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Interactive comment on "A multi-tracer approach to constraining artesian groundwater discharge into an alluvial aquifer" *by* Charlotte P. Iverach et al.

Anonymous Referee #1

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This is potentially an interesting study with important results and HESS would be a suitable place for publication. I started making detailed comments on the earlier sections (and have included them below as they may be useful) but once I got to Section 4, which represents the bulk of the scientific discussion, I came to the conclusion that the paper needed major rewriting and reorganization before it was suitable for publication. In its present form it is difficult to comprehend and I do not think it would be impactful.

I have outlined some of the problems below together with suggestions.

The results and discussion section is poorly set out and not convincingly written. For example, take the text near the start of section 4.1 (line 343):

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Discussion paper

“There is an excess of both Na+ and HCO3- in the groundwater of the LNA (Supplementary Table 2), compared to ion ratios expected from local rainfall sources and other shallow groundwater alluvial systems in eastern Australia (Martinez et al. 2017). Their abundance defines the ubiquitous presence of Na-HCO3-type groundwater we observe throughout the study area. The Na-HCO3 ratio in GAB groundwater is generally 1:1 (ppm) (Radke et al. 2000; McLean 2003), which is reinforced by the position of the regional GAB samples in Figure 3a. The Namoi River and other regional streams have lower Na+ and HCO3- concentrations and a lower Na+/HCO3- ratio than both the historic GAB data and the deeper alluvial data collected in this study.”

This paragraph makes conclusions without explaining their basis and does not adequately describe the data (it just points the reader to tables and figures where the data are summarized / plotted). There are also several concepts mixed together (the ion excesses, the comparison of water from different reservoirs).

The next part of this discussion (lines 351 to 362) alsomixes observations with conclusions and deals with a variety of processes (mixing, evapotranspiration, and calcite saturation). There are again few details; what does “towards calcite saturation” mean (what are the saturation indices, where do you discuss them)? Why is the calcrete important (is it found at groundwater discharge points in the watershed, for example?). I agree that the halogen chemistry in Fig. 4 is consistent with evaporation but you need to explain why that is so in the text (perhaps more to the point is this important for understanding recharge and mixing?).

Most of the other sections / paragraphs in the results and discussion are similarly hard to follow. For example the discussion of Tritium (lines 416 to 431) includes discussion on historic Tritium concentrations with the distribution of Tritium from this study. The latter is never illustrated (the data are in a supplemental table but the spatial variation is important so should go on a map or section). The Tritium activities are not specified so sentences such as “However, despite decreasing activities, 3H remains relatively prevalent in the deeper part of the system.” are very non-specific. The conclusion

reached “This indicates the extent of recharge from episodic flooding and shows that surface recharge reaches the deeper LNA (down to ∼80 m bgs) relatively quickly (< 70 years).” then becomes impossible to assess.

There has been a lot of work on determining residence times and mixing from concentrations of radioactive isotopes (including by the coauthors of this paper). Much more could be done to firm up the conclusions, for example some of the samples on Fig. 5 seem to not have undergone extensive mixing and probably could be used to determine residence times.

In section 4.3 it is not clear whether the Chlorine-36 data are being interpreted in terms of ages or mixing. Elsewhere, you have stressed mixing but here you calculate ages. This is despite Chlorine-36 being notoriously difficult to use for anything other than broad indications of residence times due to the input function varying (in unknown ways) over time due to climate variations. The Chlorine-36 ages are presented without much skepticism or discussion.

Calculations through Section 4 are poorly presented. For example, the discussion of mixing (lines 509-530) uses a single composition for the end-members and these is no sensitivity analysis. The results are presented without much discussion of uncertainties etc.

Section 4 is not helped by its structure. It mixes introductory material (e.g., lines 453-455), conclusions, and description. It is also not very tightly written and uses mainly qualitative descriptors rather than specific values. It is possible to mix results and discussion, but it needs skill otherwise the text becomes meandering and there is commonly not the rigor in explaining the salient features of the data before they are interpreted. The conclusions of this paper are plausible, but the way that it is written does not do them justice.

Some suggestions for revamping the paper are:

1) Separate the results and discussion and make sure that you adequately describe the important pieces data (don't just say which diagram or figure it is contained in).

2) Concentrate on what is important. The aims of this study is to understand recharge and mixing, in which case some of the details of the water chemistry seem superfluous. For example, it is important to determine whether the GAB waters and local recharge have different compositions but some of the details of the processes could be omitted. The Chlorine-36 is more valuable as an indicator of mixing rather than residence time, but recharge rates estimated from Tritium are important.

3) In a similar vein, the paper would be improved by more hydrologic information at the expense of some of the detailed geologic information. Is the interpretation of mixing consistent with the hydraulic heads? What are the groundwater flowpaths?

4) Include enough justification of calculations to make them convincing and some sensitivity analysis or discussion of uncertainties.

I am guessing that the senior author is a graduate student. The coauthors, however, are not and should have picked up on the more obvious problems with the way that this study was framed and presented.

Specific comments

Introduction

The introduction provides a general outline of the science and the reasons for carrying out the study. The first paragraph is not very clearly expressed. For example âĂć Why specify "modern infiltration" – recharge implies modern processes âĂć "Spatial and temporal data resolution and heterogeneity in hydrogeological properties result in considerable uncertainty when allocating recharge to each source and mapping pathways of flow" is very unclear. âĂć What is a "dynamic groundwater gradient"?

The introductions to papers are important as they frame the study and hopefully persuade the reader to continue reading, so it is worth making them as clear as possible.

Line 86. What do you mean by “modern/submodern”?

Line 89. It would be useful to explain briefly how the various isotopes help understand mixing as it might not be clear to all readers.

Line 96. It would be clearer if you split this material off as your objectives get lost at the end of the discussion of the techniques (perhaps put a subheading in for emphasis).

Lines 98-99. This is stating a conclusion, which you should leave until later.

Study Area

This section provides a comprehensive description of the study area. Some specific comments

Lines 139-141 is difficult to follow for anyone not familiar with eastern Australian groundwater hydrology. Can you add a key map of the basins to Fig. 2?

Lines 141-162. The description of geological framework is difficult to relate to Fig. 2 as you do not specify the age of the various units. Provide a few more details in the text.

Section 2.1 is probably too detailed for the study. While understanding the geology of the area is important, I am not convinced that the geologic history needs to be gone through in this much detail (for example, is the rainfall variation between the Miocene and today important for this study). This section could be cut fairly substantially. What would be more useful, and which is not there, are firstly some hydraulic properties (K, porosity etc) and secondly some description of groundwater flow.

Lines 197-201. This repeats material in the introduction and could be removed.

Line 205. The numerous Merrick references seem to be to a series of non-publically available documents. The reference to the Kelly et al., summary would seem sufficient.

Lines 208-209. Not clear what you mean by “There are equivalent solutions for all water balance models and the solution presented is often constrained by several factors.”

Section 2.2.1 does not add that much useful. You state that there are a range of models but provide few details. The discussion of the models seems to reside only in unavailable consultants' reports and then the point about not taking into account geochemistry is reiterated. This section could be shortened, especially as you do not make detailed comparisons with specific models later in the paper.

Figures

Fig. 1. Define "bgs". Rather than describing what is on the two axes, just label them in the graphs. Text on the map is too small (you could make the map larger and put the Australian map in an unused corner)

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