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Numerical and physical modeling of cutoff walls against saltwater intrusion

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Seawater intrusion is a relevant problem for many communities living in small islands, where the amount of fresh water available for human consumption depends on the delicate equilibrium between the natural groundwater recharge from rainfall and the surrounding sea. However, it can represent a significant issue also for coastal regions where groundwater is extracted for water supply: an excessive extraction to meet growing demands for drinking water and irrigation purposes leads to a decrease of seaward flows of fresh water and consequently to an increase of seawater intrusion into coastal aquifers.

Cutoff walls represent one of the possible strategies that can be adopted to reduce seawater intrusion into coastal aquifers and to limit the inland progression of the saltwater wedge. In this study, on the basis of several preliminary simulations developed by the SUTRA code, a cutoff wall occluding 70% of the aquifer depth is designed for a physical experiment, whose setup details are reported as follows.

The physical model represents the terminal part of a coastal aquifer and consists of a flume 500 cm long, 30 cm wide and 60 cm high, filled for an height of 49 cm with glass beads with a d50 of 0.6 mm and a uniformity coefficient d60/d10∼1.5. The resulting porous medium is homogeneous, with porosity of about 0.37 and hydraulic conductivity of about 1.3∼10-3 m/s. Upstream from the sandbox, a tank filled by freshwater provides recharge for the aquifer. The downstream tank simulates the sea and red food dye is added to the saltwater to easily visualize the salt wedge. The volume of the downstream tank is about five times the upstream one, and, due to the small filtration discharge, minimizing salt concentration variations due to the incoming freshwater flow. The hydraulic gradient during the tests is constant, due to the fixed water level in the tanks. Water levels and discharged flow rate are continuously monitored.

The cutoff wall was realized with sodium bentonite, characterized by a hydraulic conductivity of about 10-9 m/s, and an electrical resistivity comparable to that of the porous medium.

The experiment presented here had a duration of 36 h. For the first 28 h, the saltwater wedge was let to evolve until quasi-stationary conditions were obtained. In the last 8 h, water withdrawal was carried out at a distance of about 50 cm from the downstream tank by means of a draining trench. The experiment was monitored by means of photos collected with regular frequency as well as ERT (electrical resistivity tomography) with a joint surface and cross-borehole configuration, specifically designed for the laboratory flume.

The results show that the cutoff wall is effective in reducing the vertical extent of the salt wedge even if a large amount of incoming freshwater is extracted from the draining trench. On the other hand, a considerable increase of the diffuse front affects the portion of aquifer between the cutoff wall and the seaward boundary. Visual inspection and ERT results are substantially in agreement with the results obtained by the numerical simulations.