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Interactive comment on "Technical note: Water table mapping accounting for river-aquifer connectivity and human pressure" *by* Mathias Maillot et al.

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We thank the reviewers for their valuable review of our manuscript and for their constructive comments, which substantially helped improving the quality of the paper. Please find hereafter a point-by-point rebuttal with a new version of the manuscript where the correction has been made. Changes to the text in the manuscript are highlighted.

"My main comment is that the authors could have also used simpler alternative approaches to evaluate connectivity to compare with their methodology. "

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Discussion paper

=> We agree with the main comment pointing that the determination of SW-GW connection status could be improved using the methodologies mentioned further in the comment, especially to estimate the dynamics and the flow rate between stream and aquifer. However, our paper focuses on the water table mapping, only, which is a fundamental information for hydrogeologists, who derive from it, under given assumptions, such as permeability values, dynamics of the system and flow rate estimates. We choose to consider only hydraulic head and differential hydraulic head in order to set the boundary conditions of the water table mapping. Flow rate estimates between stream and aquifer will be part of a study describing the hydrological functioning of the Paris city area.

"1) Connectivity state. The authors are probably aware but have failed to mention that there are three hypothesised connectivity states for a river - alluvial aquifer system: Connected (gaining or losing), disconnected, and transitional. The transitional state was not described here and needs to be mentioned in the context of the system (transitional conditions can occur when the capillary zone intersects the riverbed. The concept of the riverbed clogging layer and the necessity of its presence to generate disconnected conditions under most field conditions in a temperate climate needs to be described.

=> It is true that transitional state and clogging layer need to be described in our paper. We added some modifications into the 2.2.1 subsection, P6, L11-18. Given the hydrological setting of our study area, we assume that there is no significant vertical stratification so that the main driver for disconnection would be the water table drawdown due to permanent pumping.

2) Hydrogeology in an urbanised area: I was uncomfortable with some of the assumptions used in the generation of the water table map, in particular that there is no recharge in urban areas due to the presence of 'impervious' structures. This is not consistent with findings elsewhere, which have shown that 'impervious' structures like road networks are never completely so. Moreover, most large old cities have large old

and leaky water distribution and sewerage networks. Whether this is the case for the study area I do not know but evidence must be provided to satisfy that no recharge occurs there. In addition and of consideration for the generation of the water table map, sewerage networks can also act as drains and thus impart an upper limit for the position of the water table.

=> The second refers to the statement made P3 L5 that recharge into urban environment is null. We thank you to point out this mistake which is a remaining artifact resulting from former version of the study. We propose to remove the two sentences since the methodology does not require to identify or quantify recharge.

3) Hydrogeological interpretation: It is probably necessary to compare the assessment made using a water table map with a more hydrogeologically-based interpretation. For example, Lamontagne et al. (Hydrological Processes 28: 1561-1572) provide a methodology where assessments of connectivity for rivers can be made using pairs of surface and groundwater level measurements for different hydrogeological properties of riverbeds and aquifers. Even though the authors may not have all the information required (e.g. riverbed hydraulic conductivity) the Lamontagne et al. approach can still be used in a sensitivity analysis context. Indeed, a sensitivity analysis should also be applied to the water table approach as well if possible - what is the potential error in the map?

=> The third point refers to the lack of quantification of reliability of the method to determine SW-GW connection status, that could be carried out applying the Lamontagne et al. 2013 methodology. This is true that the method presented in the paper is not compared to other methodologies. Indeed, such a sensibility analysis could be helpful to characterize the reliability of the methodology, however this would require to set a priori knowledge about riverbed hydraulic conductivity in order to estimate the SW-GW flow rate. As we said into the main answer, such a study constitutes the next step, after characterizing one static state of water table, that would be the description of the hydrological functioning through the description of dynamics and SW-GW flow rate. We argued this point in the corrected version, see section 3.6 P11/L5-9 in that purpose.

The empirical approach used by the authors to evaluate connectivity (Fig. 3) could be flawed based on hydrogeological principles. The lack of response of a water table to variations in surface water level could be due to a number of factors other than a river being disconnected. Indeed, even when disconnected, the specific recharge rate and flux below a river will increase at higher water levels (due to a greater head and wetted area), thus a response of the water table is still possible. On the other hand, a river could be connected but the alluvial aquifer have a very low transmissivity, which could result in a subdued variation in the water table especially if bores are at some distance from the river or the variation in river stage only for a short period of time. At a very low transmissivity, the response will only be notable when very close to the river. For a given change in river level, there will be a certain distance where the water table response can be practically measured considering other sources of variation.

=> Considering the infiltration fluxes in our area, they are stable even during flood due to the embankment of the river, which creates an almost stable wetted perimeter when no over-flooding is observed, as in our case.

=> We agree about the low transmissivity argument even though in that case the water fluxes are negligible. Being negligible, it means that the river and the aquifer are almost disconnected in that case. However, for the accuracy of our analysis, we consider a distance between piezometers and the river that is short enough to ensure water table response during flood.

Finally, several changes where operated in the text regarding the minor comments that are addressed:

P2, Line 1:'Embankments' should probably be 'levees' if they raise the water level at which water would spill into a floodplain

=> Replacing Embankments by levees

P4. Use of unsaturated zone thickness: I did not understand why this was better than using the water table elevation. It would also be preferable to use the term 'vadose zone' instead of 'unsaturated zone' considering capillary effects are of interest.

=> The main reason for using unsaturated zone depth instead of water table elevation is explained into introduction P2/L28-30:

“This methodology, that targets the unsaturated zone depth (UZD) instead of the hydraulic head, leads to lower values of the standard deviation of the estimation error for unconfined aquifer in non30 urbanized area (Kurtulus and Flipo, 2012; Mouhri et al., 2013; Rivest et al., 2008; Sagir and KurtulusÂÿ, 2017).” Furthermore, we added this point P3/L32-P4/L2: “Unlike water table, UZD can be considered as a continuous stationary variable. The supposed stationarity of a variable makes it usable for ordinary kriging methodologies. In other cases, more complex non-stationary geostatistics should be applied, requiring hypothesis about the estimated variable.”

P.20. Basis for the 10 m threshold. Some additional justification is required for using this threshold to identify disconnected conditions. Drawdown cones can be much deeper, especially when transmissivity in the aquifer is low.

=> P4-L23-29, adding explanation for the data selection step:

“The first category regroups all samples where the UZD value is affected by the pumping wells. The second category is composed by the other samples. Information about the locations of pumping wells is required to identify these samples. The observed minimal UZD of depreciated areas can be use as a threshold value to differentiate affected points from non-affected points. In this study, the samples with UZD value greater than 10 m are grouped in this category. Note that this value may vary according to the case study. This differentiation is required to elaborate a geostatistical tool (i.e. variogram model) that only depends of natural variability. Therefore, all the variographic studies are performed on this second category called unaffected UZD dataset.”

P.6, line 11. This is only correct if the river level is constant. If the river level increases, the specific recharge rate and overall recharge flux below the river will increase because of a higher hydraulic head and a larger wetted area (i.e. wider river).

=> P6-L11-18, adding some consideration to be accounted for to describe infiltration rate during disconnection: “During the switching between connection status, the SW-GW connection status is considered as a transitional state, this condition can occur when the capillary zone intersects the riverbed (Brunner et al., 2009). The disconnected SW-GW condition can occur under different settings such as in case of high hydraulic conductivity contrast between the clogging layer and the aquifer (Brunner et al., 2009; Peterson and Wilson, 1988), the lowering of the water table (Dillon and Liggett, 1983; Fox and Durnford, 2003; Osman and Bruen, 2002; Rivière et al., 2014;Wang et al., 2011)) or the biological clogging of the riverbed (Newcomer et al., 2016; Xian et al., 2019). Considering a constant river water level and river width, the disconnection occurs when any further increase of the hydraulic head difference between the water table and the river water level does not affect the infiltration rate from the stream to the underlying aquifer, which remains constant.”

Figures: Could in general all be improved - very faint lines and symbols in particular. Figure 6a was interesting and should be complemented with similar 2D cross-sections when feasible to get an idea of the shape of the water table near the river.

=> Legend and symbols were reworked for all figures.

The following illustration (Fig.1 of this answer) is an example of 2D cross sections of water table, river water level and topography. This figure shows the estimation of water table for LWC and HWC at connected and disconnected parts of the river. We think that this figure would bring redundant information with Fig.6 if included in the paper, this is why we would prefer not to do so.

Please also note the supplement to this comment:

https://www.hydrol-earth-syst-sci-discuss.net/hess-2019-101/hess-2019-101-AC2-supplement.pdf

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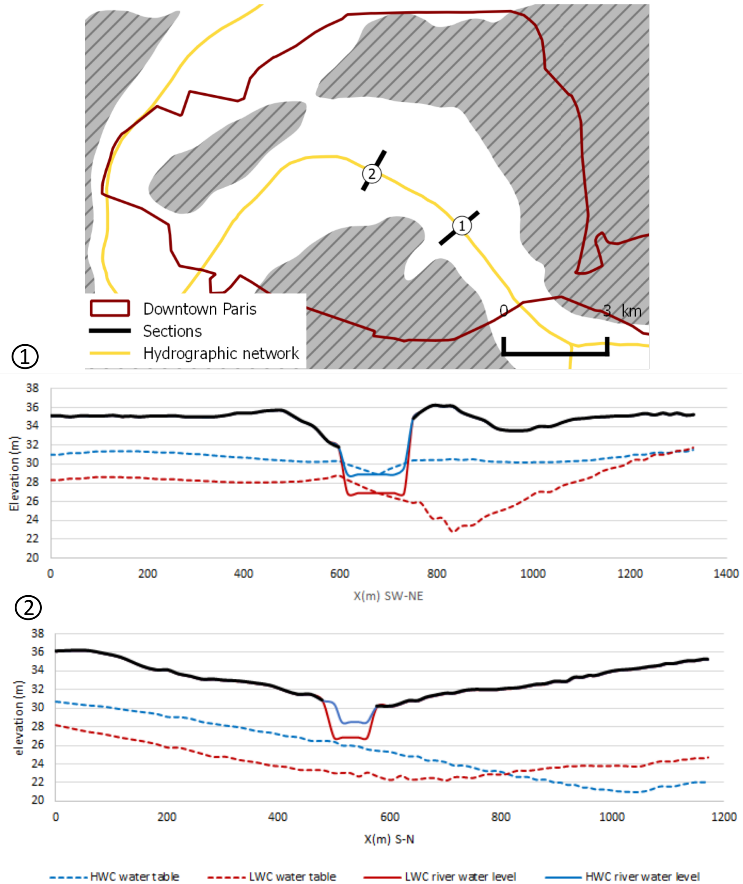

Fig. 1. 2D cross-sections for profile 1 and profile 2. Profile 1 is always connected and profile 2 is always disconnected