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The WRC operates in terms of the Water Research Act (Act 34 of 1971) and its mandate is to support water research and development as well as the building of a sustainable water research capacity in South Africa.

TECHNICAL BRIEF

Groundwater

Groundwater resource assessment

The Water Research Commission (WRC) funded a study into the development of a groundwater resource assessment methodology.

Background

With growing water demand in South Africa we have nearly reached the limits of what surface water from our rivers and dams can supply. Luckily we still have unused reserves of groundwater, and many experts call for more groundwater use and better groundwater management.

However, it can be surprisingly difficult to estimate just how much groundwater can be safely taken from a particular area of 'catchment' without harming the environment and other water users. Rivers rely on groundwater flow from the riverbed or 'baseflow' to sustain them over most of the year – and over-abstraction of groundwater can reduce river flow.

One of the main problems is deciding how much of a river's flow is due to groundwater, and what proportion is due to rainfall and surface run-off. Over the years, scientists have developed ways or 'models' of determining this proportion. The various models all rely on available data about the river systems and groundwater environments that they are studying – data that can be very limited in some areas.

The problem of quantification

Surface water-groundwater interactions take place via different mechanisms on varying scales and are influenced by numerous processes. The complexity of these interactions makes the quantification of the actual volume moving between the two water resources problematic.

There are numerous methods available for the quantification of the amount of groundwater contributing to a river's baseflow, lakes or wetlands as well as methods for quantifying the loss of water from a losing stream.

However, surface water-groundwater interaction is still poorly understood and difficult to quantify due to the inherent heterogeneity of aquifers, variable influencing factors, different time scales of surface water and groundwater, and the fact that groundwater is a hidden resources that cannot be directly measured in most cases.

A new approach

In light of the persisting lack of understanding of surface water-groundwater interactions, the importance of the groundwater contribution to streamflow and the increasing use of groundwater, a new approach to the quantification of this is proposed. Although multiple methods exist for the quantification of the groundwater contribution to streamflow, the addition of the proposed method will be advantageous. The method would be beneficial in terms of using a different dataset comprising water quality data and as part of a multi-method approach, which has been suggested by numerous authors.

The method of quantifying the groundwater contribution to streamflow currently used in the latest Groundwater Resource Assessment (GRA2) of South Africa is based on a water balance approach alone, while the proposed new method combines the water balance with solute mass balances.

The incorporated solute mass balances serve to better constrain the two sets of mass balance equations simultaneously is not a novel idea. The use of the basic principal and the Mixing Cell Model (MCM) are also fairly common, but the use of the MCM to quantify the groundwater component of streamflow is an innovative application.

Mixing Cell Model

The concept of a mixing cell is essentially based on the continuity equation. The one-dimensional continuity equation states the amount of inflow to a system will equate the amount of outflow with no change in storage, for the considered time step.

The MCM builds on this foundation by sub-dividing a system into one or more mixing cells. A water balance equation is expressed for each cell to describe the movement into and out of the cells.

The MCM requires that each of the inflows, present in the water balance equation, are chemically defined by asset of tracer concentrations. This water quality data is then used to describe a chemical mass balance equation for each cell. The chemical mass balance equation serves to constrain the water balance equation in order to produce better estimates of the various unknown inflows to the system, than estimates made from the sole use of a water balance equation.

Pilot study of the MCM

An MCMs programme was successfully applied in the current pilot studies to estimate groundwater baseflow components for the University of the Free State surface water-groundwater interaction test just outside of Bloemfontein on a site-specific scale, quaternaries C52A-C52H on a large scale along the middle Modder River section, to a set of quaternary catchments within the Limpopo Province as well as a quaternary catchment in the Limpopo Province.

Pilot study findings

The application of the MCM in South Africa has both advantages and disadvantages. However, the MCM was found to give more accurate results than the chemical hydrograph separation method applied.

When there is sufficient data for a MCM run, the MCM groundwater baseflow volume tends to be in-between the Sami and Hughes model estimates.

Considering that the Sami model was found to under-estimate the groundwater baseflow and the Hughes model to over-estimate, the MCM is a good indication of the amount of groundwater contributing to a river.

The natural environment can hardly be described by linear, homogeneous expressions or with the assumption of conservative behaviour of solutes, especially in the geochemically very active hyporheic zone separating surface and groundwater. While the model allows for a partial compensation of such violations, the infringement of assuming conservative tracers is still likely to result in errors.

A certain level of inaccuracy must thus be accepted in the quantification of natural phenomena such as the groundwater contribution to baseflow using the mixing cell or other methods. Similarly, data paucity and ungauged catchments limit the applicability of baseflow estimation models based on empirical data in large parts of the country.

Recommendations

The MCM is recommended as an additional tool used to quantify the groundwater baseflow volume in South Africa, and the following scenarios are suggested: validation, low confidence groundwater baseflow areas, physical-parameter data scarce and complex geology areas, ungauged quaternary catchments, site-specific scale and in a multiple method approach.

Further review and improvement of methodologies applied for the GRA2 project are recommended for the sections: quantification, planning potential map, recharge, aquifer classification and groundwater use.

Better primary data is needed in the following areas: existing groundwater use in South Africa (actual quantities), groundwater quality variations, both natural and anthropogenic, groundwater levels, including relationship to geology and topography, rainfall (both volumes and intensity), and rainwater quality, and river/stream flows.

Recommendations on groundwater information collection and accuracy in South Africa have been incorporated as policy recommendations:

- Finalisation and expansion of the National Groundwater Archive
- Registration of drillers and capturing of drillers' groundwater data
- Support water services institutions in the development and implementation of asset registers on groundwater infrastructure, monitoring of groundwater use, and groundwater quality
- Engage with relevant authorities to maintain hydrological and environmental monitoring programmes necessary for groundwater management.

Re-assess the funding required by Department of Water Affairs head- and regional offices for groundwater monitoring, data capture as well as the operation and maintenance of groundwater infrastructure.

Further reading:
To order the report, *Development of a groundwater resource assessment methodology for South Africa: Towards a holistic approach* (**Report No. 2048/1/13**) contact Publications at Tel: (012) 330-0340, Email: orders@wrc.org.za or Visit: www.wrc.org.za to download a free copy.