Response to Reviewers

Dear Alice Fang,

Please find our responses to the edits and comments of the reviewers below. We appreciate their feedback and look forward to the next step of the review process.

Sincerely,

The Authors

Reviewer 1:

Table

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Ruggiero et al. have produced a nice study into the link between phosphorus runoff via tile drainage and rainfall for a site in Vermont. The work has been done to a good standard and is presented clearly. Subject to three minor changes the work is ready for publication. These changes are: 1) link the work more explicitly to wider issues within the topic (beyond Vermont); 2) improve the image resolution of the figures and ensure the tables are not images; and 3) shorten the conclusion by moving much of the current content into the discussion and providing a new succinct conclusion.

* Thank you, these three changes are addressed below.

My sectional feedback is below – I thought the standard was high enough for me not to ask for line by line changes.

Introduction reads very clearly introducing the topic well, clearly and succinctly.

The study site description is thorough and clearly but could benefit from tying into why this particular areas was chosen. In essence I’m asking does this site in Vermont provide value for those in other areas of the world? Are there aspects of the geography which are transferable to other areas?

* The following paragraph has been added at the beginning of methods section 2.1:

The study area was chosen because Lake Champlain is contains eutrophic areas, and agriculture has been identified as a potentially significant P contributor in the wa-tershed [7]. Other agricultural watersheds have similar geographies, land management practices, and water quality issues, which makes this study valuable for management decisions elsewhere. For example, TD is common in the US Midwest, and has been identified as a major P export pathway to the Great Lakes [31]. Furthermore, fields with TD in this study and in the US Midwest have similar soils (high clay contents) [11], both respond rapidly to rainfall indicating highly-active PFP networks [20], and both have the potential to export the majority of annual P via TD [31].

Analytical techniques are entirely appropriate to the study conducted.

Table 2 and 3 have been screenshotted – this should be text not an image.

* The tables have been converted to text.

Figs 1, 2 and 3 seem to be at low resolution could a higher resolution (300 dpi) be provided. In figure 1 it would be good to highlight that the jitter is for plotting purposes only and does not represent anything in time.

* We changed the option in Word to not compress images and changed the default to 330 dpi. Then we deleted and repasted in the images.
* The following sentence was added to the figure caption addressing jitter:

Jitter is used for plotting only and does not correspond to dates.

The conclusion is long. I feel much of this content would be better in the discussion rather than the conclusion. This would leave space for a succinct conclusion tying back to both the key findings and wider significance. I would also recommend avoiding initialisation in the conclusion as it makes it easier to read.

* We moved the necessary content into the results and discussion section
* We made the conclusion more succinct and related it more to the findings
* The initialization was removed

References are of good quality and up to date.

Reviewer 2:

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The article describes the results of an experimental set-up for measuring Phosphorus transport through Tile Drainage flow into surface waters with a high temporal resolution approach. The experimental set up is very ambitious and Data analysis and evaluation was done timely and with different methods.

The results were described in detail. For scientists interested in land management if would be good, if a paragraph can be added in which the findings are discussed why and how this knowledge improves management and how this knowledge can contribute to get lower P loads.

* The following paragraph was added to the end of results and discussion section 3.2.3:

Because of the relationships between P export and AMC, and that P export decreased as the time since P application increased, our findings suggest that TD P loads could be reduced if MI/P application is timed. In some crops, the ideal time might be during the growing season, when plant P uptake and soil vegetative cover is at a maximum, but this is not possible in many annual crops due to the inability to access the field without damaging the crop. Another ideal time for MI/P application would be when PFP are minimized, and matrix flow dominates TD. This could be during the non-growing season when the clay soils swell and PFPs close, however in cold climates manure application is often prohibited during the winter months to reduce surface P losses from manure application on frozen or saturated soils.

For me it would be fine, if the sample fields are characterized with more details; e.g. P-content of the sol. In Europe, most soils are saturated with P and effect of fertilization are not measurable; because the P continent in the soil is too high.

* We appreciate the reviewer pointing this out. The P content of the soils were in the previous version of the manuscript but were previously only listed in the Conclusion. This detail is now listed in the methods, as well as in the discussion since content was moved from the conclusion to the discussion as per the first reviewer’s suggestion.

Reviewer 3:

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The authors use too many abbreviations in the manuscript, making the experiment description challenging to understand. Please work on the description of the methodology as it is very complex in its present form. I also suggest adding a description of all abbreviations used by the authors at the beginning of the manuscript. In my opinion, the article should be extensively rewritten to make it more understandable. Currently, too many abbreviations and language used in the article make it difficult to understand.

* The description of the abbreviations has been added to the beginning of the document. Also, abbreviations that were used only once or once after the initialization were removed.
* The abbreviations and language used here are typical of the literature in this field.
* We understand that the methods for this particular study involve some complex analysis of our data. However, we feel that the study of tile drainage hydrology has advanced considerably, and complex analysis methods are now common throughout the literature in this field. We respectfully counter the reviewer’s comment and assert that our description of our methods follows typical convention of other similar studies. We would like to maintain the current language so that is clear to other researchers what methods were used.
* In response to the reviewer’s comment that the paper is not ‘understandable’, we are unclear as to what specific text is being referred to. It is very difficult to respond to the comment that the paper should we re-written without more specifics on where it is lacking. We do feel that the paper is written to the standard of this field in the literature.

In the abstract, if you give the place of research (Vermont), please also add the country's name. This will be easier to understand for a foreign reader.

* ‘USA’ was added after Vermont in the title, abstract, and introduction.

The introduction lacks a clearly defined testable hypothesis that the authors examined in the paper. Please add this information. Also, I think the introduction chapter should be expanded with more information on the preferential flow path (PFP).

* While many studies do test a hypothesis, the goal of this study was not to do so. Instead, our objective was to characterize hydrologic phenomena in an understudied part of the agricultural landscape (tile drained fields in cold climates), and to advance data analysis methods. As such, we do not feel it is fitting to force a hypothesis into this study ad-hoc.
* Thank you for your comment, however, it is vague as to what information is lacking about PFP. Also, the other two reviewers appeared to not have the same concerns. After consideration, we understand that PFP are the focus of this paper, and the introduction could benefit from adding why we are studying them. Thus, we have included a sentence that cites an important review paper on the role of P transport to TD, which highlights PFP as a main reason why it is difficult to manage P in tile drained landscapes.
* When introducing PFP in the first paragraph, we cited a seminal paper in the field of PFP in soils, as well as two additional papers, that specifically relate PFP to the current tile drainage literature. The second paragraph of the introduction follows the introduction of PFP with a detailed explanation of the most current literature on PFP analysis in TD. Because of these reasons, we feel that there is sufficient information on PFP in the introduction for this paper.

In line 95, you use the abbreviation AHS for the first time. Please explain to your readers what it means.

* We understand how this could be confusing. AHS is the name of the field and the names of the fields are abbreviated and not defined to keep the location anonymous, which was a request by the landowner. In order to address the comment, we have placed quotation marks around the first mention of the field names (including AHS) so that it is clear they are the name of the study field.
* We apologize for any confusion but after recent events, we feel that AHS is still to revealing as the site name because of litigation that will soon release the name of the field in question. We have therefore changed AHS to F1 in the manuscript and supplemental materials. We kept the quotations (i.e. ‘F1’ and ‘DC’) when initializing the site name.

In the manuscript, it is necessary to add a map or a scheme showing the study area with all the research infrastructure. As it stands, it is not easy to understand how the experiment was designed. Moreover, a map with the location of the study area in the country's background would also be helpful.

* We understand that an image may be helpful for some readers; however, we are not able to provide an aerial image of the study fields due to their anonymous nature (as requested by the landowner). Readers of the study within the local region could easily identify the specific field if an image was included.
* We added three supplemental figures to address this comment since we felt the manuscript was already long. Figure S4 includes the study location in relation to the northeast United States. Figure S5 is a rough schematic of the field sites. Figure S6 shows the sampling equipment and infrastructure.

Furthermore, please extend the discussion of the obtained results with published results in the literature.

* We have identified three locations in the results and discussion section that were improved upon with the addition of text and citations:

1. We added a discussion paragraph comparing our findings of P loading post manure injection with similar studies that have found contrasting results to ours in terms of P export as a function of P application timing and AMC:

The relationship between P transport and AMC in this study is contrasted to other studies that have shown that event P transport to TD on clay soils is reduced during wetter AMC due to the swelling of desiccation cracks [62]. While the PFP network may have been reduced during wetter AMC via the shrink-swell nature of the soils, here, we were unable to show evidence of this. This can partly be attributed to the coarse nature of measurements, i.e. we did not examine the soil profile. Nevertheless, throughout our study, TD hydrographs responded rapidly to rainfall and had flashy rising and falling limbs suggesting that most of the event flows were transported through relatively large PFP network regardless of the AMC. Granted we believe that the PFP network represented a maximum condition during this study period because of several factors, including prolonged drought, recent TD installations, and subsoiling.

1. We clarify that during the event on 12/25/2020, the spikes in P concentrations we associate with pre-event water was mostly SRP (previously only said ‘high P’). We then expanded on the discussion with studies that found similar results to ours in terms of unsaturated macropore flow and matrix-PFP regulated SRP transport:

The peak of the drought during this study occurred in the fall of 2020, where one large event on 9/30 occurred 3 days post MI, however a large soil moisture deficit limited TD flow. There was no TD baseflow after this event and the next event that produced a TD response, which was on 12/01. Because of a lack of baseflow, we hypothesize that manure P was still abundant in the surface soils prior to the events in December. Two events in succession in December 2020 are discussed below to highlight the role of AMC on SRP transport under macropore flow. Events on 12/01/2020 and 12/25/2020 occurred during the drought and there was no baseflow prior to the event. However, soil AMC was much higher for the second event due to snow on field prior. Under this condition, peak event TP and SRP concentrations were 3-4 times higher than the peak concentrations on 12/01/2020 (Figure S3).

The use of MI in this study resulted in a highly labile source of P near the surface, which resulted in high SRP concentrations in TD when conditions were ideal for PFP transport of P-laden pre-event water. TD hydrographs may be initiated via unsaturated macropore flow, which originates at the surface and is usually associated with little to no matrix-PFP mixing. As the event continues, flow transitions to saturated macropore flow that transports both event and pre-event (i.e. matrix-displaced) water [23]. Matrix-PFP interactions in soils with high labile P (e.g. soon after P application and/or high legacy P concentrations) may contribute significantly to SRP concentrations in TD during events under saturated macropore flow because a higher proportion of pre-event-like water is transported [23], [26]. However here and in Williams et al. [62], peak event SRP concentrations at the beginning of events suggests that unsaturated macropore flow has the potential to be the dominate source of TD SRP concentrations if soil AMC is high.

1. We linked our findings to other literature that discusses the role of PFP on SRP and PP transport to tile drains, and compare our findings to others in the LCB:

Previous studies have suggested that PFP control SRP transport to TD because of the strong correlation between concentrations of water extractable P in the layer of interaction and SRP in TD [17]. Nazari et al. [17] showed that including the four-component hydrograph separation improved the prediction of SRP concentrations in TD, suggesting matrix-PFP mixing is an important indicator of SRP in TD. Thus, the four-component hydrograph separation approach could be a valuable tool for the LCB. For example, matrix-PFP interactions could improve field scale-P export models like the VT P-Index, a tool used by farmers and agricultural service providers that estimates the risk of P loss from fields based upon P source and transport factors [64]. Here, loads of all three P species were similarly correlated to the PFP hydrograph components (Table S5), suggesting that PFP activity also controls PP transport to TD [13]. PP may constitute the majority of TD TP as was shown here and elsewhere in the LCB [65], as the dispersive-like clay soils in this region are easily suspended in infiltrating waters and sorbed PP is then transported to TD via PFP.

In the summary chapter, I suggest the authors include the essential conclusions resulting from the conducted research in the form of a bullet point list.

* The following is the updated conclusion and we feel, because of its improvements from comments made by the other reviewers regarding structure and content, it need not be in bullet form:

TD was the dominant P export pathway at two sites, and annual and seasonal loads varied and were affected by the drought. The results of the two- and four-component hydrograph separations aligned with previous TD studies. Here, PFP was the dominant transport pathway during events. Results agree with the notion that annual P export from TD has the potential to be the greatest during the non-growing season, since it is the time of year with the highest TD discharge [14]. Spikes in TD P concentrations during events coincided with periods of P influxes, namely MI, herbicide application/cover crop termination, and fertilizer application at planting.

MI showed the potential for very high P concentrations in TD and AMC appeared to affect manure P export in the fall. We showed different P export dynamics between wet and dry years, as well as between events with wet and dry soil AMC. With the hydrograph separation techniques used here, we can monitor and quantify PFP activity, and thus it is possible to manage manure application during periods of high PFP transport, which would likely be the most effective way to reduce P transport to TD. It is still unclear if MI should be a BMP for field P losses as more farms use TD to adapt to climate change. Future work should include more event data to be able to quantify the differences between events following MI on wet and dry soils, as well as if MI is an improvement over surface application for subsurface P export [24], [30]. Also, while subsoiling likely reduced surface runoff, its effect on TD P export is still unknown.. The intra-event rainfall analysis showed P concentrations were higher in TD following higher intensity rainfall pulses, yet more data are needed to confirm this, as climate change is expected to have an impact on both AMC and rainfall characteristics.