Geophysical Research Abstracts
Vol. 17, EGU2015-3439-2, 2015
EGU General Assembly 2015

Generalized function of the parameters in the storage-discharge relation for low flows

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The accurate estimation of low flows can contribute to better water resource management and more reliable evaluation of the impact of climate change on water resources. For the case of low flows, the nonlinearity of the discharge Q associated with the storage S was originally proposed by Horton (1936) as the power function $Q=KS^N$, where K is a constant and N is the exponent. Although the $Q(S)$ relations for groundwater runoff from unconfined aquifers have been treated as second-order polynomial functions on the basis of the hydraulic investigation by Ding (1966), the general power function $Q = K^N S^N$ was introduced into the unit hydrograph model for overland flow and the parameters K and N were calibrated by Ding (2011). According to recent studies, the value of the exponent N is varied between 1 and 3 or higher by calibration (e.g., Wittenberg, 1994 and Ding, 2011); however, it is currently unclear whether the optimum value of N has the rule.

Fujimura *et al.* (2014) applied the general power function $Q = K^N S^N$ for low flows in mountainous basins over a period spanning more than 10 years using hourly data, and carried out sensitivity analysis using a hydrological model for 19 900 sets of the two parameters K and N, in which the exponent N was varied between 1 and 100 in steps of 0.5. The results showed that the optimum relation between N and K could be characterized by the exponential function $K=1/(\alpha N^\beta)$, where α and β are constants. Moreover, the lowest error in the sensitivity analysis was obtained by using an exponent N of 100.

The aim of this study is to extend the previous study of Fujimura *et al.* to clarify the properties of the $K(N)$ relations. A sensitivity analysis is performed efficiently using a hydrological model, in which the exponent N is varied between 1 and 100 000 along the neighborhood of the exponential function $K=1/(\alpha N^\beta)$. The hourly hydrological model used in this study comprises the Diskin-Nazimov infiltration model, groundwater recharge and groundwater runoff calculations, and a direct runoff component. The study basins are four mountainous basins in Japan with different climate and geology: the Sameura Dam basin (472km^2) and the Seto River basin (53.7km^2) within the Sameura Dam basin, which are located in western Japan and have variable of rainfall, and the Shirakawa Dam basin (206km^2) and the Sagae Dam basin (233km^2), which are located in a region of heavy snowfall in eastern Japan. The period of available hourly data for the former two basins is 20 years from 1 January 1991 to 31 December 2010, and the period for the latter two basins is 11 years and 12 years from 1 October 2003 to 30 September 2014. The analysis is evaluated using the average of daily runoff relative error (ADRE). The plot of log$K$ against log$N$ with the lowest ADRE yields a straight line, $K=1/(\alpha N^\beta)$, in which the value of β is 1.0 and the correlation coefficient of the line is 1.0 for N values in the range from 100 to 100 000. We can conveniently assume the $K(N)$ relation to be $K=1/(100\alpha)$ when N =100. Therefore, the $Q(S)$ relation can be converted to $Q=\{S/(100\alpha)\}^{100}$, where only one parameter, α, is used.

References

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