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Reply on RC1

Christopher Spence et al.

Author comment on "Assessing runoff sensitivity of North American Prairie Pothole Region basins to wetland drainage using a basin classification-based virtual modelling approach" by Christopher Spence et al., Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2022-102-AC1, 2022

Reply to Reviewer #1

Summary Comment: The topic of the paper is important and timely, however, the methods were extremely hard to follow. There was a lot of important information and clarifying details that were missing from the Methods section. The model calibration and evaluation was weak, and a discussion of the sources of uncertainty in the approach needs to be added.

Thank you for the suggestion. We have made several changes, as the review suggests, the details of which are described below.

Abstract – please add the spatial extent of the study

We will add a sentence to address this comment. "The basin class, entitled Pothole Till, which was examined extends throughout much of Canada's portion of the Prairie Pothole Region."

Line 22 – change "were" to "being" evaluated, or revise.

Will change as suggested.

Line 153 – Since Spence et al. 2022 is still in review, please clarify how this effort is distinct from this prior effort. Is the application of the model to a new catchment class the only difference?

Since this manuscript was submitted, Spence et al. (2022) has been accepted and published. We can update this. We will clarify the differences between that paper and this by changing the sentence to "This framework provides a novel tool with which to also disentangle the role of wetland drainage from that of climate on basin runoff."

Lines 171-172 – is the data that is shown in Figure 1 an output from Spence et al 2022 or from Wolfe et al 2019 or another source? It is hard to tell.

The classification shown in Figure 1 is not from Wolfe et al. It was another classification that did not include climate as an input that is used in this exercise and was used by

Spence et al. (2022). This is hopefully made clearer by the removal of "(see Spence et al., 2022)". Citing that paper is not necessary here.

Figure 1 – Indicate or clarify what the actual extent of the model and simulated data is? Or clarify in the text that the theoretical model was forced with 4 different climate datasets. If this was the case, what was the size of the simulated basin?"

Thank you for the comment. Much of the information is already in the paper. The caption in Figure states that the focus is on modelling a virtual basin of the Pothole Till class. This is also stated on Line 180 ", but instead using the Pothole Till class." In Section 2.4, *Model application*, we state the virtual basin model was run over a 46 year period using data collected at the four locations shown in Figure 1 and listed in Table 2. In Section 2.3, we state "The virtual basin (100km^2) …"

Lines 183-185 – add some basic information on the land cover, slope, elevation, and soil type, what is the spatial resolution and source of these datasets? Was land cover assumed to be stable or non-changing over the modeling effort, other than changing drained wetlands to agriculture?

We can add some detail such as "The classification approach here follows that described by Wolfe et al. (2019), using the same elevation (Farr et al., 2007), water extent and distribution (Pekel et al., 2016), surficial geology (GSC, 2014), soils (AAFC, 2015), land use (AAFC, 2016) and tillage practice (Statistics Canada, 2016) data …..."

These data permitted the typical land cover and agricultural practices in the Pothole Till class over the modelling period to be identified. It was this information that was used to parameterize the virtual basin model. Land cover (i.e. crop types, summerfallow fraction) was held constant over time in the simulations apart from converting wetlands to cropland with drainage.

Line 193 – clarify what size HRUs are used.

We can change the column in Table 1 that listed the HRU fraction of the basin to list HRU area so that these areas are clearer to the reader.

Lines 197-201 – Why not use actual wetland datasets instead of artificially created ones? There are some existing efforts by Amani et al. and Mahdianpari et al. for instance.

This is because the virtual basin modelling approach simulates no specific place within the basin class, only a representation of the typical basin within it. This avoids errors known to exist in many wetland datasets that are used to represent depressional storage in a hydrological model. We can make this point clearer by adding more explanation; "In this framework, a hydrological model of a virtual or stylized basin is parameterized using the predominant characteristics of a class. The model inputs or parameters can be manipulated to simulate the probable response to wetland drainage within a region. The output can be considered representative of how the whole of the basins of that class would respond."

Line 202 – What DEM was used to route runoff? Were any manipulations/changes made to the DEM to condition it hydrologically?

We did not need a DEM, only the catena as described in the paper, and the average routing distances of the land cover types calculated across the Pothole Till class. We can add a sentence; "Routing distances across each HRU were calculated as the average

across the 879 basins in the Pothole Till class (Table 1)."

Lines 207 – Please just list the actual source of the wetland extent data, instead of pointing to another publication, which did not generate a wetland dataset from what I can tell.

We can provide this water extent data citation to a sentence referring to the shape and scale parameters, which were determined by Wolfe et al. (2019), so we believe this is the correct reference in this instance.

Lines 211-216 – So no actual data on drainage was used? How did the simulated drainage account for drainage already present? Or was this assumed to not be relevant since the wetlands were simulated as well? It was also difficult to tell what the term "drainage" was referring to. In the U.S. PPR, drainage is usually installed under the ag fields, although historically ditches were also used to drain wetlands. Was drainage simulated by "removing" wetlands or just increasing the rate at which water left the wetland. This is important to clarify.

No. This is for two reasons. First, the virtual model did not represent a specific basin, so an actual real-life drainage plan was not simulated. The reviewer's comment suggest some description of how wetlands are drained in the Canadian Prairie is necessary as it differs from that in the United States portion of the Prairie Pothole Region. We can add a sentence explaining this; "Wetland drainage in this region is typically enacted by first removing any woody vegetation from around the wetland with backhoes and graters. Infilling and levelling is used where possible to flatten the depression. Ditches are dug between each depression to their maximum depth following the local grade to allow drainage towards the closest intermittent streambed or road ditch. These drainage techniques completely remove wetland depression storage capacity from the landscape". For this reason, we did not need to account for drainage already present, as this would be reflected in the baseline wetland distribution that was used. We are wondering if the reviewer is referring to what is called "tile drainage" in Canada. While used in Ontario and parts of southern Manitoba to drain level fields, this is not the practice we wanted to assess and it is rarely used to drain prairie pothole wetlands. The drainage was simulated by "removing" wetlands and their storage capacity and converting that area in the model to the cropland HRU. This did involve decreasing the surface roughness to allow for faster runoff in the routing module. This is explained in Section 2.6, where much of this content will be moved, as upon reading again, seemed a better place for it.

Table 1 – A lot of these parameters are not explained. The routing length is the length from where to where? Is this the average length? The LAI values seem weirdly low…why are the 0.001 in a grassland, cultivated field and shrubland? And the woodland also seems low, a LAI of ~1.5-3 would make more sense here. Look at an example paper to more appropriately parameterize these such as Asner et al. 2003, Global synthesis of leaf area index observations: implications for ecological and remote sensing studies: Global leaf area index. Depending on how the model is set up, this could influence the model findings.

We can better explain routing length in the caption, which is the distance across the HRU to the downstream HRU. The LAI values are low as they are the minimum annual values and typically represent winter where they are used as inputs to blowing snow simulations. This was a mistake and we thank the reviewer for catching this. We will change them to the annual maximum values, which are more informative.

Line 230 – what is the spatial resolution of the precipitation data, is it station data given that it is collected only at 4 locations?

It is station data collected at four locations representative of the diversity of climate in the basin class. Each set of drainage scenarios was run four times, using the station data representative of different climates in the region.

Line 252 – if 1965-2006 was used to assess model behavior, what years were used to train and calibrate the models? And if actual discharge was used, how did you guys account for the influence of existing land use and wetlands on the discharge values?

We should have better explained CRHM and relied less on referring people to Spence et al. (2022). CRHM is strongly physically based and does not require model calibration. We will add a description of this; "The models created with the CRHM algorithms, especially for its surface processes, are strongly physically based, and do not require calibration from streamflow. Furthermore, as a virtual basin has no specific location, it cannot be calibrated to streamflow observations from a gauged basin. As there are few unregulated gauged basins of the size simulated here in the Canadian Prairie Pothole Region which is a sparsely gauged region, using a model in which parameters are set based on hydrological process research rather than calibration is advantageous."

We accounted for differences between the virtual basin and the observed discharge values from actual basins by comparing to the range of observed discharge values that occur in the region.

Table 3 – where are these gages? Can these be added to figure 1?

Yes. These will be added.

Line 279-280 – where is the St. Denis NWA in relation to the study area?

This will also be added to Figure 1.

Lines – 286 – I still can't quite tell where you guys ran this simulation – across the entire pothole till? just within or near the catchments in table 3? So I can't tell what the distance is between these ponds and the modeled area, but since the climate stations used are spread across Canada, I have to assume that there are thousands of miles between some of the simulated areas and the ponds, consequently the pond depths are only compared to 1 climate forcing, but this doesn't seem adequate given that the focus of the paper is on changes in simulated wetland extent and corresponding changes in discharge.

We are hoping the new content we will add better explains that by definition, the virtual basin does not have a real geographic reference. It only represents a typical Pothole Till basin. The climate stations are from the basin class and represent the range of climates that a Pothole Till basin could be exposed to. We will add St. Denis to Figure 1 which will show that a North Battleford climate, is the closest geographically to St. Denis. We will also add content about how far apart they are; "… the closest (162 km) of the selected climate stations."

Section 2.6 – please clarify how the 4 scenarios differ….so bottom-to-top for example…wetlands were drained sequentially from the basin outlet toward the headwater streams? Was any attention paid to whether the wetland was near- or connected to a stream, or geographically isolated from the stream network in the scenarios?

We can elaborate on this; "Four sets of drainage scenarios (two based on area and two based on relative location) were implemented based on an approach progression first

demonstrated by Pomeroy et al. (2012) for the Vermilion River Basin, Alberta. The two scenarios based on area first drained wetlands 1) from smallest to largest and 2) largest to smallest and are referred to as small-to-large and large-to-small, respectively. The two scenarios based on relative location first drained wetlands 1) from those farthest from the basin outlet to those closest and 2) from those closest to the basin outlet to those farthest. These are referred to as top-to-bottom and bottom-to-top, respectively." In the relative location scenarios, yes, these were designed specifically to figure out the response based on those closer to the stream and those more likely to be geographically isolated (e.g., those farthest away).

Line 328 – add a comma between mean and minimum

Will fix. Thanks.

Line 383 – what was the distance between the N. Battleford climate and the ponds?

162 km. Will add, as noted above to a previous comment.

Lines 395-399 – what figure are these results reflecting?

Figure 3. We will add a reference to it.

Figure 3- Did the 4th location not have gage data? And since the contributing areas were of different sizes, would it make more sense to normalize the x-axis, so annual discharge per contributing area? Otherwise the Brandon comparisons really look all over the place. Also please add these value in as a table so there is some quantitative way to compare.

The 4th location (North Battleford) did not have any gauges close enough to it that met the criteria. This is already noted; "There was no gauged basin close enough in proximity to North Battleford that was entirely in PHT, thus this station is absent from the validation."

The annual discharge is normalized; it is expressed in mm in Figure 3. The numbers will be included in a new Table 4.

Figure 7 – make the font size larger, it was difficult to read this figure.

These will be fixed.

Discussion – the discussion does a nice job of contextualizing the results with the findings of others but please add a paragraph discussing the limitations of the modeling approach and sources of uncertainty given the input datasets, and limited manner that the model performance was evaluated.

We will add some content to the end of the third paragraph in Discussion to address this comment. "Something to consider with the basin classification based virtual modelling approach is that the results are representative of what would be expected in a typical PHT basin, and not any specific basin. Because the model does not represent a specific basin, good model performance should be determined not necessarily on how well simulations emulate observations from one place, but how well the variability in hydrological behaviour is captured. Departures from the modeled results will exist, depending on how different a specific basin is from the parameterized virtual basin. The results are best interpreted as how basins across the class as a whole would respond to wetland drainage. "

Comment – please revisit how the term "drainage" is used throughout the paper (e.g. line 659) since the term drainage typically refers to the movement of water through a watershed, but here it is mostly used to refer to the action of draining wetlands.

We can address this comment by adding a sentence in Section 2.6 – Drainage scenarios, that specifically states: "In the context of this paper the term "drainage" refers to wetland drainage; the act of removing surface water storage capacity from depressions, and not the movement of water through a basin."