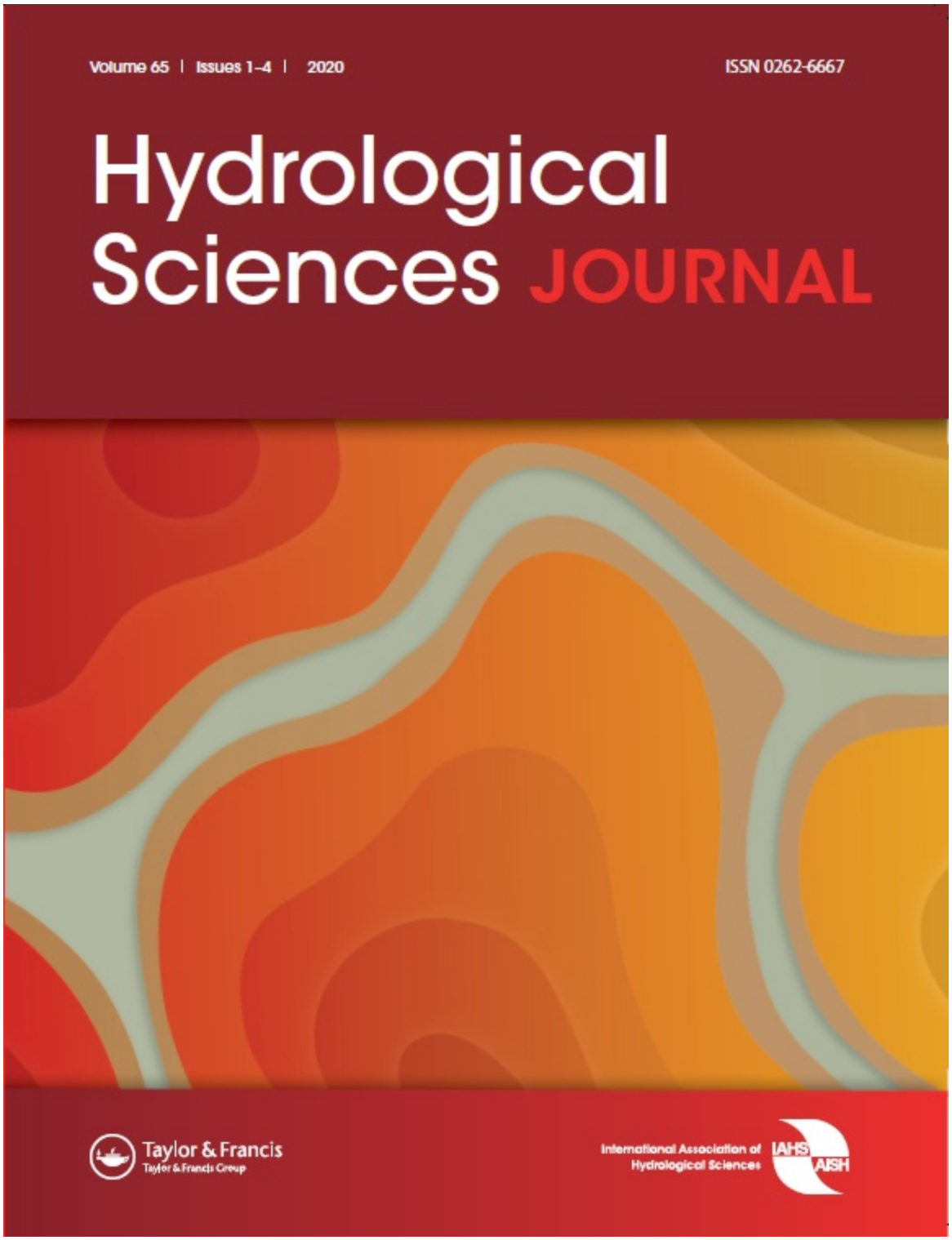

Bridging the gap: Discussion of "Guiding principles for hydrologists conducting interdisciplinary research and

fieldwork with participants”

Journal:	*Hydrological Sciences Journal*
Manuscript ID	Draft
Manuscript Type:	Reply to Discussion
Date Submitted by the Author:	n/a
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Keywords:	interdisciplinary, collaboration, social sciences, qualitative data, hydrology, fieldwork

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Reply

We thank both authors for their thoughtful insights into our original opinion piece "Guiding principles for hydrologists conducting interdisciplinary research and fieldwork with participants"

(Rangecroft et al., 2021). We fully appreciate the time invested by these two authors to reply to it and to build upon the ideas we introduced. We believe these discussions will help to inspire and guide current and future researchers and illustrate how to continue to bring together physical and social data, experiences, and perspectives, and bridge the gap between the two disciplines with respect to socio-hydrological topics. Furthermore, we are confident that these insights and experiences will help foster a deeper understanding for hydrologists and natural scientists engaging with these discussions and research.

In Quandt (2022), we get to understand in much more detail the importance of social science, and the qualitative social science approaches for researching water-related issues and topics in the field. This discussion, through its examples, demonstrates the advantages for using qualitative data collection. We believe it will encourage hydrologists to rethink the ways in which socio-hydrological knowledge can go on together and adopt a more open approach to comparing and merging quantitative and qualitative data collection. It is great to be able to bring these insights and experiences together for a more natural sciences audience, especially as many of the important points discussed by Quandt chimed with our initial thinking for our opinion paper (Rangecroft et al., 2021).

In Haeffner (2022), we see another complementary discussion from a social science perspective to help explore the importance of interdisciplinary research further. There are some key points made in this comment, including the necessary background information on interdisciplinary research, the issues around more funding available in the natural sciences, and ethics and research/experience on Indigenous lands and seas. Haeffner emphasises some very relevant points regarding the different ways of evaluating qualitative and quantitative research, and regarding the ethics of qualitative data and data collection. These discussions are extremely valuable to those conducting fieldwork with participants, and especially for those for whom this might be quite a new experience.

Here we focus on two important themes that cut across both Quandt and Haeffner's replies: 1) further discussions on the importance of perceptions and lived experiences; and 2) further discussions on collaborative working and some of the major external barriers. Both points also relate to the recently published editorial in Nature Sustainability (2021). Here, we show not only that there are water researchers interested in "how humans see water," but also how this can be studied. We further discuss the challenges of this interdisciplinary effort to overcome the gap between "elegant engineering solutions" and "messy institutions, norms and processes" which shape human-water interactions.

Perceptions and lived experiences

Haeffner (2022) mentions the importance of perceptions, which we completely agree – understanding perceptions is essential and extremely valuable. Perceptions stand at the basis of our behaviour, as research "subjects", as policy-makers, and as researchers. For example, when studying the dynamics of a river basin, leaving the perception of the residents and

decision makers out will leave us with at least one side of the story untold. We also fully agree about the importance of researching and including lived experiences, as mentioned by Quandt (2022). There are many ways to capture both. Whilst qualitative interviewing and storytelling are mentioned as the most effective, there are also many other creative methods available, for example participant observation, photovoice, archival analysis (e.g. McEwen et al., 2012; Miller & Brockie, 2015; Fantini, 2017; Rusca, 2018).

However, we would like to take this opportunity to highlight that one major limitation, and therefore a key consideration, of qualitative data is how time-consuming it can be to collect and analyse it. For example, the time required to process and analyse interview data, which may also potentially include translation of the data before analysis, depending on the project and researchers. This can be a limitation when linked to the, often short, time frame of funding, which could disincentivize the choice of collecting and using such data, resulting in a vicious circle. In addition, we also acknowledge the limitations, as well as the benefits, for how this qualitative data can be used in the end. The cost and time limitation could also result in the exclusion of rich qualitative data in dissemination results delivered back to stakeholders and participants if working to a tight project timeline and funding budget deadline.

Furthermore, as Haeffner (2022) states, lived experiences provide a huge wealth of information, but can be very case specific. It is incredibly important to enhance the transferability or applicability of the understandings and knowledge produced in these data-rich studies involving lived experiences, perhaps through lessons learned that might be useful in understanding other cases. Whilst the knowledge gained during a case study is context-dependent and not statistically generalisable, rich and detailed case studies that are well-selected in the sense that they are neither too context-specific nor too abstract, can help to produce robust theoretical explanations or concepts that are analytically transferable to other cases (Baxter, 2010). Haeffner (2022) also suggests journals allowing for longer papers with a different structure which could also help to promote this. We believe that the inclusion of this deep information on the social characteristics of the case study in comparison to other cases (e.g. with global maps of political, social, economic characteristics of regions) can also be helpful to enhance transferability. Furthermore, we think that transferability can be improved with some key qualitative metrics/threads, aligning with the social characteristics of the case study and how it can be transferred elsewhere. However, we also acknowledge that there are situations which are perhaps less transferable, such as First Nations knowledge practice which demonstrates geographically and historically distinctiveness, which results in resistance to generalisation.

With respect to qualitative data, Haeffner (2022) addresses a point that we were not able to fully explore in our original paper, qualitative evaluation criteria. Haeffner emphasises that qualitative standards favour trustworthiness and authenticity, meaning that they must be credible, confirmable, reliable, transferable, and reflexive. Knowing and applying these criteria can increase confidence in qualitative data for hydrologists, and ultimately help demonstrate that qualitative data are not just "nice to have" but are critical to contextualising quantitative data and results, such as hydrologic model results. Finally, this helps to ensure that both data sources are seen as equally important.

Collaborative working and interdisciplinary challenges

Quandt (2022) highlights an important note that scholars from the same discipline can fall into different areas of the philosophical spectrum. Collaborative research does not just involve bringing together two or more disciplines, but bringing together two or more different people (Beaumont et al., 2020). From our experiences, you may naturally find other researchers, potentially from different disciplines, or just from different parts of the spectrum in your own discipline, whom you form positive working experiences with, enabling more productive knowledge exchanges.

Whilst Quandt (2022) identifies that in general hydrologists may have much less experience collaborating with qualitative social scientists, as opposed to more quantitative social science fields, we have mixed experiences on this. We have found that it often depends on the research question of interest (as qualitative and quantitative social data are there for answering different questions), or the outputs needed, or the origin of the interdisciplinary working relationship. Regardless of if hydrologists are starting to collaborate more with either more qualitative or more quantitative social scientists, our proposed guiding principles for collaboration from our original 2021 piece are still applicable. For example, Quandt (2022) highlights the importance of case studies to allow researchers to study a specific socio-hydrological space or geographic area in a landscape. We completely agree and have seen a fantastic example from Beaumont *et al.* (2020) where a field site visit of a salt marsh was used as a way to bring together the different disciplines and perspectives of researchers as a first step in finding ways to communicate across the spectrum, with other examples found in Hayashi *et al.* (2022).

Haeffner (2022) also states that social-natural scientist collaborations “are often initiated by individual researchers rather than institutionalised by university departments”. We completely agree that there are more opportunities for positive institutional change at universities, funders and journals to encourage and support interdisciplinary work. From some of our experiences, interdisciplinary research can open new funding opportunities, however given that interdisciplinary working can require much more time, this might not be represented accurately in the funding opportunities available, or the expectations of the project and researcher involved.

However, a further problem can be exacerbated by science funding opportunities; researchers are often encouraged to focus on novelty in funding proposals, which means that new study sites are often proposed to help achieve this, which is then problematic for developing and engaging in long-term collaborations before starting funded projects. This is as much a problem for qualitative research, that needs time to build trust and thoroughly understand a specific system, as it is for quantitative research, with long-term hydrological field sites being underfunded and funding often only available for short monitoring campaigns producing a lack of long-term data. This again fuels our desire to see longer-term funding programmes for interdisciplinary research, instead of short-term project funding, to help address these challenges.

A longer-term vision and aim would ultimately lead to better research outcomes for researchers, as well as participants. For example, this is particularly the case when working in Aboriginal and

Indigenous communities. While it is essential to foster the trust and working relationship with every community before even getting to the research questions, as well as time to collectively interpret project outputs, doing so with communities that are culturally different from the researchers' community often takes understandably even longer. These connections and involvements with researchers, communities and participants take time and effort, and identify a different way of thinking between western and traditional science and culture. So, whilst there is huge importance with regards to the inclusion of traditional ecological knowledge in western science, there are often fewer funding opportunities available to help build the necessary trust and co-develop the research.

Closing remarks

We would like to re-emphasize that it is our experiences that have formed the basis of our opinion piece, so the focus was centred around working across the disciplines of hydrology/natural sciences and social science with the aim of addressing water-related challenges through the inclusion of participants in fieldwork. We acknowledge that there are many sub-disciplines within these, and many other forms of collaboration and interdisciplinary teamwork. Whilst the guiding principles themselves are universal, we know and understand that every research collaboration and project will come with its own unique experiences and challenges, and advantages. We do not claim to be addressing all possible challenges. In regard to the Nature Sustainability editorial piece (2021) "Too much and not enough", we are confident that our opinion piece, as well as the two excellent replies, show that this interdisciplinary effort is worth the challenge, and shows that water research is not "stagnant" at all. Finally, we repeat the interest in a paper with the opposite framing - guiding principles for social scientists conducting interdisciplinary water research and hydrological fieldwork, to a social science audience to help continue to build the bridge between the social sciences and hydrology in addressing water related real-world problems.

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