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Modeling groundwater recharge: YAGMod – Yet Another Groundwater flow Model.

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Water demand for the city of Hargeisa (Somaliland) is supplied by the alluvial aquifer of the Ged Deeble (GD) basin. The water production of well fields raised from $6,000\,\mathrm{m}^3/\mathrm{day}$ in the first years of the millennium up to $10,400\,\mathrm{m}^3/\mathrm{day}$ at the beginning of 2010. This trend reflects in the variation of the water table depth with time. The GD basin is connected to the Laas Dhuurre-Damal (LDD) basin through a wide outlet, at the N-E edge, and crossed by two seasonal wadis, Tog Kalqoray and Tog Ged Deeble. Modeling groundwater of this aquifer presents some difficulties mainly related to recharge sources. A first reconstruction of the basin shape, of the hydrological structure and of the mechanisms of the aquifer recharge has been obtained after some exploration activities from 2003 to 2007, including a detailed geological survey, a geoelectrical campaign, a series of pumping tests, a monitoring activity prolonged for two years. From the hydrogeological point of view, the basin is subdivided in two sections, separated by an area of low permeability. Aquifer recharge is mainly due to seasonal water infiltration from two wadis flowing across the whole area; moreover additional contributions come from an underground fracture-fault network in the upstream sector, and water flux entering from the LDD basin in the downstream sector. Although a great number of effective and well consolidated codes are available, in order to fully represent complex hydrological conditions, they require a large and rarely available data set. Therefore, an original code YAGMod, developed in FORTRAN90, has been proposed and validated by comparison of the results with Modflow and then has been applied to GD basin. An original approach is also implemented to simulate the possible drying of shallow discrete blocks. With YAGMod it is possible to simulate not only variable sources, like draining systems, but also the interaction of the aquifer with rivers and fractures, with a more general formulation than that used in other software packages, and also the effects that the water head drawdown below the top of the screened interval of a water well can have on discharge. The mathematical model considers a 2D hydraulic flow approximation, pseudo-steady conditions corresponding to the average annual flow, no-flow boundary conditions in correspondence of the crystalline bedrock and Robin boundary conditions at the edge connecting the GD basin with the widespread and thick LDD basin. Different conductance values are used for outflow or inflow Robin boundary conditions, to take into account the effect of the geometry of the two basins. Rainfall recharge has been modeled as fixed source term, and wadi's recharge as a fraction of total rainfall. The model calibration was quite difficult for the large uncertainties on the old data, and therefore a sensitivity analysis has been conducted. Different exploitation scenarios have been examined and the model outcomes show that the GD basin cannot sustainably satisfy the future water demand of the city.