Memo

Deltares
Enabling Delta Life

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Subject
Effect of the constant drinking water temperature in subsurface simulations

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This memo describes the results of the additional simulations, which were performed to assess the effect of the constant drinking water temperature boundary used in the 2D subsurface calculation done with Plaxis and reported in 11201825-000-HYE-0004-m-WP2. The additional simulations are performed since some concerns were raised on the assumption of the boundary condition and its impact on the drinking water temperature.

1 Simulation parameters

One reference case has been selected to perform the additional simulations. Table 1.1 shows the parameters used for the simulations. For more detail on this please see 11201825-000-HYE-0004-m-WP2 Summary of the results of 2-dimensional heat transfer analysis.

Table 1.1 Overview of the parameters used for the simulations

Parameter	Value
Urbanization	Middle
Ground	Dry sand
Electric cable	No
Districting heating pipe	Yes
Distance between source and drinking water pipe	2 m
Type of system	Secondary (DN160 drinking water pipeline)

In the original simulations the drinking water temperature is kept constant during the entire simulation period. With this, two simulations were performed: one with a constant drinking water temperature of 15ºC and one with a constant drinking water temperature of 25ºC. The resulting subsurface temperatures serve as boundary conditions for Wanda simulations to determine the drinking water temperature. The boundary subsurface temperature used in Wanda has been varied along the pipe line based on the drinking water temperature at that location, a more detailed explanation can be found in 11201825-000-HYE-0006 v1.0 - Wanda simulations.
Since it was questioned if the assumption of the constant drinking water temperature used in the Plaxis simulations underpredicts the minimal distance required between the drinking water pipe line and the heat source this boundary condition was investigated further. A more realistic approach was found by not imposing a temperature on the boundary of the pipe line during periods of a day where the flow of drinking water is low. This allows the drinking water temperature to vary in time. To mimic the flushing of the drinking water pipeline in the morning and evening the drinking water temperature needs to be set back to the original temperature. As this is not possible within Plaxis directly the heat capacity of the drinking water had to be set to

a low value and the temperature is imposed on the pipe wall. This results in a drop of temperature of the drinking water, mimicking the “flushing” in the morning and evening.

2 Results

Figure 2.1 shows the temperature distribution in the subsurface at the end of the 15ºC simulation and Figure 2.2 shows the temperature of the drinking water as function of the time for both a “flushing” water temperature of 15ºC and 25ºC. This graph indicates that the drinking water temperature decreases in the morning and evening, due to the imposed boundary temperature and the reducing heat capacity, which makes it easier to cool or heat the drinking water. For both cases the flushing of the drinking water, by reducing the temperature is thus partly mimicked. The main reason that the drinking water temperature does not decrease towards the “flushing temperature is that imposed heat transfer coefficient on the pipe wall that hampers the exchange of the heat from the boundary to the drinking water but is needed to simulate the heat transfer from the pipe to the soil.

Figure 2.3 shows the temperature in the subsurface as function of the distance from the drinking water pipeline. Result have been plotted for the situation with a constant drinking water temperature of 15ºC (6a15) and 25ºC (6a25) and for the additional simulation with a flushing temperature of 15ºC (6a15s) and 25ºC (6a25s). For the 15ºC drinking water temperature the results with a varying drinking water temperature boundary show a higher subsurface temperature. This will result in a higher heat flux and the drinking water temperature is expected to increase faster. However, the results for the 25ºC coincide, meaning the maximum temperature the drinking water can reach will be similar for both cases. As was mentioned before the drinking water temperature does not go back to 15ºC due to limitation in Plaxis.
To investigate the effect on the drinking water temperature also additional simulations are performed with Wanda. Figure 2.4 shows the outcome. As expected with the new simulations the drinking water reaches its maximum temperature after 24 hours, while the simulations with a constant drinking water temperature take about 48 hours.

Concluding, the additional simulations with varying drinking water temperature in the subsurface show that keeping the drinking water temperature constant leads to an underprediction of the rate at which the drinking water increases in temperature. The maximum drinking water temperature is not underpredicted.
Based on this the following steps need to be taken to come to a table with recommended distance between the drinking water pipe and a heat source.

1. Validation of the model train to assess which approach (if any) fits best with measurements.
2. If no approach fits with measurements develop a fully coupled model. Otherwise use the approach which best fits the measurements.

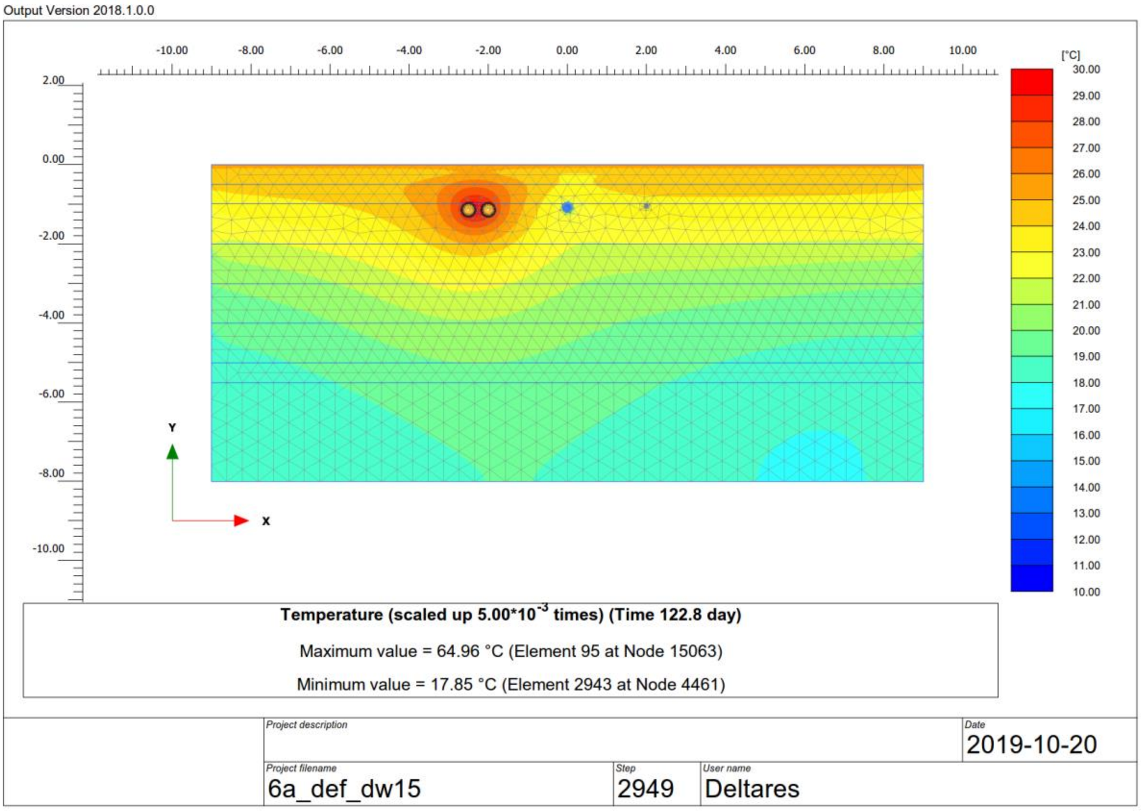

Figure 2.1, Temperature in the subsurface.

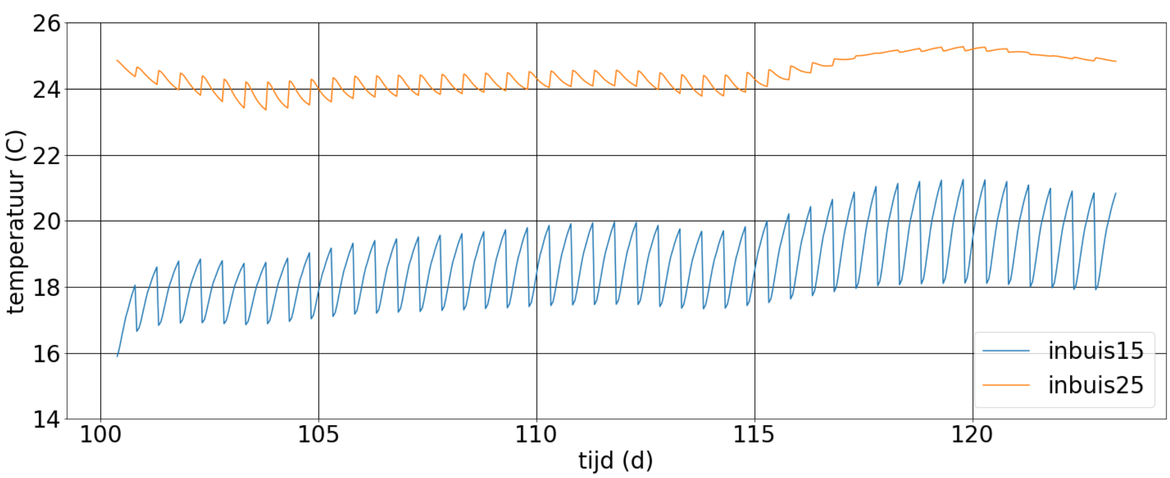

Figure 2.2, Drinking water temperature in time for the additional simulation for a start temperature of 15^{o}C and 25^{o}C

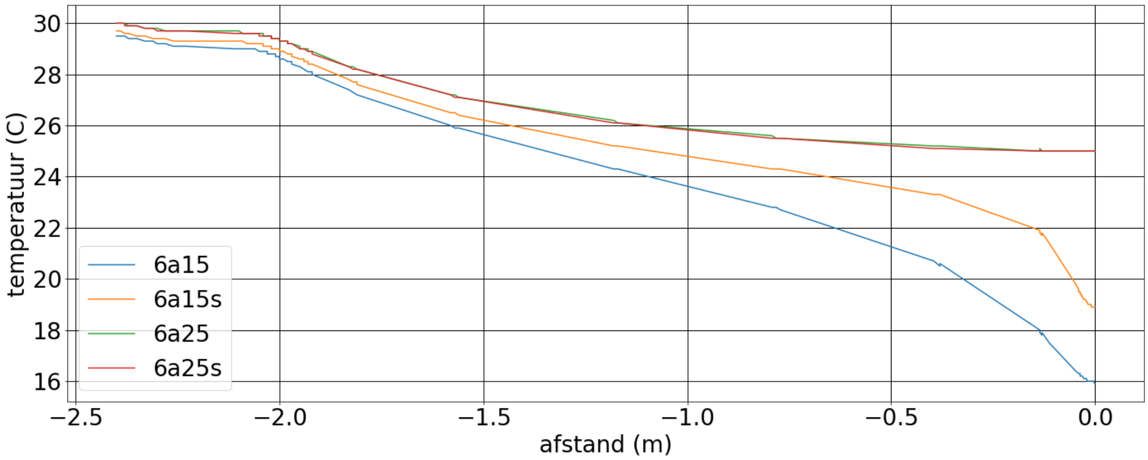

Figure 2.3, Temperature in the subsurface as function of the distance from the drinking water pipeline starting at the drinking water pipe at 0 m towards the district heating pipeline at -2.0 m.

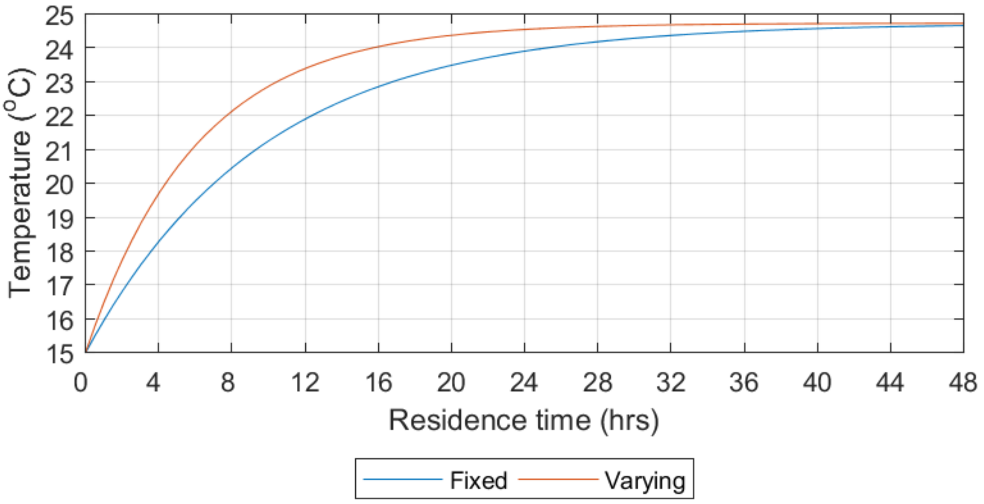

Figure 2.4, Drinking water temperature as function of the residence time, comparison between the different boundaries of the drinking water temperature in the Plaxis simulations.