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Numerical modeling of the groundwater regional flow system to assess the exploitation sustainability of the transboundary Milk River Aquifer (Alberta, Canada – Montana, USA)

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The Milk River Aquifer (MRA) is a major groundwater resource extending over southern Alberta (Canada) and northern Montana (United States), a water-short region with a semi-arid climate. Concerns about the sustainability of this transboundary resource have been raised due to the extensive use of this regional sandstone aquifer over more than 100 years. In order to evaluate the sustainability of the MRA exploitation, a numerical model of the regional groundwater flow system containing the MRA was developed.

The three-dimensional steady-state numerical model was based on the previously developed geological and conceptual models of the MRA. Besides simulation of natural conditions without exploitation, three groundwater exploitation scenarios were simulated: 1) mean abstraction rate over 108 years, 2) historical maximum abstraction rate of the MRA and 3) a theoretical high abstraction rate based on the maximum rate estimated for all MRA exploitation zones. This numerical model is also used to better understand this large regional flow system and to assess the role of groundwater capture and storage loss at the regional scale, which are key concepts related to the sustainability of aquifer exploitation.

Results first showed that the regional groundwater flow model successfully represented the 3D groundwater flow patterns under pre-development conditions and reproduced the processes highlighted in the conceptual model. Therefore, the hydraulic plausibly of the conceptual model was verified. Simulation of groundwater use scenarios showed that the MRA exploitation has led to a major change in flow patterns to support groundwater abstraction from the MRA. The flow system can adapt to large exploitation levels in the MRA and reach a new equilibrium. However, groundwater withdrawals are compensated by a loss of storage, less outflow and more inflow, especially from confining units. The average historical level of exploitation of the MRA appears sustainable whereas the other groundwater exploitation scenarios lead to major drawdowns and the loss of artesian conditions that would make the MRA exploitation economically or technically challenging. Finally, the numerical model confirmed that the MRA is an international resource and allowed the delineation of the appropriate management unit for its transboundary management.

Overall, this work provides an example of the use of a numerical model to better understand regional groundwater flow and to investigate the impact of exploitation on the flow system and the long-term reduction of groundwater storage in a regional aquifer. This numerical model provides a valuable tool to support the sustainable management of this transboundary resource.