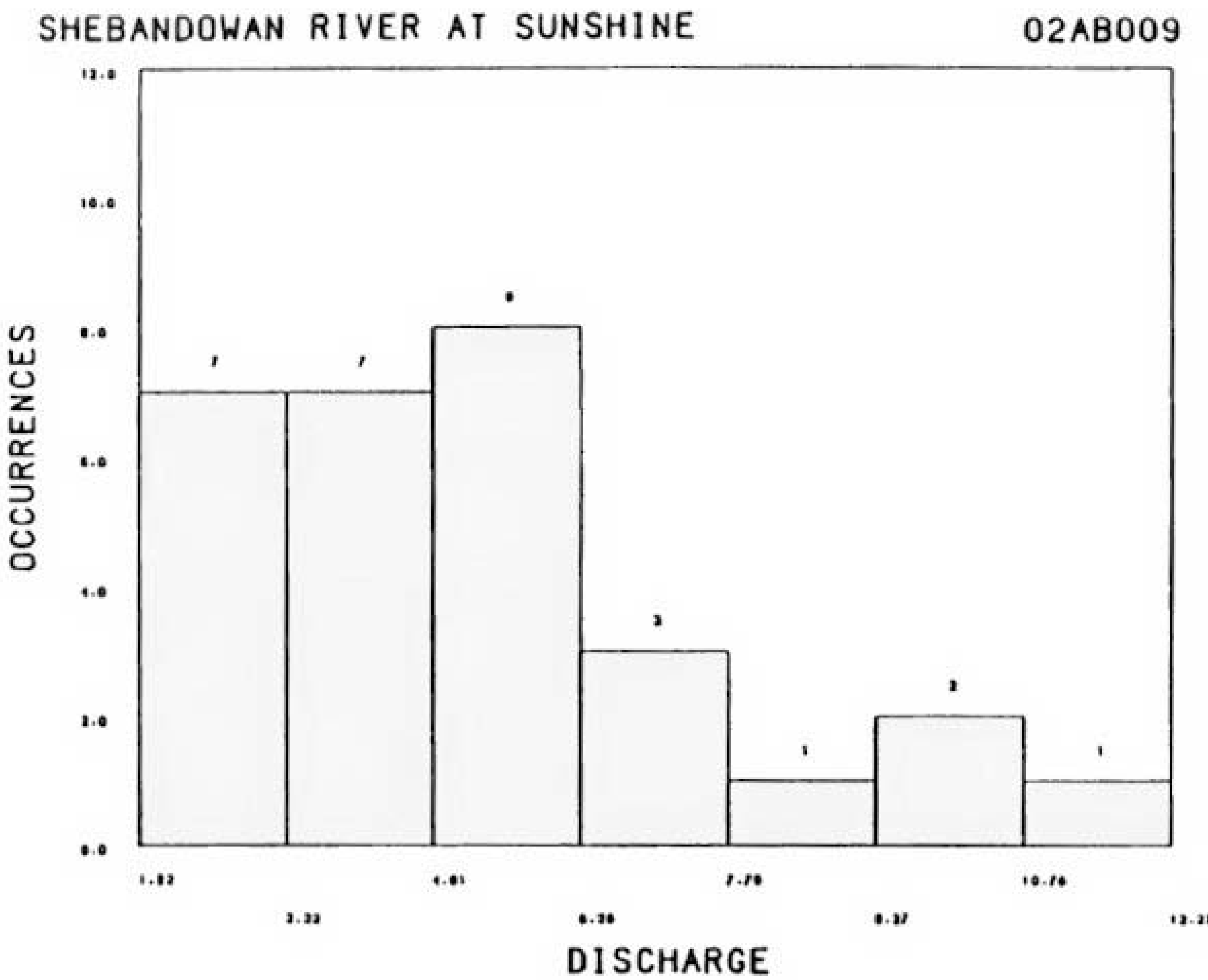

Figure 6. Histogram For Discharge: 1958 - 1986 (29 Observations).

Table 2. Summary of Data Screening All Stations.

Northeastern Region

Day Duration	Independence 1% Sig.	Independence 1% Not	Independence 1% Per.	Independence 5% Sig.	Independence 5% Not	Independence 5% Per.	Trend 1% Sig.	Trend 1% Not	Trend 1% Per.	Trend 5% Sig.	Trend 5% Not	Trend 5% Per.	Randomness 1% Sig.	Randomness 1% Not	Randomness 1% Per.	Randomness 5% Sig.	Randomness 5% Not	Randomness 5% Per.
1	53	7	0	47	13	0	50	10	0	43	17	0	46	19	0	45	19	0
3	51	9	0	44	13	0	48	12	0	40	17	0	47	18	0	45	19	0
7	50	10	0	44	16	0	50	11	0	43	19	0	47	18	0	48	17	0
15	51	9	0	46	16	0	53	7	0	42	18	0	46	19	0	48	17	0
30	54	6	0	46	14	0	50	10	0	44	16	0	49	16	0	48	17	0
TOTAL*	259	41		255	75		251	49		213	87		235	90		236	89	

Northwestern Region

Day Duration	Independence 1% Sig.	Independence 1% Not	Independence 1% Per.	Independence 5% Sig.	Independence 5% Not	Independence 5% Per.	Trend 1% Sig.	Trend 1% Not	Trend 1% Per.	Trend 5% Sig.	Trend 5% Not	Trend 5% Per.	Randomness 1% Sig.	Randomness 1% Not	Randomness 1% Per.	Randomness 5% Sig.	Randomness 5% Not	Randomness 5% Per.
1	47	20	0	42	25	0	59	8	0	49	18	0	31	36	0	46	21	0
3	48	19	0	44	23	0	60	7	0	53	14	0	29	38	0	47	23	0
7	49	18	0	45	22	0	60	7	0	53	14	0	30	37	0	50	17	0
15	51	16	0	43	24	0	62	5	0	54	13	0	31	26	0	51	16	0
30	50	15	0	42	25	0	62	5	0	50	17	0	30	37	0	48	19	0
TOTAL*	247	88		216	119		303	32		259	76		151	184		242	93	

Southwest and West Central Region

Day Duration	Independence 1% Sig.	Independence 1% Not	Independence 1% Per.	Independence 5% Sig.	Independence 5% Not	Independence 5% Per.	Trend 1% Sig.	Trend 1% Not	Trend 1% Per.	Trend 5% Sig.	Trend 5% Not	Trend 5% Per.	Randomness 1% Sig.	Randomness 1% Not	Randomness 1% Per.	Randomness 5% Sig.	Randomness 5% Not	Randomness 5% Per.
1	72	26	0	66	32	0	57	40	0	44	54	0	17	84	0	67	34	0
3	71	27	0	68	30	0	54	44	0	43	55	0	18	83	0	68	33	0
7	72	26	0	66	32	0	58	40	0	42	56	0	19	82	0	71	30	0
15	74	24	0	67	31	0	57	41	0	44	54	0	17	84	0	73	28	0
30	71	27	0	65	33	0	54	44	0	41	57	0	17	84	0	70	31	0
TOTAL*	360	130		332	158		280	270		214	276		88	417		349	156	

Central Region

Day Duration	Independence 1% Sig.	Independence 1% Not	Independence 1% Per.	Independence 5% Sig.	Independence 5% Not	Independence 5% Per.	Trend 1% Sig.	Trend 1% Not	Trend 1% Per.	Trend 5% Sig.	Trend 5% Not	Trend 5% Per.	Randomness 1% Sig.	Randomness 1% Not	Randomness 1% Per.	Randomness 5% Sig.	Randomness 5% Not	Randomness 5% Per.
1	64	11	0	56	19	0	53	22	0	37	38	0	1	75	52	62	14	0
3	65	10	0	56	19	0	52	23	0	41	34	0	1	75	52	60	16	0
7	64	11	0	56	19	0	54	21	0	37	38	0	1	75	52	62	14	0
15	66	9	0	58	17	0	49	26	3	39	36	0	0	76	100	60	16	0
30	67	8	0	56	19	0	49	26	0	38	37	0	1	75	52	66	10	0
TOTAL*	326	49		282	93		257	118		192	183		4	376		310	70	

Southeastern Region

Day Duration	Independence 1% Sig.	Independence 1% Not	Independence 1% Per.	Independence 5% Sig.	Independence 5% Not	Independence 5% Per.	Trend 1% Sig.	Trend 1% Not	Trend 1% Per.	Trend 5% Sig.	Trend 5% Not	Trend 5% Per.	Randomness 1% Sig.	Randomness 1% Not	Randomness 1% Per.	Randomness 5% Sig.	Randomness 5% Not	Randomness 5% Per.
1	39	7	0	37	9	0	41	5	0	36	10	0	22	27	0	36	13	0
3	39	7	0	36	10	0	43	3	0	38	8	0	22	27	D	35	13	0
7	40	6	0	39	7	0	43	3	0	41	5	0	23	26	0	32	12	0
15	41	5	0	37	9	0	43	3	0	42	4	0	23	26	0	40	9	0
30	43	3	0	39	7	0	44	2	0	39	7	0	24	25	0	40	9	0
TOTAL*	202	28		188	42		214	16		196	34		114	131		190	55	

* Total of the 5 durations for stations In this region

Dur: the duration the data set represents the average 30 day low flow

Sig: the number of stations which show significant dependence trend, non randomness

Not: the number of stations which show Independence, free from trend, and randomness

Per: the percent binomial probability that this number of stations would fail the men parametric tests

Tables 3 and 4 show the results of data from ≥ 20 years of record with Table 3 showing less non-regulated stations than the regulated stations on Table 4. The regulated stations show a greater percentage of values which can be said to "pass" the non-parametric test compared to those which "failed". Although the Central Region data is showing computed randomness at the 1% level of significance, the binomial probability is still "0" for all other tests.

Tables 5 and 6 summarize the analysis results for stations with less than 20 years of record. The findings suggest that neither the length of record or the effect of regulation can account for the overall conclusion that the statistical tests indicate some degree of dependence, trend and non-randomness of the low flow data sets.

It is possible that application and interpretation of the non-parametric tests at the 10% level of significance could result in fewer stations "failing" the non-parametric tests.

TABLE 3. Summary of Data Screening: Non Regulated Stations with a Period of Record Greater Or Equal to 20 Years.

Northeastern Region

	Independence						Trend						Randomness					
Day		1%			5%			1%			5%			1%			5%	
Duration	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.
1	12	0	0	11	1	0	11	1	0	10	2	0	8	4	0	11	1	0
3	12	0	0	10	2	0	11	1	0	10	2	0	8	4	0	11	1	0
7	12	0	0	11	1	0	12	0	0	10	2	0	8	4	0	11	1	0
15	12	0	0	10	2	0	12	0	0	10	2	0	8	4	0	11	1	0
30	12	0	0	10	2	0	11	1	0	10	2	0	8	4	0	11	1	0
TOTAL*	60	0		52	8		57	3		50	10		40	20		55	5	

Northwestern Region

	Independence						Trend						Randomness					
Day		1%			5%			1%			5%			1%			5%	
Duration	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.
1	10	7	0	10	7	0	15	2	0	12	5	0	11	6	0	13	4	0
3	10	7	0	10	7	0	15	2	0	13	4	0	11	6	0	14	3	0
7	10	7	0	10	7	0	15	2	0	13	4	0	11	6	0	14	3	0
15	12	5	0	10	7	0	15	2	0	14	3	0	11	6	0	14	3	0
30	12	5	0	10	7	0	15	2	0	12	5	0	11	6	0	12	5	0
TOTAL*	54	31		50	35		75	10		64	21		55	30		67	13	

Southwest and Nest Central Region

	Independence						Trend						Randomness					
Day		1%			5%			1%			5%			1%			5%	
Duration	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.
1	20	6	0	19	7	0	18	8	0	13	13	0	6	20	0	20	6	0
3	20	6	0	20	6	0	17	9	0	14	12	0	7	19	0	21	5	0
7	20	6	0	19	7	0	10	8	0	15	11	0	8	18	0	23	3	0
15	21	5	0	19	7	0	17	9	0	13	13	0	6	20	0	22	4	0
30	21	5	0	17	9	0	14	12	0	10	16	0	6	20	0	20	6	0
TOTAL*	102	28		94	36		84	46		65	65		33	97		106	24	

Central Region

	Independence						Trend						Randomness					
Day		1%			5%			1%			5%			1%			5%	
Duration	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.
1	21	3	0	17	7	0	15	9	0	11	13	0	0	24	100	20	4	0
3	21	3	0	17	7	0	16	8	0	13	11	0	0	24	100	21	3	0
7	21	3	0	18	6	0	16	8	0	11	13	0	0	24	100	19	5	0
15	21	3	0	19	5	0	14	10	0	10	14	0	0	24	100	19	5	0
30	22	2	0	18	6	0	14	10	0	10	14	0	0	24	100	21	3	0
TOTAL*	106	14		89	31		75	45		55	65		0	120		100	20	

Southeastern Region

	Independence						Trend						Randomness					
Day		1%			5%			1%			5%			1%			5%	
Duration	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.
1	6	1	0	6	1	0	6	1	0	5	2	0	2	5	0	5	2	0
3	6	1	0	5	2	0	6	1	0	5	2	0	2	5	0	5	2	0
7	6	1	0	5	2	0	6	1	0	5	2	0		5	0	5	2	0
15	6	1	0	5	2	0	6	1	0	6	1	0		5	0	6	1	0
30	7	0	0	6	1	0	6	1	0	4	1	0		5	0	6	1	0
TOTAL*	31	4		27	8		30	5		25	10		10	25		27	8	

* Total of the 5 durations for Stations in this region

Dur : The duration the data set represents is average 30 day low flow.

5ig.: The number of stations which show significant dependence, trend, non randomness

Not : The number of stations which show now independence, free from trend, and randomness

Per : The percent binomial probability that this number of stations would fail the non Parametric tests.

TA8LE 4. Summary of Data Screening: Regulated Stations with A Period of Record Greater or Equal to 20 years.

Northeastern Region

	Independence						Trend						Randomness					
0ay		1%			5%			1%			5%			1%			5%	
Duration	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.
1	21	7	0	16	12	0	20	8	0	15	13	0	21	9	0	15	15	0
3	19	9	0	14	14	0	18	10	0	15	13	0	22	8	0	15	15	0
7	18	10	0	14	14	0	19	9	0	13	15	0	22	8	0	18	12	0
15	19	9	0	15	13	0	22	6	0	14	14	0	21	9	0	18	12	0
30	22	6	0	16	12	0	20	8	0	15	13	0	24	6	0	17	13	0
T0TAL *	99	41		75	65		99	41		72	68		110	40		83	67	

Northwestern Region

	Independence						Trend						Randomness					
Day		1%			5%			1%			5%			1%			5%	
Duration	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.
1	12	12	0	9	15	0	19	5	0	14	10	0	10	14	0	11	13	0
3	14	10	0	11	I3	0	20	4	0	16	8	0	8	16	0	12	12	0
7	15	9	0	12	12	0	20	4	0	18	6	0	9	15	0	14	10	0
15	14	10	0	11	13	0	22	2	0	18	6	0	10	14	0	I5	9	0
30	15	9	0	10	14	0	22	2	0	16	8	0	9	15	0	15	9	0
TOTAL *	70	50		50	67		103	17		82	38		46	74		67	53	

Southwest and West Central Region

	Independence						Trend						Randomness					
Day		1%			5%			1%			5%			1%			5%	
Duration	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.
1	30	18	0	25	23	0	18	30	0	13	35	0	5	44	0	28	21	0
3	29	19	0	26	22	0	16	32	0	12	35	0	5	44	0	29	20	0
7	29	19	0	24	24	0	19	29	0	12	36	0	5	44	0	28	21	0
15	29	19	0	25	23	0	18	30	0	16	32	0	5	44	0	29	20	0
30	26	22	0	24	24	0	18	30	0	12	36	0	5	44	0	27	22	0
TOTAL *	143	97		124	116		89	151		65	175		25	220		141	104	

Central Region

	Independence						Trend						Randomness					
Day		1%			5%			1%			5%			1%			5%	
Duration	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.
1	25	8	0	22	11	0	21	12	0	15	18	0	1	32	Z7	25	8	0
3	26	7	0	22	11	0	20	13	0	16	17	0	I	32	27	21	12	0
7	25	8	0	22	11	0	22	11	0	15	18	0	1	32	27	25	8	0
15	27	6	0	23	10	0	19	14	0	16	17	0	0	33	100	23	10	0
30	28	5	0	22	11	0	19	14	0	14	19	0	1	32	27	27	6	0
TOTAL *	131	34		111	54		101	64		76	89		4	161		121	44	

Southeastern Region

	Independence						Trend						Randomness					
Day		1%			5%			1%			5%			1%			5%	
Duration	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.
1	10	6	0	12	7	D	15	4	0	13	6	0	5	14	0	12	7	0
3	13	6	0	11	8	0	17	2	0	15	4	0	5	14	0	13	6	0
7	14	S	0	14	5	0	17	2	0	17	2	0	6	13	0	13	6	0
15	15	4	0	12	7	0	17	2	0	17	2	0	6	13	0	15	4	0
30	16	3	0	13	6	0	18	1	0	16	3	0	7	12	0	14	5	0
TOTAL *	71	24		62	33		84	11		78	17		29	66		67	28	

* Total of the 5 durations for stations in this region
Dur: The duration the data set represents le average 30 day low flow
Sig.: The number of stations which show significant dependence, trend, non randomness
Not : The number of stations which show independence, free from trend, and randomness
Per : The percent binomial probability that this number of stations would fail the non parametric tests.

TABLE 5. Summary of Data Screening: Non Regulated Stations With A Period Of Record Less Than 20 years.

Northwestern Region

	Independence						Trend						Randomness					
Day		1%			5%			1%			5%			1%			5%	
0uration	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.
1	19	1	0	17	3	0	19	1	0	17	3	0	8	12	0	15	4	0
3	18	2	0	17	3	0	19	1	0	18	2	0	3	12	0	15	5	0
7	18	2	0	17	3	0	19	1	0	16	4	0	8	12	0	16	4	0
15	19	1	0	16	4	0	19	1	0	16	4	0	8	12	0	15	4	0
30	19	1	0	16	4	0	19	1	0	16	4	0	8	12	3	15	5	0
TOTAL	93	7		83	17		95	5		83	17		40	60		78	22	

Northeastern Region

	Independence						Trend						Randomness					
Day		1%			5%			1%			5%			1%			5%	
Duration	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.
1	14	0	0	14	0	0	13	1	0	12	2	0	11	3	0	14	0	0
3	14	0	0	14	0	0	13	1	0	12	2	3	11	3	0	14	0	0
7	14	0	0	13	1	0	13	1	0	12	2	0	11	3	0	13	1	0
15	14	0	0	13	1	0	13	1	0	12	2	0	11	3	3	13	1	0
30	14	0	0	14	0	0	13	1	0	13	1	0	11	3	0	14	0	0
TOTAL*	70	0		68	2		65	5		61	9		55	15		68	2	

Southwest and West Central Region

	Independence						Trend						Randomness					
Day		1%			5%			1%			5%			1%			5%	
Duration	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.
1	16	2	0	16	2	0	16	2	0	14	4	0	4	16	0	13	7	0
3	16	2	0	16	2	0	16	2	0	14	4	0	4	16	0	12	8	0
7	17	1	0	17	1	0	16	2	0	12	6	0	4	16	0	14	6	0
15	18	0	0	17	1	0	17	1	0	11	7	0	4	16	0	16	4	0
30	18	0	0	18	0	0	17	1	0	15	3	0	4	16	0	17	3	0
TOTAL*	85	5		84	6		82	8		66	24		20	80		72	28	

Central Region

	Independence						Trend						Randomness					
Day		1%			5%			1%			5%			1%			5%	
Duration	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.
1	10	0	0	9	1	0	9	1	0	5	5	0	0	10	100	9	1	0
3	10	0	0	9	1	0	9	1	0	5	5	0	0	10	100	10	0	0
7	10	0	0	9	1	0	9	1	0	5	5	0	0	10	100	13	0	0
15	10	0	o	9	1	0	9	1	0	6	4	0	0	10	100	13	0	0
30	10	0	0	9	1	0	9	1	0	7	3	0		10	100	10	0	0
TOTAL*	50	0		45	5		45	5		28	22		0	50		49	1	

Southeastern Region

	Independence						Trend						Randomness					
		1%			5%			1%			5%			1%			5%	
Day Duration	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.
1	8	0	0	7	1	0	8	0	0	7	1	0	7	3	0	7	3	0
3	8	0	0	8	0	0	8	0	0	7	1	0	7	3	0	7	3	0
7	8	0	0	8	0	0	8	0	0	8	0	0	7	3	0	7	3	0
15	8	0	0	8	0	0	8	0	0	8	0	0	7	3	0	7	3	0
30	8	0	0	8	0	0	8	0	0	8	0	0	7	3	0	5	2	0
TOTAL*	40	0		39	1		40	0		38	2		35	15		33	14	

* Total of the 5 durations for stations In this region
Dur: The duration the data set represents is average 30 day low flow
Sig: The number of stations which show significant dependence, trend. non randomness
Not: The number of stations which show independence, free from trend, and randomness.
Per: The percent binomial probability that this number of stations would fail the non parametric tests.

TABLE 6. Summary of Data Screening: Regulated Stations with A Period of Record Less Than 20 Years.

Northwestern Region

	Independence						Trend						Randomness					
Day		1%			5%			1%			5%			1%			5%	
Duration	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.
1	6	0	0	6	0	0	6	0	0	6	0	0	2	4	0	6	0	0
3	6	0	0	6	0	0	6	0	0	6	0	0	2	4	0	6	0	0
7	6	0	0	6	0	0	6	0	0	6	0	0	2	4	0	6	0	3
15	6	0	0	8	0	0	6	0	0	6	0	0	2	4	0	6	0	0
30	6	0	0	6	0	0	6	0	0	6	0	0	2	4	0	6	0	0
TOTAL *	30	0		30	0		30	0		30	0		10	20		30	0	

Northeastern Region

	Independence						Trend						Randomness					
Day		1%			5%			1%			5%			1%			5%	
Duration	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.
1	6	0	0	6	0	0	6	0	0	6	0	0	6	3	0	6	3	0
3	6	0	0	6	0	0	6	0	0	6	0	0	6	3	0	6	3	0
7	6	0	0	6	0	0	6	0	0	6	0	0	6	3	0	6	3	0
15	6	0	0	6	0	0	6	0	0	6	0	0	6	3	0	6	3	0
30	6	0	0	6	0	0	6	0	0	6	0	0	6	3	0	6	3	0
TOTAL*	30	0		30	0		30	0		30	0		30	15		30	15	

Southwest and West Central Region

	Independence						Trend						Randomness					
Day		1%			5%			1%			5%			1%			5%	
Duration	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.
1	6	0	0	6	0	0	5	1	0	4	2	0	2	4	0	6	0	0
3	6	0	0	6	0	I0	5	1	0	3	3	0	2	4	0	6	0	0
7	6	0	0	6	0	i0	5	1	0	3	3	0	2	4	0	6	0	0
15	6	0	0	6	0	0	5	1	0	4	2	0	2	4	0	6	0	0
30	6	0	0	6	0	0	5	1	0	1	2	0	2	4	0	6	0	0
TOTAL*	30	0		30	0		25	5		18	12		10	20		30	0	

Central Region

	Independence						Trend						Randomness					
Day		1%			5%			1%			5%			1%			5%	
Duration	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.
1	8	0	0	8	0	0	8	0	0	6	2	0	0	9	0	8	1	0
3	8	0	0	8	0	0	7	1	0	7	1	0	0	9	0	8	1	0
7	8	0	0	7	1	0	7	1	0	6	2	0	0	9	0	8	1	0
15	8	0	0	7	1	0	7	1	0	7	1	0	0	9	0	8	1	0
30	7	1	0	7	1	0	7	1	0	7	1	0	0	9	0	8	1	0
TOTAL*	39	1		37	3		36	4		33	7		0	45		40	5	

Southeastern Region

	Independence						Trend						Randomness					
Day		1%			5%			1%			5%			1%			5%	
Duration	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.	Sig.	Not	Per.
1	12	0	0	12	00		12	0	0	11	1	0	8	5	0	12	1	0
3	12	0	0	12	0	0	12	0	0	11	1	0	8	5	0	12	1	0
7	12	0	0	12	0	0	12	0	0	11	1	0	8	5	0	12	1	0
15	12	0	0	12	0	0	12	0	0	11	1	0	8	5	0	12	1	0
30	12	0	0	12	0	0	12	0	0	11	1	0	8	5	0	12	1	0
TOTAL*	60	0		60	0		60	0		55	5		40	25		60	5	

* Total of the 5 durations for stations in this region
Dur: The duration the data set represents is average 30 day low flow
Sig: The number of stations which show significant dependence, trend, non randomness
Not: The number of stations which snow independence, free from trend, and randomness
Per : The percent binomial probability that this number of stations would fall the non parametric tests