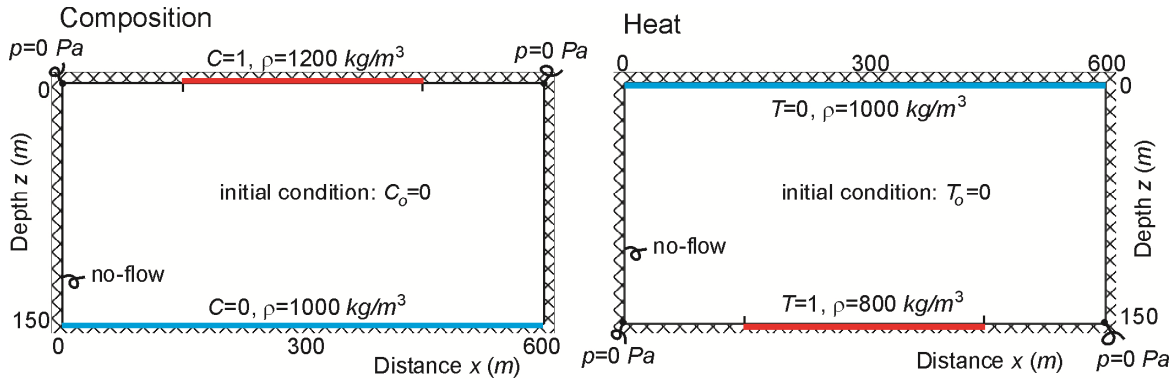


Benchmark Elder's case

Variable-density groundwater flow modelling with SEAWAT



Gualbert Oude Essink
Deltares
 Unit Soil & Division Groundwater Systems
 gualbert.oudeessink@deltares.nl

Yangxiao Zhoy
 UNESCO-IHE



Introduction

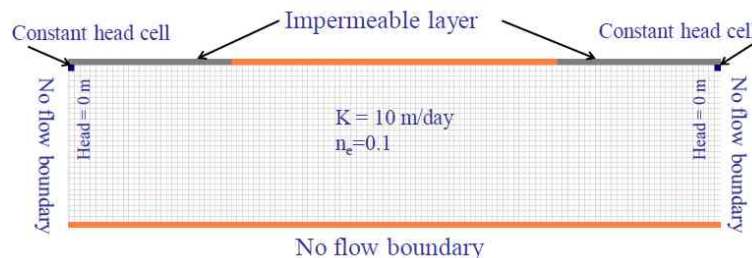
Elder salt convection flow is modelled in a rectangular box in a cross-section. A complex pattern of fingering of the denser water to mix through the box can be reproduced by a density-dependent flow model.

Parameters			
Layers	31	K_{hor}	10 m/d
Rows	1	Anisotropy K_{hor}/K_{ver}	1
Columns	120	Eff. porosity n_e	0.1
Δx	5 m	αL	0.0 m
Δy	1 m	αT	0.0 m
Δz	5 m	Molecular diffusion	0.308 m ² /d
Stress period	1	Specific storage	0.0001
Length of time	7300 days	Salinity seawater	285.7 kg/m ³
		Buoyancy	0.2

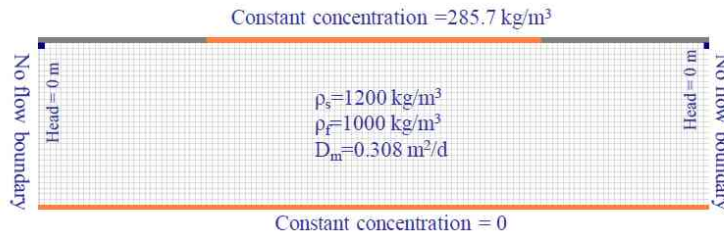
Profile of Elder's case: aquifer thickness 155m; length=600m

Parameters

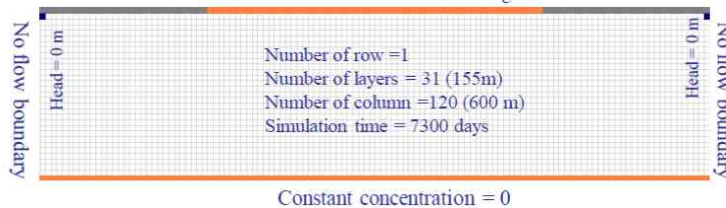
Head



Concentration



Grid



Step 1 Numerical model grid

- (1) Mesh size:
 - a. Number of layers=31; Model thickness=155m; Model top elevation=5m
 - b. Number of rows=1; Model extent=5m
 - c. Number of columns=120; model extent=600m
 - d. Vertical exaggeration=1
- (2) Layer property
 - a. All layers=confined
- (3) Boundary (IBOUND-MODFLOW)
 - a. First row, column 1 to 30 cell values = 0 (inactive)
 - b. First row, column 31 to 90, cell values =1 (active)
 - c. First row, column 91 to 120 cell values = 0 (inactive)
 - d. Second row, column 1 and column 120; cell values = -1 (constant head)
 - e. All other cells, Ibound=1 (active)
- (4) Boundary (ICBOUND-Transport models)
 - a. First row, column 31 to 90, cell values =-1 (constant concentration)
 - b. Last row, all cells, Icbound=-1 (constant concentration)
 - c. All other cells, Icbound=1 (active)
- (5) Top elevation
 - a. Layer 1=5m;; layer 31=-145m
- (6) Bottom elevation
 - a. Layer 1=0m; ...; layer 31=-150m

Step 2 Parameters

- (1) Time:
 - a. Time unit=days
 - b. Simulation=transient
 - c. Stress period=1
 - d. Period length=7200 days
 - e. Number of time steps=720
- (2) Initial hydraulic heads
 - a. Constant head cells =0m

- b. All other cells=10m
- (3) Horizontal hydraulic conductivity
 - a. All cells=10m/d
- (4) Vertical hydraulic conductivity
 - a. All cells=10m/d
- (5) Specific storage
 - a. All cells=0.0001m
- (6) Effective porosity
 - a. All cells=0.1

Step 3 MODFLOW packages

- (1) Solver package
 - a. PCG2

Step 4 MT3DMS/SEAWAT packages

- (1) Simulation settings
 - a. Species: Salt
 - b. SEAWAT (default)
- (2) Initial concentration
 - a. All cells =0
 - b. First row, column 31 to 90, cell values =285.7kg/m³
- (3) Advection
 - a. Use default
- (4) Dispersion
 - a. $\alpha_T/\alpha_L=0.1$
 - b. $\alpha_L=0m$ for all cells
- (5) Species dependent diffusion
 - a. $D_m=0.308m^2/d$ for all cells
- (6) Sink/Source concentration
 - a. Constant heat cells: Salt=35 kg/m³; other cells: Salt=0
 - b. Well: salt=0
- (7) Solver
 - a. GCG
- (8) Concentration observations
 - a. OBS1: x=250m, y=5m, layer=15
 - b. OBS1: x=300m, y=5m, layer=15
 - c. OBS1: x=400m, y=5m, layer=15
- (9) Output control
 - a. Output times: minimum=30; maximum=7200; interval=30

Step 5 Run models

- (1) Run MODFLOW
- (2) Run SEAWAT

Step 6 Presentation of model results

- (4) Contour map of salt concentrations
- (5) Break-through curves
- (6) Animate evolution of mixing