Continuous baseflow separation from time series of daily and monthly streamflow data

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Abstract

Continuous baseflow separation procedures have been frequently used to differentiate total flows into the high-frequency, low-amplitude 'baseflow' component and the low-frequency, high-amplitude 'flood' flows. In the past, such procedures have normally been applied to streamflow time-series data with time steps of 1 day or less. However, there are applications in South Africa (notably related to setting instream flow requirements) where the only available data for natural flow conditions are monthly flow volumes. A relatively experienced hydrologist can be expected to successfully calibrate a separation model using daily data, coupled with a conceptual understanding of the hydrological processes prevailing in the catchment. The same cannot be said for monthly data, as the majority of the information on short-term flow variability has been lost. As part of a regional study covering the whole of South Africa, this paper presents some example results of comparisons between daily and monthly separations. While it can be concluded that it is possible to determine regionalised parameters for monthly data separations that are useful, further information on the processes involved would be of great value to validate the methods and parameter values. This information could also form the basis for the further development of baseflow separation methods for South African flow regimes.

Introduction

From a hydrological process point of view, baseflow is considered to be that component of the total flow hydrograph that is derived from runoff processes that operate relatively slowly. Thus many of the traditional hydrograph separation approaches have focused on trying to distinguish between rapidly occurring surface runoff, slower moving interflow and even slower discharge from groundwater (Freeze, 1972). However, the conceptual basis for such distinctions can only really apply in small catchments where differential travel times, due to distance from the catchment outlet, play a minor role. In larger catchments the situation is far more complex and hydrograph shapes can be affected by a multitude of processes, some dominated by topography, others by subsurface (soils and geology) characteristics and others by spatial variations in rainfall inputs.

Further complexity is added when runoff processes are considered in more detail. A number of field studies have demonstrated that subsurface runoff processes in some catchments can operate at quite rapid rates (Ward, 1984; Putty and Prasad, 2000), while surface runoff on hillslopes may be re-infiltrated further downslope. It soon becomes apparent that, apart from a very few experimental catchments which are comprehensively instrumented, it is extremely difficult to determine what component of the total flow hydrograph can be considered as baseflow. Chemical and isotope tracing studies (Marc et al., 2001), as well as simulation modelling (Haberlandt et al., 2001) offer alternative methods for process-based hydrograph separations, however, they all require extensive time and manpower resources.

Smakhtin and Watkins (1997) and Smakhtin (2001) outline a useful separation approach that was originally reported by Nathan and McMahon (1990). Although this approach does not take any account of the source of the two separated flow components it is useful in that it separates total flows into the high-frequency, low-amplitude 'baseflow' component and the low-frequency, high-amplitude 'flood' flows. This distinction can be of great importance in some applications and specifically in the determination of the quantity component of instream flow requirements. The identification of instream flow requirements of rivers is part of the current water resource legislation for South Africa and forms part of the ecological reserve.

The ecological reserve for rivers is frequently determined using the 'Building Block Methodology' (BBM- King and Louw, 1998), which attempts to divide the instream flow requirements of rivers into four main blocks. The process is based on the use of expert opinion and involves several different ecological specialists (focusing on riparian vegetation, fish, invertebrates and geomorphology) identifying the water requirements of the river. The four blocks are the seasonal distributions of drought and maintenance low flows, and drought and maintenance high flows. Drought conditions are considered as the minimum flows that should occur, while the maintenance flows are those that are expected to occur under 'normal' conditions. The frequency with which normal conditions can be expected in a specific catchment will depend upon the magnitude-frequency characteristics of the natural flow regime (Hughes, 1999). Hughes (2001) outlines some of the hydrological procedures that are used to support the determination process and refers to the need for information on the natural flow regime characteristics, so that the flow requirements determined by the specialists can be evaluated. One of the requirements of the hydrological procedures is the ability to determine the seasonal distribution of natural low flows, as well as the likely frequency of occurrence of different size baseflows in individual calendar months. Frequently this information is required when the only source of natural flow data is time series of simulated monthly flow volumes.

This paper is designed to build on the work reported in Smakhtin (2001), critically evaluate the continuous baseflow separation approach as used with monthly data and to ultimately

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