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Discussions



# *Interactive comment on* "Subsurface flow mixing in coarse, braided river deposits" *by* E. Huber and P. Huggenberger

**Anonymous Referee #2**

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General remarks

The aim of the paper is to investigate the impact of overlapping trough fills on groundwater 3-D flow mixing processes, in the case of a coarse bedload, braided river, present-day aquifer analogue. The topic of the paper is relevant, and I enjoyed the reading. I could also learn from the paper, as well as from the comments by AR1, to whom I refer for the relevant points concerning flow and transport modeling. Hence, I shall comment mostly on the points that are close to my expertise, and that have not been discussed in depth by AR1.

1) The starting point The aim and goals of the paper are clearly stated both in the abstract and in the main body of the text, even if a better definition of "subsurface flow



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mixing" could be useful, as it was stated also by the Anonymous Reviewer 1 (AR1). I refer to his/her comments on this point.

2) The significance of the conceptual/architectural model The "structural" (Par.2.2) and "hydrogeological" (Par.2.3) components of the hydrostratigraphic model are drawn from the interpretation of 3 intersecting GPR lines, plus a very good and clever conceptual hypothesis on the shape and internal structure of the trough-fills, derived from previous works by the Authors in different settings, plus a set of poro-perm properties taken from Jussel et al. (1994). The flow and transport model is run through this object that looks to be a synthetic, conceptual model, rather than a simplified representation of the real Tagliamento aquifer. The synthetic model inherits from the real world the size and shape of the troughs only. Nothing wrong, but it should be taken into account in the discussion and conclusions: I think that You are not dealing with a specific type of heterogeneity of a real aquifer but with a plausible conceptual architecture, so this is what You can discuss. To me, the relations between this model and the different cases of the real-world, coarse-grained aquifer systems involving scour pools might deserve a brief discussion, a little bit wider than the few warnings You give in the discussion of results (Page 9303, Lines 18-29).

3) The set-up of the hydrogeological model The depth, size and shape of the overlapping troughs are interpreted by 3 GPR profiles, which look to provide a poor constraint for a 3-D structure. In the Method paragraph You state that "several common offset GPR data were acquired", then addressing to Fig.2, where three GPR profiles are shown. Is this the total number of GPR data You could acquire? If so, it could be useful to clarify the reason why only 3 profiles were interpreted; may be it was impossible to acquire more GPR data, so please specify it, otherwise the reader would expect to find the traditional grid of closely-spaced GPR profiles that would be necessary to draw a subsurface geometrical model. The textural and poro-perm parameters of the sediments are not presented, so the hydrogeological parameterization of the structural model is based on literature. In this way it is assumed that the setting of aquifer het-



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erogeneity consists of isolated conductive and anisotropic trough fills within a matrix of less conductive and isotropic sediments. The GPR profiles of Figs. 2 and 4 show that the embedding sediments are at least crudely stratified, in the part that can be seen below the troughs, as it is normal in these settings where the confluence scours are cut across older bars or trough-fills and may be covered by, or filled-up, by bars prograding into the confluence. I agree with the Authors that the hydraulic head field depends also on the whole geological fabrics, and exactly for this reason the "matrix" of the trough fills might have deserved some more attention, as well as the textural and hydrogeological parameters of the real sediments. Many of the points of the discussion and conclusions are strongly dependent from this set-up (as well as from the mathematical modeling and metrics, see the comments by AR1), so in my opininion the conclusions should be tightly attributed to the synthetic structure that has been set-up and investigated.

4) The results and conclusions I would like to start from this question by AR1 "Is it really necessary to resolve the alternating layers of open-framework gravel and bimodal gravel or would it be sufficient to simply assume a higher uniform hydraulic-conductivity value in the trough-fill inclusion, may be accounting for anisotropy?". The question is not only inherent the numerical modeling procedure (the concern of AR1) but also the hydrostratigraphic significance of the model set-up, its hydrogeological behavior and the conclusions You draw. To me the point is that You did not clearly defined the hierarchic arrangement of heterogeneity. This is not just a problem of accuracy or resolution, of billions of voxels, of computing power and time and so on. As AR1 suggests, You could just investigate the role of the highly conductive, anisotropic trough-fills, surrounded by isotropic less conductive sediments, that means the impact of the highest-order architectural elements of the hierarchic structure of the heterogeneity. This is the aim You state in the Abstract (Lines 8-10). Otherwise You could investigate (also) the role of the individual couplets filling the troughs, that is another aim You state in the Introduction (Page 9298, Lines 16-19). These couplets represent the lowest hierarchic element of heterogeneity that You drew in Your synthetic model, inside the



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trough-fills. Working at this hierarchic order, also the equivalent elements of the heterogeneity of the "matrix" (the sediments associated with the scour pools) should have been accounted for in the model. To me, at present, Your synthetic model mixes the representation of a two-order hierarchy for the troughs with the undifferentiated architecture of the associated sediments. I believe that the nesting of heterogeneity might be considered on the whole geological structure, because it affects the hydraulic head field (as You state in the Conclusion, Page 9304, lines 14 – 16).

In summary, I think that the paper deals with a relevant theme and presents interesting results. I suggest to ameliorate its present form following the suggestions by AR1 and considering whether something useful can be found also in my comments.

Specific remarks

Abstract Two more lines to describe which is the impact of the modeled trough fills on the flow field after conservative tracer injection, could complete this section, if there is some more room available for this section. Line 7: drawn (instead of draw)?

Introduction Page 9297 - Lines 3-5: may I suggest that some different or additional citations would better recall the relevant literature on coarse braided aquifers (Anderson? Bridge? Lunt? among the many others). - Lines 7-9: this statement looks to me an oversimplification of the architecture of the coarse grained, braided river aquifers. I can understand that this leads straightforwardly to the simplified model of heterogeneity presented in Fig.1, that makes the subject of the paper, and I agree that no more details are necessary in this paper. Nonetheless, I observe that this concept someway justifies the idea of a poorly sorted, isotropic and low-permeability "matrix" that hosts the highly conductive trough fills (AR1 calls them "inclusions", a term that occurs in many papers on mathematical modeling of coarse aquifers, leading this simplified concept to its extreme consequence, as it is apparent in this current literature). In my opinion this is not exactly the case, neither in general nor in the Tagliamento river case (in these settings, openwork gravels do not occur exclusively in the trough fills, the



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associated sediments do not represent an isotropic matrix).

Methods 2.1 - Page 9298 – Line 24. Was it possible to acquire a more dense grid of GPR data than the three lines that are shown in Fig.2? The set-up of the architectural model would have been more tightly constrained than with these three lines and a less conceptual representation of the troughs would have been obtained (see 2.2). Page 9299 - Lines 14-16. It would be useful to show the velocity data (listing them directly in Fig.2?). 2.2. Page 9300 This paragraph shows the set-up of the geological model of the aquifer analogue. It is taken from the real world (the Tagliamento river), but step by step it turns to a conceptual analogue. Studying such a plausible and realistic structure is a very useful exercise but, in my opinion, in the discussion and conclusions it would be necessary to stress that the flow and transport model is run through a conceptual analogue, separating the real features derived from the Tagliamento setting (the size and shape of the scour pools) from the conceptual inputs. 2.3. Page 9300 – Lines 26 and following. It is not clear to me if You derived the hydraulic properties from the Tagliamento sediments or in which other way. Tab.1 states “after Jussel et al. 1994”. Is this the source? Was it impossible to use some data from the study site? Page 9301 – Lines 4 and 5: was it necessary?

Results and discussion Page 9303 – Lines 10 – 13. In my opinion this observation holds for the synthetic conceptual model that is under investigation. How this could be true in the real Tagliamento aquifer cannot be stated. Moreover, within the model, this observation seems mostly due to the set-up and orientation of the model itself and to the scale of the grid. - Line 11 replace extend with extent

Conclusions Page 9304 – Lines 13 – 15. I agree with this statement, but the way You set-up the model seems to partly neglect the whole geological fabrics.

Figures

You relate Your case-study to the Tagliamento river. No need for a very simple location map of the study site? (a frame in Fig.2 could be sufficient) Fig.2 Strike of the GPR



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profiles? It would help to put this info also in Figs.3, 5 and 7, to help the reader to understand the architecture. Figure 4. Could You please add a scale to the photos You use for comparison? Fig.5. It is hardly observed the hydrogeological model set-up in this picture. Figure 5, 6 and 7. These pictures are a little difficult to read, because they do not show clearly the relations with the orientation of the hydrogeological model, there is no orientation of the model (so the use of “right side” and “left side” in the main text is mostly confusing the reader), no streamlines are drawn, the model view of Fig.7 is rotated with respect to Fig. 5, the injection of the tracers is not clearly located in Fig.7, there is no m-scale in Fig.7, while the text reports a long comment on what happens at which distance from the left, or right side of the model, and so on. Caption of Fig.7: “They grey body . . .” (replace they with the).

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Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 12, 9295, 2015.