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Estimation of baseflow and water transfer in karst catchments in Mediterranean Turkey by nonlinear recession analysis

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SUMMARY

Because of water transfers through fissures, cavities, caves and phreatic channels of various sizes and unknown directions, the topographic watersheds of karst catchments have little significance for their aquifers. Most of the flow in the Manavgat River in South Anatolia has its origin outside of the surface watershed and is transferred through karst pathways. Previous investigations found evidence for this by groundwater tracing techniques. In this study, flow recession analysis and baseflow separation are applied to the time series of daily flows 1992–2008 from three gauging stations. Flow recessions were found corresponding to the nonlinear storage-baseflow relationship $S = a \cdot Q^b$, with b values around 0.5 as typical for unconfined groundwater, while the coefficient a showed marked seasonal variations with higher values in the rainy winter time and decreasing values towards the dry summer. For catchments which receive water transfers from other areas, the decrease of a is retarded. Flow recession is slower since more water is available. Baseflow separation by using the same nonlinear model revealed that direct flow, which is mainly surface flow, corresponds roughly to the surface catchments while baseflow, which accounts for most of the total flow, is highly influenced by transfers from karst sink areas outside the surface watersheds. The subsurface transfer was simulated by a nonlinear reservoir routing algorithm. Time series of monthly baseflow from catchments which receive transfer water were compared with those of sinkhole (loss) areas. The procedure allows inferring the origin area of the inflows and estimating the retention or lag time of the transfer.

1. Introduction

With their complex and unique characteristics, karst aquifers are very different from other aquifers (Bakalowicz, 2005). Physical and chemical processes together with tectonic movements in limestone, dolomite and other soluble rocks have formed well-linked fissure systems in karst massifs, with dimensions varying from micrometers to several meters (Bonacci, 1993). Water is stored and circulates through the cavities, also crossing topographic watersheds, which therefore have little significance for karst aquifers. Surface water, infiltrated into the karst aquifer by means of sinkholes or sinkhole areas (poljes), feeds springs of considerable discharge at other places. Examples include the Ombla Spring in Croatia with a mean discharge of 22 m^3/s (Bonacci, 1995), the Timavo Spring in Italy with 17.4 m^3/s and the Ljubljanica Spring in Slovenia with 39 m^3/s (Milanovic, 2004). Almost one third of Turkey's surface area is covered by karstified limestone (Benzeden et al., 1993) and karst storage constitutes one third of the water potential of Turkey (Baran et al., 1987). The Mediterranean Region is the largest karst area in Turkey. Because of their huge water volumes and circulation, karst aquifers have become increasingly important for water supply and hydropower generation.

The Dumanlı Spring in the Mediterranean Region of Turkey, today submerged by the Oymapınar Reservoir, is the biggest karst spring in the world, with discharges between 36 and 100 m^3/s (Eroskay et al., 1986), which represents about one third of the annual flows in the Manavgat River. Karanjac and Altug (1980) analyzed spring recession hydrographs by using the classical exponential equation of the linear reservoir and evaluated water temperatures in order to formulate hypotheses for the recharge areas and the hydraulic system of the springs. Günay (1986) applied groundwater tracer techniques to show evidence of interbasinal hydrogeological water transfer to the Manavgat River.

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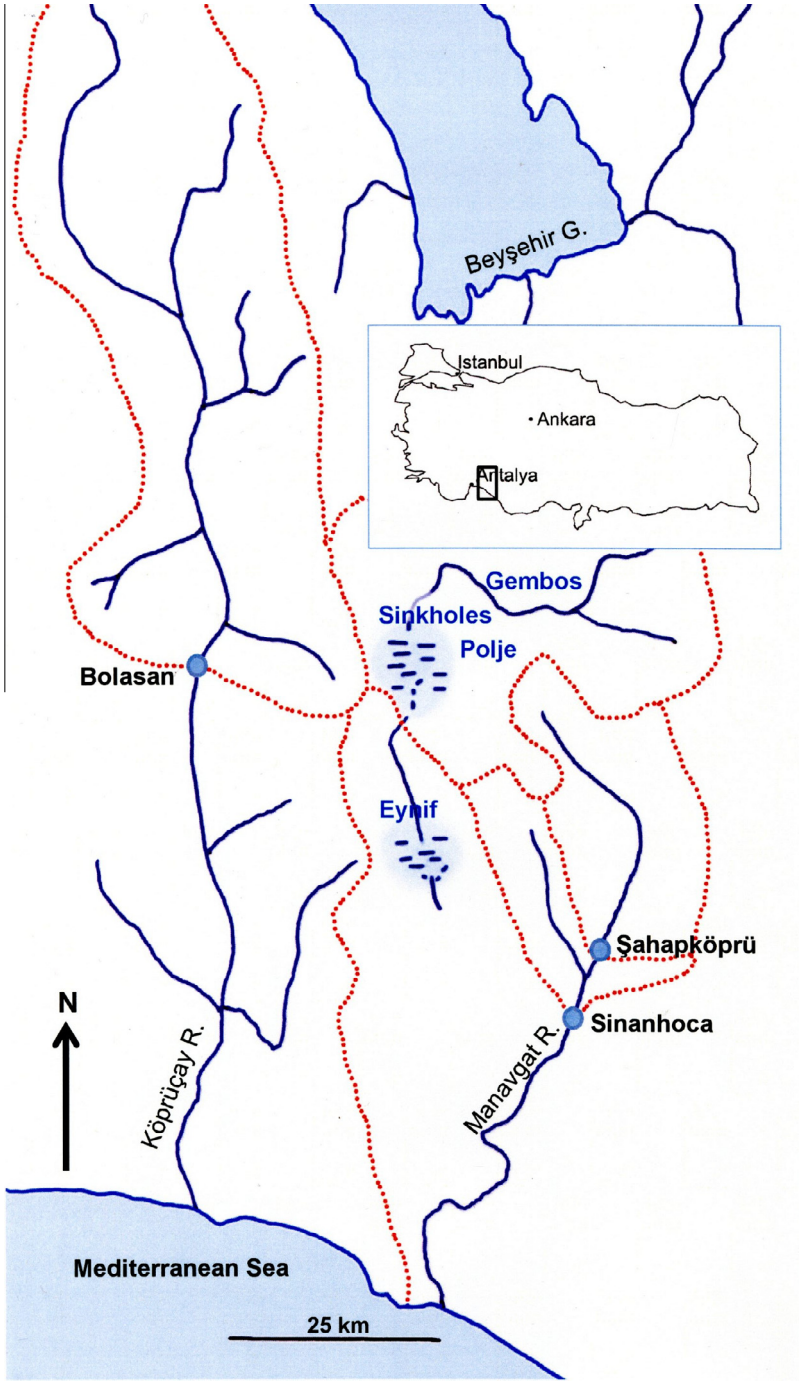

Fig. 1. Study area with watersheds and flow gauging stations, based on State Hydraulic Works (DSİ) station map.

Yurtsever and Payne (1985) modelled the nonlinear reservoir characteristic of the aquifer by three parallel linear reservoirs and analyzed environmental tritium contents for the Manavgat River at downstream Oymapınar gauging station. The first application of the nonlinear model was undertaken by Koç (2008). A seasonal variation of recession parameters was not considered.

In this study, in a first step, flow recession analysis is applied to determine aquifer characteristics. Since karst aquifers are predominantly unconfined, nonlinear reservoir recession was expected. Based on these recession parameters, in a second step, baseflow, hence karst outflow was separated from the time series of daily total flows.

2. Study area and data

This study focuses on the upper Manavgat River flowing from the Taurus Mountains to the Mediterranean Sea east of Antalya. The region has cool, rainy winters and hot, dry summers. Annual mean temperatures vary, depending on altitude, from 2 °C to 28 °C with an average of about 15 °C. Snowfall is infrequent and occurs only in higher altitudes.

Besides the gauging station of Sinanhoca at the Manavgat River, two other stations in the study region were selected, Şahapköprü, upstream of Sinanhoca, and Bolasan, on the neighboring Köprüçay River. Time series of daily flows are available for the common time