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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

Reducing uncertainties in the estimation of groundwater recharge

A WRC-funded study investigated linkages between rainfall, evapotranspiration and recharge in order to describe some possible scenarios of impacts of abstraction and climate change on South Africa's groundwater resources.

Groundwater resources

The quantification of groundwater resources is of utmost importance for future water allocations and management. Groundwater is stored in aquifers that include a static zone (permeable portion of the aquifer below the zone of natural groundwater level fluctuation) with a dynamic zone (volume of groundwater available in the zone of natural groundwater level fluctuation, above the static zone).

The key variable of the dynamic storage zone that determines natural groundwater replenishment and water table fluctuations is groundwater recharge. Several methods for the estimation of groundwater recharge were applied in the past. Results of applications of these methods showed that groundwater recharge estimates varied widely depending on methods and data used.

It is widely acknowledged that groundwater recharge estimates can be improved through improved estimation of evapotranspiration (ET) and preferential flow. Uncertainties exist in the estimation of ET that would account for below-potential water use by vegetation as well as preferential flow paths of water and contaminants.

Soil water fluxes determining groundwater recharge are also the main drivers of solute and contaminant transport by convection. In that sense, it is inevitable that processes like ET and preferential flow are also relevant to groundwater quality and the protection of groundwater resources.

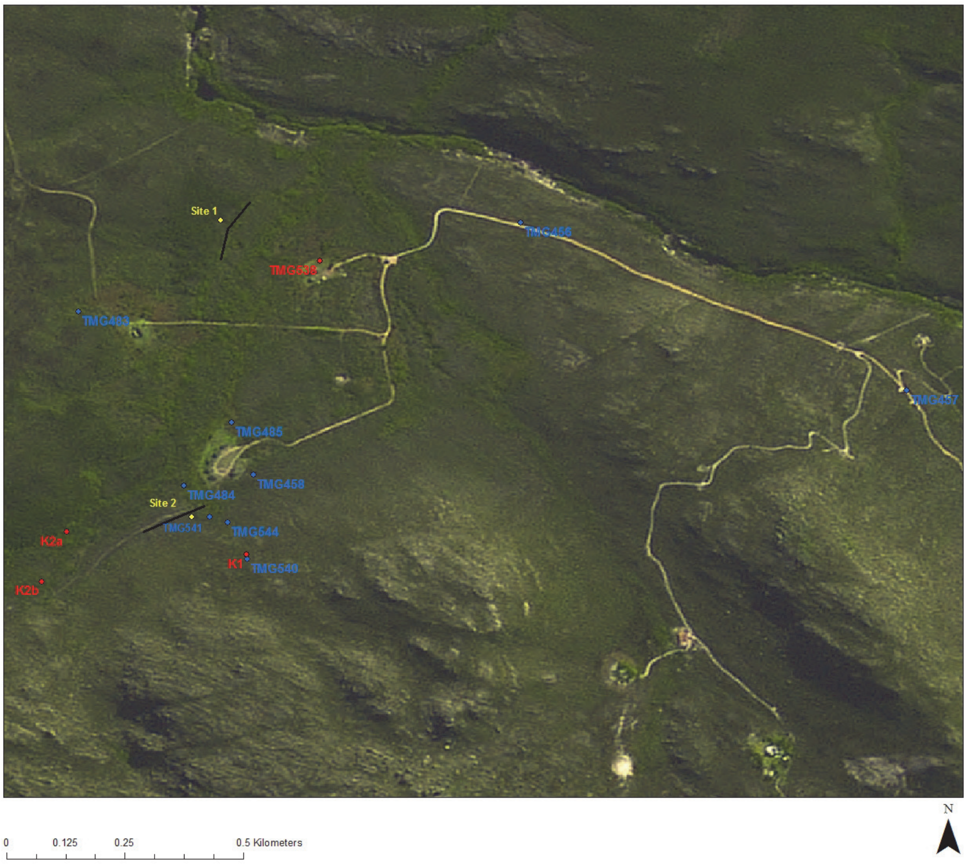
Previous research and statistical analyses of historic climatic data indicated that South Africa may be impacted severely by climate change. Little work was done, however, on the impact of climate change on groundwater resources. It is therefore necessary to investigate linkages between rainfall, ET and recharge in order to describe some possible scenarios of impacts of abstraction and climate change on groundwater resources.

Identifying knowledge gaps

Existing knowledge gaps identified in previous research included improved methodologies for the estimation of recharge were proposed; the use of hydrological models verified with field data to predict the effects of weather, vegetation, soil and geology on groundwater recharge; measurement of evapotranspiration of natural vegetation, in particular Sand Plain Fynbos and Sandstone Fynbos; estimation/measurement of preferential flows in the soil and vadose zone. Accounting for ET and preferential flow in the estimation of the water balance and groundwater recharge provides means for more informed decisions on groundwater resources assessment and management.

Improved process-based estimates of groundwater recharge

The general objective of this project was to develop improved process-based estimates of groundwater recharge. It was the first time that ET of these two types of endemic fynbos vegetation was measured and were chosen to be at season change in spring and autumn, at a time when both sunny days with high atmospheric evaporative demand and overcast days with low evapotranspiration can be expected.



QuickBird view of the Oudebosch catchment in the Kogelberg Biosphere Reserve and monitoring points. Blue: Groundwater boreholes; Red: Piezometers and weather station (TMG538); Yellow: Soil water sensors; Black: Resistivity measurement transects.

Two typified groundwater recharge mechanisms

The study sites field trials were set up to monitor all components of the hydrological system, namely weather, vegetation, soil, surface water and groundwater by using two recharge mechanisms:

- The first recharge mechanism at the study site Riverlands Nature Reserve (Western Cape) is through vertical fluxes (diffuse). This mechanism occurs typically in coastal plain sandy aquifers, on light-textured soils and shallow groundwater tables fluctuating seasonally.
- The second recharge mechanism occurs typically on undulating terrain on hillslopes, overlaying shale layers and/or fractured aquifers. A study site representing the Table Mountain Group (TMG) fractured rock aquifer was selected in the Oudebosch catchment in the Kogelberg Biosphere Reserve (Western Cape).

Preferential flow studies

Results emanating from the preferential flow studies were also used to spatially delineate soil characteristics, to generate input data and set up hydrological models and improve estimates of groundwater recharge. Less variability in the hydraulic properties of Riverlands soils was evident compared to Kogelberg.

Conceptualisation of catchment hydrology

It was demonstrated that the application of remote sensing techniques, GIS and soil surveying methods can facilitate the spatial conceptualisation of catchment hydrology, delineate soils based on surface features and terrain morphology and reduce the number of field observations required to conduct a comprehensive soil survey. A binary decision tree was developed that can aid in interpolating hydrological properties in unsampled observation sites.

Long-term monitoring benefit model calibration

The continuous long-term monitoring of weather, soil water content, vegetation and groundwater was very beneficial in terms of model calibration. Both process models used in the case studies were successful in predicting water balance components (both absolute values and temporal trends). In particular, HYDRUS-2D predicted well seasonal variations in soil water content at Riverlands, whilst MODFLOW was calibrated for two localised areas where conceptual knowledge of the system existed.

Models

Daily simulations of groundwater recharge were done with the RIB model for boreholes that displayed distinct seasonal groundwater level fluctuations. The model proved to be useful for quick estimates of groundwater recharge at locations where groundwater levels respond distinctly to rainfall. The values of groundwater recharge obtained with three selected methods (HYDRUS-2D, MODFLOW and RIB) were within the range of those obtained in other studies.

Scenario simulations with the RIB model allowed to quantify possible impacts of abstraction and climate change (reduction in rainfall) on the groundwater resource. The selection of boreholes to be used for calibration is fundamental as the measurements need to be representative of the entire area.

Uncertainty analysis

Uncertainty in the estimation of groundwater recharge has implications not only on the recharge estimation, but also on management decision-making and risk associated with the groundwater resource. The uncertainty of the estimates of groundwater recharge depends on the accuracy of measured input data into the model (e.g. scintillometer measurements, weather instrumentation, etc.) and variability in environmental factors (rainfall, groundwater levels, vegetation, hydraulic properties, etc.). The technique used in the uncertainty analysis showed that the error propagation method can be useful for analysing the influence of input data on the simulated groundwater recharge.

Implications

- *Data collection and* continuous and long-term (at least five years) ***monitoring*** is a pre-requisite in order to gain understanding of natural systems and predict catchment processes accurately.
- *Tools for spatial description* of environmental variables (e.g. vegetation, soil properties, etc.) need to be refined and made available.
- *Remote sensing tools and products* are becoming more and more popular in the estimation of water cycle variables of relevance to groundwater recharge and need to be validated and investigated.
- *Geophysical methods* (e.g. resistivity tomography) showed potential in defining preferential pathways for water in the sub-soil and should be investigated. However, the applicability is specific to a site and depend on salinity and geological characteristics.
- The *quantification of uncertainties* in catchment hydrology needs to be investigated further given the large number of tools and methods available. Long-term monitoring data are required for this purpose.

Further reading:
To obtain the report *Reducing Uncertainties of Evapotranspiration and Preferential Flow in the Estimation of Groundwater Recharge* **(Report: 1909/1/12)** contact Publications at Tel: (012) 330-0340; Fax: (012) 331-2565; Email: orders@wrc.org.za or Visit: www.wrc.org.za to download a free copy.