

## Developing Integrated Surface and Groundwater Model in Moose Lake Area of Athabasca Oil Sands Region

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### Abstract

There is a clear need to develop an integrated surface water-groundwater model in the Moose Lake area of the Athabasca oil sands region to support the protection of the hydrosphere and maintain watershed function and integrity. Such a model would enhance the understanding of the potential impacts of land disturbance, climate change and groundwater use on surface and groundwater interactions, and surface water quantity and quality in the Moose Lake area. Meanwhile, the model would be used to inform monitoring programs and decision-making by energy and land use regulators and oil sands operators. As such, a proof of concept, integrated surface and groundwater model was recently developed in this area using MIKE SHE. A preliminary model calibration using available hydrograph and lake water level data was conducted to demonstrate model performance. In addition, preliminary sensitivity analysis shows that the baseflow and groundwater recharge are highly dependent on the hydraulic conductivity of near-surface Quaternary sediments. As one of the key pathways for surface and groundwater interactions, a more detailed and updated representation of the Quaternary succession is required to improve the model performance in further model development.

### Study Area

The area of interest to this numerical modelling study is the Moose Lake (or Gardiner Lake) access management 10 km zone delineated for the Moose Lake Access Management Plan (GoA, 2021). The 10 km zone (10KMZ) is located within the Athabasca oil sands region, approximately 100 km northwest of Fort McMurray and 65 km northwest of the Hamlet of Fort McKay (Figure 1), with an area of 1,030 km<sup>2</sup>. The in-situ bitumen extraction is the primary activity associated with development disturbance in the 10KMZ. Other activities that may also contribute to landscape impacts include but are not limited to forestry, sand and gravel, petroleum and natural gas, and recreational uses (GoA, 2021). To assess possible impacts of human activities as well as climate change on surface water and support water management, part of the Moose Lake Access Management Plan, there is a clear need to develop an integrated surface water and groundwater interaction model in this area.

### Numerical Model Proof of Concept

To facilitate the communications and discussions with stakeholders regarding the development of a comprehensive surface water and groundwater interaction model in the Moose Lake area, a preliminary proof of concept, integrated hydrological model was recently built using MIKE SHE. The model domain covers the Moose Lake basin with one Hydrologic Unit Code 8 (HUC 8) watershed (Figure 1). The HUC 8 represents the delineated catchment associated with Ells River.

A node-centered, finite difference grid was generated for the model domain with a uniform grid size of 200 m by 200 m.

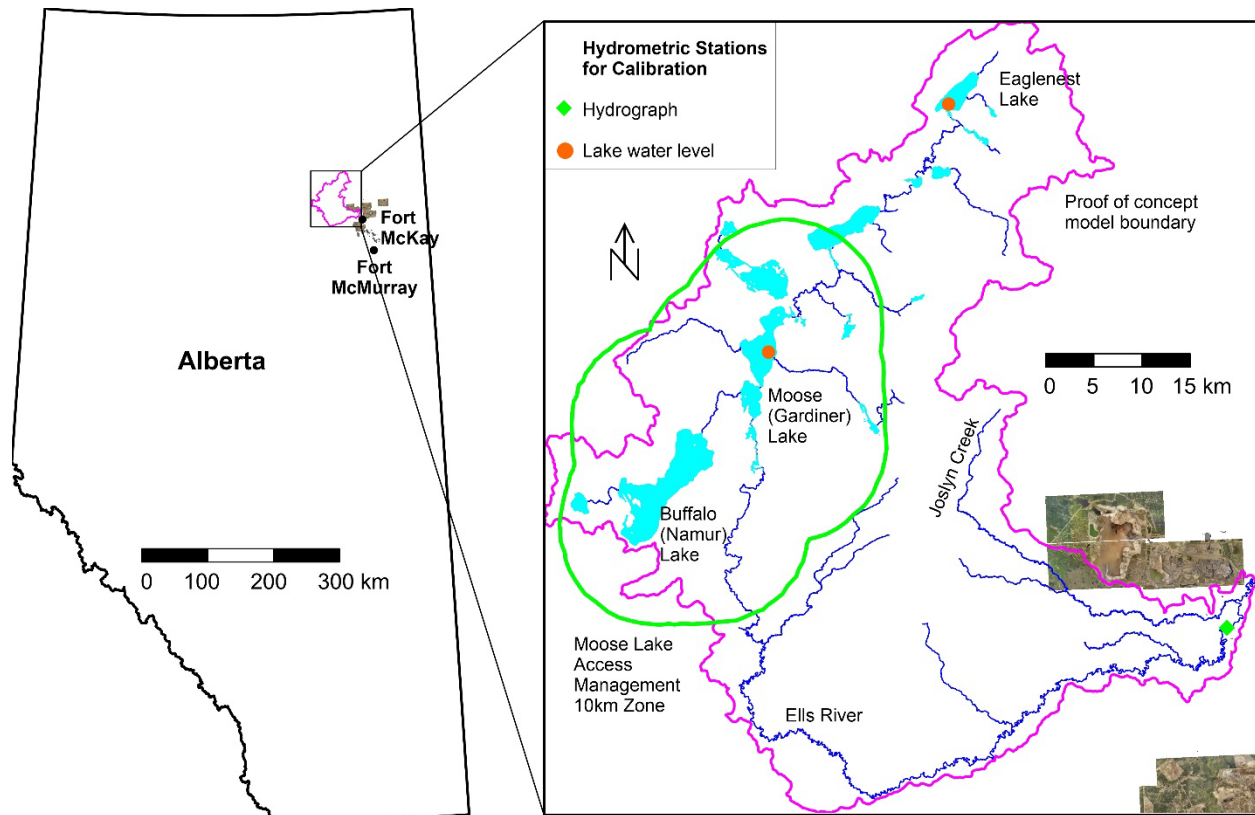


Figure 1: A map showing Study area (green outline), river network, lakes and hydrometric stations for model calibration

The model fully integrates the physical processes driving the hydrological cycles in the basin, including climate forcing, land cover and land use effects, evapotranspiration, overland flows, river and lake flows, surface water and groundwater interactions, and subsurface flows. The subsurface in the model accounts for both unsaturated zone (vadose) and saturated zone, and extends from ground surface to the base of Devonian Cold Lake Formation with a total of 10 hydrostratigraphic units (or geological layers), including Quaternary Aquifer/Aquitard, LaBiche Aquitard, Grand Rapids Aquifer, Clearwater Aquifer, Wabiskaw Aquitard, McMurray Aquifer, Beaverhill Lake Aquifer, Watt Mountain Aquiclude, Contact Rapids Aquifer and Cold lake Aquiclude.

### Model Parameterization and Calibration

Preliminary model parameterization and calibration were carried out to demonstrate the performance of this proof-of-concept model. The parameterization mainly involved the optimization of horizontal/vertical hydraulic conductivities for the 10 hydrostratigraphic units, detention storage and crop coefficient of evapotranspiration. The calibration was conducted using the hydrograph data at the downstream of Ells River and the lake water level data collected from Moose Lake and Eglenest Lake (Figure 1).

The calibration results are shown in Figures 2 and 3. The hydrograph calibration ran a 10-year period from 1975 to 1984. It is seen that the modeled hydrograph is well calibrated over the 10-year simulation period with a correlation coefficient of 0.75 and a Nash coefficient of 0.52 (Figure 2). The lake water level calibrations ran a 2 to 3-year period from 1976 to 1978. It is observed that the model is capable of reasonably reproducing the seasonal variations of the lake water levels with the correlation coefficient greater 0.7 and Nash coefficient greater than 0.4 (Figure 3).

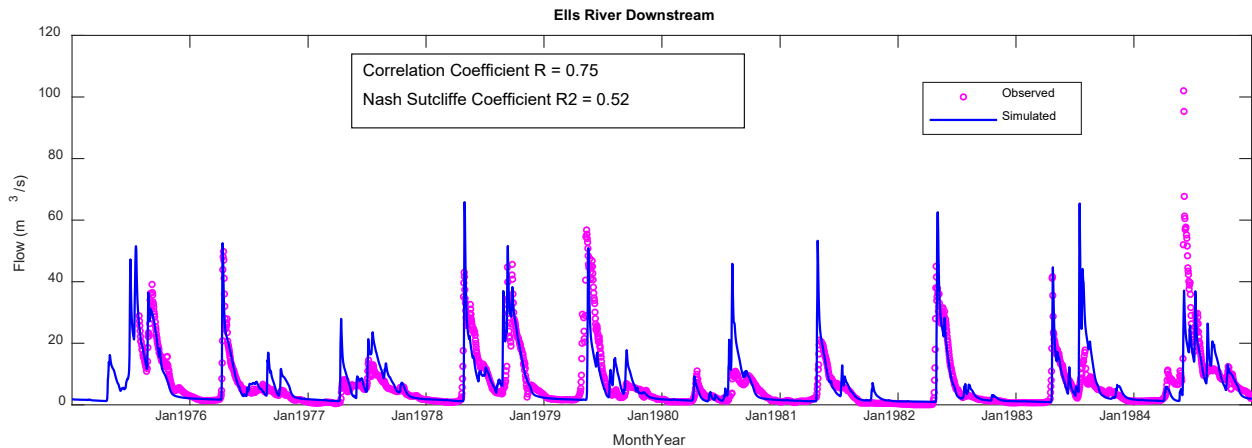


Figure 2: Time series calibration results for hydrograph at the downstream of Ells River

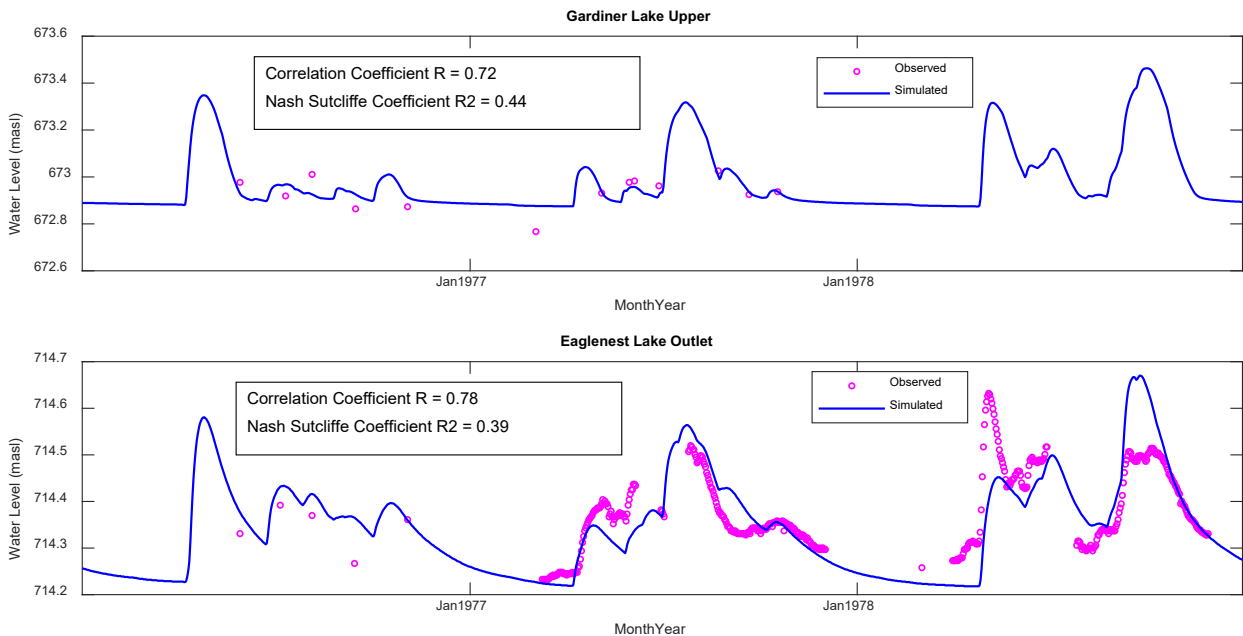


Figure 3: Time series calibration results for water levels at Moose (Gardiner) and Eaglenest lakes

## Sensitivity Analysis

To understand the sensitivity of simulation due to the inherent uncertainty in model inputs, a preliminary sensitivity analysis was conducted for the calibrated horizontal/vertical hydraulic conductivities of the Quaternary. The sensitivity of an individual model run was evaluated in comparison to the calibrated model results (baseline conditions) as described in the Model Parameterization and Calibration Section. This was done through the comparisons of the baseflows and groundwater recharges to the baseline results over the catchment scale.

The sensitivity analysis results are summarized in Table 1. It is seen that the baseflow and groundwater recharge are sensitive to the hydraulic conductivity of near-surface Quaternary sediments. As one of the key pathways for surface and groundwater interactions, a more detailed and updated representation of the Quaternary succession is thus required to improve the performance in the further development of this integrated surface water and groundwater model.

*Table 1: Percent change of mean baseflow and groundwater recharge from the baseline conditions for sensitivity runs*

Baseline conditions		Sensitivity Run	Multiplier of Quaternary hydraulic conductivity	Percent change from baseline condition	
Mean baseflow (m <sup>3</sup> /s)	Mean recharge (mm/a)			Mean baseflow (%)	Mean recharge (%)
1.40	11	Case 1	2	15	12
		Case 2	0.5	-10	-7

## References

Government of Alberta (GoA), 2021. Moose Lake Access Management Plan. ISBN 978-1-4601-5024-5, 79 p. Available at: <https://open.alberta.ca/publications/moose-lake-access-management-plan>