

Interactive comment on “Analysis of groundwater flow and stream depletion in the L-shaped fluvial aquifer” by Chao-Chih Lin et al.

D. Ferris

david.ferris@usask.ca

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The paper under review presents a semi-analytic method for describing groundwater flow in an irregular (L-shaped) unconfined aquifer bounded on two sides by contributing streams. The authors have presented a solution for groundwater flow in a steady-state condition, and, using the steady-state solution as a boundary condition, under the influence of a single pumping well. The authors' work is developed from the work of Kihm et al. in the 2007 paper “Three-dimensional numerical simulation of fully coupled groundwater flow and land deformation due to groundwater pumping in an unsaturated fluvial aquifer system” and draws heavily from the conceptual model developed therein.

Substantive Praise-Worthy Aspects:

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In this paper, the authors present a novel method for solving for the groundwater flow field for a complex hydrogeology problem. As noted by anonymous referee #1, few papers address groundwater flow in multi-unit aquifers with complex shape, so by presenting a semi-analytic solution to groundwater flow under these conditions, this paper provides insight into methodology for representing hydrologic processes.

The problem addressed by the authors also provides insight into modelling the relative contribution of aquifer storage and stream filtration water to the total water abstracted from a pumping well. The authors' work also contributes to an understanding and awareness of the interaction of surface hydrology and groundwater, a topic that should be further addressed and developed. By developing a solution for the groundwater flow field in a system incorporating these factors, the authors have made a worthy contribution to the field of hydrology and engineering.

Substantive Considerations:

This paper draws heavily on the work of Kihm et al. (2007), and I am concerned that not all the material presented has been cited correctly. Several examples of incorrectly cited material are provided below:

The sentence on P.4, L.9-10 is cited as a summary, but the wording may not be sufficiently different from the original sentence in Kihm et al. (2007, P.4).

A direct quotation from Kihm et al. (2007, P.4) that was not properly indicated or cited was detected on P.4, L.17-18.

Figure 6 is an updated reprint of Kihm et al.'s Figure 12 (2007, P.12), but is not directly cited in the figure caption.

Important assumptions made in the development of the conceptual model have not been discussed. These assumptions follow those made in Kihm et al. (2007) and include the assumption that hydrostatic conditions exist in the vertical profile through both units of the aquifer (i.e. the piezometric surface is equal to the water table at all points

C2

along the vertical profile) and that recharge to the system from vertical percolation or precipitation is negligible. These assumptions, and others, may represent significant deviations from real-world conditions, and should be explicitly stated.

Although the piezometer data presented in Kihm et al. 2007 appears to support the modelled solutions, it should be noted that piezometer observations are only available over a period of 5 days; no information is presented to validate the modelled response to pumping beyond this period.

Considering Figure 6, the 5-day observation period appears insufficient to observe any response to pumping at piezometer 3 (O3). This indicates that these data are irrelevant for the purpose of validating the transient solution for hydraulic head distribution presented by the authors.

It is also to be considered that at a time period of less than 5 days, the majority of the modelled contribution of abstracted water is from aquifer storage (SRR), with the contribution from stream filtration (SDR) increasing after this point. The absence of observed piezometer response to pumping after a time of 5 days would seem to prevent any conclusions from being drawn as to the application of the method presented by the authors in predicting aquifer response to pumping in situations with a large stream filtration component.

It is my opinion that the results presented in this paper are insufficient to draw conclusions as to the validity of the methodology presented in predicting aquifer response to pumping. The results presented, however, demonstrate consistency between the semi-analytic method presented by the authors and the numeric model developed by Kihm et al. for the same aquifer system. Likewise, it is my opinion that the results presented are insufficient to draw conclusions regarding the significance of unsaturated flow and land deformation due to the limited observed data.

The authors present the semi-analytic solution as a design tool for determining well location. The demonstrated applicability of the numeric simulations presented by Kihm

C3

et al. 2007 and the authors' solution developed in MODFLOW, validated by the semi-analytic method presented in this paper, would seem to be more flexible and appropriate tools for the design of well location.

Further to the substantive observations which I have made above, there are several additional observations of a less critical nature that I would like to make.

Strengths:

The derivation of the analytic solution appears well documented and described. This paper provides the reader with a clear description of the analytical methods used by the authors, theoretically allowing for the results to be reproduced. The literature review presented by the authors also appears to be detailed, and well-structured, providing valuable information to other scientists interested in studying groundwater flow in aquifers with complex boundaries and that are bounded by contributing streams.

Areas of Improvement:

The assumption was made that all flow is horizontal, including the flow through the overlying clay loam aquitard unit, which has been assigned a hydraulic conductivity two orders of magnitude lower than the underlying loamy sand unit. This assumption is necessary for the simplification of the groundwater flow equation to 2-dimensions, but is non-realistic and the implications of this assumption have not been addressed by the authors.

The equivalent hydraulic conductivity for horizontal flow (Eq. (48)), discussed on P.10, L.3-4, is calculated as the weighted arithmetic mean of the two units assuming the full thickness (2.5 m) of the overlying unit is available for groundwater flow. Since the overlying unit is only saturated to a maximum seasonal average thickness of 0.79 m (as described on P.4, L.9), it may be more appropriate to use the saturated thickness of the upper layer when calculating the equivalent hydraulic conductivity for the aquifer.

The logic regarding the required well setback from a stream is incomplete (P.12, L.7-9),

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and the connection between the required well setback distance from possible contaminants and the well setback distance from a stream is not clear.

As noted by anonymous referee #2, the solution presented by the authors is semi-analytical. The first use of the term “semi-analytical” by the authors is in the conclusion on P.12, L.25. The solution presented by the authors should be consistently described throughout the paper, as appropriate.

Several minor grammatical issues were found within the paper, and are listed as follows:

P.2, L.9 typo: “arbitrarily”, should be “arbitrary”

P.2, L.12-15 ambiguous references; it is not clear that the authors are referring to the work of Kihm et al. (2017)

P.2, L.12 inconsistent hyphenation of “L-shape”

P.2, L.15 missing “the”: “in <the> transient case”

P.2, L. 20 poor grammar: “to solve a regional groundwater in an. . .”

P.3, L.31 “perennial stream<s>. . .”

P.4, L.22 syntax error: “Consider that there are totally M pumping wells. . .”

(Throughout paper) inconsistent use of italics to denote units, and spaces between values and units (i.e. 6m, 6 m, 6 m)

P.2, L.34 ambiguous reference to “irregular boundaries” – what are irregular boundaries?

P.3, L.18 ambiguous reference: “principle direction aligned with the border of the sub-region”; which border?

P.13, L.6-7. Awkward transition. This should either be a new paragraph, or these sentences should be rewritten.

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Suggestions:

A careful and detailed review of the entire paper should be conducted by the authors to ensure all material is appropriately cited. The authors should revisit the description of the conceptual model and either further develop and detail the assumptions made in the development of the conceptual model or clearly state that the conceptual model and assumptions have been taken from the work of Kihm et al. (2007) and refer the readers to that paper for details.

The authors should address the implications of the simplifying assumptions when applying the results of the semi-analytic and numeric solutions for groundwater flow in this aquifer to the real world. The limitations of the 5-day observation period should be noted by the authors.

The conclusions drawn by the authors should be reconsidered. The results appear to demonstrate consistency between the semi-analytical method presented by the author and the numeric model presented by Kihm et al. (2007), and raise questions as to the significance of unsaturated flow and land deformation. Conclusions regarding real-world aquifer response to groundwater abstraction appear unsupported. It is recommended that the authors reframe their work as a method of validating the numeric simulations and as a method of developing a better understanding of the physical processes governing groundwater flow.

Reviewer Experience:

It should be noted that I am a Master of Science candidate in the field of engineering, with minimal experience in either analytical or numerical methods for describing groundwater flow. I have no prior experience refereeing academic submissions. The observations and opinions I have expressed herein should be considered with my inexperience in mind.

Proposed Fate:

C6

The authors are to be commended for their approach to this complex problem. It is my opinion that the methods and results presented by Lin, Chang, and Yeh makes a valuable contribution to the field of hydrology and engineering and are of interest to the scientific community. However, the issues noted above are significant. I recommend that this paper be resubmitted for review following the revisions suggested above. I would further recommend that extreme caution be exercised by both the authors and by the editor in vetting the submission for incorrectly cited material.

References:

Kihm J H, Kim J M, Song S H, Lee G S. 2007. Three-dimensional numerical simulation of fully coupled groundwater flow and land deformation due to groundwater pumping in an unsaturated fluvial aquifer system. *J. Hydrol.* 335:1–14. doi:<https://doi.org/10.1016/j.jhydrol.2006.09.031>.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., <https://doi.org/10.5194/hess-2017-487>, 2017.