Below are our responses to the comments from two referees regarding egusphere-2023-142, entitled: Developing a tile drainage module for Cold Regions Hydrological Model: Lessons from a farm in Southern Ontario, Canada, authors: Mazda Kompanizare et al.

The line numbers on our responses to the referees' comments are based on the latest annotated version.

Referee #1

Suggestions for revision or reasons for rejection

Please refer to line-by-line comments. Line numbers refer to the track changes manuscript version,

1)Comment

Line 232: TDM defined already? Not until line 299

Response

Thank you for catching this. We added a definition for TDM in introduction section (Line 142-145).

2)Comment

Line 248: the soil is a clay loam

Response

In Line 223, "… in heavy clay soil, …" was changed to "… in clay loam soil, …" .

3)Comment

Start on 299. Line 307. Reference conceptual model at line 307.

Response

In line 307 (older annotated version) we could not find "… conceptual model …".

4)Comment

Clarify “soil moisture” in line 308

Response

In lines 274 to 275, we revised the text to “… soil moisture (including both saturated and unsaturated soil moisture) … ”

5)Comment

Line 321 subheading. Change to water table ‘elevation’ instead of ‘position.’

Response

The change has been made (line 288).

6)Comment

Line 325- Figure 2 not 2a

Response

It was revised (Line 292).

7)Comment

Line 326. Change water level elevation to “water table elevation”

Aren’t all layers “semi-permeable” as defined by their Ks?

Response

“… water level elevation …” was changed to “… water table elevation …” (Line 291). You are right, all layers can be semi-permeable based on their Ks, but in this study we assumed the layer at the bottom of the soil layer as semi-permeable layer.

8)Comment

Line 333. field capacity defined with different symbols (thetafc vs. hfc)

Do you mean volumetric water contents at fc and matric potential at fc?

Response

They both refer to field capacity, one expressed in volume fraction (θ_{fc} mean volumetric water content) and the other expressed in units of water column (h_{fc}). We clarified this in line 305.

9)Comment

Line 342. Matric head or pressure head? Matric implies suction when the soil is dry and under tension. Matric potential ~ 0 at saturation.

Response

In lines 311 and 313 we changed the "matric head" to "water table".

10)Comment

Line 345. You switched to water table level in #3. Revise 1 and 2 to be consistent with #3.

Response

Revised to "water table".

11)Comment

Line 350-351. Much of the water between theta-fc and theta-wp is held in micropores and would not likely drain from gravitational forces and would only be available to plant roots.

Response

Based on the generic soil characteristic curve illustrated in Fig. 2, when the water table drops further than capillary fringe thickness (Condition 3), a part of the soil layer above the water table is occupied by capillary fringe with moisture content equal to θ_C (as we defined in the new revision) and above this layer is a layer of soil with soil moisture equal to field capacity. In Condition 2 the soil moisture in this upper layer is equal to θ_C, and after changing from Condition 2 to Condition 3, the moisture content in this upper layer gradually shifts from θ_C to field capacity. CRHM soil layers have an empirical soil moisture depletion curve taken from Zahner (1967) for soil moisture withdrawals to support transpiration.

12)Comment

Line 360. Hooghoudt's equation does not use matric potential it uses water table depth.

Response

The reviewer is correct. We've used the water table. This has been corrected (Line 338) "… matric potential" changed to "… water table elevation above the tile pipe". We apologize for the oversight.

13)Comment

Line 369-370. "the case with our case study…" Revise

Response

Line 340: ‘’In the particular case of the case study site, …” was revised to “ At the study site, …”.

14)Comment

Line 389. Define φc again.

Response

In line 355 and 356 we added φ_c to the relevant definition for this parameter as “ … , which consists of drainable water in the soil (φ_c) …”

15)Comment

Line 394. Matric potential or water table depth?

Response

Line 364: we changed “ … matric potential:” to “… water table elevation:”

16)Comment

Line 396. φc not defined previously. You should consider defining all variables in eq. 3

Response

In Line 356 φ_c was defined, before Equations 2 and 3.

17)Comment

Lines 422-424. Sounds like you are implying that the elevated matric potential is causing the increase in soil moisture?

Response

Line391 to 395: Since the matric potential is a negative number, we meant that during soil water seepage and concomitant soil moisture decrease, the matric potential becomes more negative, i.e., negative matric potentials with larger absolute values.

18)Comment

Line 429. How is Dd determined?

Response

We have added a new Appendix D, in that we discuss how Dd (time delay) was assessed.

19)Comment

Line 446. Include units for field capacity

Response

Lines 418-419: we added the unit of "… (volumetric water content) …".

20)Comment

Line 451. Matric potential or WTD. Believe the latter. What's the difference between dependent and state variables?

Response

Line 424: here it can be both matric potential or water table depth (WTD), since they are related. State variables are the variables that can change freely and independently during the model run (i.e. soil moisture content), which mostly represent the storage states. While the dependent variables are those who are related to other parameters such as the water table (WT) which in this study is calculated based on soil moisture and soil porosity.

In lines 284-285: "State variables" were changed to "variables".

In Line 423-424: "state variables" was changed to "outflows".

21)Comment

Line 452-454. Revise this to include a statement explaining what you used these methods for (assessing model accuracy)

Response

Lines 429 to 433: We have added a couple of sentences to discuss why we used different metrics to assess model performance.

22)Comment

Line 492: suggest replacing 'assessed accurately' with 'predicted accurately.' Figure 4. Differentiate panel A and B in the figure caption. Not clear how panel B differs.

Response

Line 469: we changed it to "… predicted accurately, …". In Figure 4's caption we added a sentence about the differences between panels a and b.

23) Comment

Line 509. Please clarify "observation gaps". How do model statistics characterize fit between observed and predicted flows? Was there consistent bias in model predictions relative to observed flows? Was there seasonal variation in model performance?

Response

There were periodic gaps in our field observations due to equipment failure. This has been clarified "Despite the gaps in the observational record dur to periodic equipment failure, the model agrees well with observations.".

We calculated the five performance metrics for soil water table (Table 2), using the observed and predicted water tables where observed values were available. Based on what is presented in Table 2 there was about 10% Bias in model water table predictions. A couple of sentences were added to the end of sections 3.3 (Lines 515-517) and 3.4 (Lines 526-535).

Also, these sentences were added to the end of section 3.4: "We calculated the performance coefficients for May-September and October-April. The results shows that surface flow biases were large and negative in May-Sept and were smaller and positive during Oct-Apri." The relevant tables for the performance coefficients for May-September and October-April were added to the text.

Table 2. Performance coefficients for surface flow, tile flow and water table (WT/SSS), as well as total (tile + surface) flow, for the simulation period of October 2011 to January 2018. The coefficients were calculated for both hourly and daily flow rates.

Performance coefficients	**Surface flow**	**Tile flow**	**WT (SSS) (m)**	**Total flow**	
NSE*	-2.29	0.31	0.49	-1.38	Coefficients calculated for hourly flow rates (mm h^{-1})
RMSE^	0.27	0.08	0.26	0.30	
Bias#	0.54	0.24	0.14	0.28	
PBias$	21.77	17.91	10.46	18.63	
RSR&	1.82	0.83	0.71	1.54	
NSE	-0.73	0.29	0.50	0.01	Coefficients calculated for daily flow rates (mm d^{-1})
RMSE	2.04	1.72	0.24	2.92	
Bias	0.35	0.20	0.09	0.22	
PBias	35.11	19.63	9.33	21.73	
RSR	1.31	0.84	0.70	0.99	

* Nash-Sutcliffe efficiency, ^Root-Mean-Square Error, #Model Bias, $Percentage Bias, &RMSE-observation standard deviation ratio

Coefficients for May-September

(The green color shows the performance coefficient which were improved compared with their original values and the red ones were worsened)

Performance coefficients	Surface flow	Tile flow	WT (SSS) (m)	Total flow	
NSE*	-18.98	0.19	0.40	-11.76	Coefficients calculated for hourly flow rates (mm h^{-1})
RMSE^	0.26	0.03	0.12	0.26	
Bias#	-1.43	0.49	0.03	0.11	
PBias$	-142.79	48.88	3.44	10.96	
RSR&	2.85	0.57	0.39	2.27	
NSE	-3.89	0.21	0.41	-1.08	Coefficients calculated for daily flow rates (mm d^{-1})
RMSE	1.39	0.73	0.11	1.66	
Bias	-1.43	0.49	0.02	0.11	
PBias	-142.79	48.88	2.07	10.96	
RSR	1.41	0.56	0.39	0.92	

* Nash-Sutcliffe efficiency, ^Root-Mean-Square Error, #Model Bias, $Percentage Bias, &RMSE-observation standard deviation ratio

Coefficients for October-April

(The green color shows the performance coefficient which were improved compared with their original values and the red ones were worsened)

Performance coefficients	Surface flow	Tile flow	WT (SSS) (m)	Total flow	
NSE*	-0.37	0.24	0.20	-0.04	Coefficients calculated for hourly flow rates (mm h^{-1})
RMSE^	0.11	0.07	0.21	0.14	
Bias#	0.87	0.14	0.11	0.24	
PBias$	86.59	13.56	11.00	24.11	
RSR&	0.90	0.67	0.77	0.79	
NSE	-0.11	0.26	0.24	0.18	Coefficients calculated for daily flow rates (mm d^{-1})
RMSE	1.50	1.56	0.21	2.40	
Bias	0.87	0.14	0.11	0.24	
PBias	86.59	13.56	10.58	24.11	

RSR	0.81	0.67	0.75	0.70

* Nash-Sutcliffe efficiency, ^Root-Mean-Square Error, #Model Bias, $Percentage Bias, &RMSE-observation standard deviation ratio

24) Comment

Figure. 5: The y-axis is a bit confusing. Please clarify the y-axis scale and why it goes negative. Is this implying the water table depth is that far below the soil surface? How could predicted water table be > 0 elevation if 0 = soil surface elevation? Your measured water table depths are never <0 in the figure. Also, it is not clear where the tile depths are located on the figure.

Response

This is an issue of using the tile pipe as the datum. We have added details to the Figure 5 caption: "the water table values on the y-axis are in metres above (or below) the tile pipe". The tile pipe is located at WT=0; thus, the negative values in the figure correspond to the periods when the water table went below the tile pipe.

25)Comment

Figure 6. Revise caption. Performance coefficients were not included.

Response

This caption has been revised.

26)Comment

Line 551. Replace "matric potential levels" with 'water table depth'.

Response

Line 523: Since the water table elevations with respect to the tile pipe elevation was reported, we revised it to "… water table elevation …".

27)Comment

More explanation of model performance in warranted. What's considered acceptable?

Did performance vary by season?

Response

Lines 429 to 433: Further discussion on the acceptable range of performance coefficients were added here. We calculated the seasonal performance coefficients and added them to the text.

28)Comment

Line 556. It might be helpful to include the coefficient of determination (R2) along with these.

Response

We agree with the reviewer that R^2 could be useful, but we consider that the 5 performance metrics used already provide a robust performance assessment. Besides that, the paper is already quite long and, in our view, adding one more metric wouldn't bring a clear added value.

29)Comment

Line 567. Field or catchment scale? Catchment implies a larger watershed doesn't it?

Response

Line 559: we changed it to "… the field-scale …". But we meant we wanted to find a general value for the capillary fringe thickness that can be used in larger-scale studies.

30)Comment

Line 582. How were values normalized? Put on 0 to 1 scale?

Response

Lines 567 to 568: Exactly, for example, by dividing the capillary fringe thickness by the tile depth we calculated the normalized thickness of the capillary fringe above the tile. The normalized values are more comparable between different fields and fluctuate around 0 and 1.

31)Comment

Lines 572-588. This section is hard to follow and the main point is not clear.

Response

In this section (Line 565 to 585) The main purpose of this section is to perform a sensitivity analysis of the effect of drainable water and capillary fringe thickness on tile flow. The variables have been normalized to enable a more generic interpretation and discussion that can be relevant to other case studies. This has been described more clearly in the manuscript (Lines 580-585).

32)Comment

Line 598: If water table depth and SSS are synonymous does it makes sense to differentiate?

Response

Although these are indeed synonymous, we differentiated WT and SSS because WT represents what we can measure in the field whereas SSS is the saturated soil storage which is calculated as a state variable within the model and is eventually translated to WT to be compared with observed WTs.

33)Comment

Line 604. "capillary fridge" to fringe. Also clarify tile discharge

Response

Line 596: "…fridge …" was revised to "…fringe …".

Line 596: By "discharge" we meant the discharge of the soil moisture to groundwater through the semi-permeable layer at the bottom pf the soil layer. We changed the "discharge" to "percolation".

34)Comment

Line 606: Matric potential or water table depth?

Response

Line 598: we changed it to "While the water table fluctuates …".

35)Comment

Line 608. Replace matric potential with water table depth.

Response

Lines 600: It was revised.

36)Comment

Line 610-613. Suggest further clarifying results from Figure 9 in discussion.
Response

Lines (600-608): We have clarified the results

37)Comment

Line 553-554. Include more discussion on model performance for surface runoff.

Response

Line 526 to 535: We added a sentence explaining why the model performance in simulation of surface flow is weaker.

38)Comment

Line 624-634. Not sure this section is necessary.

Response

Line 623 to 632: The paragraph was deleted.

39)Comment

Line 638. Replace matric potential with water table depth.

Response

Line 636: It was revised.

40)Comment

Line 642: How did you determine they were "equally important"?

Response

Line 640: we revised it to "… are important to account for …".

41)Comment

Line 657. Clarify 'holding capacity'. Soil water availability?

Response

Line 655: we have changed "holding capacity" to "non-drainable water"

42)Comment

Line 670. Writing "WT/SSS" makes it seem like a ratio

Response

Line 668: It was changed to " … WT …".

43)Comment

Line 676. Clarify water level in last portion of the sentence.

Response

Line 673: It was revised to "… water table …".

44)Comment

Line 695. follow up here is needed to clarify your point and link to the capillary fringe.

Response

Line 693 to 696: A brief follow up discussion was added here.

45)Comment

Lines 699-715. Add more on how this relates to a dynamic capillary fringe.

Response

Line 700-715: In this section we want to show the effect of regional groundwater fluctuation on the tile flow and water table fluctuations (and correspondingly the dynamic of capillary fringe). We can see that the general fluctuation of soil water table depends on the seasonal pattern of groundwater fluctuations.

46)Comment

Line 723. Change rain 'drops' to rain events.

Response

Line 723: It was "rapid drops in observed WT …", so, we kept it without change.

47)Comment

Line 730. Add a concluding sentence or two to pull together the overall importance of regional groundwater dynamics on tile flows.

Response

Lines 729 to 732: Thank you for the suggestion, which we agree. We've added a concluding sentence.

48)Comment

Line 743. Replace 'matric potential' with water table depth.

Response

Line 742-743: It was revised to " … water table elevation …", as the water table were reported as the elevation from the tile pipe.

49)Comment

Line 746. Did you measure matric potential?

Response

We did not measure matric potential as a continuous time series, but we have the sparse measurements of the matric potential in this field by our team members for other studies. We did not have the continuous time series of the matric potential, but we know that it continuously changes with variations in the soil water table elevation.

50)Comment

Line 768. Your site was clay loam soil

Response

Line 768: it was revised.

Other items

51)Comment

How does the model handle impact of frozen soil on tile flow?

Response

We did not consider the impact of frozen soil on tile flow in this study, but some soil modules in CRHM are capable of predicting the effect of frozen soil on soil moisture (Pomeroy et al., 2007; 2022).

52)Comment

Hooghoudt assumes no surface ponding, but your site experienced some ponding, as mentioned in the results. How might this affect water table/flow predictions?

Response

As we discussed in section 2.4.3, since the surface ponding happened very rarely and for short periods, we did not implement the version of Hooghoudt's equation with surface ponding in the module. But in future version we will add this capability.

53)Comment

Reread and revise Appendices for grammar as needed

Response

The writing was checked and revised in appendices.

Referee #2

Suggestions for revision or reasons for rejection

The authors have done a great job at addressing most of the comments from the reviewers and I have no comments to changes made. I also acknowledge that the study is a preliminary model development based on a single site. However, there are two elements which I still do not find quite satisfactory, these regard the parametrization and application to other locations. Please see my specific comments below which refer to the previous comment numbers. I feel these comments would be relatively straight forward to address.

1)Comment

Comment 6 by Reviewer 2

You would still need a sensitivity analysis to claim that the capillary fringe drainable water and the capillary fringe thickness are the most important parameters. How can you state that they are the most important without a sensitivity analysis and how important are the other parameters? Several review comments address the parametrization of the module also outside the particular study site, and it is important to understand the importance of the many parameters. Which can be set to global values, which need detailed investigation or calibration. Table 1, or an additional table, should include sensitivities to the simulated drainflow, and ideally indications of how there parameter values could be obtained. With so many parameters there needs to be some guidance on which parameters to focus on and why.

Response

A new sensitivity analysis that shows the sensitivity of cumulative tile flow, average water level elevation and cumulative soil to groundwater outflow to six parameters including soil saturated hydraulic conductivity, soil thickness, capillary fringe thickness, capillary fringe drainable water, sine function amplitude and sine function intercept was added as Appendix D.

Also, in Appendix D we added a section about how to evaluate the parameters for a new site.

2)Comment

Comment 7,8 and 9, by Reviewer 2

I understand that this is a preliminary study and you have focused on a single site and tried to learn from that specific site. However, the paper needs a section that specifically addresses how this module would be applied and parameterized at a location without any water table or drainflow observations. Without considering this step it is very hard to understand the value of the model. In modelling we are interested in estimating variables where they are not already measured. Such a section should refer to a sensitivity analysis and discuss the key parameters and how they would be obtained at other locations, also the need for adjusting groundwater levels annually, and how that information would be attained, should be discussed. And the section would be even better, if you could validate the module with just a single additional site, where drainflow is measured, but where you would need to transfer generic parameters from your study site or use the Deduction, Induction, Abduction approach.

Response

As we discussed in our response to previous comment, we have added a section in Appendix D about how to assess the TDM parameters for a new site, probably the site without any water table or drainflow observation. Also, in this section in Appendix D we discuss specifically how we could assess the parameters for the sine function for new sites. Unfortunately, it is not possible for us to validate the model by using it at a new site due to lack of proper data. But we certainly plan to implement the new TDM model to new sites in the future and continue improving it.