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Interactive comment on "Groundwater mean residence time of a sub-tropical barrier sand island" *by* Harald Hofmann et al.

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General comments

Reviewer 1: The paper nicely shows how environmental tracers provide information on groundwater ages and on the functioning of groundwater systems. The issue addressed in this paper – hydrogeology of sand barrier islands – is of global relevance. Presented results contribute to the understanding of this important groundwater resource and its sustainability under conditions of population growth and climate change. The paper is well written and structured. The background, environmental context and purpose of this work are clearly explained, followed by a well-balanced and comprehensive presentation of the tracer and modeling approaches. The data and modelling

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results are presented in a clear manner.

Response: We thank the reviewer for the overall positive comments on this manuscript and pointing out the global relevance of this study.

Reviewer 1: A question arises, however, what is the main contribution of this work? The discussion and conclusions sections highlight two results of the tracer exercise: (i) spatial distribution of groundwater ages identifies groundwater flow paths, (ii) low permeability units are responsible for long MRTs.

Response: As we discuss in section 5.2 and following, the paper demonstrates that groundwater flow in coastal sand masses is much more complex that previously thought. Using the tracer data combined with field observations to construct conceptual models that is outlined in the discussion is a major contribution to the overall understanding of groundwater flow in coastal sand masses. This conceptualisation is important for modelling exercises and for determining the sustainable use or groundwater and/or the potential impacts of groundwater use. We will emphasise these points more when we do the revision. Studies investigating the spatial distribution and total impact of lower permeability units in coastal sand dunes would certainly help to better understand the hydrogeology.

Reviewer 1: Ad (i). It is not surprising that the distribution of MRTs conforms the presumed picture of a "groundwater mound" with uniform recharge and dominant unconfined flows perpendicular to island's axis simply because the LPM was selected accordingly. What is an added value coming from the application of tracers? Furthermore, in my opinion the dependence of tritium concentrations on the distance from island's centre and bore depth as shown in Fig. 5 is not obvious. There is a lot of scatter in these data. Could this scatter and other discrepancies in MRT results be due to a more complex than assumed structure of groundwater flow?

Response: Figure 5 is key to understanding that flow patterns are relatively complex. There is a general trend from the centre of the island (groundwater mount to both

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coastlines, which is what one would expect for sand islands in general. However, as discussed in the paper (section 5.1) the tritium distribution and calculated MRTs are less regular. This indicates that the flow paths are more complex than assumed in some of the previous groundwater models (Leach and Gallaghar, 2008). The tritium data thus adds significant value in providing a more valid conceptualisation for any future modelling exercises than could be determined from the groundwater heads and hydraulic properties alone. This is discussed in the paper (section 5.4 & 5.5) and we will emphasise this in the revision.

Reviewer 1: The authors mention “minor” longitudinal flows due to the complex topography not discussing this question further. This is understand-able as the study is based on one transect only, which might be its main short coming. If the topography is complex, then could the longitudinal flows occur? For example, do the dunes have any dominant orientation (due to prevailing wind conditions in the past), or is the island’s relief completely irregular?

Response: According to the literature and field observations, the dunes have formed from predominantly onshore south-easterly winds. The aquifer and dune systems are elongated north-south and, while there is the possibility of some longitudinal flow, the available groundwater head data indicate that flow is predominantly eastward and westward from the centre of the island. The transect of state government groundwater bores were installed parallel to the dominant groundwater flow direction. While we recognised the possibility of longitudinal flow, there are very few bores to the north of the transect and access is limited to the south due to mining lease access restrictions. A larger more spatially distributed sampling network would have been preferable; however, we are confident that we have sampled perpendicular to the main direction of groundwater flow and thus that the pattern of MRTs is representative.

Reviewer 1: Ad (ii). The only direct evidence for that comes from a comparison of MRTs in two bores. How relevant is this finding to the overall flow patterns? Again, how widespread are peat deposits along the island? Are they continuous or patchy?

Unfortunately, the conclusions section lacks the clarity and accuracy of earlier sections. The contribution and added value of the paper should be more clearly expressed.

Response: There was only the one nested bore site available, which we agree limits the certainty of this conclusion. As peat layers are very common across the island and occur around most wetland and lake systems, this is potentially an important point. We will revise the conclusions to clarify that this is an isolated observation but one that is important in understanding the overall hydrogeology.

Specific comments

Reviewer 1: Given some ambiguity in the understanding of terms “residence time” and “transit time”it is advisable not to use them interchangeably.

Response: We thank the reviewer for the comment and will adopt “residence time” throughout the text.

Reviewer 1: Lines 83-90. A more detailed description of topography (with a picture showing the landscape?) will help to comprehend the natural setting – see the general comments. Is the vegetation cover of dunes continuous?

Response: The vegetation cover of the dunes is continuous apart from wetlands, lakes, tracks and mining operations. We will note that in the revision. We can add a picture of the environment but would prefer to add it to the supplementary materials.

Reviewer 1: Lines 92-93. How do precipitation and evapotranspiration vary seasonally?

Response: There are slight differences in precipitation and evapotranspiration between winter and summer. In general, south-east Queensland has dry winters and most of the rainfall occurs during the summer months. The mainland variability is dampened on the coast with possible rainfall across the year. Evapotranspiration is lowest in winter (June/July) and highest in summer (December/January). We will add this information to the revised text.

Reviewer 1: Figure 4. Some of groundwater samples seem to be affected by evaporation. Could the low d-excess waters indicate recharge from wetlands? On the other hand, two samples have very high d-excess values. Do the stable isotopes have in this case any potential as indicators of recharge areas and flow paths?

Response: We agree that some of the groundwater shows signs of evaporation. It is also true that evaporation does occur in the lakes at the wetlands. However, as discussed in the Discussion, the wetlands and lakes probably hold back water from directly percolating to the regional aquifer. Most lakes and wetlands are underlain by perched water tables that are not directly connected to the main aquifer. With regards to the two samples with the high d-excess, we were not able to find a systematic connection between these samples and recharge patterns.

Reviewer 1: Line 261. The decrease of tritium activities with distance from centre is obvious for the first 2500 m only – see general comments.

Response: As discussed above, this indicates the complexity of the dune systems and that flow patterns are not as simple as previously thought, which is one of the main conclusions of the paper. We will add a few more sentences to explain the data better and emphasise this finding in the Discussion.

Reviewer 1: Lines 230-1. What is a possible source of carbonate in this presumably carbonate-free geological setting? Are there any secondary carbonate deposits associated with paleosoils? If not, does the bedrock contain any carbonate? In the latter case, higher carbonate dissolution is related to groundwater contact with the bedrock or groundwater discharge from the basement.

Response: As mentioned in the text (lines 327-328), carbonate dissolution is minor and has probably affected only a few samples. The general hydrogeochemical environment has mostly lower pH values and secondary carbonates in topsoils are very unlikely. We agree that paleosoils are likely sources of DIC. An explanation for higher d13C that we haven't considered yet is sea spray, especially for those bores in the east close to the

ocean. We will add this to the discussion. The correction for DIC dissolution produces slightly younger MRTs, however, the MRTs are still longer than were initially expected probably due to the complex flow patterns.

Reviewer 1: Line 325. What is the actual carbon isotopic signature of soil DIC and how was it derived?

Response: The soil DIC 13C values are based on literature values as mentioned earlier in the paper (lines 272). We will amend this here and be more specific that the values are estimated.

Technical comments

Reviewer 1: Figure 5.A is not mentioned in text.

Response: We will add a reference to figure 5A in line 261.

Reviewer 1: Line 267. Test hole or testhole?

Response: We will correct this to “testhole”

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