Simulations of Groundwater Flow Patterns Around a Vertical Circulation Well

Y. Jin[1] (yjin@gwdg.de), E. Holzbecher[1], S. Ebneth[2], A.B. Tatomir[1]

1. Georg-August University of Göttingen, Applied Geology, Goldschmidtstr. 3, 37077 Göttingen, Germany
2. Hölscher Wasserbau GmbH, Petzower Str.4, 14542, Werder/Havel, Germany.

Introduction:

Vertical circulation wells (VCWs) consist of dual-screened sections allowing synchronous abstraction and injection of groundwater in the same borehole.

Since the last two decades, the “down-flow” type of VCWs has been widely applied for in-situ remediation, where abstraction screen is installed below the injection screen.

Recently, the “up-flow” type of VCWs is applied increasingly in groundwater dewatering in Germany and in the Netherlands (Fig.1).

Furthermore, hydrogeologists utilize the recirculation principle of VCWs for determining aquifer properties.

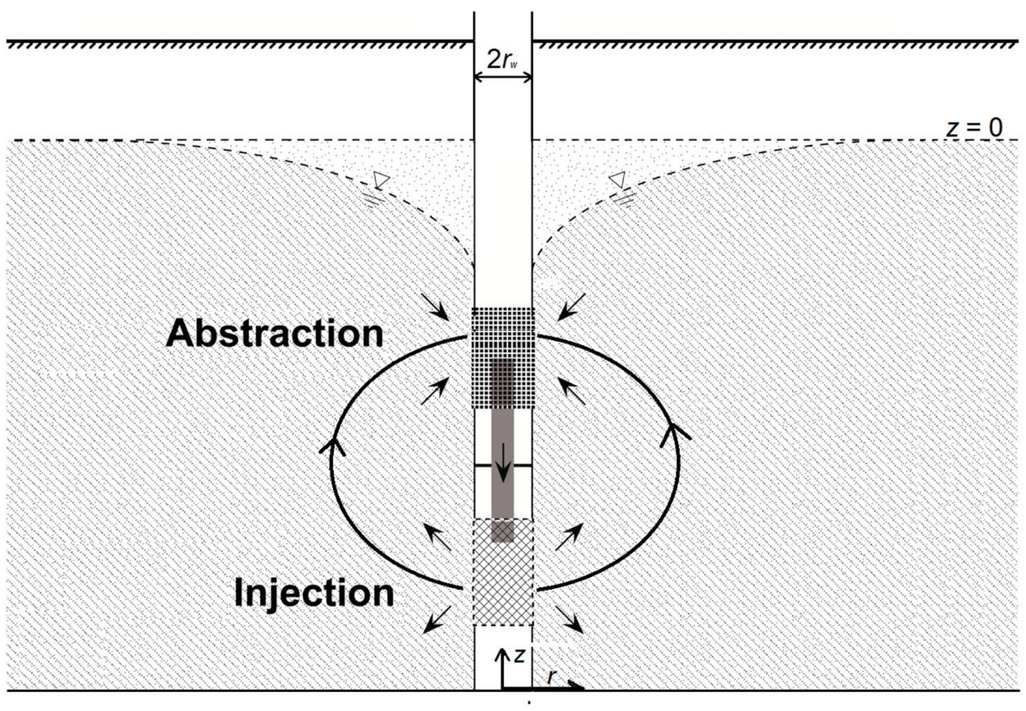

Figure 1. Conceptual model sketch of flow near a VCW.

Model components:

- Groundwater flow simulation (Darcy’s Law)

$$\nabla \cdot (\rho \mathbf{u}) = Q, \quad \mathbf{u} = -\frac{\kappa}{\mu}\nabla p$$

- Free-surface tracing (ALE)
- Streamline simulation (Poisson’s Equation)

$$\nabla \cdot (-c\nabla psi) = f, \quad \nabla = \left[\frac{\partial}{\partial r}, \frac{\partial}{\partial z}\right]$$

Conclusions: The presented model is able to provide comprehensive simulation of grounwater flow and flownet near a VCW. In addition, the movement of groundwater level can be traced by utlizing ALE algorithm.

Results:

- The potential of hydraulic head is decreased near the abstraction screen (blue), while it is increased near the injection screen (red in Fig 2 and 3). Hydraulic head equipotential lines are shown in black contours.
- The steady-state groundwater level is presented by the deformed geomerty.
- The position of streamlines represents the 20%, 40%, 60% and 80% water flow circulating around the well.
- The velocity field is shown in arrow plot.
- The flow circulation field depends strongly on aquifer anisotropy, but independent of hydraulic conductivity and flow rate (i.e., Fig 3).

Table 1. Parameter set-up

Variable	Value	Units
Pumping Depth	6	m
Injection Depth	14	m
Porosity	0.2	
Q	40	m^3/h
Kr, Kv	1×10^{-3}	m/s

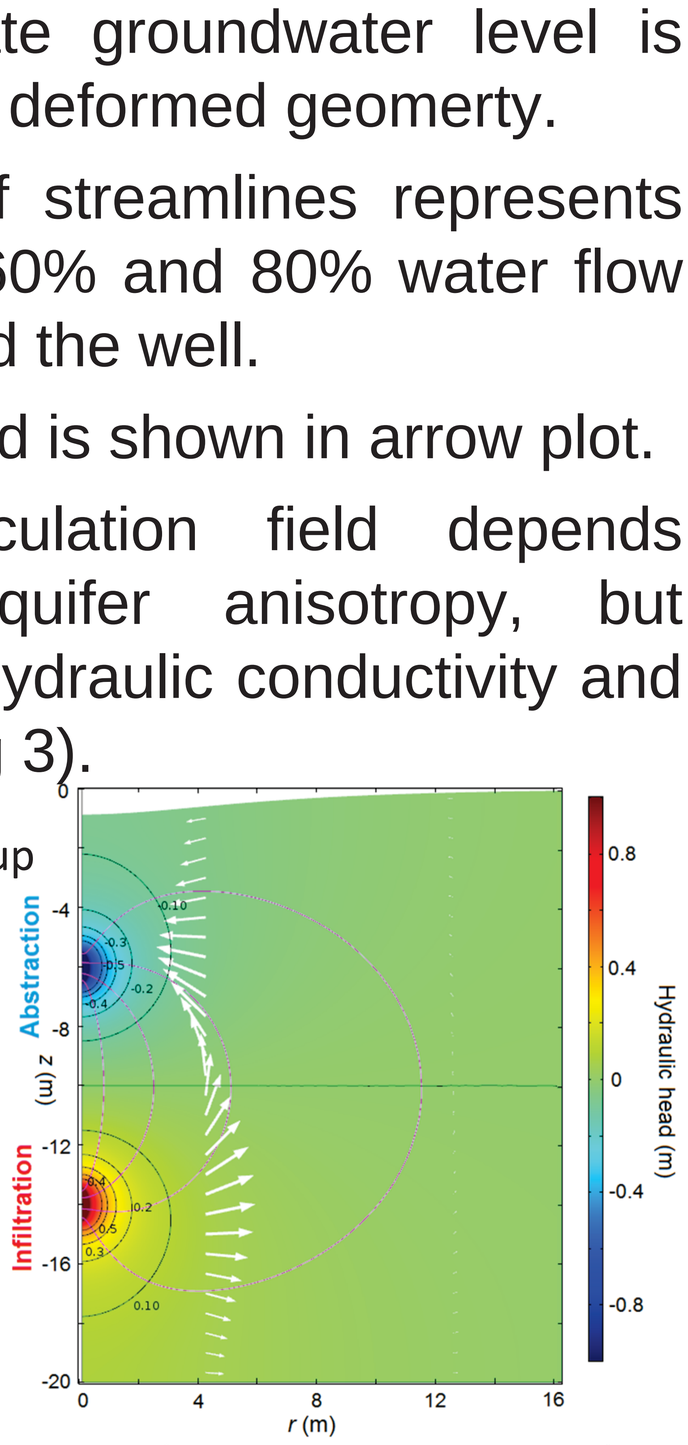

Figure 2. Modelled 2D vertical cross-section groundwater flow field near a VCW well.

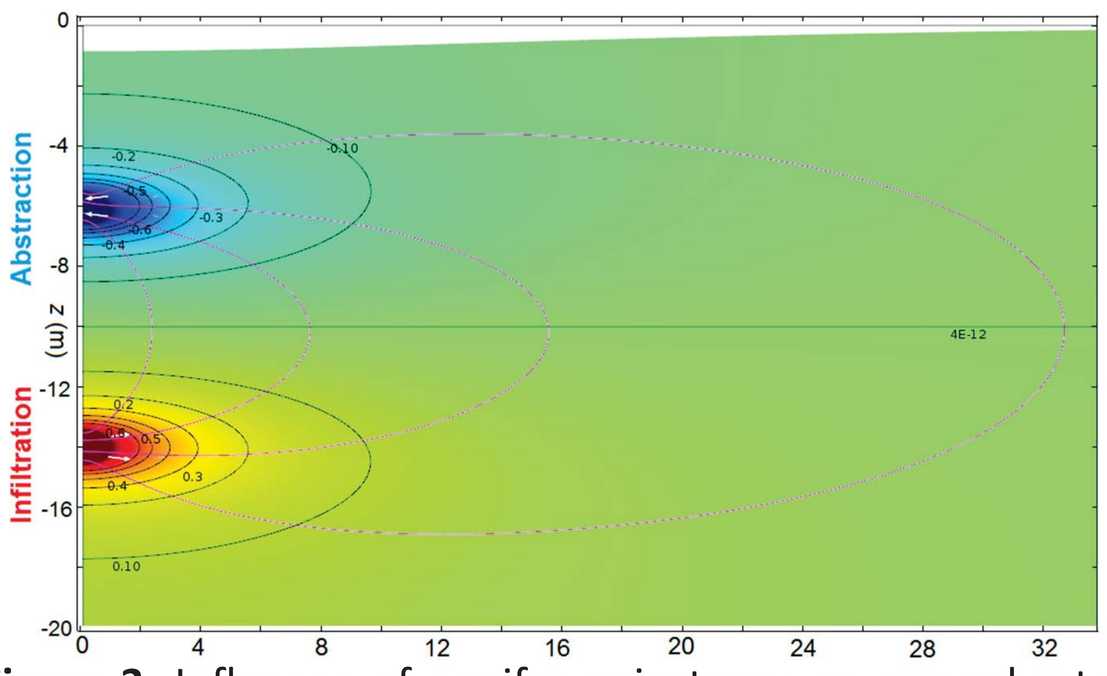

Figure 3. Influence of aquifer anisotropy on groundwater flow patterns and groundwater table (Kv/Kr=0.1)

References:
[1] Hölscher Wasserbau GmbH, Germany. http://www.hoelscher-wasserbau.de/
[2] GZG, Georg-August Universität Göttingen. http://gzg.uni-goettingen.de/

Acknowledgements:
The authors appreciate the support of ‘Deutsche Bundesstiftung Umwelt (DBU)’ for funding the presented work within the DSI-project (AZ 28299-23).