

ABSTRACT

Groundwater (GW) and surface water (SW) are the two interconnected components of the hydrological cycle. The GW-SW interaction plays a significant role in maintaining flow and transport in riverine ecosystem. Therefore, it is crucial to understand the GW-SW interaction mechanism, governing processes, interaction scale, and quantification methods. The interactions are governed by the factors like hydrological and hydrogeological properties of the streambed and the aquifer, streambed topography, vegetation, and climatic changes. Considering all the governing factors in a single model for a holistic characterisation of GW-SW interaction is challenging.

The GW-SW exchanging flux is either measured directly in the field or is quantified using numerical modelling techniques. Modelling techniques identify two governing components a) streambed and b) the underlying aquifer. The thickness and width of the streambed, the hydraulic properties of the streambed and the underlying aquifer are the key parameters. However, there are limited studies which highlight the effect of individual parameters on the exchanging flux (Q_r). The present study uses scenario-based numerical modelling to quantify their influence on the flux exchange using a 2D, steady-state and homogenous GW-SW combined model. The scenarios have been simulated using OpenGeoSys (v6.1) and adopting different hydraulic (hydraulic conductivity – K_r, K_a) and geometric (width – W_r, W_a and thickness – t_r, t_a) properties of the streambed and the aquifer. The influence of these properties on exchanging flux has been analysed under high and low streambed conductance ($K_r/t_r = C_r$). As can be seen, the aquifer properties dominate the exchanging flux at a higher C_r values, whereas for lower C_r values, streambed properties dominate the exchanging flux. The developed empirical expression provides a qualitative assessment of the influence of W_r, K_a , and t_a with respect to C_r on Q_r .

A quantitative assessment has been performed using an analytical approach on the same GW-SW setup. The developed approach can define the criteria to identify when streambed or/and aquifer properties are governing Q_r . The approach also highlights the significance of head measurement location for the flux quantification. In the case of a narrow stream with low hydraulic conductivity streambed and an aquifer with a high transmissivity, the head should be measured near the stream edge. On the other hand, for wider streams, the head should be measured at larger distances from the stream edge. The analytical approach has matched well with a similar numerical model; hence, the solution can replace the numerical modelling for a similar setup.

The 2D model can capture the individual influence of parameters. However, it is limited to the application of different boundary conditions. These boundary conditions represent the GW flow occurring in the underlying aquifer. This 2D model has been extended to a 3D model to capture the effect of the different setup of boundary conditions (flow parallel and perpendicular to the streamflow). The infiltrating flux follows a logistic relation in both the cases of GW flow. However, the flow parallel to the stream flow shows slight deviations at the higher values of the streambed conductance, which can be investigated in future modelling experiments. Field validation of the developed analytical approach and addressing complexities like streambed and aquifer heterogeneity, GW flow orientation, and external stresses like the recharge from the flood plains in a numerical model will further improve the performance.