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TNO report

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Review reports KWR

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Contents

1 Introduction

Research institutes Deltares and KWR are running a project named “Engine”, relating heating of drinking water in subsurface due to the presence of a heat network or electricity cables in the vicinity of the drink water network. Two models are delivered in this project:

- A model called BTM+ (Bodem Temperature Module), which can be used to predict the impact of heat sources on the drinking water temperature in adjacent water lines.
- A model called WTM+ (Water Temperature Module) , which calculates the water temperature inside the drinking water pipelines.

Three documents have been written, describing the models and the validation of their results. These documents are:

[1] “BTM+ model development and validation and Expert tool computations”, by dr.ir. John van Esch (2021)

[2] “Validation of drinking water temperature model during distribution”, by E.J.M Blokker, Q. Pan, J. van der Steen, H. de Kater and Ben Los. (2021)

[3] “Validation of STM+ model with heat transport measurements of ICAIR test facility”, J. van Summeren (2021) (draft)

TNO has been asked to review these documents, especially on the approach, model assumptions and model choices and their justification. With this review KWR and Deltares has confirmation that the approach taken is looked at and commented on by TNO and potential gaps identified. This report details on that review. Next sections will contain the review of each document individually. Finally, some overall comments are presented.

This document, together with the three documents which are reviewed, will be used as starting point for a meeting with KWR and Deltares where the work and results will be discussed.

2 Review

The review of the three documents is described per document. In addition, comments are digitally added in the pdf document which are given to the authors.

2.1 BTM+ model development and validation and Expert tool computations

This document describes the model development and validation of BTM+, the Bodem or Soil Temperature Module. The 1st chapter is the introduction. Theory, validation and sensitivity of the model are described in the Chapters 2 until 4 respectively. Chapter 5 details on the discussion and conclusion.

Chapter 1: Introduction

This is chapter the model and project are presented. What is not mentioned is a description of the goal of the tool. Is it to be used for design or for research? What are the acceptance criteria for validation? Maybe include also to some references to other tools or methods.

Chapter 2: Model equations.

This chapter describes the modelling approach leading to a set of equations to be solved.

From the description the coupling of the roughness layer and subsurface module is not clear. The roughness layer model is 1D and subsurface model is 2D. How is that matched? Per cell/or averaged over the whole surface. This could be explained in much more detail.

Details on the integration scheme are not given:

- Is it 1ste order?
- What is the effect of Δt?

A picture of the mesh which is used, would be insightful, also dependency of the mesh is not mentioned. Some minor comments are:

- Equation 2.20 Gss should be Gs?
- Equation 2.42, how do you get T^1_{at}?
- The part of explanation of the FEM solver is too short and not necessary. T_b is a vector containing T_{ss} and T_rl?.
- I suggest to refer to some standard literature, most symbols in equation 2:43-2.45 not explained.
- Figure 69, for the pressure, why the difference between Plaxis and BTM+?
- Difference BTM and BTM+, what are the boundary conditions. for the BTM+ on the sides? How do you compare the results? BTM is 1D BTM+ is 2D, average value or the value centre?
- I see some difference between Fig 79 and Fig. 80, and also some differences between Fig. 81 and Fig. 82. Maybe you can plot de difference to get an idea how big the difference is and can you explain them?
- Figure 3, explain what is drinking water and what is subsurface

Figure 4, explain in the text more what is shown and which values are used.
Equation 2.51 1st T^0_w should be T_b*

Chapter 3 Model validation.

When is the tool validated (what are the acceptance criteria), see also the introduction. With respect to the simulations, what is used as initial conditions for the calculations? Could you explain why are the measured values for λ not used?
Some small comments are:

- Figure 23, Sensor 7 highest temperature instead of sensor
- Page 35 Figure 21 should be 23.

Chapter 4 Model simulations.

Here a sensitivity analyses is performed of a set of parameters.

As mentioned in Chapter 2, not for the mesh though, which could also be done or refer to other documents. The mentioning of the expert tool results are a bit out of the blue. This should be introduced in more detail.
Some small comments are:

- Several references to tables of figures are wrong.
- Table 19 z_w should be $d_{dw.}$
- Table 16/20 values above 2 degrees (i.e. 2.4) are found while in the text 2 is mentioned.

Chapter 5 Conclusions

This chapters detail on the conclusion and some discussions.

A more quantitively conclusions can be made with respect to validation and sensitivity. And refer to the introduction, when is the validation successful or when can to tool be applied.

Appendix A and B

Here only some minor comments:

- Table 25 for which case are the column a and b, for T15 or T30?
- Figure 87 and 88 mention drinking water temperature in the caption but soil temperature is shown on the y-axis.

2.2 Validation of drinking water temperature model during distribution

The document contains a paper describing the WTM module. The BTM+ module is mentioned but now called STM+.

The readability of the paper can be improve if the layout of the paper is changed. Currently the layout is like this:

- Case 1 description
- Case 2 description
- Case 1 result (sensitivity)
- Case 2 result (sensitivity)
- Case 1 result (validation)
- Case 2 result (validation)

Our proposal would be to change it to this:

- Case 1 description
- Case 1 result (sensitivity)
- Case 1 result (validation)
- Case 2 description
- Case 2 result (sensitivity)
- Case 2 result (validation)

With respect to the modelling approach we see that in the WTM model there is no heat capacity in the subsurface part. This is calculated in the STM+ (or BTM+) model? And does this result that a change in T_b would have an immediate effect in the water temperature, while in reality the subsurface first has to be heated as well. Is this assumption verified to have little or no effect?

Some small comments are given in the digital document itself.

2.3 Validation of STM+ model with heat transport measurements of ICAIR test facility

This document details on the validation of the STM/BTM model using measurements taken at an experimental setup in Sheffield. The moisture content is being varied which also changes the material properties of the sand. The introduction is a bit short, but for an internal memo that is not an issue. Also here a picture of the mesh would be insightful. The setup of the document is straightforward.

Some small comments are:

- Equation 1 m_c and c_m are the same?
- Figure 8 is a table.

3 Discussion and overall comments

The review of the three documents [1]-[3] has been performed. In general the method and assumptions are consistent and well described. The validation which has been performed shows that the outcome of the model is reliable. Especially, the increase in temperature and the trends are predicted well, meaning that the warming-up of the drinking water network due to a neighbouring heating network or electricity cables can be predicted with confidence. Using absolute values should be done with care, and verified with some measurements.

Next to some textual adjustments our main recommendations with respect to approach and model assumptions are:
:

- What is purpose of the tooling and what does this mean for the validation is accuracy. For the validation in there is no mentioning of which error or mismatch is excepted to be qualified as successful. In [1] there is 2 °C stated, but in [2] a RSM of 1.1 °C is mentioned. This could be explained better.
- More details on the coupling of the roughness model and subsurface model is needed to understand if it is done consistently.
- The sensitivity of most important parameters is investigated. Except for the 1) heat capacity of the subsurface in the WTM+ and 2) the mesh and timestep in BTM+ .model.
- Explain better how the measured values for λ are used in the validation of BTM+.

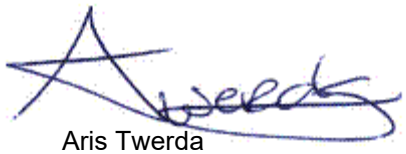
Next to that, the layout of the paper describing the WTM validation should be changed to improve the readability.

4 Signature

Delft, November 2021

E.D. Nennie
Head of department

TNO



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