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Dispersive Behavior of the Mixing Zone between a Shallow Freshwater Lens and Upward Seeping Saline Groundwater

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ABSTRACT

Introduction
Salt water intrusion and upward seepage of salt groundwater is a widespread problem in low-lying areas of coastal zones that are important for agriculture or ecology, such as in the North and West regions of the Netherlands, Southwest Florida, and many other deltaic areas, for example Camargue in France and the Nile delta in Egypt. Where the soil surface is situated below sea level, saline groundwater moves upward into superficial water networks. On the other hand, infiltrating rainwater forms small-scale fresh water lenses. The system is also comparable to the situation that develops when "skimming wells" are used, for example for irrigation in Northern India.
The lenses we are studying have a thickness ranging from less then one up to several meters, their width depending on drainage density (generally 20-500 m). Field data show that the transition zone can be as thick as the fresh water lens itself. Therefore a sharp interface model cannot be assumed suitable to analyze such lenses (Sakr, 1999). When comparing numerical and analytical models for steady situations, when flow lines are parallel to the transition zone, we found that the analytical model represents the centre of the transition zone quite accurately. The width can be estimated only roughly.
Climate change and human influence, through water level control and/or pumping, cause these lenses to grow or shrink. During this volume change, flow lines have a component perpendicular to the transition zone between fresh and saline water. This increases longitudinal dispersion, and thereby widens the transition zone further.

Research
This work is a combination of numerical modeling, dimension analysis and fieldwork; we use SUTRA (Voss and Provost, 2003), which is capable of including both density dependence and unsaturated zones. To characterize the shape of the lens and the transition zone we use spatial moments. For 2 sites in the Southwest of the Netherlands we are continuously monitoring salinity at different locations and at several depths, in cooperation with Deltares, The Netherlands.

We quantified the contribution of diffusion and dispersion to the mixing process for the different phases of lens formation, when a fresh water lens grows from initially saline conditions to steady state. While the lens is growing, longitudinal dispersion dominates the (wide) mixing zone. Gradually, when the lens approaches steady state, the dominating process changes. In the middle of the field, diffusion becomes dominating, whereas transverse dispersion is most important near the ditch. In general, the width of the transition zone decreases, since both transverse dispersion and diffusion are smaller then longitudinal diffusion. Currently we are working on the effect of seasons, dry spells, and changing climatic conditions. The latter does not only influence precipitation and evaporation, but also the saline seepage, through sea level changes. Calculations show remarkably fast responses of thin lenses. This means that droughts may have their effect on root zone salinity at an earlier stage then we expected beforehand. The influence of ditches/ drains on the lens behavior is large for a zone of approximately 10 m around it. This shows the importance of careful management of ditch level and quality. We are working towards a tool that can help us identify areas or situations where crop or natural vegetation is actually threatened by saline water reaching the root zone.

REFERENCES

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