A hydrological framework for persistent river pools, Bourke et al., hess-2021-461, Leannah Sies

The main objective of the study was to incorporate relevant literature on groundwater springs and surface-ground water interaction with a modern suite of diagnostic tools. This framework is meant to increase the understanding of the most important hydraulic mechanisms for the persistency of pools along non-perennial rivers and gain knowledge on their susceptibility to climate change and human activities. In accomplishing this, the hydraulic mechanisms that support river pools are classified as perched surface water, alluvial through flow and regional groundwater discharge controlled by geological features or topographic lows. A diagnostic tool suite to elucidate these hydraulic mechanism is presented. Landscape positioning, remote sensing, water balances and tracer techniques are discussed. Also, the susceptibility of each mechanism to climate change and human activities such as water abstraction is considered. Finally, the diagnostic tools presented are applied to three pools in the Hamersley basins in Australia to demonstrate their use and the difficulties related to their application in the real world.

As mentioned in the introduction of the paper persistent surface water pools along non-perennial rivers are an important water source for plants, animals an humans. However, their persistence is threatened by climate change and human activities such as water abstraction. In my opinion the authors did an interesting work by addressing this important but novel topic. I believe that creating a hydrological framework to understand the dominant hydraulic mechanisms supporting persistent river pools is relevant in effectively managing these pools and their cultural and ecological functions. Although the results are not surprising as they mostly summarize our existing knowledge, I believe the way it is presented is a valuable tool in future research. Because of the author's innovative hydrological look at river pools and the paper's contribution to the understanding of the hydrological system of river pools I believe the manuscript is appropriate for HESS. However, the message the paper tries to convey, the importance of river pool persistence and the usefulness of the diagnostic tool suite, is not as strong as could be. Therefore, some changes are needed to increase the readability and convincingness of the paper. Section 6, the conclusions and recommendations, need to be changed such that it better reflects the message conveyed by the rest of the paper. Besides this, I think some structural adaptations are needed and a stronger linkage between each section is necessary. Below, I have addressed these issues in more detail. After these are solved, I would recommend the manuscript for publication.

Major Comments

Conclusions and recommendations

The conclusions and recommendations in section 6 are well formulated and easy to read. However, I found that the conclusions and recommendations do not fully reflect the message that is conveyed in the rest of the paper. For example, in my opinion the fact that it has been 100 years since groundwater springs were documented is not important in this paper. Still, this is where the section starts with. In contrast, the dominant hydraulic mechanisms and their classification are not specifically mentioned whereas these are much more relevant in the scope of this paper. Also, the structure of the conclusions is not in line with the structure of the rest of the paper. For example, the conclusions on section 4, the susceptibility of the processes, is discussed before the diagnostic tool suite of section 3 is mentioned. Not only does section 6 not reflect the relevance of each topic properly, also new topics are addressed. For example, in the conclusions it is discussed whether more detailed data of less pools provides more insight than snapshots of many pools. This question is not introduced before and, in my opinion, distracts from the potential this paper has regarding the evaluation of the demonstrated diagnostic tool suite. Lastly, the recommendations done could use some more detail to better stress the use of this paper as stepping stone for future research. For example, it is mentioned that the biological and sedimentological processes need to be added to the framework. Why is this important? Are there hints this would massively change the systems known

from this framework? Furthermore, it is mentioned that this framework is subject to refinements as sufficient data becomes available. This makes me wonder, what is sufficient data? What does this mean for the current accuracy of the framework? To summarize, I believe that section 6 does not fully reflect the message of the paper as the focus is not solely on the relevant issues, its structure is different from the paper and the potential of the framework in identifying the knowledge gap of this research field is not worked out sufficiently.

I believe that due to these issues the conclusions drawn are less strong. Because the focus is not solely on the relevant issues the message conveyed by the paper is less clear and likely to have less impact. The lack of structure reduces the readability of the paper and, as mentioned before, the recommendations paragraph simply has more potential.

To solve these issues I would recommend changing the structure such that it is in line with the framework. Think of the objective of each of the sections written and reflect on whether this goal is reached. What is learned from this and what future research would you recommend? By doing this the readability is increased and it is easier for the authors to make sure everything is included and no new things are added without reason. If the readability remains an issue, I recommend adding a short introduction to the structure of the conclusion. As the framework in this paper contributes to understanding what knowledge gaps there are in this research field I would suggest stressing that these recommendations are results, no shortcomings, of this framework. Also, I would suggest going into more detail. A question the authors may ask themselves to reach the appropriate level of detail is what the use of the framework is for the future research suggested? And also, what is the use of the future research for the framework? If the authors spend some more time on this I believe section 6 can from a strong and convincing ending to this paper and can contribute to future management of river pools.

Structural adaptations

The structure of the paper is nicely introduced at the end of section 1. However, I found the structure of the paper illogical mainly due to the order of the sections. In section 4, as well as in section 2, a more in depth understanding of the processes occurring is gained. However, already in section 3, tools are given to quantify these processes. I think this can be done better. An example of this can be found in a paper written by one of the co-authors and referred to several times. In “an overview of the hydrology of non-perennial rivers and streams” first the processes are discussed (section 2,4), then common approaches and measuring challenges are highlighted (section 3), the hydraulic understanding is synthesized (in this situation the case studies in section 5) and finally future research directions are given (section 6).

I believe that the illogical structure reduces the readability of the paper. Also, I think this structure is one of the reasons the sections are rarely coupled (see “improve linkage between sections”). To solve this issue I suggest to simply switch section 3 and section 4.

Improve linkage between each section

Although I believe the paper is nicely separated in several sections, while reading the paper I found that the different sections are rarely linked to each other. This not only holds for section 6, the conclusions and recommendations but also for the other sections. For example, in section 3 the diagnostic tools are discussed. It is mentioned that these tools are used to distinguish the pools outlined in the previous section. However, I miss what information is needed to accomplish this. Also, I think the tools presented need to be better coupled to what is known from the previous section on the processes they elucidate. For example, for the first heading the focus is on remote sensing and landscape position. However, these methods are not related to the earlier made distinguishment between regional discharge controlled by geological features and regional discharge controlled by topographic lows. Not only is section 3 rarely coupled to the previous section, also the

coupling with the case studies is poorly done. For example, remote sensing is not used as a method in the case studies although it is discussed as part of the diagnostic tool suite. In contrast, a tracer technique with oxygen isotopes is used, but this method is not introduced before.

Because of this poor coupling of the sections, the paper comes across as less convincing than it could be. Also, especially for readers that aren't as experienced with the topic as the authors, this poor coupling causes the paper to be complex although this is definitely not needed. Furthermore, because of the poor coupling of especially section 3, I even doubt if the goal of the case studies is met. It is said, the goal is to demonstrate how the diagnostic tool suite infer the hydraulic mechanisms supporting pool resistance and to see the complexity of applying these methods in the real-world situation. Therefore, a coupling to a concrete diagnostic tool suite (section 3) inferring the hydraulic mechanism from section 2 and 5 is needed.

To solve this issue, I would suggest changing the overall approach. I recommend making a clear overview on what needs to be known in determining the dominant hydraulic mechanism and find the best diagnostic tools for each parameter/information. This might lead to a step-by-step plan on how to figure out what the most dominant hydraulic mechanism is and what the susceptibility of the pool is (of course this depends on the situation but this can be included). I advise making a table similar to table 1 but now for the diagnostic tools. This concrete diagnostic tool suite can then be applied to the case studies stepwise. If the conclusions on the mode of occurrence then agrees with what is found by Dogramaci the authors properly demonstrated the diagnostic tool suite worked. Furthermore, to better couple the sections I would recommend adding a paragraph to each section that links it to the previous section. By re-structuring as recommended in the previous paragraph, the linkage between the sections can be made stronger. I see the paper as follows:

- Section 1 is an introduction to why it is important that the river pools persist and this study is done.
- Section 2 gives insight in what hydraulic mechanism are important for this persistence.
- Section 3 gives insight in how these mechanisms/fluxes can be changed due to climate change or under a different water regime (the susceptibility of these fluxes).
- Section 4 starts with a paragraph on what fluxes/ mechanisms need to be quantified to understand the susceptibility of a pool after which a step-by-step plan is presented on how to access all the needed information while discussing the accuracy of the used methods.
- Section 5 applies the step-by-step plan on existing pools.
- Section 6 goes specifically deeper into the usefulness of this step-by-step plan as the end product of the paper and highlights several future research directions that will address missing information.

To summarize, to convey the message stronger and increase the readability of the paper section 6 needs to be changed such that it properly reflects the paper. Also, section 3 and 4 need to be switched giving the paper a more logic structure. Finally, the sections need to be stronger linked by adding a coupling paragraph and focussing on a more concrete diagnostic tool suite that links section 2 and 5 clearly to section 6.

Minor comments

<u>General comment 1:</u> It is mentioned that the water balance of the pools is only considered after surface flows have ceased. That sounds good, however, shouldn't the period of time the pool is disconnected from the surface water play a key role in their susceptibility to changes? How long do the pools have to withstand on their own and when do they get a refill? This seems especially relevant in the case of perched surface water.

<u>General comment 2:</u> I found that the aims and objectives were not clearly stated. Because of this it is hard to figure what is the most important to the authors. By adding a sentence like " the aim of this

study is to contribute to the understanding of the persistency of river pools" and "the objectives of this study are to create a framework for understanding the hydraulic mechanisms supporting persistent river pools and demonstrate the use of this framework with help of three case studies." this can easily be solved. By adding these, the readability of the paper improves.

General comment 3: The classification of hydraulic mechanisms that are most important for the persistence of river pools is nicely done and may provide an important tool in future research. Also, table 1 adequately summarized the framework making it of good use.

General comment 4: Using the case studies to demonstrate the use of the tool suite is a interesting approach and does massively improve the applicability of the manuscript. An extra suggestion to make the case studies clearer is to be consistent in the use of arrows in the figures (8,9,10) explaining the direction of the flow.

General comment 5- *This paper does not include a discussion. Because of this the completeness of the framework is not discussed. By adding a separate heading or paying more attention to this in section 6 the readers have no reason to question the completeness of the framework.*

P1, title: The title is nicely formulated. The novel approach is stressed clear by the use of the word hydrological. The title makes clear that this paper is a framework including much of what is known. The use of the words "persistent river pools" tells us that the paper focusses on the persistence of pools along rivers. A small suggestion I'd like to make it to also include the non-perennial character of these rivers . An optional title could be "A hydrological framework of persistent pools along non-perennial rivers.

P1, line 24: As I understood it well, the case studies are also meant to see the difficulties of applying the diagnostic tool suite to a real situation. Consider adding this to be true to the readers.

P2, line 41: Consider adding "such as pumping/water abstraction" for the human activities.

P3, line 53: Is 'host to primary productivity" meant?

P12, line 257: extra "the" before "groundwater system".

P14 line 285-289: example might be to obvious to include.

P15, line 311: It is stated that maps of geological contacts are readily available but information on hydraulic properties is not known in priori. Of course this depends on the location. However, if hydraulic properties are already known this Is probably a result of the method they described afterwards so a minor change in formulation would solve this.

P15, line 314: minor flaws in sentence structure.

P15, line 315-317: The information provided by deposition of geological precipitates (the occurrence of carbonates associated with ground water discharge) does not belong here as it is not directly linked to landscape positioning and/ or remote sensing. Instead I would put in under "tracer techniques" as in this subsection the geochemical properties of the water and streambeds are discussed.

P16, line 347: The reason why it is considered in absence of rain is missing. In my opinion rain can easily be included as ET is already considered. Also, in line 367 rain is included as refill for the alluvium water level.

P17, line 372: Make a clear distinguishment between regional ground water discharge, local groundwater discharge and alluvial through flow.

P17, line 379-383: The limitations of using the Darcy equations in a real world situation are nicely reported.

P18, line 401: Although I am acknowledged with the use of isotopes to quantify water sources I do not understand what is meant by the term "overlapping values". Therefore I would suggest changing this to "However, in a system where water is recirculated (irrigation, mining e.g.) stable isotopes have shown to be of limited use for constraining the relevant contribution of different recharge sources." (Bourke et al., 2015).

P18, line 405: minor flaws in sentence structure.

P19, line 426: "indicate" instead of "indicates".

P19, line 429: add "the" in front of ^{222}Rn mass.

P21, line 471: "may" instead of "my".

P22, line 494: There is referred to (Cook et al., 2003). In the bibliography this paper is not found.

P25, line 534: Change "a subset of these (22 pools)" to "a subset (22 pools) of these" .

P25, line 534: Elaborate on why only 3 of the 22 pools are analysed. Do you think this suffices?

P25, line 551: change "permeability" to "permeable".

P28, line 578: claiming that the pools have not been impacted by human activities but considering climate change is, in my opinion, a contradiction. Specify the human activities (water abstraction etc.) to avoid this.

P29, line 603: "the that"

P35, line 732: measuring temperatures at dawn to reduce effect of direct solar radiation needs to be in section 3.

P38, line 771: include (Shanafield et al., 2021) as a source for frameworks of non-perennial streams.

P38, line 780-783: Not clear to me. Is it in addition to what was mentioned before on the novel hydrological approach?

P38, line 812: This paper deserves to end with a positive note.

Bibliography

Bourke, S. A., Cook, P. G., Dogramaci, S., and Kipfer, R. Partitioning sources of recharge in environments with groundwater recirculation using carbon-14 and CFC-12, Journal of Hydrology, 525, 418-428, 2015

Dogramaci S. Springs, pools and seeps in the Hamersley Basin, NW Australia, internal report for Rio Tinto Iron Ore, 2016

Shanafield, M., Bourke, S.A., Zimmer, M.A. Costigan, K.H. An overview of the hydrology of non-perennial rivers and streams. Wiley Interdisciplinary Reviews: Water, 8(2), e1504, 2021