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Hydrology and Earth System Sciences
Discussions

Interactive comment on "Thermal damping and retardation in karst conduits" *by* A. J. Luhmann et al.

A. J. Luhmann et al.

luhm0031@umn.edu

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Below you will find our responses (in plain text) to the comments from Anonymous Referee #1 (in bold text). We thank Anonymous Referee #1 for his/her time and effort in helping us to improve our manuscript.

The authors present analytical and numerical solutions for relating conduit geometry with thermal damping and retardation. The manuscript is overall well written and the topic interesting. Moreover, the findings are of interest of the scientific community and may be useful to give some light in inferring karst conduit properties. I have not reviewed the mathematical development for analytical solutions. It seems to be correct but I leave this task to another referee.

Although I consider that the manuscript is acceptable for publication at Hess in its current format, I propose some minor issues that, in my opinion, could improve this manuscript: - Section 5 page 9602; Hydraulic boundary conditions are not clear. The authors impose velocity just at the conduit or fracture inlet? Is there flow across the matrix? The authors say that the calculation of f does not affect to the results. Is the model insensitive to this parameter or is it a consequence of the imposed boundary conditions? What if you impose head instead of velocity?

We will clarify our hydraulic boundary conditions. Velocity is imposed along the entire conduit. As most simulations model full pipe flow, there are no spatial velocity gradients. The model does not incorporate flow across the matrix, but we do briefly discuss the effects of dilution from more diffuse flow paths on thermal damping and retardation.

The value of f does affect the results, and the model is sensitive to this parameter. However, simulation results do not depend on whether the von Kármán Equation or the Colebrook-White Equation is used to calculate f.

There is no difference in the model if we impose head instead of velocity. Each velocity used in the simulations is equivalent to a specific hydraulic head, given the particular properties of the flow path. In karst conduits with full pipe flow, the Darcy-Weisbach equation relates head to velocity.

The authors explain the number of elements within the grid but it would be more useful an explanation of the model sensitivity to this grid (it seem they have some numerical dispersion that could be produced because of a grid effect). What about the time stepping? –

We will add a brief discussion that clarifies that neither the grid nor the time stepping affected the modeled results. We increased the number of elements to increase the grid resolution and decreased the relative and absolute tolerances (which control time-stepping in COMSOL) to decrease the time stepping for some simulations that appear to be affected by numerical dispersion. However, neither of these changes provided different results.

Section 6.3.2, page 9610; Regarding the variable velocity setting I miss a figure showing the fitting between analytical solutions and numerical simulations and an explanation about why the authors chose that range of velocities. As it is the most interesting case, I would pay more attention to this topic.

In the variable flow velocity section, we chose a range in velocity that mimics flow in a natural conduit, although this choice is certainly not unique. Furthermore, we chose to vary velocity using a Gaussian function, which is only one of many possible approximations of natural pulses. It would be difficult if not impossible to develop a general understanding of the effect of variable velocity on thermal damping and retardation relationships.

The modeling work seems to be correct, crossing a wide range of different assumptions. I have noticed some limitations of the model while reading the manuscript, however, they are well discussed on section 8.2 so nothing to say. - Section 7, page 9616;

As for the field study, the authors chose as a section title "An example field study to test the theory". I do not see the testing, I can see a good application to estimate the geometry of conduits applying their solutions but I cannot see how the authors check that the estimation of conduit diameter is correct. Explain better or change the title to something like "Theory application to a field study". The authors claim within the abstract too that they have confirmed their relationships with a tracer experiment. They should change that affirmation if they do not explain better within section 7.

We will modify the text so that it is clear that we are testing a portion of the theory. We conducted two tracer studies at the same site three days apart. The only variable that changed significantly from one study to the next was recharge duration. Because of

this, we derive Eq. (53) and use the recharge durations from both studies as well as the thermal retardation during the first study to predict the thermal retardation during both pulses of the second study. There is good agreement between this prediction and the actual retardation values from the second study. In this way, we tested a portion of the theory. Furthermore, we will add some discussion about an excavation at the field site that supports our estimates of hydraulic diameter based on the damping and retardation relationships.

Some technical corrections: - Page 9616, line 3: explict would be explicit - Page 9612, line 10: simlations would be simulations –

We will correct these typos.

Table 6: when the authors explain what Θ means they say advection and conduction time ratio. I would say conduction and advection time ratio, it may lead to errors while reading.

We will correct this definition.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 11, 9589, 2014.