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Transient,spatially-varied recharge for groundwater modeling

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This study is aimed at producing spatially and temporally varying groundwater recharge for transient groundwater modeling in a pilot watershed in the North Okanagan, Canada. The recharge modeling is undertaken by using a Richard's equation based finite element code (HYDRUS-1D) [Simunek et al., 2002], ArcGISTM [ESRI, 2011], ROSETTA [Schaap et al., 2001], in situ observations of soil temperature and soil moisture and a long term gridded climate data [Nielsen et al., 2010].

The public version of HYDUS-1D [Simunek et al., 2002] and another beta version with a detailed freezing and thawing module [Hansson et al., 2004] are first used to simulate soil temperature, snow pack and soil moisture over a one year experimental period. Statistical analysis of the results show both versions of HYDRUS-1D reproduce observed variables to the same degree. Correlation coefficients for soil temperature simulation were estimated at 0.9 and 0.8, at depths of 10 cm and 50 cm respectively; and for soil moisture, 0.8 and 0.6 at 10 cm and 50 cm respectively. This and other standard measures of model performance (root mean square error and average error) showed a promising performance of the HYDRUS-1D code in our pilot watershed.

After evaluating model performance using field data and ROSETTA derived soil hydraulic parameters, the HYDRUS-1D code is coupled with ArcGISTM to produce spatially and temporally varying recharge maps throughout the Deep Creek watershed. Temporal and spatial analysis of 25 years daily recharge results at various representative points across the study watershed reveal significant temporal and spatial variations; average recharge estimated at 77.8 $\pm$ 50.8mm /year. This significant variation over the years, caused by antecedent soil moisture condition and climatic condition, illustrates the common flaw of assigning a constant percentage of precipitation throughout the simulation period.

Groundwater recharge modeling has previously been attempted in the Okanagan Basin and other parts of Canada by using the HELP code. However, HELP has known limitations related with boundary conditions as well as spatial and temporal discretization options, and thus cannot simulate highly variable fluxes near boundaries. The limitations are even more pronounced in semi-arid areas like the Okanagan Basin where upward fluxes can be high, because HELP assumes that water below evaporative zone simply drains to the base of a soil column without accounting for upward fluxes. In addition to these limitations, previous studies that used HELP for recharge estimation, [Towes and Allen, 2009; Jyrkama and Sykes, 2007], did not attempt to verify model performance in their study area. The study here presents an integrated procedure that can help address some of these often neglected modelling challenges.

The significance of the method in transient groundwater modeling is demonstrated by applying the spatially and temporally varying recharge boundary condition to a saturated zone groundwater model, MIKESHE [DHI, 2009a]. The water table simulated using this method is found to be within 0.6 m of the observed values, whereas the water levels estimated using uniform recharge boundary condition can fluctuate by as much as 1.6 m. Root mean square errors were estimated at 0.3 and 0.94 respectively.