Reconstructing the Natural Streamflow of La Grande Rivière, Québec, Canada

Marco A. Hernández-Henríquez, Theo J. Mlynowski, and Stephen J. Déry

Environmental Science and Engineering Program, University of Northern British Columbia, Prince George, British Columbia, Canada

INTRODUCTION

• La Grande Rivière is one of the largest rivers (by volume) in eastern Canada, draining a total area of 97,600 km² as it travels westward from its headwaters in north central Québec to its outlet at James Bay

• Hydro-Québec developed La Grande Rivière's hydroelectric potential during the late 1970's and early 1980's, giving rise to the La Grande Rivière Hydroelectric Complex

• Natural flow records of La Grande Rivière are only available until 1978, making it difficult for hydrological studies to assess long-term trends and variability in discharge

• The goal of this study is to develop a reliable method for reconstructing the natural streamflow of La Grande Rivière for the period 1979-2004

• The proposed method encompasses pre-regulated hydrometric data from La Grande Rivière (1960-1978) and two of its neighbouring rivers (1960-2004)

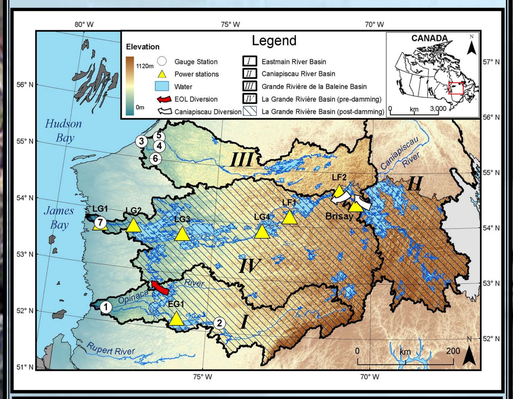
• We evaluate the accuracy of the reconstruction methodology and analyze the reconstructed flows for interannual variability and trends

• The reconstructed flows are compared to naturalized discharge values and the anthropogenic influence on the discharge of La Grande Rivière is investigated

STUDY SITE

• The La Grande Rivière Hydroelectric Project is located in the taiga region of northwestern Québec that extends from 48°N to 55°N and covers an area of 350,000 km²

• This hydroelectric complex encompasses the drainage basin of La Grande Rivière along with the flows diverted from the Caniapiscau, Opinaca, and Eastmain rivers



Map of northwestern Québec showing the location of the hydrometric gauges along the Eastmain River, Grande Rivière de la Baleine, and La Grande Rivière. Some of the main power stations and diversions associated with the La Grande Rivière Hydroelectric Complex are also shown. The EOL Diversion pertains to the Eastmain-Opinaca-La Grande Diversion that was commissioned in 1980.

DATA

• Observed daily hydrometric data from the Eastmain River and Grande Rivière de la Baleine are used to reconstruct the flows of La Grande Rivière for the period 1979 to 2004

• We only use observed hydrometric data from gauges located upstream of any major anthropogenic effect whenever necessary

• Daily discharge data were obtained from Environment Canada's online Hydrometric Database (HYDAT) and the Ministère de l'Environnement du Québec

• Additional monthly discharge rates for La Grande Rivière were obtained from Ouranos and the power generation company Hydro-Québec

• The Ouranos dataset (1981-2000) is a reconstruction of the natural flow for La Grande Rivière near its outlet into James Bay

• The Hydro-Québec dataset (1995-2004) provides the observed anthropogenically influenced discharge rates

METHODS

• Hydrometric data (1960-2004) from two neighbouring rivers are combined and used in conjunction with La Grande Rivière's pre-regulated (1960-1978) discharge time series

• Statistical analyses reveal a good correspondence ($r^2 = 0.63$, $p < 0.01$) and near 1:1 ratio between the sum of the Eastmain River and Grande Rivière de la Baleine and La Grande Rivière's 1960-1978 natural flow records **(Figure 1)**

• The mean monthly discharge and standard deviation values for La Grande Rivière (1960-1978) and Eastmain+Grande Rivière de la Baleine (1960-2004) are computed

• We standardized the Eastmain+Grande Rivière de la Baleine monthly discharge time series by subtracting their 45-year mean monthly discharge and dividing it by its corresponding standard deviation

• La Grande Rivière's 1960-2004 monthly streamflows are then reconstructed by multiplying the mean monthly standard deviation values (1960-1978) with the Eastmain+Grande Rivière de la Baleine standardized monthly discharge values (1960-2004) and then adding the mean monthly discharge (1960-1978)

• Correlation and error analyses between the observed and reconstructed flows (1960-1978) of La Grande Rivière are performed to assess the accuracy of the method

• La Grande Rivière's reconstructed flows are compared to the Ouranos naturalized flows (1981-2000) and Hydro-Québec's anthropogenically influenced flows (1995-2004)

• Variability in the streamflow time series is assessed by computing the coefficient of variation in discharge

• Mann-Kendall test is used to asses trends in total annual river discharge (1960-2004) and Kendall-Theil Robust Lines are used to determine the sign and magnitude of these trends (significant when $p < 0.05$)

RESULTS

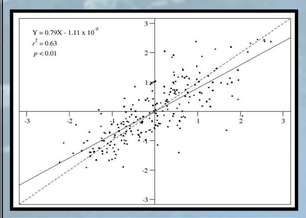


Figure 1. Comparison of the standardized anomalies in mean monthly discharge for La Grande Rivière and Eastmain+Grande Rivière de la Baleine for the period 1960-1978. The black line is the linear regression and the dashed line is the 1:1 line. The coefficient of determination (r^2) and probability value (p) are also given.

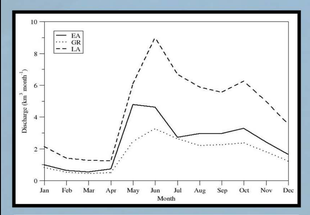


Figure 2. Annual cycle of mean monthly discharge for the Eastmain (EA), Grande Rivière de la Baleine (GR), and La Grande Rivière (LA) for the period 1960-1978.

• Each nival river exhibits a natural flow pattern throughout the year and thus experiences peak flows in the spring or early summer and secondary peak flows in the fall **(Figure 2)**

•The accuracy of the proposed method is confirmed by the low error rates and high degree of correspondence ($r^2 = 0.99$, $p < 0.01$) exhibited between La Grande Rivière's 1960-1978 observed and reconstructed monthly streamflow time series **(Figure 3)**

• Comparison between the reconstructed discharge rates and naturalized flows (1981-2000) obtained from Ouranos further verifies the methodology as 90% ($p < 0.01$) of the variance between the two datasets is explained **(Figure 4)**

• La Grande Rivière's reconstructed flows exhibit variability and a natural flow pattern that is indicative of nival rivers, whereas the anthropogenically influenced flow rates from Hydro-Québec (1995-2004) show minimal streamflow variability and a flattened annual hydrograph **(Figure 5)**

• Trend analyses (1960-2004) in total annual discharge reveal opposite trends from the Eastmain and Grande Rivière de la Baleine that cancel each other out when these two rivers are used to reconstruct La Grande Rivière's streamflows **(Figure 6)**

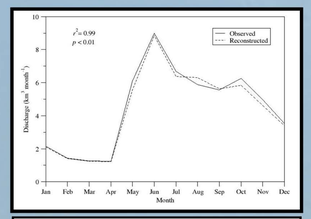


Figure 3. La Grande Rivière's observed and reconstructed annual cycle of mean monthly discharge for the period 1960-1978. The coefficient of determination (r^2) and probability value (p) are also given.

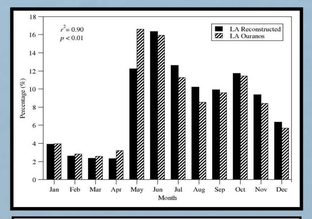


Figure 4. Monthly mean percentage of the total annual flow for La Grande Rivière's (LA) reconstructed flows and the "naturalized" discharge inferred from Ouranos for the period 1981-2000. The coefficient of determination (r^2) and probability value (p) are also given.

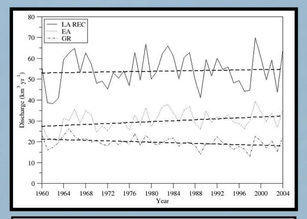


Figure 6. Temporal evolution of the annual discharge of La Grande Rivière (Reconstructed) (LA REC), Eastmain (EA), and Grande Rivière de la Baleine (GR), 1960-2004. Kendall-Theil Robust Lines are denoted by thick dashed lines.

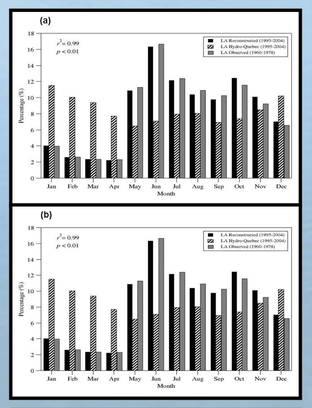


Figure 5. (a) Monthly mean percentage of the total annual flow and (b) coefficient of variation for La Grande Rivière's (LA) reconstructed flows and the anthropogenically influenced discharge from Hydro-Québec for the period 1995-2004. The pre-dam (1960-1978) observed mean monthly discharge data for La Grande Rivière are shown. The coefficient of determination (r^2) and probability value (p) are also given (Note: Hydro-Québec time series is not used in correlation analysis).

CONCLUSION

• Long-term discharge records are an integral component of hydrological studies investigating the temporal evolution of freshwater runoff in a river system

• Regulation of rivers by dams, diversions, and reservoirs leads to perturbed streamflow time series, making it difficult to assess seasonal trends and interannual variability

• This study presents a reliable method for reconstructing the 1979-2004 natural streamflow of La Grande Rivière

• Hydrometric data from the Eastmain River and Grande Rivière de la Baleine were successfully combined to reconstruct the naturalized streamflow time series of La Grande Rivière

• The low error rates and high degree of correspondence between La Grande Rivière's observed and reconstructed flows confirm the accuracy of the proposed method

• Future hydrological studies will now be able to assess La Grande Rivière's long-term trends and variability in discharge

• The proposed method can also be employed to reconstruct the natural flows of other regulated rivers as well as those not having complete hydrometric records

• In doing so, future studies will be better able to identify how climatic forcings are affecting the hydrological response of a region in addition to assessing the magnitude of human impact and investigating the natural variations in the hydrological cycle of the basin

REFERENCE

Hernández-Henríquez, M. A., Mlynowski, T. J. and Déry, S. J. (2009) Reconstructing the natural streamflow of La Grande Rivière, Québec, Canada. Submitted to Canadian Water Resources Journal.

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