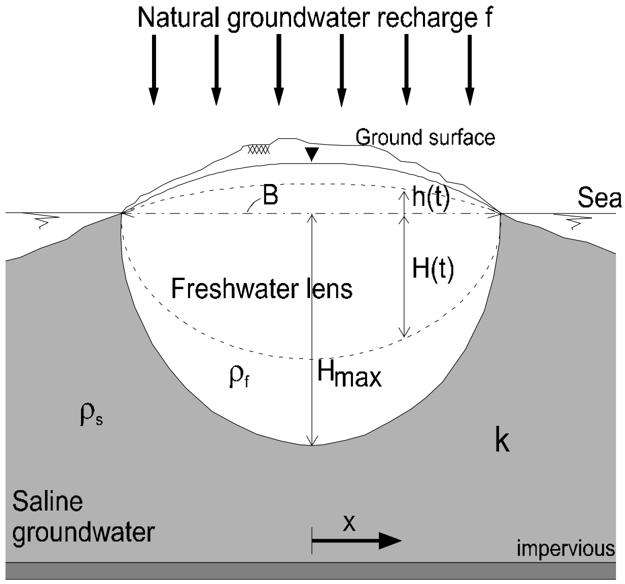
Evolution of a freshwater lens in a coastal area

Variable-density groundwater flow modelling with SEAWAT



Gualbert Oude Essink
Deltares
Unit Subsurface and Groundwater Systems
gualbert.oudeessink@deltares.nl

Introduction

Analysis of a homogeneous aquifer with the following geometry: horizontal *L*=10 km by vertical *D*=150 m. The profile is two-dimensional. Discretisation: 100*15 rectangular cells, so Δx=100 m and Δz=10 m. Hydrostatic pressure at the left and right boundary: viz. freshwater head only increases with depth due to density differences. In the central part of the aquifer, over a length of 40 cells (4 km) a natural groundwater recharge is taking place at t=0 year, with a rate of 360 mm/year. Initially the salt concentration is equal to 35000 mg Cl^-/l. In the beginning, no hydrodynamic dispersion is taken into account: D_{mol}=0 m^2/s, $\alpha_L=\alpha_{TH}=\alpha_{TV}$=0 m, as well as R_d=1 (no retardation). Other soil parameters are: hydraulic conductivity *k*=20 m/d; porosity n_e=0.35 and anisotropy=k_{vert}/k_{hor}=0.1. Each cell contains initially 16 particles, convergence criterion is 10^{-8} m and numerical time step Δt=1.0 year. Courant number is 0.95.

Parameters			
Layers	15	K_{hor}	20 m/d
Rows	1	T (=K_{hor}*thickness cell)	200 m^2/d
Columns	100	Anisotropy K_{hor}/K_{ver}	10
Δx	100 m	ne	0.35
Δy	1 m	αL	0 m
Δz	10 m	αT	0 m
Stress periods	10	recharge	360 mm/y
Initial concentration	35000 mg/l	Recharge concentration	0 mg/l
bouyancy	0.025		

Exercise 1: geometry of the problem
Check PMWIN input files: heads, time-characteristics, IBOUND, MODFLOW; SEAWAT parameters.

- Run SEAWAT.
- Check the concentration results.
- Place at least 5 observation wells at interesting points, to see the change in concentration can be seen as a function of time.
- Create an EXCEL-figure with the output of the observation wells. How fast has the lens 95% of its final volume?

Exercise 2: analytical versus numerical solution for steady-state situation
The steady-state analytical solution of the position of the fresh-saline interface is known:

$$H = \sqrt{\frac{f(0.25B^2 - x^2)}{k(1+\alpha)\alpha}}$$

See the lecture notes. Analyse whether or not the analytical and numerical solutions for the steady-state situation are in comparison with each other.

Exercise 3: effect of dispersion

- Simulate dispersion by changing the dispersion from 0.0m to α_L=1.0 m ('Models'->'MT3DMS / SEAWAT'->'Dispersion'); use default α_{TH}=α_{TV}=0.1 m.
- Run SEAWAT.
- Analyse the effect due to the differences compare with the reference case.

Exercise 4: determine the maximum extraction rate without serious upconing of saline groundwater

- Place in PMWIN/Models/MODFLOW/Flow Packages/Well, a self determined extraction rate in three extraction wells. Place three observation points in the extraction wells. Note that the concentration under the dunes at t=0 years is initially still 35000 mg TDS/l.
- Run SEAWAT.
- How much groundwater (approximately, in m3/year/m') can be extracted without serious upconing of saline and brackish groundwater (serious means a TDS-concentration>300 mg/l. Make only a coarse, quick calculation. Is the amount of groundwater extracted much; say the length L of the island is 10 km; can drinking water at the island with 100.000 people be supplied?
- What to do to reduce the upconing (no calculations, just give suggestions)?