Hydrol. Earth Syst. Sci. Discuss., 12, C1661–C1668, 2015
www.hydrol-earth-syst-sci-discuss.net/12/C1661/2015/

Hydrology and Earth System Sciences
Discussions

HESSD

12, C1661–C1668, 2015

Interactive Comment

Interactive comment on "Vulnerability of groundwater resources to interaction with river water in a boreal catchment" *by* A. Rautio et al.

A. Rautio et al.

anne.rautio@helsinki.fi

Received and published: 21 May 2015

A Author Comment.

The manuscript HESSD-2014-556 "Vulnerability of groundwater resources to interaction with river water in a boreal catchment" by A. Rautio, A.-L. Kivimäki, K. Korkka-Niemi, M. Nygård, V.-P. Salonen, K. Lahti, and H. Vahtera

We would like to thank the reviewers for making the comments and suggestions on the paper and for recognizing the potential of a manuscript. We appreciate their insightful and comprehensive comments that helped us to make changes and clarifications in the way how our data presented and discussed. The suggestions and comments helped to improve the manuscript considerably. We followed large majority of the reviewer's comments and suggestions when preparing the revised version of the manuscript. However, we have maintain our views and opinions in some points. General and detailed comments addressing all questions/comments/suggestions of the reviewer #2 are listed below.

Anonymous Referee #2

General comments:

Intro is not well in line with the actual study. Authors address flooding and water quality, which are not central to the methods or outcomes of the study. I would like to see more text related to methods in the intro.

We have reorganized the introduction and added chapter about thermal methods. We have also added water quality monitoring data (nitrate, dissolved organic carbon and turbidity) that will be more in perspective with vulnerability aspect. We have removed some sentences about the flooding.

Authors stress the possible contamination of GW with RW in the discussion section (P2456). Their data shows clearly GW discharge to streams, but they do not provide any evidence of flow in the opposite direction. Fact that there is interaction, doesn't tell us that there is a clear risk of contamination due to flow direction reversal at a given site. Contamination by bank infiltration is of course a well-known risk in general, but in my opinion the authors do not have convincing enough data to highlight this issue so much in the manuscript. Perhaps some simple estimates of the hydraulic heads in between the river (low flow and flood) and the location of water abstraction could be used to justify risk of contamination. In this regard on P2438 L12-14 authors address the first main aim well with this study, but in my opinion fail to prove much insight to the latter.

We have added the water quality monitoring data from high flow season. This data showed the RW infiltration into the production wells on high flow season and potential vulnerability of production wells. The abstraction wells are locating in proximity of main stream channel (Fig. 3) which increase the risk of contamination.

This is a nice case study with multiple methods used, but unfortunately I do not much novelty in any of them individually. I see, that authors could focus their discussion on what benefits do use of multiple methods bring to understanding of GW-RW interactions, instead of trying to force a management angle to the paper. Perhaps the authors could further expand their toolbox of methods by including stream flow measurements, referred to in the discussion, to this manuscript? And discuss more thoroughly the weaknesses and strengths of the methods based on their data.

We have added following sentence to address what is new in this study. Many previous studies have used the TIR to identify, classify thermal anomalies and modelling the stream water temperatures but not with the hydrogeochemical variables to explore the connection between anomalous stream water temperatures and GW−SW interaction indicative geochemical variables to assess the potential vulnerability of intake plants in proximity of main stream channels. We have maintained the management angle in paper due to the water quality monitoring data showed the contamination risk of production wells and proved that GW-SW interaction zones (discharge zones/low flow season) can be potential risks for water intake plants during the high flow season.

Specific comments:

Flow of intro, the first chapter is not related to the second one. You could use text currently on P2438 L4-L9 onwards to create link from GW-SW interaction to study catchment. P2438 L8 – It would be interesting if you could set you results of GW-RW interaction in this context. Do your field studies give any insight on the effect of GW on water quality and quantity?

We have reorganized the introduction as suggested. Our results (AIR, stable isotopes and DSi) indicate that in smaller tributaries, the water flowing in the streams is predominantly GW originating from the headwater aquifers in the low-flow period GW (e.g.

HESSD
12, C1661–C1668, 2015

Interactive Comment

Palojoki). Also Brander (2013) observed with river flow measurements both GW discharge into the river and RW recharging the aquifer.

P2444 L16 number of samples per site is not very clear, perhaps create a table for this?

We have added the numbers of samples per site in the text.

P2444 L23 – How were the spring identified, and were they considered to represent GW quality?

Springs (sampled springs) were identified based on their anomalously low temperature with field measurements. The springs were considered to represent the GW quality.

3.3 Statistics – You state that ": : :in order to assess the GW component. Please clarify what are you assessing exactly? Does the population taken within GW area differ from outside samples? Do you differentiate up- or downstream form GW area, for the "no GW effect group"? I would expect the GW signal to be seen also downstream

We have added followingly: To test if the GW input could also be seen in RW quality inside the classified aquifers, the non-parametric Mann-Whitney U-test for two unrelated or independent populations (Rock, 1988; Ranta et al., 1991) were performed using IBM SPSS Statistics 22 on RW samples ($n = 36$) in order to assess the GW component in RW. Yes, there was a statistically significant difference ($p < 0.05$) between the "GW effect" sites and "no GW effect" sites e.g. inside or outside the mapped GW area in the measured DSi and d-excess values. No, we did not differentiate the up- or downstream directions.

Section 4.1 until P2446 L12 in description of methods, in my opinion

In our opinion the number of thermal images are fitting into the results and classification of anomalies is results and partly interpretation of results.

P2447 L11-16 – This paragraph is difficult to understand. I read figures in a way that point 0 is the river outlet, so the river flows from 20km (left) to 0 km (right). This doesn't agree with you wording telling that artificial GW cools the river water. Instead we see a sudden warming. Please clarify what you mean by distance upstream and to which direction does the river flow?

This was unclearly marked in figures and we have corrected that. We have added distance from upstream on the X-axis and arrow to clarify the river flow direction.

P2448-2449 – interpretation of figs. 6 and 7 is quite confusing. In many occasions I'm not sure to which of the subplots the authors are referring to. Perhaps consider dividing the data into more plots, instead of trying to fit in too many subplots. Or at least please refer to the letter of subplot more actively.

We have made improvements into the figures (increased font size) and referred more preciously to the figures.

P2451 L22-26 - Can we see this stratification in your plots? And furthermore, is the location lacking AIR observed GW discharge? It would be interesting, if you can explicitly demonstrate with your dataset that stratification is hiding GW discharge.

Yes, we can see clearly the stratification on figures 6c and 7c. The river surface water temperature is quite constant and close to 23-24 Celsius degrees in all cross-sections, e.g. the bigger the difference between the surface and bottom the stronger the vertical stratification in water column. In Hyvinkäänkylä study site, the river surface water temperature were warm and the AIR missed this subsurface GW discharge. However, there were large springs in side of the river which were clearly seen in AIR images. The cold water in lower parts of River Vantaa at Hyvinkäänkylä study site would missed without the field measurements.

P2453 L8-L10 – To me this is not very obvious in the data. I would interpret stratification also downstream the pool in cross-sections OO' and PP' section 5.3 – much of this regarding chemical tracers and M-W U test should be moved to results section, as they are central evidence of GW-SW interaction in the streams.

The stratification decreased as the water depth decreased. We have changed the word disappear to decrease. We have kept the M-W U test in discussion as it include the interpretation.

P2458 – L4 – "This research provided new insights for water management." I don't agree with this statement, what are the new insights here. Please also note the supplement to this comment: http://www.hydrol-earth-syst-sci-discuss.net/12/C788/2015/hessd-12-C788-2015- supplement.pdf

We have added followingly to clarify the new insights. This research provided new insights for water management, and the results could be used in evaluating the possible effects of GW and RW exchange on water quality in the identified exchange zones. Based on the results of this research potential GW quality deterioration during peak-flow periods has been acknowledged at several waterworks. Infiltration of RW through permeable strata was observed to affect GW quality in some water intake wells installed into sand and gravel deposits in the vicinity of river bed. In order to avoid disruption in the drinking water supply new locations of groundwater intake wells and intensified monitoring of hydraulic heads as well as quality of GW between river bed and wells have been considered at these water intake areas.

Please also note the supplement to this comment:
http://www.hydrol-earth-syst-sci-discuss.net/12/C1661/2015/hessd-12-C1661-2015-supplement.pdf

---

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 12, 2435, 2015.

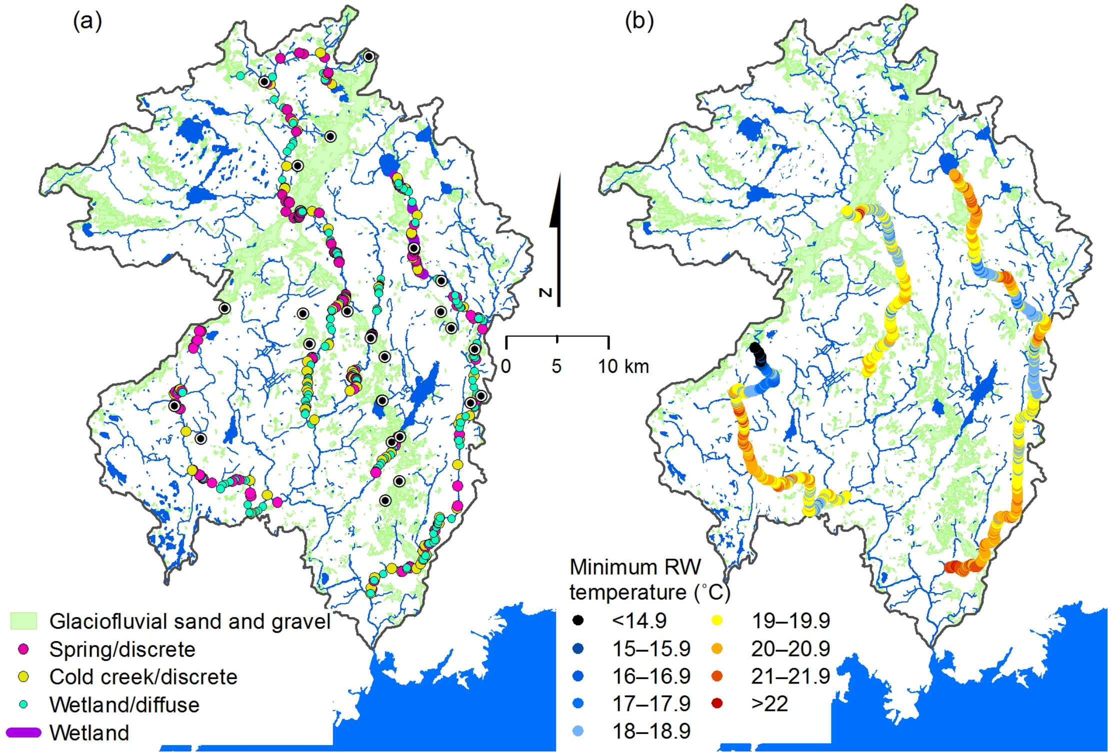
(a)
(b)
N
0
5
10 km
Glaciofluvial sand and gravel
Spring/discrete
Cold creek/discrete
Wetland/diffuse
Wetland
Minimum RW temperature (°C)
<14.9
15–15.9
16–16.9
17–17.9
18–18.9
19–19.9
20–20.9
21–21.9
>22

Fig. 1.

Interactive
Comment

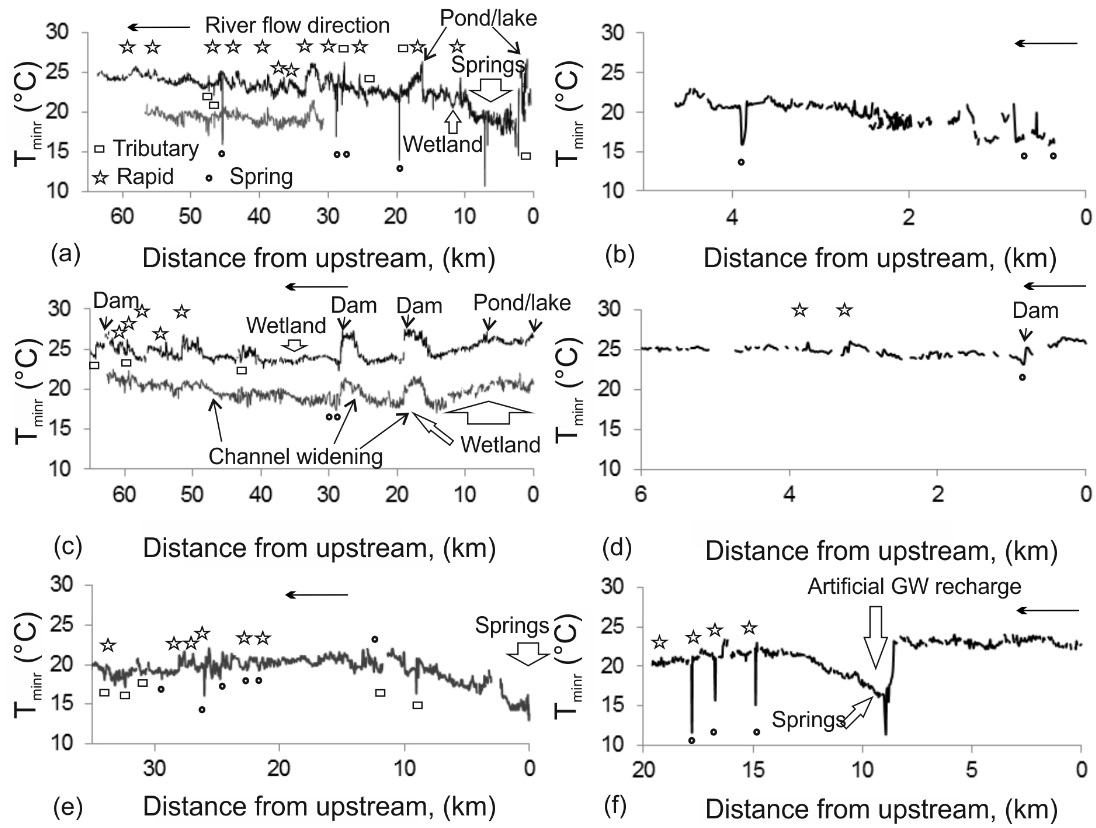

Fig. 2.