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Relationship between groundwater discharge and catchment area in considering small-scale variability

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In forested catchments, most of the rainfall infiltrates into the ground, is influenced by evapotranspiration, passes through various pathways, is stored in soil and bedrock layers, and finally discharges to streams. The flow pathways and locations of storage sites regulate the chemical evolution of groundwater. Therefore, to predict stream water discharge and chemistry in forested catchments, it is necessary to acquire a sufficient understanding of the groundwater dynamics. Many studies, including model calculations and empirical research, have targeted the relationships between groundwater dynamics and catchment area. Most of these studies indicted increases in both groundwater discharge and the contribution of deeper groundwater with catchment area. However, few studies have considered the spatial variability of groundwater discharge among small catchments. In addition, there have been few studies with multiple observations of water discharge and chemistry. Therefore, it remains unclear how the relationships between groundwater and catchment area differ among groundwaters with different flow pathways and whether there is a disconnection of groundwater discharge processes between small and large catchments. Inokawa catchment (5.07 km^2), with bedrock consisting of Neogene age sedimentary rock, was examined. Stream water discharge and chemistry were observed at multiple points, and soil water and groundwater chemistry were observed in a hillslope (0.01 km^2). Using end-member mixing analysis (EMMA), stream water was separated into a shallow groundwater component, which mainly passes through and is stored in the soil layer, and a deep groundwater component, which mainly passes through and is stored in the bedrock layer. The deep groundwater was further divided into three types, $CaHCO_3$, $NaHCO_3$, and NaCl types, based on the chemical characteristics. The relationships between groundwater discharge and catchment area were then examined. Shallow groundwater discharge decreased with catchment area, while deep groundwater discharge increased with catchment area. In addition, the contributions of $NaHCO_3$ type and NaCl type groundwater, which were thought to pass through deeper bedrock than $CaHCO_3$ type groundwater, increased largely with catchment area. Both shallow groundwater discharge and all types of deep groundwater discharge showed large variability in small catchments ($<$0.1 km^2). The observed values in larger catchments were all within the range of observed values in small catchments. The results indicated that a disconnection of groundwater discharge processes did not occur at this site. However, the $NaHCO_3$ and NaCl types of groundwater were observed at fewer sampling points than $CaHCO_3$ type groundwater. Therefore, if deeper groundwater pathways become dominant, the disconnection of groundwater discharge processes between small and large catchments would be expected to become more obvious.

Keywords: groundwater discharge, catchment area, water chemistry, EMMA, scaling