Feasibility of mixed hydraulic barriers to remediate seawater-intrusion in shallow aquifers

Pia Ebeling[1], Marc Walther[1,2], Niels Schütze[1], Ali Al-Maktoumi[3], Falk Händel[1], Thomas Vienken[2], Ulf Mallast[2]

[1] Technische Universität Dresden, Dresden, Germany
[2] Helmholtz-Center for Environmental Research – UFZ, Leipzig, Germany
[3] Sultan Qaboos University

ABSTRACT

Seawater intrusion is a global phenomenon, which is mainly caused by overexploitation of coastal aquifers and can severly detoriate fresh groundwater resources. Coastal zones are often densely populated and thus have a high water demand (Oude Essink, 2001), especially in urbanized, arid and semi-arid areas (Bear, 1999). At the same time, coastal aquifers often serve as major freshwater resources (Bear, 1999). Therefore, measures to control seawater intrusion and protect the valuable freshwater resources are crucial. The mixed hydraulic barrier approach combines an injection (positive) and extraction (negative) barrier, whereby water is extracted seaward of the injection (compare Figure 1). The combined measure holds promising advantages especially for arid areas because extracted water provides a resource for infiltration, which is why it is also known as Abstraction-Desalination-Recharge (ADR). However, few studies exist that investigate its feasibility (Mahesha, 1996; Rastogi et al., 2004; Abd-Elhamid and Javadi, 2011) nor has it been implemented or tested in real-world cases. Existing studies mainly use sharp interface models without accounting for transient or dispersive processes and sensitivity of parameters and interdependencies are still unsatisfyingly understood. Therefore, the applicability of the mixed barrier approach to remediate seawater intrusion in shallow, unconsolidated aquifers within a reasonable time scale was further investigated. To this end, we set up a synthetic 2D variable-density model of six unconfined aquifers and run management scenarios in transient mode, for which the conceptual model is shown in Figure 1.

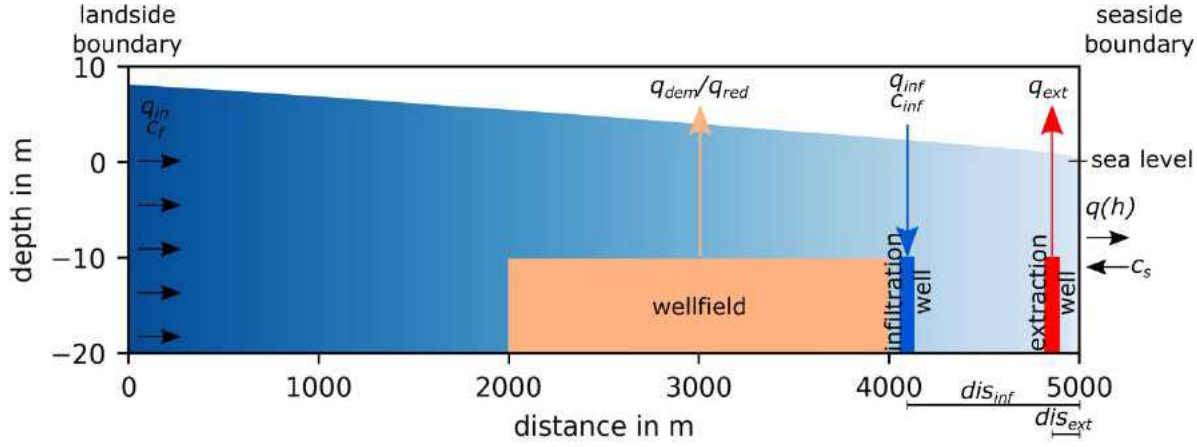

Figure 1. Conceptual model and varied management parameters, q_{dem}/q_{red} – abstractions to meet the regional water demand, q_{ext} – extraction rate, q_{inf} – infiltration rate, c_{inf} – infiltration concentration, dis_{ext} – distance to coast of the extraction barrier, dis_{inf} – distance to coast of the infiltration barrier.

We jointly varied the parameters hydraulic conductivity, porosity, infiltration and extraction rate, barrier locations, infiltration concentration, and reduction of water demand to determine the parameter's impact and interdependencies. Results showed that the hydraulic conductivity defines the overall, site-specific remediation potential. Concerning the management parameters, reducing regional abstractions and installing a positive barrier enhance remediation most. However, locating the injection well within the salt wedge poses the risk of trapping salt landside. In case injected water is still brackish, the risk of polluting inland water resources exists if injected water continues to partly flow landward from the injection point. The negative barrier proved hydraulically rather insensitive and might even impede remediation at a later stage by maintaining low heads and thus triggering SWI up to this point. Remediation mechanisms underlying parameter combinations were recognised.

REFERENCES

Abd-Elhamid, H. F. & Javadi, A. A. A Cost-Effective Method to Control Seawater Intrusion in Coastal Aquifers. *Water Resources Management* **25,** 2755–2780 (2011).

Bear, J. *Seawater intrusion in coastal aquifers: concepts, methods, and practices*. (Kluwer, 1999).

Mahesha, A. Control of Seawater Intrusion through Injection-Extraction Well System. *Journal of Irrigation and Drainage Engineering* **122,** 314–317 (1996).

Oude Essink, G. H. . Improving fresh groundwater supply—problems and solutions. *Ocean & Coastal Management* **44,** 429–449 (2001).

Rastogi, A. K., Choi, G. W. & Ukarande, S. K. Diffused interface model to prevent ingress of sea water in multi-layer coastal aquifers. *Journal of Spatial Hydrology* **4,** (2004).