Quantifying flood-water impacts on a lake water budget via volume-dependent transient stable isotope mass balance

Janie Masse-Dufresne et al.

This study uses field sampling and a mass balance model of stable isotopes ^{2}H and ^{18}O to estimate the relative contributions of flood water and groundwater to an artificial lake over one year. The article further illustrates that while groundwater input is an important component of the lake water balance, considering temporary storage of flood water input in the subsurface reduces the magnitude of regional groundwater contribution. The authors have improved the manuscript by incorporating their responses to reviewer comments on the previous version. However, further work is required to clearly draw out the objectives of the study, and clarify the conceptual model of the lake water balance and effects on the calculated water balance.

General comments:

1. The conceptual model of the lake water balance is not clearly described or consistently applied in the manuscript. For example, the lake is the water source for a bank filtration system (S2.1), but this information is not included in the conceptualization of groundwater – surface water interactions (S2.2) or the identification of water fluxes (S3.4). Presumably, the presence of this system influences both the rate and timing of water loss from the lake, at least at this boundary.
2. Given the significant limitations to the data and modelling effort, it may be advisable to emphasise throughout the manuscript that the values produced are first-order estimates.
3. The manuscript requires thorough editing in order to improve clarity. I fully appreciate the challenges associated with working in multiple languages. Thorough editing will help draw out the science that is currently getting lost here.
4. I suggest a further check to ensure that all changes indicated in responses to reviewers have been incorporated, as some vital information has been either lost or not included, inclusion of which would strengthen the manuscript (see line by line points below).

Abstract

Line 13-16: The main objective of this study…water supply. Suggest generalizing. Remove “important”.

Line 17: The lake typically receives… Replace “important” with “substantial”. Perennial connection indicates that the connection is always present. The manuscript indicates instead that the connection is established only when lake a topographic threshold is exceeded. Suggest revisiting abstract after revision. Streamline and clearly indicate the uncertainty of water budget estimates.

S1 Introduction

Line 34: What do you mean by “outcome”?

Line 51-56: Recently, Haig …. ungauged systems. Condense. Impacts of floods and droughts on what?

Line 58: This objective is not specific enough. Currently, it reads like a case study. Rephrase to specify what is new about your study.

Line 60: “(and bank storage)”. Including bank storage? Although it is unclear whether bank storage is the correct term to apply here. Why do you believe that the process in question is bank storage and not floodplain recharge (or a combination of the two?).

Line 61: Is it in an urban area? This is not indicated on Figure 1.

Line 67: Generally, the hypothesis comes first. Is this actually an assumption?

Line 68: “unneglectable”. Replace with either important or not negligible, depending on your meaning. Given the presence of a bank filtration system adjacent to the lake, wouldn’t you expect the groundwater flux out of the lake to be important?

Line 74 to end of S1: The introduction may make more sense if you move this section to before Line 58. This would allow you to clearly show what is novel about your study.

Line 71: Delete “recurring perennial”.

Line 73: Delete “indicative”. Check that a 100-year flood (more correctly, a flood with an Average Recurrence Interval of 100 years) is generally considered an extreme event. With changing climates, floods that were formerly considered to have ARIs of 100 years are being re-classified to higher frequencies.

S2 Study Site

Line 89: Was the lake created by sand dredging, or is the sand-dredging on-going as suggested in the responses to reviewers? The latter has implications for mixing in parts of the lake.

Line 90: How do you know that Lake A is the main water source for the bank filtration system, and not Lake B? Do you have an estimate of the volumes of water extracted from the bank filtration system? How do they compare to the lake volume and the flood-water input volume? Also, please include Lake B in this section. Currently it is not mentioned.

Line 93: An assessment of the impact of uncertainty… Perhaps you could delete this sentence and replace it with an error estimate after the lake volume e.g., 4.7×10^6 m^3 ± ? m^3

Line 98: Unless I have missed it, this stream is not mentioned further in the manuscript. Please add some words here to indicate this.

Line 99-104: Please reword this section to clarify the surface water flows. My interpretation is that water flows from Lake A to Lake D-M through S2 and S3 for 7 months of the year, and for the other 5 months, it flows from Lake D-M to Lake A across the floodplain and in the streams. These time periods are fairly equal, so it seems odd to describe the reversal as temporary.

Line 105-106: There is no evidence of wells outside the paleochannel in Figure 1c. Where does the evidence come from that this layer is thin? Also, the topographic threshold show on Figure 3 appears to be within the clay as depicted in Figure 1c. Please clarify.

Line 107-110: Why is this significant for this study? Does the Ottawa River flow through Lake D-M? Clarify wording. Unclear why it matters that the St Lawrence River is a drinking water source for Montreal and Quebec in the context of this study.

Line 115: Clarify that water level monitoring at VP is groundwater level. Suggest shortening caption by using correct references for data sources and including them in the data list.

Line 124: To me this section reads more as a conceptual model of the Lake A water balance. Consider revising the title.

Line 126: Suggest arranging so that the condition that comes first in the figure also comes first in the sentence – switch figure order or sentence order. I also suggest coming up with a different descriptor than "normal" – as previously mentioned, the time difference between he two conditions appears to be small.

Line 129: Fig 2b?

Line 130: replace "Contrastingly" with "In contrast".

Line 131: Replace "neglectable" with "negligible".

Line 128-133: It would be helpful to rewrite this section to clarify your conceptual model of the lake water balance under the two conditions. My current understanding is as follows:

1. Flood-water input. The level of Lake DM rises quickly due to inputs from its larger catchment. Inputs to Lake A include surface water inputs (Is) by overland flow and streamflow (S2 and S3), and precipitation (P). The resulting water level in Lake A is assumed to be higher than the surrounding groundwater; this hydraulic gradient precludes groundwater input (Ig), but increases groundwater output (Qg) above that which occurs due to the bank filtration system. Water is also lost through evaporation (E). *Please clarify if there are streamflow losses during this period as indicated on Line 134, and if so, where.*
2. Otherwise: Without flood-water inputs, the water level of Lake A falls due to outputs to E and surface water outflows (Qs) through S2 and S3, and Qg due to bank filtration system. The water level in Lake A falls more quickly than the surrounding groundwater and so the hydraulic gradient between Lake A and groundwater switches, and groundwater flows into Lake A (Ig).

With the above clarifications, this seems like a fairly reasonable conceptual model. However, it does not quite place the lake in its full hydrological context. It may be reasonable to assume that lake water flows as groundwater NE from Lake A to the bank filtration system, but what is occurring at the other lake boundaries? Are there other areas where lake discharge occurs to the groundwater when flooding is not occurring? Also, given the situation described, it seems reasonable that overland flow infiltrates into the ground on the Lake DM side (SE?) of Lake A as well as being pushed out from Lake A as bank storage. With repeated flooding events, does this not have the ability to create groundwater with very different chemistry and isotopic signature to regional groundwater/groundwater on other sides of the lake that are not subjected to flooding? Not that the bank storage and floodplain (albeit small) "groundwaters" will have essentially the same isotopic signature, and so are indistinguishable using the tools in this study.

S3 Methods

Line 141: Are the level loggers pressure transducers? State the start and end time of the measurement periods rather than just the start.

Line 149: What are the further computations you are referring to? Atmospheric pressure corrections?

Line 154: “close to the surface near the lake edge”. State the approximate depth and distance. Also include the timeframe for sampling.

Line 163: Does this mean that the direction of regional groundwater flow is from NE to SW? Do you assume that this “regional groundwater” also contributes to Lake A, or is the bank filtration system a complete barrier?

Line 179-182: Is it necessary to include ^{17}O? Results for this isotope are not reported in this manuscript.

Line 186: for lakes?

Line 187: Did you perform computations with both types of models? If not, suggest rewording and adding a reference that shows that both models yield similar results. Do they provide an understanding of groundwater-surface water interactions or estimates of the sources of lake inputs and output flow paths?

Line 193: Clarify the term water yield in your study context.

Line 197. Change “advocated” to “selected”. This supports the general point that any quantities are only first-order estimates.

Line 205-206: “during the ice-free period”. How do you justify applying it over the whole year then? The manuscript mentions that the lake freezes over. I have not further reviewed the isotopic model development.

Line 236: Which observed values?

Line 237: More correctly, the outflow from the lake will be proportional to the difference between the lake water level and the adjacent groundwater level. It would be useful to plot the difference between Lake A water level and the groundwater level to test whether this linear assumption is justified. It is rather unfortunate that the Lake A level data is not available for a longer period, as after high flows there is clearly a difference in the lake water levels, even if they follow a similar pattern. Is there any groundwater level data available on other sides of Lake A? This would also help determine if the Ig and Qg fluxes varied around the lake. Depending on the pumping volume of the bank filtration system, it is plausible that using the groundwater level at VP will overestimate the hydraulic gradient and hence the groundwater flux out of the lake. Again, what role is the bank filtration system playing here? How is the system operated? Continuously?

Line 241: Qmin on Figure 3 corresponds to the lowest water level at VP, not the lowest water level measured in Lake A. The lowest level for Lake DM was in November. Clarify.

Line 245: It may be helpful here somewhere to simply state the water balance equations for the two conditions.

Line 250: Unless the source water for S1 also comes from a large catchment at similar latitude, this is a bold statement. I suggest deleting, and leaving the reason for excluding S1 to the fact that the flows are tiny by comparison. If you state this on Line 98, there is no reason to mention this stream here.

S4 Results

Line 256: Suggest revising this statement to say that major flooding occurs as a result of springtime snowmelt and minor flooding due to fall precipitation.

Line 259: Figure 3?

Line 263-265: Are the water level variations synchronous (happening at exactly the same time) or following the same pattern, but with a small lag that could be expected due to travel time? Amend to be clear that data is not available for Lake A up to late July. Does the water level measured at VP ever exceed ground level?

Line 267: What is this natural threshold? It needs to be clearly explained earlier in the manuscript.

Line 273: What I take from the manual water level measurements is that 1) the water level of Lake A is always higher than the groundwater level measured at VP and 2) Lake A and Lake DM do not always have similar water levels, regardless of whether the water level is above or below the topographic threshold. It would be useful to explain these aspects in the context of the Lake A water balance developed in S2.

Line 275: Isn't the actual volume increasing?

Line 281: Was a manual measurement of Lake A water level taken at the start of the study period? It isn't shown on Fig 3.

Line 282-286: Unclear the importance of the lake being dredged. Unless there is evidence of a low hydraulic conductivity layer around the edges of the lake, wouldn't you expect hydraulic connection when the lake is situated in alluvial sands? Perhaps rephrase to indicate that gross water fluxes are likely to exceed net water fluxes due to the surrounding geology and measured hydraulic gradients. A critical point that is missing here (and from the lake water balance conceptual model) is where the water goes when it drains from Lake A, whether surface or subsurface. The levels indicated on Fig 3 suggest that, at least in the early stages, the water is not draining to Lake DM.

Line 289: It is misleading to say that the shaded area represents flood water inputs. Won't surface water inputs from Lake DM to Lake A be received at all times that the water level of Lake DM is above the topographic threshold? Clarify throughout document and in the figure.

Line 298: Why 2016? The rest of the sampling was conducted in 2017.

Line 309: What is the justification for this? Do the three sample indicate temporal change in the flood-water inputs? How would this affect the calculated water budget?

Line 310: Similar to what? Unclear why this is relevant.

Line 313-Line 320: Suggest considering Jasechko et al. (2017) (doi: 10.1002/hyp.11175) and Welch et al. (2018) (doi: 10.1002/hyp.11396), which demonstrate widespread cold season bias to groundwater recharge in similar climates. Do you have any isotopic data from either of the observation wells?

Line 330: Did you perform significance testing to determine this? If yes, present the results. If not, change the wording.

Line 337: What are these scenarios (A and B) and what do they represent? It is difficult to interpret the following results without understanding this.

Line 369: Why do you consider these have stopped? Fig 3 indicates that the level in Lake DM remains higher than Lake A until Lake A measurements cease.

Line 375: How do you reconcile this with the fact that inspection of Fig 6 indicates that the isotopic match is closer for Scenario B?

Line 391: Consider moving the definition of mean flushing time to the methods. It is referred to extensively in the following pages and is hard to find here buried in a paragraph. The flushing time for Scenario B is approximately 30% lower than for Scenario A – is this not a fairly large difference?

Line 401: Suggest including explanation provided to reviewer that this sensitivity analysis was conducted OAT.

Line 404: This range of δIs does not cover the range of observed flood water inputs.

Line 408: Given the heat capacity of water, it seems unusual to use this as the only boundary for varying water temperature.

Line 416: As previously mentioned, this is not the only time when a hydraulic connection appears to form. How does amending this assumption affect the results?

Line 420: It would be helpful to state specifics for the change in LMWL and δIs/g and water balance.

Line 421: What are the impacts on the water budget of holding δIs/g constant? This at least needs to be discussed as a study limitation. Similarly, the assumption of a well-mixed lake needs to be discussed, given the obvious isotopic stratification.

Line 435: I suggest deleting this reference to the discussion and including analysis of the likely temporal change in groundwater inputs here in the results (Lines 448-470). Perhaps you could consider modifying your model to include two different groundwater inputs – one that reflects the regional groundwater, and one that reflects the mixture between flood-water inputs through the floodplain or bank storage and this regional groundwater. Consider also doing a simple calculation to estimate the potential volume of flood water that could be stored in the subsurface using values for alluvial sands available in the literature (if there are no local measurements) and the maximum depth that the groundwater level lowers in the dry season.

S5 Discussion

Line 509: “expected increases in water levels…” Which water levels?

Line 521: It is unclear how this study tracks human impacts on the water cycle.

Line 535: Another big missing piece in the data currently presented is the lack of water level measurements around the lake and through time that support the hypothesis that groundwater discharges into the lake. See also comment on Line 421.

S6 Conclusions

This section can be made more succinct. Focus on the major findings. No need to repeat volumes.