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TECHNICAL BRIEF

Groundwater

Historically, the interaction between surface water and groundwater is poorly understood, and even more difficult to quantify. A prototype tool was developed through a WRC research project to quantify groundwater's contribution to baseflow in rivers.

Quantifying Groundwater's Contribution to Baseflow

The need to quantify the groundwater contribution to river flow

Promulgation of the National Water Act (Act 36 of 1998) requires water to be set aside for basic human needs and aquatic ecosystems before allocation to other potential users. During the course of developing tools and methods for quantifying the Ecological Reserve, it emerged that interaction between surface water and groundwater is poorly understood, and even more difficult to quantify.

In other words, there is great uncertainty regarding the relative contributions of groundwater and surface water to river flow. By applying various baseflow separation techniques, it has also become evident that baseflow in some rivers is not equivalent to groundwater discharge into those rivers, and that interflow also plays a contributing role to observed low flows.

By implication, this means that the role of groundwater in sustaining the Reserve (particularly during low flow periods) varies significantly across South Africa. In some instances, the role of groundwater will be substantial and any Reserve determination will require a major input into assessing the groundwater component. In other instances, groundwater's role will be very small, with a concomitantly small geohydrological input into the study.

The availability of tools to assess and quantify the role of groundwater in sustaining the Reserve would greatly facilitate the prioritisation of groundwater-related efforts linked to the daunting task of establishing Resource Directed Measures for South Africa's rivers. In particular, such tools would assist in optimising the allocation of human and financial resources for this purpose.

Developing an appropriate tool

A research project was launched with the aim of developing a prototype tool to be used to identify rivers in South Africa dependent on groundwater for sustaining of baseflow and to quantify the groundwater contribution to baseflow in such rivers.

The first step was to use currently available national scale data to prepare a set of **GIS-based maps** indicating the degree of groundwater contribution to baseflow. A valuable source of such national-scale data has been the dataset generated during a previous study, termed the Groundwater Resource Assessment Phase II (GRAII) project.

A map of the baseflow index of quaternary catchments has provided a first-approximation means of inferring where in South Africa groundwater makes a significant contribution to baseflow. In this context, the probability of groundwater contributing to baseflow is considered low where the baseflow index is less than 0.05, such as in the drier western part of South Africa, and high where the baseflow index is greater than 0.25.

The point of departure for the development of the model to quantify the groundwater contribution to baseflow has been the Pitman hydrological model, as previously modified to be more explicit with regard to groundwater interaction routines. Proceeding from this point, the model has been taken through several further development phases and testing routines. The resulting revised model considers recharge, groundwater discharge to streamflow and abstraction, and is applicable to a wide range of catchment situations. In modifying the model, care has also been taken to restrict additional parameters to the absolute minimum.

Following on this development, the modified Pitman model has been incorporated into the SPATSIM modelling framework to enhance its capabilities as a tool for Ecological Reserve determinations. The SPATSIM software package links spatial data with other types of data (for example parameter tables and time series) and various other hydrological simulation models, and also includes input, output and analysis routines.

Testing the tool

The newly-modified Pitman model, incorporating the new groundwater algorithms, has been widely tested, with the purpose of developing guidelines for parameter estimation and model calibration, as well as assessing the validity of the model outputs across a range of quaternary catchments within South Africa.

Model calibration against the widely-used, existing WR90 simulated monthly time series data, has shown that the revised algorithms, while taking into account groundwater factors, generate results that are intuitively realistic, as well as replicating hydrographs produced using the original Pitman model.

Some problems have been encountered in dolomitic catchments, but these are thought to be the result of the original modelling approach used for these catchments in WR90, and not due to problems with the modified Pitman model as such. Based on the calibration and testing of the revised Pitman model in 17 quaternary catchments, guidelines for estimating the groundwater parameters used in the model have been developed.

Conclusion

The well-known rainfall-runoff Pitman model has been successfully modified to take account of groundwater. Using national scale parameters pertaining to recharge, transmissivity, storativity and slope, the model can now be used to estimate the contribution of groundwater to baseflow.

It can successfully replicate previously-derived hydrographs, at the same time providing intuitively correct assessments of surface water-groundwater interactions. The modified model can also be used to identify those areas in which groundwater plays an important role in sustaining baseflow, thus allowing for the optimisation of the allocation of human and financial resources for Reserve determinations.

Although originally set as an objective, extending the use of the model to ensure that the groundwater contribution to baseflow is not impacted by abstraction, proved to be not possible at this stage. **Since the modified Pitman model operates on a quaternary catchment basis, it is not feasible to apply the model to site-specific conditions.**

Incorporation of the modified Pitman model into the SPATSIM software provides hydrologists with a useful tool to quantify surface-groundwater interaction at a catchment scale. Proper training in the use of the software is required to yield reliable results. It is therefore proposed that training courses be held to obtain the greatest benefit from this research effort.

Further reading:
Quantification of the Groundwater Contribution to Baseflow (**Report No: 1498/1/07**). To order this report contact Publications at Tel: (012) 330-0340; Fax: (012) 331-2565; E-mail: orders@wrc.org.za