Exploring the potential of horizontal wells for Aquifer Storage and Recovery

Simon Kreipl, Boris M. van Breukelen, Mark Bakker

Department of Water Management, Faculty of Civil Engineering and Geosciences, Delft University of Technology, Delft, The Netherlands

Introduction

- In **Aquifer Storage and Recovery (ASR)** water from times of surplus is stored in the subsurface with a well and later recovered with the same well in times of scarcity
- An example application of ASR is to balance water supply (winter) and demand (summer) in regions with strong seasonal fluctuations in rainfall and evaporation

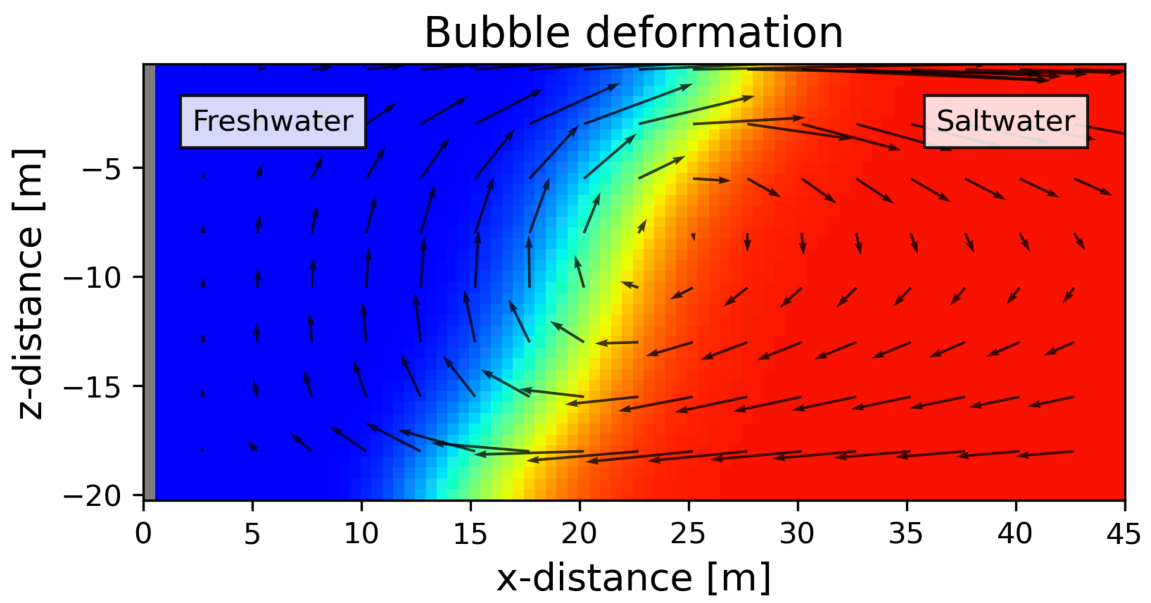
Horizontal wells

- In low aquifer thickness and low hydraulic conductivity conditions, the injection of water results in large pressure gradients around the well

→**Horizontal wells distribute pumping pressures and mitigate large pressure gradients**

- In saline groundwater conditions the buoyancy effect and dispersion deform the freshwater bubble and reduce the recovery efficiency ($RE = V_{out}/V_{in}$)

→**Horizontal wells may be less sensitive to these adverse impacts and enhance the recovery efficiency**



Objectives

- Develop design guidelines for ASR with horizontal wells (e.g., depth of well, length of well)
- **Quantify potential benefits of horizontal wells over vertical wells for ASR**

Methods

- Density-dependent numerical groundwater modeling with SEAWAT V4 (FloPy)
- Comparison of horizontal well ASR with vertical well ASR
- 1 ASR cycle: 100 d injection | 160 d storage | Extraction while $C_{well} < C_{max}$

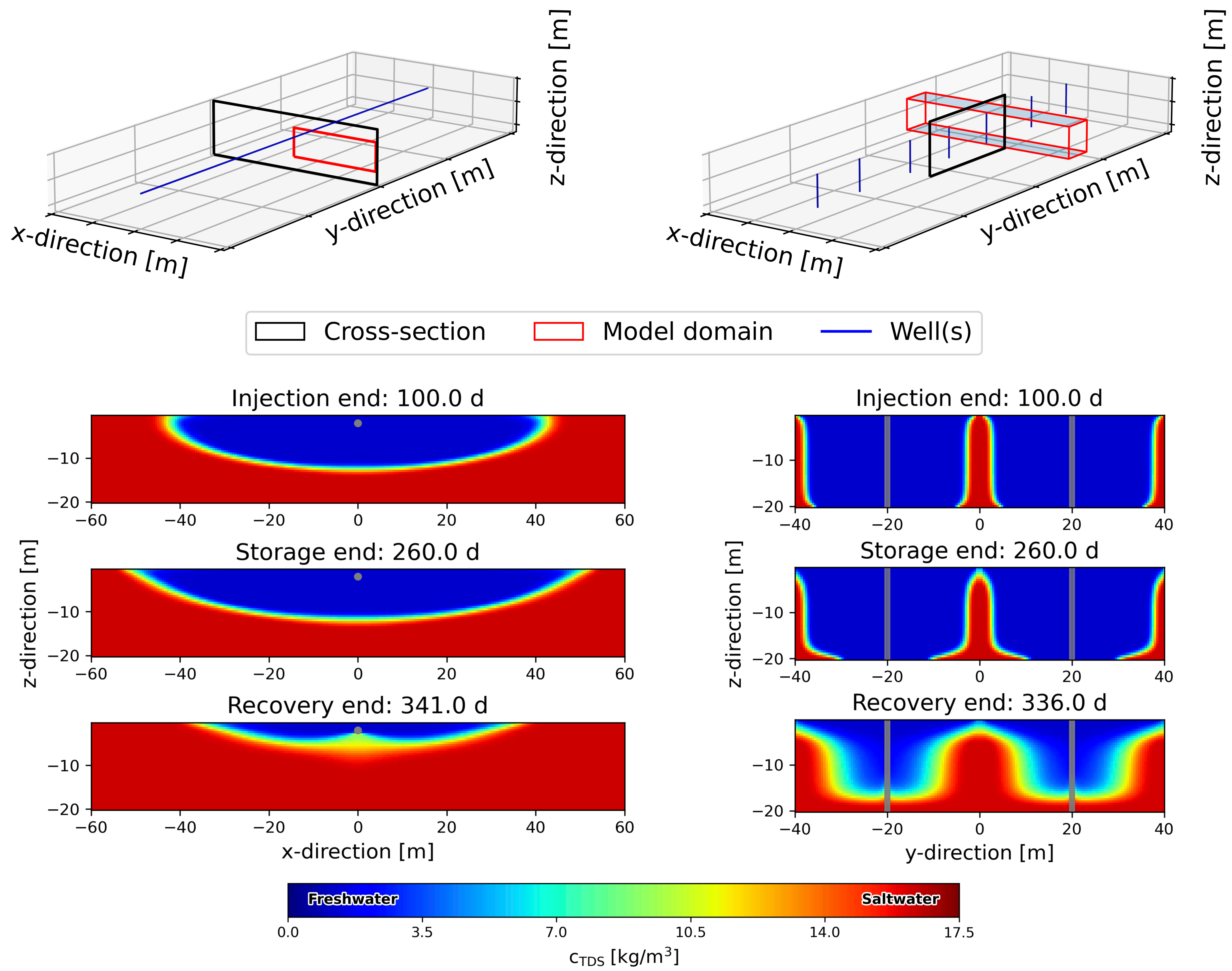
Models

Horizontal well

- Infinitely long horizontal well
- 2D model of one slice
- Q_{HW} = pumping rate per horizontal well length

Vertical well

- Infinitely long line of vertical wells
- 3D model of one well (with impermeable boundaries between wells)
- Q_{VW} = pumping rate / distance between two wells = Q_{HW}



Scenario analysis

- Buoyancy effects are mainly influenced by the aquifer hydraulic conductivity (K_h) and the groundwater salinity (c_{TDS})
- To investigate the influence of buoyancy, simulations are repeated for various K_h and c_{TDS} values:

	Unit	Scenarios				
K_h*	m/d	5	10	25	35	50
c_{TDS}	kg/m³	2.25	4.5	8.75	17.5	35.0

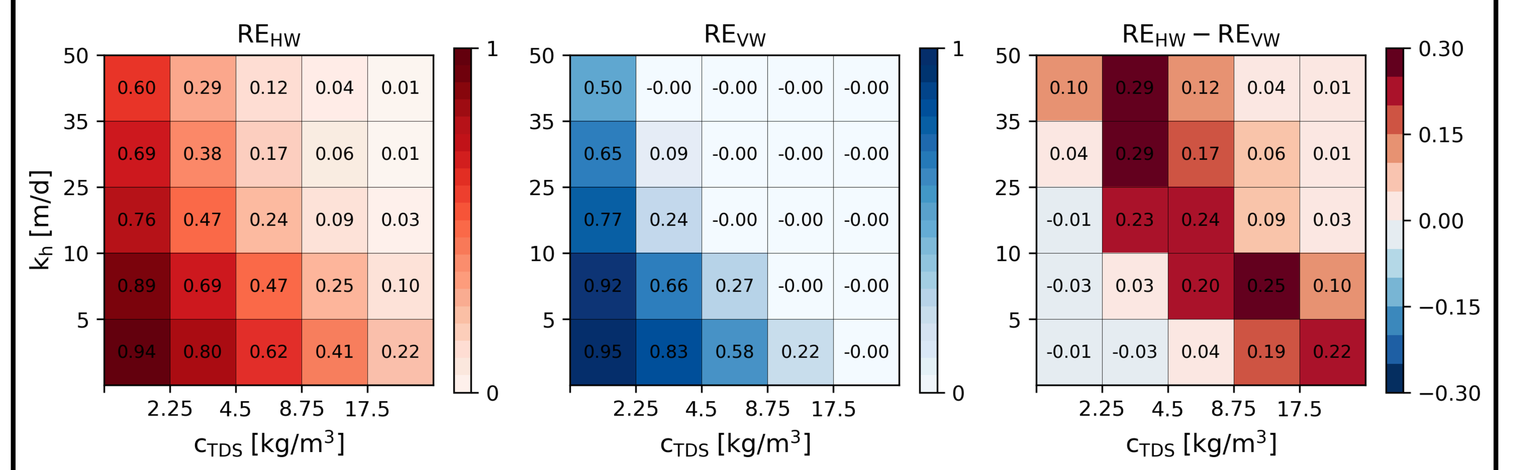
*$K_h/K_v=2$

Recovery efficiency

- Vertical wells are favorable in conditions with low K_h and low c_{TDS}
- Horizontal wells are favourable at (i) medium/high c_{TDS} and low K_h or (ii) medium/high K_h and low c_{TDS}

→**Buoyancy effects have a smaller impact on horizontal well systems**

- Both systems not suitable for high K_h and high c_{TDS}



Conclusions

- **Horizontal wells can increase the recovery efficiency of ASR systems in saline conditions**
- Horizontal wells can replace multiple vertical wells for low thickness and low hydraulic conductivity conditions

TU Delft | AGRICOAST Scientific Research Program | ACACIA WATER | NWO | Sharing is encouraged

Abstract ID: EGU24-1441

Presenting author: S.Kreipl@tudelft.nl