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Hydrology and Earth System Sciences Discussions

Interactive comment on "Comparison of different base flow separation methods in a lowland catchment" *by* A. L. Gonzales et al.

A. L. Gonzales et al.

arpadgon@hotmail.com

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We highly appreciate the comments from the three reviewers: Referee # 1 (anonymous), Mr. Aksoy and Referee # 2 (anonymous). This will improve the quality of the final manuscript. Hereby our responses to the general issues raised by the reviewers: i) We will add a more general discussion on which method to use to separate baseflow (Referee # 1), ii) We will improve the technical writing and let the manuscript be checked by a native speaker (Referee # 1 and Referee # 2), iii) We will consider the suggested additions to the literature part of the paper (Mr. Askoy), and iv) We will consider separating discussion from conclusions (Referee # 2). Following, we would like to reply to the major comments individually. We will incorporate all minor comments in

the revised manuscript. Referee # 1: The manuscript by Gonzales et al.: "Comparison of different base ïňĆow separation methods in a lowland catchment" compares several tracer based two-component separations as well as a three-component separation on the one hand with several different non-tracer based separation techniques on the other hand. It is of special interest in that it shows the uncertainties or range/variability of results associated with both approaches. As the choice of non-tracer based separation method strongly inïňĆuences the result (making results obtained with different methods, i.e. in different studies, very difïňĄcult to compare), a general recommendation as to which method to choose or how to choose would be very helpful. In this study, the tracer based separation (even though it was only carried out for three events) aided in choosing the most appropriate non-tracer based separation technique which was then applied over a longer time series. The discussion on this will be extended in the revised paper. Among the non-tracer based methods discussed in the study two alternatives are recommended: 1) to use the rating curve method (Sellinger, 1996; Kliner and Knezek, 1974) when a representative set of observation wells are available, or 2) to calibrate the Eckhardt's filtering method (Eckhardt, 2005) using tracer observations that could be carried out for a couple of events. Choice of the method is dependent on data availability and local circumstances. Referee # 1: In the abstract the authors remark that none of the many baseïňĆow separation methods focuses on lowlands. As a consequence, I was expecting something like a discussion of the advantages and disadvantages of the many different methods that were applied in this study, especially concerning their applicability in lowland areas. Which of the methods might be useful in mountainous areas but not in lowlands? This could be discussed in more detail. Can you give a general recommendation in that for lowland areas generally those non-tracer based separation methods should be applied which allow for a highly dynamic baseïňĆow response during events? Is it recommended to always carry out at least a two-component tracer based baseïňĆow separation (how many events are needed?) in order to choose the best non-tracer based separation technique? Is it likely that this chosen separation technique might vary depending on season? (One method might be closer to the tracer results during the dry months, another during the wet season?) I can understand that you currently do not have the data to answer this question conclusively, however, you still might be able to say something about it in the discussion section. See previous response. The simple graphical (Linsley et al., 1975) and the local minimum hysep 3 (Sloto and Crouse, 1996) methods might be useful in mountainous areas when the base flow is approximately constant during a runoff event. However, they do not give good results in lowland areas (and might also not in mountainous areas) where groundwater shows a dynamic response during runoff generation. Eckhardt's method calibrated with tracer observations may perform well in any situation because the calibration process introduces information about the catchment's behavior in the method. The rating curve method synthesizes the base flow behavior from the dynamics of the groundwater table. Therefore, it may also perform well in any situation, except if the groundwater observations are influenced by the surface water dynamics, e.g. when using observation wells too close to the river channel. Performing a tracer-based base flow separation is always useful, and can reveal an unexpected behavior of the catchment. The number of components to separate depends on the physical and chemical characteristics of the catchment. Therefore, a two component separation is not always possible i.e. if there are more than two end members (with different signatures), two-component separation will yield unrealistic results, including for instance negative flows. Thus, the number of end members should be determined prior to separation. If the rating curve method is selected for base flow separation, the groundwater dynamics may automatically take into account the seasonal behavior changes. If Eckhardt's method is used, calibration might be needed for different seasons. Referee # 1: (page 3489 l.25-28) why were especially these methods chosen? All of these methods represent a different approach to base flow separation. Methods i and ii are classical methods frequently used in engineering applications. Method iii is a new recursive filtering method that improves its predecessors (see Eckhardt, 2005 for more details). Method iv is an alternative approach that reconstructs the base flow hydrograph raising limb with information of the recession limb. Method v takes advan-

tage of the intrinsic relation between groundwater levels and base flow. Referee # 1: (page 3499 l.16) Is there a spatial trend or pattern in the dissolved silica concentrations in groundwater? Could it be that during events areas with higher concentrations contribute which cancel out the low conc. of surface runoff? The spatial trend in the dissolved silica concentrations was not studied. Actually, dissolved silica in groundwater was only observed at the experimental field, where variations from 5.0 to 15.0 mg/l were observed. Nevertheless, spatial variation is overcome by observing dissolved silica concentration at the outlet of the catchment during low flow periods. It is not possible that groundwater contributions from areas with higher concentrations cancel out low concentrations of surface runoff. On the contrary, it is the difference between concentrations what makes it possible to separate the components. Referee # 1: (page 3500 l.9-11) what is the range in concentrations in the deep groundwater wells? how do you know that the shallow groundwater is not contributing to ïňĆow during recession periods? Deuterium was analyzed for only one deep groundwater sample (-48.2‰ at OWCanal, the observation well positioned right beneath the canal. Magnesium in groundwater samples varied from 6.3 to 16.4 mg/l. It is assumed that a reasonable time after the precipitation event, shallow groundwater contribution to stream flow is null or negligible. Referee # 1: (Page 3500 l.20-22) surface runoff was a discharge component even some days after the rain event- so how can you assume that you only have deep groundwater contribution during recession periods? Some surface runoff can still be found a few days after an event, but then the base flow period is dominated by deep groundwater. Clarification on the use of the unit hydrograph baseflow separation method (Su, 1995) Figure 1 (below) shows how the separation in this study was carried out exactly. The figure shows several responses that can be isolated from the measured hydrograph at the outlet of the catchment. (1) is a slow, probably smoothed reaction. For instance, it could be the reaction of deep groundwater to a seasonal impulse like rain during the previous summer. (2) is a reaction to an event prior to the research period, from which only the last part of the recession limb can be seen. (3), (4), (5) and (6) can be interpreted as groundwater reactions to specific rain events.

Finally, (7) may be another slow reaction. More reactions can be identified in the same way until the complete hydrograph is approximately reproduced and even the surface runoff components are identified. For the purposes of this research, it is assumed that the groundwater components are identified, and the remaining discharge corresponds to surface runoff, agreeing approximately with the results of other methods like e.g. the local minimums method. Referee # 1: I would be interested to know more about the chemistry of the inïňĆow to the study area at the inlets. Do you also ïňĄnd some sort of dynamics here which are not due to runoff processes as they are found in the study area? Only one inflow water sample was taken during the study. Therefore its dynamics are unknown. However, it is expected that the dynamics are similar to the dynamics at the main stream gauge. The inflow discharges are low compared to the flow at the main outlet of the catchment which makes it possible to assume that the influence of the inlet chemistry is negligible. Referee # 1: In what way does the management of the weirs and inlets inïňĆuence the response at the main stream gauge? Inlet inflows during winter (research period) are small or even zero and their influence on the response at the main gauge are negligible. On the contrary, weir management during floods reduce the flow at the main gauge by diverting water to other canals (catchments). This is done to maintain water tables within desired intervals and to prevent flooding. The baseflow and surface runoff ratio of diverted water was not determined. Clarification on sampling and measuring intervals. Water levels were registered automatically every 15 minutes. Water samples at the outlet of the catchment were taken every 4 hours during and short after a precipitation event, and every 8 hours during the recession period. Switching from 4 to 8 hours was decided based on the difference in electrical conductivity from one sample to another.

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Please also note the Supplement to this comment.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 6, 3483, 2009.

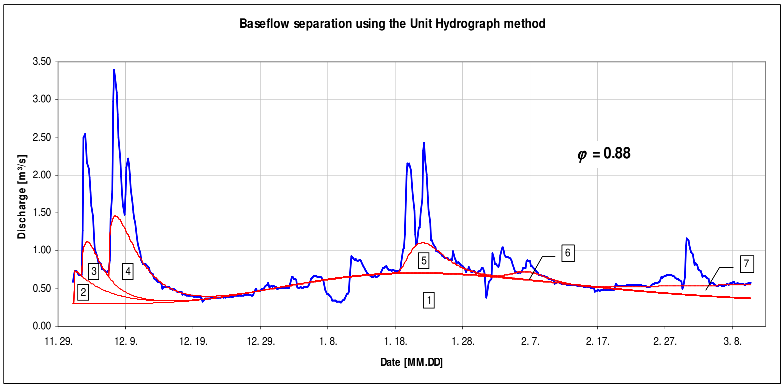

Fig. 1. Baseflow separation using the unit hydrograph method (Su, 1995).