

Thank you so much to the referee for the constructive comments. All the comments have been addressed and are detailed below.

This manuscript presents some interesting comments on a “Spatial characterization of long-term hydrological change in the Arkavathy watershed adjacent to Bangalore, India” by Penny et al. (2018), previously published in HESS. The manuscript critiques the Penny paper on a number of points. I am aware that a previous submission of this commentary has caused a large number of comments on the HESSD forum. However, I (on purpose) have not read the details of this conversation to remain as objective as possible in my current review.

Response: Thank you so much for your observations and pragmatic approach.

The presented critiques on the Penny et al can be summarized as follows:

- 1) Various sources of ground data (streamflow, groundwater, precipitation, reservoir levels) exist, which are not acknowledged (or used) in the Penny et al. paper.
- 2) Past literature has discussed hydrological changes in this region, which, again, is not acknowledged in the Penny et al. paper.
- 3) Several assumptions in the Penny et al analyses are argued to be misleading.

These are interesting points that are may be relevant for HESS; especially highlighting the data availability of in this region helps to support future hydrological inferences of this region.

Response: Thank you for the feedback.

However, at present, the manuscript does not provide a structured scientific critique of the Penny et al paper that would lead to me recommending publishing this in HESS. Before I can recommend publication, the authors should address the following points:

Response: Sure, we have provided our responses to all the queries raised.

[1] A critique of the Penny paper (in my opinion) requires tackling the main claims of their work. At present this critique does not clearly list the main claims of Penny et al., and therefore it also does not use the main findings of Penny et al. as the core of what needs to be “critiqued”. In the context of the main current critiques, I expect that the authors show (or logically argue) how:

- i) the data which is available leads to substantially different conclusions on the key findings of Penny,
- (ii) how past literature relates to the main findings of Penny et al,
- (iii) how a more realistic representation of reservoirs (i.e. section 4) affects the main findings of Penny et al, and
- (iv) how a better representation of the main assumptions and inferences of Penny et al that are listed in section 5, affect their main findings:

Properly addressing this point requires: (i) a better list of the main findings of Penny et al., (ii) a quantitative analysis (or very structured reasoning) that uses “better assumptions” and the available data to yield different conclusions than Penny et al.

Once such changes are made (if feasible), this critique could be changed into something that opens by an abstract that looks something like:

"Recent work by Penny et al. (2018) quantifies hydrological changes in the Arkavathy watershed, India, and finds that [LIST MAIN CLAIMS OF PENNY]. Here, we show how using local data and more realistic assumptions reveals that [LIST REVISED CLAIMS]."

Response: Thanks for sharing this feedback. In response to the above comments, we would like to state the following:

- 1] Our aim is to highlight the limitations of the methodological approach followed by Penny et al which is more suitable for the un-gauged catchment. In this reference only, we have explained how some of the assumptions and inferences (section 6) considered by Penny et al, for a watershed which is gauged, are factually incorrect. To this, we have provided analysis using secondary data (rainfall and groundwater levels) and literature.
- 2] The onus of relating with the existing literature in terms of approach, methodology and findings of those studies was with Penny et al. which they did not attempt. We have highlighted this in section 3 of the original manuscript.
- 3] Even If Penny et al. wanted to test their methodology for the academic purpose, the results should have been compared with those obtained using the available official data sets. The point we have highlighted in the conclusion section too.
- 4] In the abstract too, we have clearly highlighted the problems with their methodological approach. In fact, we finalised the abstract only after incorporating comments from the Editor.

[2] In many instances, the critique discusses the analysis of the Penny et al. paper without providing context for someone that is not familiar with all details of the Penny et al. work. For this critique to be more suitable for publication, I recommend that you always assume that the reader is not familiar with the details of this work, and you write the critique as a work that can be read as a stand-alone piece. In the list of detailed suggestions provided below, I have highlighted cases where sufficient background was lacking. However, I am unsure if this list is comprehensive, so please consider the entire text on this aspect in revising the paper.

Response: Thanks for providing a detailed list of suggestions. We have attended to all such suggestions, and will also do one more round of check before submitting the final revised manuscript.

[3] the overall quality of writing leads to many cases of inaccurate or unclear statements. In the detailed comments, I have highlighted where this is the case. However, I am unsure if this list is comprehensive, so please consider the entire text on this aspect in revising the paper.

Response: Thanks, we have addressed all such queries, and will also do one more round of check before submitting the final revised manuscript.

Detailed comments

PAGE 1

L9-14: see suggestion for reframing the work according to the major comment provided above, and the suggestion that the abstract will be much more useful if you state it something like: "Recent work by Penny et al. (2018) quantifies hydrological changes in the Arkavathy watershed, India, and finds that [LIST MAIN CLAIMS OF PENNY]. Here, we show how using local data and more realistic assumptions reveal that [LIST REVISED CLAIMS]."

Response: We have already explained in one of the previous responses that our aim is to highlight the flaws with the methodological approach followed by Penny et al. and the abstract clearly states it.

L16: replace "more so" by "especially".

Response: Thanks, it will be replaced in the revised manuscript.

L16: The increase in water demand is independent of how arid a place is (i.e. the Moon is an arid place, but water DEMAND is very low, and not changing). Maybe you want to state something about

water “stress” or a statement about “scarcity”? However, at present this argument is inaccurate. Please rephrase.

Response: We have argued that globally there has been increase in water demand for countries in arid and semi-arid regions. We are not saying that aridity results in increase in water demand but it surely induces water stress. For instance, in India, most of the agricultural prosperous regions (North-western and western India) are semi-arid to arid with increasing water demand for agriculture being now met or planned to be met through inter-basin water transfers. Indira-Gandhi Nahar Project and Sardar Sarovar Narmada Project are some examples. We will make the argument clearer in in the revised manuscript.

L17-18: “closure” is unclear wording in “are on the verge of closure or are already closed, with”. (I understand what you mean, but why not simply replace it by “have”. Also, do you have any references supporting this statement?)

Response: Agreed, we will revise the statement in the revised manuscript. Sure, we will also provide the reference for the same (IWMI published some studies).

L20: Maybe “rivers and aquifers” is better since “aquifers” are parts of catchments”?

Response: Here we have used term catchment as it may have structures to harvest surface runoff. Hence, rivers cannot be considered as the only source of surface water.

L20-24: this explanation seems redundant. In case you’d you like to keep it, please rephrase the text as you only cover part of the potential causes of hydrological changes.

Response: We would like to keep it as it informs readers on the potential reasons for long-term changes in runoff and groundwater availability. In our opinion, this is very much related to the theme of article being commented upon.

L24: "In addition to" or "apart from"?

Response: As suggested, we will make a change in the revised manuscript.

L25-26: "as most of the time it is the people in the latter that get affected by the hydrological changes occurring upstream." seems like a statement that can be supported by a reference?

Response: Yes, we will provide reference/s in support of this statement in the revised manuscript. Thanks for pointing this out.

PAGE 2

L1: "thus" is not warranted here. "Which suggests" or "which may lead to" seems more appropriate.

Response: ‘This suggests’ seems to be better, in any case we will make the correction in the revised manuscript.

L5: "A few recent" or "Several"?

Response: India has made tremendous progress with its water resources data management system, India-WRIS being a perfect example of it. Researchers are regularly using data sets and information (on Hydrology, groundwater, and meteorology) from India-WRIS. Thus, we would like to keep this sentence as it is.

L5-7: Your wording suggests that this is an issue that is more wide-spread than the two citations that are listed here. Providing a more comprehensive reference list would be useful.

Response: In our experience, in most of the cases such perceptions are from the researchers based in institutions outside India. It is usual that they may not have access to right sources of data and information. Nevertheless, we will explore whether we can find one or two more such studies.

L7: "the official agencies" suggests you refer to specific agencies. Do you mean "official agencies" in a broader sense? If that is the case, remove "the".

Response: Fine, we will remove 'the' in the revised manuscript.

L8: "are debated among the researchers." do you mean "discussed in person" or "discussed on published works". If the latter is the case, please cite some examples.

Response: Yes, we mean discussed in-person.

L8: Please cite the studies which refer to "In some cases"

Response: Thanks, we will add references in the revised manuscript.

L18-29: So if these data are available, show the reader how if they lead to the same or differences inferences than the main points of the Penny et al paper.

Response: We would like to clarify that our objective of the commentary is to highlight that when official validated data sets are available, why RS and GIS is being adapted as a methodological approach to assess hydrological changes? Because of the latter approach, Penny et al. has made some assumptions which are incorrect. This assessment is based on our experience of working in river basins in India and also on various other studies which have been cited in section 3. We also specify in the conclusion section that 'their approach would have benefitted by comparing the results obtained from the distributed assessment (appropriate for un-gauged catchments) with the integral assessment based on officially available long term data'.

Entire section 3: state HOW previous literature relates to their work, rather than just stating they did mention past works in this regions

Response: This is what we have suggested that they should have 'analysed the existing studies on river basin management in India by including a critique on the approach, methodology and findings of those studies if they find them to be lacking in any way' (L 7-9, section 3, page 3). The real issue is Penny et al. did not even attempt to relate to the existing studies.

PAGE 3

L31: "somewhat hard to comprehend" is vague. Can you be more specific?

Response: There are certain changes which have been made in consultation with the editor, this is one of them. We have no problem if it needs to be further revised.

Section 4: “surface water extent” seems clearer than “water spread area”.

Response: In our opinion, when it comes to highlighting changes, water spread area appears more scientific. Extent denotes a range.

PAGE 4

L3-9: Assuming zero outflow sounds naïve, but does it really matter given Penny et al state that when overflows occur “S is equal to its maximum S_{max} , so that variations in overflow cannot contribute to changes in observed S”? Thus, are these overflows not (implicitly) accounted for by having defined a maximum storage?

Response: We have checked again on the ‘outflow’ assumption in Penny et al. They state ‘variations in Q_{out} can be neglected, for two reasons: first, because watershed managers report that tanks rarely overflow, so Q_{out} (overflows leaving the tank) can reasonably be approximated as=0, and, second, because any overflow that does occur implies that S is equal to its maximum S_{max} , so that variations in overflow cannot contribute to changes in observed S’. There are two different reasons. We would like to clarify that our argument is for the first part of this statement that Q_{out} can reasonably be approximated as=0. This assumption will certainly affect the results as Q_{out} is one of the variables used for eq. 1 in Penny et al. Hence, we would like to retain this argument as it is.

L10: I would change section heading because "unit" implies that the authors made some errors in the dimensions of the analysis (which is not the case).

Response: We assume this is a suggestion for Section Title 4 on page 3. We will replace ‘unit’ with ‘assessment unit’ in the revised manuscript.

L10-20: It is fine to show precipitation time-series, but it would be much more useful to actually calculate how these precipitation time-series affect reservoir behavior. Reservoirs buffer variations in rainfall and therefore do not necessarily show the same place-to-place variations as observed in the rainfall time series.

Response: Thanks for sharing this observation. However, Penny et al. have used tanks as their assessment units which actually are much smaller in scale than reservoirs and thus have limited capacity to buffer variations in rainfall. We have highlighted this, please refer to lines 18-21 on page 4 of the original manuscript.

L22-24: Since these data exist, show us what these data look like and state if they are consistent, or contradicting, the findings of Penny et al.

Response: We have analysed the groundwater data for the Arkavathy watershed which has been presented in detail in section 6. Please refer to lines 4-13 on page 5 and Figure 3 on page 10 of the original manuscript.

L26-27: “Our contention is that farmers’ data might be useful to understand the socioeconomic aspects of local groundwater use but certainly not for understanding ground- water behaviour at the local or regional scale.” It may be more fruitful to say “We explain how” rather than “Our contention is”:

Response: It is a reality based on our experience of working in hard rock regions of India, hence the word contention is used. We will replace 'Our contention' with 'Our experience' in the revised manuscript.

L30: "very sweeping inference" why "sweeping" in this context?

Response: Sweeping in two context: 1] As we explained in previous lines (27-28, page 4), recall or perception based data cannot be used for understanding groundwater behaviour at the local or regional scale; and, 2] As we have explained in lines 30-33 on page 4 and lines 1-3 on page 5, groundwater behaviour in hard rock formations (as in Arkavathy watershed) is a complex phenomenon, thus measurements must essentially be the static water levels (as monitored by CGWB, an official agency) and not any other dynamic water levels (as encountered in wells which are regularly pumped by farmers) due to 'unsteady-state' conditions that exist in the area surrounding the wells.

PAGE 5

L4-6: "Contrary to the findings of Penny et al. (2018), the data of observation wells installed by CGWB that monitor groundwater level in the basin indicate that the groundwater fluctuation due to draft is positive in a major part of Cauvery middle sub-basin where Arkavathy lies." If this is the case please SHOW these data, rather than just state it.

Response: We have presented the data set in Figure 3 on page 10 of the original manuscript.

L9: "because of the negative gradient with respect to surface water bodies" do you mean something like "because they are located at lower elevations than surrounding surface water bodies"?

Response: By the negative gradient we mean that the water level in wells is at the lower elevation with respect to the water level in the surface water bodies. We have further explained this phenomenon in lines 9-12 on page 5 of the original manuscript.

L9-10: "inflows received by stream passing through Indian cities are wastewater." If this is the case, do you have any supporting this statement, or is this statement based on your local expert knowledge?

Response: This is based on expert knowledge and as well as studies pointing to closed nature of river basins in Peninsular India (where Arkavathy watershed lies). We have already agreed to provide reference with respect to the closed nature of these river basins.

L10: what do you mean by "the quantum of the flow"?

Response: It refers to the amount of water, we will make it explicit in the revised version of the manuscript.

L9-13: This is an interesting statement, but, at present, it seems to rely purely on speculation, rather than any data supporting that this is happening:

Response: As indicated in one of the previous responses, this is based on our local expert knowledge on the hydrology and geo-hydrology of the Peninsular India which is mostly underlain by hard rocks. In this region, wells go dry during summers (seasonal groundwater scarcity) but surface water bodies continue to receive wastewater from the city. We have provided data on amount of wastewater

which flows from Bangalore city to one of the reservoirs in Arkavathy watershed (line 12-13, page 5). This leads to higher hydraulic gradient in the stream than in the groundwater (as wells are dry). We will further strengthen the paragraph by including discussion on the seasonal groundwater scarcity aspects and providing some references for the same.

L15: "quite" seems redundant

Response: We will remove it in the revised manuscript.

L19: "will only yield misleading results" is a purely speculative (and very likely to be wrong) statement.

Response: Misleading in terms of approach which we have discussed all along our commentary. We will make it clear in the revised manuscript.

L15-22: Similar to the changes that are needed for the abstract. Rather than stating that Penny et al are wrong, SHOW how they are wrong

Response: We will again emphasize, our commentary is on the approach followed by Penny et al., which we have discussed in detail. Even the conclusion (lines 19-23 on page 5) ends with the same note.