Appendix

January 4, 2023

Saskatchewan Conservation and Development Association
Saskatchewan Water Security Agency

Analysis of Wetland Mitigation Policy Outcomes
Hydrology and Flooding – Response to Reviewers

Reviewer's comments were extracted from their individual review documents. Review comments are presented in black text below. Responses from the author are provided in red.

REVIEWER

Overall Comments:

1. The CDA ratio analysis is an accepted practice for drawing general conclusions about basin hydrology. The method is supported by several volumes of research by the principal authors and others as indicated in this report. Thank you.
2. The current analysis and data sets provided give an approximation of the hydrologic impacts of drainage and provide a useful baseline for subsequent analysis as well as estimates of percentage increase/decrease in flow which can be used to draw preliminary conclusions of the impact of the drainage measures on flood peaks and volumes, wildlife, groundwater, and water quality indicators. The actual volumes and flood peaks will have to be calculated separately using empirical relationships between run off and effective area or by developing watershed models such as the USDA's Soil and Water Assessment Tool (SWAT) or others such as the Cold Regions Hydrologic Model (CRHM). Agreed.
3. Selection of the current level of drainage or 80% retention of wetlands as a "base line" value against which other drainage scenarios are evaluated seems reasonable. Thank you.
4. The authors have indicated that additional refinement of drainage in the north-east is required. I would agree. Appreciated.
5. The procedure for estimating return period flows as a function of CDA ratio and using a logarithmic distribution, as illustrated in figure 4- 2, seems reasonable. Similarly, the assignment of the 1:500 flood to a CDA of 1.0 is a reasonable with the caveat that there may be cases where anomalies in basin configuration (severe depressional area for example) would indicate a value less than 1.0. Agreed – text updated.
6. The study would likely benefit from consideration of the 1:2 and 1:10 volumes in the study of an Annual Unit Runoff published by PFRA in 1994. I worked on the maps for an updated version of this in 2012 but not sure if it was published. The statistical estimates of 1:2 and 1:10 annual unit runoff volumes (dam3/km2) from either version of the Annual Unit Runoff Study might be used to verify or adjust flow estimates. This is a great idea, but unfortunately not something that we have the time or budget for at this stage of the report writing. I have flagged this in the recommendations for future work section at the end of the report
7. The hydrology report does not address trends and to be fair their proposal did not address hydrologic stationarity nor climate change. However, departure from hydrologic stationarity could

play a significant role in the success or failure of future policy decisions. There is ample evidence that the next 100 years will not be the same as the next 100 years. As evidence I cite the June 2010 flood for Maple Creek where the constructed flood peak was estimated to have been four times anything that might have occurred in the previous 100 years. Should this be flagged as requiring further study? A discussion of the limitations of the CDA method with respect climate change has been added in a new Section 6.1.

Wording in Figures 5.8, 5.9 and 5.10 - The figures are described in the text as indicating increases in historical runoff volumes yet the table headings and sub-headings in 5.8 and 5.9 refer to "% Increase in historical CDA ratio" at current wetland retention. Figure 5.10 uses the sub-heading % increase in historical runoff volume at wetland retention floor". Was there something different in the information in Table 5-10? No, this was an editorial oversight. % increase in historical CDA ratio is the same as % increase in historical runoff volume as per the CDA methodology. Tables in the main body of the report have been updated to all refer to runoff volume for consistency.

The CDA Methodology - The use of effective drainage area is well documented in academic literature and recognized within the hydrologic and broader water resource community. It assumes that increases or decreases in area would logically result in corresponding changes in flow volumes and flood peaks. The authors have not only examined these sources but have participated in previous studies using this methodology. Thank you.

There is one significant difference between flow estimates from CDA and those derived from actual records and that is in the efficiency of the contributing area. A drained area by design is more efficient, likely to approach 100% while an undrained area will contain depressional storage, less efficient flow paths and other impediments to runoff. This is a good point and has been added to the discussion of limitations of the CDA method. It also helps explain why the CDA method breaks down in the northeast.

Status of Drainage in Saskatchewan – The study identifies drainage scenarios by 10 per cent starting with an estimate of historic wetlands and terminating with a floor value consisting of protected areas and areas classed as unsuitable for agriculture. Included is an estimate of the current wetland retention appears to be somewhere near 80%. This serves as a baseline. Any departures from the current levels will be scrutinized closely. Agree.

Costs and Benefits of Changes in Drainage – The report indicates that decisions to increase drainage would increase downstream flows causing flood damage and requiring investments in flood mitigation. Also increased drainage would increase nutrient and sediment loading on the receiving stream. For in-province and transboundary waters this might mean excursions from established water quality guidelines. The impacts on water quality are examined in more detail by Williamson in the Water Quality Assessment of Wetland Drainage and Retention Scenarios. Yes.

The other side of the argument is that drainage will benefit agricultural production while further retention of wetlands will take land out of production with a predictable loss of revenues. The ¼ section data in this report will provide a starting point for the analysis of costs and benefits. Agree. I believe WSA is supporting this type of trade-off evaluation.

<u>PFRA Reports</u> – The study uses the gross and effective drainage area delineations developed initially by PFRA and later published by AAFC. As well the authors have sourced the PFRA Small Dam Design Manual which has developed a relationship between peak flow and effective drainage area for small watersheds. The authors have concluded that this specific method would be unsuitable for estimating peaks on larger basins. While this is true, I applied a general rule from the Small Dam Design Manual that suggests instantaneous peak flows might increase by 60 to 70% of the predicted increases in EDA. See discussion in Section 6.3. This is a very rough estimate for a situation that requires site specific investigation.

One older report entitled the Magnitude and Frequency of Floods Study (circa 1960) establishes relationships between 1:2, 1:10 and higher floods and effective drainage areas. The study uses actual and extended flow arrays for the period 1911-1958 with a couple of exceptions for lesser periods as shown in Figure 3. The information is old but might provide insight into the flood response from EDAs of larger watersheds. Unable to find this report. Contacted Doug Johnson at WSA, but he was also unable to find it.

Another PFRA report that might be used directly or might provide insight into a working methodology to support the current hydrology study is Hydrology Report #135 Annual Unit Runoff on the Canadian Prairies, PFRA, February 1994 which I will refer to as the Median Annual Unit Runoff (MAUR) study. The MAUR provides estimates of the median (1:2) annual unit runoff and the 1:10 runoff for 392 hydrometric stations on the Prairies. This includes stations within the study area of this report. The Assiniboine, Qu'Appelle, and Souris River basins are well represented in the MAUR report. Examples of stations used and the median and 1:10 flood peaks are shown in Figures 1 and 2. Again, this is a great idea. Unfortunately, I'm not able to include this additional analysis at this stage of the process. Future work could include a review of this work to verify the results presented in my report. This would likely be a continued high-level analysis and these MAUR values are becoming somewhat outdated. Strategic model-based analysis may be more informative and robust at this stage of wetland policy development.

How might the 1:10 flows differ? The contributing drainage area ratio (CDA) method shows greatest increase in flooding at the 10-year return period. This flow estimate is based on effective drainage area. The 1:10 volumes from the MAUR study on the other hand would result from increased precipitation as well as an increase in contributing area. So, it might be quite feasible to utilize the MAUR results for at least preliminary estimates of the impacts of drainage or conversely the impacts of wetland retention which can be compared with those from the current hydrology study. Correct, the CDA method assumes the climate is stationarity, which we know it is not, so the change in return period runoff volume is only due to increases in EDA. Please see comments about regarding the inclusion of MAUR in this report. While it is not feasible to conduct further analysis for the final report, this suggestion is appreciated.

<u>Report Structure and Editing</u> – At times, the paragraphs are quite lengthy and filled with a lot of detail. Shorter paragraphs focusing on one aspect would improve readability. Minor edits are required to correct spelling, duplicate phrases etc. Thank you for these observations. The report has undergone an editorial review withing AE to catch these issues.

January 4, 2023

REVIEWER

Report 4 – Analysis of Wetland Mitigation Policy Outcomes: Hydrology and Flooding

Report Accessibility:

Overall, I found the reports each had clear objectives with the descriptions of the research and the application of methodology to be appropriate and quite comprehensive. However, I did find that the presentation in all reports was, at times, difficult to follow and not accessible to a reader who was not an expert in the field. While I understand that this is necessary to complete the work at the level of rigour required, I provide the following suggestions to enable a broader audience to engage with the work completed:

- It was not apparent to me who the intended audience is for these reports. A clear statement of the primary audience would enable the reader to better position themselves as they interpret and evaluate the findings. Added to Executive Summary and Introduction.
- While I found all 4 reports well written, there were a small number of minor edits that I identified:
  - Report 4 – page 2-6, second paragraph, second sentence, the word decreased is included twice, one of these should be deleted. Thank you. Deleted.
  - Report 4 – page 2-9, section 2.3.2.2, opening parenthesis before Badiou should be moved. Thank you. Moved.
- Each of the reports should include a detailed glossary of terms. I would also suggest that equivalent terms across reports should be defined and applied consistently. Below I provide an incomplete list of the terms I thought required definition in a glossary: Glossary added before introduction. Consistent application of these terms across reports is beyond the scope of this edit, but could be considered if the reports are joined and edited as one unit at a later date.
  - Report 4:
    - Contributing drainage area
    - Effective drainage area
    - Non-effective drainage area
    - Effective gross drainage area
    - Instantaneous peak flow
    - Return period
    - Peak discharge
    - Annual flow volume
    - Spring streamflow volume
    - Mean annual spring peak discharge
    - Hydrologically equivalent wetland
    - Wetland area fraction
    - Gross drainage area/basin
    - Major drainage area/basin
    - Sub drainage area/basin
    - Sub-sub drainage area/basin

- All of the reports highlighted significant levels of uncertainty with respect to the results. This makes the interpretation and the application of the results difficult. This is clearly not unexpected in any analysis addressing more complex environmental issues. The Intergovernmental Panel on

Climate Change (IPCC) has developed a terminology framework to address confidence and certainty with respect to climate science. I would suggest a similar approach applied to the findings of these reports could make the results more accessible and useable by relevant stakeholders. I have attached a basic summary of the terminology used by the IPCC to represent levels of confidence and likelihood of an outcome to illustrate this point: This suggestion is appreciated. However, consistency across reports cannot be guaranteed at this stage of editing. If the reports are consolidated and edited as one unit, it may be possible to edit for consistency later.

Confidence Terminology	Degree of confidence in being correct
Very high confidence	At least 9 out of 10 chance
High confidence	About 8 out of 10 chance
Medium confidence	About 5 out of 10 chance
Low confidence	About 2 out of 10 chance
Very low confidence	Less than 1 out of 10 chance

Likelihood Terminology	Likelihood of the occurrence/ outcome
Virtually certain	> 99% probability
Extremely likely	> 95% probability
Very likely	> 90% probability
Likely	> 66% probability
More likely than not	> 50% probability
About as likely as not	33 to 66% probability
Unlikely	< 33% probability
Very unlikely	< 10% probability
Extremely unlikely	< 5% probability
Exceptionally unlikely	< 1% probability

Report Concerns:
In general, I found the reports to provide excellent reviews of the science and together represent a good start at developing a more comprehensive understanding of the role of wetland drainage, wetland retention and wetland restoration in a number of downstream environmental costs. While my disciplinary background does not enable me to identify any specific errors or methodological concerns with respect to the individual reports, I did identify the following:

- In Report 4 it was highlighted that the predicted impact of "current wetland scenarios" are likely underestimated due to overestimated current wetland area in most or all basins due to the assumption that partially drained wetland retain 50% of their historical wetland area. As the authors highlight,"… the impact of "current wetland scenarios" should be considered much higher than reported in this study, with "current" losses of wetland area being up to 50% higher than estimates shown in this report". I am not completely sure if this is an artifact of errors in the CWI information or due to assumptions used in the specific research. Nonetheless, this seems to be an important concern that needs to be carefully acknowledged. This issue is an artifact of both the CWI dataset and an assumption made in this specific research. In the CWI dataset, some wetlands are classified as "partially drained". These "partially drained" wetland polygons not been resized to reflect the current "partially drained" wetland area. Instead, these wetland polygons are the size of the original or historical wetland area. As such, data users are required to assume a fraction of remaining wetland area in "partially drained" wetlands. As a team, we decided to assume that "partially drained" wetlands retained 50% of their historical wetland area. Additional text is provided in Section 6.2 to help the reader understand this issue more clearly – including reference to tables in Appendix A where the area of "partially drained" and "farmed" wetlands is listed for each major basin.

- In Report 4 the recent report by Rahman (2021) was highlighted. The authors of Report 4 summarize that "…wetland drainage density is underestimated in southeastern Saskatchewan where landscape contouring is a more common drainage method than trench-like ditching that occurs further north. This explains the higher estimated increase in EDA for the Assiniboine River basin using the quarter section method. Most importantly, this example also suggests that "current" wetland retention scenarios were likely overestimated in this study, resulting in potentially underestimated impacts of current wetland retention scenarios on runoff volumes." I would suggest that with agricultural producers having greater access to improved GPS technology and remote sensing tools along with improvements in drainage equipment, land contouring is becoming a more viable alternative to manage surface water on agricultural land. As a result, this approach to identify drainage could be a significant gap in the data the reports are based on. Agreed. Added to the discussion in Section 6.2.

- The Steward and Kantrud wetland classification system uses vegetation patterns and plant species to determine wetland permanence and wetland class. Therefore, I felt that there should be more discussion about the impacts on the results of assuming that wetlands less than 0.5 acres are predominantly Class 1 and 2 wetlands, wetlands less than 3 acres are predominantly Class 3 wetlands and wetlands less than 5 acres are predominantly Class 5 wetlands. I understand the reason for using wetland size as a proxy for wetland permanence but the limitations of this assumption should be clearly stated. Consistent with this comment the author of Report 2 states that "Seasonal wetlands (Class 3) cannot be defined exclusively by size category, due to a wide range of areas in this class, but WSA wetland inventory data indicate that many wetlands < .10 ha (0.25 acres) are typically Classes 1 and 2. An extremely careful examination of the existing data might provide deeper insights into defining sizes of class 3 wetlands….". Agreed. Clarity on this topic was added in Section 4.2.3 and 6.4.1.

- The discussion in Report 4 had a strong focus on explaining and applying the CDA method. However, the author then concludes that the "CDA method does not work to estimate changes in peak flow characteristics, general estimates of instantaneous peak flow changes were made based on log-log relationships between EDA and instantaneous peak flow as outlined in the PFRA Small Dam Design and Construction Manual ". I do not understand the full implications of this but it is concerning if the primary method adopted in the report does not provide results that are useful and applicable to policy development questions. Fair point. This is also major concern of mine. Unfortunately, analysis of the impact of drainage on peak flows needs to be more site-specific than the scope of this project allowed. More work is needed on this topic.

<u>Report Applications:</u>
Reviewer provides three recommendations for further applications and/or studies related to the topic of wetland mitigation policy analysis. These are thoughtful suggestions for further work on this topic and I agree they would be informative for management decisions and policy development.

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REVIEWER

General comments:

The logic, methodology and limitations are adequately explained in the report. The report also describes the difficulties in attempting an analysis of this type over the large geographic area encompassed by the prairie pothole region within Saskatchewan. Thank you. Yes, there are several difficulties in attempting this analysis at such a large geographic area.

The methodology is sound in so far as it uses logical methods to estimate the change in runoff due to an increase in the effective drainage area resulting from removing wetlands from the landscape. Appreciated.

Insofar as this study is concerned it achieves the goal of identifying the theoretical changes in runoff volume that will occur with reductions in wetland area. One of the main shortcomings of the method is that it cannot be calibrated or verified other than in very general relationships. Agree.

It also does not estimate the change in peak flow rates that may result from wetland drainage. An increase in flow rates is one of the main concerns when any watershed drainage occurs. I believe that the authors are correct that is infeasible to do this on the geographic scale attempted in this study, but it limits the methods utility in quantifying impacts and helping to define policy. Agree. An unfortunate reality of the scale of the questions being asked. Might further investigate peak flow basin transfer methods.

Some additional points should be kept in mind. Wetland drainage does not generally occur in isolation, and it's usually accompanied by additional channel improvements either in anticipation of wetland drainage or as a result of needing to accommodate higher runoff volumes and peak flow rates. Community groups (operating under different names across the prairies) have historically been formed in an attempt to deal with a perception of inadequate drainage and with the expressed purpose to improve the channel drainage, which subsequently allows additional wetland drainage. A fair point. Can try to incorporate this observation as it is true and a helpful part of the discussion.

Analysis of the combined effects of the decrease in storage, increase in effective drainage area and improved conveyance can only be achieved through a detailed analysis the simulates the watershed hydrologic characteristics as well as the changes in land use and volume of storage over time. It is also very much watershed specific. Agree. More case studies that include modelling are needed.

The base date for analysis will to some degree reflect changes that have already occurred in the landscape since settlement and conversion to agriculture. In this study, the base for the wetland inventory appears to be approximately 1970. Unfortunately, this would not capture drainage which occurred before 1970, which the Water Security Agency has identified is significant in many watersheds. A fair point. Unfortunately, we had to pick a "historical" condition for this work, and we did the best with the data available.

Another factor which most of the modeling carried out to date and referenced in this study is that it does not explicitly consider is changes and improvements to the local drainage infrastructure which has occurred over many years and has altered how quickly water will leave the watershed. Agree. This relates to the previous comments about improved efficiencies in drainage channels and infrastructure.

In much of the prairie landscape every road is a potential barrier to drainage due to low natural topographic gradients and the conveyance infrastructure can be the limiting factor in peak flow rates, especially for lower probability events. The definition of the watershed area and whether the design flows are based on the gross or the effective watershed area can make a significant difference in the design of the hydraulic capacity of the infrastructure. Agree. Can add to discussion.

It is when a reduction in watershed storage and associated improvements in hydraulic conveyance that we see the largest impacts on downstream flow rates. Unfortunately, the EDA Method cannot estimate this change. Agree. This is in-line with previous comments and can be added to the discussion in the report.

I believe that the authors are correct that is infeasible to do this on the geographic scale attempted in this study. Thank you. I appreciate your comments on this aspect and will update the discussion to mention these specific limitations of the CDA method.

In conclusion, the report **Analysis of Wetland Mitigation Policy Outcomes - Hydrology and Flooding**, uses a logical approach to attempt to quantify the changes in runoff volume that will occur in major basins for various levels of wetland drainage. The method cannot identify the changes in flow rates that may be associated with the changes in runoff volume and as a result it may limit the utility to identify acceptable levels of wetland drainage from a policy perspective. Very fair. The analysis completed was with limited budget. Additional funding could be used to evaluate the impact of wetland drainage on peak flows in select watersheds and/or explore some of the hydraulic aspects of drainage channel installations related to wetland drainage.

January 4, 2023

REVIEWER

General comments on all reports:

"Who is the audience?" More thought needs to be given to definitions of terms used, simpler and higher-level summaries of key results and the analytical decision behind them. In most cases, the information is available, but is often buried in technical discussion and will not be easily discerned by most readers. Put more work into the summaries and recommendations, ensuring that critical analytical approaches are highlights along with the uncertainties that go with these decisions. Ensure that results are communicated clearly, along with the uncertainties and biases inherent in the numbers. Thank you for this observation. Statements about the intended audience were added to the Executive Summary and Introduction. Readers were assumed to have some technical knowledge of prairie hydrology.

An apparent underestimation of historic drainage – at least to this reviewer, but was also highlighted in the hydrology study – is perhaps the most significant shortfall in the entire set of analyses. If the WLI significantly underestimates historic drainage, it affects this entire exercise. The hydrology report highlights a possible underestimation of "current" drainage levels due to a probable over-estimation of "partially drained" wetland area. This issue is discussed at length in the report and edits have been made to clarify the reason for uncertainty in the "partially drained" wetland area. A new Section 6.1 was also added to discuss the limitations of the CDA method and CWI dataset in more detail.

Lastly, some thought should be given as to how these reports integrate, not only from a design and layout standpoint, but in terms of a synthesis of relevant information from each into a coherent summary. This was not in the terms of reference for anyone at this time, but it will be a key consideration going forward. Agree.

Generally speaking, and with the exception of the water quality analysis, the reviews downplayed interprovincial considerations, other than those required by treaty (Souris River) or agreement (Prairie Provinces Water Board). The water quality paper was explicit is assessing issues of concern in Manitoba basins. It would have useful to see more explicit discussion along these lines in the hydrology paper as well. The ISRB and PPWB have formal agreements on water quantity. These agreements are specific to the allocation of water volumes to each jurisdiction and primarily come into play during drought conditions. There are no formal targets or agreements in place to restrict the volume of water leaving Saskatchewan provincial boundaries. Currently, there is only a Memorandum of Understanding between Saskatchewan and Manitoba, which is highlighted in the hydrology report. Further, water quality measurements and targets are a more useful tool for evaluating and managing flow conditions between provinces because they can be used to set specific acceptable ranges under all types of flow conditions. Water quality targets can be the tool needed to change land-use/behaviours/treatment upstream. Water quantity targets cannot do the same due to variability in climate conditions.

Hydrology and Flooding: General Comments

I found this report a challenging read. It would be very useful to have had a glossary of terms used, especially for those who are not hydrologists. Some areas are well written, but the overall tendency is towards dense narrative where the non-hydrology crowd (me) struggled to find summary statements that would have rewarded the reader's diligence. If this report is intended for audiences beyond those with a detailed understanding of hydrology, more attention to how the report communicates is required. A Glossary has been added and the summary statements in the Executive Summary have been edited for clarity. The audience was assumed to have technical knowledge in prairie hydrology, which is now stated in the Executive Summary and Introduction.

While some key findings are summarized in the executive summary discussion and conclusion, the consultants could have done more here to summarize reasons for analyses chosen (or rejected) as well as potential biases in the approaches chosen. Most policy makers and advocates in the policy arena will not get beyond these sections, so more complete summaries are key. This is a fair point. However, this report was written for a technical audience with the expectation that these types of details would be later highlighted for policy makers. Additional discussion of approaches and potential biases has been added in Section 6. A conscious effort was made to not suggest a specific policy target, but instead provide information and analysis to support decision making.

As with other studies, limitations in the Saskatchewan WLI are apparent. This study makes rather clear statements about the WLI's limitations, which is helpful context for this analysis as well as for the other reports. I have commented on this apparent limitation in the other reports and will not repeat them here. Thank you.

The consultants conclude that models available - SWAT and CRHM – would have been better predictors than approach chosen, but they also say that these models cannot be applied broadly. That is unfortunate. Agree. Given the time and budget available, only high-level analysis was possible.

It is understandable that the consultants would have adopted a more simplified approach – Contributing Drainage Area (CDA) to conduct their analyses but it is nevertheless disappointing because of the significant limitations. In a number of places I was looking for more explicit statements as to the limitations of this approach. While it is discussed in various places in the extensive report, there should be more explicit statements in the summaries. Does the CDA overestimate or underestimate drainage impacts on average? Highlighting comparisons between the CDA and other models would be useful, as it would point to potential biases at larger scales. Clear statements from these discussions, presented in summary form in the executive summary, discussion or conclusions sections will help many readers who are not hydrologists capable of wading through the details. Fair. A new Section 6.1 was added to the discussion to address the limitations of the CDA method and CWI dataset. Comparison of the CDA method results and recent modelling results is provided in Section 6.2 with a summary paragraph at the end. Summary bullets in the Executive Summary and Conclusions were edited for clarity.

Different analytical approaches were taken re: the impact of wetland drainage on peak flows – perhaps one of the most important considerations in wetland policy development – but statements ended up being quite equivocal I looked for clear statements here and did not find any. I did note what appears to me to be a contradiction between a statement regarding peak flows in the Executive Summary vs section 6.3.2. The consultants should be encouraged to offer more insight and expert opinion on this subject, as it is one of the most important elements of the hydrology review. Thank you for flagging the contradiction, it has been corrected. I agree that peak flows are an important element of this review. Unfortunately, making peak flow assessments at the geographic scale of this study with any level of accuracy was incredibly difficult due to the reasons discussed in the report. A new statement has been added to the Executive Summary and Conclusions suggesting that the province avoid a policy target of 50% retention of historical wetland area– citing large increases in runoff volumes and peak flows.

REVIEWER

Page 4: Size is not synonymous with class. For example, there is a large overlap in sizes of ponds of different permanence classes, particularly classes III and IV, and it is important to describe this. Good point. Additional text has been added.

Page 11 (and in methods, results). The authors have done a nice job describing the (dynamic) role and nature of effective and (non) contributing areas, and the influencing role of wetlands. Historical wetland areas more correctly described as estimated historical wetland areas. It is notable that the estimates of wetland loss from all of the basins (e.g., 5-9) are lower than well published estimates (e.g., see comments on Wildlife Chapter), which highlights the need for caveats around the baseline used in this analysis. Comparisons to this baseline risk underestimating the change in streamflow due to historical drainage in SK. (alternatively, as has been acknowledged, current levels of drainage could also be underestimated, but given that the data used to establish the baseline being quite recent (~10–15 years) while wetland drainage has been ongoing for more than a century, it would seem likely that the historical condition has not been accurately captured). The limitations of documenting a historical condition with current data should be described. This is a good point. Rather than adding "estimated" ahead of "historical" throughout the report, a definition of "historical" wetlands in the CWI dataset was added in Section 2.2. This definition states that "historical" wetland areas in the CWI dataset are estimated. A new Section 6.1 was also added to the Discussion to highlight these limitations of the CWI dataset.

In section 2.2 (page 15), it is stated that:

"LiDAR surveys offer the ability to recreate a digital representation of the land surface and then use automated programs to identify landscape depressions that are likely to form wetlands. LiDAR-delineated wetlands are therefore defined by their topographic spill point rather than soil or vegetation characteristics."

I would recommend offering further clarification here, as this description seems to be strictly focused on depressions that are not holding water at the time of the LiDAR survey. There are LiDAR methods available to identify water surfaces, and also canopy height, so inundated wetlands and those with a tree ring are possible to identify with LiDAR. Fair. Updated.

In section 2.3:

"Wetland restoration from 9.5% of the basin area ("current" air photos from 2005) to 12% of the basin area ("historical" air photos from 1968) decreased peak discharge by 23% during a relatively dry model period from 1990-1994 (Yang et al., 2010)".

It is worth emphasizing here that in dry conditions referred to, much of the watershed is not contributing, so even with drainage, large increases are not expected, because many of the remaining wetlands won't reach their spill point. Fair. Added.

In the example below, what was the relative expansion of the EDA (size of the non-contributing area matters here, because 50% of a very small NCDS isn't much of an increase)?

"Expansion of the EDA by 50% of the non-contributing drainage area increased spring peak flows by 113% and annual flow volumes by 98% during a model period of 1997 to 2009,which… " Good point. This section now has bullet points to better describe each modelling study. EDA expansion by 50% changed the wetland area fraction from 11% to 6%. Table 2-1 was added to summarize the results of each modelling study by change in wetland area fraction.

In this section, it is worth also citing Spence et al. (under revision; https://hess.copernicus.org/preprints/hess-2022-102/#discussion) as their work fits in the context of your overview of hydrological modelling with CRHM in the PPR. They demonstrate that median annual flows are the most responsive to drainage (because the driest years are too dry to connect, and the wettest years are connected even in the absence of drainage, and so don't change as much), and can triple at high levels of drainage. This is an important distinction to make with the CDA analysis. Great. Thank you for providing this reference. Added.

I'm finding this and similar descriptions a bit opaque:
"wetland drainage from 11% of the basin area (air photos collected in 2009) to 0% of the basin area"
Because it can be interpreted as the 11% is the drainage (and not wetland land cover), and the reader ends up relying on the results to properly interpret what is being described. Consider something more straightforward like: "drainage scenarios that reduce wetland coverage from 11% to 0% of basin area…." Thank you for the example. Text updated accordingly.

Clarification of what is meant by 'basin' in the following statement. Is it 'EDA' which is meant?
"Using a method similar to (Badiou et al., 2018), which is based on the density of the hydrographic network and agricultural drainage features, Harrison (2019) estimated that artificial drainage increased the basin by about 26% in areas with available data." Good catch. Updated to EDA.

In this section, the report does a nice job of describing the limitations of the CDA approach. One of the keys in the context of wetland drainage is that drainage activities are very much place-based, while the CDA method looks at larger watersheds. While the spatial variation in physical land structure is acknowledged, one additional source of spatial variation is the local climate (see also comments above re response in dry and wet conditions), which varies in important ways across the domain shown in Figure 3-1, and also within the watershed boundaries in Figure 3-2. In this context, two drainage projects in different corners of a larger watershed would differ in response with differences in local climate (e.g. where one is wetter and one drier, as tends to happen in moving westward across SK), even with comparable basin physiography. This should be discussed. Likewise, it would seem necessary to evaluate watersheds that are consistent with the scale of network drainage approaches. What are the limitations of using an analysis for basins that are one or more orders of magnitude larger? Discussion added in new Section 6.1.

It is also worth noting emerging research which uses a virtual basin approach to hydrological model application for wetland drainage scenario analysis. One product under development (PHyDAP: https://gwf.usask.ca/prairiewater/documents/prairie-hydrolog-data-product-exec-summary-v3.pdf) is designed for use in association with a hydraulic model. This will offer an approach that is less computationally intensive than a full build-out of a hydrologic/hydraulic model, but also offer a more robust information than a statistical approach like the CDA. This is one method that could be used to answer questions around peak flows at the drainage scale, as the authors recommend. Thank you for flagging this. PHyDAP is now noted in the recommendations for future study.

While I take the points on practicality behind the CDA, one could argue that the CDA serves as a useful first (screening) step to identify areas (sub-sub basins) of the province where the risk of hydrological impact of wetland drainage is higher/lower. It may be equally 'practical' to conduct a detailed (model-based) investigation at select locations where drainage is proposed/planned in order to have more robust and diverse information, and further reduce any risk around the drainage approvals decision process. The context around the use of the tool/approach and the robustness of the information generated from any approach is an important consideration. This is worth discussing further. Agree that this additional modelling work is needed. Unfortunately, the CDA method was the only possibility given the time and budget available for this work. More discussion of the above is now provided in the first paragraph of Section 6.1.

Figure 3-6 should include a legend in addition to the partial description provided in the text. Added.

In table 4.1, the wetland scenario with 20% retention yields a level lower than the floor scenario. Some explanation of how this scenario was established and which of the conditions governing the drainage scenario were not followed to establish this scenario is needed. This was a typo that has been updated.

Section 4.1

More detail on how the wetlands were removed in each of the drainage scenarios is required. Are all wetlands removed from randomly selected quarter sections, or are the wetlands removed at random irrespective of quarter section? The locations of wetlands and their order of removal was not required for the CDA analysis, which only considers changes in wetland area. This is a good question, because wetland spatial layout (i.e., distance between, degree of clustering, etc.) matters for wetland fill-and-spill runoff dynamics and specific changes in contributing area in smaller basins, however those considerations are beyond the scope of the CDA method.

An underlying assumption of the CDA method is that any drainage of wetlands within the EDA does not change streamflow. Correct. Given that this drainage nonetheless removes depressional storage, it is probable that this approach underestimates streamflow response to drainage. Yes. While acknowledged in the discussion, further exploration of the impact drainage in these basin areas can have on these relationships for high-frequency low volume events is warranted. Fair, Another Reviewer had a similar request. Perhaps a (coarse but) simple exercise to quantify depressional storage and relate this to annual runoff volumes could be employed. Agree this would be nice, but not practical within current budget. Again, this is an areawhere this information can prove key to identifying cumulative impacts (e.g., environmental flows/habitat).

Section 5.

Given the wide ranging CWI for the sub-sub-basins considered, it is important to consider the level of uncertainty associated with CWI coverage. In cases where coverage is <<50% (e.g. NSRB), the analysis extrapolates sub-basin behaviour to the full basin area (using basin EDA). With wetland areas unknown for the majority of the basin, there are risks that basin response could well be under or overestimated. Some effort to describe or document this uncertainty associated with cases of low CWI coverage should be documented. Some understanding of this uncertainty will be key to guiding decision making should this approach be used to assess impacts. Additional text is provided Section 5.2 to clarify the method when CWI coverage was limited. The method would err on the side of underestimating impacts, because drainage is only considered in the area with CWI coverage, yet the results were compared to the EDA of the entire basin. More clarity is also added to Section 5.3.4 for the NSB.

Section 6

While I understand why such an analysis was not possible here if complete quarter section wetland drainage was the approach used, it is worth noting that four different wetland drainage scenarios were considered in Spence et al. (link above) so this might be worth reviewing as it pertains to the questions around excluding small wetlands from wetland retention policies. Their analysis did not find meaningful differences in runoff response when draining wetlands from smallest to largest or largest to smallest. Added this information and citation to the end of section 6.4.1 on size or class exclusions.

A citation to support this statement should be provided:
"This suggests peak flows could be increasing in sub-sub basins of the Carrot River since peak flows can have a significant impact on downstream water quality". Re-written to cite personal communication with Dough Johnson regarding Carrot River water quality and Baulch et al. (2021) for peak flow impacts on downstream water quality.

In section 6.3.2, perhaps it is worth describing what the outcomes of excluding the wetland classes would be in and of themselves. It makes sense that the ceiling would be raised as a result of their exclusion, but it is also worthwhile to comment on what runoff change would be expected according to CDA if all <0.25, <0.5, etc. were lost. Perhaps there is a policy scenario where no additional drainage (of larger wetlands) is permitted, and this analysis would provide additional context. This is now section 6.4.1. The term exclusion means that wetlands in that class could be freely drained, as stated in paragraph 3. The impact of excluding incrementally larger wetland sizes is presented in this section, which answers the scenario suggested above. The new ceiling and associated increase in runoff volume is given for each size class exclusion in the Assiniboine, Qu'Appelle and Souris River basins. Tables is Section 5 and Appendices A and B can be used to estimate the impact of any variety of additional scenarios one wants to consider.

Agreed, and one environmental cost of tile drainage is increased nutrient export. I recognize this is beyond the scope of this analysis, but with earlier mentions of nutrients, it would be valuable to acknowledge this here.
"While this is a more expensive option for draining wetlands compared to surface ditching, one environmental benefit is reduced peak flows." Good point. This is likely to be a hot topic as land values skyrocket. Added.

Overall:
The report does a good job describing the approach used to estimate changes in annual runoff associated with wetland drainage, and summarizing the results of the analysis. In places some of the text becomes repetitive, and in places some additional detail would add clarity, but the approach is generally well documented. The report presents a case for the CDA approach rather than hydrological (or hydraulic) modelling, despite the inability of this method to identify peak flows for example. There is room to better describe some of the uncertainties associated with the method, especially in the context of policy development. Given the rationale to use a large spatial scale-approach to inform what can be very local impacts of wetland drainage, documentation of this uncertainty is important and should be more explicitly incorporated. Thank you for this detailed review and helpful suggestions. Greater documentation of uncertainty in the methods has been added following your specific comments above.