Reply to Reviewer #2

- The authors should explain why they preferred the Neumann no-flow boundary conditions at $x \to \infty$ and $y \to \pm\infty$. It is typical, in the hydrogeology literature, to set these as Dirichlet bc's of the form $h|_{x\to\infty} = 0$, because the pumping well has no effect at such large distance.

Reply: The Theis solution can be derived from the confined flow equation for the remote boundary condition with either the zero-head (Dirichlet) boundary or Neumann no-flow boundary. In reality, both boundary conditions have the same physical meaning; i.e., the pumping well has no effect on the flow at a very large distance. By the same token, we can also derive the same solution as presented in the paper from the zero-head condition specified at the remote boundary.

- Normally, I would not have a problem with the boundary condition imposed at $x = 0$, namely, $h|_{x=0} = 0$. In this case however, this is not a suitable boundary condition when one is discussing stream depletion. The authors provide their own definition of stream depletion, but to my knowledge, and as suggested by the term, stream depletion implies decreasing river stage induced by pumping from a nearby well. The condition $h|_{x=0} = 0$ by definition implies no change in water level in the stream, and therefore, no depletion. Depletion of the stream implies that one can not fix the head at the stream/aquifer contact. To formulate the problem in terms of stream depletion, one should impose a Robin (or General, Newton) type boundary condition of the form

$$\left.\frac{\partial h}{\partial x}\right|_{x=0} = \beta h|_{x=0}$$

where β is a proportionality that is related to stream conductance. Of course, should the author decide to stick with the boundary condition used in the manuscript, they should not use the term stream depletion, but something like stream contribution to water extracted from the pumping well.

Reply: Stream depletion represents either direct depletion of the stream or reduction of groundwater flow relative to infiltration from the stream. We choose the latter as the definition of stream depletion in our manuscript. In addition, the latter has been adopted in most hydrogeology literatures (e.g., Hunt, 1999; Zlotnik and Huang, 1999; Bulter et al., 2001; Chen and Yin, 2004; Sun and Zhan, 2007;

Bulter et al., 2007; Yeh et al., 2008; Zlotnik and Tartakovsky, 2008).

The stream is considered to have much larger quantities of water in comparison with that flows to the pumping well. The depletion of water from the stream is generally negligible. The boundary condition at $x=0$ can therefore be assumed as $h|_{x=0}=0$.

- The solution assumes the stream fully penetrates the confined aquifer. This should be stated explicitly in the manuscript. Additionally, they assume the head level in the stream is coincident with the top of the aquifer. These are over simplifications. The latter of these two assumptions is also problematic because the potentiometric surface of a confined aquifer is rarely coincident with the aquifer's upper boundary. They should revise their conceptual model to one that is more realistic. The river-head, if it coincides with the aquifer potentiometric surface, should be above the upper boundary of the aquifer.

Reply: Thanks for the comments. To include the description of the stream fully penetrating the aquifer, a new sentence is added in the revised manuscript as "The origin of the coordinate system is located at the top of the upper boundary of the aquifer and the intersection between the aquifer and stream fully penetrating the one. The top of the stream is chosen as the reference datum." (lines 18-21, pages 3)

The conceptual model demonstrated in Figures 1 and 2 has been modified and shown below:

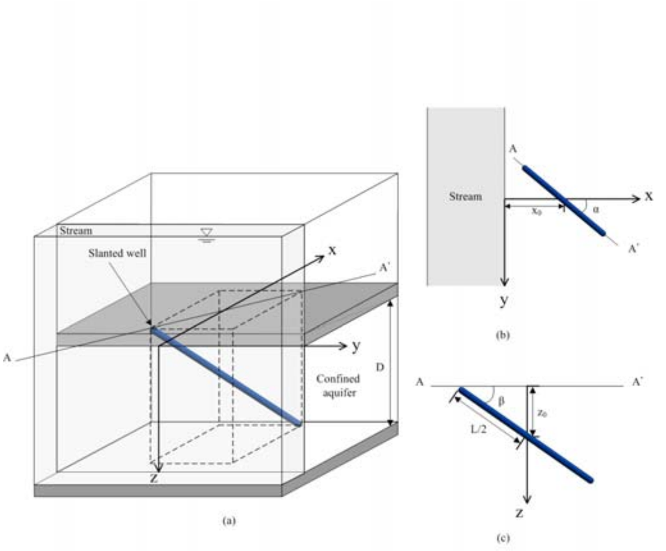

Figure 1

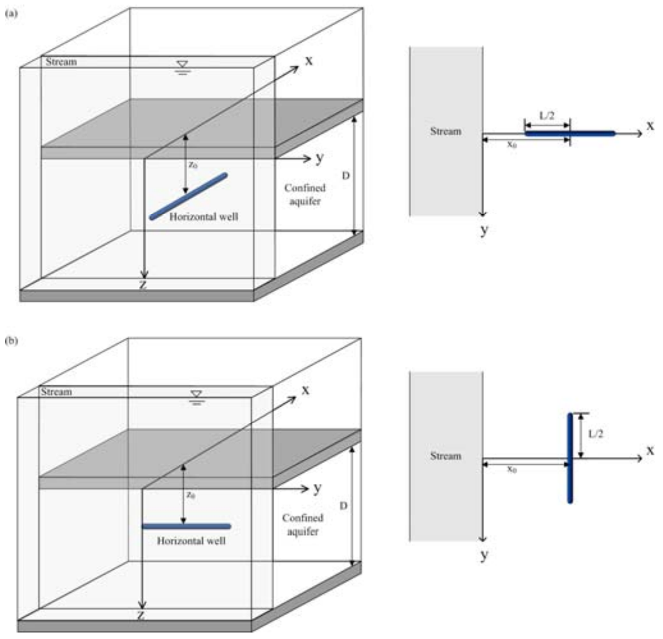

Figure 2

- For the case of the boundary condition $h|_{x=0} = 0$, why not solve the problem on $x \in (-\infty, +\infty)$, and then use the method of images (superposition) to get the solution on $x \in (0, +\infty)$? This may be simpler, as one can just use the Fourier transform instead of the Fourier sine transform. Just a suggestion.

Reply: The method of images can be applied to evaluate the drawdown of the groundwater from a pumping well. However, this method can not be used to derive the solution for the stream depletion rate (SDR). Therefore, the use of boundary condition $h|_{x=0} = 0$ is inevitable for obtaining the SDR.

References

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