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Hydrology and Earth System Sciences
Discussions

Interactive comment on "Hydrogeology of an alpine rockfall aquifer system and its role in flood attenuation and maintaining baseflow" *by* U. Lauber et al.

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Reply to comments of an anonymous referee on the manuscript "Hydrogeology of an alpine rockfall aquifer system and its role in flood attenuation and maintaining baseflow" by U. Lauber et al.

Summary of the reviewer: The paper reports on an interesting study. The presentation of related work and its comparison with the results of the study should be expanded.

Reply: We thank the anonymous reviewer for her/his very useful and valuable comments that will contribute to improve the manuscript. Most of the referees' remarks will

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be taken into account. According to her/his comments, we will perform the following changes:

General comments:

1) At the end of chapter one I missed a short review of related literature (Alpine aquifers) leading to open questions which might be answered in the paper and thus tying the general ideas at the beginning of the chapter to the concrete goals presented in the last paragraph of the chapter.

Reply: We will expand the literature review and add an overview of Alpine aquifers with a special focus on Alpine alluvial/rockfall aquifers. We will also modify and extend the text in order to clarify the relation between the general research background and the concrete goals of this study.

2) There are different definitions of the term discharge response: p. 6807 L. 27: discharge response = ratio between direct discharge and precipitation intensity (Onda et al. 2006, Zillgens et al. 2007) p. 6814 L. 13: "The discharge response is calculated by dividing the amount of direct discharge (QP-QI) by the precipitation intensity (Ppeak), a unit conversion factor and the catchment area (A) (Blume et al. 2007)". p. 6829, Tab. 2: "discharge response: ratio between direct discharge (QP-QI) and precipitation (Ppeak*A)" In Tab. 2 peak rainfall is given in mm (with the comment: "note that the maximum resolution of sum of precipitation is 6 h), which might be called maximum precipitation intensity (mm/6h). Thus the definition at p. 6807 L. 27 should be adapted (maximum precipitation intensity). Direct discharge is a well-known term und describes the difference of event discharge and base flow, summed up over time, resulting in a volume [m^3]. I recommend to use another word for the difference of initial discharge [m^3/s] and peak discharge [m^3/s] in order to avoid misunderstandings. The unit conversion factor is mentioned only once. Catchment area misses in the first definition. I could not find any explanations in the cited literature (searching for the term discharge response). I would recommend to harmonize the definition of discharge response at

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all parts of the paper.

Reply: The reviewer's remarks are reasonable. We will clearly define the term "discharge response" and use it consistently throughout the revised paper.

3) It would be interesting to get some distinct information on the grain sizes of the investigated aquifer. Of course, the description (e.g. coarse grained delta sediments, fine limnic sediments) gives a good impression of the composition of the sediments, and of course rockfall and alluvial sediments are very heterogeneous, thus it is difficult to give information on the percentages of gravel, sand, silt and clay of the two rockfall and the two alluvial aquifers. However, concrete numbers could help to compare the results of this study with others.

Reply: Several geomorphologic studies have been conducted in the area, but no study has investigated the grain size distribution quantitatively. Small drillings, conducted in the alluvial deposits, describe the structure and composition of the sediments qualitatively (Niederheide 2003). The rockfall deposits comprise very large blocks (> 100 m3) that do not allow any sampling or measurements.

4) Data from 2002-2011 are available (chapter 3.2). Though obviously incomplete (p. 6814, first paragraph), it would be interesting to get mean values for the whole measurement period, for example to get to know, if the conditions described for 2006 (begin of snowmelt in April, characteristic discharge maximum of about 7 m^3/s) represent mean values or outliers within the time period 2002 - 2011. It is well argued why hydrographs from 2006 and 2011 were chosen. Nevertheless a view to the data of 2005 would be very interesting due to the extreme flood event in August.

Reply: A table with monthly mean discharge values of the measurement period will be added in the supplementary material. Because of the high number of figures, we will not show the hydrograph of 2005. However, we will add a note that the hydrograph is available in the publication of Morche et al. (2007).

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5) Chapter 4: results and discussions: I would recommend to extend the comparison between the results of the presented study and results published in literature by other working groups. In the present version, the study presents very interesting results. Their benefit would increase significantly, if they would be related to the results of similar studies as demanded by McDonnell (2003).

Reply: We thank the reviewer for acknowledging the importance of the study. We will extent the comparison of our results with other studies to increase the significance of the presented work, although there is only few literature investigating similar alpine aquifer systems.

6) “Alpine“ can start with a capital letter (Alpine – belonging to the Alps) or a small letter (alpine in the sense of situated at high elevation). Botanists associate a special altitudinal belt with the word "alpine“. Thus it might be clearer to use "Alpine“ instead of "alpine“ to avoid confusions.

Reply: Revisions will be made.

7) (e.g. p. 6809 L. 9) : "Geography and Geology“ are scientific disciplines. Although the words "geography and geology“ are commonly used in this context (description of a catchment), it would be more correct if the heading would be called "geographical and geological settings“. The same is valid for hydrology, hydrogeology and lithologies.

Reply: Revisions will be made.

8) The extreme event in 2006 is mentioned several times. Although the “hard facts” may be extracted from table 2, it would help to get some more information on why this event was extreme. Especially: What is the difference between the event 7 Aug 2006 and 7 Aug 2011? Both rainfall events lasted 12 h, both had high precipitation sums, but discharge response is only extraordinary high on 7 Aug 2006. Do you have any information on the temperature of these events (snow!)?

Reply: We agree with the reviewer that more information would be desirable. Informa-

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tion on temperature and snow cover is available, but does not explain the event. The temperature of the event in 2006 is 0.2°C (snow height before and after the event was 15 cm), while the temperature of the event in 2011 is 4.1°C (snow height before and after the event was 0 cm). Apparently, the precipitation event on 7th Aug 2006 with (100 mm in 6 h) must have had much greater precipitation intensity than other events, e.g., the event on 7th Aug 2011 (310 mm in 6 h). However, because of the maximum resolution of precipitation of 6 h, it is not possible to obtain clear information about the precipitation intensity.

Specific comments:

p. 6807 L. 22-24: as far as I know Merz and Blöschl (2009) analysed event hydrographs, not spring hydrographs

Reply: Revisions will be made.

p. 6808 L. 3-6: High topographic gradients lead to a high peak discharge due to high flow velocities, if surface flow develops. However, high topographic gradients do not necessarily lead to a high amount of surface flow. E.g. coarse talus slopes are steep, but do usually not show any surface flow, flat areas are often covered by fine-grained fluvial sediments reducing their infiltration capacity and thus producing surface flow (e.g. Löhmannsröben 2002).

Reply: We agree. Especially low permeable beds result in a high amount of surface runoff.

p. 6010 L. 5: At p. 6809 L. 15 two cirques are mentioned, here "sequences of cirques“: sounds as if there would be many cirques (sequentially situated).

Reply: Revisions will be made.

p. 6811, L17-18: GS-RD is "at the downstream end of the valley“ contradicts to my feeling to p.6812 L. 20: GS-RD is "at the outlet of the alluvial/rockfall aquifer system“. If there is really a contradiction depends on the definition of "the downstream end of the

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valley“ – I would say it is situated at the lower end of the Partnachklamm. Thus I would say the description of the position of GS-RD given at p.6812 L. 20 fits better.

Reply: Revisions will be made.

p. 6811, chapter 2.2: Fig. 1 contains also SP-R3 and SP-RU which are not explained in this chapter. Although they are mentioned later on, it might be helpful to give an complete overview at this stage.

Reply: Revisions will be made.

p. 6812, L 10: Was the sampling interval equidistant (4 h)?

Reply: The sampling interval was not equidistant but increased with increasing distance to the injection point. Information will be added to the manuscript.

p. 6812, L. 11: "The final samples were collected three weeks after injection“: I would prefer a sentence like "sampling was stopped three weeks after injection“ in order to stress that there was no day without sampling.

Reply: We will change this sentence as suggested, but in fact, there were some days without sampling.

p. 6817, L. 4: Is it possible to identify a threshold (rainfall intensity, precipitation sum) describing the "intense or prolonged precipitation events“?

Reply: We understand the remarks of the reviewer, and we would like to provide more information. However, because of the lack of data, it is not possible to identify a threshold. First, the precipitation sum is not a clear indicator, because the generation of surface runoff depends on the rainfall intensity. Secondly, the rainfall intensity is not a powerful parameter in this case, because the maximum temporal resolution is 6 hours. Nevertheless, we will provide some graphs in the revised supplementary material, which will make data relations more clear.

p. 6821, L. 14: The sentence starts with the discharge ratio (peak discharge minus

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initial discharge) and switches to the discharge variability which is something else (the ratio between maximum and minimum discharge according to Schmidt and Morche (2006)). Please define the term discharge variability if used! It would be better to compare discharge ratio values with each other and not with discharge variability values, although there is probably a connection between both of them.

Reply: Actually, our expression was not clear. According to our definition (p.6814, l.15-16), the discharge ratio is the ratio between maximum and minimum discharge. Thus, both values have the same definition and can be compared. However, we will replace the term discharge variability, as it is misleading in this case.

p. 6829 Table 2: Event 20 May 2006: rainfall duration 6 h, peak rainfall 8 mm, but sum of precipitation until peak discharge 37 mm. If the resolution of the sum of precipitation is 6 h, I assume, that the peak rainfall of 8 mm refers to 6 h. Where do then the 37 mm come from? (Apart from this event, all events shown in Tab. S1 which last 6 h, have the same value in p sum and Peak rainfall.)

Reply: The number will be corrected.

Technical comments:

p. 6808 L. 3: As can be seen from my comments, I am not an English native speaker, thus I might be wrong. However, I am not sure, if the construction "of low permeability bedrock“ is correct (better: bedrock of low permeability).

Reply: This will be checked.

p. 6808 L 7: particularly instead of particular

Reply: Changes will be made.

p. 6809 L. 18: I would omit the first "thick“ as the thickness is anyway mentioned in the next words

Reply: Changes will be made.

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p. 6010 L. 1: I would omit "however“ as "only“ points out the contrast already.

Reply: Changes will be made.

p. 6811 L. 2: Is "the headwaters Partnach stream“ gramatically correct?

Reply: Changes will be made.

p. 6811, L. 8: "spring“ instead of "springs“

Reply: Changes will be made.

p. 6831 Figure 1: In chapter 2.1 two cirques are mentioned. It would be helpful to see the second cirque in the figure. The intermittent stream southwest of Partnach karst spring crosses the topographic divide. (b) Zugspitzplatt cirque instead of Zugspitz cirque Please mention the function of the rectangle in the figure (extent of figure 2?)

Reply: Corrections will be made.

p. 6835 Figure 5: The lower line leading to the arrows with question marks is not visible. The labels are very small.

Reply: Changes will be made.

p. 6836 Figure 6: The legend is missing (different kinds of arrows, dashed lines, black double points under the dashed lines). A label for the aquifer between the alluvial plains / rockfall deposits and the karst aquifer would be helpful (Quarternary sediments?).

Reply: Changes will be made.

p. 6837 Figure 7: Why is the tracer recovery curve for SP-R1 longer than for SP-R2? I understood from chapter 4.2 that mean discharge was measured only during the main part of the tracer breakthrough. Wouldn't it be more honest to restrict the tracer recovery curve to this time period?

Reply: The last sample at SP-R1 was collected 455 h after injection, while the last sample analysed from SP-R2 was 315 h after injection. A sample taken after 454

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hours got lost. Therefore, the tracer recovery curve for SP-R1 is longer than for SP-R2. At SP-R1 and SP-R2, discharge was measured during main tracer breakthrough, and tracer recovery is extrapolated during the tailing of the breakthrough curve. However, the extrapolation does not change the results substantially, e.g., recovery at SP-R1 would be 29.5% without extrapolation and 30.0% with extrapolation. Tracer recovery from SP-R3 is not extrapolated – discharge data is available for the entire measuring period (at GS-RD). The calculation and extrapolation of tracer recovery at SP-R1 and SP-R2 is reasonable because of the continuous discharge records at GS-RD. The data at GS-RD show a steady but slow decrease of discharge after the tracer injection. Thus, the extrapolated recovery of the tracer at SP-R1 and SP-R2 enables to estimate the approximate maximum recovery of the tracer.

p. 6840, Figure 10: Legend: FIT TRF, underline: FIT-IRF

Reply: Changes will be made.

p. 6841, Figure 11: In the corresponding text (p. 6820) one can read about a correlation between the hydrologic flow conditions and the lag times. It would be helpful to classify the 38 events shown in Fig. 11 according to the text (high, medium and low flow conditions).

Reply: Changes will be made.

References:

Löhmannsröben, R. (2002): Die Bedeutung des Bodens im Zusammenhang mit der hydrologischen Regionalisierung. In: Wiener Mitteilungen Band 164: Niederschlag-Abfluss Modellierung – Simulation und Prognose, p. 201 – 213. McDonnell, J.J. (2003): Where does water go when it rains? Moving beyond the variable source area concept of rainfall-runoff response. In: Hydrological processes 17, pp. 1869 – 1875.

Niederheide, A. (2003): Der zeitlich variable Aufbau eines Sedimentspeichers im Reintal (Bayerische Alpen). – Unveröff. Dipl.-Arb., Geographisches Institut, Rheinische

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