Modeling of Usage of Air Injection Well in a Geothermal System

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Outline

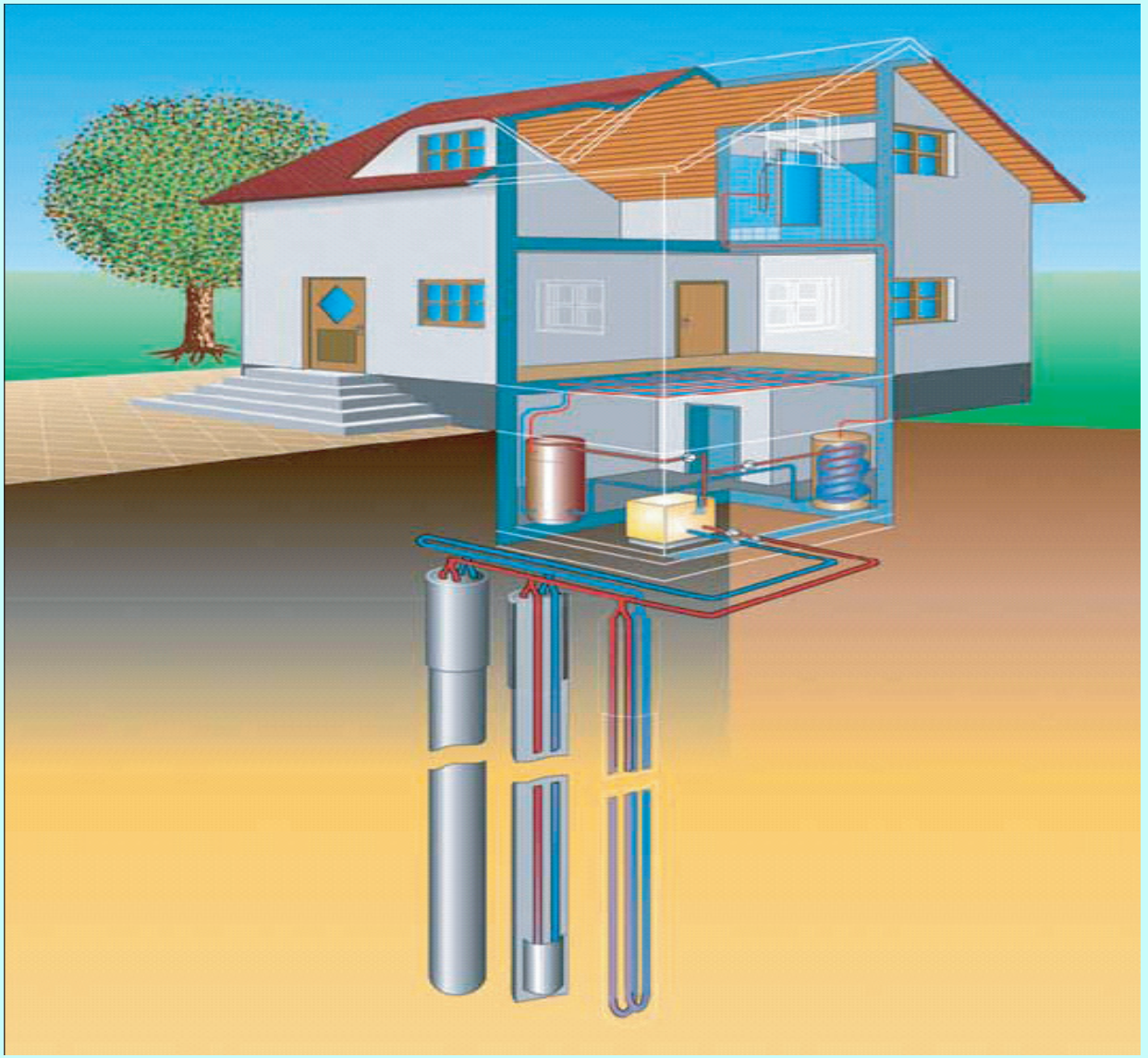
1 Introduction

2 Numerical modeling of an air injection well

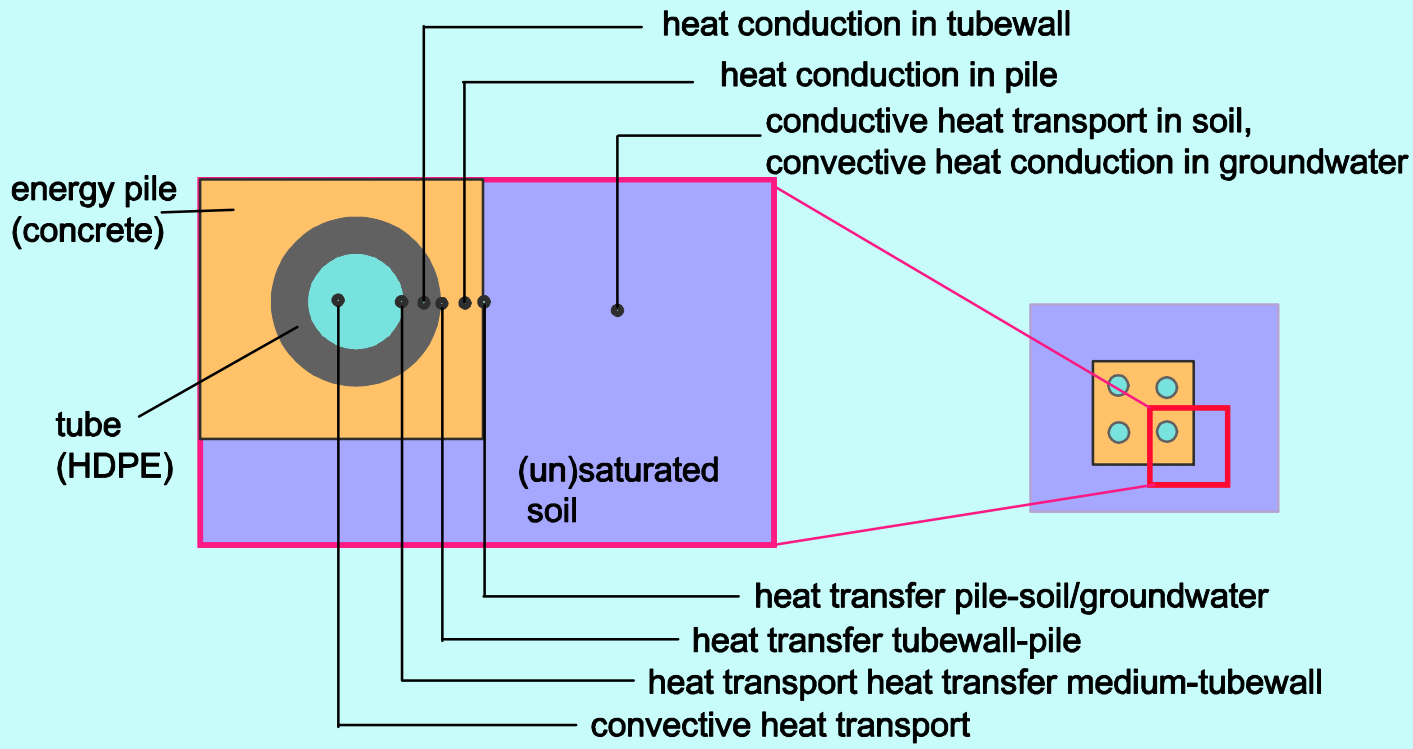
3 Results of simulations

4 Conclusion and outlook

Borehole heat exchanger

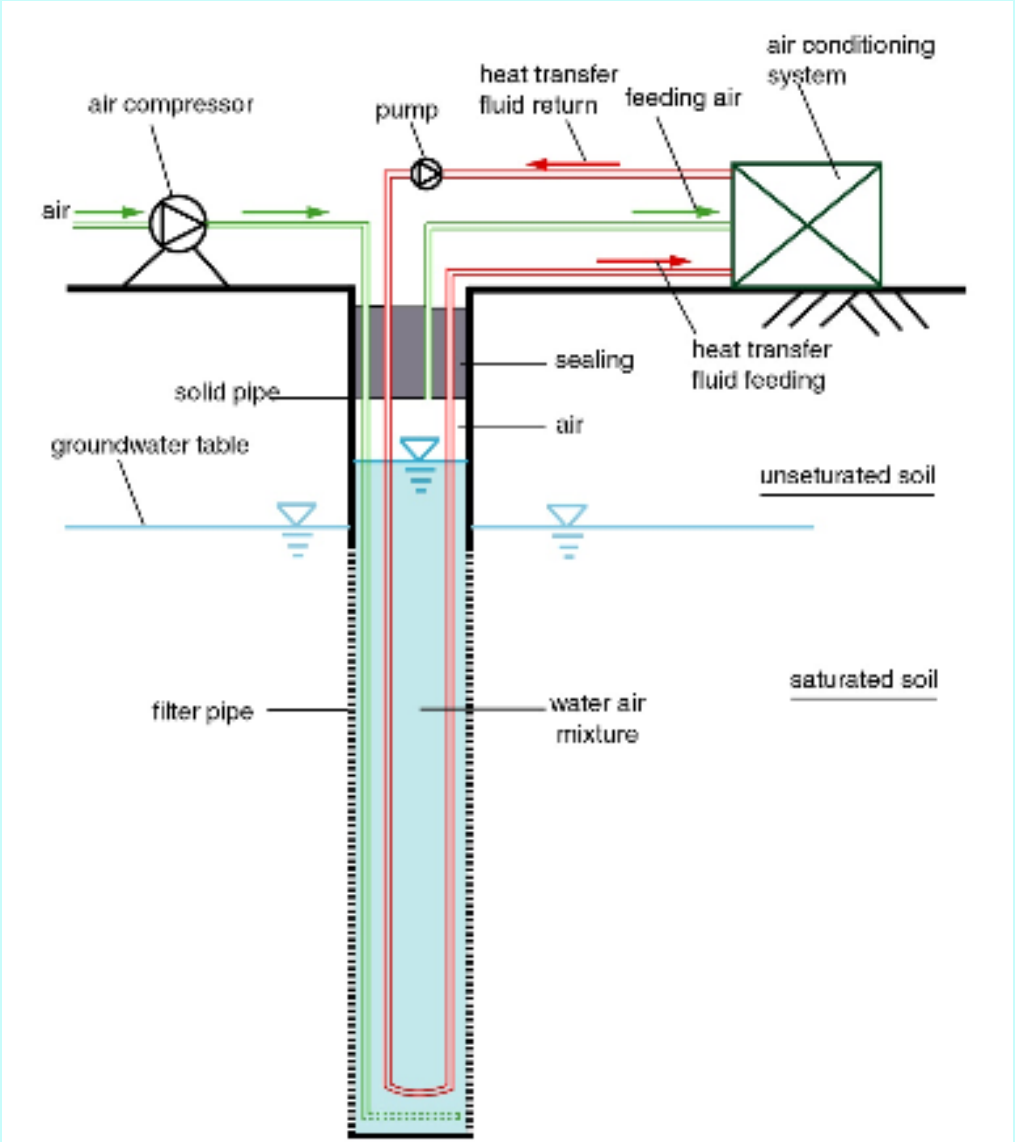


Heat transfer mechanisms of soil heat exchanger

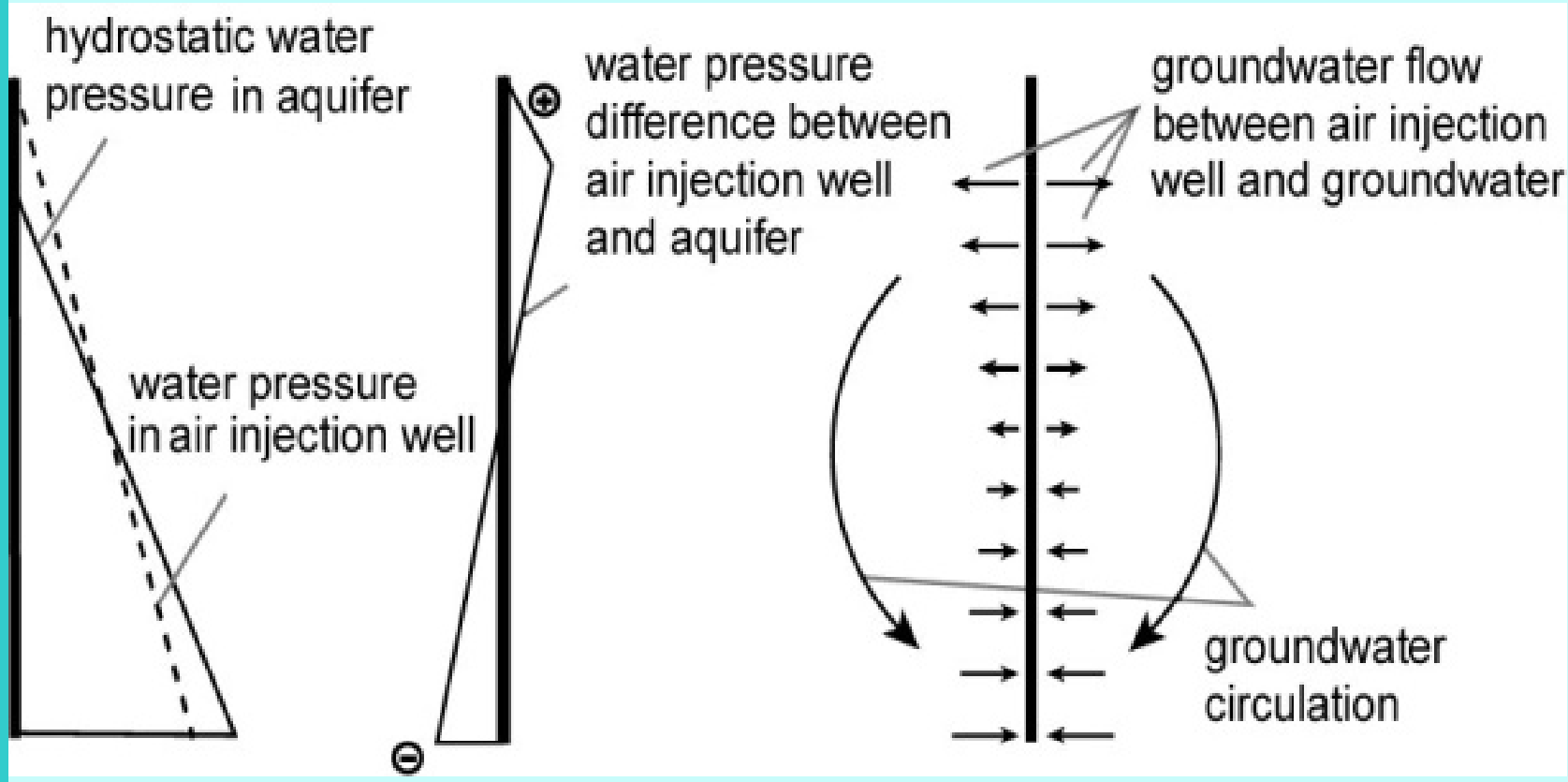


$$\underbrace{(\rho \cdot c)_{soil} \frac{\partial \vartheta}{\partial t}}_{\text{Time change}} = \underbrace{\operatorname{div}(k \cdot \operatorname{grad}\vartheta)}_{\text{Conduction}} - \underbrace{v \cdot \operatorname{grad}\vartheta}_{\text{Convection}} + \underbrace{\int \dot{w}}_{\text{Heat scoure}}$$

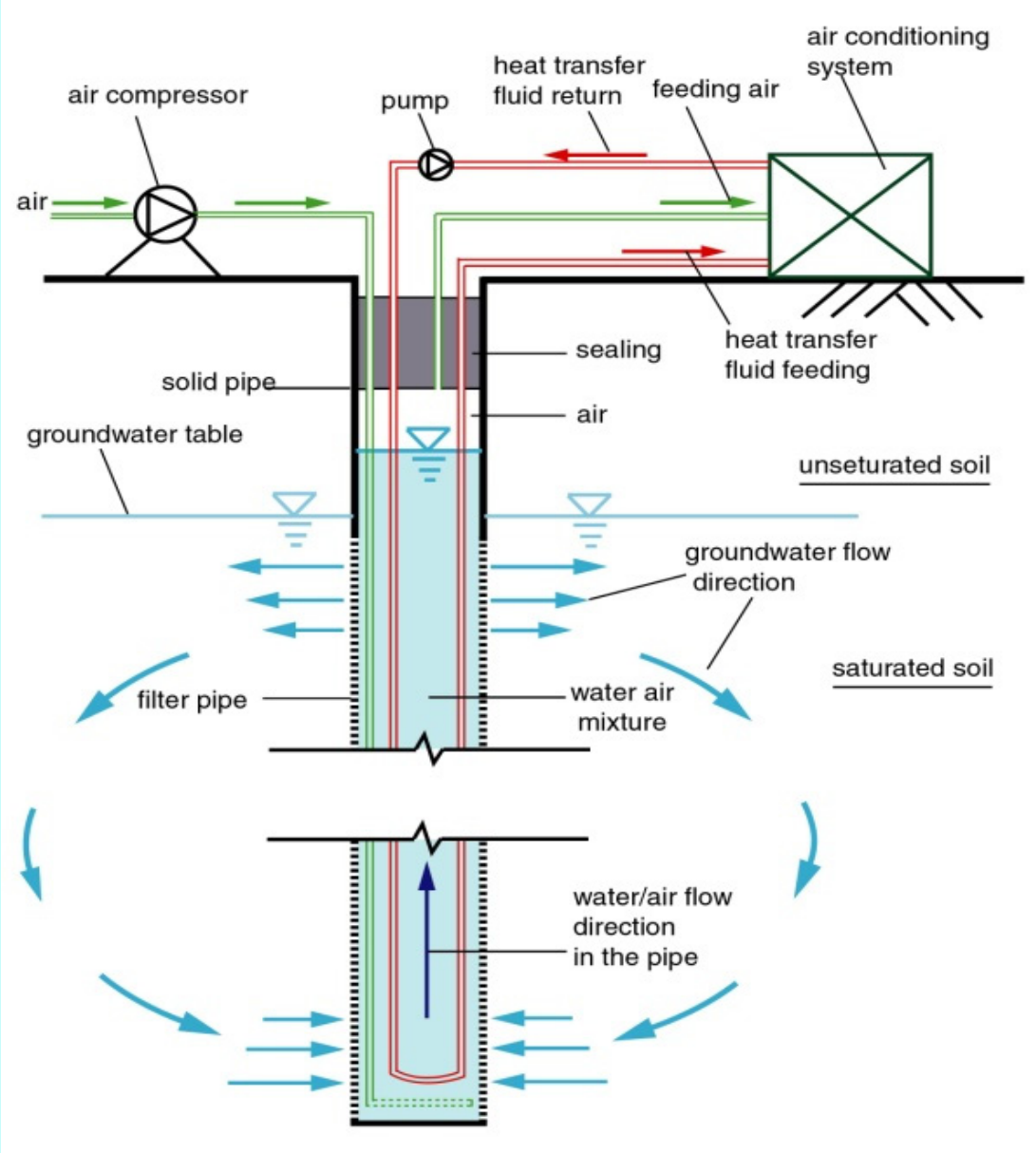
Combined air injection well with a borehole heat exchanger and air conditioning system



Distribution of water pressure and difference between air injection well and aquifer

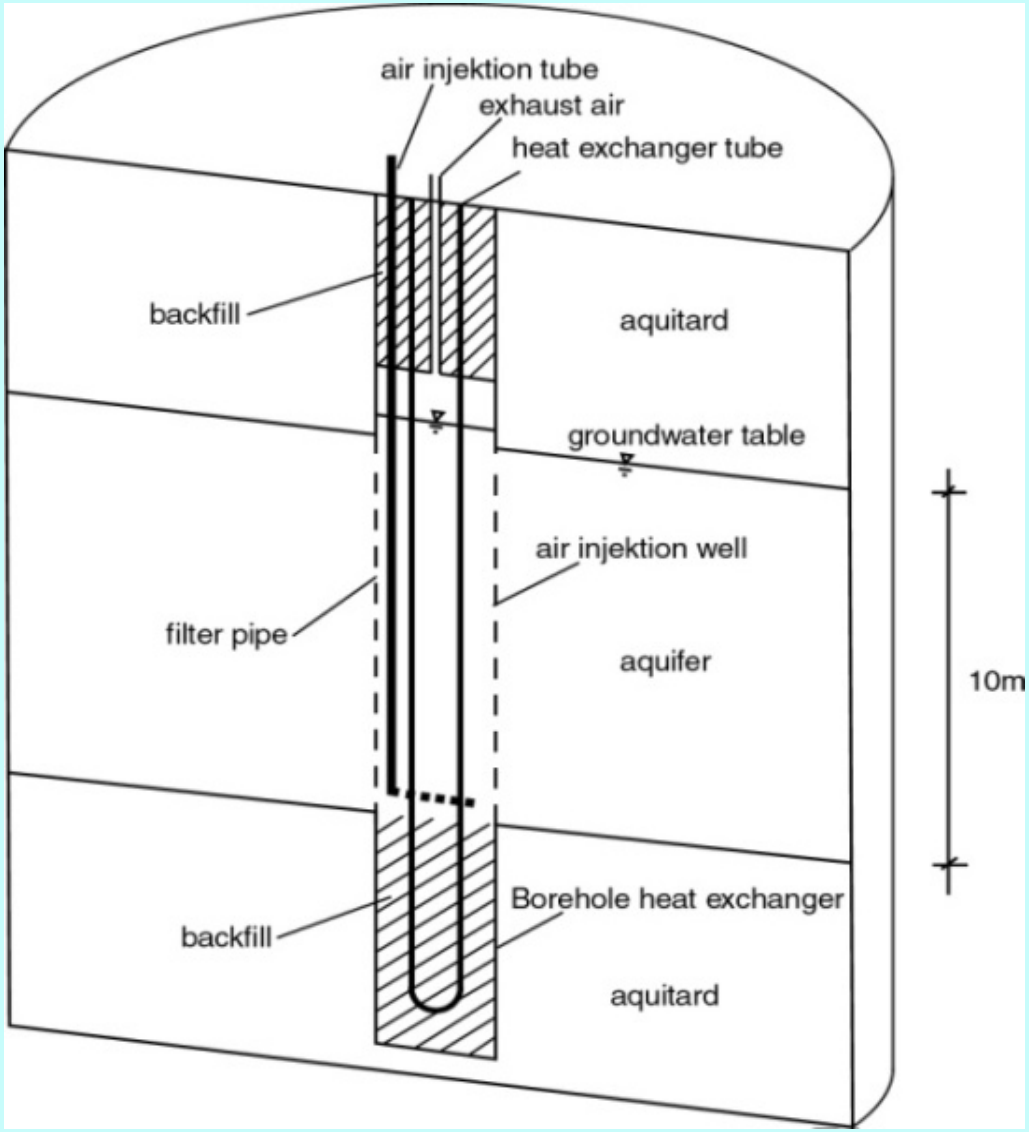


Groundwater circulation



2 Numerical modeling

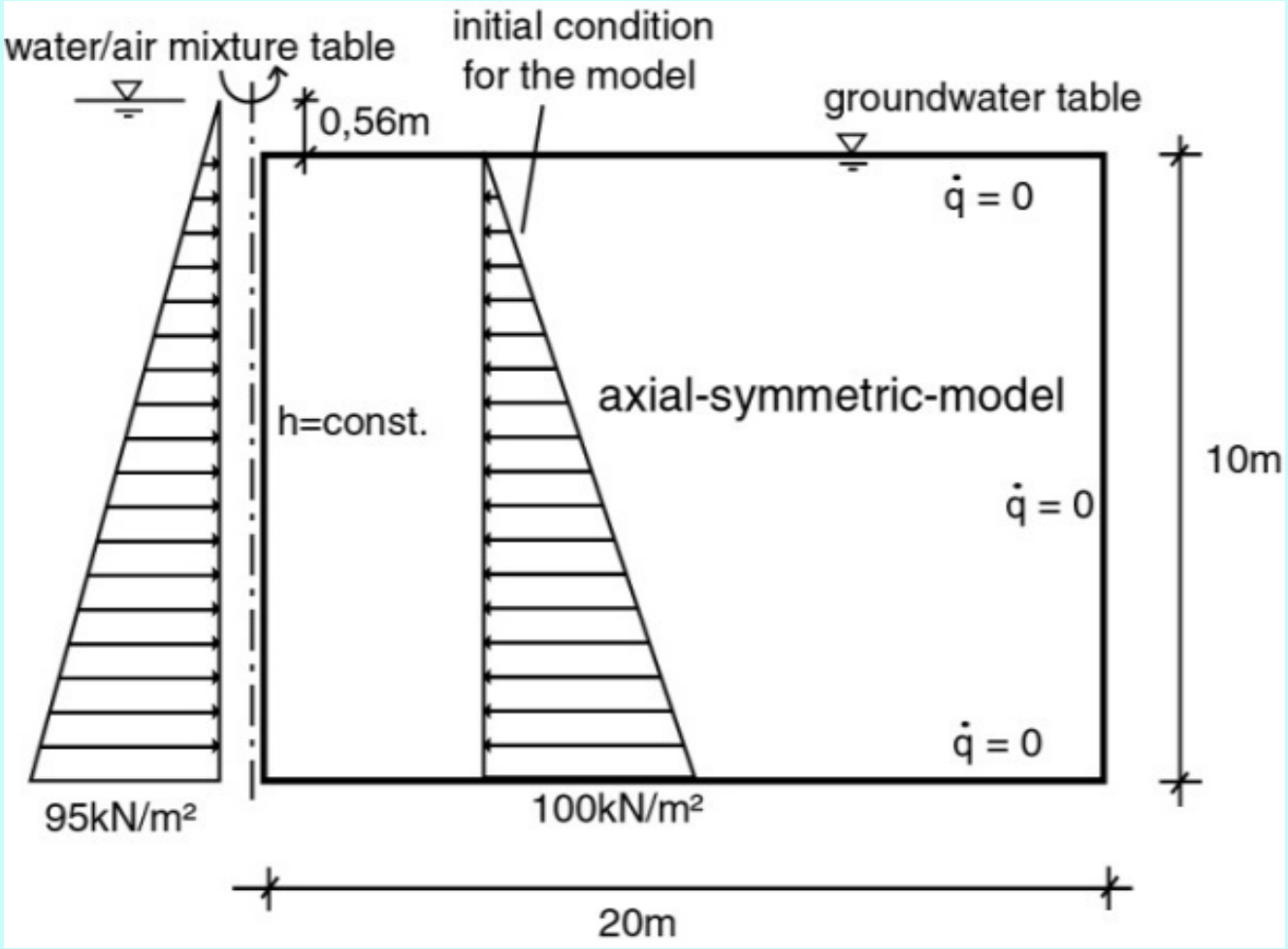
Basis system



- One Aquifer between 2 aquitards
- Above and under the aquifer, the BHE is filled
- BHE in aquifer is piped
- Heat transfer and 2 phase fluid flow in the well is not considered
- Axial symmetric

Thermal conductivity (k)	2.53 W/(m•K)
Specific heat capacity (c)	1750 kJ/(kg•K)
Drainable porosity (n)	0.35
Density (ρ)	2100 kg/m³
Hydraulic conductivity	10^{-5} m/s

Boundary and initial conditions



$\vartheta = 20°C$ at the wall of air injecion well and
$\text{grad}\,\vartheta = 0$ for all other boundaries.
$\vartheta(t=o) = 10°C$

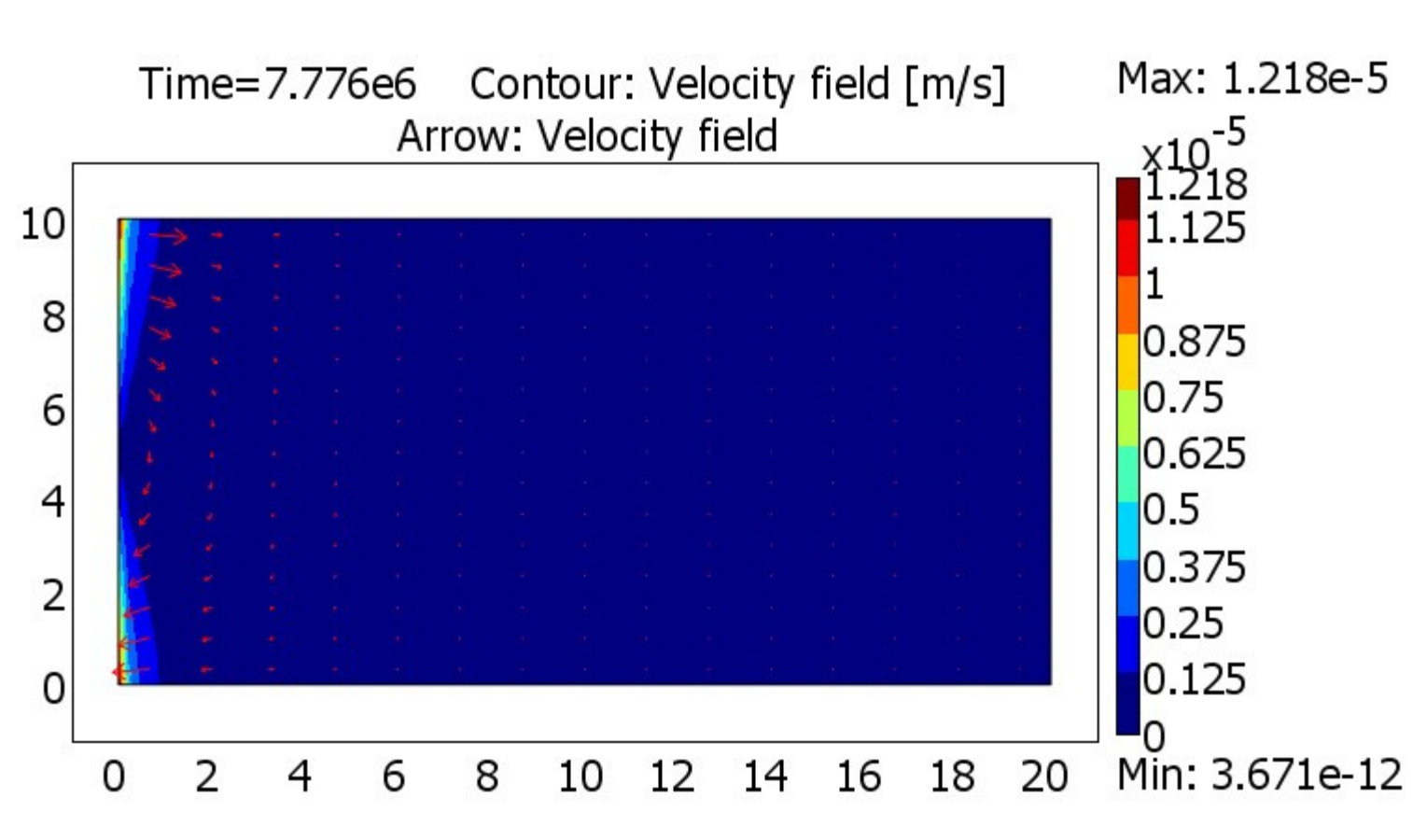
2 physics: groundwater flow and heat transfer

Sequential simulation:

- in the first step: groundwater flow, steady state
- In the second step: heat transfer, 90 days

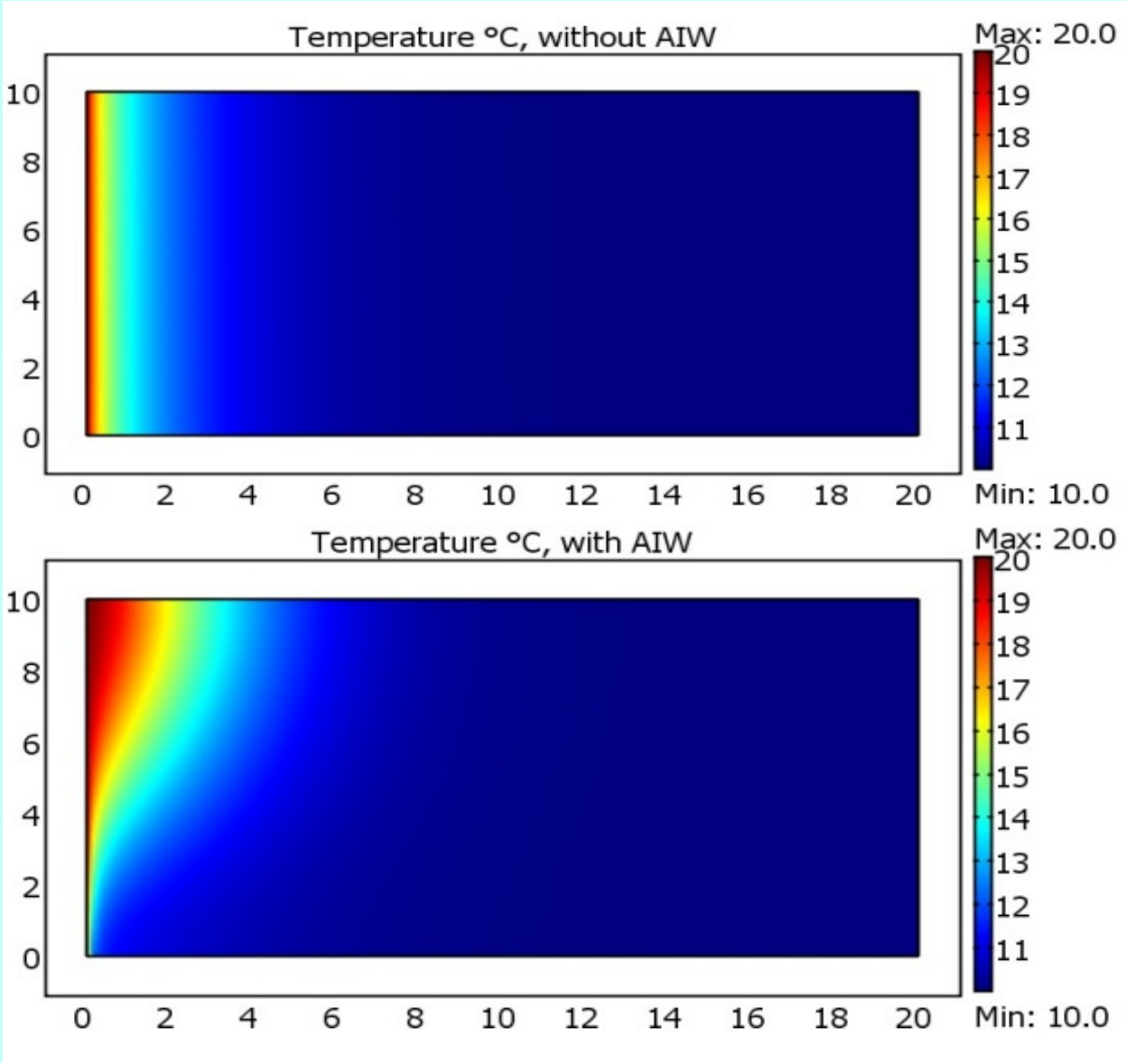
3 Results of simulations

Groundwater flow velocity field around the air injection well



3 Results of simulations

Temperature field after an heat injection period of 3 months



Specific Heat Injection Capacity

The total injected surface heat quantity $e_h(t)$ in kWh/m after a certain time t can be calculated using the equation:

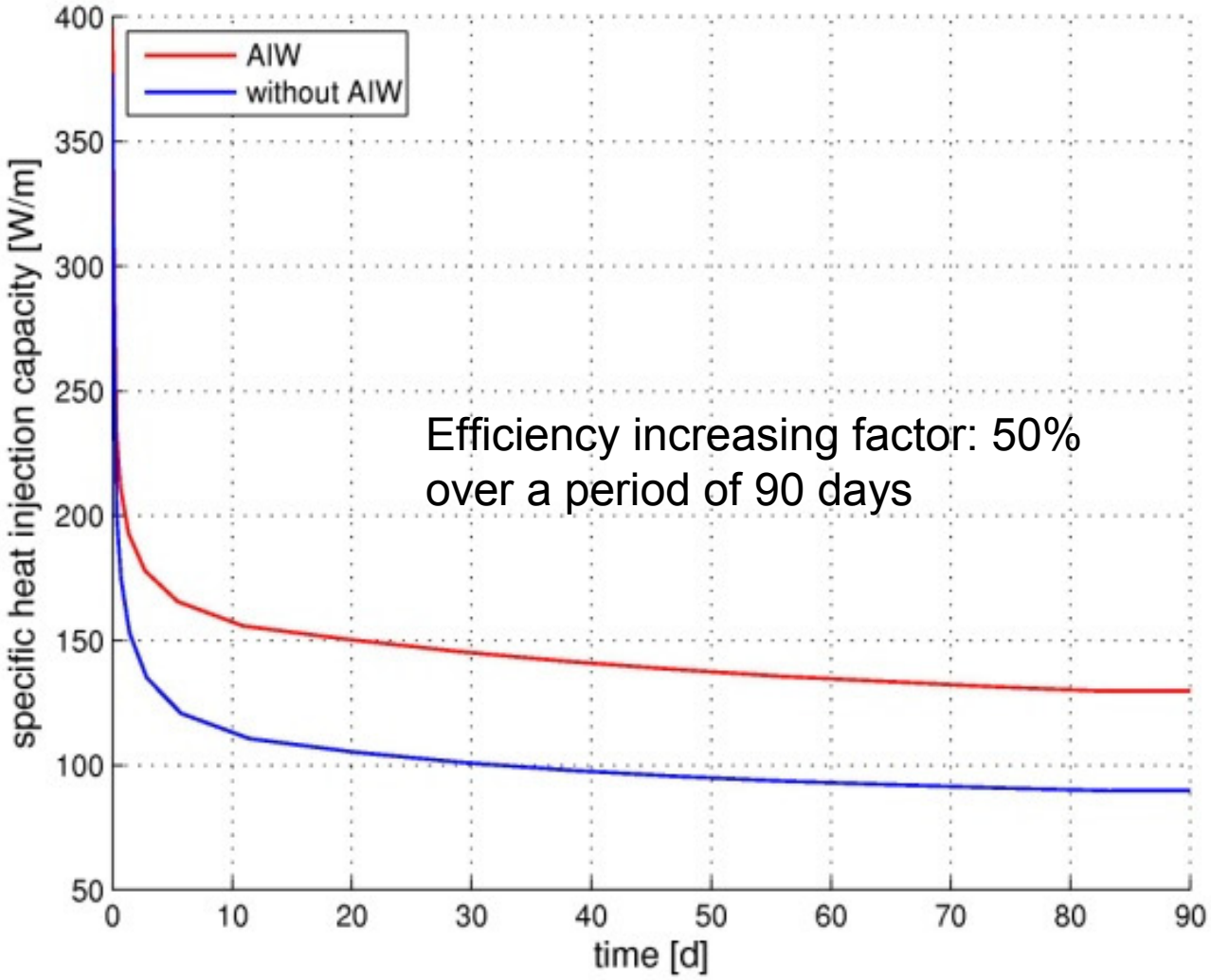
$$e_h(t) = \int_{\Omega} \rho c \left[T(t) - T_0 \right] dA$$

The specific heat injection capacity $P_s(t)$ is a time dependent value:

$$P_s(t_n) = \frac{E_h(t_n) - E_h(t_{n-1})}{l \cdot (t_n - t_{n-1})}$$

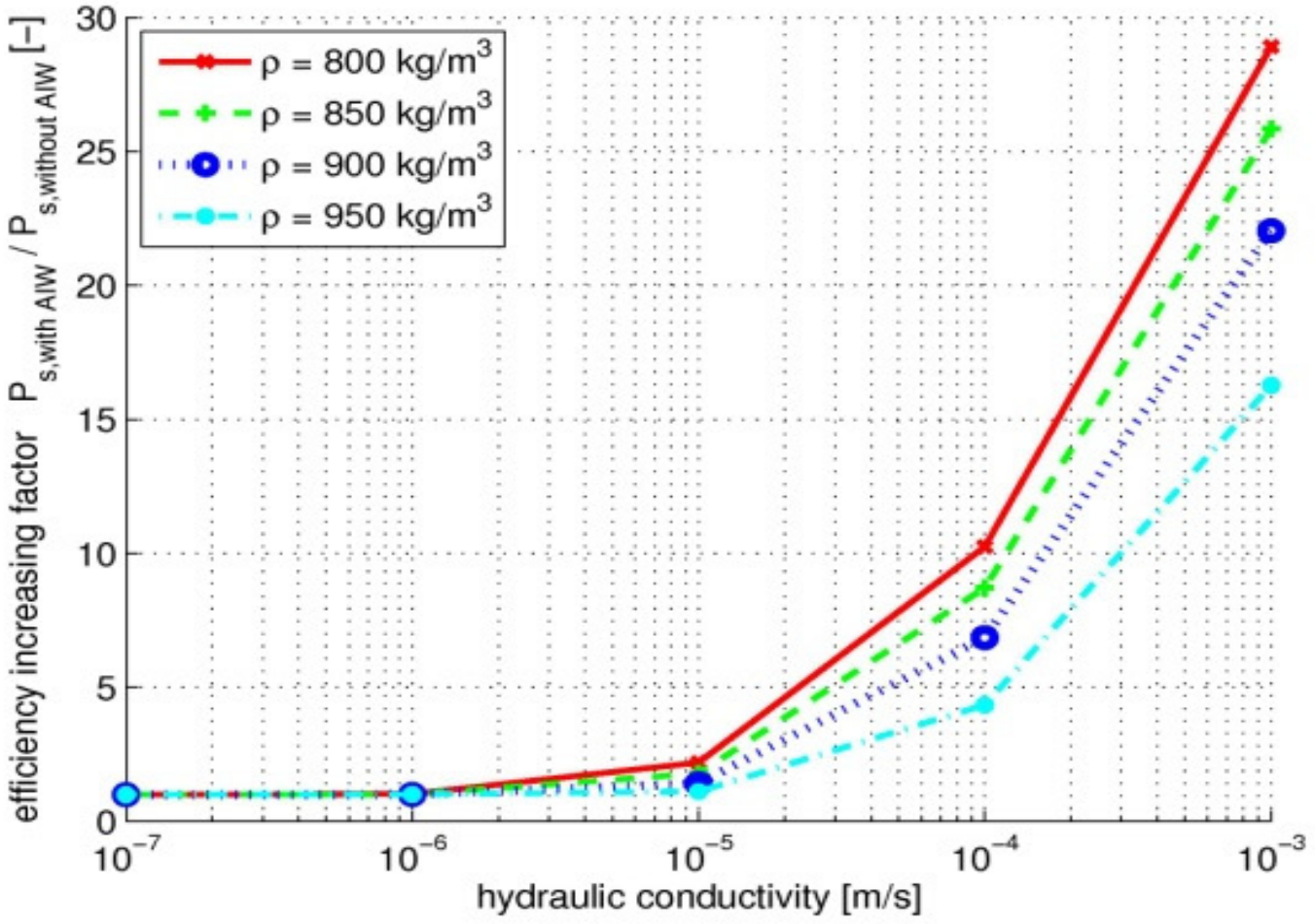
3 Results of simulations

Calculated time dependent specific heat injection capacity



4 Groundwater induction

Calculated relative efficiency increasing factor in dependent of hydraulic conductivity and water/air mixture density



4 Conclusion and outlook

Conclusion and outlook

- 2D-Simulation of air injection wells was successful
- the combination of air injection well in borehole can improve the heat injection capacity vastly
- 3D-Simulation will also be performed
- Laboratory and field test are planned, in order to verify the numerical results

Thanks for Your attention