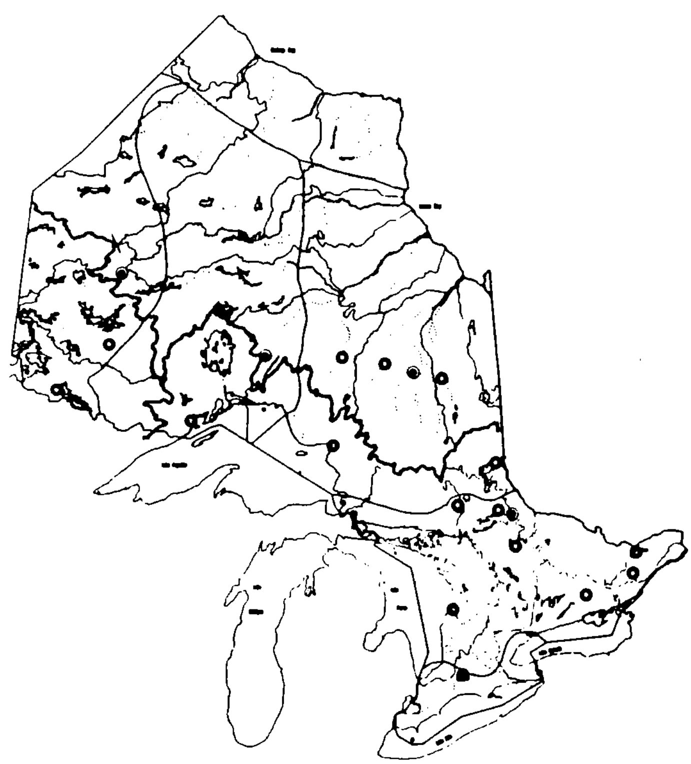
Environment Canada, Inland Waters Directorate
Water Resources Branch

Criteria Development to Identify Surface Water Monitoring Stations Applicable for Climate Change Studies



March 1992

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1.0 INTRODUCTION

In 1990, the Canadian Federal Government published Canada's Green Plan (Environment Canada, 1990). This plan was a review of the Government's environmental responsibilities with respect to the goals and objectives it should be meeting.

Mandates and objectives of various departments, of Environment Canada, would then be revised to reflect any changes in priorities of goals identified by the above review. The Conservation Protection Branch of Environment Canada produced the document "A Greenprint for C&P Water Programs" (Inland Waters Directorate, 1991) which summarized the roles of various sub-departments and identified revised emphasis that was related to their specific programs. The above review identified Climate Change Information as a high priority objective.

The Water Resources Branch maintains an active gauging network in Ontario of over 400 hydrometric stations. The station network is constantly evolving as dictated by data requirements, economics and environmental goals and priorities. Constant review of this network is undertaken on the basis of maintaining a long term record database in hydrologically homogeneous regions.

Surface water characteristics are directly related to climate. Hence, a study of the surface water resources is an important component of any investigation involving climate change. Since climate change investigations have become a priority, it is therefore important to review the existing streamflow gauging network to identify stations which may ultimately become useful in identifying the effect of climate change on surface water resources.

In response, the Ontario Regional office of the Water Resources Branch commissioned the following study in January, 1992. The objectives of the study are to :

- Determine what criteria would qualify stations in the network as appropriate stations to identify for climate trend analysis.
- Screening stations in the existing network file and determine a subset of stations representative of the above criteria.
- Examine some of the characteristic flows (i.e. maximum, means and minimums) for the subset with regards to trend.
- Recommend future investigations with regards to the establishment of a surface water monitoring network which can be used for climate change research.

The report summarizes the development of criteria for selecting appropriate stations (Section 2.0), the process of station selection from available information (Section 3.0), a review of selected flow characteristics in regards to possible trends (Section 4.0), and a summary of conclusions and recommendations of the findings (Section 5.0).

2.0 CRITERIA DEVELOPMENT

In order to establish the current "state of science" in climate change studies, two approaches were undertaken. The first involved a literature review of recent papers and studies (summarized in Section 2.1). The second included discussions between climate and water resource specialists (summarized in Section 2.2). Station selection criteria were then developed and are summarized in Section 2.3.

2.1 Summary of Literature Review

2.1.1 Relevant Streamflow Station Criteria

Most of the studies available were found to concentrate on assessment of potential hydrometric impacts as a result of various climate change scenarios. Therefore, in order to extract some criteria for identification of hydrometric stations appropriate for monitoring and assessing climate change impacts on streamflow, relevant selection parameters were undertaken from these studies. Table 2.1 summarizes information relevant to hydrometric station selection for climate change studies such as:

- author
- year of study
- record length used in the study
- regulation type
- spatial relationship of climate grids
- climate parameters investigated
- flow characteristics reviewed
- pertinent results.

The review of station characteristics indicates the use of record lengths of typically 10 to greater than 70 years. It could be inferred that a 30 year record length is a possible minimum standard.

Most of the investigations screened out regulated stations. Hydrometric and climate station networks used in Regional climate change studies were noted to have a spatial density of one station for every 10^2 km^2 to 10^6 km^2 area. Records of precipitation and temperature were reviewed in all studies and some additional parameters such as; sunshine, humidity, evaporation, wind speed, evapotranspiration and soil moisture were also reviewed in several studies. Most of the studies examined the effect of climate change on mean monthly, low flows and high flows.

TABLE 2.1
SUMMARY OF STATION CHARACTERISTICS IDENTIFIED FROM THE LITERATURE REVIEW

Author	Year	Record Length (years)	Regulation Type	Size of Climate Zones	Climate Parameters	Flow Values	Temperature Results
Goertz	1987	30+	Natural	7-8 Nodes in Ontario (1.3×10^5 km^2)	Precipitation Temperature	Monthly Runoff	Seasonal Changes
Byrne	1991	70+	N.A.	450 km x 700 km (3.4×10^5 km^2)	Precipitation Temperature Sunshine Humidity	Low Flows High Flows (10 day averages)	Seasonal Changes
Pilon	1991	40 - 60	Natural	7 Atlantic (3.0×10^4 km^2) 27 Canada (3.7×10^5 km^2) (spatial distribution is inadequate)	N.A.	Low Flows High Flows Monthly Means	N.A.
Burrell	1991	>10	Natural	39 Stations in New Brunswick (7.3×10^2 km^2)	Precipitation Temperature Evaporation	Low Flows High Flows 1/3/5 year moving averages	No Long Term Trend Evident in 20 year cycle
Verhoog	1987	N.A.	N.A.	N.A.	Precipitation Evapotranspiration Windspeed Humidity Sunshine	Mean annual runoff sedimentation changes	Geomorphic and vegetation regimes
Gleink	1987	20 - 60	N.A.	Regional 10^5 - 10^6 km^2 Watershed 10^2 - 10^5 km^2	Precipitation Temperature Evapotranspiration Soil Moisture	Mean annual flow High Flow Low Flow	Seasonal variations

Some additional characteristics reviewed were n-day average flows, annual mean flows, n-year moving averages and changes in the sedimentation regime.

The main emphasis of the majority of studies was changes to the seasonal magnitude and temporal occurrence changes in flow regimes.

2.1.2 Climate Change Effects on Hydrometric Information

In addition to the above review the literature was also summarized to determine the possible effects on surface water relating to the effect of climate change. While some of the literature discussed climate change as a cyclic action with no real long term monotonic direction (Burrell, 1992) most of the recent studies dealt with the possible effect of global warming on the hydrologic cycle, caused by a doubling of atmospheric CO_2.

The consensus of these papers indicates that global warming will have a dramatic effect on rates and timing of precipitation and evapotranspiration. Many investigations suggested that climate change could result in a reduction of soil moisture in numerous regions throughout the world. This could occur due to the following factors:

- a decrease in snow as a proportion of winter precipitation;
- an earlier and faster snow melt due to higher average temperatures;
- more severe evapotranspiration during the warmer summer months; and,
- lower precipitation rates during the summer months.

The decrease in snow as a proportion of winter precipitation and earlier and faster spring melts may result in increased potential for flooding in areas currently susceptible to spring flooding. Also, the increased variability of stream flow means that water supplies under natural runoff conditions will decline during the summer months.

Several investigations (Pilon 1991, Goertz 1987, Tasker 1990 see Appendix A) also suggested that a net rise in the temperature could result in an increase in annual precipitation. F.H. Verhoog notes that a net rise in temperature of 4.5° C could result in an increase in annual precipitation including most of Canada. Other regions of the world, particularly arid and semi-arid regions, would experience a net decrease in precipitation.

Increases in the evapotranspiration rate may be related more to an increase in atmospheric CO_2 as well as global warming. The suggestion has been made that as the concentration of CO_2 increases significant changes in the way plant life will convert water and nutrients into energy will also occur. This may result in much higher transpiration rates.

An investigation was undertaken by the Water Resources Branch (Goertz, 1987) in the mid 1980's, to assess the impacts of climate change on basin runoff. The assessment was based on hydrologic modelling of a single basin in Ontario. The study involved modifications to monthly temperatures and precipitation rates and the results of the analysis showed dramatic changes in runoff relative to the changes in precipitation and temperature. In addition, results showed that changes in runoff were dependent more on precipitation than on temperature and the ratio between the change in precipitation and the change in runoff may be quite large.

The impacts of climate change on precipitation and evapotranspiration as described in the literature reviewed for this study, may be quite dramatic and significant in the future. This underscores the need for continued long term, collection of hydrological and climatological data. More accurate assessments of the effect of climate change on hydrology would be possible in the future with an accurate, long term hydrometric database.

2.1.3 Climate Zones in Ontario

From the literature review and professional discussions, it was identified that hydrometric representation of distinct climate zones in Ontario was desirable.

A recent publication by Environment Canada (1989) entitled Eco-climatic Regions of Canada, identified 4 major divisions for climate zones in Ontario and each major zone was divided into several sub-zones.

Eco-climatic regions are zones on the surface of the earth which are characterized by particular ecological responses to climate. The eco-climatic region is therefore a combination of the climate and ecological relationship between the living and non-living components of the environment.

Since the delineation of eco-climatic regions is based largely on the vegetative response to climate it was assumed that these regions might be effective in monitoring changes in climate. A number of the papers reviewed for this study held that, in addition to increased CO_2 levels, a major indicator of climate change would be changes in vegetation.

The four major eco-climatic zones were subsequently modified (i.e. a large zone in Northern Ontario was subdivided into three zones, see Section 2.2 and 3.0) resulting in six eco-climatic regions for Ontario.

The six eco-climatic regions are identified as follows:

Low Subarctic (LS):	This region is dominated by stands of black spruce, with dwarf birch, Labrador Tea, and moss. Summers are cool and last for four to five months. Winters are very cold and snowy.
Humid Mid-Boreal (MBh):	This region is characterized by stands of whit spruce, balsam fir, and paper birch. The summers are warm and winters are cold with average daily temperatures greater than 0°C lasting for approximately 7 months. The growing season lasts from around mid-june to early september (approximately 75 days). Summer precipitation averages 100 mm per month while winter precipitation is around 50 mm per month.
Subhumid Mid-Boreal (MBs):	This region is characterized by stands of trembling aspen and balsam poplar. The summers are warm and moist,, while the winters are very cold and snowy. Average annual precipitation is approximately 430 mm. The frost free period ranges from 80 to 120 days.
Moist Mid-Boreal (MBx):	This region is characterized by stands of white spruce, balsam fir, jack pine, and black spruce. Summers are warm and rainy and winters are cold and snowy. Average annual precipitation is approximately 800 mm.
Humid Mid-Cool Temperate (MCTh):	The tree species common in this region include sugar maple, beech, and eastern hemlock. The summers are warm and the winters are mild. Mean daily temperatures above 0°C extend from April to November. Monthly precipitation is evenly distributed throughout the year and averages 70 mm.
Humid High Moderate Temperate (HMTh):	The tree species common in this region include sugar maple, beech, white oak, red oak and shagbark hickory. Summers are humid and hot and mean daily temperatures are above 0°C eight to nine months of the year. Winter are mild and snowy with monthly precipitation averaging 75 mm.

2.2 Summary of Meeting Results

Additional information was obtained through discussions with staff of the Water Resources Branch and the Atmospheric Environment Service (AES). This information is summarized as follows.

Distinct Climate Regions

- AES is involved in ongoing studies and have identified climate regions in Canada. (This information was provided and there appears to be two regions in Ontario).
- The Eco-Climate Regions (Canadian Wildlife, 1989) was presented by CCL and subsequently were discussed. It was generally agreed that the major divisions may be a good indication of distinct climate zones since the division was based on climate, soil, vegetation, wildlife and water.
- It was pointed out that in Northern Ontario there are distinct areas from west to east.
- It was also suggested that major drainage basin sub-divisions might represent a feasible alternative to review as boundaries for sub-climatic zones etc.
- Climate zones are expected to shift and therefore, location of hydrometric stations based only on climate zone location may not be reasonable. (In addition, hydrometric station locations should be located centrally - i.e. away from borders to avoid noise from random border shifts).

Climate Change

- Discussions focused on the ability to identify monotonic trend and/or cyclic climate change.
- It appears that most long term climate records (i.e. 100-200 years) may not be sufficient to quantify trends as either increasing or decreasing.
- Results from an ongoing temperature study indicate that over the last decade, a 1°C increase in mean annual temperature has been observed. AES staff are currently reviewing the statistical significance of these results.

Record Length

- A list of long term climate stations (used in the temperature study) was obtained from AES.

- AES is also concerned with short record length stations, and will in the near future, be undertaking a study to re-create long-term climate characteristics through known inter-relationships (i.e. tree ecology etc).

- AES used a 100 year long data base which was populated by inter-correlating short and long term records for the temperature study.

- It was generally agreed that a 30 year minimum record length is fairly short, recent studies on ice breakup characteristics undertaken by staff at AES used station record lengths of 30-35 years.

Parameters

- Most participants agreed that temperature and precipitation are the parameters most frequently discussed in the literature with regards to the effects on hydrometric characteristics.

- AES currently is developing a historical data base to use with climate change studies. Temperature is the main focus of the data base at this time.

- Evaporation, sunshine, and wind were other parameters which may be important for climate/hydrometric change studies.

- The urban heat islands of Toronto and Montreal have been identified as areas recommended to be avoided (AES used London and Peterborough stations as closest stations in their long term temperature station network).

- The pros and cons of selecting hydrometric drainage areas were identified as part of the hydrometric screening (i.e. large basins may reflect scales of existing global climate models (GCM's) where small basins may reflect local characteristics.

- It was also suggested that water levels may be important for climate change analysis with regards to the Great Lakes.

Locational and Spatial Relationships

The minimum density of climate stations and hydrometric stations was discussed.

- It was indicated that temperature data may be applicable up to a 200km radius.

- Precipitation data may be valid up to 50km from the meteorological stations in northern Ontario.

- Conservative seasonal changes indicated that in southern Ontario a 10km radius may be recommended for precipitation.

- The above values were discussed as subjective approximations only.

- Other characteristics such as elevation and basin physiography, may play an important role in describing hydro-climatic relationships.

- Watershed versus regional hydrometric climate network issues were also discussed.

- Approximately 8 nodes represent the Ontario region in the present GCM's.

- A refinement of grid size down to 75km to 95km was identified as the possible next step in improving. Although this would require significant increases in the present computational power.

  The authors of the present study indicated that it would appear that the hydrometric climate change network would contain about 10-15 stations. AES staff indicated that more would be better, but they are also aware of the economics of the network and record length inter-relationships.

2.3 Station Selection Criteria

The information acquired through the literature review and the data obtained from Environment Canada were used to develop the station selection criteria. The literature review clearly indicated that stream flow stations used to monitor trends in climate should presently have a long term record of at least 30 years. These hydrometric stations should be unregulated, that is that these stations should have a minimum of human interference and represent natural stream flow conditions. Additional hydrometric station selection criteria are:

- representation of distinct climate regions
- centrally located in a climate region to avoid border noise
- location with respect to proximity of long term climate stations
- representation of major drainage basins
- availability of additional parameter information (e.g. sediment and water quality information).

Since climate station location and hydrometric station location interrelationships are important, and there is no designated climate station network for use in climate change studies, a preliminary attempt has been made to identify identifying appropriate index climate stations.

Climate stations should also have a long term record of 30 years or more. They should monitor at least precipitation and temperature. Climate experts also implied that climate stations should be ranked in the following order:

- Climate stations currently used by AES to monitor climate trend;
- Climate stations used to delineate the eco-climatic regions in canada;

- Climate stations measuring parameters other than precipitation and temperature; and,
- Climate stations measuring precipitation and temperature.

3.0 STATION SELECTION

Based on the results of the literature review and the discussions with AES Staff, a map of distinct climate regions in Ontario was developed. This map was essentially based on the major eco-climate regions identified in Section 2.1 and professional interpretation of climate factors in Ontario (see Figure 3.1).

Subsequent to identification of the main eco-climate regions, the analysis focused on screening available climate and hydrometric data bases for stations with appropriate characteristics. In Section 3.1 the methodology for climatological station selection is summarized while section 3.2 summarizes the hydrometric selection process.

3.1 Climate Station Screening

3.1.2 Screening Criteria

The climatological stations data base was screened for stations that were currently operating and monitored for precipitation and temperature. This data base contains over 4,100 records (some stations were represented in a number of records due to data collection format changes and discontinuous records) and was current to 1989. The large data base was then condensed so that all data for each climatological station was summarized per record. additional screening criteria of currently active stations, with minimum record length of 30 years, measuring parameters of precipitation and temperature resulted in a master list of 243 climatological stations (see Appendix C). Stations located within a 50km radius of Toronto were omitted to avoid any urban heat island affects.

3.1.3 Ranking Methodology

The climate stations were divided into four priority groups based on information from discussions with Atmospheric Environment Service staff, which was then added to the master climatological database. The priority groups were given the following ranking.

Figure 3.1
Climate Zones of Ontario

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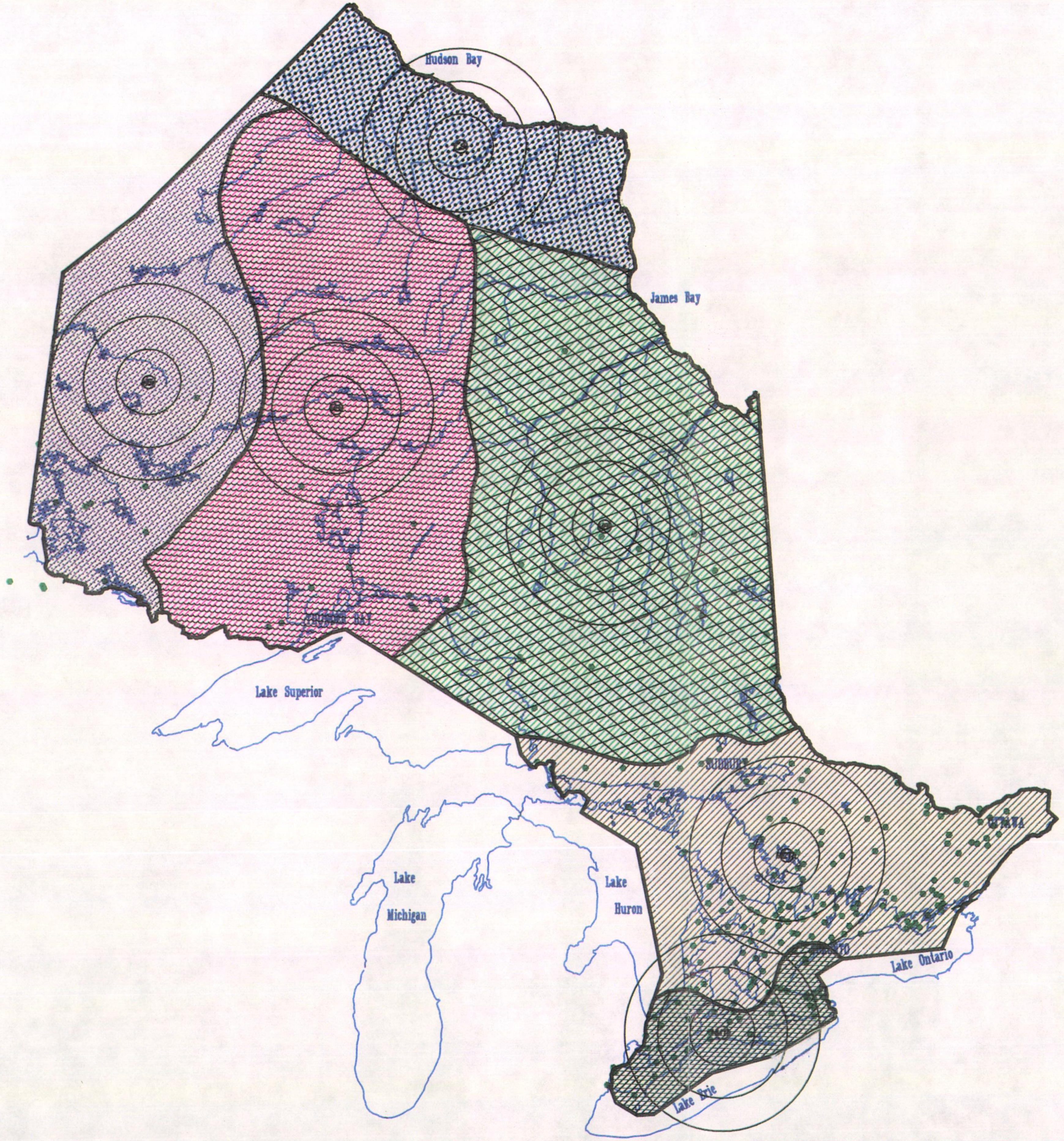

LEGEND

Climate Stations

Ecoclimatic Boudaries

Centroid of Climate Region

50 Km Radius Intervals

MODERATE TEMPERATE HUMID

SUBARCTIC

BOREAL HUMID

BOREAL SUBHUMID

BOREAL MOIST

COOL TEMPERATE HUMID

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1. Climate stations currently used by AES to monitor climate trend
2. Climate stations used to delineate the eco-climatic regions in Canada
3. Climate stations measuring parameters other than precipitation and temperature
4. Climate stations measuring precipitation and temperature

The master climatological stations were then screened using the following ranking formula:

$$R = (100/p) + (50/c) + ((50 \cdot r)/100)$$

Where: R = the station ranking score
p = the station priority ranking
c = the station's distance to the centroid of the eco-climatic region (km)
r = the station's period of record (years)

Table 3.1 lists the stations which had a ranking score of greater than 75.

Further review was then carried out on the selected stations based on station ranking, location and additional parameter availability. Table 3.2 identifies five climatological stations which were selected as the most appropriate to represent the climate regions identified in this study. The sixth region had no climate station available for selection. In our opinion, these stations should be considered to be important base reference station locations in future climate station selections for a climate change network.

TABLE 3.2
RECOMMENDED CLIMATE STATIONS FOR USE AS INDEX STATIONS FOR HYDROMETRIC NETWORK ANALYSIS

				PARAMETERS									
NUMBER	STATION NAME	FROM	TO	P	T	W	E	S	P	ECO ZONE	c	r	R
6144475	LONDON A	1940	1990	X	X			S	1	HMTh	36.090	50.00	127.77
6085700	NORTH BAY A	1939	1990	X	X			S	1	MCTh	145.970	51.00	126.19
6073975	KAPUS-KASING A	1937	1990	X	X				1	MBh	70.930	53.00	127.91
6034075	KENORA A	1938	1990	X	X				1	MBx	581.440	52.00	126.17
6016525	PICKLE LAKE	1930	1990	X	X	U	A		1	MBs	387.610	60.00	130.26

Legend: P - Precipitation T - Temperature W - Wind Speed E - Evaporation S - Sunshine
c - Centroid Distance r - Record Length R - Ranking Score p - station priority ranking

TABLE 3.1
SUMMARY OF CLIMATE STATIONS WITH A RANKING SCORE OF GREATER THAN 75

NUMBER	STATION NAME	FROM	TO						p	ECO CLIMATE ZONE	c	r	R
6130257	AMHERSTBURG	1882	1990	X	X				4	HMTh	175.500	108.00	79.57
6137147	RIDGETOWN	1883	1990	X	X				4	HMTh	65.610	107.00	80.02
6136694	PORT STANLEY	1871	1990	X	X				4	HMTh	5.190	119.00	103.75
6148120	STRATHROY	1879	1990	X	X				4	HMTh	43.130	111.00	82.82
6139445	WELLAND	1872	1990	X	X				4	HMTh	162.070	118.00	84.62
6144475	LONDON A	1940	1990	X	X			S	1	HMTh	36.090	50.00	127.77
6149625	WOODSTOCK	1870	1990	X	X				4	HMTh	60.350	120.00	86.66
6136626	PORT DALHOUSIE	1874	1990	X	X				4	HMTh	168.320	116.00	83.59
6137285	ST CATHARINES	1882	1990	X	X				4	HMTh	170.630	108.00	79.59
6137287	ST CATHARINES A	1971	1990	X	X	U			1	HMTh	176.690	19.00	110.07
6151866	COPETOWN	1882	1990	X	X				4	MCTh	204.090	108.00	79.49
6156670	PORT HOPE	1882	1990	X	X				4	MCTh	173.900	108.00	79.58
6124700	LUCKNOW	1885	1990	X	X				4	MCTh	182.760	105.00	78.05
6150689	BELLEVILLE	1866	1990	X	X				4	MCTh	212.040	124.00	87.47
6112171	DURHAM	1882	1990	X	X				4	MCTh	127.210	108.00	79.79
6166418	PETERBOROUGH A	1969	1990	X	X	U			1	MCTh	148.840	21.00	111.17
6119500	WIARTON A	1947	1990	X	X			S	1	MCTh	109.820	43.00	122.41
6165195	MINDEN	1883	1990	X	X				4	MCTh	88.020	107.00	79.64
6092925	GORE BAY A	1947	1990	X	X				1	MCTh	239.820	43.00	121.92
6085700	NORTH BAY A	1939	1990	X	X			S	1	MCTh	145.970	51.00	126.19
6072225	EARLTON A	1938	1990	X	X				1	MBh	342.620	52.00	126.29
6059D09	WAWA A	1976	1990	X	X	U			1	MBh	225.970	14.00	107.44
6041109	CAMERON FALLS	1924	1990	X	X				2	MBx	240.680	66.00	83.42
6073975	KAPUSKASING A	1937	1990	X	X				1	MBh	70.930	53.00	127.91
6034075	KENORA A	1938	1990	X	X				1	MBx	581.440	52.00	126.17
6032117	DRYDEN	1914	1990	X	X				2	MBs	550.620	76.00	88.18
6075425	MOOSONEE	1932	1990	X	X	U	A	S	1	MBh	227.130	58.00	129.44
6016525	PICKLE LAKE	1930	1990	X	X	U	A		1	MBs	387.610	60.00	130.26

Legend: P - Precipitation T - Temperature W - Wind Speed E - Evaporation S - Sunshine c - Centroid Distance r - Record Length R - Ranking Score p - station priority ranking

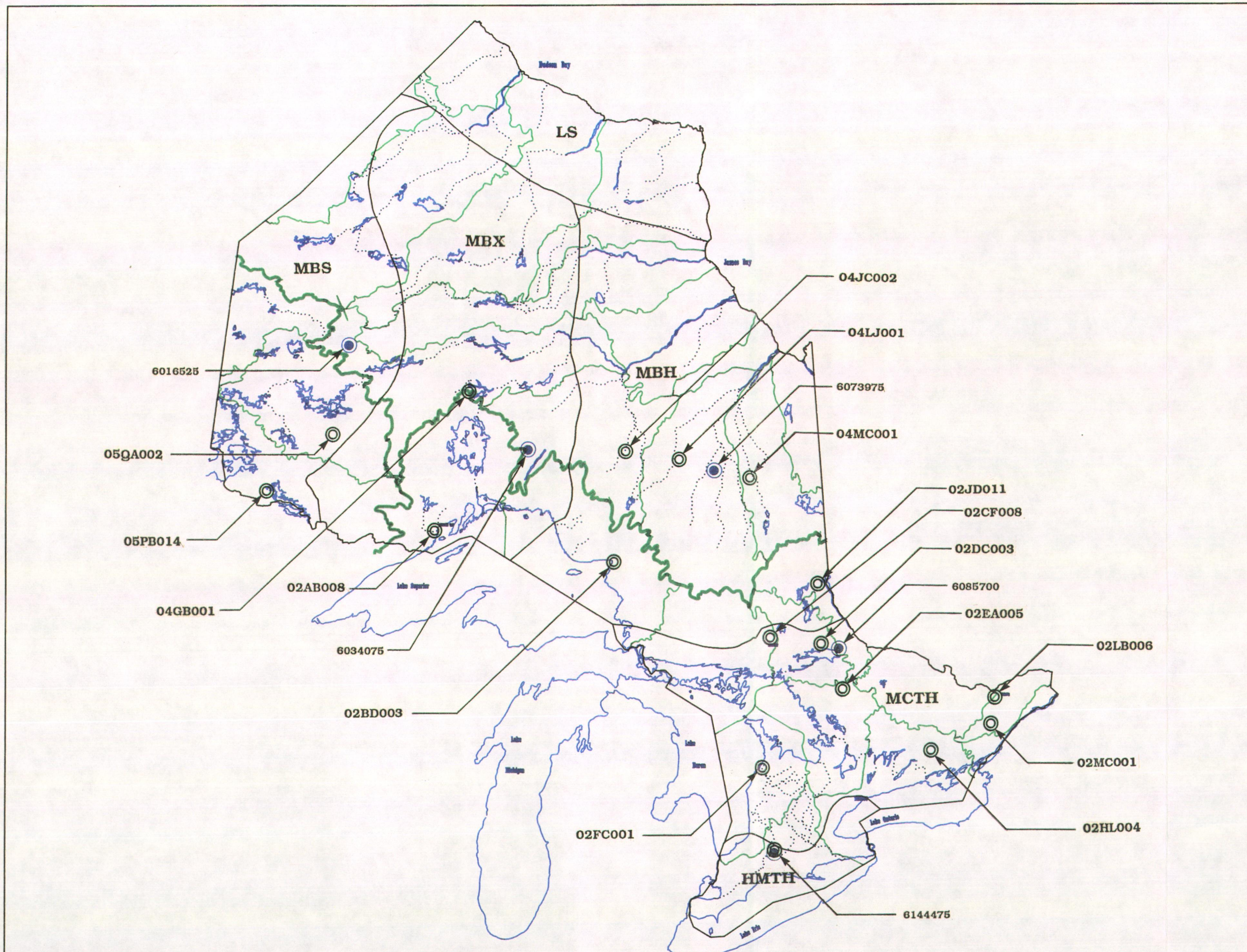

Figure 3.2
Stations Recommended for use in a Hydrometric Station Climate Change Network

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- Top Ranked Climate Stations
- Top Ranked Hydex Stations
- Climate Zones
- Drainage Basins
- Main Rivers
- Main Drainage Divide

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3.2 Hydrometric Station Screening

The data used for this analysis was obtained from the "HYDAT" version 3.0 optical disk supplied by the Inland Waters Directorate of Environment Canada. The optical disk contains data describing 743 flow monitoring stations in Ontario.

An initial screening of the hydrometric database was undertaken to identify currently operating, unregulated flow monitoring stations with more than 30 years of record. Application of this criteria resulted in a list of 41 acceptable hydrometric stations. The locations of these stations was such that the spatial distribution of stations was considered not representative of the six eco-climate regions (identified in Section 2.1 and Section 3.1).

Since the 41 stations were not sufficient to spatially represent an Ontario hydrometric climate change network, a relaxation of the selection criteria was required. It was therefore decided to relax the regulation index and accept some stations identified as having some regulation (heavily regulated stations were omitted completely). This screening was completed using a combination of filters contained in the "HYDAT" software and dBASE IV. These station locations were plotted onto a map of Ontario using our TerraSoft G.I.S. system. The result was a database of approximately 178 streamflow stations. These stations and characteristics are tabulated in Appendix C.

It was identified that the 41 acceptable stations, would represent natural flow conditions and hence, would be best suited to review station flow characteristic trends in Ontario (see Section 4.0 for details).

A secondary screening of hydrometric stations was undertaken to determine which of the above noted stations would be best for climate trend studies. The six eco-climate zones were plotted onto a map of Ontario using the TerraSoft G.I.S. software. The G.I.S. was then used to determine the centroid location of each of the six zones. The centroids of major drainage basins within each climate region were also identified. A special screening of stations within a 50 km radius of Toronto identified 13 stations which were omitted from the data set due to assumed heat island effects.

The secondary screening of the hydrometric stations was based on the following equation:

$$R = (100/p) + (100/d) + (100/C_l) + (50/c) + ((r \cdot 50)/100)$$

Where: R = the hydrometric station's ranking score
p = the station's priority ranking (with regard to regulation)
d = the station's distance to the centroid of the drainage basin (km)
C_l = the station's distance from the climate station chosen for the zone (km)
c = the station's distance to the centroid of the eco-climate zone (km)
r = the station's record length (years)

Table 3.3 lists hydrometric stations with a ranking score greater than 100. Seventeen hydrometric stations were then chosen based on each having the highest ranking score in its respective drainage basin (see Table 3.4).

As the table illustrates, all but one of the climate zones are represented and all but four of the recommended stations are identified as not being significantly influenced by regulation. The four regulated stations regulation and flow characteristics should be examined to identify or verify that the regulation can be accounted for by indepth station reviews and/or naturalization techniques.

The selection of seventeen stations results in a spatial density of approximately 6.3×10^4 km^2 per station which is consistent with Regional climate change networks. The average record length is approximately 47 years, which also meets the minimum standard identified previously. The location of the 17 stations is illustrated on Figure 3.2.

TABLE 3.3
SUMMARY OF HYDROMETRIC STATIONS WITH RANKING SCORE OF GREATER THAN 100

NUMBER	STATION	FROM	TO	AREA	REG.	C	D	CI	p	BASIN	ZONE	R
02EA005	NORTH MAGNETAWAN RIVER NEAR BURK'S FALLS	1915	1990	321.00	N	75.46	8.57	75.39	1	2E	MCTh	151.65
02FC001	SAUGEEN RIVER NEAR PORT ELGIN	1914	1990	3960.00	N	139.07	19.23	261.53	1	2F	MCTh	144.44
04LJ001	MISSINAIBI RIVER AT MATTICE	1920	1990	8640.00	N	8.99	67.65	66.56	1	4L	MBh	144.04
02GD013	WYE CREEK NEAR THORNDALE	1953	1990	38.90	N	41.62	23.63	5.58	1	2G	HMTh	142.38
02EC002	BLACK RIVER NEAR WASHAGO	1915	1990	1520.00	N	60.08	35.23	183.23	1	2E	MCTh	142.22
02FC002	SAUGEEN RIVER NEAR WALKERTON	1914	1990	2150.00	N	146.99	34.01	282.60	1	2F	MCTh	142.13
05PB014	TURTLE RIVER NEAR MINE CENTRE	1914	1990	4870.00	N	651.04	73.30	309.35	1	5P	MBs	140.26
05QA002	ENGLISH RIVER AT UMFREVILLE	1921	1990	6230.00	N	546.27	71.18	167.94	1	5Q	MBs	137.09
02FB007	SYDENHAM RIVER NEAR OWEN SOUND	1915	1990	181.00	N	107.85	16.72	237.46	1	2F	MCTh	135.86
05QA001	ENGLISH RIVER NEAR SIOUX LOOKOUT	1921	1981	13900.00	N	518.51	36.48	161.83	1	5Q	MBs	133.96
02GD003	NORTH THAMES RIVER BELOW FANSHAWE DAM	1915	1990	1450.00	R	35.70	22.07	2.43	2	2G	HMTh	131.13
02GA010	NITH RIVER NEAR CANNING	1913	1990	1030.00	N	216.42	50.49	382.39	1	2G	MCTh	130.49
02BD003	MAGPIE RIVER NEAR MICHIPICOTEN	1939	1990	1930.00	N	231.49	29.09	250.13	1	2B	MBh	130.05
02FF002	AUSABLE RIVER NEAR SPRINGBANK	1945	1990	865.00	N	51.94	157.04	40.40	1	2F	HMTh	127.07
02GD010	FISH CREEK NEAR PROSPECT HILL	1945	1990	150.00	N	234.62	39.61	377.40	1	2G	MCTh	126.00
02ED003	NOTTAWASAGA RIVER NEAR BAXTER	1947	1990	1180.00	N	93.69	32.93	237.92	1	2E	MCTh	125.99
02GG002	SYDENHAM RIVER NEAR ALVINSTON	1947	1990	730.00	N	52.61	75.10	62.60	1	2G	HMTh	125.88
02LB007	SOUTH NATION RIVER AT SPENCERVILLE	1948	1990	246.00	N	306.08	30.67	313.08	1	2L	MCTh	125.24
02GC010	BIG OTTER CREEK AT TILLSONBURG	1960	1990	342.00	N	43.26	19.07	38.94	1	2G	HMTh	124.47
02LB006	CASTOR RIVER AT RUSSELL	1948	1990	433.00	N	317.75	154.82	301.68	1	2K	MCTh	122.63
04JC002	NAGAGAMI RIVER AT HIGHWAY NO. 11	1950	1990	2410.00	N	98.61	102.05	166.84	1	4J	MBh	122.59
02FC011	CARRICK CREEK NEAR CARLSRUHE	1953	1990	163.00	N	144.23	36.83	281.54	1	2F	MCTh	122.42
02GA018	NITH RIVER AT NEW HAMBURG	1950	1989	552.00	N	201.68	54.43	347.08	1	2G	MCTh	122.37
02FF004	SOUTH PARKHILL CREEK NEAR PARKHILL	1955	1990	41.40	N	62.20	150.11	47.35	1	2F	HMTh	121.58
04LF001	KAPUSKASING RIVER AT KAPUSKASING	1918	1990	6760.00	R	73.80	37.02	3.18	2	4L	MBh	121.34
02AB008	NEEBING RIVER NEAR THUNDER BAY	1953	1990	187.00	N	324.47	95.73	111.49	1	2A	MBx	121.10
04JC003	SHEKAK RIVER AT HIGHWAY NO. 11	1950	1987	3290.00	N	89.10	110.59	157.20	1	4J	MBh	121.10
02FA001	SAUBLE RIVER AT SAUBLE FALLS	1957	1990	927.00	N	124.03	30.62	239.12	1	2F	MCTh	121.09
02HL004	SKOOTAMATTA RIVER NEAR ACTINOLITE	1955	1990	712.00	N	200.53	83.21	253.28	1	2H	MCTh	119.85
02MC001	RAISIN RIVER NEAR WILLIAMSTOWN	1960	1990	404.00	N	350.03	30.02	334.76	1	2L	MCTh	119.27
02HA006	TWENTY MILE CREEK AT BALLS FALLS	1957	1990	293.00	N	157.98	162.28	144.03	1	2H	HMTh	118.63
05QA004	STURGEON RIVER AT MCDOUGALL MILLS	1961	1990	4450.00	N	511.76	35.87	139.19	1	5Q	MBs	118.60
02HD008	BOWMANVILLE CREEK AT BOWMANVILLE	1959	1990	82.90	N	156.07	58.64	274.79	1	2H	MCTh	118.39

NUMBER	STATION	FROM	TO	AREA	REG.	C	D	CI	p	BASIN	ZONE	R
02EA005	NORTH MAGNETAWAN RIVER NEAR BURK'S FALLS	1915	1990	321.00	N	75.46	8.57	75.39	1	2E	MCTh	151.65
02HM002	DEPOT CREEK AT BELLROCK	1957	1990	189.00	N	239.84	121.70	282.90	1	2H	MCTh	118.38
02GB009	KENNY CREEK NEAR BURFORD	1961	1990	91.90	N	227.95	42.38	373.92	1	2G	MCTh	117.85
02CF008	WHITSON RIVER AT VAL CARON	1960	1990	179.00	N	193.08	112.90	129.35	1	2C	MCTh	117.42
02EA006	MAGNETAWAN RIVER NEAR BURK'S FALLS	1915	1990	650.00	R	70.15	7.95	80.94	2	2E	MCTh	102.53

Legend:

Number	- Station Identification
Station	- Station Name
From	- Starting Year of Record
To	- Last Year of Record
Area	- Drainage Area to Gauge
Reg	- Regulation Identification
C	- see text list
D	- see text list
c_i	- see text list
P	- see text list
Basin	- Major Drainage Basin
Zone	- Climatic Zone
R	- Ranking Score

TABLE 3.4
HYDROMETRIC STATIONS RECOMMENDED FOR SELECTION
FOR USE IN A CLIMATE CHANGE NETWORK

NUMBER	STATION	FROM	TO	REG.	BASIN	ZONE	RANKING
05QA002	ENGLISH RIVER AT UMFREVILLE	1921	1990	N	5Q	MBs	137.09
05PB014	TURTLE RIVER NEAR MINE CENTRE	1914	1990	N	5P	MBs	140.26
04LB001	MATTAGAMI RIVER AT SMOOTH ROCK FALLS	1920	1990	R	4M	MBh	90.86
04LJ001	MISSINAIBI RIVER AT MATTICE	1920	1990	N	4L	MBh	144.04
04JC002	NAGAGAMI RIVER AT HIGHWAY NO. 11	1950	1990	N	4J	MBh	122.59
04GB001	OGOKI RIVER AT WABOOSE FALLS DAM	1941	1990	R	4G	MBx	78.30
02LB007	SOUTH NATION RIVER AT SPENCERVILLE	1948	1990	N	2L	MCTh	125.24
02LB006	CASTOR RIVER AT RUSSELL	1948	1990	N	2K	MCTh	122.63
02JD011	LADY EVELYN RIVER AT LADY EVELYN LAKE	1946	1990	R	2J	MBh	87.63
02HL004	SKOOTAMATTA RIVER NEAR ACTINOLITE	1955	1990	N	2H	MCTh	119.85
02GD013	WYE CREEK NEAR THORNDALE	1953	1990	N	2G	HMTh	142.36
02FC001	SAUGEEN RIVER NEAR PORT ELGIN	1914	1990	N	2F	MCTh	144.44
02EA005	NORTH MAGNETAWAN RIVER NEAR BURK'S FALLS	1915	1990	N	2E	MCTh	151.65
02DC003	STURGEON RIVER AT CRYSTAL FALLS	1921	1990	R	2D	MCTh	91.29
02CF008	WHITSON RIVER AT VAL CARON	1960	1990	N	2C	MCTh	117.42
02BD003	MAGPIE RIVER NEAR MICHIPICOTEN	1939	1990	N	2B	MBh	130.05
02AB008	NEEBING RIVER NEAR THUNDER BAY	1953	1990	N	2A	MBx	121.10

4.0 REVIEW OF SELECTED STATION CHARACTERISTICS

Several recent studies have found that some flow characteristics exhibit trend (Cumming Cockburn 1989, Cumming Cockburn 1992, R.M. Leith, 1990). In the literature review, it was indicated that climate changes could have an effect on the magnitude of low, high, extreme and mean flows. In addition, several climate studies have indicated a possible effect on the temporal distribution of the extreme flows.

To review the characteristics of the following streamflow stations, non-parametric statistical tests (i.e. the Mann-Kendall Test) were used to examine trends in the following:

a) annual 7 day average consecutive day low flows for the period of record,
b) the julian day on which the low flow period occurred,
c) the maximum daily peak flows for the period of record,
d) the julian day on which the peak flow occurred,
e) the monthly mean flows for the period of record,
f) the annual mean flows for the period of record.

(For test description, see Appendix B).

The data set reviewed consisted of the 41 stations identified in Section 3.0 as current stations with a minimum of 30 years of record that are not identified as having significant regulation (see Table 4.1). This table includes 13 of the 17 stations recommended for selection for use in a Hydrometric Climate Change network.

TABLE 4.1
CURRENT HYDROMETRIC STATIONS WITH OVER 30 YEARS OF RECORD IDENTIFIED AS NOT HAVING SIGNIFICANT REGULATION

NUMBER	STATION	FROM	TO	RECORD LENGTH
02AB008	NEEBING RIVER NEAR THUNDER BAY	1953	1990	38
02BD003	MAGPIE RIVER NEAR MICHIPICOTEN	1939	1990	52
02CF008	WHITSON RIVER AT VAL CARON	1960	1990	31
02ED003	NOTTAWASAGA RIVER NEAR BAXTER	1947	1990	44
02EC002	BLACK RIVER NEAR WASHAGO	1915	1990	76
02EA005	NORTH MAGNETAWAN RIVER NEAR BURK'S FALLS	1915	1990	76
02FA001	SAUBLE RIVER AT SAUBLE FALLS	1957	1990	34
02FF004	SOUTH PARKHILL CREEK NEAR PARKHILL	1955	1990	36
02FC011	CARRICK CREEK NEAR CARLSRUHE	1953	1990	38
02FF002	AUSABLE RIVER NEAR SPRINGBANK	1945	1990	46
02FB007	SYDENHAM RIVER NEAR OWEN SOUND	1915	1990	58
02FC002	SAUGEEN RIVER NEAR WALKERTON	1914	1990	77
02FC001	SAUGEEN RIVER NEAR PORT ELGIN	1914	1990	77
02GB009	KENNY CREEK NEAR BURFORD	1961	1990	30
02GA018	NITH RIVER AT NEW HAMBURG	1950	1989	40
02GC010	BIG OTTER CREEK AT TILLSONBURG	1960	1990	31
02GG002	SYDENHAM RIVER NEAR ALVINSTON	1947	1990	44
02GD010	FISH CREEK NEAR PROSPECT HILL	1945	1990	46
02GA010	NITH RIVER NEAR CANNING	1913	1990	56
02GD013	WYE CREEK NEAR THORNDALE	1953	1990	38
02HC019	DUFFINS CREEK ABOVE PICKERING	1960	1990	31
02HC009	EAST HUMBER RIVER NEAR PINE GROVE	1953	1990	38
02HD008	OSHAWA CREEK AT OSHAWA	1959	1990	32
02HC018	LYNDE CREEK NEAR WHITBY	1959	1990	30
02HC013	HIGHLAND CREEK NEAR WEST HILL	1956	1990	34
02HB004	EAST OAKVILLE CREEK NEAR OMAGH	1956	1990	35
02HM002	DEPOT CREEK AT BELLROCK	1957	1990	34
02HD006	BOWMANVILLE CREEK AT BOWMANVILLE	1959	1990	32
02HA006	TWENTY MILE CREEK AT BALLS FALLS	1957	1990	34
02HL004	SKOOTAMATTA RIVER NEAR ACTINOLITE	1955	1990	36
02LB006	CASTOR RIVER AT RUSSELL	1948	1990	43
02MC001	RAISIN RIVER NEAR WILLIAMSTOWN	1960	1990	31
02LB007	SOUTH NATION RIVER AT SPENCERVILLE	1948	1990	43
04JC003	SHEKAK RIVER AT HIGHWAY NO. 11	1950	1987	38
04JC002	NAGAGAMI RIVER AT HIGHWAY NO. 11	1950	1990	41
04LJ001	MISSINAIBI RIVER AT MATTICE	1920	1990	71
05PB014	TURTLE RIVER NEAR MINE CENTRE	1914	1990	77
05QA004	STURGEON RIVER AT MCDOUGALL MILLS	1961	1990	30
05QA001	ENGLISH RIVER NEAR SIOUX LOOKOUT	1921	1981	61
05QA002	ENGLISH RIVER AT UMFREVILLE	1921	1990	70

The Spearman Rank Correlation test for trend was completed for analysis of the extreme flow characteristics. This information is not listed herein, since previous studies carried out by Cumming Cockburn Limited (Regionalization of Low Flow Characteristics for North-eastern and North-western Regions of Ontario, 1991), indicated that results of both tests are generally found to be in agreement. It should be noted that the comparison of the two tests identifies that the Spearman Rank Correlation test contains a more strict condition than the Mann-Kendall test. (A table summarizing the test comparisons for low flows from the above noted report is given in Appendix B).

The sign of the Mann-Kendall's tau indicates the direction of a monotonic trend. For example, a tau statistic of 0.23 indicates an increasing trend and -0.23 tau would indicate a decreasing trend.

There has been much discussion with respect to the validity of non-parametric tests (such as those noted above) for determining trends from streamflow characteristics due to the small sample size available for analysis. As authors of this study, we neither support nor disagree with the above statement and are using the results as only an indicator of possible flow regime changes and caution reviewers to do the same.

Table 4.2 summarizes the results of the monthly annual mean flows and extreme flow data series analyzed with respect to 95% confidence limit. The date of occurrences of the extreme flow series was converted to a julian day to review the temporal changes of the extreme flows.

The following conclusions are drawn from a review of Table 4.2:

i) Mean Flows

- Mean monthly flows are increasing, especially in the September to January period for most stations. Over 50 percent of the stations are demonstrating this trend.
- Some stations indicate a downward trend for monthly means flows for the period of April to September (approximately 25 percent of the stations show this).
- Approximately 30% of the stations indicate an increase in mean annual flow.
- Approximately 5% of the stations analyzed indicate a decrease in mean annual flow.

Table 4.2

Statistical Results of Mann and Kendall Test of Monthly and Annual Mean Flows, Annual Lowflows, Annual Peak Flows and Julian Dates of Extreme Flow Characteristics

tau statistic

STATION	REC	MEAN FLOWS													7 DAY AVG. LOWFLO			DAILY PEAK FLOW		
NUMBER	LEN	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUA	REC.	FLOW	J-DAY	REC.	FLOW	J-DAY
02AA001	66		0.21												67			67		
02AB008	37														36	0.24				
02BD003	29							-0.27							50	-0.26				
02CF008	14														27	-0.41	0.57	28		
02EA005	75										0.17				74			74		
02EC002	75		0.24				-0.26	-0.21	-0.23						74			74		
02ED003	41						0.26		0.33	0.30	0.27	0.25			42	0.36		42		
02FA001	33	0.26				-0.27					0.37	0.32	0.28	0.27	32			32		
02FB007	52		0.20						0.25	0.27	0.30	0.33		0.24	56	0.34		56		
02FC001	76									0.18	0.17	0.20			75			75		
02FC002	76								0.21	0.24	0.22	0.23	0.16	0.16	75	0.33	-0.17	75		
02FC011	37			0.25								0.35			36			36		
02FF002	43						0.23			0.38	0.27	0.29			44	0.33		44		
02FF004	13					0.44				0.59				0.59	31	-0.47	0.45	32	0.56	
02GA010	47									0.21	0.22	0.28			54	0.25		54	0.19	
02GB009	28							0.39			0.34	0.33			25	0.30		28		
02GC010	30	0.26								0.38	0.40	0.42	0.26	0.36	29			29		
02GD010	39										0.28	0.29		0.26	43			44		
02GD013	15														31			36		
02GG002	42														42			32		
02HA006	25						0.33				0.29			0.28	21	0.34		33		
02HB004	33	0.29								0.45	0.29	0.26	0.26	0.26	32	0.40		36		
02HC009	37											0.25			36	0.27				
02HC013	30	0.38	0.26			0.49	0.64	0.59	0.63	0.59	0.59	0.52	0.47	0.59	32	0.55		32		
02HC018	26						0.29			0.35	0.45	0.36		0.39	28	0.42		28		
02HC019	28	0.29		0.29			0.35			0.35	0.37			0.43	29	0.34		29	0.52	-0.31
02HD006	30									0.51	0.44	0.34			30	0.29		30		-0.36
02HD008	30									0.31	0.43	0.29			29	0.45		30		
02HL004	33	0.30	0.32	0.34		-0.28												34		-0.24
02HM002	34				-0.42		0.43	0.41	0.45	0.47	0.37	0.26		0.25	32	0.45		32	-0.34	
02LB006	23				-0.31										41		0.28	41		
02LB007	37				-0.24										33	-0.29	0.40	33		
02LB008	14													-0.43	27			41		
02MC001	30		0.27												39			29		
04JC002	40						-0.24								69			39		
04LJ001	70				0.17										68	0.26		69		-0.20
05PA006	68	0.17			0.22	0.17			0.19	0.17	0.17			0.24	75	0.24		68	0.26	
05PB014	67	0.23	0.22	0.23				0.20						0.20	35			75		
05QA002	69	0.20	0.21	0.22	0.25										68			68		
05QA004	29								-0.30	-0.27					28			28		
05QE009	27				-0.30									-0.29	29			29	0.43	-0.30

0.32 upward trend with tau = 0.32 > 0.0 (shaded)
-0.21 downward trend with tau = -0.21 < 0.0

Note: All statiod characteristics identified above are significant at the 5% level

Table 4.3

Statistical results of Mann and Kendal Test of Monthly and Meand Annual Mean Flows, Annual Lowflows, Annual Peak Flows and Julian Dates of Extreme Flow Characteristics standard normal variate Z

STATION	RC	MEAN FLOWS													7 DAY AVG LOWFLOW			DAILY PEAK FLOW		
NUMBER	YR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL	REC	FLOW	J-DAY	REC	FLOW	J-DAY
02AA001	66	1.88	2.45	1.53	-0.75	-0.17	-0.74	0.32	1.59	1.00	1.42	0.45	1.40	0.63	67	1.55	0.18	67	-0.47	0.61
02AB008	37	0.37	0.85	-0.25	-1.02	-0.37	1.33	1.66	1.90	1.07	1.09	0.89	-0.05	0.82	36	2.04	0.71			
02BD003	29	0.26	-0.28	-0.32	0.28	-0.64	-1.54	-2.06	-1.14	-0.69	0.56	1.33	1.13	-0.32	50	-2.62	-1.62			
02CF008	14	0.33	0.55	0.11	0.00	-0.66	0.55	0.22	-0.22	-1.21	-0.77	0.22	-0.11	0.16	27	-3.00	4.17	28	1.03	0.71
02EA005	75	0.43	0.50	0.32	0.01	-1.33	-0.91	-0.27	0.77	1.40	2.18	0.93	0.91	0.82	74	1.50	-1.64	74	1.06	-0.35
02EC002	75	1.61	3.07	0.76	-0.75	-1.93	-3.28	-2.70	-2.92	-1.36	0.22	1.81	1.63	0.20	74	-1.11	-0.95	74	0.45	0.76
02ED003	41	0.83	0.20	0.91	-1.29	1.04	2.41	0.45	3.07	2.74	2.50	2.28	1.68	0.93	42	3.36	-1.29	42	-0.85	-1.19
02FA001	33	2.09	1.47	1.94	-1.32	2.15	-0.46	-0.11	-0.50	1.84	3.04	2.57	2.28	2.15	32	0.08	-1.04	32	-0.45	-0.45
02FB007	52	1.45	2.04	-0.36	0.19	0.30	1.03	1.22	2.56	2.86	3.16	3.42	1.79	2.49	56	3.74	-1.49	56	1.05	-0.62
02FC001	76	0.15	0.83	-0.52	0.24	-0.09	0.63	-0.01	1.67	2.33	2.14	2.58	1.65	1.32	75	1.25	-1.08	75	0.93	-0.48
02FC002	76	0.57	1.27	0.22	0.03	0.06	1.04	0.65	2.73	3.04	2.80	2.98	1.99	2.01	75	4.14	-2.19	75	1.41	-0.88
02FC011	37	1.57	0.09	2.18	-0.60	-0.10	1.28	-0.37	0.75	1.48	1.84	3.03	1.22	1.66	36	1.39	-0.05	36	1.51	-0.35
02FE002	43	0.05	-0.69	0.27	0.78	-0.32	2.18	1.54	1.88	3.54	2.55	2.69	1.15	1.63	44	3.15	-1.78	44	1.11	-0.77
02FE004	13	1.22	1.40	1.28	0.00	2.02	-0.43	0.92	1.95	2.75	1.89	0.67	1.40	2.75	31	-3.69	3.55	32	4.52	0.78
02GA010	47	-0.44	-0.39	-1.10	0.00	0.77	1.26	0.62	1.53	2.06	2.21	2.81	1.94	1.06	54	2.67	-0.72	54	1.97	-0.39
02GB009	28	1.05	0.63	-0.51	0.24	0.97	1.66	2.90	1.32	1.86	2.53	2.43	0.87	1.80	25	2.08	-1.05	28	1.24	-0.14
02GC010	30	1.96	1.32	0.61	0.59	0.39	1.37	1.20	0.89	2.91	3.09	3.21	2.00	2.75	29	0.73	-1.44	29	1.56	-1.01
02GD010	39	0.99	0.21	0.57	0.40	-1.22	1.62	1.91	0.96	1.81	2.52	2.56	1.80	2.29	43	0.42	-0.23	44	1.41	-0.88
02GD013	15	1.19	-0.05	-1.58	-1.49	-0.20	0.40	0.05	0.00	0.00	0.94	0.50	0.05	-0.20	31	-1.80	1.89	36	1.17	-0.78
02GG002	42	-0.56	-1.24	-0.09	-0.64	-0.69	0.43	-0.38	0.38	1.73	1.67	1.77	0.64	-0.04	42	1.11	-1.22			
02HA006	25	0.72	1.14	-1.17	0.86	1.26	2.27	0.70	0.72	1.05	2.01	1.10	1.40	1.96	21	2.11	0.66	32	1.28	-0.50
02HB004	33	2.37	1.01	0.82	-0.62	0.33	1.35	1.78	1.95	3.64	2.32	2.14	2.14	2.12	32	3.23	-1.38	33	1.19	0.05
02HC009	37	1.60	0.71	1.12	-0.22	0.94	1.60	1.69	1.80	1.92	1.58	2.18	1.44	1.65	36	2.34	0.50	36	1.59	-1.05
02HC013	30	2.94	1.96	0.95	1.20	3.78	4.92	4.55	4.85	4.59	4.57	4.00	3.64	4.59	32	4.43	-0.97	32	1.67	1.18
02HC018	26	1.63	1.23	1.41	1.10	1.10	2.07	1.32	1.10	2.51	3.17	2.56	1.37	2.76	28	3.10	0.06	28	0.69	-1.44
02HC019	28	2.13	1.09	2.17	-0.28	0.99	2.63	0.30	1.24	2.63	2.71	1.72	0.77	3.22	29	2.59	-0.17	29	3.96	-2.34
02HD006	30	0.91	0.14	1.77	0.09	0.70	0.75	-0.95	1.18	3.91	3.39	2.59	1.07	1.94	30	2.19	-1.61	30	0.89	-2.77
02HD008	30	1.78	0.89	1.39	-0.20	-0.45	-0.37	0.00	-0.30	2.41	3.34	2.23	1.77	1.20	29	3.40	-0.60	30	0.71	-1.05
02HL004	33	2.46	2.62	2.77	-0.60	-2.25	-0.70	0.15	0.79	0.54	1.75	1.44	1.56	1.80				34	1.69	-1.97
02HM002	34	1.84	1.16	1.39	-3.47	0.16	3.56	3.37	3.72	3.85	3.07	2.15	0.71	2.06	32	3.58	-0.60	32	-2.74	-1.20
02LB006	23	0.92	1.48	0.42	-2.06	0.05	0.05	0.00	0.00	-0.26	1.06	1.27	0.40	-0.87	41	-1.33	2.53	41	-0.98	-0.22
02LB007	37	-0.64	0.30	-0.03	-2.05	0.52	0.52	-0.82	-0.58	0.41	1.82	1.56	1.35	-0.72	35	0.58	0.11	33	-0.19	-1.16
02LB008	14	0.44	0.66	0.00	-0.44	0.77	0.27	0.22	1.21	-0.66	0.11	0.99	-0.22	-2.08	33	-2.32	3.25	41	-1.27	-0.51
02MC001	30	1.46	2.09	1.05	-1.86	0.39	1.43	1.50	0.29	-0.54	1.16	0.73	1.03	0.45	27	-0.77	-0.90	29	-0.51	-0.32
04JC002	40	0.97	1.15	1.56	-0.22	-0.38	-2.18	-0.08	1.00	1.13	1.22	1.24	-0.17	0.01	39	1.26	-0.44	39	-0.01	-0.80
04LJ001	70	0.68	0.55	0.68	2.04	-0.81	-0.85	0.35	-0.34	-0.22	1.09	0.95	0.15	0.49	69	0.06	-0.25	69	0.16	-2.44
05PA006	68	2.05	1.82	1.57	2.63	1.99	1.76	1.52	2.30	2.10	2.02	1.87	1.78	2.85	68	3.14	-0.41	68	3.18	-0.31
05PB014	67	2.74	2.64	2.72	1.47	0.70	1.89	2.35	1.80	1.46	1.66	1.43	1.89	2.42	75	3.05	0.32	75	1.88	0.11
05QA002	69	2.47	2.51	2.67	3.03	0.76	1.29	0.81	0.87	0.81	1.15	1.38	1.75	1.48	68	1.14	-0.60	68	1.27	-0.19
05QA004	29	-0.47	-0.98	-1.24	-0.45	-0.54	-1.54	-0.98	-2.23	-2.03	-1.50	-1.24	-1.28	-1.41	28	-1.40	-0.06	28	-0.57	-1.07
05QE009	27	-1.27	-1.79	-1.79	-2.17	-1.83	-1.52	-1.08	-0.83	-1.21	-1.46	-1.58	-1.63	-2.11	29	-1.58	-0.66	29	5.54	-3.90

2.51 Magnitude of Z > 1.96 and therefore stations show trend at the 0.05 level

ii) Low Flows

- Approximately 35% of the stations in the low flow data series illustrated an upward trend.
- Approximately 10% of the stations in the low flow data series illustrated a downward trend.
- Approximately 10% of the occurrence of low flows indicate an upward trend (i.e. the low flow periods are happening later in the year).
- One station (02FC002) indicates the low flow characteristic is occurring earlier in the year.

iii) Peak Flows

- Approximately 10% of the stations in the peak flow data sets indicate an upward trend.
- One station (02HL004) indicates a downward trend in the magnitude of peak flows.
- Approximately 10% of the peak stations in the flow julian day data base exhibits a downward trend indicating that peak flows may be occurring earlier in the year.

Table 4.3 summarizes the Mann-Kendall standard normal variate (z) statistics. Review of this table indicates fewer stations are significant at the 1% level, however, the overall pattern is similar to that summarized above. No analysis was performed to examine the possibilities of the above finding being a result of randomness.

Of the 17 stations recommended in Section 3.3, data from flow characteristics trend analysis is available for 13. These 13 stations and the Mann and Kendall tau stations (for those stations significant at the 5% level) are summarized in Table 4.4.

The following comments apply to the 13 recommended stations illustrated in Table 4.4.

- Only one station's complete set of flow characteristics are free from trend (02GD013).
- Twenty-one out of a possible 156 monthly mean flow series show significant trend.
- Five of the twenty-one monthly mean flows indicate a negative trend.
- Station 05PB014 is the only station of the selected stations which shows a significant trend for annual mean flow and it is increasing.
- Five of twelve stations indicate a significant trend with respect to the magnitude of low flows. Three of these show a downward trend.

Table 4.4

Statistical Results of Mann and Kendall Test of Monthly and Annual Mean Flows,
Annual Lowflows, Annual Peak Flows and Julian Dates of Extreme Flow Characteristics
tau statistic

Stations Recommended for Selection for use in Climate Change Studies

STATION	REC LEN	MEAN FLOWS												
NUMBER	(YEARS)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
02AB008	37													
02BD003	29							-0.27						
02CF008	14													
02EA005	75										0.17			
02FC001	76									0.18	0.17	0.20		
02GD013	15													
02HL004	33	0.30	0.32	0.34		-0.28								
02LB006	23				-0.31									
02LB007	37				-0.24									
04JC002	40						-0.24							
04LJ001	70				0.17									
05PB014	67	0.23	0.22	0.23				0.20						0.20
05QA002	69	0.20	0.21	0.22	0.25									

STATION	7 DAY AVG. LOWFLOW			DAILY PEAK FLOW		
NUMBER	REC LEN	FLOW	J-DAY	REC LEN	FLOW	J-DAY
02AB008	36	0.24				
02BD003	50	-0.26				
02CF008	27	-0.41	0.57	28		
02EA005	74			74		
02FC001	75			75		
02GD013	31			36		
02HL004				34		-0.24
02LB006	41		0.28	41		
02LB007	33	-0.29	0.40	33		
04JC002	69			39		
04LJ001	68	0.26		69		-0.20
05PB014	35			75		
05QA002	68			68		

0.32 (shaded) upward trend with tau = 0.32 > 0.0
-0.21 downward trend with tau = -0.21 < 0.0

Note: All station characteristics identified above are significant at the 5% level

- Three of twelve stations indicate a significant increasing trend for the time of occurrence of low flows (i.e. low flows are occurring later in the year).
- No significant magnitude of peak flows trends were identified.
- Two of the eleven stations show a significant trend for the time of occurrence (julian day) of peak flows both test indicate a downward trend (i.e. peak flows are occurring earlier in the year).

This preliminary information tends to indicate that some change may be occurring with respect to extreme flow characteristics. It also appears to indicate that low flows and monthly mean flows for many stations have been impacted by some change scenario over the periods of record.

Finally, a graphical technique referred to as the Robust Locally Weighted Regression Smooth (RLWRS) was used to provide some further insight for selected subsets of data (a description of the technique is given in Appendix B).

Selected data for the following stations (i.e. some of those recommended for selection in Section 3.0) showing significant trends are illustrated on the accompanying figures.

The Magpie River near Michipicoten (02BD003) monthly mean flows for July are illustrated on Figure 4.1. The trend analysis identified a significant downward trend in mean flow for this stations data for the month of July. Review of Figure 4.1 indicates that the trend may be due to high flow values recorded prior to 1966 and subsequent to the 1959 missing data period.

The magnitude of the 7 day average annual consecutive low flows for the Whitson River at Val Caron (02CF008) indicate a downward trend as indicated on Figure 4.2. There appears to be two populations for this data (i.e. data prior to 1975 seems significantly different from data after 1975.) Figure 4.3 illustrates an increasing trend for the julian dates of the low flow occurrence (for station 02CF008) with a similar population split for data before and after 1975. The data indicates that the low flows prior to 1975 were occurring in the winter months and after 1975 seem to be occurring primarily in the summer months. Low flow history indicates that winter low flows are generally larger than summer low flows. It is not known if this is a function of climate change or perhaps changes in the watershed characteristics.

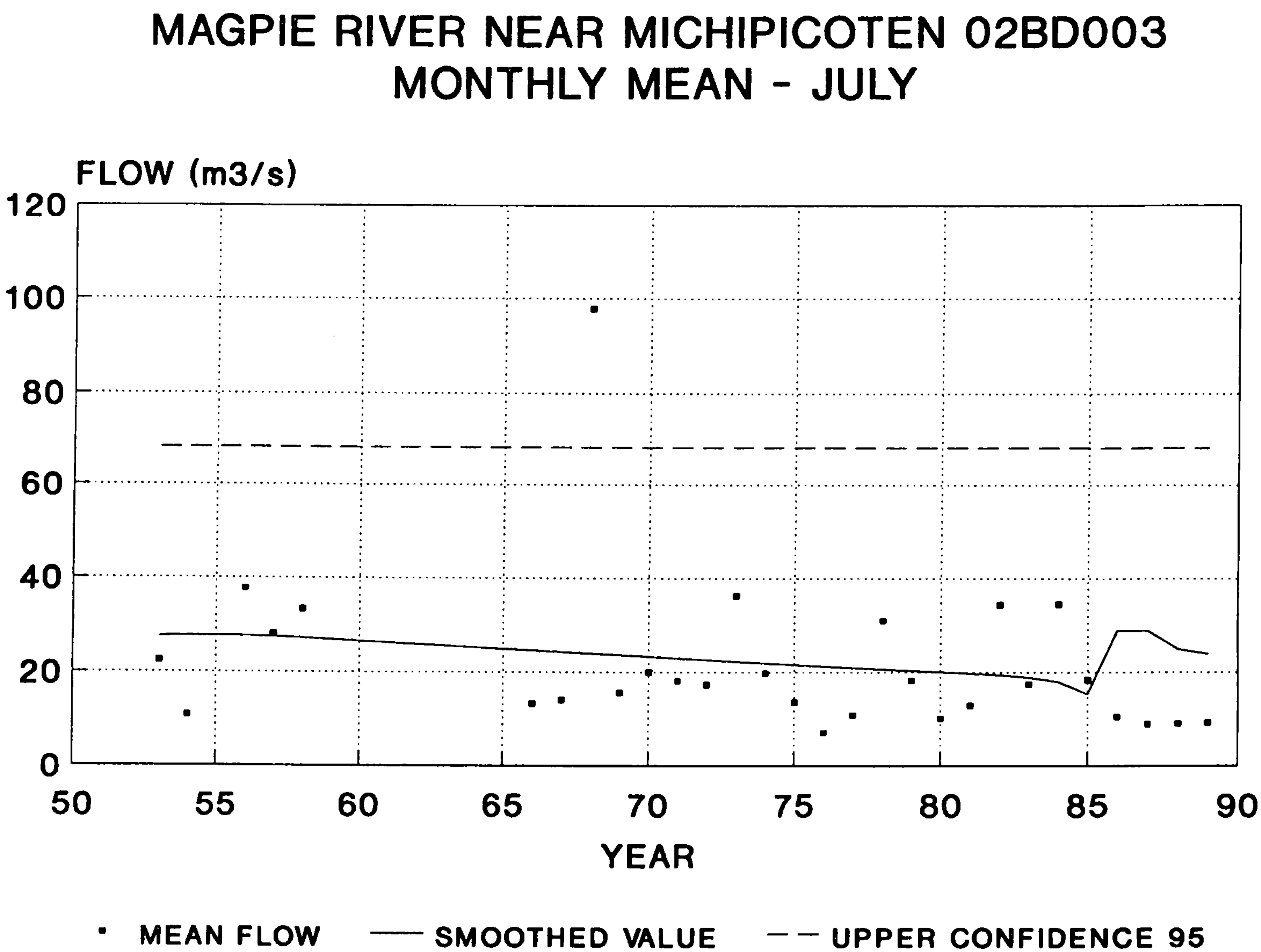

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Figure 4.1

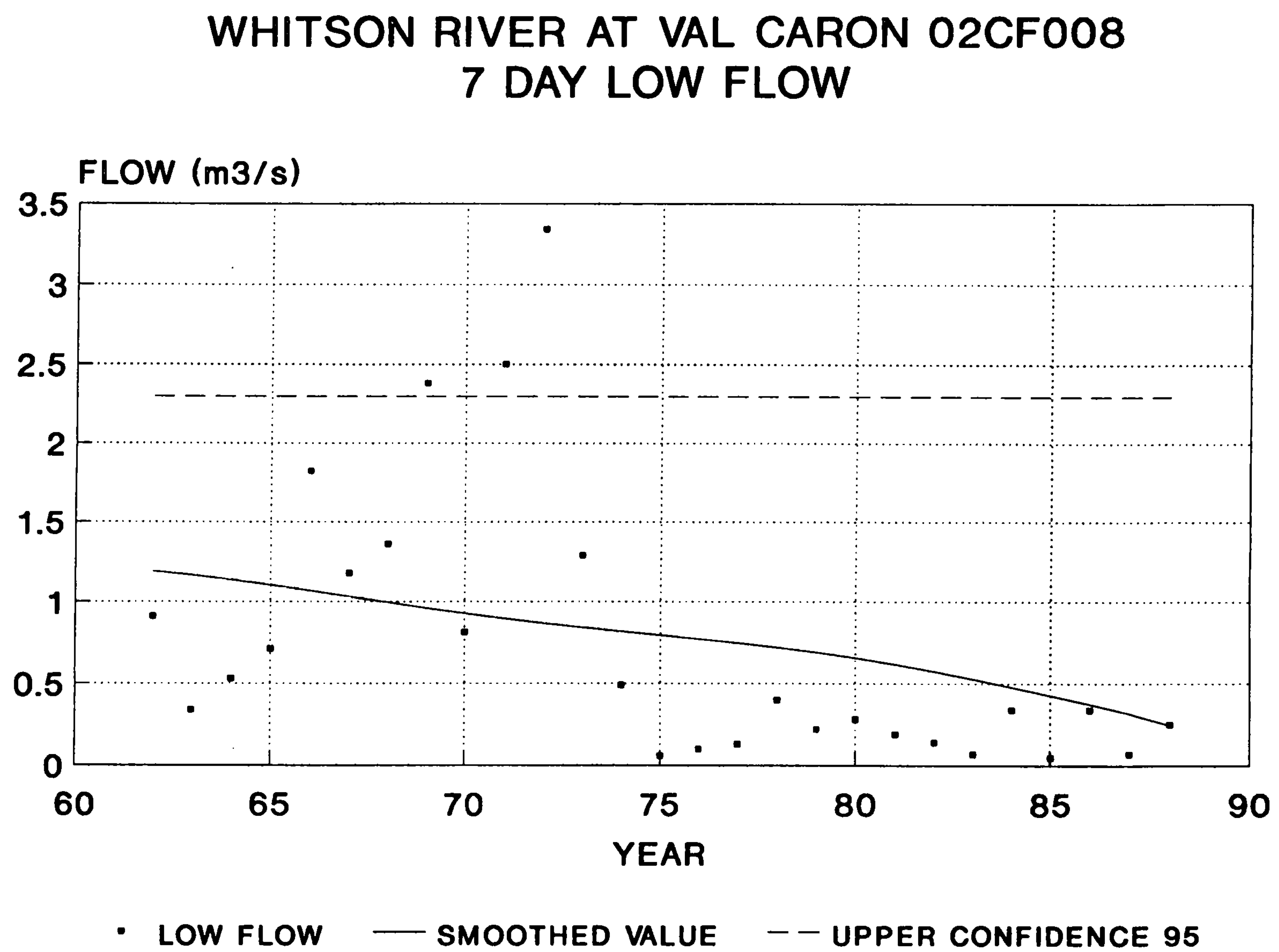

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Figure 4.2

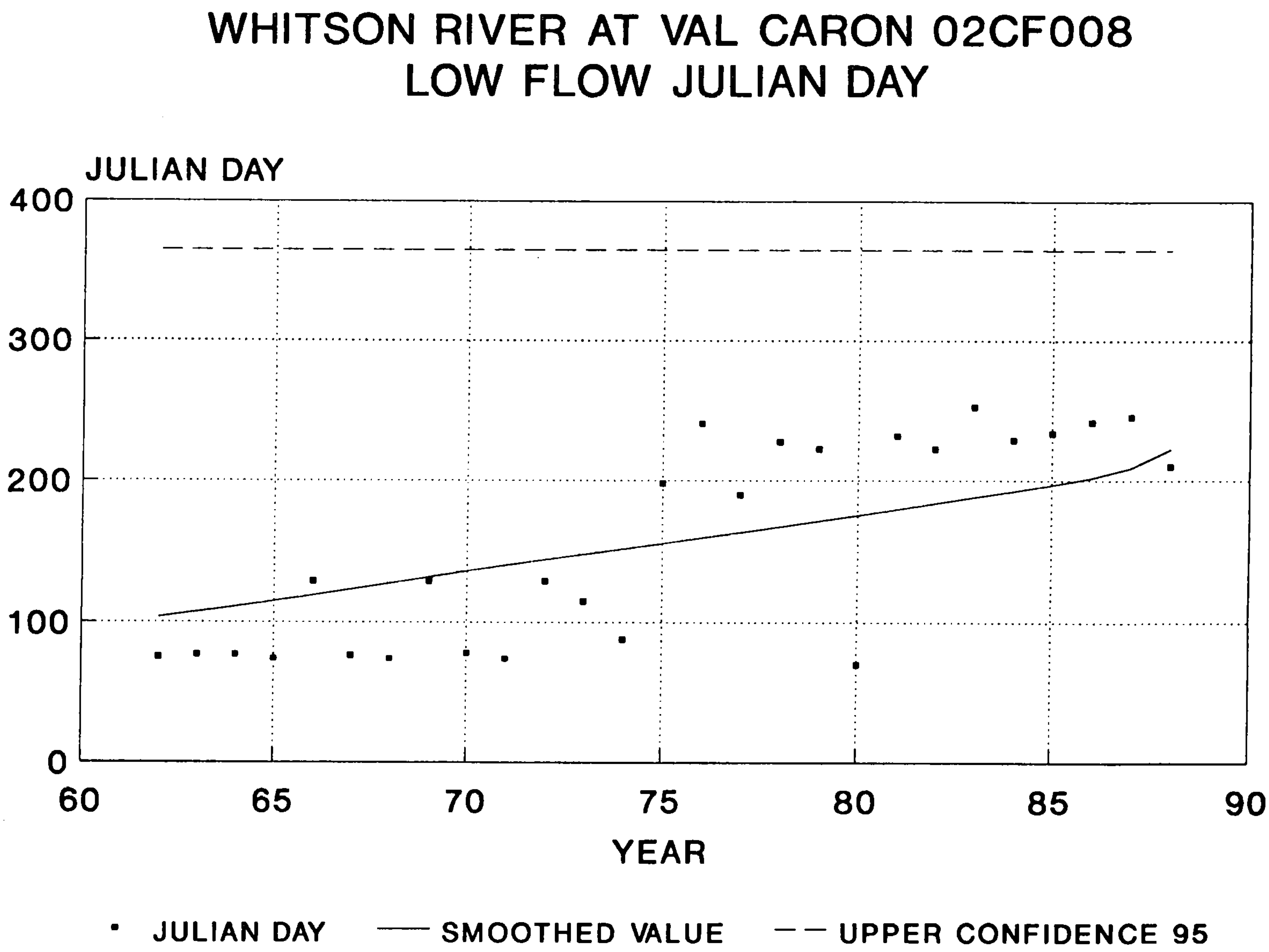

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Figure 4.3

The peak flow for the Skootamatta River near Actinolite (02HL004) shows a decreasing trend analysis for the timing of daily peak flow occurrence (see Figure 4.4). No explanation for this result is readily apparent.

The mean monthly flow for the month of July shows a significant increasing trend for Turtle River near Mine Centre (05PB014) (see Figure 4.5).

The above analyses are not meant to be exhaustive and were undertaken only to indicate that an investigation of the trend causative factors should be undertaken and that graphical techniques (such as the RLWRS) are important for illustrating possible avenues of research for understanding trend in selected flow characteristics. All stations showing significant trend in selected flor characteristics, including those indicated as regulated, should be reviewed in detail and abnormalities such as those indicated for station 02CF008, Whitson River at Val Caron should be investigated further. However, detailed trend studies are beyond the scope of the present investigations.

In addition to the above graphical analysis, the 13 selected hydrometric stations trend characteristics were examined spatially. Figure 4.6 summarizes the monthly mean statistics for each of the 12 months via a box chart with positive and negative significant trends, colour coded green and red respectively. Some grouping may be apparent, for example:

i) two westerly stations indicate increases in monthly mean flows in winter and spring seasons,

ii) two centrally located stations indicate a decrease in monthly mean flows for the summer season,

iii) spring monthly mean flows appear to be decreasing while fall monthly mean flows appear to be increasing in southeastern Ontario.

The amount of data presented on Figure 4.6, in our opinion, is insufficient to draw any conclusions. Annual mean flows, and extreme value flow, trend characteristics are illustrated on Figure 4.7. Similarly, there appears to be insufficient information on which to base valid conclusions.

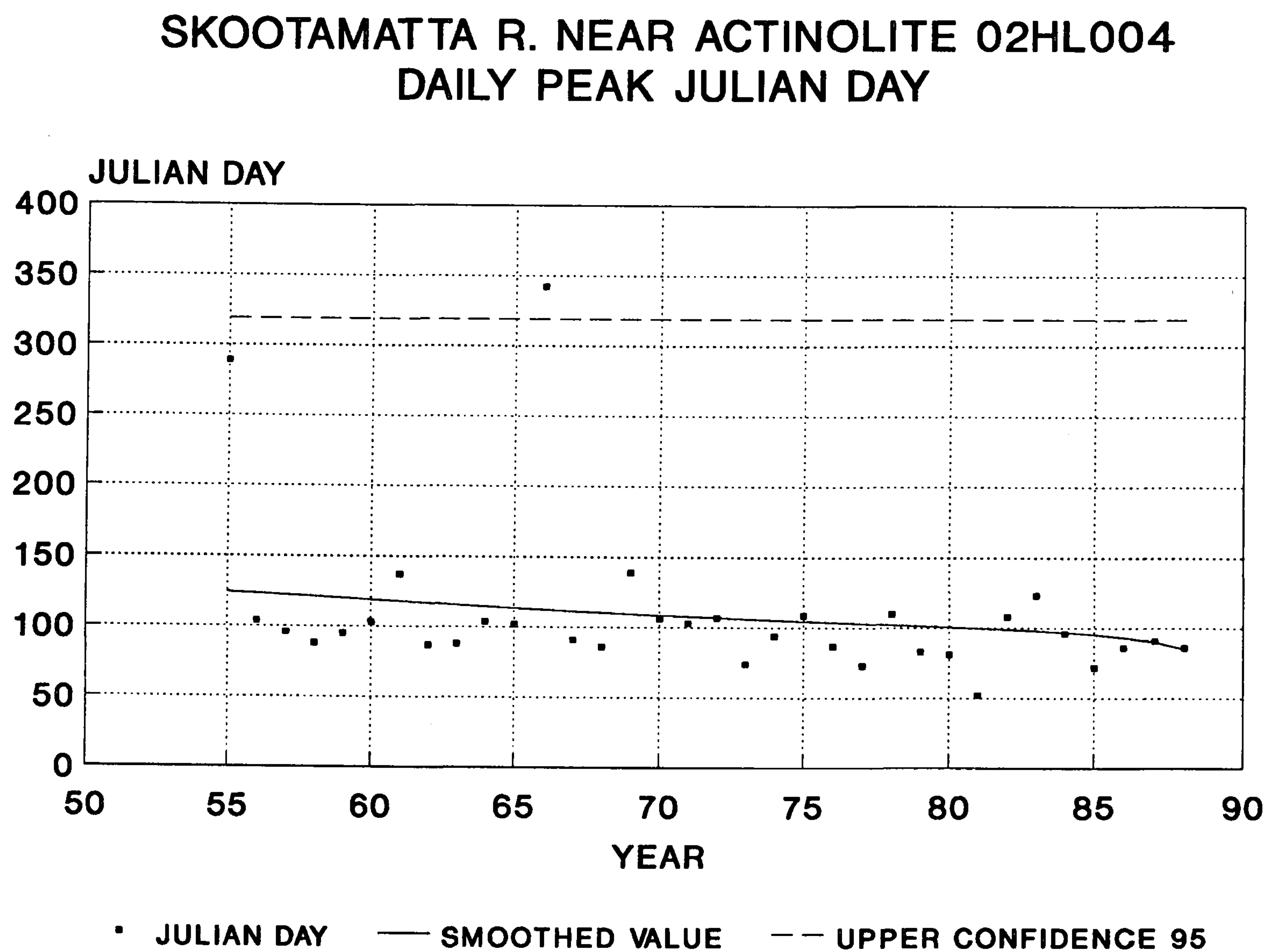

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Figure 4.4

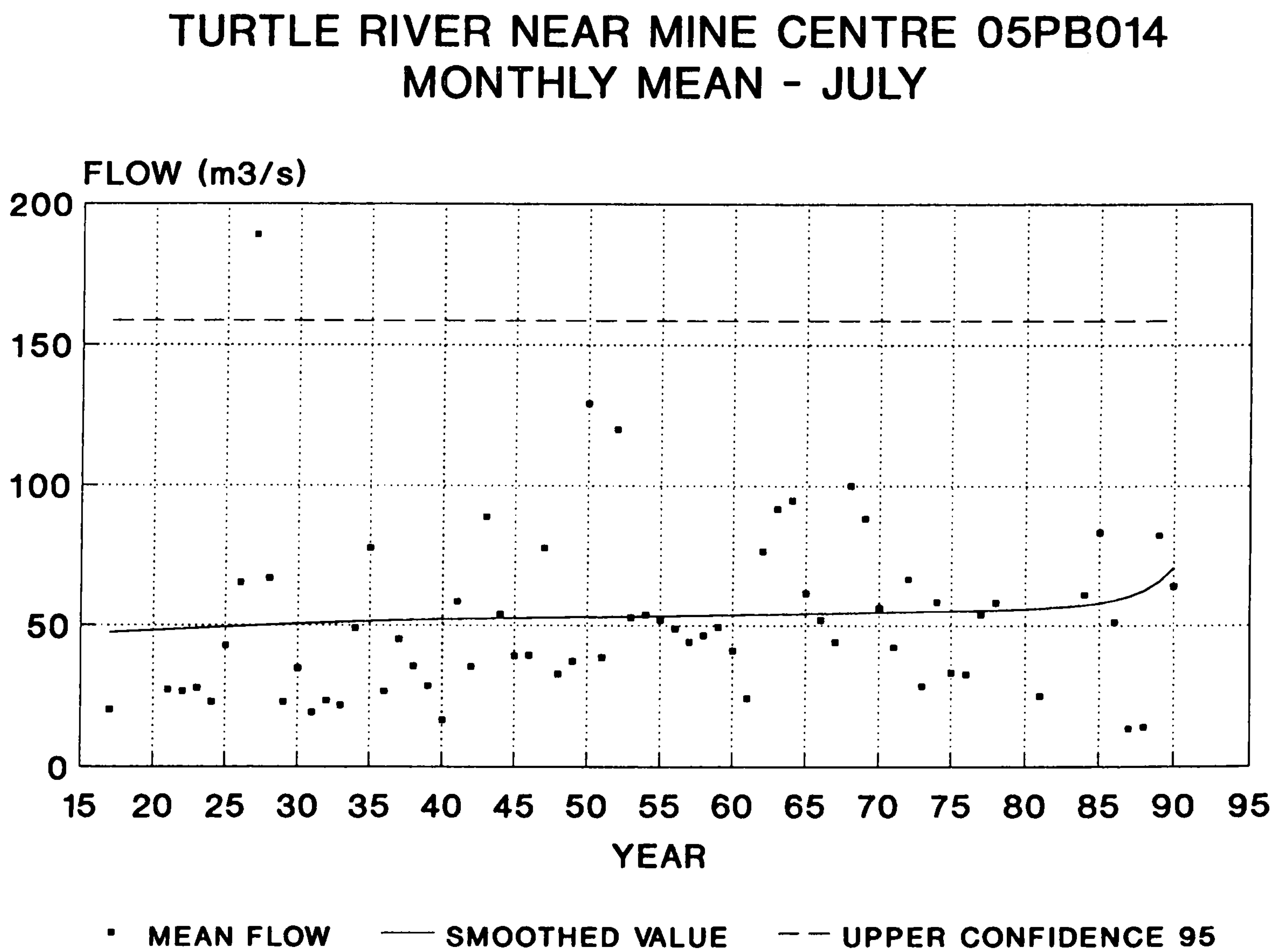

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Figure 4.5

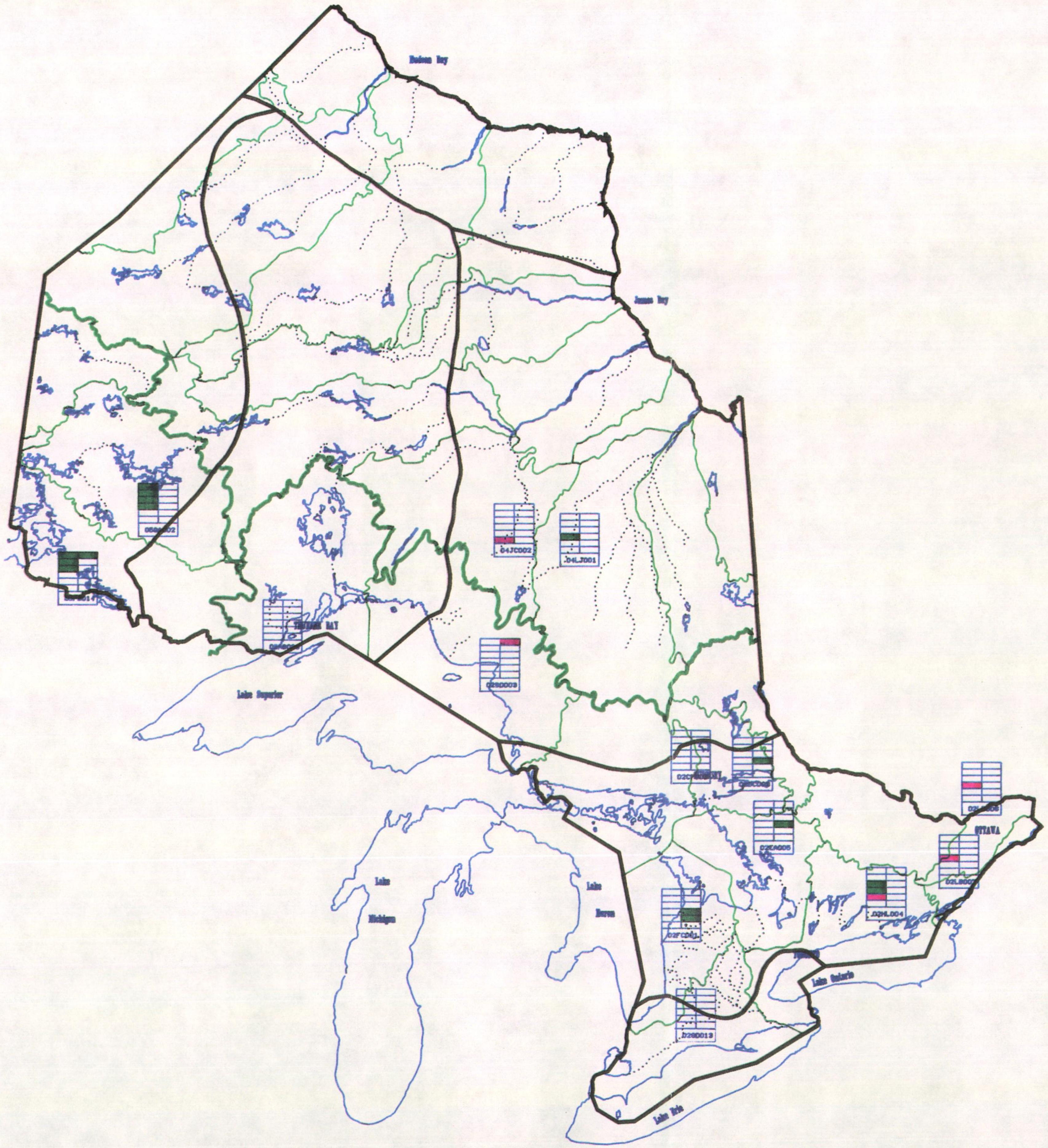

Figure 4.6

Spatial Analysis of Trend Test Results (Monthly Mean)

Criteria Development to Identify Surface Water Monitoring Stations Applicable for Climate Trend Studies

LEGEND

jan	jul
feb	aug
mar	sep
apr	oct
may	nov
jun	dec
number	

Negative Trend

Positive Trend

Climate Zones

Drainage Basins

Main Rivers

Main Drainage Divide

Environment Canada
Inland Waters Directorate
Water Resources Branch

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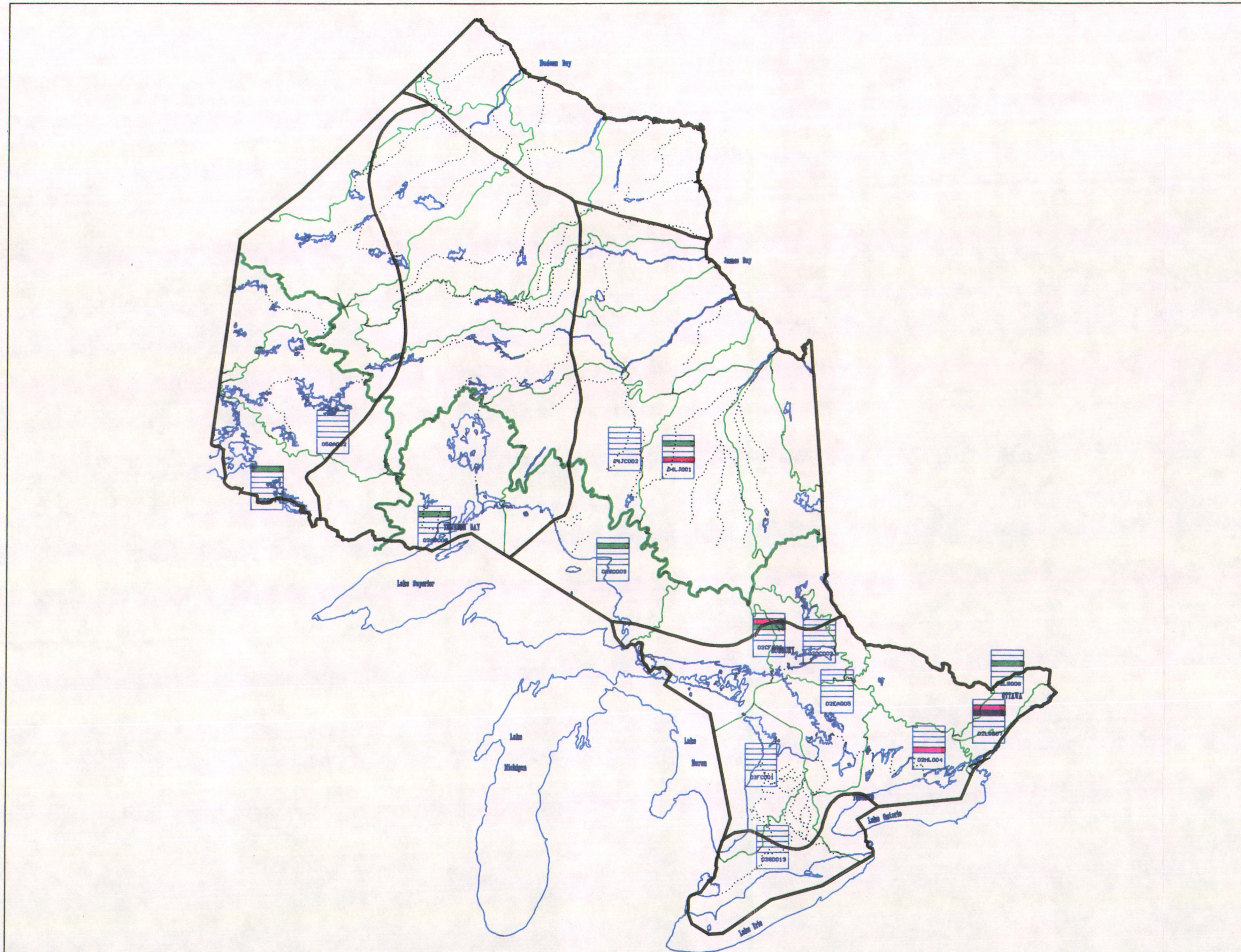

Figure 4.7

Spatial Analysis of Trend Test Results

(Annual Mean and Extremes)

Criteria Development to Identify Surface Water Monitoring Stations Applicable for Climate Trend Studies

LEGEND

annual mean flow

7 day average low flow

occurence of low flow

daily peak flow

occurence of peak flow

number

Negative Trend

Positive Trend

Climate Zones

Drainage Basins

Main Rivers

Main Drainage Divide

Environment Canada

Inland Waters Directorate

Water Resources Branch

Cumming Cockburn Limited

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Geographical Information System procedures have been developed through this project to easily analyze trend test results spatially. It is recommended that trend results be examined using a larger data base to identify possible regional affects spatially in future studies.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

- Temperature and Precipitation are the most used climatic parameters for climate change studies involving hydrometric data.

- There are 6 distinct climate regions in Ontario.

- There are 41 streamflow stations not identified as regulated and with a minimum of 30 years of record.

- The locations of the above 41 stations are inadequate to reflect climate change regions in Ontario.

- The flow characteristics of stations identified as having significant regulation and the impact of regulation are not easily determined from published data.

- The record lengths of some hydrometric stations (i.e. 30 years) are marginally acceptable for analysis of climate change.

- Data availability in the optical disk format has proven effective in the efficient review of large amounts of data.

- Geographic Information Systems technology has proven very useful for efficiently identifying complete spatial analysis on large data sets.

- The following parameters were considered important for selecting climate stations for use in defining a hydrometric station network in Ontario:

  i) climate regions
  ii) long term data sets (can be extended through nearby gauge correlation)
  iii) position within a climate region
  iv) minimum parameters measured (i.e. daily precipitation and temperature)
  v) additional parameters (i.e. sunshine, evaporation etc.).

- The following parameters were considered important for determining a hydrometric network for analyzing climate change in Ontario:

  i) length of record
  ii) type of record (i.e. natural is preferred over regulated)
  iii) climate regions represented
  iv) major drainage basins represented
  v) location of the hydrometric station with regards to: - climate region centroid
  - major drainage basin centroid
  - regional climate station
  vi) additional parameters (i.e. such as sediment information)

- Many streamflow station discharge characteristics such as the magnitude of mean and low flows appears to be changing over time.

- Low flows appear to be happening later in the year and high flows earlier in the year for some hydrometric stations. This supports the findings from the literature review.

- Lake level stations were not analyzed, however, they would be important for analysis of climate change relationships within the Great Lakes.

5.2 Recommendations

- As Atmospheric Environment Service develops the climate change, climate station network in Ontario, the results of this study should be reviewed with respect to the network of climate stations for studying climate change effects of the selection process for the recommended hydrometric stations for climate change analysis.

- Additional data on stations identified as regulated in the Hydex database should be available and deregulation techniques should be examined with respect to the process, thereby, making more effective use of the Water Resources Branch data set.

- Inter-correlation studies should be undertaken to extend the streamflow data series length in an attempt to provide longer record lengths for climate change studies.

- Since trend is apparent in many flow series and the causative factors are not understood, it is recommended that detailed trend studies be undertaken to analyze this phenomena further.

- Stations identified in Table 3.3 require review with respect to:

  i) data quality
  ii) operating costs
  iii) data continuity
  iv) effects of regulation
  v) security of funding
  vi) additional parameters measures (i.e. thickness, water, temperature, sediment regime)
  vii) etc.

- Station profile and WRB staff reviews should be used to review the above material.

- Table 3.4 summarizes those stations recommended for selection as hydrometric streamflow stations for use in future climate change studies.

- Stations with missing records should be reviewed and missing data estimated, if possible, by appropriate techniques.

- Further study is required to determine a water level station network applicable for climate change studies.

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APPENDIX A

SUMMARY OF PAPERS REVIEWED

TITLE: Impact of Climate Change on the Morphology of River Basins

AUTHOR: F.H. Verhoog

SOURCE: The influence of Climate Change and Climatic Variability on the Hydrologic Regime and Water Resources, IAHS # 168, 1987

This paper relates the change in global climate to a change in the morphology of river basins. As the mean annual temperature rises, a result of the doubling of the CO_2 concentrations in the atmosphere, the hydrologic characteristics of river basins around the world will change. A net rise in temperature of 4.5°C could result in an increase of 7 to 11% in the annual precipitation rate. Such increases would be experienced in many regions of the world including most of Canada. Other regions of the world would experience a net decrease in the annual precipitation rate. The majority of the world would see increases in the evapotranspiration rate.

The majority of the rivers in the world have a runoff ratio of less than 0.5. In dryer basins, where runoff ratios are in the range of 0.01 to 0.20, the sensitivity to changes in precipitation is much greater than more humid basins. Therefore, the effect of global warming is more pronounced in semi-arid regions than in sub-humid regions.

The major variables that effect the morphology of a river are discharge and sediment load. Changes in channel morphology have an impact on the hydrology of the basin. Conversely, changes in the hydrologic regime could completely change the morphologic characteristics of the river.

A major change in the hydrologic regime would completely change the channel morphology. A decrease in precipitation in the head waters will not only cause a decrease in annual discharge, but, through a reduction in vegetation density will increase peak discharge and the ratio of suspended sediments to water. As such, more sediments will be deposited resulting in a wider shallower channel.

An increase in precipitation will increase annual discharge which will increase the vegetation density resulting in lower peak discharge and, thus, a lower ratio of suspended sediments to water. This will result in a narrower and deeper channel.

TITLE: Hydrometric Data in Support of Climate Change Studies in Canada

AUTHOR: P.J. Pilon, K.D. Harvey, D.R. Kimmett

SOURCE: Water Resources Branch, Inland Waters Directorate, Environment Canada

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This paper was presented to the NATO Advance Research Workshop on Opportunities for Hydrological data in Support of Climate Change Studies.

The purpose of this paper was to examine the use of hydrometric data and analytical tools in support of climate change studies in Canada. The data could be used in analyses to detect climate change and the assessment of potential impact of climate change on the hydrologic cycle.

There are two main applications of hydrometric data in climate change studies:

1. Detection and monitoring of climate change; and,
2. Assessment of the potential impacts of climate change.

Application 1, requires those hydrometric stations with long term, contemporaneous data for several parameters of the hydrologic cycle. As such, the Water Resources Branch has begun to identify a national network by identifying 27 natural hydrometric stations with more than 50 years of record. These stations have either minimal human interference or natural conditions. The network could be expanded to include natural stations with fewer than 50 years of record. This may be necessary to fill spatial gaps in the network.

Global climate models are currently being used to mathematically model climate change. These models are considered to be over simplified and do not provide output that is useful to hydrologic investigations.. This is an area where hydrologic climate models can be useful. Although it is recommended to use stations with long periods of record, the recorded period should be sufficient to provide data to calibrate and validate the hydrologic model being used. A natural flow record is not a requirement provided that the model can simulate the natural processes of the basin. The hydrometric data in Canada have largely been applied to study the potential impacts of climate change on water resources rather than to detect climate change.

Some of the points relative to this investigation are;

- Natural or pristine basins should be used to avoid impacts of humans on natural processes;
- Long term hydrometric records inevitably demonstrate trends;
- Seven sites selected were for Atlantic region based on climate data availability and assessment of the length and quality of hydrologic data;
- National network of 27 long term stations based on 50 or more years of record and natural flow characteristics or minimal human interference;
- Common Global Climate Models are too broad for atmosphere/climate/hydrometric comparisons;
- Monthly mean, high and low flows were analyzed on a monthly basis.

TITLE: An Assessment of Climate Change/Variability Impacts on Runoff in Ontario, Canada

AUTHOR: H. Goertz

SOURCE: Water Resources Branch, Inland Waters/Lands Directorate, Environment Canada, June 1987

The purpose of this assessment was to investigate impacts on basin runoff due to climate change or variability. Assessment was based on hydrologic modelling in a single basin in Ontario. Modifications to monthly temperatures and precipitation input data were used to produce various combinations of temperature and precipitation. The changes in temperature ranged from -4°C to +4°C and the changes in precipitation ranged from -25% to +25%.

Dramatic changes in runoff amounts and patterns were observed relative to the changes in precipitation and temperature. Even changes in precipitation only yielded large changes in runoff. From the modelling results and other sources, it can be anticipated that the ratio between change in runoff to change in precipitation will be quite large.

Therefore, there will be a need for long term continuous hydrological data as further studies are carried out and longer periods of record are required. Better assessment of hydrological changes or trends would be possible in the future with an accurate and longer database.

The following station characteristics were noted in this study:

- The use of data from unregulated streamflow stations was recommended;
- Hydrometric data from the Water Survey of Canada gauge , Sauble River at Sauble Falls (record length 30+ years) was used for this study;
- Climate data from the Wiarton climate station was used;
- Spatial nodes for global climate models (GISS and GFDL) indicate 7 to 8 nodes within the Great Lakes Region;
- Temperature and precipitation are noted as the most effective parameters for interrelating hydrometric and climatologic data;
- It was noted that the results are inconclusive due to noise range of the data reviewed.

TITLE:	Predicting Temporal and Volumetric Changes in Runoff Regimes Under Climate Warming Scenarios
AUTHOR:	J.M. Byrne and R.B. McNaughton
SOURCE:	Canadian Water Resources Journal, Volume 16, No. 2, 1991

Potential global warming may have a major impact on regions with major developments in irrigation agriculture. Warmer temperatures could add to the potential water use of crops and other plant life, and runoff volumes could be lower due to greater evapotranspiration potential by crops and natural vegetation. The major observations made under this study were:

- Climate warming in winter increases the probability of heavier winter snowfall;
- Summer conditions have an increased probability of lower precipitation;
- There is no evidence to suggest that spring snow water equivalent values will decline significantly with significant climate warming;
- The winter season will shorten significantly, resulting in earlier spring runoff. The availability of stream flow water supplies under natural runoff conditions will decline during the summer months.

The watersheds in the lee of the Rocky Mountains contain approximately 25% of Canada's irrigated farm land. Any reduction in summer stream flow will have a negative impact on agricultural production.

The following points summarize the relevant information with respect to the ongoing study:

- A spatial surface grid of 4.5° latitude and 7° longitude are common for Global Climate Models;
- The Oldman and Bow River systems were analyzed.

TITLE: Global Climatic Changes and Regional Hydrology Impacts and Responses

AUTHOR: P.H. Gleick

SOURCE: The Influence of Climate Change and Climatic Variability on the Hydrologic Regime and Water Resources, IAHS #168, 1987.

This paper discussed the effect of global climate change and, in particular, global warming, on regional or local hydrology. Regional hydrologic effects are dependent on changes in climatic conditions and the water resources characteristics of the region. These hydrologic changes fall into distinct categories: changes in timing of water availability; changes in the magnitude of the magnitude of water availability; and, changes in hydrologic variability.

Recent research into climate change suggest that reductions in summer soil moisture may occur in many regions throughout the world. This would be the result of a decrease in snow as a proportion of winter precipitation, an earlier snow melt due to higher average temperatures, and more sever evapotranspiration during the summer months.

Hydrologic changes may have serious impact on the agricultural water supply, flood and drought probabilities, ground water use and recharge rates, the price and quality of water, and reservoir design and operations.

TITLE: Paleorecharge, Climatologic Variability, and Water Resource Management

AUTHOR: W.J. Stone

SOURCE: The Influence of Climate Change and Climatic Variability on the Hydrologic Regime and Water Resources, IAHS #168, 1987.

The purpose of this paper is to discuss the implications for water resource management and waste disposal planning related to both the timing and trends of climatohydrologic variability. The paper compares modern and paleoracharge rates to assess the climatic variability. The paper's findings were based on three case studies; one in an arid region of south Australia, and two in New Mexico. The results of these studies show that all three locations had higher recharge rates in the past than they do now. These wetter periods were preceded by dryer periods. Most of these periods correspond to paleoclimatohydrologic regimes noted in previous studies. The differences in recharge rates are important in water resources management and waste disposal planning. Modern paleorecharge rates can be used as a "worst case" in designing waste disposal facilities.

APPENDIX B

TREND ANALYSIS

Trend Analysis

the following sections describe the Mann and Kendall, Spearman's Rho Test and the Robust Locally Weighted Regression Smooth data analysis techniques used for the trend analysis used in this study.

i) Mann-Kendall Test

Mann (1945) and Kendall (1975) present a non-parametric test for trend. Letting $X_1, X_2, ..., X_n$ be a sequence of low flow over time. Mann proposed to test the null hypothesis, H_o, that the data comes from a population where the random variables are independent and identically distributed. The alternative hypothesis, H_l, is the data following a monotonic trend over time. Under H_o, the Mann-Kendall test statistic is:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn(x_j - x_k) \quad (1)$$

where

$$sgn = \begin{cases} 1 & X > 0 \\ 0 & X = 0 \\ -1 & X < 0 \end{cases}$$

Kendall shows that S is asymptotically normally distributed and gave the mean and variance of S:

$$E(S) = 0 \quad (2)$$

$$Var(S) = n(n-1)(2n+5)/18 \quad (3)$$

A positive value of S indicates there is an upward trend where the data set increases with time. On the other hand, a negative value of S means that there is a downward trend. Because it is known that S is asymptotically normally distributed and has a mean of zero and variance given by equation 3, one can check whether or not an upward or downward trend is significantly different from zero. If the S is significantly different from zero, based upon the available information, H_0 can be rejected at a chosen significant level and the presence of a monotonic trend, H_l, can be accepted.

The exact distribution of S for $n \geq 10$ was derived. Even for small values of n, the normality approximation is good provided one employs the standard normal variate Z given by:

$$Z = \begin{cases} (S-1)/(Var(S))^{½} & \text{if } S > 0 \\ 0 & \text{if } S = 0 \\ (S+1)/(Var(S))^{½} & \text{if } S < 0 \end{cases} \quad (4)$$

A statistic which is closely related to S is Kendall's tau defined by:

$$\tau = S/D \quad (5)$$

where $D = n(n-1)/2$ (6)

Due to the relationship between τ and S, the distribution of τ can be easily obtained from the distribution of S.

ii) Spearman's Rho Test

Spearman (1904) introduced a non-parametric coefficient of rank correlation denoted as ρ_{xy} which is based upon the squared differences of ranks between two variables. By letting one of the variables represent time, Spearman's rho test can be interpreted as a trend test.

Let the sample consist of a bivariate sample (X_i, ti_1) for i=1, 2, ..., n, where n is the sample size. Suppose that the values of X variable are ranked from smallest to largest such that the rank of the smallest value is one and that of the largest value is n. Let $R_1^{(X)}$represent the rank of X variable measured at time t_i. Likewise, the values of Y variable can be ranked and $R_i^{(Y)}$ can represent the value of the rank for the Y variable. The sum of the squared differences of the rank is:

$$S(d^2)=D^2=\sum_{i=1}^{n}(R_i^{(X)}-R_i^{(Y)})^2 \tag{7}$$

Spearman's rho is then defined as:

$$\rho_{XY}=1-\frac{6S(d^2)}{n^3-n} \tag{8}$$

When the two rankings of X and Y are identical $\rho_{xy} = 1$, whereas $\rho_{xy} = -1$ when the rankings of X and Y are in reverse order.

When using ρ_{xT} in a statistical test to check for a trend, the null hypothesis, H_o, is that there is no correlation, that is no trend on the time series. ρ_{xT} is distributed as $N\ (0, \frac{1}{n-1})$, where n is the sample size. The alternative hypothesis, H_1, is that there is correlation between X and T variables. If the estimated value of ρ_{xT} is significantly different from zero, then one can argue that time and X variable are significantly correlated, which in turn means there is a trend.

iii) Robust Locally Weighted Regression Smooth

In essence, the robust locally weighted regression is a method for smoothing a scatter of (X_i, Y_i), i = 1, 2, ..., n, in which the fitted value at X_k is in the value of a polynomial fitted to the data using weighted least squares. The weight for (X_i, Y_i), is large if X_i is close to X_k and is small if this is not the case. To display graphically the RLWRS on the scatter plot of (X_i, Y_i), one plots (X_i, Y_i) on the same graph as the scatter plot of (X_i, Y_i), where (X_i, Y_i) is called the smoothed point at X_i and Y_i is called the fitted value at X_i.

General Procedure: The general idea behind the smoothing procedure is as follows. Let W be a weight function which has the following properties:

1) W (x) > 0 for $|X| < 1$
2) W (-X) = W (X)
3) W (X) is a non-increasing function for $X \geq 0$
4) W (X) = 0 for $|X| \geq 1$

If one lets 0<f<1 and r be f_n rounded to the nearest integer, the outline of the procedure is as given below. For each X_i, weight W_k (X_i), are defined for all X_k, k = 1, 2, ..., n, by employing the weight function W. To accomplish this, centre W at X_i and scale W so that the point at which W first becomes zero is the rth nearest neighbour of X_i. To obtain the initial fitted value, Y_i, at each X_i, a dth degree polynomial is fitted to the data using weighted least squares with weights W_k (X_i). This procedure is called locally weighted regression. Based upon the size of the residual Y - Y_i, a different set of weights, δ_i , is defined for each (X_i, Y_i). In general, large residuals produce small weights while small residuals result in large weights. Because large residuals cause small weights, the effects of extremes tend to be toned down or smoothed, thereby making the procedure robust. After replacing W_k (X_i) by $\delta_i \, W_k \, (X_1)$, new fitted values are computed using locally weighted regression. The determination of new weights and fitted values are repeated as often as required. All of the foregoing steps are referred to as robust locally weighted regression.

In the smoothing procedure, points in the neighbourhood of (X_i, Y_i) are used to calculate Y_1. Because the weights W_k (X_i) decrease as the distance of X_k from X_i increases, points whose abscissae are closer to X_i, have a larger effect upon the calculation of Y_i while further points play a lesser role. By increasing f, the neighbourhood of points affecting Y_l becomes larger. Therefore, larger values of f tend to cause smoother curves.

In the RLWRS procedure, local regression means that regression at a given point is carried out for a subset of nearest neighbours such that the observations closer to the specified point are given larger weights. By taking the size of the residuals into account for obtaining revised weights, robustness is brought into the procedure. Finally, the robust locally weighted regression analysis is carried out for each observation.

Specific Procedure:

1) Let the distance from X_i to the rth nearest neighbour of X_i be denoted by hi for each i. Hence, hi is the smallest number among $|X_i - X_j|$, for j=1, 2, ..., n. For k = 1, 2, ..., n, let

$$W_k (X_l = W ((X_k - X_l)/hi) \tag{9}$$

A possible form for the weight function is the tricube given by:

$$W(X) = \begin{cases} (1 - |X|^3)^3 & \text{for } |X| < 1 \\ 0 & \text{for } |X| > 1 \end{cases} \tag{10}$$

2) The second step describes how locally weighted regression is carried out. For each i, determine the estimates $\beta_j (X_l)_1\ j=1, ..., d,$ of the parameters in a polynomial regression of degree d of Y_k on X_k. This is fitted using weighted least squares having weight $W_k (X_l)$ for (X_k, Y_k). Therefore, the $\beta_j (X_l)$ are the values of β_l which minimize

$$\sum_{k=1}^{n} w_k(x_i)(y_k - \beta_0 - \beta_1 x_k - \beta_2 x_k^2 - \cdots - \beta_d x_k^d)^2 \tag{11}$$

When using locally weighted regression of degree d, the smoothed point at X_l is (X_l, Y_l) for which Y_l is the fitted value of the regression at X_l. Hence

$$\hat{y}_i = \sum_{j=0}^{d} \hat{\beta}_j(x_i) x_i^j = \sum_{k=1}^{n} r_k(x_i) y_k \tag{12}$$

Where $\gamma_k (X_1)$ does not depend on Y_l, j=1, 2, ..., n. The $\gamma_k (X_1)$ are the coefficients for the Y_k coming from the regression.

3) Let the bisquare weight function be given by:

$$B(X) = \begin{cases} (1 - X^2)^2 & \text{for } |X| < 1 \\ 0 & \text{for } |X| \geq 1 \end{cases} \quad (13)$$

Let the residuals for the current fitted values be $e_i = Y_i - Y_i$. The robustness weights are defined by:

$$\delta_K = \beta\ (e_k/6S) \quad (14)$$

where S is the median of the $|e_1|$

4) For each i, determine new Y_i by fitting a dth degree polynomial using weighted least squares having the weight $\delta_k\ W_k\ (X_k)$ at (X_k, Y_k).

5) Interactively execute steps 3 and 4 for a total t' times. The final Y_i constitute the fitted values for the robust locally weighted regression and the (X_i, Y_i), i = 1, 2, ..., n, from the RLWRS. An increase in f causes an increase in the smoothness of the RLWRS. f = 0.5 often produces reasonable results. In practice, one can experiment with two or three value of f and select the one which produces the most informative smooth.

The parameter d is the order of the polynomial that is locally fitted to each point. d = 1, a linear polynomial usually results in a good smoothed curve that does not require high computational effort.

The parameter t' stands for the number of iterations. t' = 1 is sufficient for most applications.

TABLE 1 (a)

SUMMARY OF SIGNIFICANT RESULTS

NORTHWESTERN REGION

Station No.	Trend (7 Day Low Flow)													
	Spearman Test							Mann-Kendall Test						
	S.C.	D.F.	S.T.	5%		1%		t	S.D.	Z	5%		1%	
				T.L.	T.I.	T.L.	T.I.				T.L.	T.I.	T.L.	T.I.
02AB008	-0.351	31	-2.088	-2.04	Yes	-2.745	No	0.25	64.5	2.03	1.96	Yes	2.57	No
02AB013	0.431	33	2.743	2.036	Yes	2.736	Yes	-0.313	70.4	-2.627	1.96	Yes	2.57	Yes
02AD008	0.505	34	3.407	2.034	Yes	2.732	Yes	-0.33	73.4	-2.82	1.96	Yes	2.57	Yes
02AE001	-0.608	10	-2.424	-2.228	Yes	-3.169	No	0.455	14.6	1.992	1.96	Yes	2.57	No
04CB001	0.521	17	2.517	2.11	Yes	2.898	No	-0.368	28.6	-2.169	1.96	Yes	2.57	No
04FA002	0.537	17	2.624	2.11	Yes	2.898	No	-0.263	28.6	-1.539	1.96	No	2.57	No
04FA003	0.532	17	2.589	2.11	Yes	2.898	No	-0.409	28.6	-2.414	1.96	Yes	2.57	No
04GA001	0.874	49	12.619	2.012	Yes	2.684	Yes	-0.625	123.1	-6.465	1.96	Yes	2.57	Yes
04JD002	0.573	46	4.742	2.015	Yes	2.691	Yes	-0.224	112.5	-2.24	1.96	Yes	2.57	No
05PA006	-0.331	62	-2.762	-1.998	Yes	-2.659	Yes	0.213	172.6	2.485	1.96	Yes	2.57	No
05PB009	0.416	21	2.094	2.080	Yes	2.831	No	-0.269	37.9	-1.77	1.96	No	2.57	No
05PB014	-0.365	61	-3.061	-2.0	Yes	-2.659	Yes	0.233	168.6	2.693	1.96	Yes	2.57	Yes
05PD023	0.546	13	2.351	2.16	Yes	3.012	No	-0.343	20.2	-1.733	1.96	No	2.57	No
05PE006	-0.611	77	-6.778	-1.994	Yes	-2.648	Yes	0.437	236.2	5.69	1.96	Yes	2.57	Yes
05PE011	-0.239	71	-2.071	-1.996	Yes	-2.652	No	0.161	209.9	2.014	1.96	Yes	2.57	No
05QE008	0.652	15	3.33	2.131	Yes	2.947	Yes	-0.5	29.3	-2.761	1.96	Yes	2.57	Yes

LEGEND:

S.C. : Spearman Coefficient
D.F. : Degrees of Freedom
S.T. : Studentized Coefficient

T.L. : Test Limit
T.I. : Trend Indicator
t : Tau
S.D. : Standard Deviation
Z : Mann-Kendall Variable

TABLE 1 (b)

NORTHEASTERN REGION

Station No.	Trend (7 Day Low Flow)													
	Spearman Test							Mann-Kendall Test						
	S.C.	D.F.	S.T.	5%		1%		t	S.D.	Z	5%		1%	
				T.L.	T.I.	T.L.	T.I.				T.L.	T.I.	T.L.	T.I.
02BD002	-0.528	57	-4.693	-2.003	Yes	-2.667	Yes	0.389	152.9	4.34	1.96	Yes	2.57	Yes
02BE002	-0.495	49	-3.983	-2.012	Yes	-2.684	Yes	0.398	123.1	4.11	1.96	Yes	2.57	Yes
02CC008	-0.607	30	-4.406	-2.042	Yes	-2.750	Yes	0.448	61.7	3.584	1.96	Yes	2.57	Yes
02CE004	0.31	64	2.610	1.999	Yes	2.657	No	-0.195	180.7	-2.308	1.96	Yes	2.57	No
02CF004	0.363	66	3.168	1.998	Yes	2.656	Yes	-0.25	188.9	-3.007	1.96	Yes	2.57	Yes
02CF005	0.607	25	3.824	2.060	Yes	2.787	Yes	-0.422	49.9	-3.064	1.96	Yes	2.57	Yes
02CF007	0.478	24	-2.663	-2.064	Yes	-2.797	No	0.323	45.4	2.293	1.96	Yes	2.57	No
02DB005	0.474	32	3.043	2.038	Yes	2.741	Yes	-0.314	67.5	-2.594	1.96	Yes	2.57	Yes
02DC007	-0.419	46	-3.128	-2.015	Yes	-2.691	Yes	0.119	112.5	1.182	1.96	No	2.57	No
02DC008	-0.29	46	-2.057	-2.015	Yes	-2.691	No	-0.166	112.5	1.653	1.96	No	2.57	No
02DD010	-0.43	23	-2.285	-2.069	Yes	-2.807	No	0.33	43.8	2.289	1.96	Yes	2.57	No
02EA013	-0.696	9	-2.908	-2.262	Yes	-3.25	No	0.473	12.8	1.946	1.96	No	2.57	No
02JD012	-0.688	39	-5.915	-2.023	Yes	-2.709	Yes	0.449	89.0	4.122	1.96	Yes	2.57	Yes
04LD001	-0.318	61	-2.623	-2.0	Yes	-2.659	No	0.217	168.6	2.503	1.96	Yes	2.57	No
04LG002	0.512	21	2.730	2.08	Yes	2.831	No	-0.360	37.9	-2.377	1.96	Yes	2.57	No
04MD002	0.429	46	3.224	2.015	Yes	2.691	Yes	-0.213	112.5	-2.124	1.96	Yes	2.57	No
04MD004	-0.927	8	-7.005	-2.306	Yes	-3.355	Yes	0.778	11.2	3.041	1.96	Yes	2.57	Yes
04MD004	-0.927	8	-7.005	-2.306	Yes	-3.355	Yes	0.778	11.8	3.04	1.96	Yes	2.57	Yes
04ME004	0.492	23	2.713	2.069	Yes	2.807	No	-0.387	42.8	-2.686	1.96	Yes	2.57	Yes
04MF001	0.536	18	2.69	2.101	Yes	2.878	No	-0.374	30.8	-2.271	1.96	Yes	2.57	No

LEGEND: S.C. : Spearman Coefficient S.T. : Studentized Coefficient T.I. : Trend Indicator S.D. : Standard Deviation

APPENDIX C

INITIAL DATABASES USED FOR STATION SELECTION

TABLE C.1
CURRENT CLIMATE STATIONS IN ONTARIO

NUMBER	STATION	FROM	TO	PARAMETER					p	ZONE	C	r	R
				P	T	W	E	S					
6085700	NORTH BAY A	1939	1990	X	X			S	1	MCTh	145.970	51.00	126.19
6119500	WIARTON A	1947	1990	X	X			S	1	MCTh	109.820	43.00	122.41
6092925	GORE BAY A	1947	1990	X	X				1	MCTh	239.820	43.00	121.92
6166418	PETERBOROUGH A	1969	1990	X	X	U			1	MCTh	148.840	21.00	111.17
6150689	BELLEVILLE	1866	1990	X	X				4	MCTh	212.040	124.00	87.47
6112171	DURHAM	1882	1990	X	X				4	MCTh	127.210	108.00	79.79
6165195	MINDEN	1883	1990	X	X				4	MCTh	88.020	107.00	79.64
6156670	PORT HOPE	1882	1990	X	X				4	MCTh	173.900	108.00	79.58
6151866	COPETOWN	1882	1990	X	X				4	MCTh	204.090	108.00	79.49
6124700	LUCKNOW	1885	1990	X	X				4	MCTh	182.760	105.00	78.05
6112133	DUNCHURCH	1898	1990	X	X				4	MCTh	60.910	92.00	72.64
6121025	BRUCEFIELD	1903	1990	X	X				4	MCTh	217.790	87.00	68.96
6101820	COMBERMERE	1954	1990	X	X				2	MCTh	173.760	36.00	68.58
6104025	KEMPTVILLE	1928	1990	X	X	B	A	S	3	MCTh	300.010	62.00	64.67
6105460	MORRISBURG	1913	1990	X	X				4	MCTh	323.870	77.00	63.81
6104146	KINGSTON A	1930	1990	X	X			S	3	MCTh	258.000	60.00	63.72
6068980	TURBINE	1914	1990	X	X				4	MCTh	201.140	76.00	63.50
6084770	MADAWASKA	1915	1990	X	X				4	MCTh	151.820	75.00	63.16
6151137	CAMPBELLFORD	1915	1990	X	X				4	MCTh	178.710	75.00	63.06
6156533	PICTON	1915	1990	X	X				4	MCTh	235.500	75.00	62.92
6142400	FERGUS SHAND DAM	1939	1990	X	X	B			3	MCTh	154.430	51.00	59.48
6155854	ORONO	1923	1990	X	X				4	MCTh	155.220	67.00	59.14

TABLE C.1
CURRENT CLIMATE STATIONS IN ONTARIO

NUMBER	STATION	FROM	TO	PARAMETER					p	ZONE	C	r	R
				P	T	W	E	S					
6115525	MUSKOKA A	1934	1990	X	X				4	MCTh	42.420	56.00	55.36
6158875	TRENTON A	1935	1990	X	X				4	MCTh	205.680	55.00	52.99
6068150	SUDBURY A	1954	1990	X	X			S	3	MCTh	187.050	36.00	51.87
6101901	CORNWALL ONT HYDRO	1954	1990	X	X	B		S	3	MCTh	341.930	36.00	51.63
6126210	PAISLEY	1961	1990	X	X	B			3	MCTh	152.800	29.00	48.49
6115099	MIDHURST	1947	1990	X	X				4	MCTh	69.360	43.00	47.94
6159449	WELLINGTON	1948	1990	X	X				4	MCTh	227.670	42.00	46.44
6149387	WATERLOO WELLINGTON A	1966	1990	X	X	U	A		3	MCTh	185.670	24.00	45.87
6101494	CHENAUX	1950	1990	X	X				4	MCTh	244.150	40.00	45.41
6101440	CHATS FALLS	1950	1990	X	X				4	MCTh	269.830	40.00	45.37
6113490	HONEY HBR BEAUSOLEIL	1974	1990	X	X	B		S	3	MCTh	25.230	16.00	45.30
6166455	PETERBOROUGH TRENT U	1968	1990	X	X	B	A	S	3	MCTh	142.620	22.00	45.03
6111467	CHATSWORTH	1952	1990	X	X				4	MCTh	114.470	38.00	44.87
6159127	VALENS	1968	1990	X	X	B			3	MCTh	189.760	22.00	44.86
6146711	PRESTON	1953	1990	X	X				4	MCTh	191.860	37.00	44.02
6145267	MONTICELLO	1954	1990	X	X				4	MCTh	130.730	36.00	43.76
6107247	RUSSELL	1954	1990	X	X				4	MCTh	316.700	36.00	43.32
6142803	GLEN ALLAN	1955	1990	X	X				4	MCTh	170.230	35.00	43.09
6112340	ESSA ONT HYDRO	1958	1990	X	X				4	MCTh	78.150	32.00	42.28
6164433	LINDSAY FROST	1974	1990	X	X	B		S	3	MCTh	119.500	16.00	42.17
6057590	SAULT STE MARIE 2	1957	1990	X	X				4	MCTh	392.470	33.00	41.75
6143069	GUELPH ARBORETUM	1975	1990	X	X			S	3	MCTh	172.100	15.00	41.41

TABLE C.1
CURRENT CLIMATE STATIONS IN ONTARIO

NUMBER	STATION	FROM	TO	PARAMETER					p	ZONE	C	r	R
				P	T	W	E	S					
6120819	BLYTH	1959	1990	X	X				4	MCTh	194.610	31.00	41.01
6100345	ARNPRIOR GRANDON	1959	1990	X	X				4	MCTh	259.970	31.00	40.88
6101335	CHALK RIVER AEC	1960	1990	X	X				4	MCTh	220.870	30.00	40.45
6101265	CATARAQUI TS	1960	1990	X	X				4	MCTh	251.220	30.00	40.40
6104175	KINGSTON PUMPING STATION	1960	1990	X	X				4	MCTh	264.790	30.00	40.38
6107955	SOUTH MOUNTAIN	1960	1990	X	X				4	MCTh	308.230	30.00	40.32
6122370	EXETER	1961	1990	X	X				4	MCTh	232.460	29.00	39.93
6084300	LAKE OPEONGO	1962	1990	X	X				4	MCTh	130.490	28.00	39.77
6065250	MONETVILLE	1963	1990	X	X				4	MCTh	125.090	27.00	39.30
6115820	ORILLIA TS	1965	1990	X	X				4	MCTh	59.490	25.00	39.18
6164432	LINDSAY FILTRATION PLANT	1964	1990	X	X				4	MCTh	117.950	26.00	38.85
6140348	ARTHUR	1964	1990	X	X				4	MCTh	151.180	26.00	38.66
6166428	PETERBOROUGH DOBBIN TS	1965	1990	X	X				4	MCTh	139.620	25.00	38.22
6150816	BLOOMFIELD WEST	1966	1990	X	X				4	MCTh	230.620	24.00	37.43
61519JM	CRESSY	1966	1990	X	X				4	MCTh	248.210	24.00	37.40
611HBEC	THORNBURY SLAMA	1968	1990	X	X				4	MCTh	77.220	22.00	37.30
6103367	HARTINGTON IHD	1967	1990	X	X				4	MCTh	244.260	23.00	36.91
6102832	GLEN GORDON	1967	1990	X	X				4	MCTh	354.370	23.00	36.78
6107002	RENFREW	1968	1990	X	X				4	MCTh	240.040	22.00	36.42
6116750	PROTON STATION	1969	1990	X	X				4	MCTh	114.650	21.00	36.37
6082612	FRENCH R CHAUDIERE DAM	1969	1990	X	X				4	MCTh	118.130	21.00	36.35
6111769	COLDWATER WARMINSTER	1971	1990	X	X				4	MCTh	54.310	19.00	36.34

TABLE C.1
CURRENT CLIMATE STATIONS IN ONTARIO

NUMBER	STATION	FROM	TO	PARAMETER					p	ZONE	C	r	R
				P	T	W	E	S					
6101958	DALHOUSIE MILLS	1968	1990	X	X				4	MCTh	358.630	22.00	36.28
6116902	RAVENSHOE	1970	1990	X	X				4	MCTh	100.720	20.00	35.99
6106398	PETAWAWA A	1969	1990	X	X				4	MCTh	218.210	21.00	35.96
6068158	SUDBURY SCIENCE NORTH	1986	1990	X	X			S	3	MCTh	180.290	4.00	35.89
6141919	CROMARTY	1970	1990	X	X				4	MCTh	219.270	20.00	35.46
611KBE0	EGBERT CARE	1988	1990	X	X	B		S	3	MCTh	93.770	2.00	35.40
6055210	MISSISSAGI ONT HYDRO	1970	1990	X	X				4	MCTh	321.720	20.00	35.31
6111859	COOKSTOWN	1972	1990	X	X				4	MCTh	97.740	18.00	35.02
6116258	PARRY SOUND MARTYR IS	1975	1990	X	X				4	MCTh	41.810	15.00	34.89
6117684	SHANTY BAY	1973	1990	X	X				4	MCTh	76.360	17.00	34.81
6082178	DWIGHT	1973	1990	X	X				4	MCTh	80.370	17.00	34.74
6113329	HANOVER	1972	1990	X	X				4	MCTh	141.540	18.00	34.71
6147188	ROSEVILLE	1972	1990	X	X				4	MCTh	198.290	18.00	34.50
6117682	SEVERN BRIDGE	1975	1990	X	X				4	MCTh	51.250	15.00	34.45
6102808	GLENBURNIE	1972	1990	X	X				4	MCTh	259.940	18.00	34.38
6110218	ALLISTON NELSON	1973	1990	X	X				4	MCTh	122.610	17.00	34.32
6116702	POWASSAN	1974	1990	X	X				4	MCTh	125.690	16.00	33.80
616PA87	ROSEDALE	1975	1990	X	X				4	MCTh	99.390	15.00	33.51
6110606	BEATRICE 2	1979	1990	X	X				4	MCTh	33.430	11.00	33.49
6139142	VINELAND BALLS FALLS	1974	1990	X	X				4	MCTh	218.730	16.00	33.46
6112072	DORSET MOE	1976	1990	X	X				4	MCTh	72.070	14.00	33.39
6116255	PARRY SOUND	1979	1990	X	X				4	MCTh	36.340	11.00	33.25

TABLE C.1
CURRENT CLIMATE STATIONS IN ONTARIO

NUMBER	STATION	FROM	TO	PARAMETER					p	ZONE	C	r	R
				P	T	W	E	S					
6161050	BURLEIGH FALLS	1975	1990	X	X				4	MCTh	137.120	15.00	33.23
611C001	GRAVENHURST BOOTH	1980	1990	X	X				4	MCTh	37.050	10.00	32.70
6117957	SOUTH RIVER	1977	1990	X	X				4	MCTh	91.370	13.00	32.59
6127418	SALTFORD	1976	1990	X	X				4	MCTh	208.250	14.00	32.48
6121969	DASHWOOD	1976	1990	X	X				4	MCTh	237.120	14.00	32.42
6104725	LYNDHURST SHAWMERE	1976	1990	X	X				4	MCTh	278.420	14.00	32.36
6100398	AVONMORE	1976	1990	X	X				4	MCTh	334.910	14.00	32.30
6104882	MALLORYTOWN LANDING	1977	1990	X	X				4	MCTh	293.310	13.00	31.84
6123672	HURON PARK	1978	1990	X	X				4	MCTh	236.150	12.00	31.42
6151136	CAMPBELLCROFT GANARASKA	1979	1990	X	X				4	MCTh	152.690	11.00	31.15
6147693	SHELBURNE WPCP	1981	1990	X	X				4	MCTh	113.850	9.00	30.38
6153853	JANETVILLE	1981	1990	X	X				4	MCTh	133.670	9.00	30.25
6154995	MARMORA	1981	1990	X	X				4	MCTh	176.690	9.00	30.07
6064460	LIVELY	1981	1990	X	X				4	MCTh	183.380	9.00	30.05
6102857	GODFREY	1981	1990	X	X				4	MCTh	244.730	9.00	29.91
6119274	WALTERS FALLS	1983	1990	X	X				4	MCTh	95.650	7.00	29.55
6119129	VALLENTYNE	1983	1990	X	X				4	MCTh	103.330	7.00	29.47
6107836	SMITHS FALLS TS	1982	1990	X	X				4	MCTh	279.020	8.00	29.36
6050805	BLIND RIVER HYDRO CENTRE	1982	1990	X	X				4	MCTh	285.900	8.00	29.35
6156682	PORT PERRY NONQUON	1983	1990	X	X				4	MCTh	122.610	7.00	29.32
6080HB6	BONFIELD	1983	1990	X	X				4	MCTh	141.030	7.00	29.21

TABLE C.1
CURRENT CLIMATE STATIONS IN ONTARIO

NUMBER	STATION	FROM	TO	PARAMETER					p	ZONE	C	r	R
				P	T	W	E	S					
6153357	HAROLD WILDWOOD	1983	1990	X	X				4	MCTh	191.060	7.00	29.02
6065006	MASSEY	1983	1990	X	X				4	MCTh	215.550	7.00	28.96
6101502	CHESTERVILLE 2	1983	1990	X	X				4	MCTh	322.860	7.00	28.81
6115130	MIDLAND HURONIA A	1987	1990	X	X				4	MCTh	44.640	3.00	28.74
6110HK7	BORDEN STP	1985	1990	X	X				4	MCTh	86.120	5.00	28.66
6117750	SINGHAMPTON	1985	1990	X	X				4	MCTh	87.320	5.00	28.65
611DR50	MAPLE GROVE	1985	1990	X	X				4	MCTh	86.760	5.00	28.65
6147229	RUSKVIEW	1985	1990	X	X				4	MCTh	96.780	5.00	28.53
6155148	MILFORD	1984	1990	X	X				4	MCTh	244.100	6.00	28.41
6102J13	DRUMMOND CENTRE	1984	1990	X	X				4	MCTh	263.350	6.00	28.38
6101250	CARLETON PLACE	1984	1990	X	X				4	MCTh	266.900	6.00	28.37
6052268	ELLIOT LAKE STANLEIGH	1984	1990	X	X				4	MCTh	271.300	6.00	28.37
6151309	CENTREVILLE	1985	1990	X	X				4	MCTh	231.300	5.00	27.93
6160820	BOBCAYGEON	1986	1990	X	X				4	MCTh	112.850	4.00	27.89
6128206	TARA	1986	1990	X	X				4	MCTh	123.530	4.00	27.81
6107533	SARSFIELD	1985	1990	X	X				4	MCTh	319.530	5.00	27.81
61110M6	BURK'S FALLS 2	1988	1990	X	X				4	MCTh	58.870	2.00	27.70
614NFK0	NEWTON	1986	1990	X	X				4	MCTh	186.530	4.00	27.54
6094449	LITTLE CURRENT	1986	1990	X	X				4	MCTh	196.970	4.00	27.51
6169647	WOODVILLE	1987	1990	X	X				4	MCTh	100.280	3.00	27.50
6163171	HALIBURTON 3	1987	1990	X	X				4	MCTh	101.450	3.00	27.49
615EMR7	MOUNTAINVIEW	1986	1990	X	X				4	MCTh	223.640	4.00	27.45

TABLE C.1
CURRENT CLIMATE STATIONS IN ONTARIO

NUMBER	STATION	FROM	TO	PARAMETER P	T	W	E	S	p	ZONE	C	r	R
6109558	WOLFE ISLAND	1986	1990	X	X				4	MCTh	265.040	4.00	27.38
6107276	ST. ALBERT	1986	1990	X	X				4	MCTh	332.260	4.00	27.30
6160473	BANCROFT OMNR	1987	1990	X	X				4	MCTh	151.520	3.00	27.16
6069K90	WARREN	1987	1990	X	X				4	MCTh	154.930	3.00	27.15
6110439	AYTON	1988	1990	X	X				4	MCTh	136.390	2.00	26.73
6128323	TOBERMORY CYPRUS LAKE	1988	1990	X	X				4	MCTh	140.490	2.00	26.71
611K661	GAMEBRIDGE	1989	1990	X	X				4	MCTh	83.950	1.00	26.69
6054078	KENTVALE	1988	1990	X	X				4	MCTh	362.250	2.00	26.28
6050NNP	BAR RIVER	1988	1990	X	X				4	MCTh	368.740	2.00	26.27
6157012	RICHMOND HILL	1959	1990	X	X				4	MCTh	136.070	31.00	0.00
6155878	OSHAWA WPCP	1969	1990	X	X				4	MCTh	155.330	21.00	0.00
6158084	STOUFFVILLE WPCP	1971	1990	X	X				4	MCTh	131.010	19.00	0.00
6158520	TORONTO ELLESMERE	1959	1990	X	X				4	MCTh	151.580	31.00	0.00
6150103	ALBION FIELD CENTRE	1969	1990	X	X				4	MCTh	136.070	21.00	0.00
6155877	OSHAWA FIRE HALL #3	1976	1990	X	X				4	MCTh	148.000	14.00	0.00
6150863	BRADFORD MUCK RESEARCH	1974	1990	X	X				4	MCTh	117.390	16.00	0.00
6154142	KING SMOKE TREE	1974	1990	X	X				4	MCTh	119.640	16.00	0.00
6034075	KENORA A	1938	1990	X	X				1	MBx	581.440	52.00	126.17
6041109	CAMERON FALLS	1924	1990	X	X				2	MBx	240.680	66.00	83.42
6022475	FORT FRANCES	1892	1990	X	X				4	MBx	512.570	98.00	74.20
6046770	PUKASKWA NATL PARK	1983	1990	X	X	B			3	MBx	354.710	7.00	37.12
6048230	TERRACE BAY	1972	1990	X	X				4	MBx	307.010	18.00	34.33

TABLE C.1
CURRENT CLIMATE STATIONS IN ONTARIO

NUMBER	STATION	FROM	TO	PARAMETER					p	ZONE	C	r	R
				P	T	W	E	S					
6042MJ7	FLINT	1979	1990	X	X				4	MBx	330.390	11.00	30.80
6049466	WHITEFISH LAKE	1980	1990	X	X				4	MBx	341.770	10.00	30.29
6040011	ABITIBI CAMP 11	1983	1990	X	X				4	MBx	270.380	7.00	28.87
6040330	ARMSTRONG JELLIEN	1987	1990	X	X				4	MBx	122.480	3.00	27.32
6044961	MARATHON A	1988	1990	X	X				4	MBx	339.570	2.00	26.29
6016525	PICKLE LAKE	1930	1990	X	X	U	A		1	MBs	387.610	60.00	130.26
6032117	DRYDEN	1914	1990	X	X				2	MBs	550.620	76.00	88.18
6025203	MINE CENTRE	1914	1990	X	X				4	MBs	659.570	76.00	63.15
6032119	DRYDEN A	1969	1990	X	X	U			2	MBs	544.570	21.00	60.68
6012198	EAR FALLS	1928	1990	X	X				4	MBs	474.660	62.00	56.21
6037775	SIOUX LOOKOUT A	1938	1990	X	X				4	MBs	513.260	52.00	51.19
6047810	SLATE ISLAND	1966	1990	X	X	B			3	MBs	816.440	24.00	45.46
6022476	FORT FRANCES A	1976	1990	X	X	U			3	MBs	681.230	14.00	40.48
6027825	SLEEMAN	1964	1990	X	X				4	MBs	706.690	26.00	38.14
6033697	IGNACE TCPL 58	1969	1990	X	X				4	MBs	582.880	21.00	35.67
6034077	KENORA TCPL 49	1969	1990	X	X				4	MBs	607.100	21.00	35.66
602K300	EMO RADBOURNE	1978	1990	X	X				4	MBs	687.840	12.00	31.15
6020559	BARWICK	1978	1990	X	X				4	MBs	697.670	12.00	31.14
6042716	GERALDTON A	1981	1990	X	X				4	MBs	708.720	9.00	29.64
6032192	EAGLE RIVER	1986	1990	X	X				4	MBs	552.410	4.00	27.18
6075425	MOOSONEE	1932	1990	X	X	U	A	S	1	MBh	227.130	58.00	129.44
6073975	KAPUSKASING A	1937	1990	X	X				1	MBh	70.930	53.00	127.91

TABLE C.1
CURRENT CLIMATE STATIONS IN ONTARIO

NUMBER	STATION	FROM	TO	PARAMETER					p	ZONE	C	r	R
				P	T	W	E	S					
6072225	EARLTON A	1938	1990	X	X				1	MBh	342.620	52.00	126.29
6059D09	WAWA A	1976	1990	X	X	U			1	MBh	225.970	14.00	107.44
6071712	COCHRANE	1910	1990	X	X				4	MBh	192.420	80.00	65.52
6073810	IROQUOIS FALLS	1913	1990	X	X				4	MBh	231.980	77.00	63.93
6074209	KIRKLAND LAKE	1915	1990	X	X				4	MBh	305.860	75.00	62.83
6053570	HORNEPAYNE	1916	1990	X	X				4	MBh	126.210	74.00	62.79
6073840	ISLAND FALLS	1926	1990	X	X				4	MBh	150.650	64.00	57.66
6077845	SMOKY FALLS	1933	1990	X	X				4	MBh	89.360	57.00	54.62
6075024	MATTICE TCPL	1966	1990	X	X				4	MBh	13.410	24.00	44.46
6078285	TIMMINS A	1955	1990	X	X				4	MBh	194.790	35.00	43.01
6044903	MANITOUWADGE	1956	1990	X	X				4	MBh	198.380	34.00	42.50
6072460	FORT ALBANY	1968	1990	X	X				4	MBh	276.780	22.00	36.36
6076572	PORCUPINE ONT HYDRO	1969	1990	X	X				4	MBh	207.430	21.00	35.98
6053463	HIGH FALLS	1976	1990	X	X				4	MBh	228.670	14.00	32.44
6055302	MONTREAL FALLS	1976	1990	X	X				4	MBh	287.510	14.00	32.35
6061361	CHAPLEAU A	1978	1990	X	X				4	MBh	208.990	12.00	31.48
6043452	HEMLO NORANDA	1985	1990	X	X				4	MBh	224.380	5.00	27.95
6144475	LONDON A	1940	1990	X	X			S	1	HMTh	36.090	50.00	127.77
6137287	ST CATHARINES A	1971	1990	X	X	U			1	HMTh	176.690	19.00	110.07
6136694	PORT STANLEY	1871	1990	X	X				4	HMTh	5.190	119.00	103.75
6149625	WOODSTOCK	1870	1990	X	X				4	HMTh	60.350	120.00	86.66
6139445	WELLAND	1872	1990	X	X				4	HMTh	162.070	118.00	84.62

TABLE C.1
CURRENT CLIMATE STATIONS IN ONTARIO

NUMBER	STATION	FROM	TO	PARAMETER					p	ZONE	C	r	R
				P	T	W	E	S					
6136626	PORT DALHOUSIE	1874	1990	X	X				4	HMTh	168.320	116.00	83.59
6148120	STRATHROY	1879	1990	X	X				4	HMTh	43.130	111.00	82.82
6137147	RIDGETOWN	1883	1990	X	X				4	HMTh	65.610	107.00	80.02
6137285	ST CATHARINES	1882	1990	X	X				4	HMTh	170.630	108.00	79.59
6130257	AMHERSTBURG	1882	1990	X	X				4	HMTh	175.500	108.00	79.57
6139145	VINELAND STATION	1915	1990	X	X	B		S	3	HMTh	158.450	75.00	71.46
6135638	NIAGARA FALLS	1902	1990	X	X				4	HMTh	180.990	88.00	69.55
6139265	WALLACEBURG	1905	1990	X	X				4	HMTh	99.160	85.00	68.51
6153300	HAMILTON RBG	1950	1990	X	X	B	A	S	3	HMTh	128.060	40.00	54.11
6139525	WINDSOR A	1940	1990	X	X				4	HMTh	156.710	50.00	50.64
6133120	HAGERSVILLE	1948	1990	X	X				4	HMTh	98.520	42.00	47.02
6127514	SARNIA A	1967	1990	X	X	U		S	3	HMTh	91.700	23.00	45.92
6137161	RIDGEVILLE	1950	1990	X	X				4	HMTh	158.310	40.00	45.63
6137362	ST THOMAS WPCP	1980	1990	X	X				4	HMTh	6.480	10.00	45.43
6155183	MILLGROVE	1951	1990	X	X				4	HMTh	124.250	39.00	45.30
6137399	ST WILLIAMS	1954	1990	X	X				4	HMTh	60.650	36.00	44.65
6135583	NEW GLASGOW	1957	1990	X	X				4	HMTh	43.150	33.00	43.82
6132090	DRESDEN	1956	1990	X	X				4	HMTh	81.890	34.00	43.22
613FN58	POINT PELEE	1974	1990	X	X	B			3	HMTh	149.110	16.00	42.00
6153290	HAMILTON MUNICIPAL LAB	1958	1990	X	X				4	HMTh	134.260	32.00	41.74
6126499	PETROLIA TOWN	1960	1990	X	X				4	HMTh	78.610	30.00	41.27
6142420	FOLDENS	1963	1990	X	X				4	HMTh	50.420	27.00	40.48

TABLE C.1
CURRENT CLIMATE STATIONS IN ONTARIO

NUMBER	STATION	FROM	TO	PARAMETER					p	ZONE	C	r	R
				P	T	W	E	S					
6136606	PORT COLBORNE	1964	1990	X	X				4	HMTh	160.460	26.00	38.62
6139143	VINELAND RITTENHOUSE	1965	1990	X	X				4	HMTh	156.520	25.00	38.14
6137306	ST CATHARINES POWER GLEN	1965	1990	X	X				4	HMTh	167.580	25.00	38.10
6131415	CHATHAM WPCP	1983	1990	X	X	B			3	HMTh	93.290	7.00	37.91
6143722	ILDERTON BEAR CREEK	1971	1990	X	X				4	HMTh	40.750	19.00	36.95
61219J1	COURTRIGHT	1969	1990	X	X				4	HMTh	99.980	21.00	36.50
6141933	CULLODEN EASEY	1974	1990	X	X				4	HMTh	35.500	16.00	35.82
6155097	MIDDLEPORT TS	1980	1990	X	X				4	HMTh	108.460	10.00	30.92
6139533	WINDSOR FORD PLANT	1980	1990	X	X				4	HMTh	157.240	10.00	30.64
6135657	NIAGARA FALLS NPCSH	1980	1990	X	X				4	HMTh	183.300	10.00	30.55
6137176	RODNEY	1984	1990	X	X				4	HMTh	40.420	6.00	30.47
6143465	HILLSBURGH	1981	1990	X	X				4	HMTh	147.080	9.00	30.18
6135FF4	NIAGARA ON THE LAKE	1983	1990	X	X				4	HMTh	181.710	7.00	29.05
6137979	SPRINGFORD	1986	1990	X	X				4	HMTh	50.730	4.00	28.97
612HKLR	THEDFORD	1986	1990	X	X				4	HMTh	71.510	4.00	28.40
6136619	PORT CREWE	1988	1990	X	X				4	HMTh	106.370	2.00	26.94
6159575	WOODBRIDGE	1948	1990	X	X				4	HMTh	180.940	42.00	0.00
6158738	TORONTO MALVERN	1974	1990	X	X				4	HMTh	204.100	16.00	0.00
615HMAK	TORONTO BUTTONVILLE A	1986	1990	X	X				4	HMTh	200.000	4.00	0.00
6156516	PICKERING DUNBARTON	1986	1990	X	X				4	HMTh	213.170	4.00	0.00
6158665	TORONTO ISLAND A	1939	1990	X	X	U			3	HMTh	182.080	51.00	0.00

TABLE C.1
CURRENT CLIMATE STATIONS IN ONTARIO

NUMBER	STATION	FROM	TO	PARAMETER					p	ZONE	C	r	R
				P	T	W	E	S					
6158741	TORONTO METRO ZOO	1976	1990	X	X				4	HMTh	208.630	14.00	0.00
6154950	MAPLE	1957	1990	X	X				4	HMTh	193.300	33.00	0.00
6158350	TORONTO	1840	1990	X	X			S	3	HMTh	184.620	150.00	0.00

TABLE C.2
CURRENT HYDROMETRIC STATIONS IN ONTARIO MEASURING FLOW

NUMBER	STATION	FROM	TO	RECORD	REG.	p	BASIN	ZONE	RANKING
02GB001	GRAND RIVER AT BRANTFORD	1913	1990	55	R	2	2G	MCTh	79.67
02GD005	NORTH THAMES RIVER AT ST. MARYS	1938	1990	53	R	2	2G	MCTh	79.56
02GE003	THAMES RIVER AT THAMESVILLE	1938	1990	50	R	2	2G	HMTh	77.86
02GD009	TROUT CREEK NEAR ST. MARYS	1945	1990	46	R	2	2G	MCTh	76.16
02GD011	CEDAR CREEK AT WOODSTOCK	1951	1990	40	R	2	2G	MCTh	74.22
02GD012	THAMES RIVER AT WOODSTOCK	1952	1990	39	R	2	2G	MCTh	73.47
02GC006	BIG CREEK NEAR DELHI	1955	1990	36	R	2	2G	HMTh	73.39
02GC007	BIG CREEK NEAR WALSINGHAM	1955	1990	36	R	2	2G	HMTh	73.01
02GA015	SPEED RIVER BELOW GUELPH	1950	1990	41	R	2	2G	MCTh	72.22
02GA016	GRAND RIVER BELOW SHAND DAM	1950	1990	41	R	2	2G	MCTh	72.12
02GB006	HORNER CREEK NEAR PRINCETON	1953	1990	38	R	2	2G	MCTh	71.81
02GD014	NORTH THAMES RIVER NEAR MITCHELL	1953	1990	38	R	2	2G	MCTh	71.14
02GC008	LYNN RIVER AT SIMCOE	1957	1990	34	R	2	2G	HMTh	70.89
02GA033	LUTTERAL CREEK NEAR OUSTIC	1953	1990	37	R	2	2G	MCTh	70.13
02GA023	CANAGAGIGUE CREEK NEAR ELMIRA	1956	1990	35	R	2	2G	MCTh	69.32
02GA014	GRAND RIVER NEAR MARSVILLE	1947	1990	34	R	2	2G	MCTh	68.55
02GA024	LAUREL CREEK AT WATERLOO	1959	1990	32	R	2	2G	MCTh	67.97
02GA028	CONESTOGO RIVER AT GLEN ALLAN	1959	1990	32	R	2	2G	MCTh	67.80
02GB010	MCKENZIE CREEK NEAR CALEDONIA	1961	1990	30	R	2	2G	HMTh	67.70
02GB008	WHITEMANS CREEK NEAR MOUNT VERNON	1961	1990	30	R	2	2G	MCTh	67.43
02FC001	SAUGEEN RIVER NEAR PORT ELGIN	1914	1990	77	N	1	2F	MCTh	144.44
02FC002	SAUGEEN RIVER NEAR WALKERTON	1914	1990	77	N	1	2F	MCTh	142.13
02FB007	SYDENHAM RIVER NEAR OWEN SOUND	1915	1990	58	N	1	2F	MCTh	135.86

TABLE C.2
CURRENT HYDROMETRIC STATIONS IN ONTARIO MEASURING FLOW

NUMBER	STATION	FROM	TO	RECORD	REG.	p	BASIN	ZONE	RANKING
02HC019	DUFFINS CREEK ABOVE PICKERING	1960	1990	31	N	1	2H	MCTh	0.00
02HB008	CREDIT RIVER WEST BRANCH AT NORVAL	1960	1990	31	R	2	2H	HMTh	0.00
02HC003	HUMBER RIVER AT WESTON	1945	1990	46	R	2	2H	HMTh	0.00
02HC018	LYNDE CREEK NEAR WHITBY	1959	1990	30	N	1	2H	MCTh	0.00
02HC022	ROUGE RIVER NEAR MARKHAM	1961	1990	30	R	2	2H	HMTh	0.00
02HB004	EAST OAKVILLE CREEK NEAR OMAGH	1956	1990	35	N	1	2H	HMTh	0.00
02HC006	DUFFINS CREEK AT PICKERING	1945	1989	45	R	2	2H	MCTh	0.00
02GD013	WYE CREEK NEAR THORNDALE	1953	1990	38	N	1	2G	HMTh	142.36
02GD003	NORTH THAMES RIVER BELOW FANSHAWE DAM	1915	1990	68	R	2	2G	HMTh	131.13
02GA010	NITH RIVER NEAR CANNING	1913	1990	56	N	1	2G	MCTh	130.49
02GD010	FISH CREEK NEAR PROSPECT HILL	1945	1990	46	N	1	2G	MCTh	126.00
02GG002	SYDENHAM RIVER NEAR ALVINSTON	1947	1990	44	N	1	2G	HMTh	125.88
02GC010	BIG OTTER CREEK AT TILLSONBURG	1960	1990	31	N	1	2G	HMTh	124.47
02GA018	NITH RIVER AT NEW HAMBURG	1950	1989	40	N	1	2G	MCTh	122.37
02GB009	KENNY CREEK NEAR BURFORD	1961	1990	30	N	1	2G	MCTh	117.85
02GD001	THAMES RIVER NEAR EALING	1915	1990	76	R	2	2G	HMTh	106.89
02GE002	THAMES RIVER AT BYRON	1922	1990	62	R	2	2G	HMTh	92.03
02GD004	MIDDLE THAMES RIVER AT THAMESFORD	1938	1990	53	R	2	2G	HMTh	91.72
02GA003	GRAND RIVER AT GALT	1913	1990	78	R	2	2G	MCTh	90.96
02GD008	MEDWAY RIVER AT LONDON	1945	1990	46	R	2	2G	HMTh	87.77
02GC002	KETTLE CREEK AT ST. THOMAS	1945	1990	38	R	2	2G	HMTh	83.67
02GD015	NORTH THAMES RIVER NEAR THORNDALE	1953	1990	38	R	2	2G	HMTh	82.33
02GD016	THAMES RIVER AT INGERSOLL	1957	1990	34	R	2	2G	HMTh	80.17

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NUMBER	STATION	FROM	TO	RECORD	REG.	p	BASIN	ZONE	RANKING
02JD006	MONTREAL RIVER AT INDIAN CHUTE	1923	1957	35	R	2	2J	MBh	69.91
02HL004	SKOOTAMATTA RIVER NEAR ACTINOLITE	1955	1990	36	N	1	2H	MCTh	119.85
02HA006	TWENTY MILE CREEK AT BALLS FALLS	1957	1990	34	N	1	2H	HMTh	118.63
02HD006	BOWMANVILLE CREEK AT BOWMANVILLE	1959	1990	32	N	1	2H	MCTh	118.39
02HM002	DEPOT CREEK AT BELLROCK	1957	1990	34	N	1	2H	MCTh	118.38
02HA003	NIAGARA RIVER AT QUEENSTON	1860	1990	131	R	2	2H	HMTh	117.02
02HL001	MOIRA RIVER NEAR FOXBORO	1915	1990	76	R	2	2H	MCTh	89.91
02HB001	CREDIT RIVER NEAR CATARACT	1915	1990	76	R	2	2H	MCTh	89.42
02HK002	TRENT RIVER AT HEALEY FALLS	1949	1990	42	R	2	2H	MCTh	73.70
02HM001	NAPANEE RIVER NEAR NAPANEE	1915	1974	42	R	2	2H	MCTh	72.46
02HL003	BLACK RIVER NEAR ACTINOLITE	1955	1990	36	R	2	2H	MCTh	69.91
02HD004	NORTH WEST GANARASKA RIVER NEAR OSACA	1958	1990	33	R	2	2H	MCTh	69.49
02HD003	GANARASKA RIVER NEAR OSACA	1958	1990	33	R	2	2H	MCTh	69.37
02HB005	OAKVILLE CREEK AT MILTON	1957	1990	34	R	2	2H	HMTh	68.85
02HA007	WELLAND RIVER BELOW CAISTOR CORNERS	1957	1990	34	R	2	2H	HMTh	68.72
02HK003	CROWE RIVER AT MARMORA	1959	1990	32	R	2	2H	MCTh	68.46
02HM003	SALMON RIVER NEAR SHANNONVILLE	1958	1990	33	R	2	2H	MCTh	68.15
02HC005	DON RIVER AT YORK MILLS	1945	1990	43	R	2	2H	HMTh	0.00
02HC009	EAST HUMBER RIVER NEAR PINE GROVE	1953	1990	38	N	1	2H	HMTh	0.00
02HC013	HIGHLAND CREEK NEAR WEST HILL	1956	1990	34	N	1	2H	HMTh	0.00
02HD008	OSHAWA CREEK AT OSHAWA	1959	1990	32	N	1	2H	MCTh	0.00
02HB002	CREDIT RIVER AT ERINDALE	1945	1990	44	R	2	2H	HMTh	0.00
02HC017	ETOBICOKE CREEK AT BRAMPTON	1957	1990	34	R	2	2H	HMTh	0.00

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CURRENT HYDROMETRIC STATIONS IN ONTARIO MEASURING FLOW

NUMBER	STATION	FROM	TO	RECORD	REG.	p	BASIN	ZONE	RANKING
04JC003	SHEKAK RIVER AT HIGHWAY NO. 11	1950	1987	38	N	1	4J	MBh	121.10
04JD002	KENOGAMI RIVER AT KENOGAMI DAM	1939	1990	52	R	2	4J	MBx	78.02
04GB001	OGOKI RIVER AT WABOOSE FALLS DAM	1941	1990	50	R	2	4G	MBx	78.30
02LB007	SOUTH NATION RIVER AT SPENCERVILLE	1948	1990	43	N	1	2L	MCTh	125.24
02MC001	RAISIN RIVER NEAR WILLIAMSTOWN	1960	1990	31	N	1	2L	MCTh	119.27
02MB005	ST. LAWRENCE RIVER AT IROQUOIS	1860	1958	99	R	2	2L	MCTh	104.18
02LB009	SOUTH NATION RIVER AT CHESTERVILLE	1949	1990	38	R	2	2L	MCTh	81.67
02MC002	ST. LAWRENCE RIVER AT CORNWALL	1958	1990	33	R	2	2L	MCTh	72.47
02LB006	CASTOR RIVER AT RUSSELL	1948	1990	43	N	1	2K	MCTh	122.63
02KB001	PETAWAWA RIVER NEAR PETAWAWA	1915	1990	76	R	2	2K	MCTh	90.84
02KD002	YORK RIVER NEAR BANCROFT	1915	1990	76	R	2	2K	MCTh	90.66
02KF009	OTTAWA RIVER AT CHATS FALLS	1915	1990	76	R	2	2K	MCTh	89.57
02KF006	MISSISSIPPI RIVER AT APPLETON	1918	1990	73	R	2	2K	MCTh	87.94
02KC009	BONNECHERE RIVER NEAR CASTLEFORD	1921	1990	70	R	2	2K	MCTh	86.86
02KD004	MADAWASKA RIVER AT PALMER RAPIDS	1930	1990	61	R	2	2K	MCTh	84.79
02KD007	MADAWASKA RIVER AT BARK LAKE DAM	1942	1990	49	R	2	2K	MCTh	81.42
02LA004	RIDEAU RIVER AT OTTAWA	1933	1990	58	R	2	2K	MCTh	80.27
02KE005	MADAWASKA RIVER AT STEWARTVILLE	1949	1990	42	R	2	2K	MCTh	72.80
02KF007	MISSISSIPPI RIVER AT RAGGED CHUTE	1919	1957	39	R	2	2K	MCTh	71.16
02KF005	OTTAWA RIVER AT BRITANNIA	1960	1990	31	R	2	2K	MCTh	66.81
02JD011	LADY EVELYN RIVER AT LADY EVELYN LAKE	1946	1990	45	R	2	2J	MBh	87.63
02JE021	MATABITCHUAN RIVER AT RABBIT LAKE DAM	1946	1990	45	R	2	2J	MBh	74.75
02JD012	WEST MONTREAL RIVER AT MISTINIKON LAKE DAM	1946	1990	45	R	2	2J	MBh	74.38

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NUMBER	STATION	FROM	TO	RECORD	REG.	p	BASIN	ZONE	RANKING
05QA002	ENGLISH RIVER AT UMFREVILLE	1921	1990	70	N	1	5Q	MBs	137.09
05QA001	ENGLISH RIVER NEAR SIOUX LOOKOUT	1921	1981	61	N	1	5Q	MBs	133.96
05QA004	STURGEON RIVER AT MCDOUGALL MILLS	1961	1990	30	N	1	5Q	MBs	118.60
05QB006	LAKE ST. JOSEPH DIVERSION AT ROOT PORTAGE	1957	1990	34	R	2	5Q	MBs	70.30
05PB014	TURTLE RIVER NEAR MINE CENTRE	1914	1990	77	N	1	5P	MBs	140.26
05QE006	ENGLISH RIVER AT EAR FALLS	1907	1990	84	R	2	5P	MBs	92.92
05QD002	WABIGOON RIVER BELOW RAILWAY BRIDGE, NEAR QUIBELL	1914	1953	40	R	2	5P	MBs	70.96
05QD006	WABIGOON RIVER NEAR QUIBELL	1953	1990	38	R	2	5P	MBs	69.97
04LB001	MATTAGAMI RIVER AT SMOOTH ROCK FALLS	1920	1990	71	R	2	4M	MBh	90.86
04MC001	ABITIBI RIVER AT IROQUOIS FALLS	1920	1990	71	R	2	4M	MBh	87.80
04ME002	ABITIBI RIVER AT ABITIBI CANYON	1929	1990	61	R	2	4M	MBh	83.31
04MD002	FREDERICK HOUSE RIVER AT FREDERICK HOUSE LAKE DAM	1938	1990	53	R	2	4M	MBh	79.49
04ME001	ABITIBI RIVER AT ISLAND FALLS	1924	1967	42	R	2	4M	MBh	74.75
04MC002	ABITIBI RIVER AT TWIN FALLS	1949	1990	42	R	2	4M	MBh	73.17
04MB003	WATABEAG RIVER AT WATABEAG LAKE DAM	1954	1990	37	R	2	4M	MBh	70.08
04ME003	ABITIBI RIVER AT ONAKAWANA	1959	1990	32	R	2	4M	MBh	67.64
04ME004	ABITIBI RIVER AT OTTER RAPIDS	1961	1990	30	R	2	4M	MBh	67.24
04LJ001	MISSINAIBI RIVER AT MATTICE	1920	1990	71	N	1	4L	MBh	144.04
04LF001	KAPUSKASING RIVER AT KAPUSKASING	1918	1990	73	R	2	4L	MBh	121.34
04LD001	GROUNDHOG RIVER AT FAUQUIER	1920	1990	71	R	2	4L	MBh	90.40
04LG001	MATTAGAMI RIVER AT SMOKY FALLS	1926	1963	38	R	2	4L	MBh	71.89
04JC002	NAGAGAMI RIVER AT HIGHWAY NO. 11	1950	1990	41	N	1	4J	MBh	122.59