Reply to Reviewer #2

1. While the paper points out challenges in measuring gw-sw interaction, including a nice summary table by method, the challenges do not link up with the specific issues in braided rivers. In other words, the challenges would apply to all river types. For instance, the authors mention how heterogeneity makes it difficult to measure flow. While braided streams may be more heterogeneous (however that is defined), all streams would benefit from methods that address heterogeneity. I would have liked to see how the cross-sectional heterogeneity (in contrast to along reach) impacts measurement techniques. That said, Genereux's group has some papers illustrating both along-reach and cross section variation in streambed K, so even this aspect is not unique to braided rivers. The advantages and disadvantages sections list challenges that would apply to other stream types as well. The abstract and conclusions emphasize the need for multiple methods and consideration of scale in selecting methods, but again these recommendations apply to any river type. Without details about why a particular method works elsewhere but not on braided rivers, the paper lacks focus. It does not suffice to say a method is "more difficult" when it is difficult in a variety of river settings.

Response: Thank you for the constructive feedback. We agree that many of the challenges of conducting studies in braided rivers are also present in other river environments. However, in braided rivers these challenges tend to occur to a larger degree. We have attempted to convey this within the introduction and particularly in the paragraph at L60. However, we agree that this point can be made with greater clarity and we intend to revise the introduction in order to do so.

During the process of writing the review paper, we critically examined all published studies we could find on measuring groundwater-surface water interactions in braided rivers. We looked at all of the techniques used in these studies and attempted to summarise for the reader what was effective and what was not. In terms of a particular method that works elsewhere but likely not in a gravel-bed braided river, we specifically mention seepage meters in L773-778. However, we believe we can improve the manuscript in this respect, for example we can discuss how there have been various designs of mini-piezometers used in rivers, but many of these designs would be unlikely to be effective in gravel-bed braided rivers, which is why we point the reader to studies where they have been deployed successfully. Flow gauging for calculating catchment or reach-scale water budgets is another method that may be effective in

other river environments but is very challenging in braided rivers. For example, because of the errors associated with flow gauging it is very difficult to estimate losses or gains in reaches with a sufficient degree of accuracy. Flow gauging does not differentiate between groundwater inflow and hyporheic water re-emerging in streams, and given the significant portion of flow in braided rivers that occurs within the riverbed, this is a considerable issue. As another example, it is very difficult to take undisturbed core samples for hydraulic conductivity tests when the river substrate contains coarse gravels, as gravel-bed braided rivers do.

2. The paper provides a map of locations with braided streams, but does not justify why these locations are included and not others. The definition of what "concentrated" means in terms of distribution of braided streams is not provided. There is a list of braided streams in the US on https://commons.wikimedia.org/wiki/Category:Braided_rivers_in_the_United_States_by_state, which suggested that braided rivers are important in the US too, yet no sites there are listed. To list the map as a significant feature of the paper ("to the authors' knowledge, this is the first map of its kind") but provide no details on how the map was generated is frustrating to the reader.

Response: Thank you for your feedback on Fig. 1. We agree that the term "concentrated" is ambiguous and we will replace it in the text at L27 and L881 with "mainly found". This conforms to wording used in our justification for only displaying a selection of regions where braided rivers occur, at L64-66: "There are instances of braided rivers at locations outside of these regions (e.g., Russia, U.S., Scotland), however these locations are not shown in Figure 1 because, at a global scale, they are not where braided rivers are mainly found." To further justify our selection of locations displayed, we will add the following sentence to the manuscript at L64: "The regions displayed in Figure 1 are regularly cited in literature on braided rivers as the main regions where this river type can be found (e.g., Tockner et al., 2006; Hibbert & Brown, 2001)." We propose to add Russia to Fig. 1 based on comments in studies (Chalov & Alexeevsky (2015), Alexeevsky et al. (2013)) about the high number of braided rivers in the country.

In regard to braided rivers in the United States, we respectfully point to L64, where we did mention the U.S. containing braided rivers. Thank you for pointing to the Wikipedia link (https://commons.wikimedia.org/wiki/Category:Braided_rivers_in_the_United_States_by_state) , however it does not appear that this is a reliable authority on instances of braided rivers in the U.S. The webpage is a list of user-generated images that have included tags with the wording "braided river", however many of the images shown here do not appear to be of braided rivers (e.g. on the pages for Alabama, Virginia, Utah and Massachusetts).

3. The word "hyporheic" only appears in the abstract and end of the paper, not in the main body. This mention in the abstract should be removed since it is not a topic covered in the paper. It is probably better left to another paper as the issues in measuring hyporheic flow differ significantly.

Response: Thank you for your comment, however the term "hyporheic" was mentioned 16 times throughout the paper, and it was specifically discussed in conjunction with several of the cited studies. We believe this review would be significantly lacking if we did not include information on hyporheic flow processes. As we have noted at L100, issues surrounding hyporheic zone processes are of great importance in the management of braided rivers. There is a significant amount of river flow that occurs within the hyporheic zone in braided rivers. Further, as highlighted at L377, it is often difficult to distinguish between regional groundwater discharge into rivers and re-emerging river water from the hyporheic zone. While this is an issue that would be faced in other river environments, it is likely that this is more of an issue in braided rivers which 1) have highly permeable river bed strata, and 2) have a significant amount of river flow that occurs within the streambed. As Referee #1 highlighted (see comment #9), we need to clarify what we mean by hyporheic flow and the hyporheic zone, as well as better explain the related research gaps. Please refer to our response to Referee #1 (comment #9) for more details on how we intend to clarify this in the revised manuscript.

4. The modeling discussion is focused too much on MODFLOW. The description of MODFLOW packages can be found elsewhere and there are other models that incorporate groundwater-surface water interaction that could be discussed. For example, a recent special issue in Groundwater on integrated modeling included a paper on streambed heterogeneity. There is also a recent review paper on modeling gw-sw interaction in Reviews of Geophysics

that provides a broader view. The abstract mentions the need for new approaches in modeling, but the paper does not provide sufficient direction to justify this as a conclusion of the paper. The conclusion the models need more data and more sensitivity analysis has been stated many times before.

Response: In the review we focussed on MODFLOW as this is the code that most previous studies have used to model groundwater-surface water exchange in braided rivers. We agree that the description of MODFLOW packages can be found elsewhere and in the revised manuscript we will remove details of these. Sentences from L676 to 687 will be replaced with the following: "Several packages are available in MODFLOW for simulating surface water-groundwater interaction and further details about the application and limitations of these can be found in Brunner et al. (2009, 2010).

We agree that it would be helpful to include specific recommendations on new approaches to modelling including codes (such as HydroGeoSphere) and methods such as those detailed in Brunner et al. (2017).

5. I was surprised that fiber optic temperature systems (also known as DTS for distributed temperature systems) and geophysics were not discussed. These methods have been mentioned in other reviews and provide broader coverage which might benefit braided streams. I found it odd to bring up thermal imaging for the first time in the discussion section rather than in the review of methods, especially since it is mentioned in the abstract and it is one of the more promising techniques for heterogeneous systems. An example of the benefits of thermal imaging might provide an interesting figure.

Response: Thank you for your suggestions. We agree that the manuscript would benefit from discussing geophysical techniques and DTS as possible methods to apply in braided rivers. We have replied to this in more detail in our response to Reviewer #1 (see Comments #4, 7, 23 and 50). We will add more detail on additional methods that can be applied in an expanded "Key gaps and possibilities" section of the revised manuscript.

6. On the topic of figures, the figures were lacking in illustrative examples of applications. There was a map, but the other figures were photos or diagrams and didn't show quantitative

challenges or opportunities. In other words, I think it would help the readers' understanding to include data figures.

Response: In the revised manuscript we will consider adding additional figures that may be helpful to illustrate the techniques discussed.

7. One place that the paper focuses on braided streams is the literature review of methods. The paper summarizes applications in braided streams and the table of methods lists braided stream citations. However, the literature summary sections of the paper are a bit dry. They list highlights of each paper one after another. I think some of these papers could be describing non-braided streams and the reader would not know. This type of literature review needs to be briefer and provide synthesis of issues specific to the problem identified. In addition, a significant number of references (estimated 25% based on the first page of the bibliography) are not readily available literature but reports or theses (typically from NZ). Many readers will not have ready access and the focus on one region is not justified.

Response: We agree that it would be beneficial to shorten the sections that discuss prior literature, and we intend to do this in the revised manuscript.

We endeavoured to make it clear through the introduction that the review focusses on braided rivers, so that if there were other types of rivers discussed, we would specifically note this. We will add a sentence to this effect in the introduction, making this explicit.

In regard to technical reports and theses that have been cited, we apologise for not including URLs in the reference list and will fix this in the revised manuscript. We will also remove the following references that are not publicly available: Anderson (2004), Davey (2004), Aichison-Earl & Ritson (2013), Williams & Aitchison-Earl (2006).

We realise that there is a heavy weighting on studies conducted in New Zealand and this is not intentional by any means. The vast majority of published studies on this topic that we were able to find were based in New Zealand. In fact we chose not to discuss several New Zealand studies in the methods section as we felt studies from this country were over-represented. Through the process of gathering literature, we did consider possible reasons for the apparent over-representation of New Zealand studies. We considered that search engine results may have been weighted to display New Zealand studies as the authors were based in

New Zealand. To assess whether this was the case, in addition to more general searches, we specifically searched for literature in countries or regions (e.g., Italy) where braided rivers are common. This search method produced some, but not many, additional relevant references. Further, the majority of search engines used were via scientific indexing sites (e.g., Web of Science), which to the authors' knowledge, do not tailor search results in the way that Google does. We do acknowledge that we are likely to have missed literature published in languages other than English, but this issue is likely not unique to our review.

8. It can be difficult to meet the standards of a review article. In the end, I ask myself whether I would give this paper to colleagues to read, or just keep recommending Kalbus et al. or LaBaugh and Rosenberry as review papers on the topic. I do not think there is enough new material here for me to consider this paper to be an update on the earlier papers. If revising, I would recommend a very short review paper, which introduces Table 1 and gives the reader the reference list for readers to select topics on their own (rather than the one line summaries of each paper). The shorter paper also needs to provide the reader with an approach to braided streams that is distinctly different than other streams – this message will take additional synthesis and thus I would consider it to be a new paper rather than a resubmission. Hence, I am recommending rejection and significant redirection for any new submittal.

Response: We are grateful to the reviewer for their constructive comments. While there have been a number of review papers on surface water-groundwater interaction, none have focused on braided rivers previously and this is the gap we are wanting to address. We would argue that braided rivers have features that are unique enough to warrant a review paper that focuses on this river type specifically. As detailed above, we intend to revise the introduction to clarify the unique characteristics of braided rivers. We will shorten the review of previous studies in Section 3 and increase our use of Table 1 to provide guidance to the reader, as suggested. Also, we will work on expanded the "Key gaps and possibilities" section to enhance the novelty of the paper by suggesting emerging and promising techniques being used in other environments and that are likely to have application in braided rivers.

We have had very positive feedback on this manuscript from numerous groundwater researchers and managers within our networks and we look forward to using the guidance

provided by the reviewer to improve the manuscript. We are confident that we can achieve that as part of the current submission.

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