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.

We thank the reviewer for taking the time to review our manuscript closely. We have accepted the majority of suggestions detailed below, in particular the suggestion to reorganise the results-discussion sections. Throughout this response reviewer comments are bold whereas our responses are normal font.

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):

"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 results and discussion have been split now and both sections have been updated. The results section starts at line 357 and is split into major ions, water stable isotopes and isotopic tracers. The discussion section at line 438 and contains the same headings as the original paper.

The next part of this discussion (lines 351 to 362) also mixes 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?).

The discussion on calcrete has been deleted in the streamlining of the manuscript in our attempt to remove anything that was tangential to the primary story we are presenting.

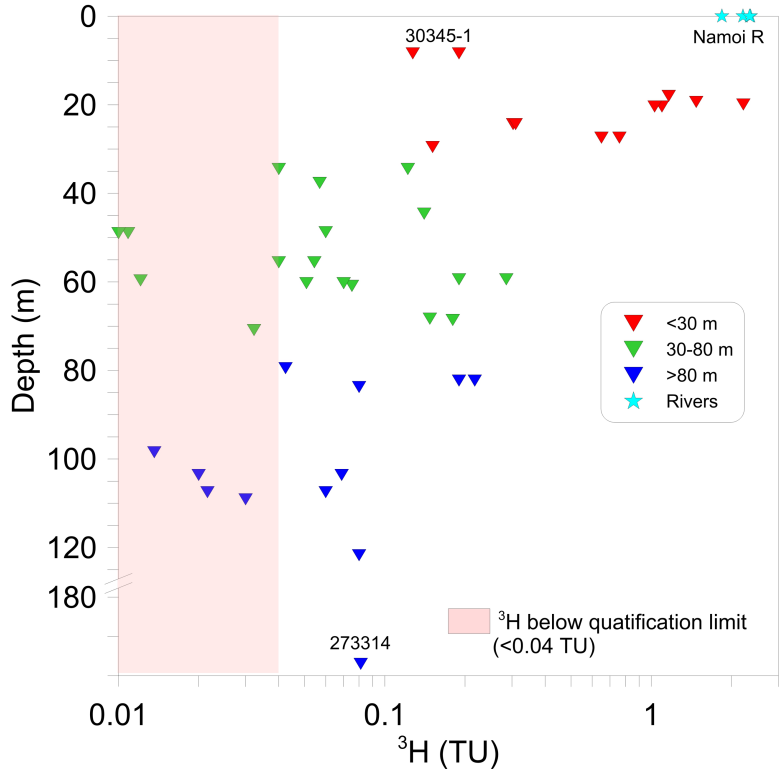
I agree that the halogen chemistry in Fig. 4 is consistent with evaporation but you need to explain why that is so in the text (perhaps more to the point is this important for understanding recharge and mixing?).

At line 453 as part of the new discussion we state "As we assume that Cl^- is behaving conservatively (Appelo & Postma 2005) we surmise that increases in dissolved major ion

concentrations concomitant with increases in Cl^- in the shallow groundwater are likely to be a result of evaporation" to explain our interpretations regarding the increases in major ion chemistry. Additionally, this comment now refers to the new Figure 3a, b, and c in the results section. Further, all parts of figure 3 are also primarily used to show mixing between the GAB and the alluvial groundwater.

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.

3H activities are now included and described in the results section (Section 4.3 – line 417). Past data is introduced mentioned in the discussion (lines 483-488), to put our results into regional and temporal context. We have now added a plot of 3H (TU) vs depth (Figure 5 - as seen below) so that the reader can easily put into context the activity of 3H at a given depth throughout the LNA. The rest of the discussion has been edited so that any results are now in the results section and the writing cleaned up.



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.

It is correct that some samples in the old Figure 5 (now Figure 6 in the revised manuscript) have not undergone extensive mixing. That is firmly portrayed in the original figure 6 (now Figure 7) for the same dataset. We included residence time ranges in figure 6 (now 7) for both end-members. However, this is not a paper about complex dating corrections and decoupling of residence times in mixed samples, which we have now emphasised at lines 108-112. The emphasis is on identifying main groundwater sources within an alluvial aquifer, the use of a multi-tracer approach and to bring attention to water managers about the dangers of utilising simple hydrogeological models without incorporating any hydrochemical evidence.

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 scepticism or discussion.

We agree that 36Cl can be notoriously difficult to interpret and we have acknowledged this in text now (lines 87-90). However, the Pilliga Sandstone has low and fairly consistent Cl concentrations, so if there was ever a system where 36Cl could be used to say something about GAB residence times, it is this one (this has also been mentioned at the same location: lines 87-90). This is the same for the Coonamble Embayment elsewhere (eg. Mahara et al. 2007). There is an abundance of regional background information on 36Cl, which we refer to throughout the manuscript. Using similar assumptions applied to 36Cl elsewhere in the GAB, we provide some residence times (line 520), only applicable for the extreme GAB end-member. The caution and scepticism regarding "absolute ages" is incorporated in figure 6 (now Figure 7). The 36Cl section (section 5.2 – line 506) reinforces the mixing processes and only provides some residence time interpretation for the extreme end-members, similarly to what is done with 3H (see original figure 6).

Mahara, Y., Habermehl, M.A., Miyakawa, K., Shimada, J. and Mizuochi, Y. (2007) Can the 4He clock be calibrated by 36Cl for groundwater dating? Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms 259, 536-546.

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.

We have added a 'Geochemical calculations' section (section 3.3 – line 326) to explain our calculations in the old results and discussion. Regarding uncertainties, mixing and other processes (such as evapotranspiration and irrigation returns) can overprint the simple Cl mixing. However, the Cl mixing isn't considered in isolation – this is where our multiple tracers come into effect. For example, samples with [Cl] < 31 mg/L, 3H activities above our detection limit (> 0.04 TU) and/or 14C > 90 pmc are considered as 100% modern (< 70 a) flood recharge (eg. 36001-1&2, 25329-1, 30345-1, 25332-1, 25327-1&2). In this case, two samples (25327-1&2) with anomalously high NO_3 concentrations could be influenced by potential irrigation returns. Conversely, samples recovered from generally deeper piezometers along the B-B' section in figure 2 have higher Cl concentration that coincide with 3H below or very close to

the detection limit, 14C contents generally < 5 pmc and, most importantly, 36Cl/Cl below 58 ($x10^{-15}$) and are considered to be comprised of a higher percentage of GAB groundwater.

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.

The results and discussion have now been split and the writing throughout the entire paper tightened. All the results are now explained using their specific numbers in section 4 and we have aimed to remove most of the qualitative descriptors.

Some suggestions for revamping the paper are:
1) Separate the results and discussion and make sure that you adequately describe the important pieces of the data (don't just say which diagram or figure it is contained in).

Results and discussion have been separated. The results section now describes important aspects of the data such as parameter ranges and trends (Section 4).

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.

The manuscript has been cleaned up substantially, primarily as a result of the restructure. Discussions on sustainability have been omitted and the geochemistry of the groundwater, and our multi-tracer approach to estimating GAB discharge made the focus. We have further included clarification of the 3H results (Figure 5 and section 5.1.1 – line 476) and detail on how we use the 36Cl data (section 3.3 – line 326, section 5.2 - 506, Figure 2).

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?

The geologic information has been considerably shortened and we have added more hydrologic information such as the general groundwater flowpaths and K values (lines 180-184).

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

Please refer to our comments above regarding the calculations.

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, Why specify "modern infiltration" – recharge implies modern processes

The first paragraph has been restructured and edited. "modern" has been removed

"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.

At lines 53-54 this sentence has been revised to make it more comprehensible. "…mapping pathways of flow" has been removed as it wasn't pertinent to the story (compared to allocating sources of recharge) and made the sentence laborious.

What is a "dynamic groundwater gradient"?

"Dynamic groundwater gradient" has been changed to "…change in the magnitude of groundwater gradients and direction over time…" (line 56).

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"?

Submodern has been removed.

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.

We have included a simple sentence at lines 77-79 to explain how various isotopes help understand mixing ("Isotopes of dissolved species can be useful for elucidating groundwater mixing provided the different sources of groundwater have distinctly different and consistent isotopic signatures"). We also refer to Bentley et al. 1986; Andrews & Fontes 1993; Love et al. 2000; Moya et al. 2016 at this location for the reader to peruse for further information.

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).

We have made this a new paragraph so as to emphasise the objectives (lines 97-109).

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

We have changed the end of the introduction (lines 97-109) to now state only what we did, rather than what we found and moved the conclusions to the end of the manuscript.

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?

We have included a map of the basins in the Supplementary Information for the readers' perusal, which shows the extent of the GAB, the Surat Basin within the GAB and the overlap of the Surat and the Murray-Darling. We have adapted the image to show the location of the study area.

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.

Age of the various units has been specified in text throughout lines 141-156 now.

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.

This section has been shortened considerably. There is no porosity or permeability data for the region, however we have added some K values and we explain the general direction of groundwater flow (lines 180-184).

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

This section at 188-192 has been shortened, however not removed completely because it highlights the gap in the literature regarding the use of catchment water balance models together with hydrochemical data.

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.

The references have been eliminated and instead Merrick 2000, a PhD thesis available through the UTS library, has been used (line 196). Additionally, Kelly et al. 2007 has been included in many of these places.

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."

We agree and this sentence has been changed to "There are multiple plausible solutions for all…" (line 198).

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.

This section is core to the problem with respect to the issue of water balance modelling in the

Namoi. We have removed the references to unavailable reports and replaced with a PhD thesis (Merrick 2000) but we have left the section (beginning at line 194) in the manuscript so that the 22% GAB contribution that we later use for comparison to our estimates of 70% have some basis.

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)

Bgs has been defined. We describe the axes rather than place them on the graphs because the font is too small otherwise and the repetition of labelling the axes on every graph was taking up too much room. The map has been made larger and the map of Australia placed in an unused corner of the map.