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Modelling the groundwater ecological threshold in water stressed catchments using the MT3D solute transport extension to incorporate isotopic tracers

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In semi-arid regions across the world where rainfall is low, groundwater is a critical resource for sustaining human and ecological life. Along the west coast of South Africa, groundwater is seen as an extremely vulnerable resource and is often impacted by high salinity levels due to low mean annual precipitation, high evaporation rates, variable water rock interaction and both wet and dry deposition of marine salts. Groundwater abstraction for mining and agriculture along the west coast has put further pressure on groundwater reserves and this restricts development possibilities in the poor rural communities of the region as well as threatening the biodiversity of the region. Sustainable management of groundwater in this region requires establishing appropriate groundwater pumping volumes such that both the ecological reserve and human needs are met. This is often done through groundwater modelling of the deeper groundwater system but most models tend to be decoupled from the surface water system. Numerous downscaled climate models for the west coast of South Africa suggest that mean annual precipitation will be markedly reduced whilst potential evaporation will increase resulting in substantially less recharge to the surrounding groundwater system.

The construction of a groundwater model that can be used to determine the sustainability of groundwater abstraction generally requires a dense network of monitoring boreholes. Due to the large cost of these instruments, groundwater models are often not constructed or they are calibrated incorrectly. In this study a groundwater model was constructed to establish the sustainable pumping yield for maintaining the ecological reserve. The model was constructed using MODFLOW and utilising the MT3D extension to incorporate isotope tracers. The ArcHydro package within GIS was used to determine the catchment boundary of the model and formed the no flow zone of the domain. Drains and time variant constant head cells were assigned to rivers and dams within these catchments. Remote sensed data and geological mapping was used to determine the lithological units within the models and hydraulic conductivity values were derived from literature for these different units. Recharge measurements for the region were determined from previous studies with the catchment and static water levels, which form the starting heads within the models were determined using the Bayesian interpolation tool from field measured water levels. A validation site, the Verlorenvlei catchment on the west coast of South Africa, where there was an existing groundwater model constructed using a dense network of instruments and where there was access to a number of isotope tracers, including Sr, O, and H, that could be used to populate the MT3D solute transport extension, was used to test the model. The results indicate that current pumping volumes are above the ecological threshold and that recharge will diminish as a result of changing climate conditions.