ANNEX 1

HYDROLOGY STUDIES
AND
PROPOSED OPERATING PLAN

ANNEX 1-A

HYDROLOGY REVIEW REPORT

Xeneca Power Development Inc.

Hydrology Review

For

Wanatango Hydro Project

H333384
Rev. 0
October 6, 2009

Project Report

October 6, 2009

Xeneca Power Development Inc.
Wanatango Falls
Hydrology Review

		DISTRIBUTION
Xeneca	Attention: Mr. Patrick Gillette Xeneca Power Development Inc. 5160 Yonge Street, Suite 520 Toronto, Ontario M2N 6L9	1 hard copy and 1 electronic copy (posted to Xeneca FTP site)
Jim Law/File H333384	Hatch, Oakville	1 hard copy

Xeneca Power Development Inc.
Wanatango Falls

Hydrology Review

Prepared by: Mark Orton — October 6, 2009 (Date)

Approvals

Hatch

Approved by: Jim Law — October 6, 2009 (Date)

Xeneca Power

Approved by: (Not required) Patrick Gillette — October 6, 2009 (Date)

Report Disclaimer

This report has been prepared by Hatch Ltd. for the sole and exclusive use of Xeneca Power (the "Client") for the purpose of assisting the management of the Client in making decisions with respect to the Wanatango Falls Hydropower Project and shall not be (a) used for any other purpose, or (b) provided to, relied upon or used by any third party.

This report contains opinions, conclusions and recommendations made by Hatch Ltd. (Hatch), using its professional judgment and reasonable care. Any use of or reliance upon this report and estimate by Client is subject to the following conditions:

a) the report being read in the context of and subject to the terms of the agreement between Hatch and the Client including any methodologies, procedures, techniques, assumptions and other relevant terms or conditions that were specified or agreed therein;

b) the report being read as a whole, with sections or parts hereof read or relied upon in context;

c) the conditions of the site may change over time (or may have already changed) due to natural forces or human intervention, and Hatch takes no responsibility for the impact that such changes may have on the accuracy or validity of the observations, conclusions and recommendations set out in this report; and

d) the report is based on information made available to Hatch by the Client or by certain third parties; and unless stated otherwise in the Agreement, Hatch has not verified the accuracy, completeness or validity of such information, makes no representation regarding its accuracy and hereby disclaims any liability in connection therewith.

Table of Contents

List of Tables

List of Figures

1. Introduction

The objective of this report is to develop a flow series for the Frederickhouse River that can be used to assess the hydroelectric generating potential of the Wanatango Falls Hydropower site.

Flows in the Frederickhouse River have not been measured or monitored in the past at Wanatango Falls, so a long term flow series at this location must be synthesized from flow records at other gauge(s) on the Frederickhouse River and on other rivers in the region.

Figure 1 shows the Frederickhouse River watershed at the Wanatango Falls Hydropower site and at the Water Survey of Canada (WSC) stations on the river. Figure 2 shows the Frederickhouse River Basin and the locations of WSC streamflow gauges and the annual average precipitation distribution in the region.

Flow synthesis generally follows these steps:

- Estimation of the expected mean annual runoff at the site
- Definition of the seasonal flow pattern
- Assessing the variability of runoff from year to year
- Synthesis of a long term daily flow record that meets the above parameters.

2. Mean Annual Runoff

Mean annual runoff (MAR) describes how much of the rainfall and snowmelt in the basin drains past the site on average each year. MAR is usually expressed in units of mm over the drainage basin, for ease of comparison with precipitation (rain and snow) and evaporation, which are also expressed in mm.

The estimation of MAR for an ungauged site depends on the extent of regional information available and whether a water level monitoring gauge has been installed at the site. MAR estimation makes use of the following approaches, depending on the level of information available:

- A regional water balance analysis using precipitation and evapotranspiration data.
- Estimation of the long term average flow (LTAF) at a gauge on the same river.
- Regional runoff trends from a network of established streamflow stations.
- Flow synthesis from the gauged record on the same river.

2.1 Regional Water Balance

Where regional flow data is very limited MAR must be estimated from regional isohyets of equal precipitation and estimates of evapotranspiration, which tends to decrease from south to north across Ontario. MAR is then estimated as the difference between long term average precipitation and evapotranspiration loss.

The streamflow station network in and around the Frederickhouse River basin is extensive and this simplistic approach was not used directly to estimate the MAR at the Wanatango Falls site.

2.2 Long Term Flow in the Frederickhouse River

Flows were measured on the Frederickhouse River at Frederickhouse, between 1915 and 1919 and at Frederickhouse Lake Dam between 1939 and 1994. These flow records are published by the Water Survey of Canada as stations 04MD001 and 04MD002, respectively. The flow record at station 04MD001 is too short to generate a long term flow series, but the 04MD002 station appears to be a suitable representative gauge. At Frederickhouse Lake Dam the river has a drainage area of 2,906 km^2, which is 98% of the drainage area at Wanatango Falls (2,970 km^2). The mean annual flow at station 04MD002 for 1939 to 1994 was 32.4 m^3/s. The flows at this station are classified as "Regulated" by WSC and the flow data was supplied by Ontario Power Generation.

There is no generating station at Frederickhouse Lake Dam and the reservoir is operated to regulate flows at Island Falls, Abitibi Canyon and Otter Rapids generating stations on the Abitibi River, of which the Frederickhouse River is a tributary. This operating objective has meant that historically no releases were made from the Frederickhouse reservoir approximately 10% of the time.

Flow records that depend on reservoir operations are sometimes subject to changes in equipment or discharge ratings and should be checked for statistical consistency over the period of record.

2.3 Flow Data Screening

The WSC flow series at Frederickhouse Lake Dam gives a flow record of 56 years to analyse the generation potential of the site. However, before using such a lengthy flow record it is important to screen the data for non-stationarity. A stationary flow series is a flow series that is free of significant trends or other statistical anomalies that might have resulted from influences such as deforestation, climate change, upstream development, equipment changes or changes in the flow monitoring station. The annual flow series for 04MD002 was screened for randomness, trend, serial correlation and homogeneity. The record exhibits slight negative trend, but this is not significant at the 5% level.

As a result of this screening it was decided that the full period of flow, 1939-94 could be taken as representative of the present flow regime in the Frederickhouse River and these 56 years were adopted for flow synthesis. Table 1 shows monthly flows for the Frederickhouse River at Frederickhouse Lake Dam [04MD002] for this period.

2.4 Regional Runoff

A series of rivers north and west of the Frederickhouse River drain the Canadian Shield north to Hudson's Bay. A runoff analysis of these rivers gives an indication whether the flow records for the Frederickhouse River fit the runoff trends in the region. The closest streamflow stations to the Frederickhouse River are the Porcupine River [04MD004], which drains into the Frederickhouse River, and the Mattagami River [04LA002], which is also regulated for power generation. An assessment of natural runoff downstream of Frederickhouse Lake Dam can be estimated from the incremental inflows between Frederickhouse Lake Dam on the Frederickhouse River [04MD002], Iroquois Falls on the Abitibi River [04MC001], and Island Falls on the Abitibi River [04ME001].

Table 1 Mean Monthly Flows for the Frederickhouse River at Frederickhouse Lake Dam (04MD002)

Year	January	February	March	April	May	June	July	August	September	October	November	December	Year
1939	23.4	60.1	19.2	8.8	147.1	27.3	48.5	10.0	12.9	41.1	24.8	31.7	37.9
1940	31.4	31.0	34.2	22.4	49.6	62.5	38.9	7.6	28.4	17.3	34.1	29.8	32.2
1941	28.6	30.2	31.9	57.3	54.5	18.1	16.8	41.3	54.2	66.6	60.5	34.2	41.2
1942	16.3	46.7	61.5	56.8	42.7	7.1	6.0	9.0	17.5	45.4	30.7	11.8	29.2
1943	24.8	41.3	46.0	25.0	34.0	72.5	27.8	14.2	17.1	19.0	4.9	25.8	29.3
1944	25.2	29.6	37.9	32.3	38.0	21.9	18.6	9.2	48.3	45.2	28.3	19.4	29.5
1945	39.1	33.7	23.9	44.1	73.0	60.0	25.8	5.7	14.9	25.5	31.7	26.0	33.6
1946	5.7	18.3	73.6	29.2	66.0	41.0	22.4	11.1	11.8	15.6	4.7	15.6	26.4
1947	46.5	46.6	45.9	43.2	171.9	115.8	1.4	4.8	13.5	27.5	35.7	41.5	49.5
1948	22.5	3.6	3.8	28.9	47.4	20.4	12.7	17.7	19.7	42.5	14.0	15.9	20.8
1949	30.5	34.3	35.8	19.6	28.5	39.7	33.0	39.9	23.6	35.8	24.0	25.1	30.8
1950	15.1	5.8	18.4	32.9	94.5	59.8	51.3	48.1	38.8	17.8	18.3	29.5	36.1
1951	35.3	32.4	47.0	70.1	30.2	40.3	17.8	8.8	34.2	43.0	47.3	34.7	36.7
1952	59.0	48.0	39.5	14.1	44.6	42.2	28.8	19.0	17.0	23.8	13.7	16.8	30.5
1953	75.0	38.8	44.5	42.7	46.8	35.1	19.0	30.1	5.1	26.7	22.0	24.7	34.3
1954	46.9	47.5	56.4	29.0	57.4	41.1	26.9	25.4	25.5	54.7	32.3	31.3	39.6
1955	41.4	43.2	47.1	26.0	0.1	35.1	28.9	6.5	18.2	1.3	4.2	36.6	23.9
1956	27.8	36.6	45.4	23.7	66.0	39.3	33.1	17.2	18.9	35.6	30.3	24.2	33.2
1957	23.2	27.0	48.6	17.1	6.2	47.6	88.6	31.3	26.4	10.8	19.6	36.7	32.0
1958	42.9	45.1	44.3	15.0	0.0	2.4	42.1	21.7	5.9	41.9	34.6	28.2	27.0
1959	39.9	38.4	49.9	23.2	28.6	33.8	49.4	0.0	0.0	0.0	24.5	48.7	28.0
1960	31.1	36.4	24.9	14.7	208.7	36.3	21.2	10.2	27.2	23.4	15.3	26.2	39.8
1961	34.1	28.9	42.2	9.2	35.6	61.7	43.2	18.5	89.6	29.2	50.2	30.9	39.4
1962	58.0	52.0	43.5	10.2	70.4	20.9	24.3	14.1	28.6	27.0	24.5	16.2	32.4
1963	26.3	23.0	28.4	42.3	18.4	38.2	24.0	22.7	20.2	22.4	4.4	18.1	24.0
1964	49.8	56.7	42.0	44.7	60.9	81.0	20.5	7.9	13.4	39.3	26.2	24.0	38.7
1965	33.4	59.6	53.7	7.6	83.4	7.7	11.2	31.6	54.7	63.0	13.5	18.5	36.5
1966	46.8	66.8	44.6	30.1	29.3	57.3	10.0	1.1	2.6	69.8	44.9	43.4	37.0
1967	44.2	44.8	66.4	116.0	76.5	60.7	7.2	19.6	51.5	9.1	17.0	23.9	44.6
1968	34.6	38.9	68.9	17.7	41.1	51.6	57.2	13.2	18.1	4.3	14.0	38.6	33.2
1969	34.1	34.6	45.1	21.4	67.8	24.1	16.0	5.4	6.4	35.8	43.2	35.6	30.8
1970	59.3	46.6	21.8	5.9	29.7	63.4	17.7	13.5	26.6	1.6	4.6	9.4	24.8
1971	30.5	50.7	64.1	19.3	76.6	24.7	7.8	5.9	7.6	11.9	26.7	33.4	29.9
1972	33.1	47.3	50.9	21.2	28.2	72.1	24.7	10.7	9.2	5.1	18.1	36.2	29.6
1973	33.1	37.2	60.0	6.1	52.9	25.7	21.3	4.8	5.2	16.1	21.5	33.6	26.5
1974	28.1	34.5	48.2	15.6	65.8	61.2	20.7	18.3	20.0	15.2	19.4	29.8	31.4
1975	29.6	25.3	48.6	30.6	11.4	72.1	7.2	0.0	0.1	1.3	28.9	34.9	24.1
1976	45.4	50.4	43.8	116.3	49.1	13.4	1.3	0.5	7.9	18.8	4.3	1.1	29.2
1977	48.0	48.4	34.8	49.9	12.3	0.0	0.0	0.0	25.5	17.7	17.5	36.3	24.0
1978	40.3	47.5	47.0	13.5	51.8	48.2	37.8	11.4	33.2	35.5	9.2	29.4	33.7
1979	48.4	55.1	21.3	36.8	105.7	10.1	28.6	20.1	23.1	24.7	35.4	36.3	37.1
1980	36.0	50.3	38.3	15.0	56.3	25.1	8.8	3.9	9.4	23.1	27.7	6.3	24.9
1981	48.8	55.2	41.2	28.5	53.6	25.9	12.6	8.5	7.6	20.8	24.6	19.3	28.7
1982	23.1	71.9	42.2	5.6	32.5	1.5	26.1	7.3	16.3	80.6	24.8	17.4	28.9
1983	52.6	46.1	63.6	0.0	99.7	79.0	1.3	1.0	8.1	66.2	64.1	28.1	42.5
1984	51.6	55.1	25.8	15.7	14.8	47.1	43.2	0.0	0.0	12.5	32.5	25.9	26.9
1985	50.4	49.7	55.2	27.2	23.8	15.0	48.7	10.2	18.0	0.4	34.3	25.3	29.8
1986	37.8	59.3	43.9	3.0	63.4	1.7	2.5	34.6	34.1	47.6	41.2	38.4	33.9
1987	38.3	48.1	27.7	0.0	0.0	0.0	12.2	25.0	0.7	66.2	62.9	26.0	25.5
1988	35.9	35.6	49.2	7.8	163.1	31.7	19.7	78.6	67.1	74.9	163.8	70.8	66.9
1989	49.0	40.9	22.9	18.7	91.8	51.8	33.4	12.2	7.7	6.5	10.7	25.9	31.5
1990	42.4	39.4	51.3	40.1	57.3	21.6	47.7	1.5	6.5	78.1	41.0	34.2	38.5
1991	50.7	51.7	27.3	33.5	29.6	8.2	8.6	0.0	0.0	19.1	43.0	39.2	25.6
1992	35.5	43.8	22.7	7.0	52.9	2.8	6.9	10.0	38.7	38.4	35.3	38.8	27.8
1993	36.0	35.4	35.5	0.5	45.3	50.6	3.4	34.7	25.3	29.8	37.5	28.1	30.1
1994	51.4	68.1	22.9	3.4	18.2	36.7	4.9	12.5	17.6	21.0	38.2	35.5	27.3
Mean	38.0	42.4	41.5	26.7	55.4	37.4	23.6	15.1	21.1	30.2	29.6	28.6	32.5

Table 2 shows the runoff at each streamflow station adjusted to the period 1939-94.

Table 2 Mean Annual Runoff in mm for 1939-1994

River	Abitibi	Abitibi	Abitibi	Porcupine	Frederickhouse		Mattagami	
Nat/Reg	Reg	Reg	Reg	Nat	Reg	Reg	Reg	Reg
Year	04ME001	04MC001	Net Inflow	04MD004	04MD001	04MD002	04LA002	04LB001
D.A.	20700	13300	4530	401	3260	2870	5540	10000
39-94 Runoff	416	418	419	463	-	357	389	348

The mean annual runoff for 1939-94 at these seven streamflow stations varies from 348 to 463 mm. A reliable estimate could not be made for 04MD001, because the record was too short. The high runoff estimate for the Porcupine River is unreliable as flows are influenced by return flows from a mine tailings area, which pumps water from Nighthawk Lake, and WSC indicates that water levels at the 04MD004 gauge have been affected by beaver activity. The estimated MAR for the Frederickhouse River, 357 mm, lies between the estimated runoffs for the Mattagami River at Timmins [04LA002] 389 mm and Smooth Rock Falls [04LB001] 348 mm, and can be considered consistent with runoff trends in the region.

3. Seasonal Flow Pattern

A run-of-river hydroelectric project uses natural river flows, without the benefit of storage regulation through a reservoir. Thus it is important to know not only how much flow passes the dam, but also the distribution and timing of flows. This means that it is important to examine the seasonal flow pattern of streamflow stations that might be considered as a base for simulating a daily flow record at the dam.

The seasonal runoff patterns at Wanatango Falls will be dictated by the operation of Frederickhouse Lake Dam but will also include "Natural" inflows from the small drainage area below Frederickhouse Lake Dam. The natural flow record for the Missinaibi River at Mattice [04LJ001] has been included in the flow analysis, in addition to selected stations from Table 2, because its flow record covers the years 1939-94, the 04MD002 record period. Figure 3 shows the seasonal flow pattern for the streamflow records, with each month expressed as a ratio to the LTAF.

The differences between regulated and natural river flows are very clear in Figure 3, particularly in the winter and spring. In the regulated river systems of the Frederickhouse River [04MD002] and the Mattagami River [04LA002] the reservoirs are full in the summer and fall and are drawn down in the winter, to supplement flows in the lowest flow season, filling again during the spring freshet. Average seasonal flow variation in these rivers is from 50% to 200% of LTAF.

In contrast "Natural" flow rivers exhibit a more extreme seasonal pattern, with minimum flows of 15-25% LTAF occurring in March and maximum flow of 325-400% LTAF occurring in May. The average seasonal pattern of streamflow station 04LJ001, the Missinaibi River at Mattice, closely resembles the natural incremental inflow pattern expected below Frederickhouse Lake Dam. This means it can be used as a representative station to synthesize the "Natural" inflows between Frederickhouse Lake Dam and Wanatango Falls.

4. Annual Flow Variability

The third component of a long term flow record required for generation analysis is flow variability from year to year. The LTAF and the seasonal flow pattern summarize the long term average characteristics of the flow series expected at the dam site. However, these flows will vary from year to year and will influence the generating potential of the site.

Figure 4 shows the variation in mean annual flow for the five streamflow stations in Figure 3, expressed as ratios of the LTAF at each site. This figure demonstrates the importance of synthesizing a multi-year flow record to capture the full range of flow variation that could be expected over the life of the project. Although a direct comparison between the regulated and natural flow records is not quite correct on a calendar year basis, because water stored in the spring of one year is released in the winter of the following year, the record for Frederickhouse Lake Dam follows the same pattern as the other streamflow stations in the region.

The complete records for the period show that sequences of up to nine years with below average flow could be expected in the future.

5. Turbinable Flow

The Run-of-River plant proposed for the Wanatango Falls hydropower site must use river flows as they arrive, without the use of reservoir storage to regulate flows. The principal hydrological tool used to evaluate run-of-river plants is the flow duration curve. This curve ranks all flows from lowest to highest and plots them against the percent of time they are exceeded. This enables the analyst to compute the volume of flow that will pass through the turbine(s) for a given turbine discharge capacity.

Figure 5 shows the flow duration curves for the WSC streamflow stations with flows expressed as ratios of the LTAF at each site.

The wide seasonal variation in flows seen at the natural flow stations is reflected in the flow duration curves. The flow in these rivers is less than the LTAF for ±75% of the year because a large part of the annual runoff is the result of snowmelt, which generally occurs in only two to four months of the year. The regulated rivers store a lot of this snowmelt runoff and release it during low flow periods. As a result flow in the Frederickhouse River at Frederickhouse Lake Dam [04MD002] is less than the LTAF for ±58% of the time.

The shape of the flow duration curve for station 04MD002 means that, with a turbine discharge up to 2 x LTAF, a greater proportion of the river flow can be used to generate power than would be the case without Frederickhouse Lake Dam operation.

6. Long Term Daily Flow Synthesis

Synthesis of a long term daily flow series at an ungauged site requires selection of an historic streamflow record that has the same characteristics as those expected at the dam to prorate to the site. Here the availability of flow data for the Frederickhouse River at Frederickhouse Lake Dam [04MD002] makes this the obvious choice as the representative gauge. Furthermore, the previous sections have demonstrated that the 04MD002 record fits the flow patterns expected by the rivers in the region. At Wanatango Falls the outflow from Frederickhouse Lake Dam to the Frederickhouse River is supplemented by natural inflows from sub-basin 09 (See Figure 1), an additional 64 km^2.

Daily flows from this local sub-basin can be synthesized by prorating 04LJ001 flows for 1939-94 by the ratio of LTAFs. The LTAF for the Missinaibi River is 106.2 m^3/s.

As noted in Section 2.1, the long term runoff can be estimated as:

Runoff = Precipitation – Evaporation Loss

Annual average precipitation over each sub-basin can be estimated from Figure 2. Annual average lake evaporation loss in Ontario is well correlated with latitude, as shown in Appendix B, thus:

Annual average lake evaporation = -36.123*Latitude + 2296.6 mm

Actual evaporation loss can be estimated as a constant (=0.875 in the Wanatango region from calibration) times lake evaporation.

The long term average flow for the local Wanatango Falls inflow can be estimated and results are as follows:

MAR of 384 mm and a LTAF of 0.78 m^3/s for SB09.

The daily flow at Wanatango Falls is then computed as:

04MD002 daily flow + 0.78/106.2*04LJ001 daily flow

Where: 0.78 m^3/s is the LTAF for SB09 and 106.2 m^3/s is the LTAF for the Missinaibi River at Mattice.

The computed 1939-94 LTAF for the Frederickhouse River at Wanatango Falls is 33.2 m^3/s.

7. Results

The principal output of this hydrology review is a 56-year daily flow series that can be used in the generation potential analysis of the Wanatango Falls hydropower site. This dataset is too large to include in this report, but the following characteristics of the flow series are reproduced here to confirm their adherence to the objectives stated throughout the report:

- Tables 3 A monthly flow summary table for the Wanatango Falls site
- Figure 6 A seasonal flow pattern for the Wanatango Falls site
- Figure 7 An annual flow variation diagram for the Wanatango Falls site
- Figure 8 A daily flow duration curve for the Wanatango Falls site.

In addition to the above Hatch has prepared Flow Metrics for the Frederickhouse River at the Wanatango Falls site using the synthesized 56-year daily flow series.

The Flow Metrics sheets have been attached as Appendix A.

The flow series dataset is provided on CD-ROM in Appendix C

8. Recommendations for Future Work

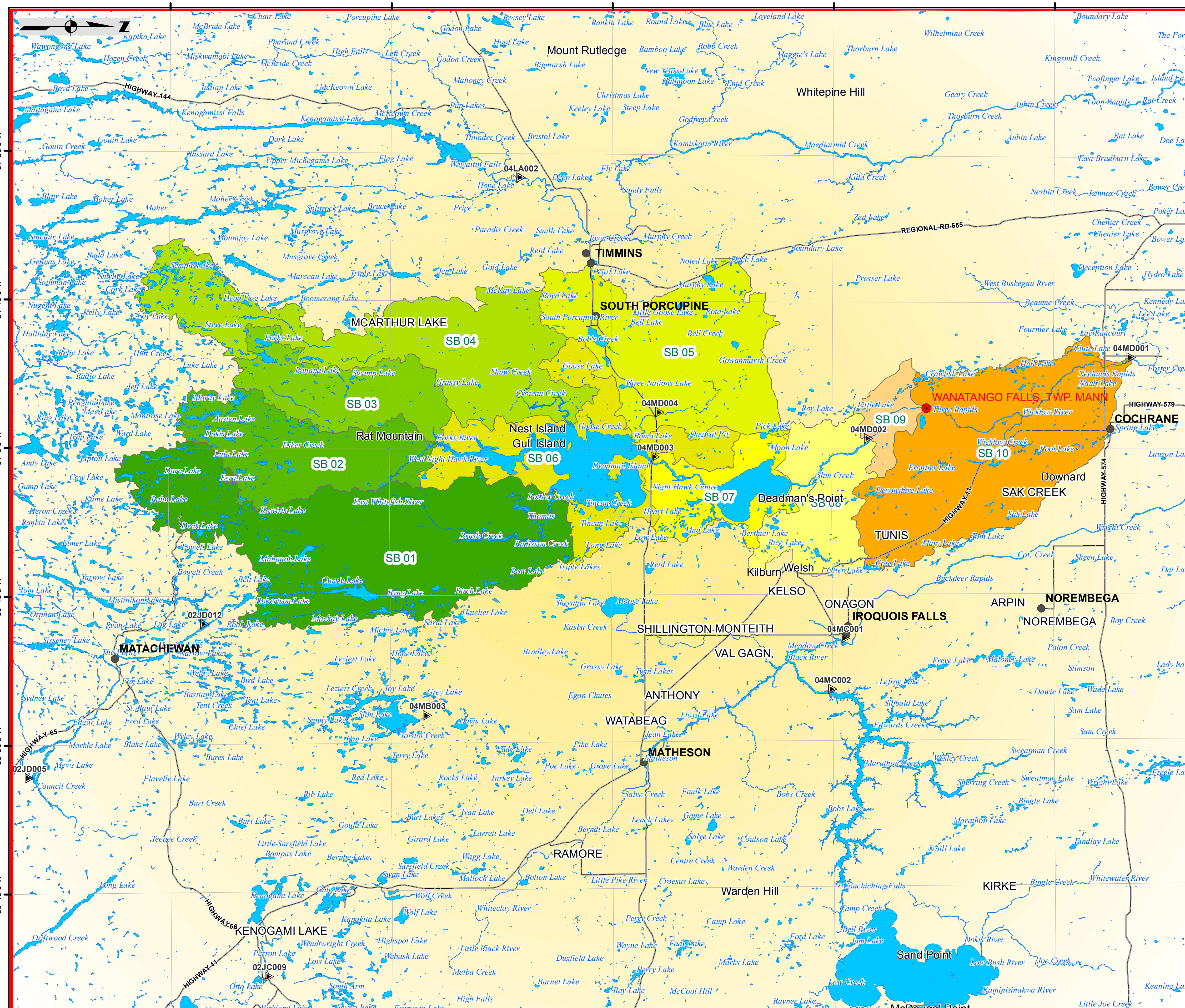
1. It is recommended that should the project move forward Xeneca contact OPG to request recent flow data for Frederickhouse Lake Dam, i.e. flow data for the period 1995 to present. It is not expected that this additional data will significantly alter the LTAF however it may affect generation should the seasonal operation of Frederickhouse Lake Dam have changed since 1994.
2. The flow series derived for the Wanatango site is intended for generation potential analysis and should not be used for final flood design or low flow estimates. Detailed flood and low flow estimates should be undertaken during the Environmental Assessment and Project Design phases. It is further recommended that these analyses be undertaken following consultation with OPG detailing the current operation of Frederickhouse Lake Dam.

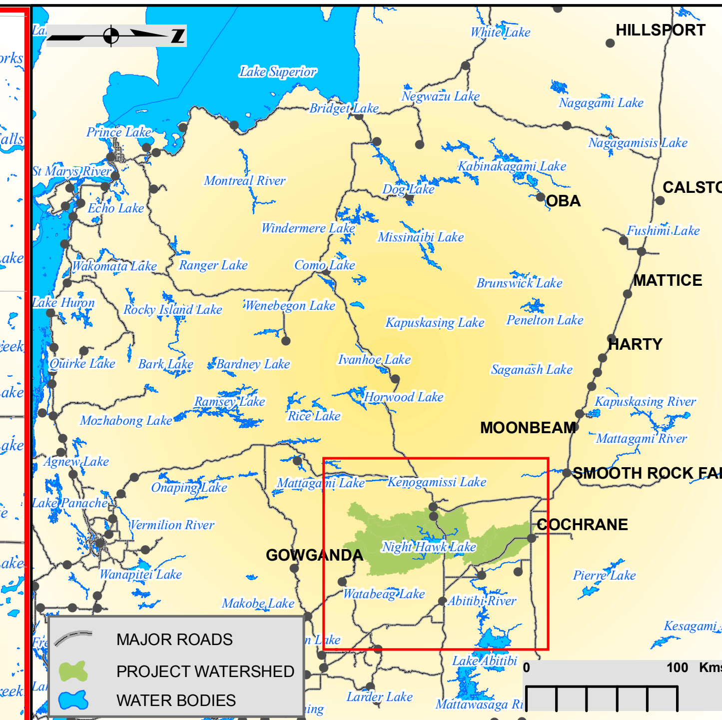
Table 3 Mean Monthly Flows in the Frederickhouse River at Wanatango Falls

Year	January	February	March	April	May	June	July	August	September	October	November	December	Year
1939	23.6	60.2	19.3	9.2	152.8	28.8	49.1	10.5	13.5	41.7	25.2	31.9	38.8
1940	31.6	31.2	34.3	22.7	54.3	64.5	39.5	7.8	28.7	17.6	34.5	30.1	33.0
1941	28.8	30.4	32.0	58.9	58.0	18.9	17.0	41.7	55.6	68.3	61.4	34.8	42.2
1942	16.6	46.8	61.6	58.8	45.4	7.7	6.2	9.2	18.7	47.0	31.8	12.2	30.0
1943	25.0	41.4	46.1	25.5	37.6	74.8	28.6	14.4	17.2	19.1	5.2	26.0	30.0
1944	25.3	29.7	38.0	32.8	41.6	23.1	18.9	9.5	49.0	45.9	28.7	19.7	30.1
1945	39.3	33.8	24.3	46.3	74.2	61.0	26.4	6.1	15.3	25.9	32.8	26.5	34.3
1946	6.0	18.5	74.1	30.9	69.1	42.3	22.9	11.2	12.1	15.9	5.5	16.1	27.2
1947	46.7	46.7	46.0	43.4	176.9	119.4	2.3	5.3	13.8	27.8	35.9	41.6	50.5
1948	22.6	3.7	3.8	30.6	49.4	20.9	12.9	18.1	20.0	42.7	14.6	16.5	21.4
1949	30.7	34.5	35.9	20.6	31.8	40.7	33.3	40.1	23.8	36.4	24.5	25.3	31.5
1950	15.3	5.9	18.5	33.2	99.4	62.0	52.4	48.4	39.0	18.2	18.8	29.9	37.0
1951	35.5	32.6	47.1	72.9	33.4	41.1	18.3	9.0	34.4	43.6	48.2	35.3	37.5
1952	59.2	48.1	39.6	15.9	46.6	43.9	29.3	19.2	17.2	24.0	14.1	17.5	31.2
1953	75.2	39.0	44.6	43.4	51.5	36.5	19.4	30.3	5.3	27.0	22.2	25.3	35.0
1954	47.1	47.6	56.5	30.1	61.2	42.3	27.6	25.8	25.7	56.0	33.2	31.6	40.4
1955	41.5	43.3	47.2	27.9	1.6	35.8	29.1	6.7	18.3	1.7	4.7	36.9	24.4
1956	28.0	36.8	45.5	24.0	69.3	41.1	34.3	17.7	19.7	36.1	30.6	24.4	34.0
1957	23.4	27.1	48.7	19.0	8.7	48.4	89.3	31.5	26.8	11.2	20.4	37.2	32.7
1958	43.0	45.1	44.4	16.3	1.2	3.9	43.1	22.1	7.0	42.7	35.6	28.5	27.8
1959	40.1	38.5	50.0	23.8	31.8	34.6	49.6	0.3	0.6	1.4	25.4	49.1	28.8
1960	31.3	36.6	25.0	16.0	214.7	37.6	21.5	10.6	27.4	23.6	15.7	26.5	40.7
1961	34.2	29.0	42.3	10.5	39.1	63.3	44.3	18.8	90.9	30.8	51.1	31.3	40.4
1962	58.2	52.2	43.7	10.5	73.7	22.2	24.6	14.9	30.3	27.5	24.9	16.5	33.2
1963	26.5	23.1	28.5	43.1	20.9	40.4	24.6	22.9	20.4	22.7	4.6	18.3	24.6
1964	50.0	56.8	42.1	46.3	64.3	82.6	21.3	8.6	14.0	40.6	27.1	24.4	39.7
1965	33.6	59.8	53.8	8.1	87.1	8.7	11.5	32.1	55.6	64.4	14.0	18.9	37.3
1966	47.1	66.9	44.8	31.1	33.1	58.5	10.6	1.6	2.9	71.6	45.7	43.9	38.0
1967	44.5	45.0	66.5	118.1	80.3	61.8	7.7	19.9	51.6	9.4	17.3	24.1	45.3
1968	34.8	39.0	69.0	20.6	42.6	52.9	59.5	13.8	19.1	5.6	14.8	39.0	34.3
1969	34.4	34.8	45.3	23.3	71.1	25.0	16.4	5.6	6.6	36.5	43.8	36.0	31.6
1970	59.4	46.7	21.9	6.4	32.5	64.7	18.6	13.8	27.0	2.1	5.2	9.7	25.5
1971	30.7	50.8	64.2	19.7	80.3	25.9	8.4	6.2	8.0	12.6	27.4	34.2	30.6
1972	33.4	47.4	51.0	21.5	31.7	73.5	25.5	11.1	9.5	5.7	18.4	36.4	30.3
1973	33.2	37.3	60.2	7.9	55.7	27.0	22.4	5.7	6.0	16.8	22.1	34.0	27.4
1974	28.3	34.7	48.4	15.8	69.4	62.6	21.2	18.8	20.5	16.3	20.2	30.1	32.2
1975	29.7	25.4	48.7	30.9	13.8	73.2	7.4	0.1	0.2	1.4	29.3	35.2	24.5
1976	45.5	50.5	43.9	119.0	51.0	13.9	1.5	0.6	7.9	18.8	4.3	1.2	29.7
1977	48.0	48.4	34.9	52.6	13.9	0.7	0.4	0.2	26.6	18.7	18.3	36.6	24.7
1978	40.4	47.6	47.1	13.6	55.5	49.8	39.0	11.7	33.5	36.7	9.6	29.6	34.5
1979	48.5	55.2	21.4	38.4	111.7	12.0	29.1	20.3	23.7	26.3	36.5	36.7	38.3
1980	36.2	50.5	38.4	16.4	58.7	26.1	9.2	4.1	9.6	23.6	28.0	6.4	25.5
1981	48.9	55.3	41.4	30.5	56.7	26.9	12.9	8.6	7.7	20.9	24.8	19.4	29.4
1982	23.2	72.0	42.3	6.1	35.5	2.0	27.1	7.5	17.2	82.5	26.1	18.0	29.8
1983	52.8	46.3	63.8	0.8	104.2	80.6	1.7	1.1	8.6	67.0	64.6	28.5	43.4
1984	51.8	55.2	25.9	17.6	16.7	48.5	44.5	0.3	0.1	12.8	32.9	26.2	27.6
1985	50.6	49.8	55.3	28.7	25.8	15.9	49.6	10.8	18.2	1.2	34.8	25.6	30.4
1986	38.0	59.4	44.0	5.2	65.3	2.1	2.7	34.7	34.4	48.3	41.7	38.7	34.5
1987	38.4	48.2	27.8	1.5	0.7	0.5	13.0	25.5	0.8	66.6	63.5	26.4	26.0
1988	36.1	35.7	48.7	9.4	165.6	32.3	19.9	79.2	67.5	75.3	165.1	71.5	67.3
1989	49.3	41.1	17.4	19.2	96.3	53.1	33.8	12.5	7.8	6.7	11.6	26.2	31.3
1990	42.6	39.5	51.7	42.4	60.1	22.9	48.6	1.8	6.9	79.1	42.1	34.6	39.5
1991	50.9	51.8	34.0	37.2	31.3	8.7	8.8	0.1	0.4	20.3	43.8	39.6	27.1
1992	35.7	44.0	22.8	8.5	57.1	3.4	7.3	10.5	39.5	39.5	36.1	39.3	28.6
1993	36.2	35.6	32.3	1.9	48.4	52.2	4.2	35.5	26.1	30.7	38.0	28.4	30.8
1994	51.5	68.2	22.9	4.5	20.4	37.9	5.6	13.3	17.8	21.2	38.2	35.5	27.8
Mean	38.2	42.5	41.6	28.0	58.6	38.6	24.2	15.5	21.5	31.0	30.3	29.0	33.2

Mark Orton
MO:ll

FIGURES





NOTES:

1. MAPPING INFORMATION SHOWN ON THE DRAWING HAS BEEN DERIVED FROM THE DIGITAL DATA FROM MNR DATABASE
2. PROJECTED COORDINATE SYSTEM IS NAD 1983, UTM ZONE 17N.

LEGEND

- WATER BODIES
- SUB-BASINS

SUB BASIN ID	DRAINAGE	AREA (km^2)
SB 01	WHITEFISH RIVER	737
SB 02	NIGHT HAWK RIVER	279
SB 03	FORKS RIVER	208
SB 04	REDSTONE RIVER	489
SB 05	PORCUPINE RIVER	444
SB 06	NIGHT HAWK LAKE LOCAL	379
SB 07	FREDERICKHOUSE LAKE LOCAL	169
SB 08	FREDERICKHOUSE DAM, 04MD002 LOCAL	201
SB 09	WANATANGO FALLS LOCAL	64
SB 10	WSC GAUGE 04MD001 LOCAL	559

DRAINAGE AREA SUMMARY:

LOCATION	AREA (km^2)
GAUGE - 04MD002	2906
WANATANGO FALLS	2970

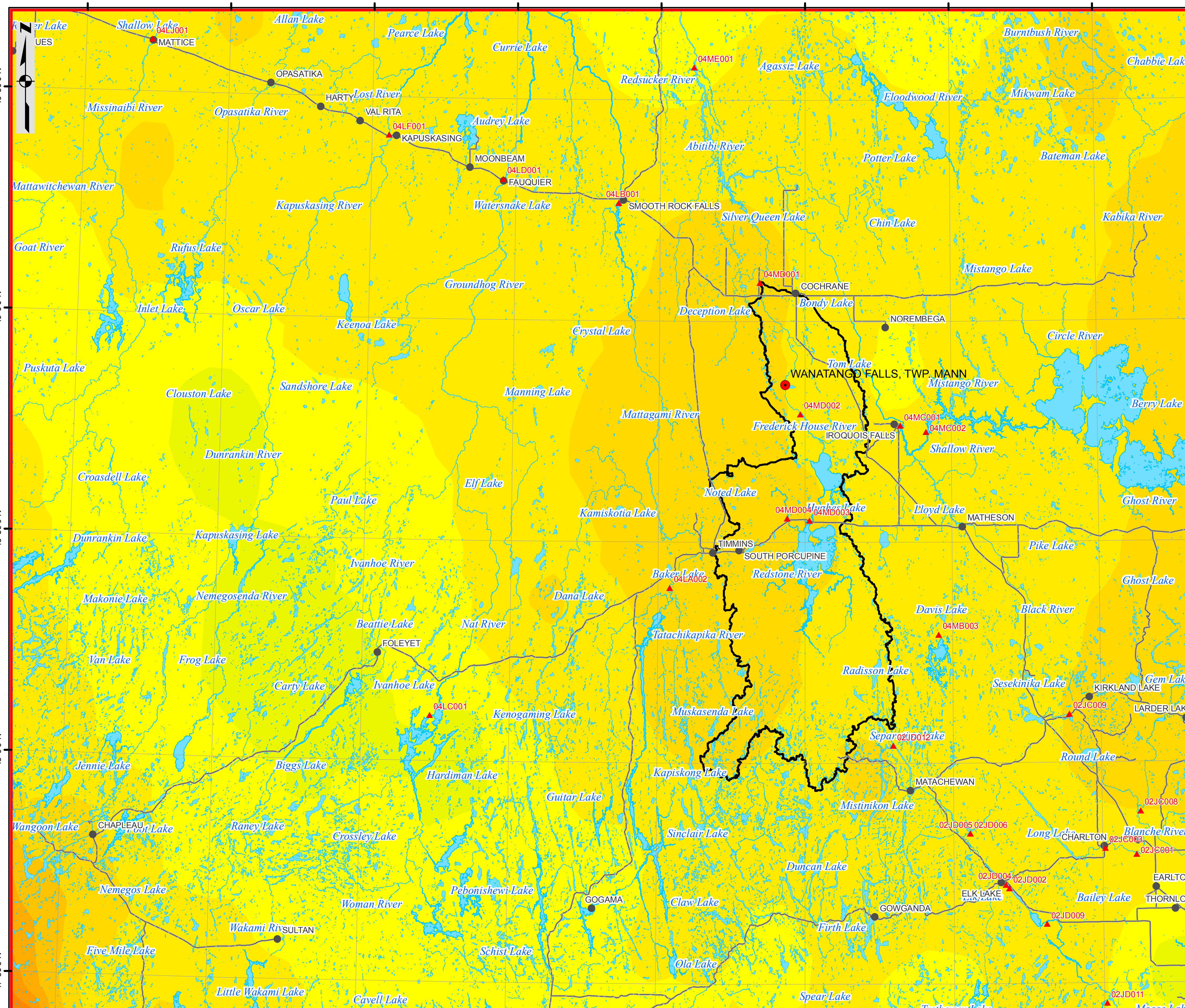
Xeneca Power Development Inc.

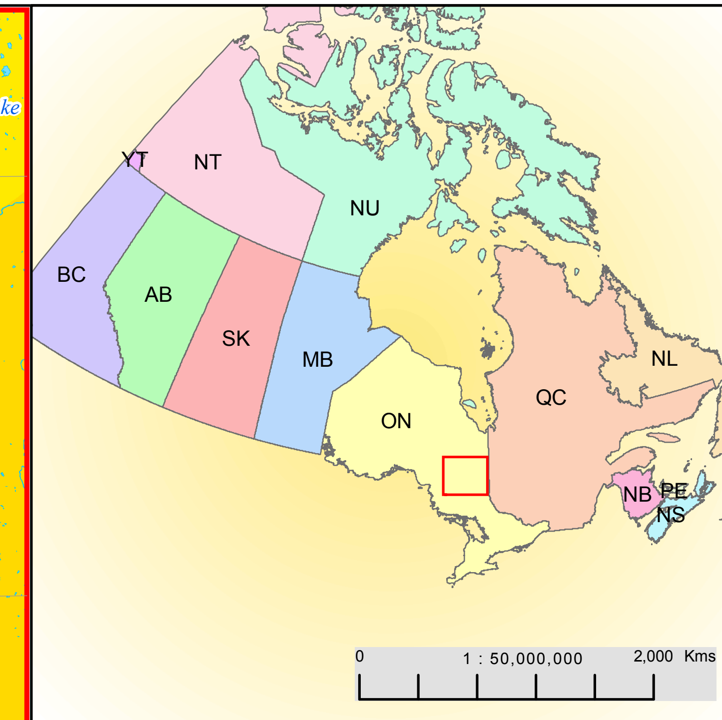
0 1 : 500,000 20 Kms

XENECA POWER
WANATANGO FALLS HYDRO DEVELOPMENT
WANATANGO FALLS WATERSHED

FIGURE 1

HATCH





NOTES:
1. MAPPING INFORMATION SHOWN ON THE DRAWING HAS BEEN DERIVED FROM THE DIGITAL DATA FROM MNR DATABASE
2. PROJECTED COORDINATE SYSTEM IS NAD 1983, UTM ZONE 17N.
3. PRECIPIATION DERIVED USES MONTHLY CLIMATE DATA (1961-1990) SOURCE: CANADA GRIDDED CLIMATE DATA, RON HOPKINSON HTTP://WWW.CICS.UVIC.CA/CLIMATE/DATA.HTM

LEGEND

- POPULATED PLACES
- GAUGING STATION
- WATER BODIES
- ROAD NETWORK
- GAUGE 04MD001 WATERSHED

ANNUAL AVG. PRECIPITATION (MM)

451 - 478	692 - 717	931 - 957
479 - 505	718 - 744	958 - 983
506 - 531	745 - 771	984 - 1,010
532 - 558	772 - 797	1,011 - 1,036
559 - 584	798 - 824	1,037 - 1,063
585 - 611	825 - 850	1,064 - 1,090
612 - 638	851 - 877	1,091 - 1,116
639 - 664	878 - 903	1,117 - 1,143
665 - 691	904 - 930	1,144 - 1,169

Xeneca Power Development Inc.

0 1 : 1,000,000 50 Kms

XENECA POWER
WANATANGO FALLS HYDRO DEVELOPMENT
ANNUAL AVG. PRECIPITATION

FIGURE 2

HATCH

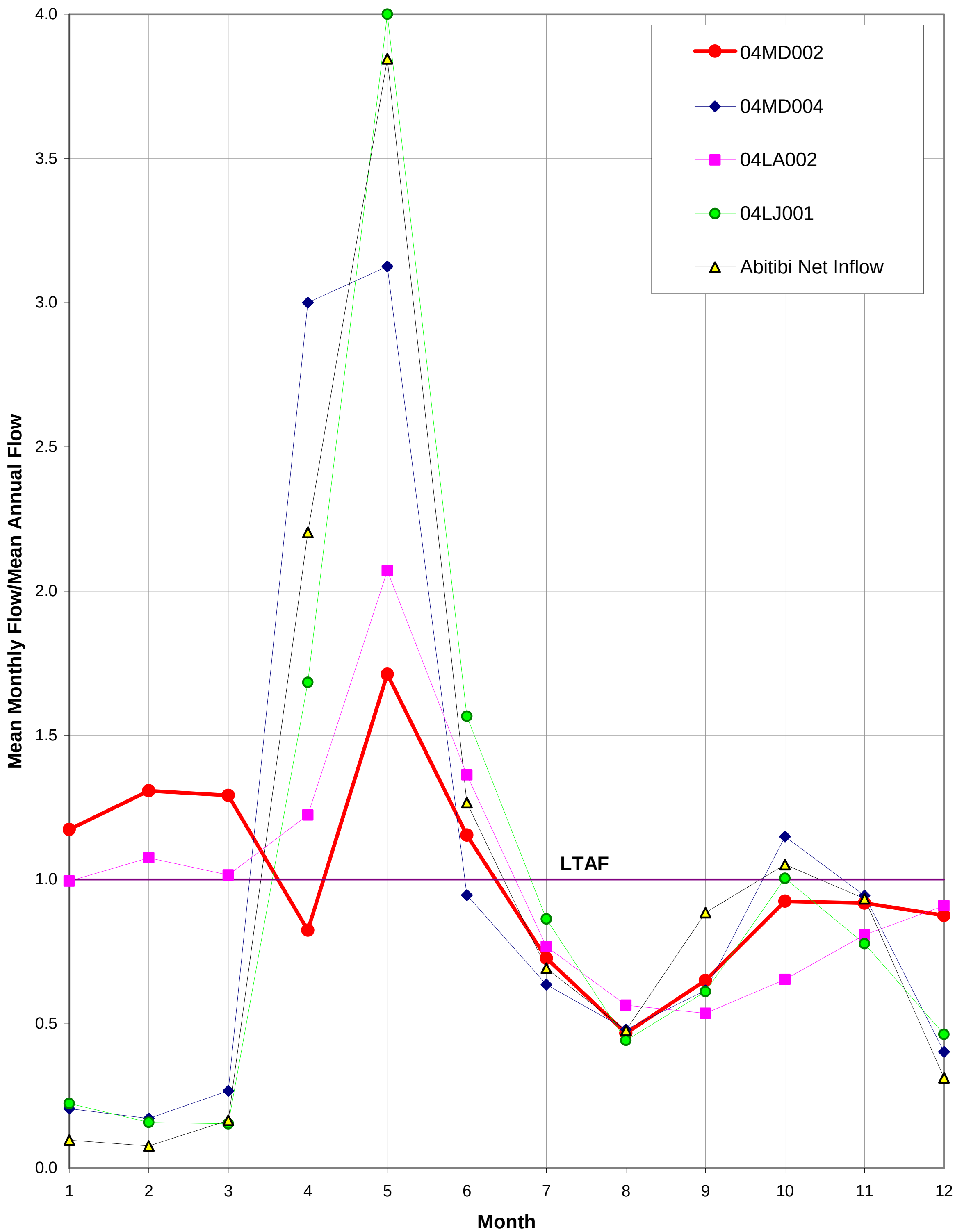


Figure 3
Xeneca Power
Wanatango Falls
Seasonal Flow Patterns

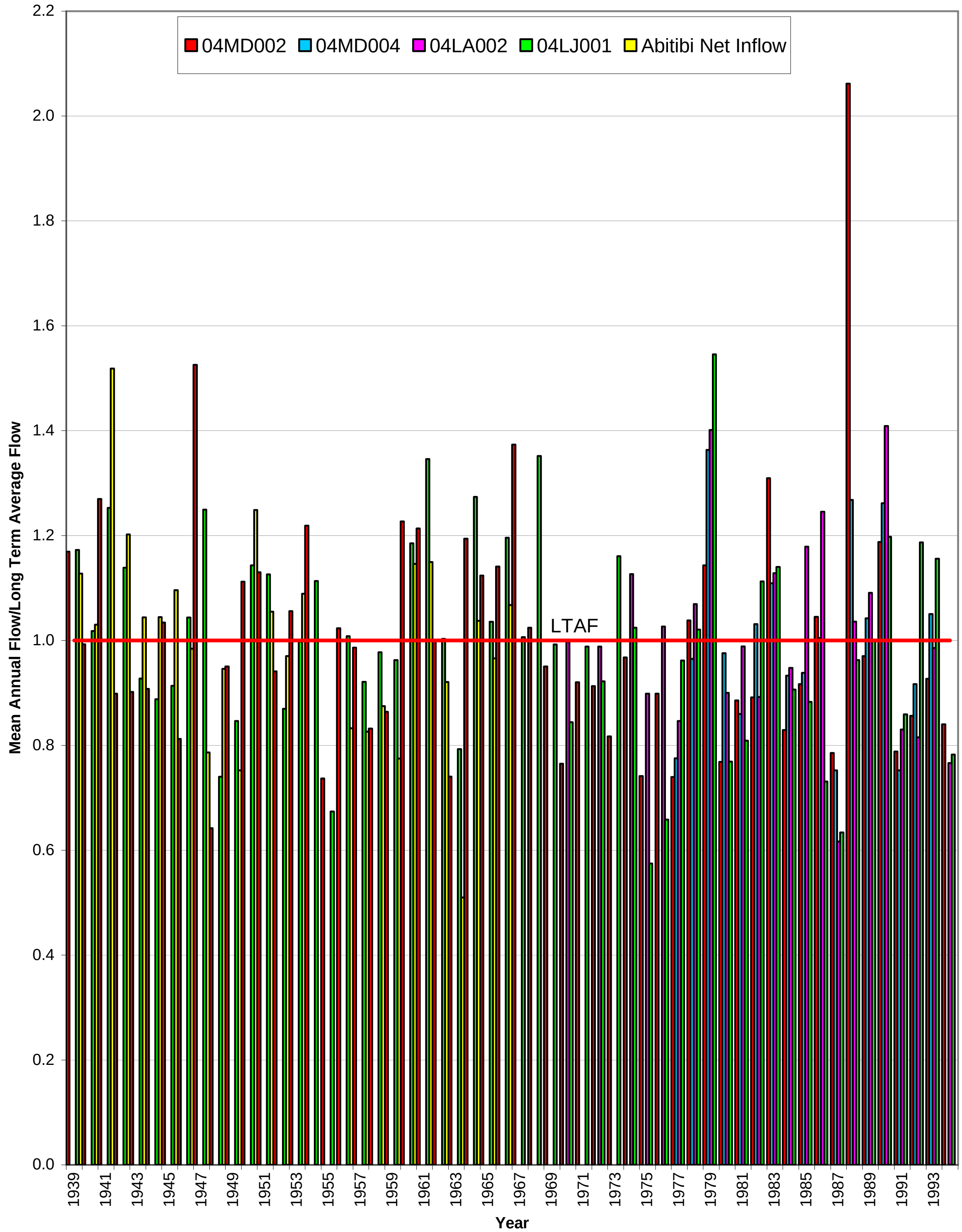


Figure 4
Xeneca Power
Wanatango Falls
Annual Flow Variability

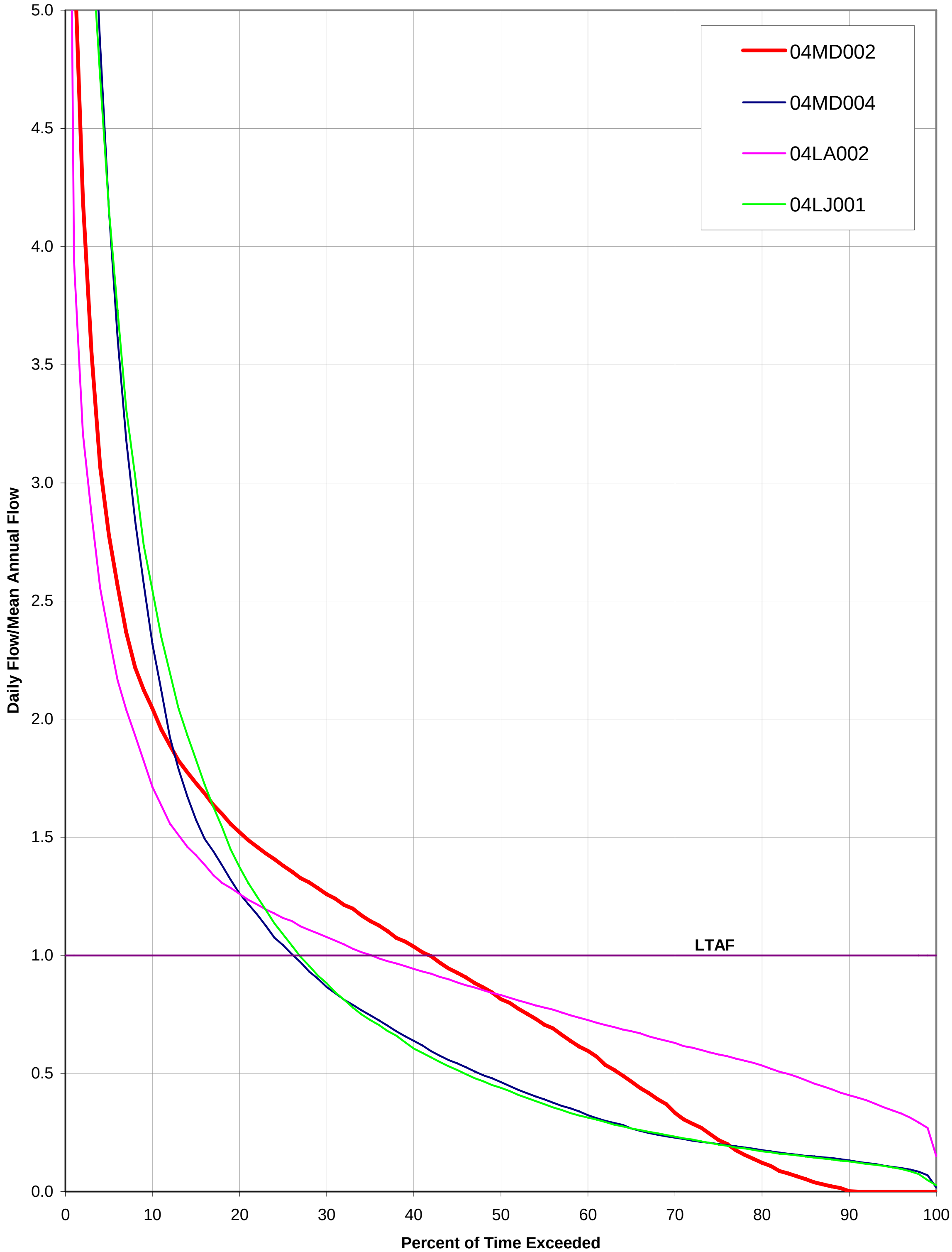


Figure 5
Xeneca Power
Wanatango Falls

Flow Duration Curve for the Frederickhouse River at Frederickhouse Lake Dam

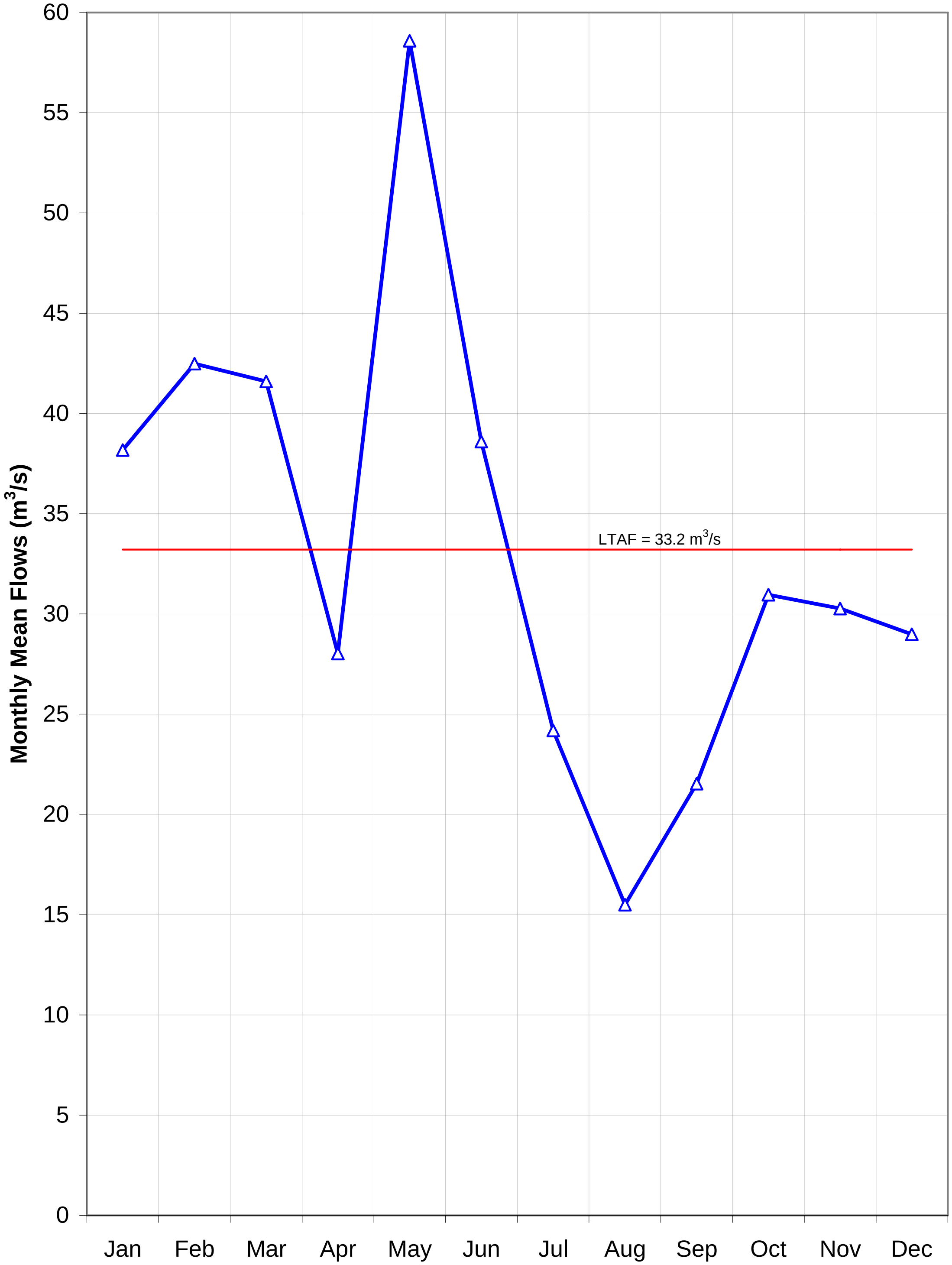


Figure 6
Xeneca Power
Wanatango Falls
Fredericknhouse River at Wanatango Falls – Seasonal Flow Pattern

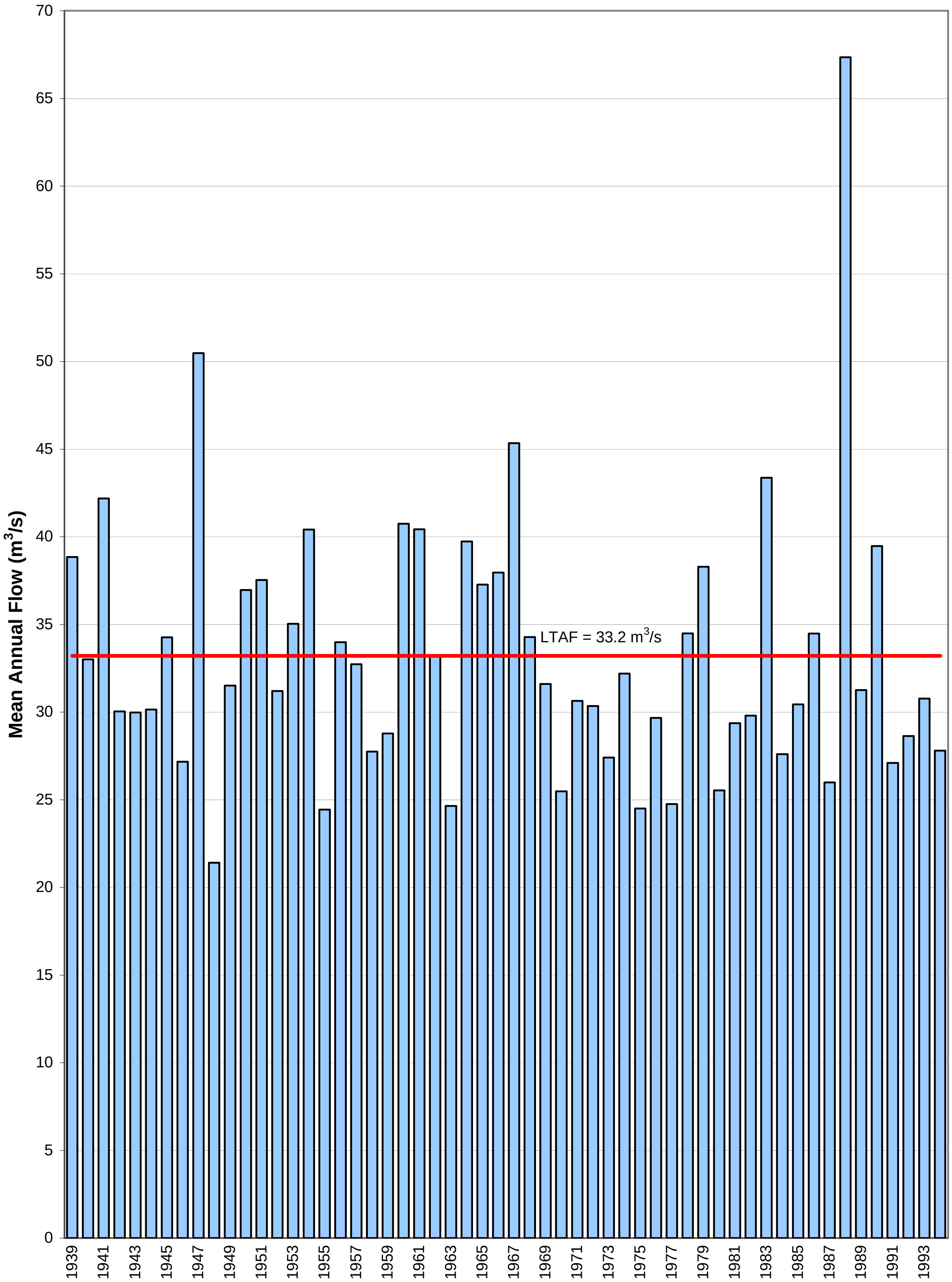


Figure 7
Xeneca Power
Wanatango Falls
Frederickhouse River at Wanatango Falls – Annual Flow Variability

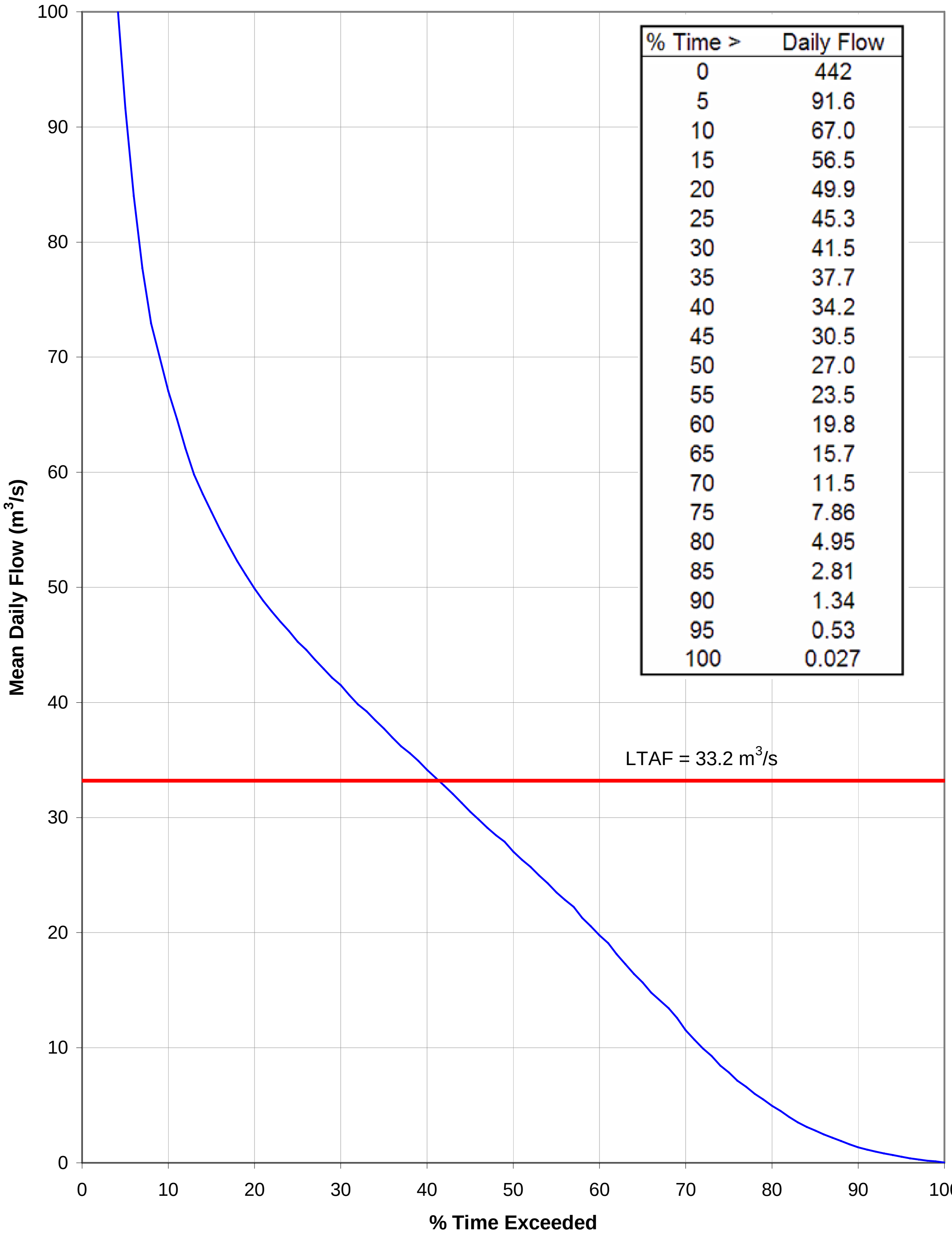


Figure 8
Xeneca Power
Wanatango Falls
Frederickhouse River at Wanatango Falls – Daily Flow Duration Curve

HATCH™

APPENDIX A

Flow Metrics

WANATANGO FALLS - FREDERICKHOUSE RIVER NATURAL FLOW METRICS DATA SHEET

STATION INFORMATION	
SITE ID	0
RIVER NAME	FREDERICKHOUSE RIVER
SITE NAME	WANATANGO FALLS
REGION	NORTHEAST
DISTRICT	COCHRANE
DRAINAGE AREA	2970 km^2
OWNER	XENECA POWER

Flow metrics are provided for the potential waterpower site based on the Water Survey of Canada (WSC) gauging station, Frederickhouse River at Frederickhouse Lake Dam (04MD002). Metrics are based on WSC flows from 1939 to 1994 (56 years).

The flow records for the site have been synthesized by pro-rating gauge flows at 04LJ001 by the ratio of the runoff and drainage areas for local runoff and adding to 04MD002 flows. Other descriptive metrics have been included in the data sheet to provide a more complete description of the ranges of streamflow on the river system and to facilitate comparisons between river systems.

Annual (1939 - 1994):

I. Streamflow Time Series

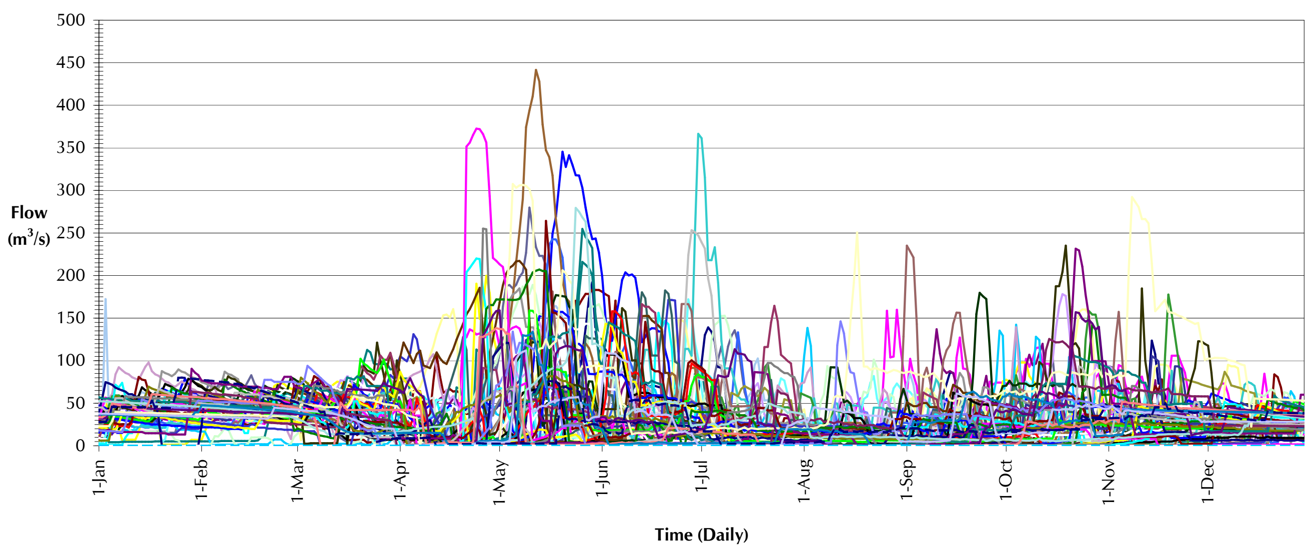


Figure 1 : Annual Daily flow hydrographs from 1939 to 1994.

Table 1 : Annual flow metrics based on 56 years of data.

Descriptive Metric		
Mean Annual Flow	33.21	m^3/s
20% Time Exceeded Flow	49.90	m^3/s
Median Flow	27.05	m^3/s
80% Time Exceeded Flow	4.95	m^3/s
Mean Rising Rate of Change of Flow	6.28	$m^3/s/day$
Mean Falling Rate of Change of Flow	-3.66	$m^3/s/day$
Extreme Low Flow Conditions:		
7-day-avg. low flow in 2-yr return period, $7Q_2$	0.50	m^3/s
7-day-avg. low flow in 10-yr return period, $7Q_{10}$	0.08	m^3/s
7-day-avg. low flow in 20-yr return period, $7Q_{20}$	0.04	m^3/s
Target Metric		
Riparian Flows (Q_2 - Q_{20})	181 -331	m^3/s
Bankfull Flows ($Q_{1.5}$ - $Q_{1.7}$)	154 -166	m^3/s

II. Flow Duration

Time Exceeded %	Flow (m^3/s)
0%	441.6
1%	173.2
5%	91.6
10%	67.0
20%	49.9
30%	41.5
40%	34.2
50%	27.0
60%	19.8
70%	11.5
80%	5.0
90%	1.3
95%	0.5
99%	0.1
100%	0.0

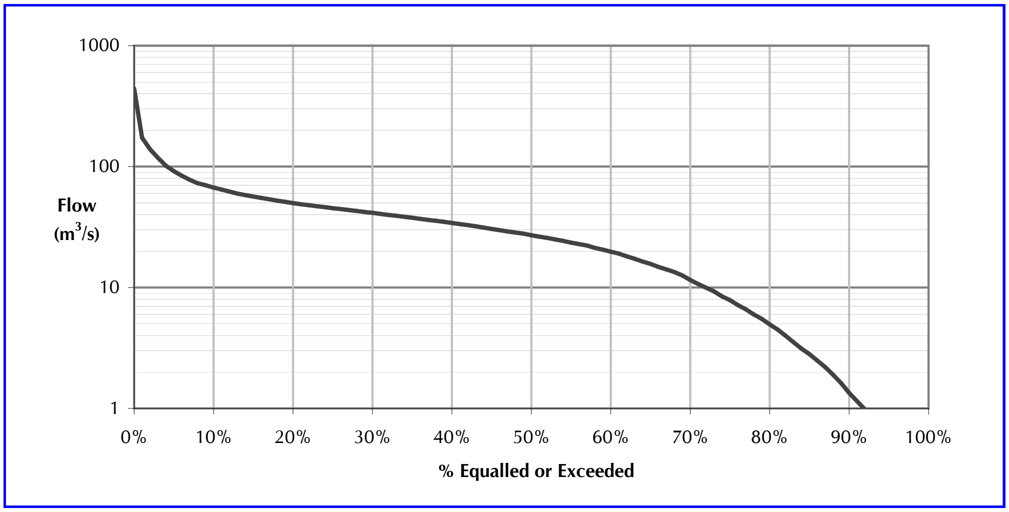


Table 2 & Figure 2 : Flow duration table and curve displaying flow vs. percent time exceeded over 56 years.

III. Flood Frequency Analysis

Return Period (years)	Flow (m^3/s)
1.05	95.2
1.25	132.0
1.5	154.1
1.7	166.4
2	180.7
5	246.2
10	289.5
20	331.1
50	384.9
100	425.2

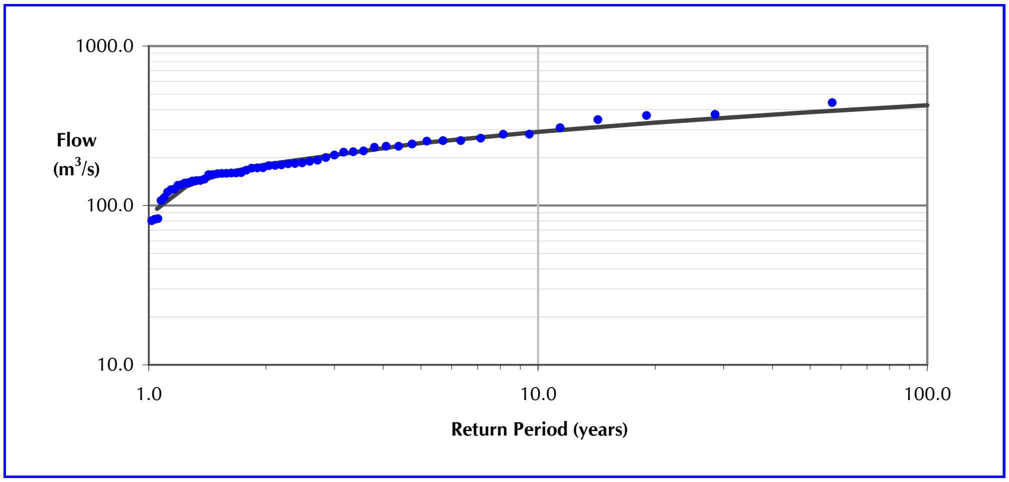


Table 3 & Figure 3 : Flood frequency analysis and curve fitted by the Gumble probability distribution.

IV. Low Flow Frequency Analysis (Performed using 7-day-average low flow)

Return Period (years)	Flow (m^3/s)
1.005	3.49
1.01	3.06
1.11	1.58
1.25	1.12
2	0.50
5	0.17
10	0.08
20	0.04
50	0.02
100	0.01

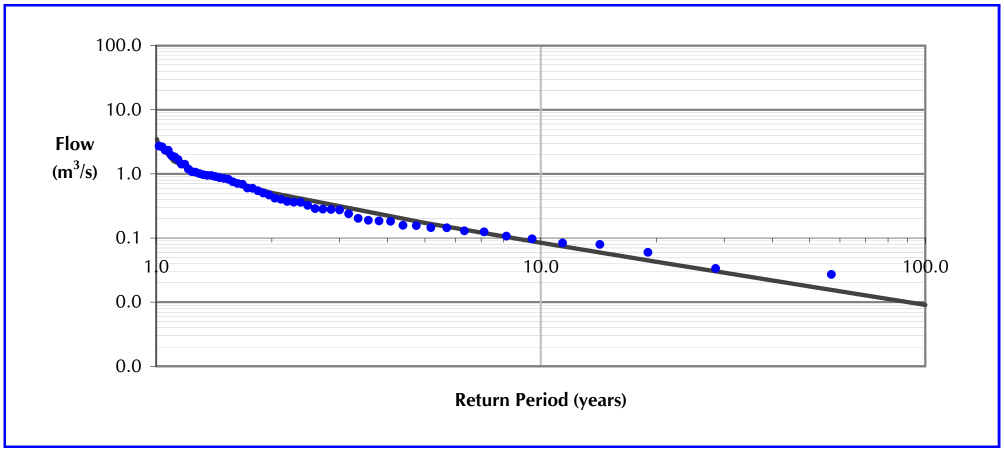


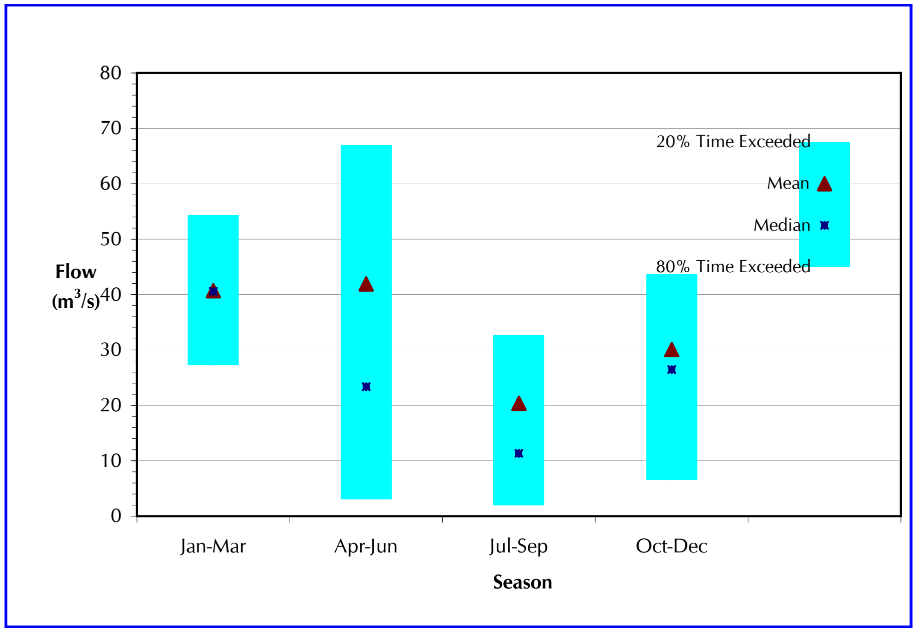
Table 4 & Figure 4 : 7-day-average low flow frequency analysis and curve fitted by the Gumble probability distribution.

Seasonal :

I. Flow Duration

Table 5 & Figure 5 : Seasonal median flow duration for determining minimum flow targets.

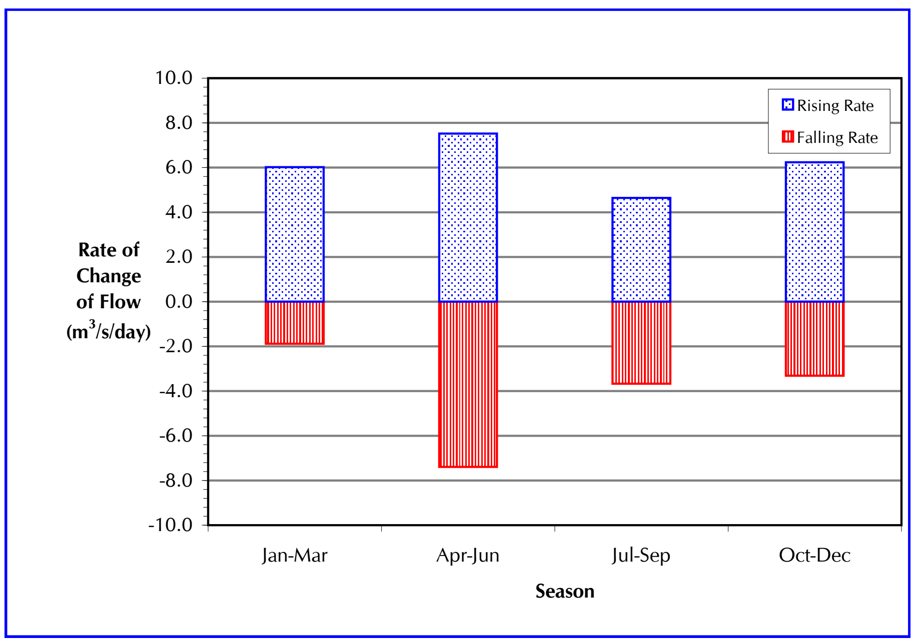
Season	20% Time Exceeded (m^3/s)	Median (m^3/s)	80% Time Exceeded (m^3/s)
Jan-Mar	54.3	40.6	27.2
Apr-Jun	66.9	23.4	3.0
Jul-Sep	32.7	11.4	1.9
Oct-Dec	43.7	26.5	6.5



II. Rate of Change of Flow

Table 6 & Figure 6 : Seasonal rising and falling rates of change of flow for determining ramping rate targets.

Season	Rising Rate ($m^3/s/day$)	Falling Rate ($m^3/s/day$)
Jan-Mar	6.02	-1.88
Apr-Jun	7.52	-7.39
Jul-Sep	4.64	-3.67
Oct-Dec	6.24	-3.31

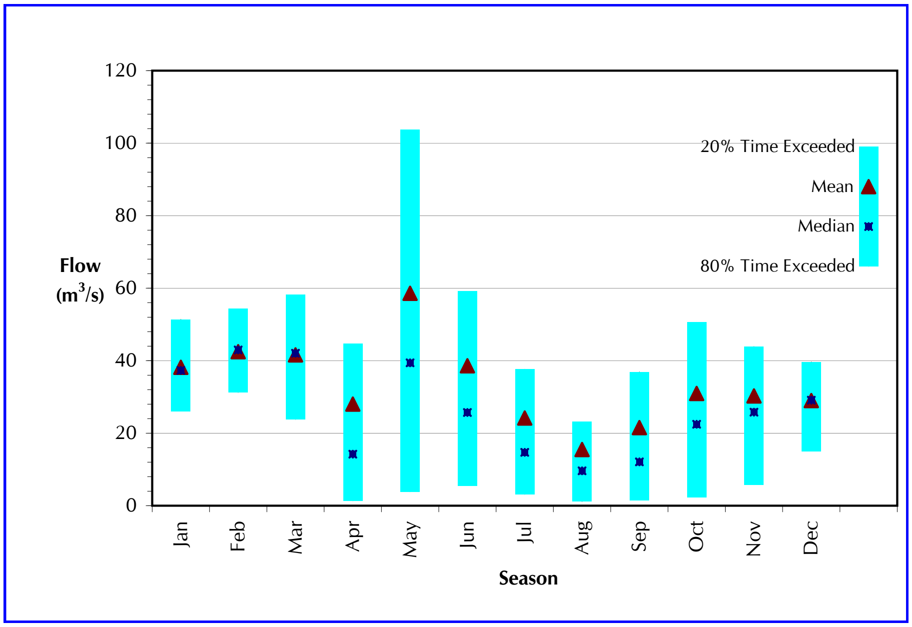


Monthly :

I. Flow Duration

Table 7 & Figure 7 : Monthly median flow duration for determining minimum flow targets.

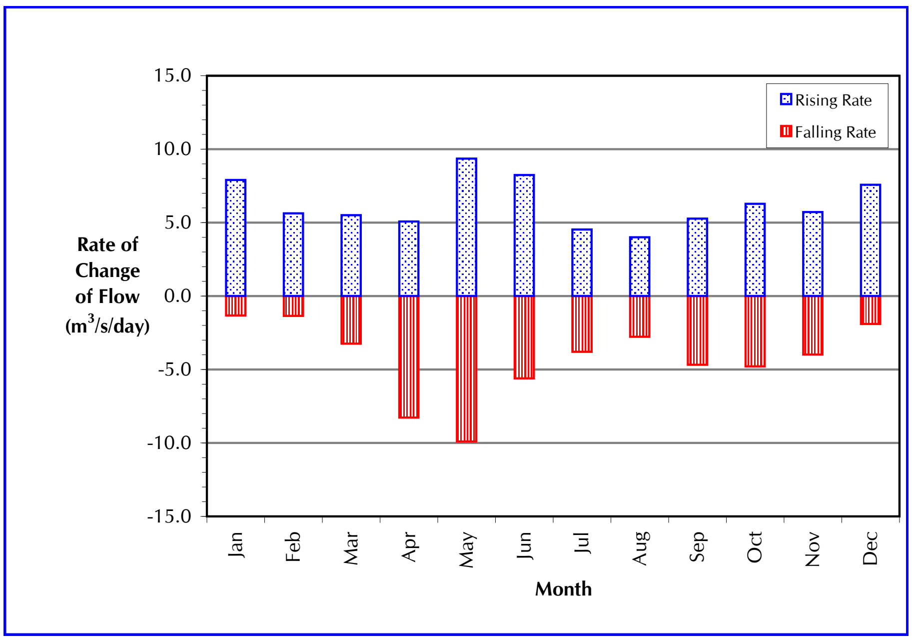
Month	20% Time Exceeded (m^3/s)	Median (m^3/s)	80% Time Exceeded (m^3/s)
Jan	51.4	37.3	26.0
Feb	54.3	43.0	31.2
Mar	58.1	42.1	23.8
Apr	44.7	14.2	1.3
May	103.7	39.4	3.8
Jun	59.2	25.7	5.5
Jul	37.7	14.7	3.1
Aug	23.1	9.6	1.1
Sep	36.9	12.1	1.5
Oct	50.6	22.5	2.3
Nov	43.9	25.8	5.8
Dec	39.7	29.1	15.0



II. Rate of Change of Flow

Table 8 & Figure 8 : Monthly rising and falling rates of change of flow for determining ramping rate targets.

Month	Rising Rate ($m^3/s/day$)	Falling Rate ($m^3/s/day$)
Jan	7.90	-1.33
Feb	5.63	-1.35
Mar	5.50	-3.24
Apr	5.08	-8.27
May	9.36	-9.90
Jun	8.24	-5.61
Jul	4.53	-3.80
Aug	4.01	-2.77
Sep	5.27	-4.68
Oct	6.28	-4.79
Nov	5.72	-3.98
Dec	7.58	-1.90



APPENDIX B

Lake Evaporation vs. Latitude in Ontario

Lake Evaporation vs. Latitude in Ontario

Lake evaporation in Ontario generally occurs between April and November each year when lakes are free of ice. Lake evaporation varies with extra terrestrial radiation, temperature, vapour pressure, humidity and wind speed. Although lake evaporation varies from year it is more stable than evapotranspiration or general evaporation loss in a river basin because it does not depend on the surficial geology or land use in the basin, which can affect the precipitation reaching the ground and the soil moisture available for transpiration.

Lake Evaporation datasets in Ontario are limited and not always complete, but Environment Canada publishes average lake evaporation data for some climate stations in the online Canadian Climate Normals or Averages 1971-2000 series.

The table below shows Annual Average Lake Evaporation data for six climate stations in Ontario and one each from Manitoba and Quebec.

Station	Province	Latitude ° N	Altitude m	Annual E_{Lake} mm
Amos	QUE	48.57	310	538
Atikokan	ONT	48.80	442	538
Delhi	ONT	42.87	232	709
Harrow	ONT	42.02	191	789
Moosonee	ONT	51.27	8	433
Ottawa	ONT	45.37	79	672
Rawson Lake	ONT	49.65	358	556
Norway House Forestry	MAN	54.00	217	320

The *Evaporation Atlas for the Contiguous 48 United States, NOAA Technical Report NWS 33, Washington D.C. June, 1982* shows that annual free water surface evaporation from shallow lakes (1956-70) varies approximately linearly with latitude in the states contiguous with the Province of Ontario.

To investigate whether this trend persists in Ontario the annual average lake evaporation data above were plotted against climate station latitude in Figure B-1. A linear regression equation fitted to this data set has a correlation coefficient $R^2 = 0.9655$ and gives the relationship for annual average lake evaporation:

$E_{Lake} = 2296.6 - 36.123 * \text{Latitude}$

Where: E_{Lake} is annual average lake evaporation in mm

Latitude is in decimal ° N.

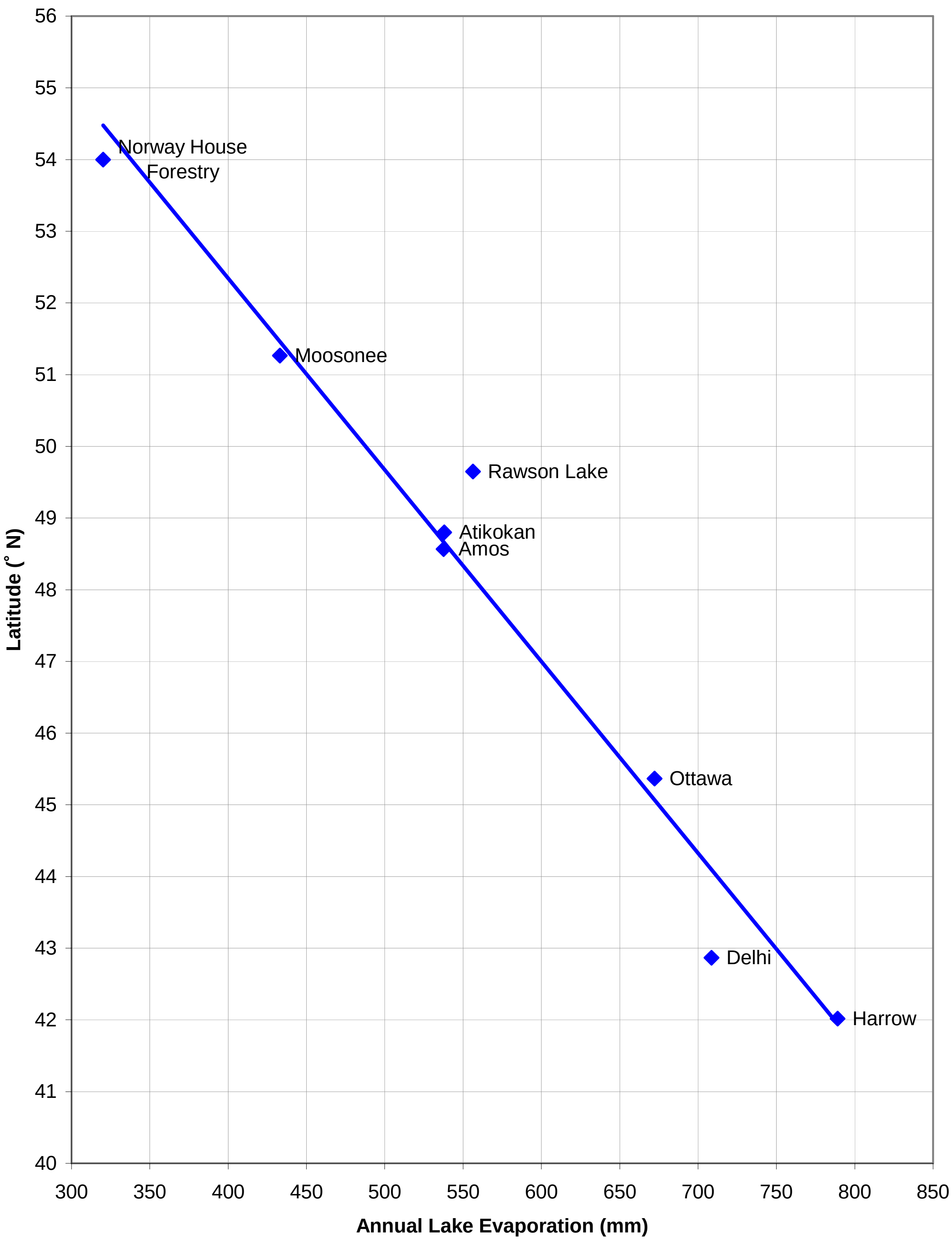


Figure B-1
Xeneca Power
Wanatango Hydropower Site
Annual Average Lake Evaporation vs. Latitude

A typical monthly lake evaporation distribution for the project sites is shown in Figure B-2.

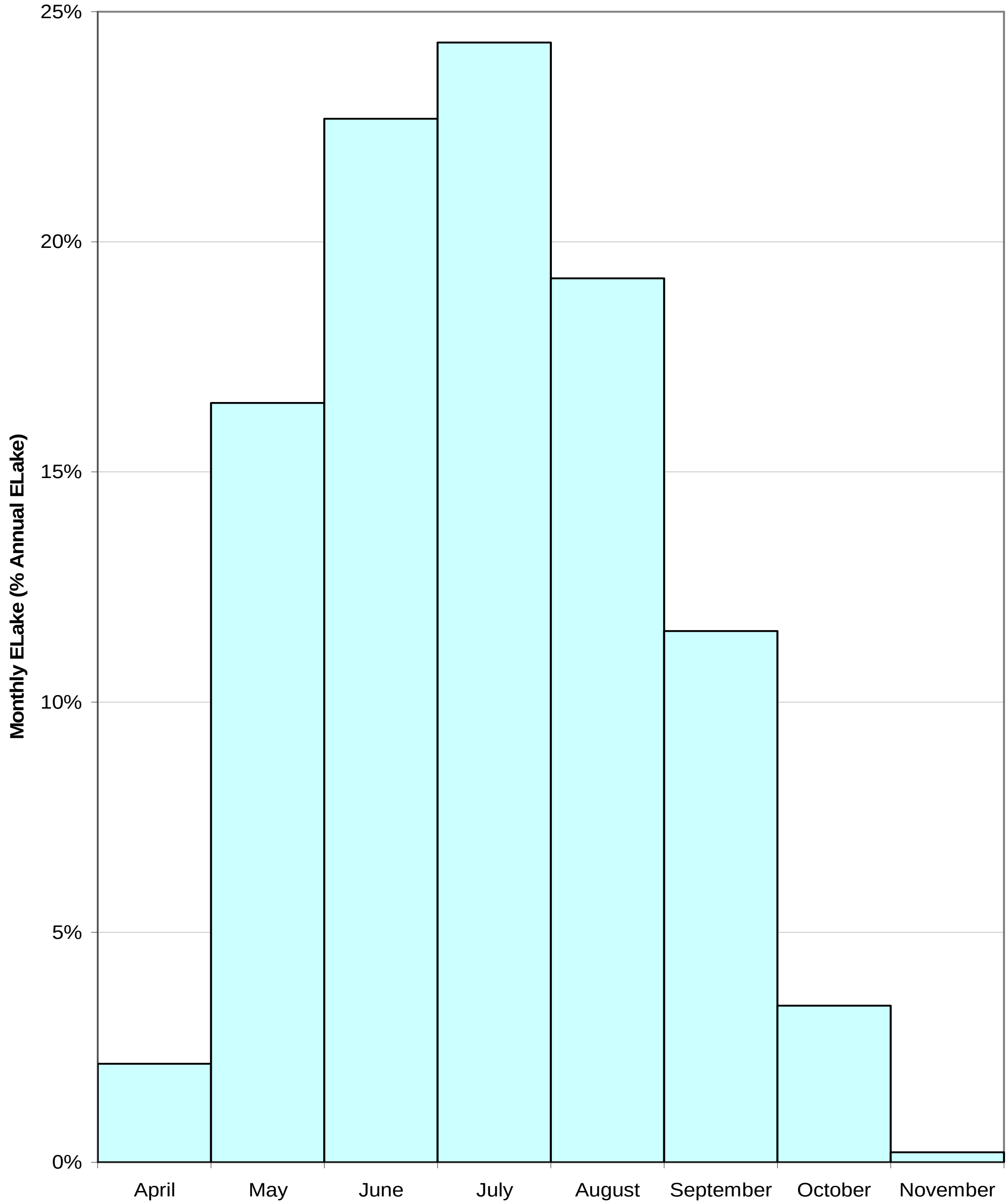


Figure B-2
Xeneca Power
Wanatango Hydropower Site
Monthly Lake Evaporation Distribution in Ontario

APPENDIX C

CD-ROM containing Flow Series Dataset

1235 North Service Road West
Oakville, Ontario, Canada L6M 2W2
Tel 905 469 3400 ◆ Fax 905 469 3404