Coupled hydrologic-operations modelling for the simulation of hydropower operations in the Lower Nelson River Basin

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Background and Motivation

Projected changes in discharge and high uncertainty in the Hudson Bay Complex pose concerns to energy security in the Lower Nelson River Basin where over 70% of Manitoba's hydroelectricity is generated.

In order to forecast future flows, the study requires a model which can simultaneously simulate complex hydrology and reservoir regulations in the Lower Nelson River Basin. The study couples a physically-based hydrologic model (WATFLOOD/HEC-HMS) with a water management model (MODSIM-DSS) in order to solve this problem.

For the preliminary run, MODSIM was modelled using system mass-balance approach. Second phase coupling will be done with custom coded operations in MODSIM.

The model coupling is facilitated using a Python script.

Preliminary Run Results

❖ Model coupling

- Three data exchange points between the two models (reservoirs with storage capacity); other generating stations are Run-Of-the-River (ROR) stations
- Reservoir inflow calculated by WATFLOOD/HEC-HMS
- Reservoir release calculated by MODSIM

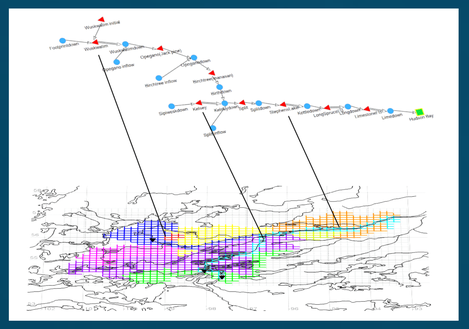


Figure 1: Schematic of coupling locations between WATFLOOD and MODSIM models of the Lower Nelson River Basin

❖ Improved simulation of reservoir releases

- Enhanced reservoir release complexity/flexibility
- Improved KGE values

Name	Lake Type	WATFLOOD Only	HEC-HMS Only	MODSIM Only	WATFLOOD Coupled	HEC-HMS Coupled
Cross Lake	Natural	0.93	0.97	0.99	NA	NA
Sipiwesk Lake	Natural	0.95	NA	0.99	NA	NA
Kelsey GS	Control	0.92	0.95	0.98	0.92	0.95
Split Lake	Natural	0.93	0.94	0.97	0.94	0.95
Kettle GS	**Control**	**0.86**	**0.88**	**0.93**	**0.93**	**0.92**
Longspruce GS	**Control**	**0.86**	**0.88**	**0.94**	**0.93**	**0.93**
Wuskwatim GS	**Control**	**0.94**	**0.90**	**0.95**	**0.93**	**0.93**
Opegano Lake	Natural	NA	NA	0.91	0.94	0.94
Birchtree Lake	Natural	NA	NA	0.91	0.93	0.93
WSC 05TG001	**N/A**	**0.87**	**0.79**	**NA**	**0.86**	**0.85**

Table 1: KGE values of Major Lakes/Reservoirs in the Lower Nelson River Basin for 2010-2016 period
NA values for WATFLOOD and HEC-HMS indicate that the lakes/reservoirs are not included in the models. NA values for coupled models indicate that the lakes/reservoirs are not included the historical analysis but will be included for the future analysis.

Model Coupling

Model coupling

- Facilitated using Python wrapper script
- Python extracted, formatted and passed input/output (I/O) data between models (WATFLOOD, HEC-HMS ↔ MODSIM)
- Requires 2 iterations prior to convergence
- 2010-2017 simulation runs take ~ 10 min for 2 iterations (running both models twice)
- Convergence if maximum percent difference in each coupling reservoir < 10%

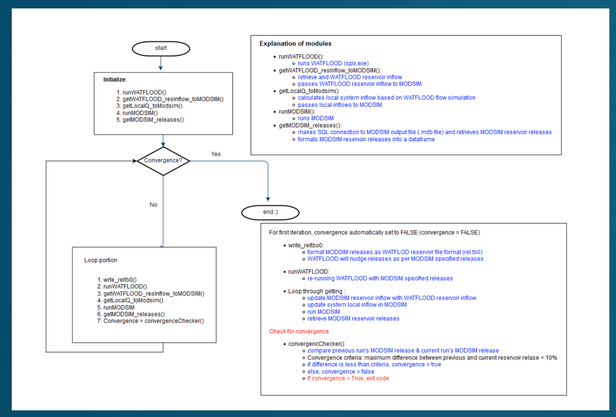
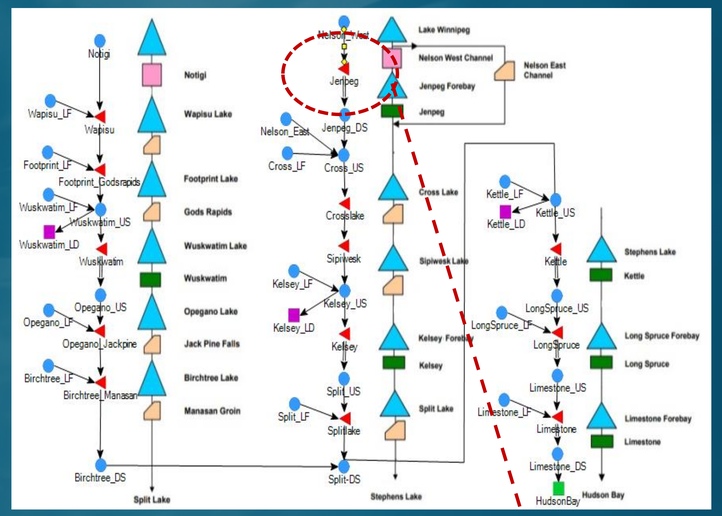


Figure 2: Flow diagram of Python script for WATFLOOD-MODSIM coupling
Python script for HEC-HMS – MODSIM works in a similar procedure

MODSIM-DDS



NSE scores at Jenpeg (2013-2018)	Mass-balance Model	Operational Model
Elevation	1	0.81
Power	0.99	0.99
Outflow	0.98	0.89

Ex. Jenpeg rule curve
Target storage = Initial storage + (Inflow – Outflow)

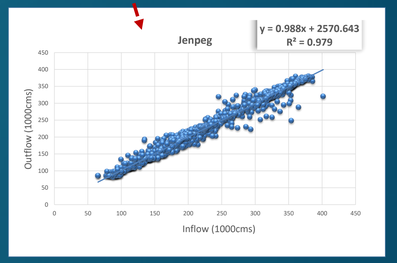


Figure 3: Schematic of MODSIM model of Lower Nelson River Basin
In the custom coded operational version of MODSIM, the operational rule curves replace the target storages set in the mass-balance version for each reservoir. The operational version of MODSIM performs slightly worse than the mass-balanced version but with still high NSE score

Plans for Future Work

Part 1b: Assessment of coupling with custom coded operational model of MODSIM

- Instead of operating reservoirs according to target storages (system solved using mass balance), operate using custom coded operational rule curves
- Evaluate simulation improvement

Part 2a: Assessment of current hydropower operations under future climate

- Run the coupled model under 19 climate scenarios
- Assess changes in annual power production
- Assess operation robustness (system demand satisfaction)

Conclusions

1. **MODSIM is capable of simulating natural and regulated reservoirs with high accuracy**
   - Average reservoir KGE = 0.95
2. **Model coupling improves flow simulation**
   - Improvement or no effect in flow performance, however, enhanced reservoir operation capabilities are facilitated
   - Possible operational optimization with future flow forecast analysis

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