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Interactive Comment

Interactive comment on "Thermal-Plume fibre Optic Tracking (T-POT) test for flow velocity measurement in groundwater boreholes" *by* T. Read et al.

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We thank the reviewer #1 for their constructive comments (in italic). We hope to have addressed these in the revised manuscript, and our reply to each comment is included below:

General Comments:

"The application described in this article is, to the best of my knowledge, novel and timely. The method and results described in this article constitute worthy contributions to the growing use of DTS in hydrological work. On this basis the work is publishable.

However, the manuscript may or may not be suitable for print as submitted, depending on the author's vision for it. The length, scope and detail provided in this paper is appropriate for a Correspondence or Note paper, but is less than expected for a full research article."

We thank the reviewer #1 for their comment on the style of the research article and in depth review. We had always envisioned that we would present this in a Technical Note or Methods Note form, and wish that this be considered as such rather than a full research article.

"For example, the article is entirely concerned with flow rates in a pumped borehole with virtually no discussion on how this relates to flow rates in the surrounding formation."

The aim of the method presented is to determine vertical flow rates inside the well rather than natural gradient flows in the aquifer. In the introduction we state that the flow in the well is completely different to natural gradient flow in an aquifer: "In all cases, the flows are not indicative of flow in the formation itself since the presence of the well as a high permeability vertical conduit may allow the short circuiting of flow." Nevertheless, we aim to quantify the in-well flow as this can still be an important diagnostic.

"Further, an estimate was given for the rate of water flow due to density differences between the ambient water and the heated water, but the details of the calculation were omitted as were any cited sources for making an estimate of this kind. This kind of calculation is not straightforward and deserves a higher measure of explanation in a full research paper."

We have now expanded details of this calculation in the discussion as we feel that even in a Methods Note, further explanation is required as pointed out by the reviewer.

"The scope of the article is quite narrow and should be broadened a little to include discussion on how the estimated velocities could be used for practical advantage. Too little given on how this would work be useful in determining ambient flow in the formation,

which is presumably an ultimate goal.“

This is not the aim – rather, to simply measure the vertical flow in the well.

“From the limited information provided, it appears that density flow would be a large concern except where ambient flows were substantial. An expanded discussion of the limiting conditions would be a useful addition.”

In the discussion section, we now discuss the measurement limitations in terms of maximum and minimum velocities and depth resolution.

“The total Qs don’t add up to match the pumping rate. The discussion was a bit vague on why, except noting that 1) some density flow is likely occurring, and 2) the effect of poorly resolved plumes above B3-1. Are those the only sources of error here?”

$Q_{B3-1,2,3}$, which should equal to the pumping rate Q_a, is at most 20% below this figure. The data from above fracture B1, from which $Q_{B3-1,2,3}$ is calculated, are only marginally above the noise level. This, therefore, likely contributes significantly to this error. We also now list other potential sources of error.

“The flow in the borehole this test is unquestionably turbulent. How will this relate to near laminar flow in fractures under conditions without pumping? Some discussion of the nature of flow (turbulent vs. laminar) in fractures should be alluded to? Will the linearity seen here be the rule? A little discussion on this would be appropriate since it could be an important aspect of the methods ultimate viability.”

We agree that when pumped, the flow in the well will be turbulent. However, we have not added a discussion of the nature of the flow in the fractures, or, whether the linear scaling would always be a feature, as we feel this goes beyond the scope of this method paper.

Detailed Comments:

“Some mention of density flow due to varying salt content should be made. In open

water, such as the case of a borehole, the tiniest difference in fluid density (fourth or fifth decimal place) will result in very noticeable flow."

We have added a sentence stating this.

"The discussion seems to be limited to the case where flow enters the borehole from a single fracture. If there are multiple fracture sets the 1D model won't work - at least not without special considerations. Since the paper goes on to discuss a multi-fracture system, this issue should be brought up at this point."

We now go on to explain that multiple fractures increase the complexity of the response in borehole dilution tests.

"The DTS cable was continuous to a depth of 80 m yet the data are truncated at a depth of 68 m, where the heater was placed. Why? From the reader's point of view, background variability might be discerned from the lower section of the cable, which would help evaluate the sensitivity of measurements above 68 m depth."

We have re-plotted the data so that the instrument noise relative to the T-POT signal strength can more easily be seen. The data were truncated since we also carried out other experiments (that we do not aim to publish) in the section below the T-POT heater. This caused some warming below fracture B3-3, and since there is no vertical flow in the well here, the heat remained for a long time and appeared in variable extents in Figure 2a-e. This was decided to be more confusing, hence we do not show data from here.

"The 'elongated' plumes in the shallowest locations in Figure 2 are not visually discernable at all. Also, the symbols in Figure 2 are not explained in the caption or legend. I think they identify the curve peaks. The one in (e) that is associated with line 8 is very peculiar - what is going on there?"

There is now an explanation of the symbols in the text and figure caption. In Figure 3e, the peak associated with the 8 minute temperature depth profile appeared in a strange location as the T-POT signal was at or below the noise level by this time, hence determining the location using the automated method resulted in some clearly incorrect locations. In fact, after subtracting background temperature profiles as suggested by Referee #2, this point now is located at a more realistic depth, which is a merely due to a coincidence rather than an improvement in the signal to noise ratio.

"More detail is needed to show how the sampling interval ends up being 1.1 m (and later 1.8 m). The moving average is fine, but what is the spacing of the individual points that are averaged, and on a continuous cable how are those points determined to be at the minimum point spacing?"

In the revised manuscript we now explain the moving spatial and temporal averaging used to arrive at the curves in Figure 3. The 1.1 m number comes from averaging 9 temperature measurements, each spaced by 0.12 m. However, we now no longer refer to this, as the 'smoothed' curves in Figure 3 still contain data spaced by 0.12 m. So the comparison of this with a 1.1 m averaged DTS temperature measurent is not valid, unless we were to then interpolate the smoothed data set every 1.1 m.

"More details on the Rayleigh number calculation is warranted since the value reported represents the lower limit of flow detection for the system."

We have now significantly expanded on this in the discussion section.

"Why should contributions from B3-2 and B3-2 be hard to resolve? Qtot is constant and you can calculate Q at the bottom, Qbottom+Qmiddle, and Qbottom+Qmiddle+Qtop=Qtot. Need more explanation."

We now explain this in the text that the transmissivity of B3-1 is $<<$ B3-2, hence the contribution of B3-1 to the flow as a % of what is already there is too small to resolve.

Interactive comment on Geosci. Instrum. Method. Data Syst. Discuss., 5, 161, 2015.