# AUTHORS' RESPONSE TO REVIEWERS

We thank the two reviewers for providing us with valuable feedback on our manuscript. The reviewers had quite divergent thoughts on the draft we submitted, and the revisions we propose aim to address the key points raised by anonymous Reviewer #2, as (s)he had the greatest number of concerns. We offer a middle ground that we think will enhance the clarity and focus of the paper while shortening its length. Details of the proposed changes are outlined below (reviewer comments are in blue), and we think these changes will lead to a strengthened version of our manuscript that will be of interest and use to HESS readers.

## Response to reviewer #1:

Thank you for the opportunity to review the draft manuscript "Rapid surface water volume estimations in beaver ponds" by Daniel J. Karran, Cherie J. Westbrook, Joseph M. Wheaton, Carol A. Johnston, and Angela Bedard-Haughn. I found this article to be a very interesting description of a method for determination of storage in beaver ponds using a minimum of input information. The authors make a compelling argument for this method with examples. I found this draft to be very clean and well written.

Please consider the following comments.1. eqn 8: Just to be clear about where equation 8 came from, add: "For ease of visual interpretation, equations 6 and 7 can be combined as:" 2. eqn 9: Is this correct? If eqn 8 is substituted into eqn 9, you get RD = RDˆp/2 3. p 5, ln 5 – I don't understand the statement "thereby eliminating issues of scale and aiding in the analysis of error."

Equation 9 is used to fit a power function to the actual points on the bathymetric curve, which makes Equation 8 redundant, and its inclusion confusing. Thus, we will remove Equation 8 from the revised manuscript. We will also more plainly state that the intentions of Equations 6-9 are to scale the bathymetric curves to one another to facilitate comparison among them.

eqn. 10 – define Vland. Also, add more description to the paragraph starting at page 5, line 6. It is hard to understand BI just by reading the text (e.g. what is the "reference solid" that you refer to). I had to refer to Strahler, 1952 to understand this paragraph.

Vland will be defined in the revised manuscript (Eqn 10). We will also improve our description of BI, probably using a simple example, in the revised manuscript to improve understandability.

table 1 – what is the column "n" in the table? I assume number of ponds at the site.

Yes, "n" does indeed represent pond numbers. We will add this to the table caption.

## Response to reviewer #2:

This study explores the capabilities of different geometric methods to estimate surface water storage in beaver ponds; to do so, the authors use topographic datasets from multiple beaver ponds that range in hydrogeologic setting. The paper is generally well written (but see technical corrections) and presents results in informative, polished figures. The paper's main contribution is its quantitative comparison of different methods, which require different input datasets (from simply dam length to coupled measures of water depth and inundated area), to predict beaver surface water storage (see Section 4.4). Considering the number of beaver ponds and their contribution to watershed storage and release, such assessed tools are useful for watershed assessments, planning, and modeling over large spatial scales. However, I find the paper too long and with unnecessary text for a focused evaluation of methodologies for storage volume estimation. With that said, there are also opportunities (often alluded to in the text) to expand the work, where the focus is broader: beaver pond morphologies, their drivers, and their implications. As such, I see two options to reframe the paper that should be considered:

Technical Note: Streamline the paper's text and focus to compare methods for predicting volumes. This will also require clarifying some of the methods and their linkages (see specific comments below). Text to consider removing/shortening includes: Page 1, Line 25 through Page 2, Line 23. Rather, the introduction could succinctly state: beaver ponds are ubiquitous and important to watershed water storage, highlighting the need for methods to quickly estimate storage use; methods have been developed for other wetland features, and here we apply these for beaver ponds. Section 2.5. No need to describe the sites in detail (e.g., vegetation); instead, simply present needed information (hydrogeologic setting, DEM datasets) in the table. Text distributed throughout results (e.g., Page 8, Lines 26-31) that describes the variation in beaver pond morphology. This text should be retained for Option 2 (below), but removed for a technical note solely focusing on a methodology. Similarly, Sections 4.2 and 4.3 could be removed for a technical note; instead, the discussion should simply revisit the methods to discuss tradeoffs between accuracy and data needs among the methods evaluated (i.e., section 4.4).

Research Article: For this option, the manuscript could be expanded, where it focuses on the variation, drivers, and implications of a suite of morphological metrics (in addition to storage volume) for beaver ponds. At times, the manuscript points to some of these topics (e.g., the importance of SI for groundwater exchange, beaver ponds store less water than potholes b/c of ontogeny of ponds, time variation of pond mor-phometry, etc), but these points seem somewhat tangential for the current manuscript focus. However, the paper could make a meaningful comparison across ponds and regions by deemphasizing the volume storage methodology and including: 1) a full comparison of the different metrics (SI, storage, dam lengths, maximum depth, etc) across systems, 2) analyses of their drivers (e.g., predictive relationships with stream order, watershed slope, etc), and 3) focused intro and discussion text regarding implications (cumulative storage, perimeter to area ratios for water exchange and habitat, sediment storage, etc). Again, there is some mention of such topics (e.g., Section 4.5), but a quantitative evaluation of the drivers and importance of beaver morphology means a full treatise on this subject, where the volume storage estimation is one method applied. For this option, authors could consider either just including the 40 ponds used here (in which case, the actual bathymetric curves could be used), or they could use the 40 ponds to verify the Simple V-A-h method, and then use a

larger set of ponds with available required datasets to derive volume, SI, and other metrics. In short, I contend that the manuscript is lacking clear and organized scope. The two options suggested above will help frame the work in a clear way, be it as a technical note or an evaluation of beaver pond morphologies; I believe either option will provide a valuable contribution. Given this suggested shift in scope, specific comments depend on option chosen. As such, I have limited the number of comments below, and include only those that should be addressed regardless of option, or that I point to an Option specific revision.

Our goal was to discover tools useful for estimating surface water storage in beaver ponds at large and small spatial scales – ones that are easy to apply in relatively data-sparse environments, and ones that hold potential for incorporation into hydrological models in future research initiatives. While we agree with reviewer 2 that a full treatise on beaver pond morphology is needed, enhancement of water storage on the landscape owing to biota – in our case beaver damming activities - is the focus of our paper. Indeed, a treatise on beaver pond morphology may not yet be possible. For our research, we contacted all the leading beaver impact researchers across the world and learned pond morphometry is rarely documented as part of their research initiates. Thus, the 40 ponds we studied represent nearly the whole of the global population of beaver ponds with detailed morphometric measurements.

That said, we agree with reviewer 2's suggestion to streamline the paper's text and focus. But, we do not think the streamlining will reduce the text and content enough to align the manuscript with requirements for a technical note. Reduction of the manuscript to a technical note would require solely evaluating the Simplified V-A-h method. Such focus would be of more limited interest and use to readers of HESS as it would eliminate our evaluation and discussion of tools useful for estimating surface water volumes at larger spatial scales. The discussion of tools for estimating surface water storage volumes at larger scales originates through our characterization of pond morphometry.

To shorten the paper, we will, as reviewer 2 suggests, reduce the length of the Introduction. We will re-focus the Introduction to succinctly make the following points: beaver ponds are ubiquitous and important to watershed water storage, highlight the need for methods to quickly estimate storage use; identify methods that have been developed for other types of wetlands, and state how we here apply these to beaver ponds. We also foresee shortening section 2.5 by removing non-critical site detail, such as the description of site vegetation. We plan to retain section 4.2 as it is critical to discussion of our results. Section 4.3 will be removed in its entirety.

Page 1, Line 14: Be specific when discussing surface water storage as a function of stage vs. storage capacity.

We will make the suggested changes

Page 2, Line 6: Why are beaver populations expected to increase with climate change?

We will detail that climate change is expected to produce a modest expansion of the northern range limit of beaver by 2055 (Jarema et al., 2009).

Page 2, Lines 12 – 23: Too much focus here on restoration, even for Option 2, and especially for a technical note. Instead, informing restoration is just one importance of good volume estimation.

We agree that informing restoration is just one importance of good volume estimation and will change the text to say so instead of going into detail on the application of the method to restoration.

Page 2, Line 31: Define basin morphometry.

We will follow the example of Brooks and Hayashi (2002) and define basin morphometry parenthetically as "(surface, volume, depth)."

Page 3, Line 2: Qualify "with little additional effort".

We will qualify this statement to make it less subjective

Methods: For option 1, a conceptual 2-panel figure (cross section and plan view) would really help to define terms used in the equations.

We will include a figure like this in the revised paper to help define terms used in the equations.

The methods are hard to follow; some reorganization and explicit text to link methods would help; how this is done will depend on the manuscript's new scope. For Option 1, this would mean revising Section 2.2 to explicitly distinguish the variables that were used for simple predictions of volume (dam length, SI) versus the relationships that were used to evaluate model predictions (i.e., Dact). It could also be clearer what Dact and Dest refer to; the "actual V-h relationship or point on the bathymetric curve" makes that confusing without more clarification. It might help to switch 2.2 and 2.3. For Option 2, methods would reflect the various different metrics used to describe pond bathymetry and how these were compared across sites.

The methods will be modified in accordance to the suggestions provided for Option 1 and addition of a figure, as suggested in the last comment.

Page 5, Eqns 8 and 9: Where is the exponent in Eqn 8 that then appears as p/2?

As identified by Reviewer #1, there is an error in equation 8, which will be removed from the revised paper and replaced by equation 9.

Section 2.4: Again this information could be streamlined and probably just included in a table.

We will make the suggested changes

Section 4.3: Points raised here are not addressed by the results. For Option 1, remove text altogether, other than just pointing to the importance of a simple method to estimate storage considering this time variability. For Option 2, consider retaining text, but only if some results can point to this time variability.

We will remove section 4.3 entirely as suggested by the reviewer.

Page 12, Lines 29-31: Good point and method application.

Thank you.

Section 4.5. Example of inferences that could be expanded in Option 2 but minimized in Option 1.

**S**ection 4.5 will be fleshed out with examples based on the changes we indicated above.

Page 1 Line 27: Complete sentences should be follow semicolons. This needs to be addressed throughout in a number of places (e.g., Page 2, Line 27)

Page 2, Line 8: "by virtue of the fact that it.." Awkward.

Page 9, Line 4: Need a comma after Aerr.

These three grammatical changes will be made.

Page 2, Line 32: : : :basin morphometry are not considered.

We will change 'is' following 'basin morphometry' to 'are' to make grammatical sense.