Responses to the Referee #2 (Claire Cote)

We appreciate the Referee #2 for her comments on our paper. Below we attach our brief response to the issues raised by the reviewer in expectation of a successful discussion.

General Comments The objectives of this manuscript are not clear, are focused on minor modelling considerations and do not contribute valuable findings to the field of waste cover design. This is unfortunate as it forms part of a broader program of work that would bring interesting findings worth publishing. For mine reclamation covers, key objectives of the design should be that (1) it will lead to successful ecosystem restoration (eg. plants are growing successfully) (2) the quality of the seepage does not lead to impacts on the receiving environment and (3) it addresses any other objective identified as part of design and mine closure planning. The manuscript does not clearly state how it contributes to the understanding of how the selected cover designs will meet these objectives.

Response: The authors agree regarding the design objectives for mine reclamation covers. However; we humbly disagree with the reviewer's perspective on our paper. The purpose of the study was to highlight how climate and parameter uncertainty might be incorporated into these designs so that the variability and uncertainty associated with the reviewer's objective 1 (e.g. AET) and objective 2 (e.g. amount of NP) can be more fully characterized. In our humble opinion it appears that the reviewer has misinterpreted the primary objectives and contribution of the paper.

Among other things, models are used to provide a simplified mathematical representation of reality so that various scenarios can be analysed. If we change the parameters in the mathematical representation, the results from the model will be different. It does not meant the reality itself has changed, so I struggle to understand what the study is trying to prove. It seems like a circular proposition. If we modify the van Genuchten parameters then of course the predicted water balance will be different. The issue is not the value of the parameters but our ability to understand how changes to the water balance can prevent the design from meeting the objectives stated above.

*Response: We agree with the reviewer's view of models; however, it would be of great value to a designer to be able to assign 'uncertainty' to a particular design (parameters or climate) since these uncertainties are directly tied to risk (i.e. cost * expectation). You can change parameters all you like but it doesn't tell you anything about the source of the uncertainty or quantify the magnitude of this uncertainty. Again – the reviewer's comment, although correct in and of itself, makes us wonder if the reviewer understood the purpose of the paper.*

For instance, a design is developed specifically to minimize seepage but a modification in the surrounding environment leads to increased seepage and risk to the receiving environment. Statistical analysis can assist with quantifying the probability of that scenario and this is what we should be focusing on. If the scenario is likely then there is a requirement to develop mitigation options, such as installation of additional monitoring equipment to capture changes and mitigate them. The values of the hydraulic parameters in the mathematical representation are not that relevant to the mitigation of the issue.

Response: We fully agree that the key is assigning probability to the predictions. We humbly disagree that there then is no value in assessing the potential impact that uncertainty in hydraulic parameters (and climate) have in this assessment of uncertainty.

With advances in mathematical software, particularly Mathematica, MatLab or R, there is less and less of a need to develop specific mathematical approaches for solving soil science or environmental science problems. With the Wolfram Language now in the public domain, it is even less justifiable. I have never heard of the Latin Hypercube Sampling, but looking at the description in the manuscript, all I would need to do in Mathematica is to Map the Range function unto the parameters. It seems very straight forward and certainly does not justify a publication. Hydrus 1D could probably be re-coded in Mathematica very quickly and the predictions would be much faster and much more stable. It does not seem that there has been much evolution in the field of vadose zone hydrological modelling in the last 20 years.

Response: The unsupported and unjustifiable opinion of the reviewer seems to highlight either a lack of understanding or an anchored bias. If 'all I would need to do' was true then why has this type of study on sources of uncertainty in soil cover water balance been published previously? We strongly disagree with the statement that there is 'less of a need to develop specific mathematical approaches'. Mathematics and numerical models are simply tools. But we are trying to utilize these tools in a unique way to gain some insight into a critical problem in the evaluation of long-term soil cover performance.

There would be value in re-assessing these models in light of advances in mathematical software. In terms of developing a more robust approach to test the performance of cover design, I would suggest leaching experiments on large columns, which can reproduce leaching results much more quickly than what can be obtained in the field. It is a more reliable method to investigate the impact of variations in the water balance. The greatest long term risk to the viability of soil covers and associated ecosystems is climate change with associated variations in temperature and precipitation. Column tests can provide an indication of expected changes in soil water behaviour under extreme precipitation or temperature regimes. This would be a much more robust contribution than mathematical manipulations of soil parameters. Another key gap seems to be the assessment of snow pack height on cover behaviour. This could also be investigated with column testing. Assessment against HESS criteria

Response: Modelling, including the types of evaluation of uncertainty we have proposed, doesn't preclude but rather builds on strong field or even column based data gathering.

However, the reviewer's confidence in solving this problem through the use of column testing is misplaced and misinformed. Column tests and small/short-term field cover tests have proven repeatedly to be difficult to interpret relative to long-term cover performance over large spatial and temporal scales. The suggestion that snow pack height is best investigated in column tests is particularly incongruent.

The paper is well-written, well-referenced and well-structured. Figures, tables and cross-references are fine. The key issue relates to the value of the contribution to the hydrological community. The objectives and research questions are ill defined. The paper does not present novel concepts, ideas or tools. Clear conclusion are provided but they do not contribute much to the assessment of the performance of cover designs. The description of experiments and calculations are complete and precise. The authors give proper credit to related work. The work described in the paper is part of a broader project that is very interesting. The title clearly reflects the contents of the paper. The abstract provides a concise and complete summary.The language is fluent and precise. The number and quality of references appropriate There is no need to provide details about the Latin Hypercube Sampling methodology, it is a routine calculation.

Response: The authors want to thank the reviewer for taking the time to read the paper and provide her perspectives and comments.

Where there has been constructive and useful recommendations we will make appropriate changes. However, overall the comments of the reviewer appear to betray both a misunderstanding of the actual goal (and value) of the paper and/or betray some anchoring bias towards completely different approaches to study soil cover performance (e.g. not using physics based models but rather column testing).

We have attempted to respond positively to the apparent confusion of the reviewer regarding our contribution by further refining the following comments. We sincerely thank RC2 Claire Cote for bringing the following issues to our attention which will definitely improve the quality of our manuscript.

Novelty and Contribution to the hydrological community:

Long-term cover performance is commonly evaluated without quantification of the uncertainties which may originate from various sources including: climate, soil hydraulic parameters, vegetation index (i.e. leaf area index) etc. The use of a single set of model parameters in the design of reclamation covers precludes our ability to quantify the potential impact of uncertainties in parameters or climate and consequently makes it impossible to quantify the associated risks in performance. While our previous study (Alam et al. 2018a) investigated the impacts of climate in changing climatic conditions on the long-term cover performance, this study investigates the sources of uncertainty associated with the evaluation of long-term cover performances. This study considers a unique way to characterize the spatial and temporal uncertainty in the total parameter uncertainty utilizing field monitoring data from 13 treatment covers (replicated in triplicate and monitored in four consecutive years). The field monitoring data includes water content, soil temperature, and soil suction values recorded at various depths at each of the treatment covers. There are few instances in the literature where such a large data record is available to quantify uncertainty. It has not been attempted previously in the context of oil sands reclamation covers. While the use of Hydrus-1D inverse modelling tool to optimize soil hydraulic parameters (both VG and saturated hydraulic conductivity) is not new, the use of this tool to develop probability distributions for optimized parameter sets from multiple sites and years is novel, particularly when one of the parameters (Ks) can be directly compared to field measured distributions. Since, the risks associated with a cover design would be based on the probability distributions of water balance components, it seems reasonable to use a computationally efficient sampling method (PLHS in this case) to obtain all possible probability distributions of the optimized parameters, which was motivation for the current study. (P33L10-16 to P34L1-10)

Objective and research questions:

The key research question of this study is as follows: What is the influence of soil hydraulic parameter uncertainty on the long-term cover performance of the reclamation covers in northern Alberta, Canada. This question led us to the following study objectives: (i)Identify the most-efficient way to characterize distributions of the optimized hydraulic parameters from a physically-based water balance model for an oil sands reclamation covers in northern Alberta, Canada and (ii) Quantify relative uncertainty from various sources associated with the long-term water balance of the reclamation covers. (P3L27-31)

Conclusion on the assessment of cover designs:

We included this in our responses to RC1; however, we are repeating it here for ease of reference. We added to our conclusion, "Design of reclamation covers are typically based on the long-term simulations of AET and NP using a single parameter set that excludes the incorporation of parameter variability in simulating NP rates. This approach is likely to underestimate the possible ranges of NP rates. The elevated NP rates that develop when parameter variability is incorporated is an important finding which will need to be considered by industry in developing their closure designs. The consequences could be elevated volumes of water yield from the reclamation covers to the adjacent surface water bodies as well as associated increases in rates of chemical loading from the underlying mine waste. Given the role that climate change is expected to play in future water balances of reclamation covers and the similar magnitude of impact played by parameter variability in simulating NP, integration of both climate change impacts and parameter variability across the landscapes needs to be adopted in the mine reclamation cover design in future." (P35L10-18)