# Developing an Integrated Water Management Tool for Winnipeg River's Hydropower System

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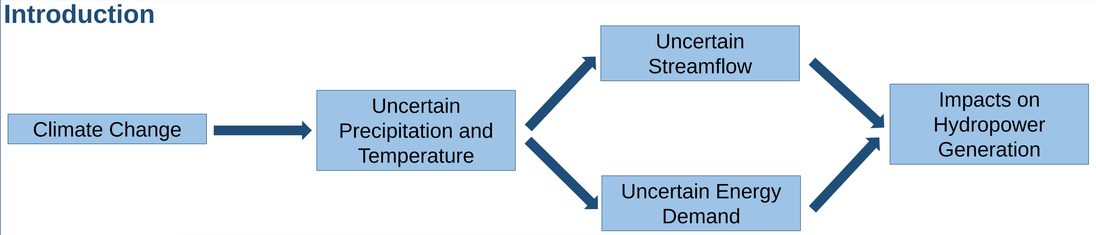
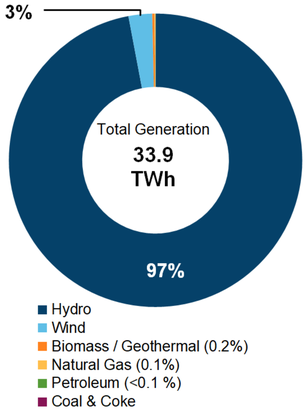
## Introduction




- Manitoba Dependency on Hydropower
- Importance of Climate Change Impacts Assessment in Manitoba

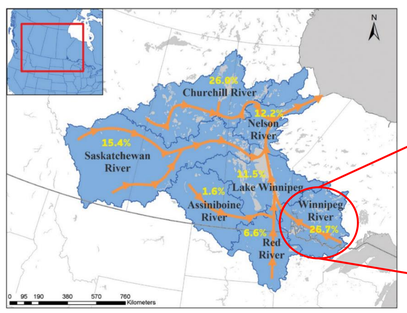

Location of Manitoba Province



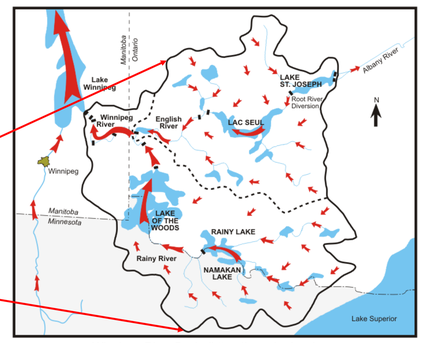
Electricity Production in Manitoba (CER – Canada's Energy Future 2021 Data Appendices)

## Study Area & Data

- Winnipeg River Basin: Located in Nelson-Churchill River basin

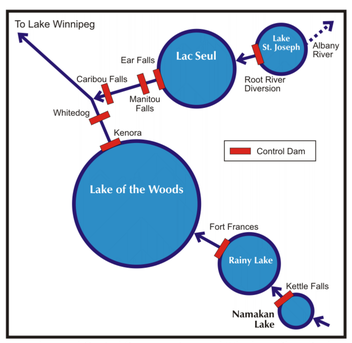


Location of Nelson-Churchill River Basin (the percentages show share of each basin in the watershed's flow) (Manitoba Hydro, 2015)



Winnipeg River Basin (https://www.lwcb.ca)

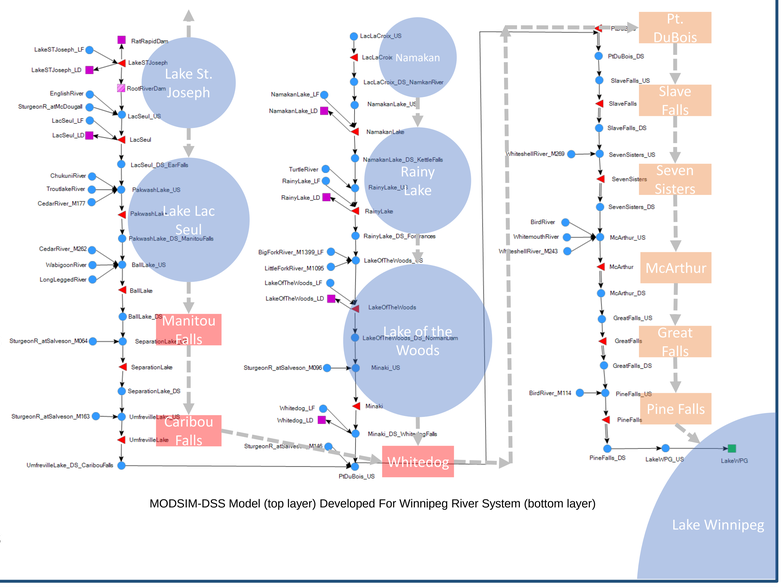
- Winnipeg river basin contributes to 26.7% of flow in the Nelson-Churchill River basin
- English and Rainy rivers join together in Winnipeg River in Manitoba
- Lakes in Ontario: Lake St. Joseph, Lac Seul, Namakan Lake, Rainy Lake, Lake of the Woods, and other smaller lakes
- Lake of the Woods and Lac Seul as the biggest lakes control the outflow to the Winnipeg River
- Average stream flow in Winnipeg River varies between 800 to 1500 (cms) throughout a year
- 6 Hydropower stations within the Winnipeg River in Manitoba
- Nominal Hydropower Generation Capacity: 662 (MW)
- Contributes to 11% of hydropower generation in Manitoba
- Other hydropower stations in Ontario: not directly connected to the Manitoba power system
- Data provided by Manitoba Hydro: 1980 to 2018
- Historical Water Level, Inflow, Outflow from Lakes and Control Dams, Stage-Storage Table, Hydropower Efficiency Table, and Hydropower Generation



Lakes and Control Dams Upstream of Winnipeg River Basin (https://www.lwcb.ca)

## Methodology

- MODSIM-DSS: Integrated water management platform
- Rule Curve: target storages in each lake and control dams
- Defining the target hydropower generation
- Two models for daily simulation of Winnipeg River System:
  1. Mass-Balance Model: Feeding the model using the historical data
  2. Operational Model: Defining the target storages using the custom coding capability of MODSIM-DSS
- Linear Regression and Historical Daily Median were used to define the target storage in operational model
- Monthly and yearly regression equations were used for the lakes and control dams located in Ontario
- Independent variables of regression equations: Day of Year, Inflow, Storage, and Outflow in previous time step
- Historical Daily Median Storage were used for hydropower stations in Winnipeg River
- Running the Operational model for 15 stochastic scenarios: applying percent change (-10% to +10%) to historical time series of inflow and hydropower demand:



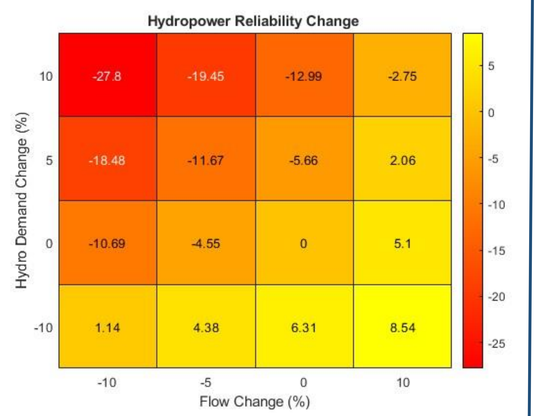
MODSIM-DSS Model (top layer) Developed For Winnipeg River System (bottom layer)

## Result & Discussion

1. Model Evaluation
   - Metrics: MAE, PBIAS, and NSE
   - Hydropower generation and outflows from lakes and control dams
   - Good performance for both Mass-Balance and Operational Models
2. Stochastic Scenarios
   - Reliability of supplying more than 95% of hydropower demand
   - 9 out of 15 scenarios resulted in hydropower reliability decrease
   - Asymmetrical impacts: Hydropower reliability is approximately twice as sensitive to decreases in flow compared to increases. Similarly, twice as sensitive to increases in hydro demand compared to decreases.
   - Hydro demand increase resulted in reliability increase in 1 out of 8 scenarios
   - 10% increase in flow decreased the hydropower reliability in 1 out of 4 simulations
   - In case of 10% flow increase, there is a threshold (between 5 and 10 percent) for increasing the hydropower demand without decreasing its reliability

Evaluation Results of Operational Model for Important Control Points

| Branch | Lake | Total Outflow MAE (cms) | Total Outflow PBIAS (%) | Total Outflow NSE | Hydro Outflow MAE (cms) | Hydro Outflow PBIAS (%) | Hydro Outflow NSE | Hydro Generation MAE (MWh) | Hydro Generation PBIAS (%) | Hydro Generation NSE |
|---|---|---|---|---|---|---|---|---|---|---|
| English River | ST. Joseph (Albany) | 16.40 | -14.27 | 0.41 | - | - | - | - | - | - |
| | ST. Joseph (Root) | 22.39 | 3.11 | 0.05 | - | - | - | - | - | - |
| | Lac Seul | 46.79 | 1.02 | 0.80 | - | - | - | - | - | - |
| Rainy River | Namakan Lake | 19.10 | 0.02 | 0.94 | - | - | - | - | - | - |
| | Rainy Lake | 50.66 | 0.04 | 0.89 | - | - | - | - | - | - |
| | Lake of the Woods | 88.34 | -0.09 | 0.81 | - | - | - | - | - | - |
| Winnipeg River | Pointe du Bois | 121.84 | -1.83 | 0.87 | 20.29 | -3.74 | 0.95 | 11.07 | -0.88 | 0.98 |
| | Slave Falls | 121.53 | -1.66 | 0.87 | 71.62 | -8.77 | 0.78 | 12.77 | -1.02 | 0.97 |
| | Seven Sisters | 118.68 | -0.80 | 0.88 | 70.96 | -7.98 | 0.85 | 43.21 | -1.44 | 0.96 |
| | McArthur | 132.37 | -1.34 | 0.88 | 68.38 | -4.86 | 0.82 | 35.44 | -3.14 | 0.89 |
| | Great Falls | 128.27 | -1.41 | 0.88 | 41.21 | -4.91 | 0.90 | 29.60 | -1.17 | 0.96 |
| | Pine Falls | 123.38 | -1.75 | 0.88 | 53.00 | -4.73 | 0.81 | 34.66 | -2.00 | 0.91 |



Reliability Change for different stochastic scenarios

## Conclusion & Future Work

- Climate change impact assessment on hydropower generation in Winnipeg River system located in Manitoba.
- Streamflow increase does not guarantee higher and more reliable hydropower generation in Winnipeg River System
- Running the model for climate scenarios (CMIP5) and comparing the result
- Running the model for synthetic future scenarios generated by stochastic weather generators

**Acknowledgement** The authors gratefully acknowledge Manitoba Hydro and their expert staff who have contributed to data sharing required to conduct this study. This research was supported by "Canada First Research Excellence Fund (CFREF) - University of Saskatchewan"

EGU General Assembly 2023 · University of Manitoba · Manitoba Hydro · Integrated Modelling Program for Canada (IMPC) · Global Water Futures