

## Review of Kopp *et al.* 'Impact of long-term drainage on summer groundwater flow patterns in the Mer Bleue peatland, Ontario, Canada' submitted to *Hydrology and Earth System Sciences Discussions*.

### Overview and recommendation.

This paper describes a study of the sub-surface hydrology of two parts of a raised bog affected by a drainage ditch that has been in place for c. 90 years. The authors suggest that the drying caused by the ditch can be regarded as an analogue for a drying climate; thus, the results could give insights into how peatlands might respond to future climate change. Although interesting, I'm not sure such an argument is that convincing and would have liked a more detailed discussion of why a ditch might be expected to replicate some of the changes expected from climatic drying.

The authors investigated hydraulic heads and hydraulic conductivities ( $K$ ) to assess how flow patterns and changes in peat properties might have differed in two parts of the bog either side of the ditch. Their data set is quite large and they have certainly obtained some useful measurements. However, I have two substantive concerns about the quality of the data and hence the authors' interpretation of their results. First, the authors don't seem to have taken account of the potential effect of peat smearing around piezometer intakes on estimates of peat  $K$ . There are published protocols that suggest that piezometers to be used for  $K$  tests should be (i) constructed with intakes that have high levels of perforation (50-70%) and (ii) 'developed' to remove smeared or low- $K$  skins around the intake. As far as I can tell the authors have not used these protocols so I question the validity of their  $K$  data. Secondly, the authors don't appear to have taken proper account of differences in piezometer responsiveness when interpreting their head data. Differential responses can lead to apparent hydraulic gradients between instruments when none actually exist. Just because piezometers show a response to rainfall doesn't mean that the response is a faithful reflection of changes in the peat around the piezometer. Therefore, I am not convinced the head patterns they observed represent the real behaviour of the bog; the patterns may be measurement artifacts (in part, at least). I think some of the data are probably of good quality, including the piezometer data presented in Figure 2, but I'd like to know more about the data collected from other instruments (Figure 3).

Given these concerns, I don't think the paper is publishable in its current form. I'd recommend a substantive revision where greater attention is given to data quality, especially in the interpretations of flow directions within the peat.

I have other, more minor, concerns about the paper, and these are articulated in the 'Detailed comments' section below. In that section I also elaborate on the more major concerns outlined above. Where a concern is more major, I have used a plum-coloured font.

Finally, I operate a policy of 'open reviewing' and would like my name to be made known to the authors.

### Detailed comments.

**Abstract, line 17:** I don't follow/understand the sentence starting on this line with "When water...".

**Page 34, line 25.** This is an old estimate of C storage in northern peatlands. More recent estimates suggest a larger store (see, e.g., Yu *et al.* (2010), *GRL*, doi:10.1029/2010GL043584).

**Page 35, line 20.** The plant genus names in the sentence starting on this line should be italicised. I don't know journal policy, but the adjectival case should, perhaps, also be hyphenated ("...*Sphagnum*-dominated bog...").

**Page 35, line 23.** I assume years are meant here. Is before present before 1950 (some hydrological readers may not know the dating convention implied here)?

**Page 36, line 22.** " insight into..."?

**Page 37, line 16.** "Sphagnum" should be italicised. This point applies to botanical names given elsewhere in the document.

**Page 37, line 23.** "leave" should read 'leaf'.

**Page 38, line 21.** But surely one would expect  $E_t$  to differ between the "Bog" and "Forest", so why use  $E_t$  estimates from single station elsewhere on the bog?

**Page 39, line 5.** How were the piezometers installed? Was the response times of the piezometers measured (see Hanschke, T. and Baird, A.J. 2001. Time-lag errors associated with the use of simple standpipe piezometers in wetland soils. *Wetlands* 21(3), 412-421). I'm a little concerned that some of the piezometers may have had slow response times and given misleading values leading to errors in the estimated hydraulic gradients.

**Page 39, line 13.** I don't follow what was done here. Slowly-responding piezometers tend to give damped responses. Also, in any pair of piezometers between which head differences are being measured, problems can occur if the instruments respond differently to changes in head in the peat around them.

**Page 39, line 21.** It is implied here that the piezometers measured  $K_h$ . Actually, piezometers such as those used by the authors measure an undefined mix of  $K_h$  and  $K_v$  as noted by SurrIDGE *et al.* (2005, *HP*, doi: 10.1002/hyp.5653). No information is given on how the slug tests were conducted. If the intakes were screened with mosquito mesh, did that cause smearing of the peat around the intake during piezometer installation? Were the piezometers 'developed'? Was slug injection or slug withdrawal used? All of these are potentially-important considerations as noted by Baird *et al.* (2004, *HP*, doi: 10.1002/hyp.1375).

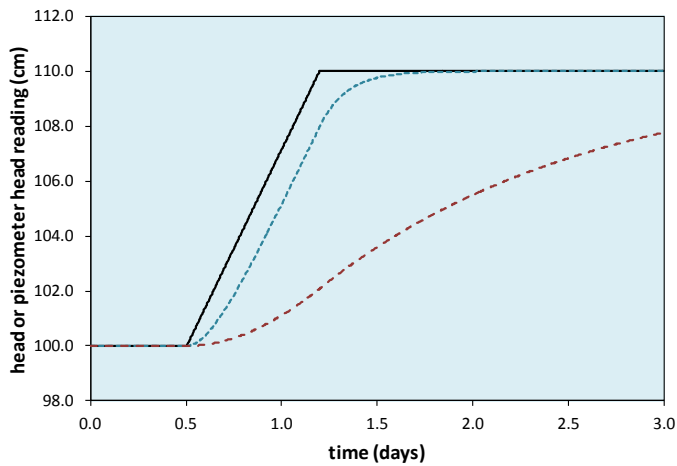
**Page 39, lines 23 and 24.** How is anisotropy defined here? As  $K_h/K_v$ ? More information should be given. And is it reasonable to expect anisotropy of the peat in the areas affected by drainage to be the same as in the pristine area of the bog?

**Page 40, line 2.** Given that piezometers can also be sampled for their gas, I suggest rewording as follows: 'Peat pore-water was sampled from the piezometers ...'.

**Page 41, line 15.** I'm not quite sure what is meant by "calibration targets" here.

**Page 41, line 21.** Why was a paired  $t$  test used? The statistical design of the study is rather complicated. Piezometers either side of the ditch could be regarded as being independent of each other, which suggests that a two-sample  $t$  test for independent samples should have been used. And, rather than do several  $t$  tests, one for each depth, it might have been better if a two-way, repeated-measures, ANOVA had been used, with location ("Bog" and "Forest") as one factor and depth as a second factor, with depth being the factor with repeated measures (if piezometers at different depths in each bank were very close to each other).

**Page 42, section 3.2.** Some of the  $K$  values are low and may have been caused by smearing of peat around the piezometer intakes, leading to low rates of head recovery during slug tests. Low recovery rates also mean that head readings from some of the piezometers cannot be regarded as reliable. To illustrate this point I modelled a situation where two piezometers of the same design as that in the study were installed in peat. I assumed that one piezometer had an effective  $K$  of  $3 \times 10^{-8} \text{ m s}^{-1}$  and one an effective  $K$  of  $3 \times 10^{-7} \text{ m s}^{-1}$ . By 'effective  $K$ ' I mean the  $K$  of the peat controlling the flow of water into or out of the piezometer. This could mean the smeared peat around a poorly-installed piezometer or just the naturally-low  $K$  around the instrument. I assumed a flow system in which there was no vertical head change and assumed water tables and hence heads at all depths increased by 10 cm over a 17-hour period in response to rainfall, after which they remained stable. I also assumed that, prior to the head increase, both piezometers were in equilibrium with the prevailing head (100 cm). The results are shown below, where the head is shown as a solid black line, the higher- $K$  piezometer by a dashed blue line and the lower- $K$  piezometer by a dashed red-brown line.



From the figure it can be seen that there is an apparent large head difference between the two piezometers, suggesting flow between the higher- $K$  instrument and the lower- $K$  instrument. However, the difference is entirely an artifact of the differential response time. That is why it is important to understand response time when interpreting head data from banks of piezometers. More on this matter can be found in Hanschke and Baird (2001) as previously referenced. The values of  $K$  used here are within the range reported by the authors, so I suspect similar artifacts are present in their data and need to be properly accounted for in a major revision of the paper.

**Page 43, line 22.** I agree, but the piezometers shown in Figure 2 had similar  $K$  values ("Bog"), so would be expected to show similar types of response, or relatively high  $K$  values ("Forest") so one would expect similar responses. It would have been interesting to have seen results from piezometers such as B200-1.0 and F15-0.5 that had lower  $K$  values than used in my analysis above. I'm afraid I would not trust the data from those instruments because response times for these would have been of the order of days, not even hours. Overall, I'm unconvinced by the results in section 3.2.

**Page 43, line 23.** Okay, but the piezometers concerned had relatively high  $K$  values. What was the situation with piezometers like B200-1.0, B15-1.0, and F15-0.5 that had low  $K$  values; how did they respond?

**Section 3.4 and Figure 3.** Until the response-time error of the piezometers is properly addressed I don't think firm conclusions regarding flow directions and the magnitude of hydraulic gradients can be drawn from the piezometer data.

**Page 45, line 10.** Conjunctive adverbs like 'however' should be preceded by a longer pause/stop than a comma; I suggest a semi-colon or a full stop (period).

**Page 46, line 5.** I cannot agree. I'd like to see a comparison of data from higher- $K$  piezometers and lower- $K$  piezometers. I suspect the results will show something similar to my simple model results above – i.e., apparent hydraulic gradients that are better explained by differential piezometer responses to the same head change. Even slowly-responding piezometers can show a response to rainfall (changes in head) but that does not mean that they have registered the change in the system adequately (see the example of the lower- $K$  piezometer in my analysis above).

**Page 46, line 28.** But were they significantly lower?

**Page 47, line 11.** Okay, but this is not known for sure. I guess much will depend on how the bog has developed over time in different places. I can imagine plausible scenarios where the profile was the same (as suggested by the authors) but also those where the profile was very different. Much depends on the developmental history of the bog.

**Page 48, lines 12-21.** This is plausible, but is there any evidence of the tree roots in the peat at the two depths on the "Forest" side?

**Page 49, line 9.** But Rosa and Larocque used piezometers with highly-perforated intakes and also undertook 'development' (Baird *et al.*, 2004).after piezometer installation to help remove any low-permeability skins or smeared peat around the piezometer intake. However, it appears that the authors did not adopt these protocols for their tests, so I cannot agree with their statement that their results were as reliable as those of Rosa and Laroque.

**Page 50, line 18.** Vertical-upwards flow can be expected near a ditch, when water is discharging from a soil. Such upwards vertical flow doesn't necessarily imply recharge from an underlying substrate.

**Page 51, line 8.** I think the authors are right to question the usefulness of long-term drainage as an analogue for a change to a drier climate, but this limitation is perhaps something that could have been foreseen. In any revision of the paper (see my overview), it may make sense to change the rationale of the paper and to remove the ditch-as-dry-climate analogue.

A handwritten signature in blue ink that reads "Andrew Baird".

Andy Baird

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