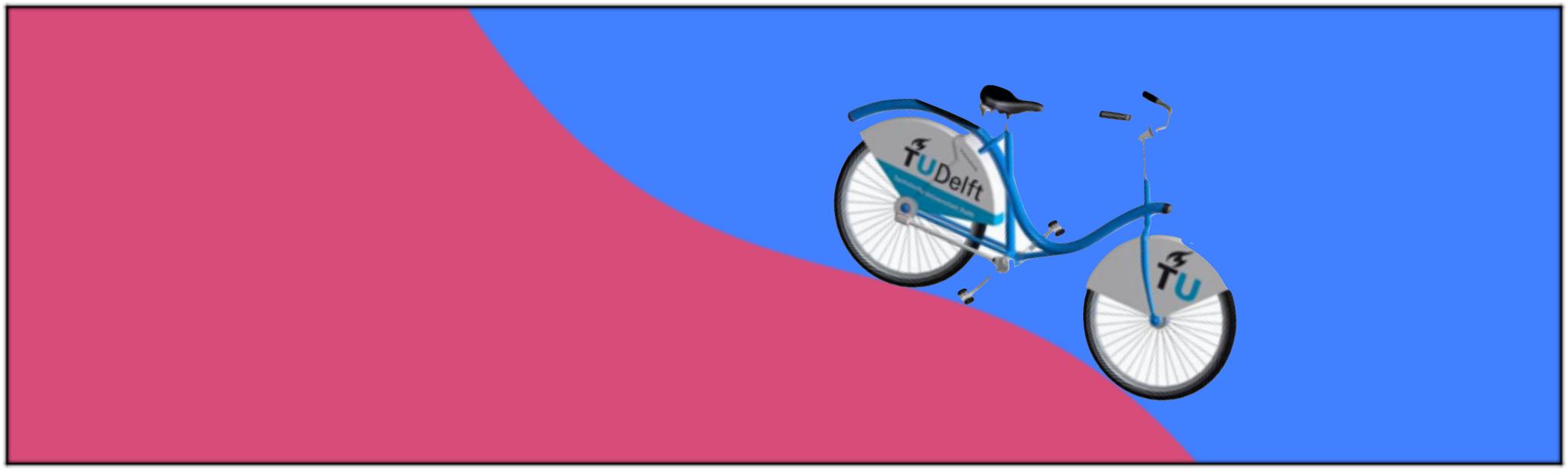
Modeling Regional Seawater Intrusion With SWI2



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What processes do we need in a coastal aquifer model?

Processes are often included because they exist, not because they matter (free after H. Haitjema)

Do we really need:

Dispersive mixing?

Inversion in aquifer?

Vertical fingering?

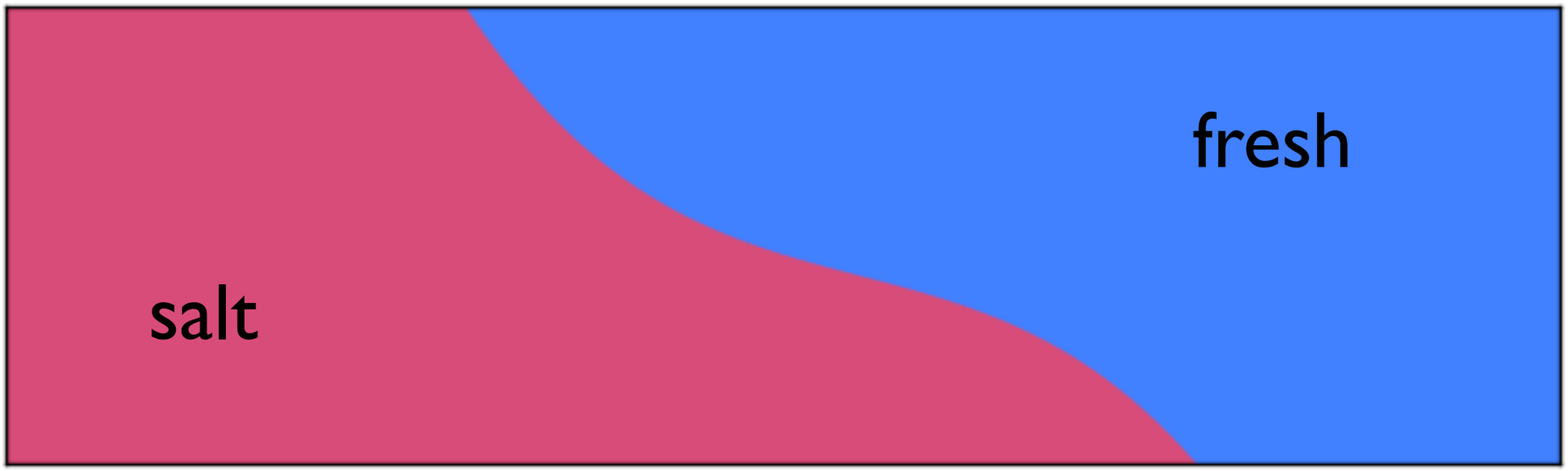
Viscosity variations?

Sea Water Intrusion (SWI) package for MODFLOW

- Simulate one aquifer with one model layer
- No (numerical) mixing of salinities during simulation
- Inversion between layers but not within layers

Seawater intrusion may be simulated in existing MODFLOW model through addition of one input file

Easy example of the approach: Rotation of an interface

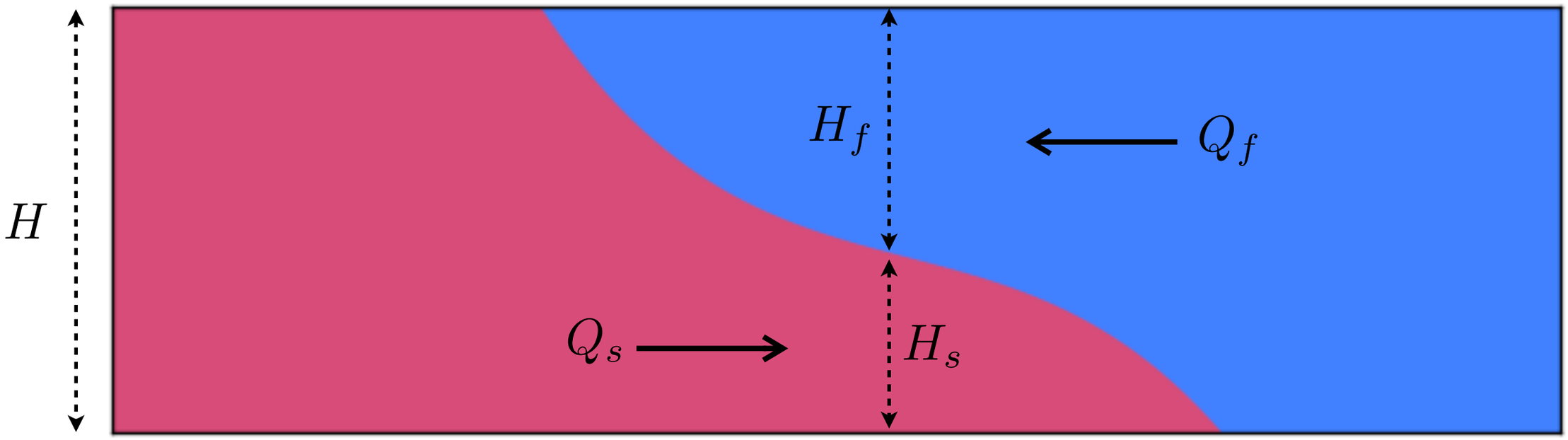


Interface elevation: $\zeta(x,t)$

Interface tries to rotate to horizontal position (in absence of any other flow)

h is freshwater head at top of aquifer

$$Q_f = -K H_f \frac{\partial h}{\partial x}$$



$$Q_s = -K H_s \frac{\partial h}{\partial x} - K H_s \frac{\rho_s - \rho_f}{\rho_f} \frac{\partial \zeta}{\partial x}$$

Continuity of flow in the aquifer

$$Q_x = Q_f + Q_s$$

$$\frac{\partial Q_x}{\partial x} = -S\frac{\partial h}{\partial t} + N$$

$$\frac{\partial}{\partial x}\left(KH\frac{\partial h}{\partial x}\right) = S\frac{\partial h}{\partial t} - N - \frac{\partial}{\partial x}\left(KH_s\frac{\rho_s - \rho_f}{\rho_f}\frac{\partial \zeta}{\partial x}\right)$$

Pseudo source term

Continuity of flow below the interface

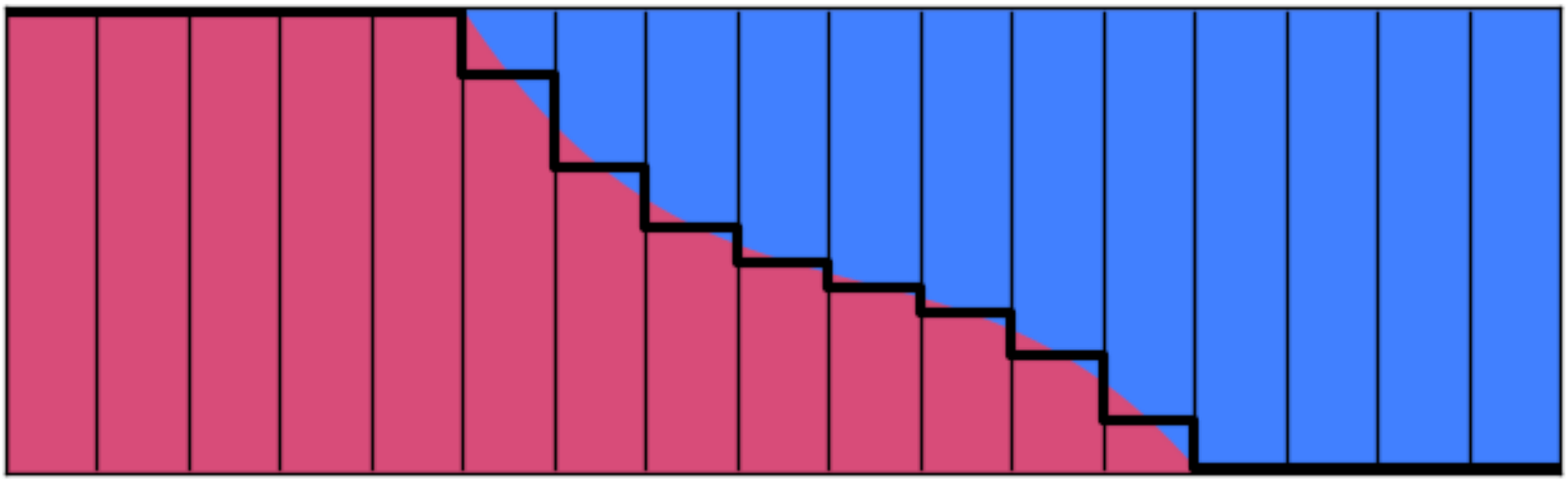
$$\frac{\partial Q_s}{\partial x} = -n\frac{\partial \zeta}{\partial t}$$

$$\frac{\partial}{\partial x}\left(KH_s\frac{\rho_s - \rho_f}{\rho_f}\frac{\partial \zeta}{\partial x}\right) = n\frac{\partial \zeta}{\partial t} - \frac{\partial}{\partial x}\left(KH_s\frac{\partial h}{\partial x}\right)$$

Pseudo source term

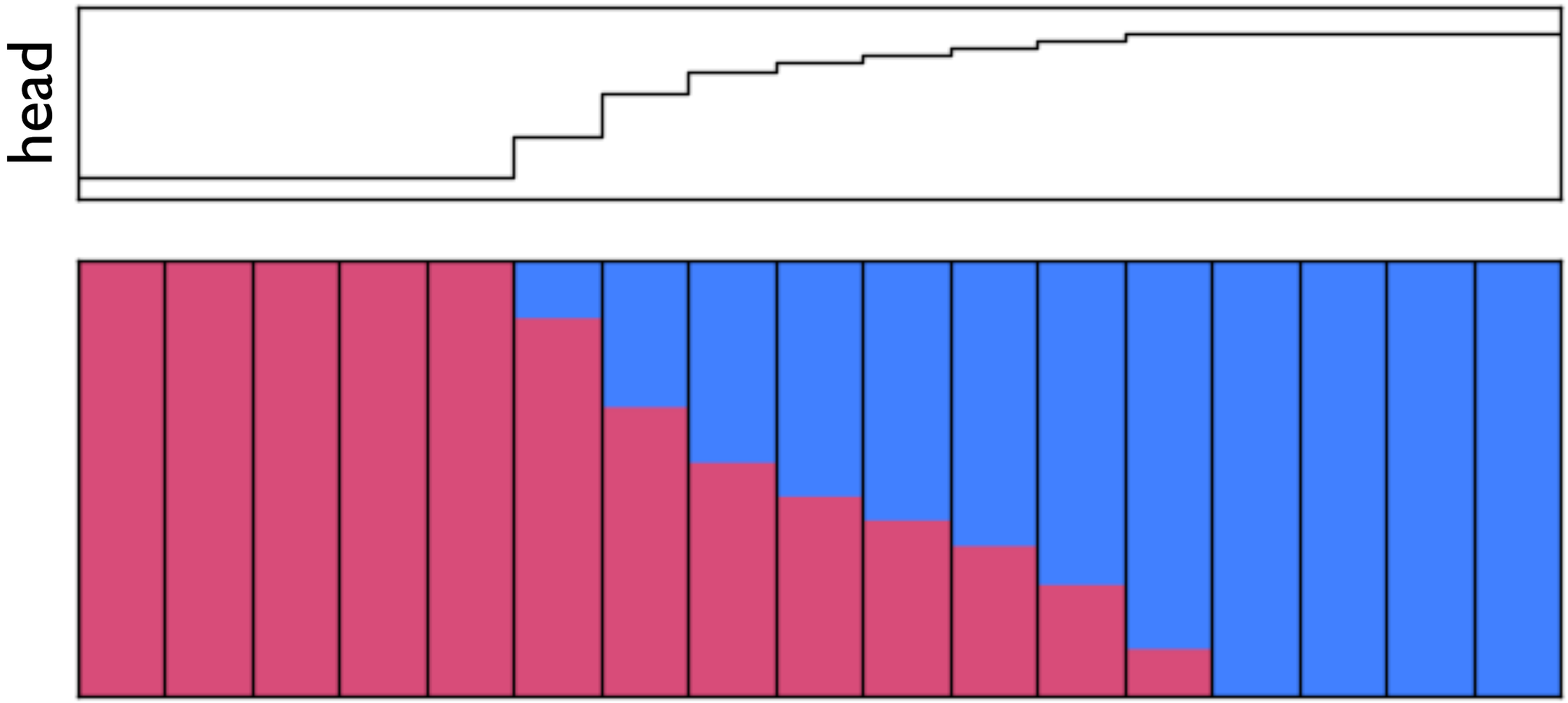
Details: Bakker, WRR, 2003

Discretize aquifer into cells
Specify interface in every cell



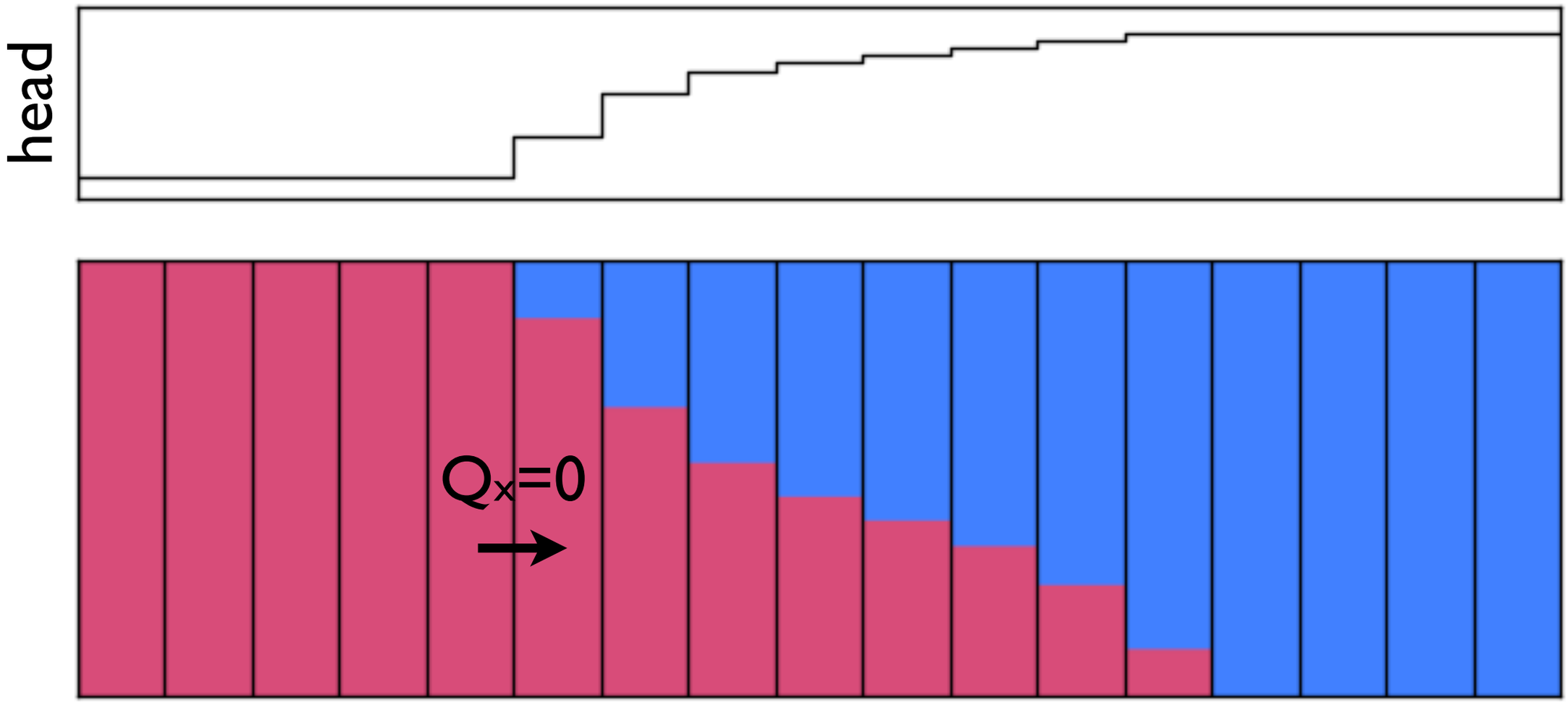
Water is salt when it is below the interface in an aquifer

Solve for the head in the entire model

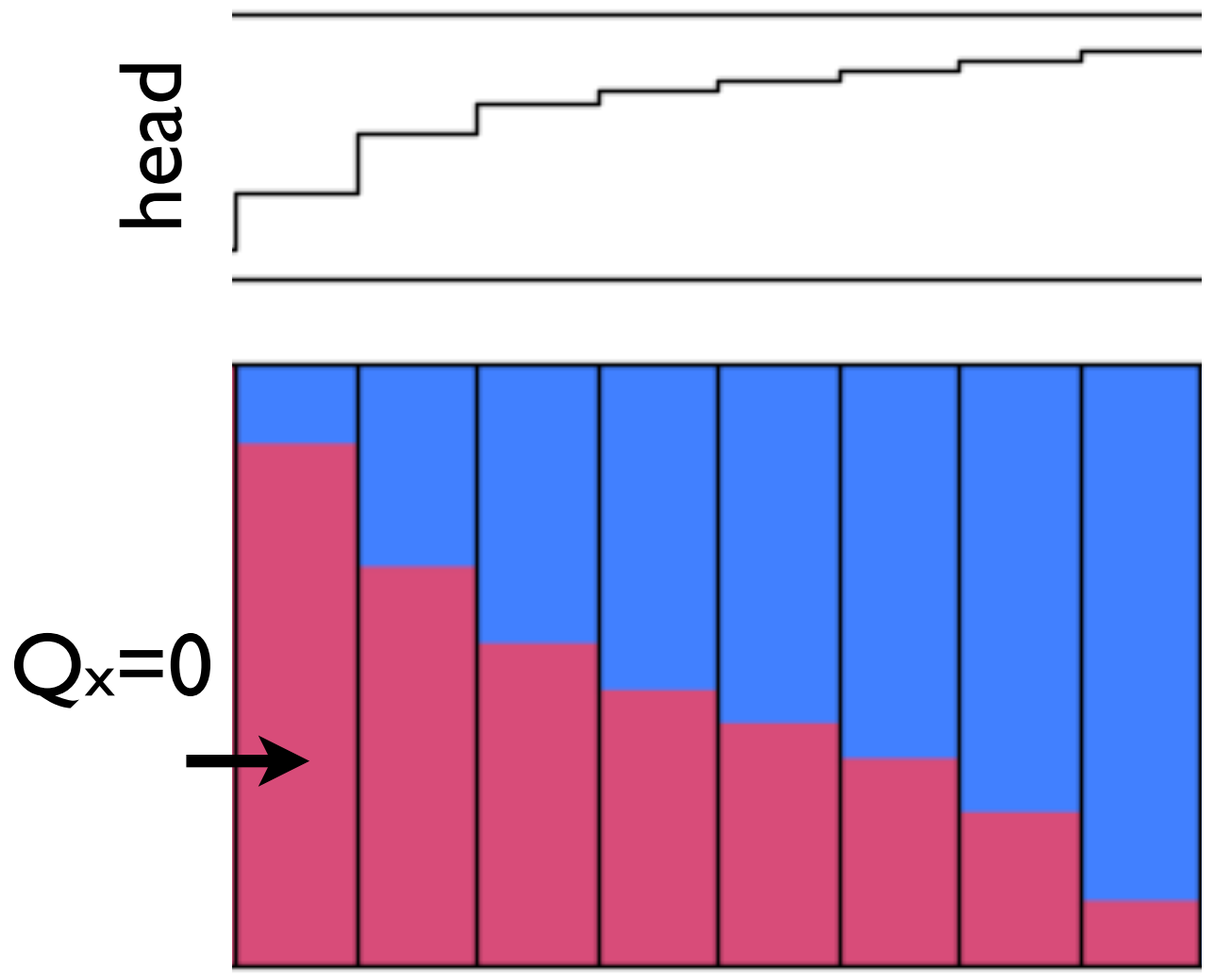


Include interface position in pseudo-source term

Determine the inflow/outflow below the interface

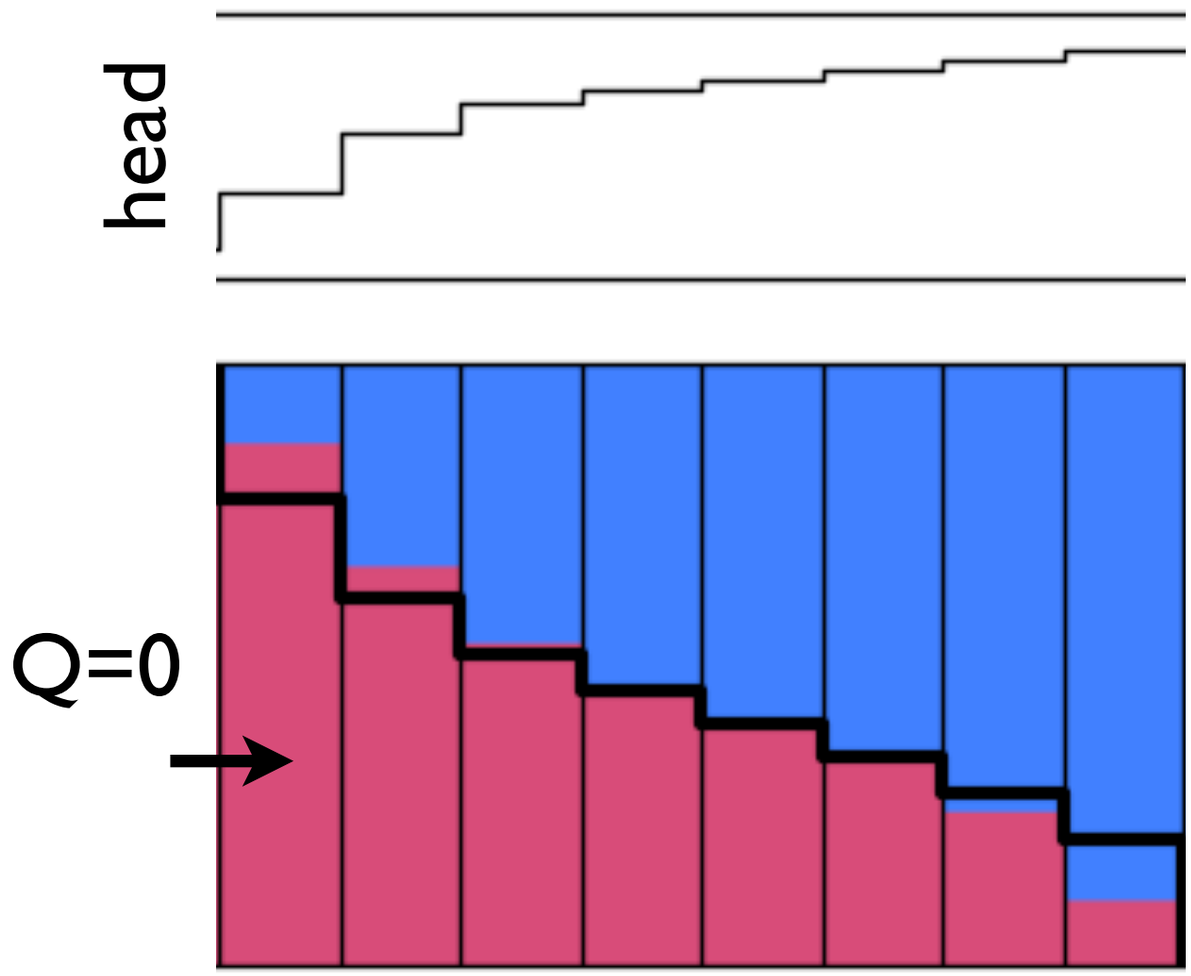


Solve for the new position of the interface in the domain where interface is 'active' only



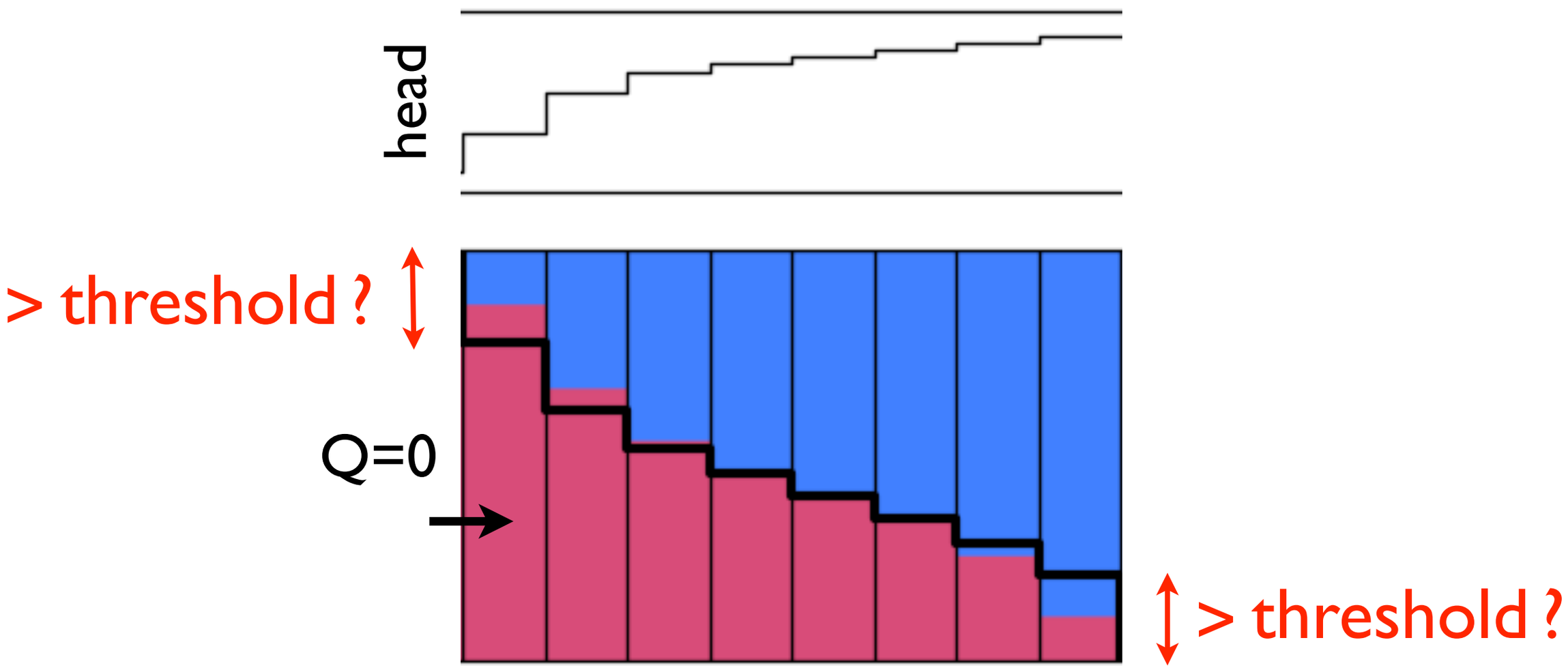
Include head solution in pseudo-source term

Solve for the new position of the interface in the domain where interface is 'active' only

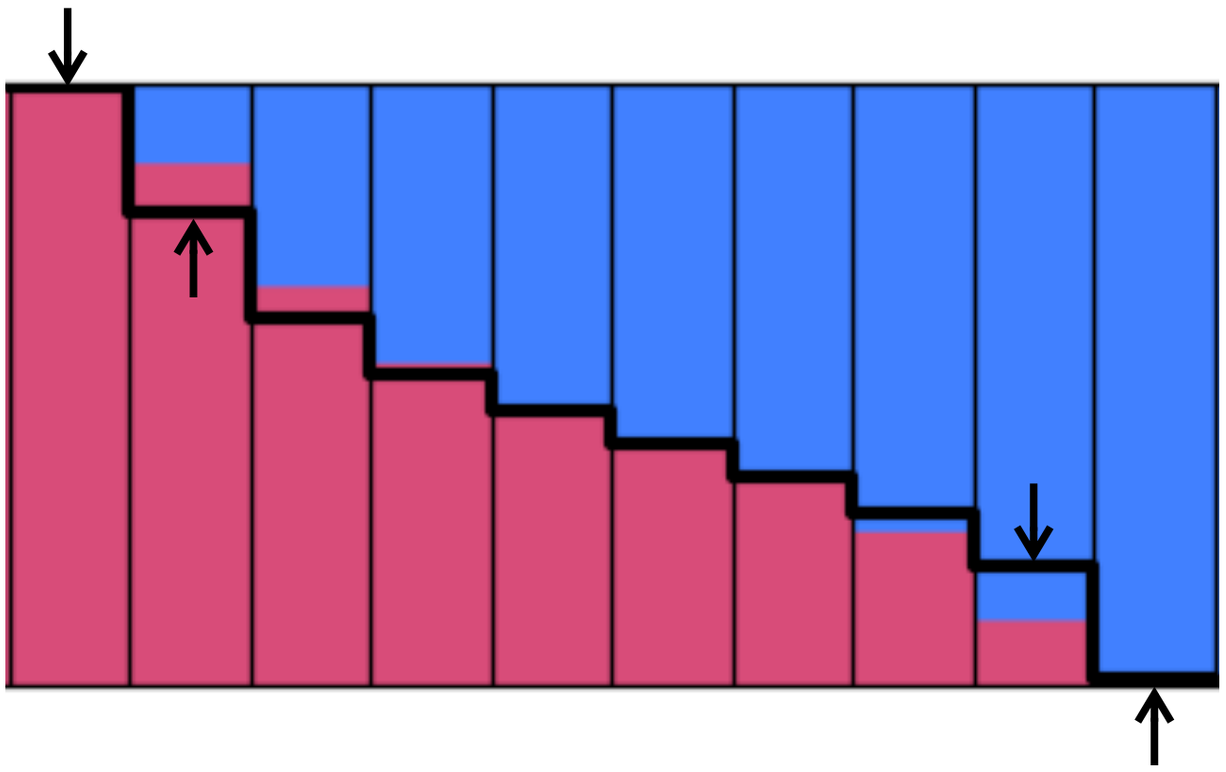


Include head solution in pseudo-source term

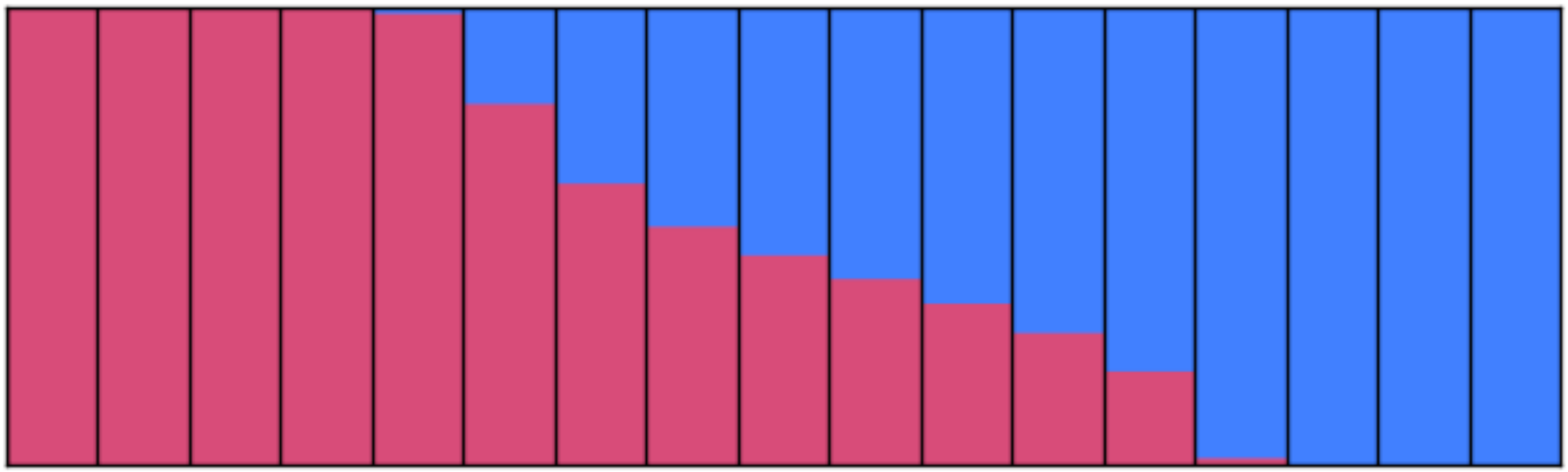
Check if tips and toes move to adjacent cell



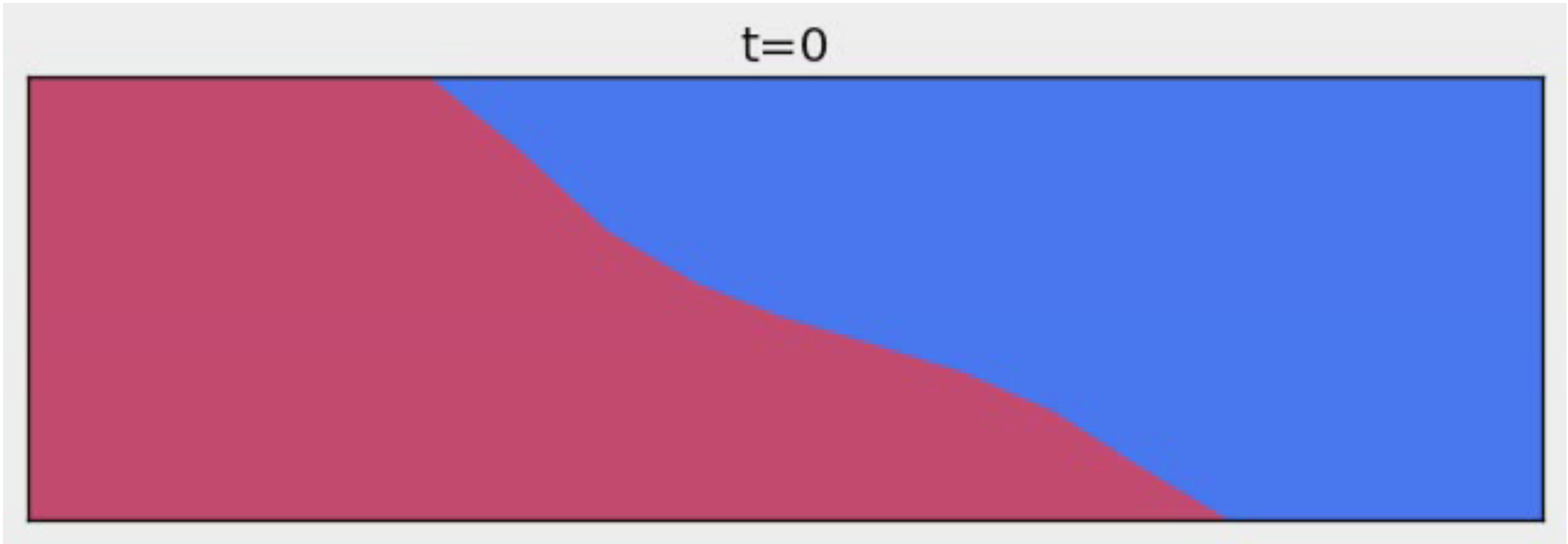
If above threshold, move tip/toe into next cell



Ready for the next time step

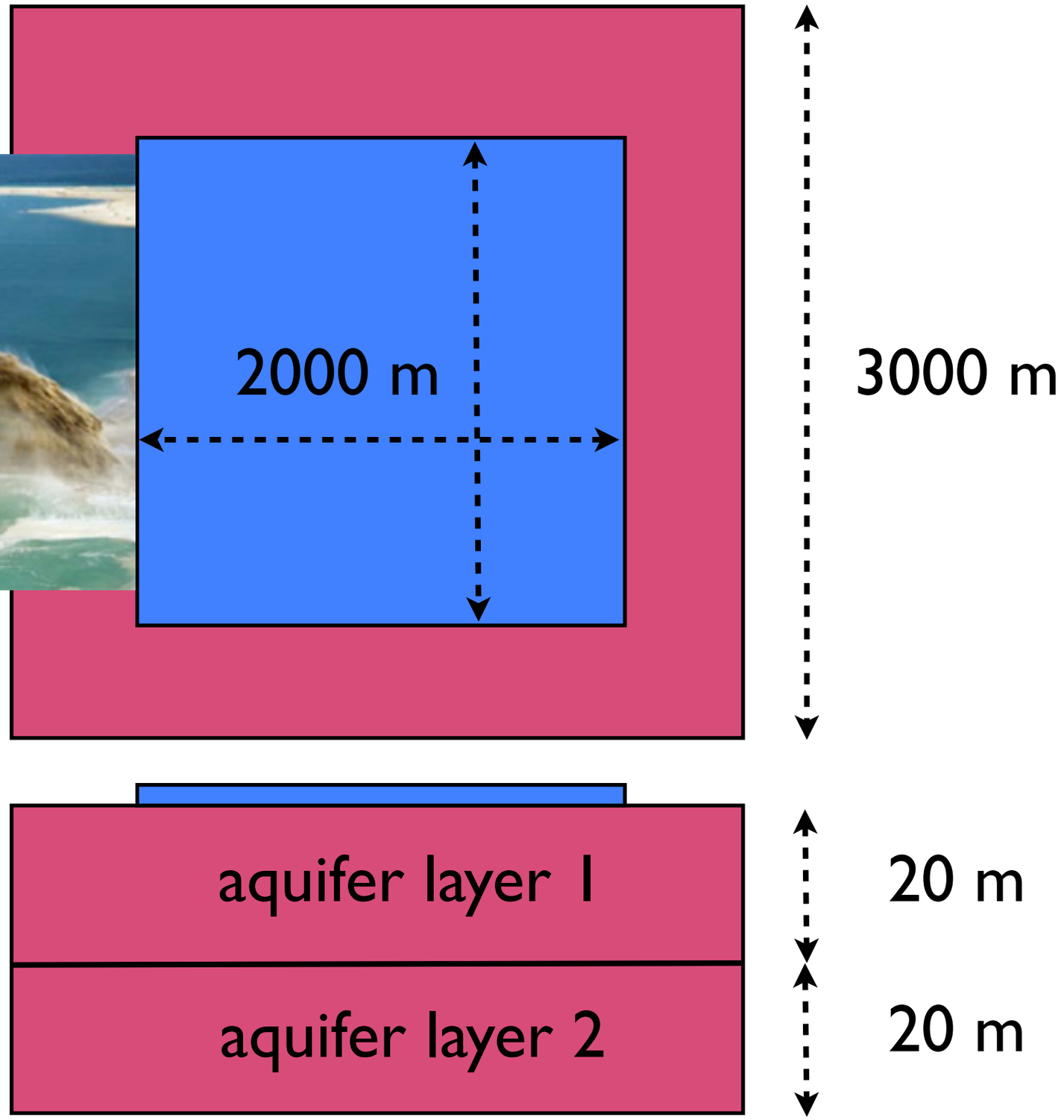


Interface moves to horizontal position

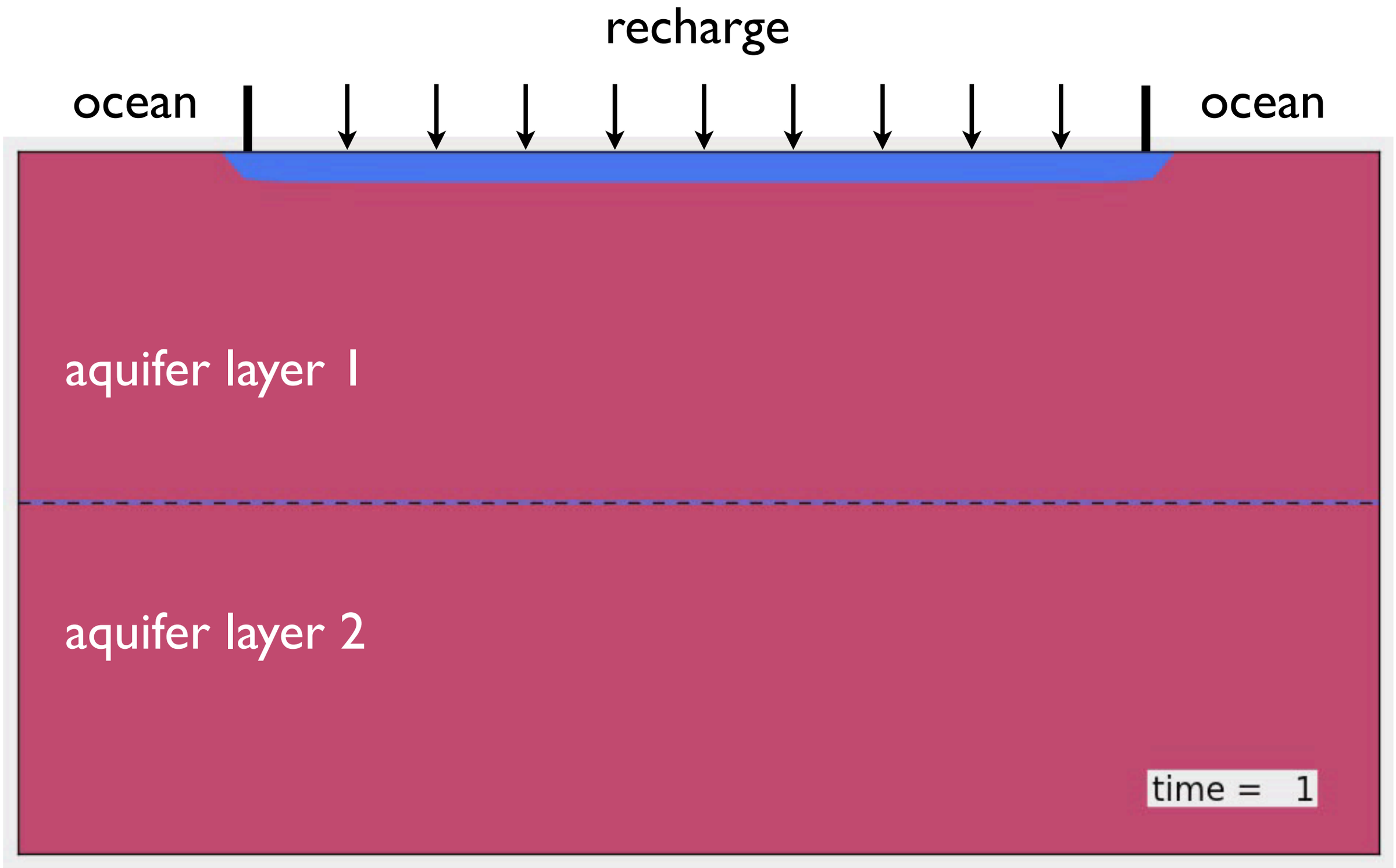


Example: Freshwater lens below an island

dredging and rainbowing



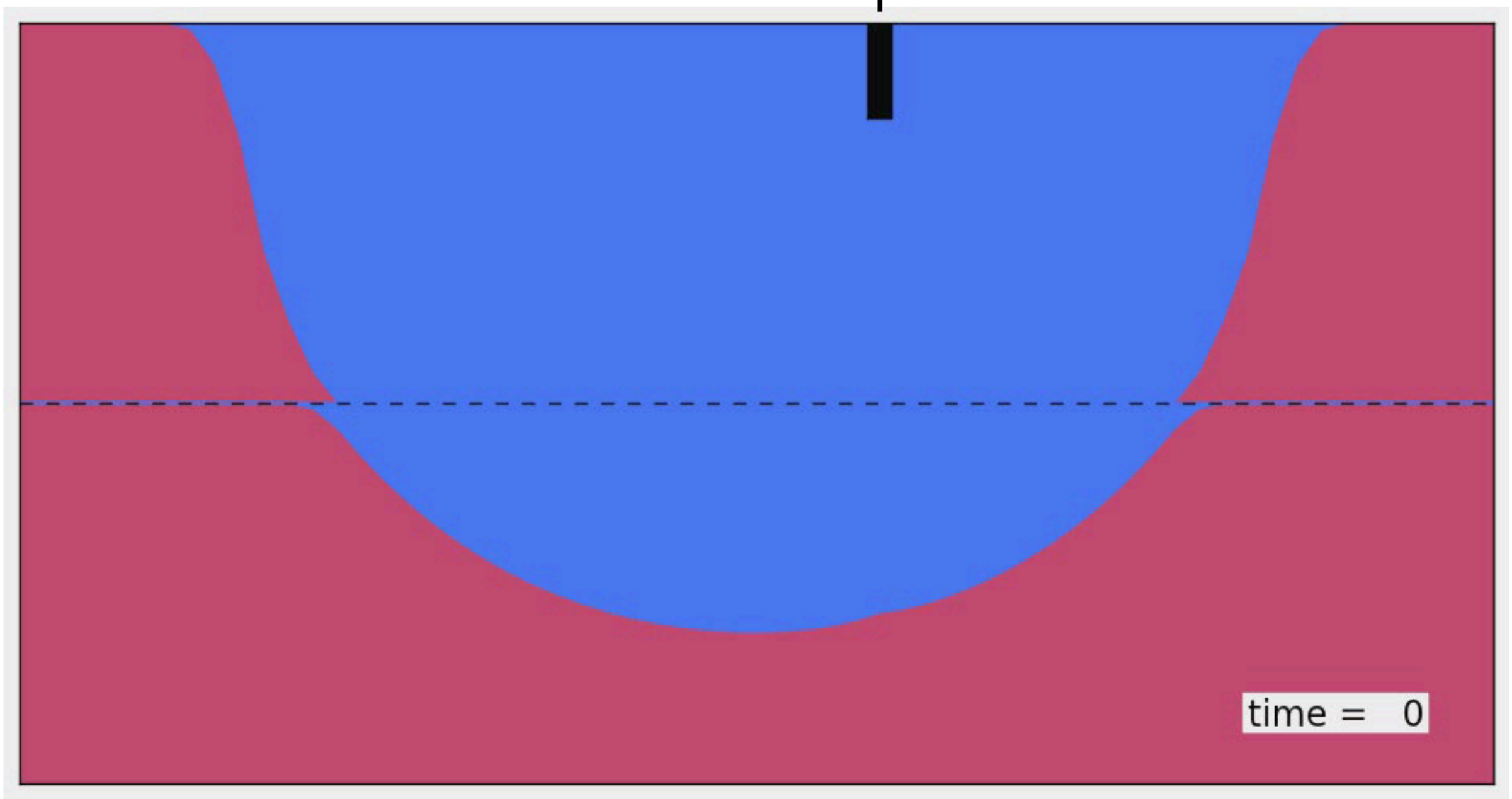
West-East cross-section through center of island

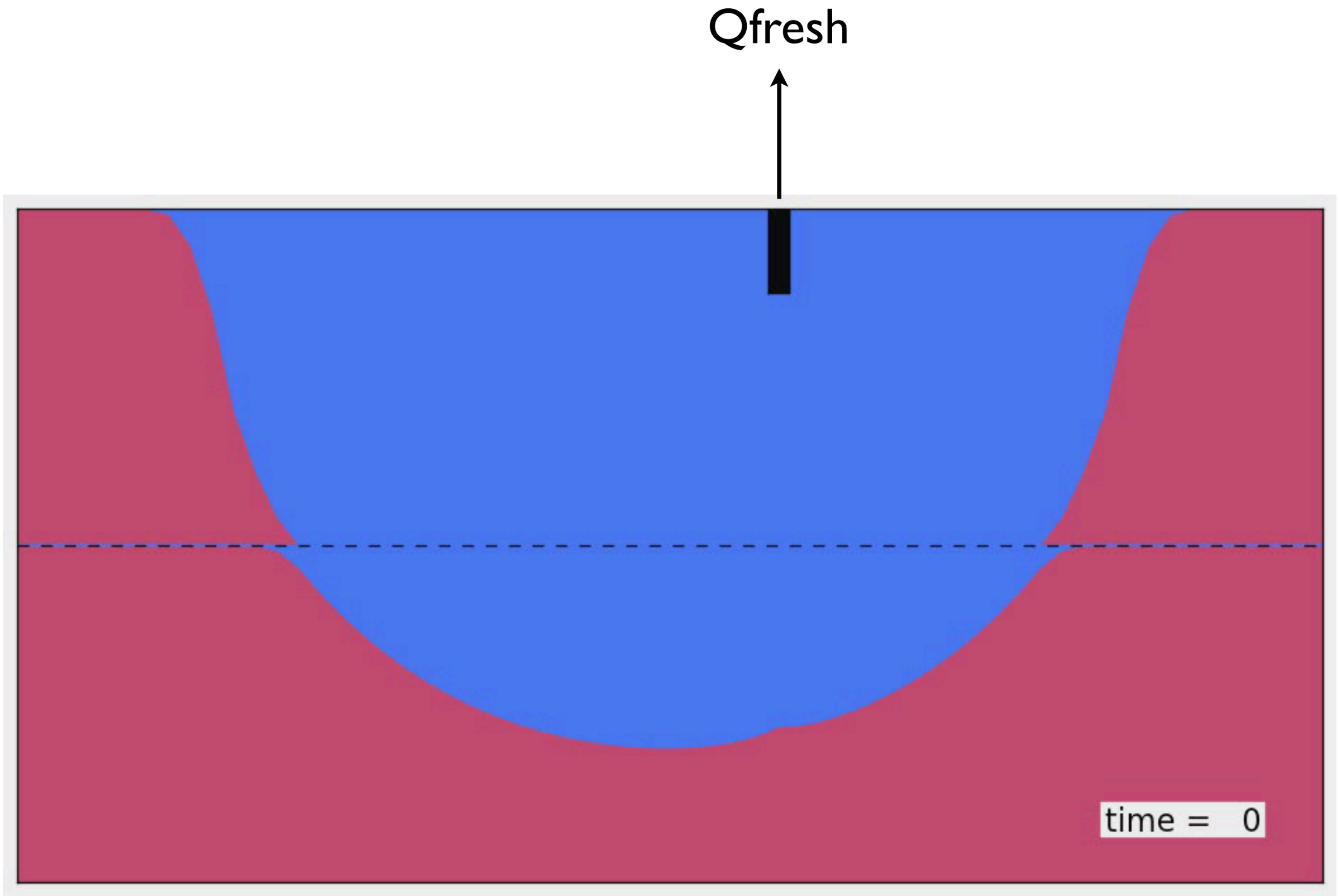


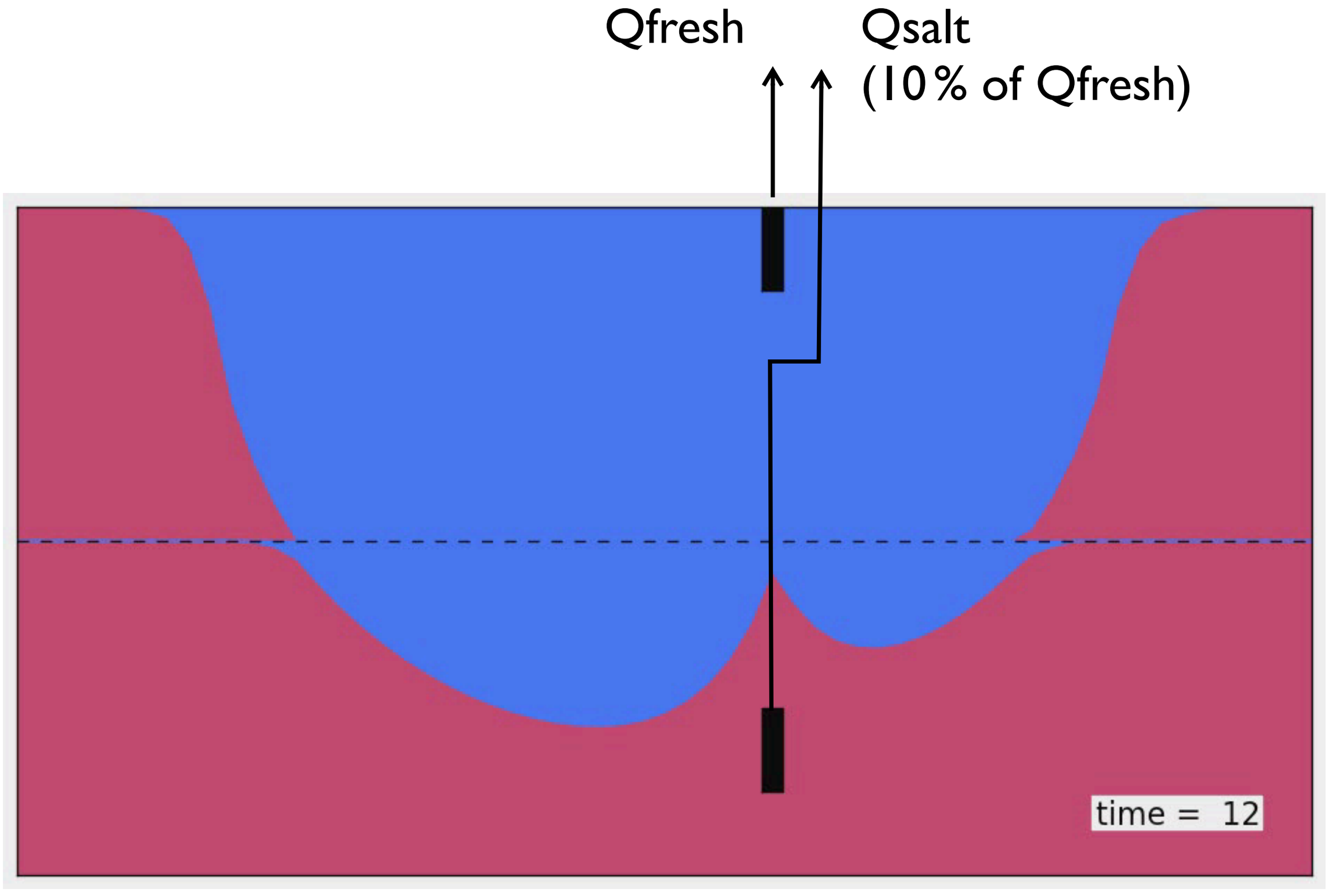
Vertical exaggeration: 40X

Qfresh

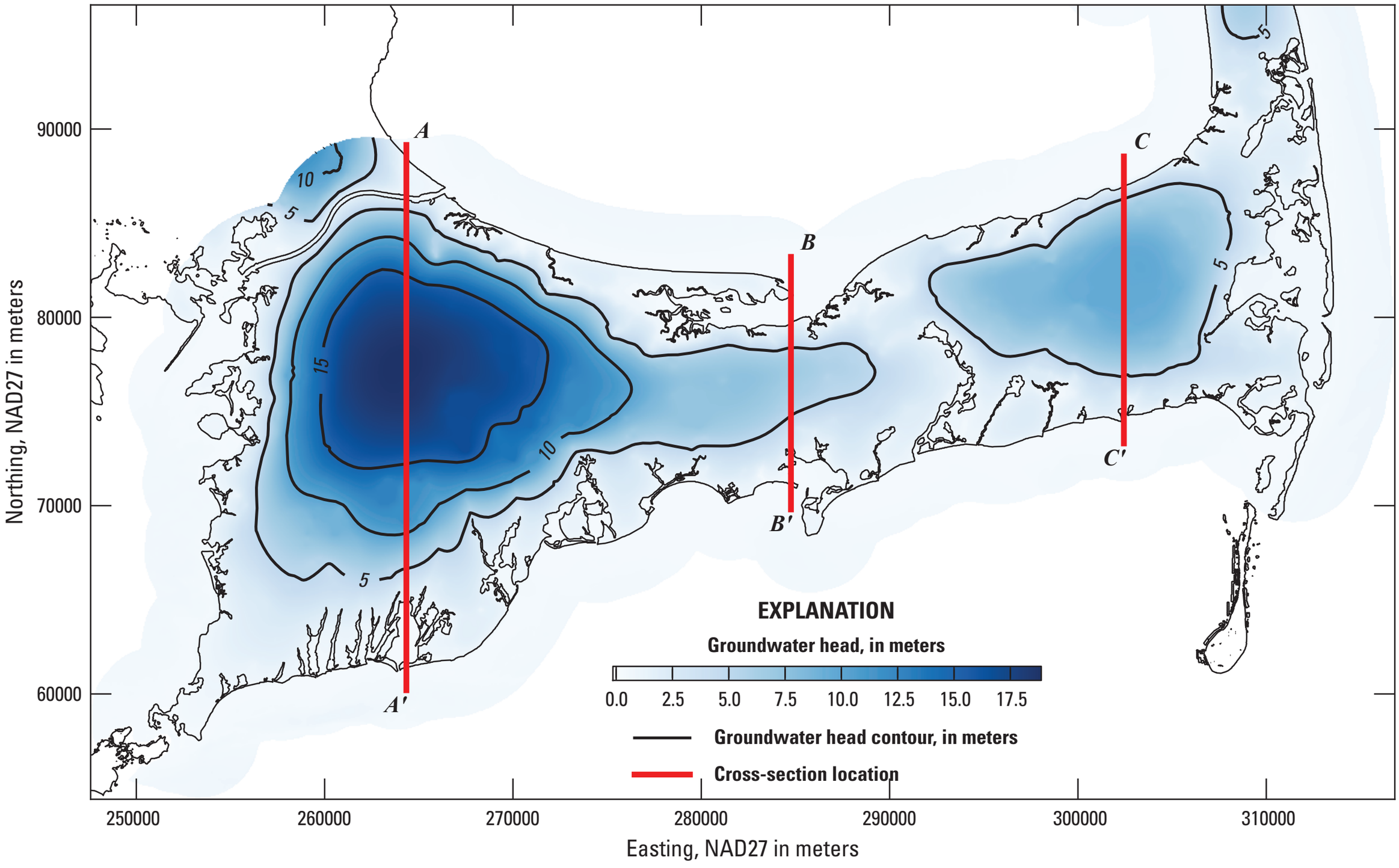
15% of total recharge



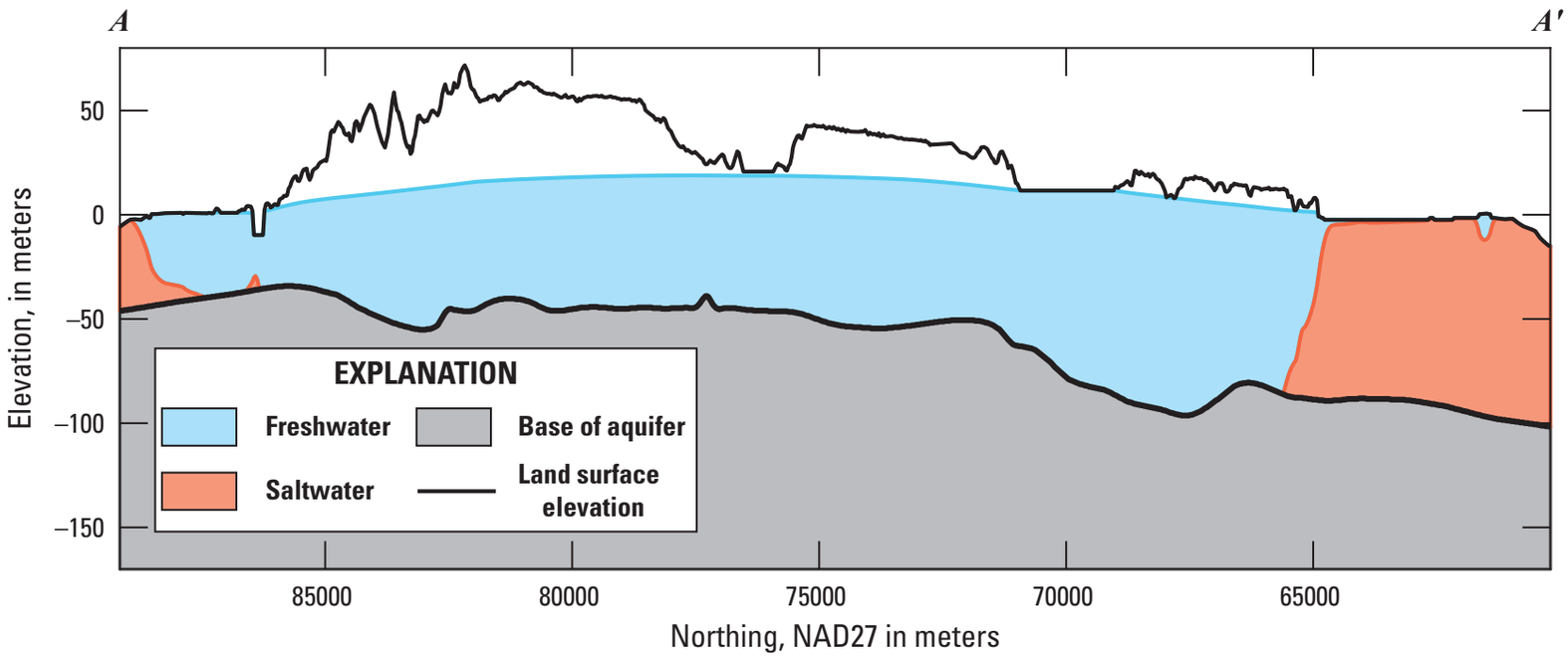

Qfresh
time = 0

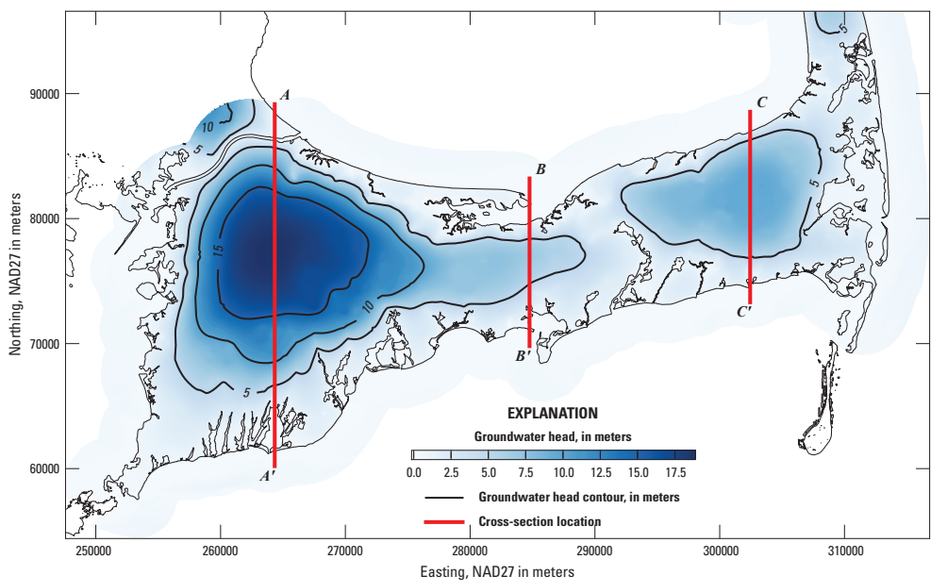

Qfresh
Qsalt
(10% of Qfresh)
time = 12

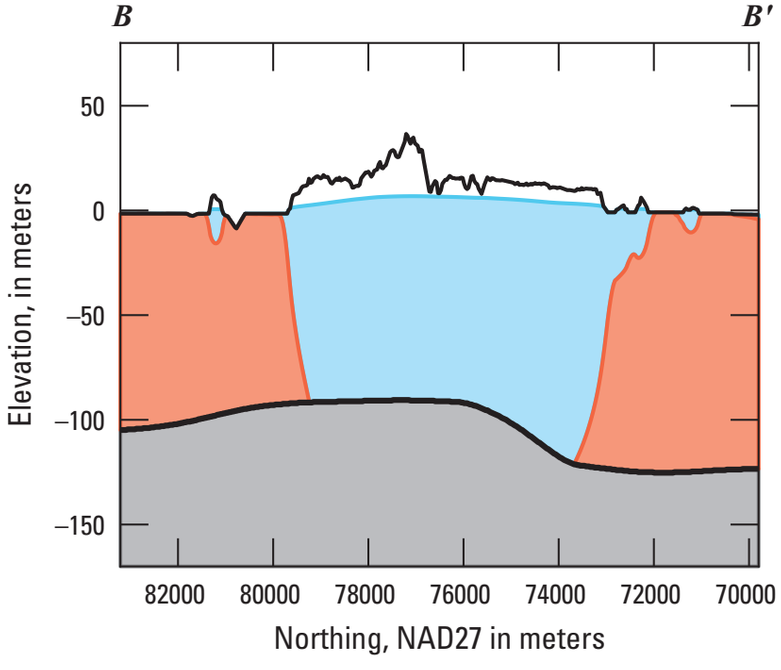
Regional model: Cape Cod

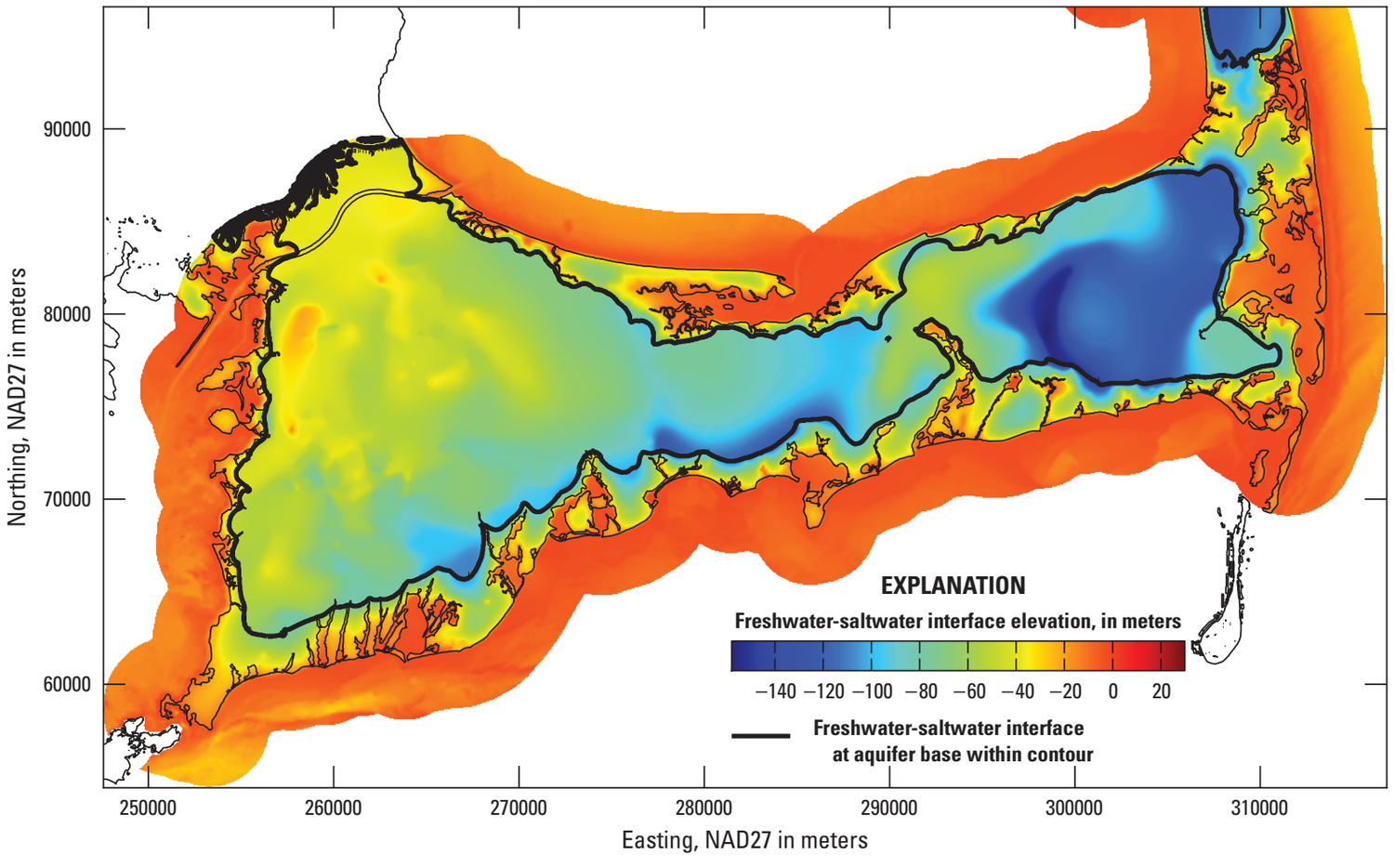


Steady position of interface in cross-section and plan view

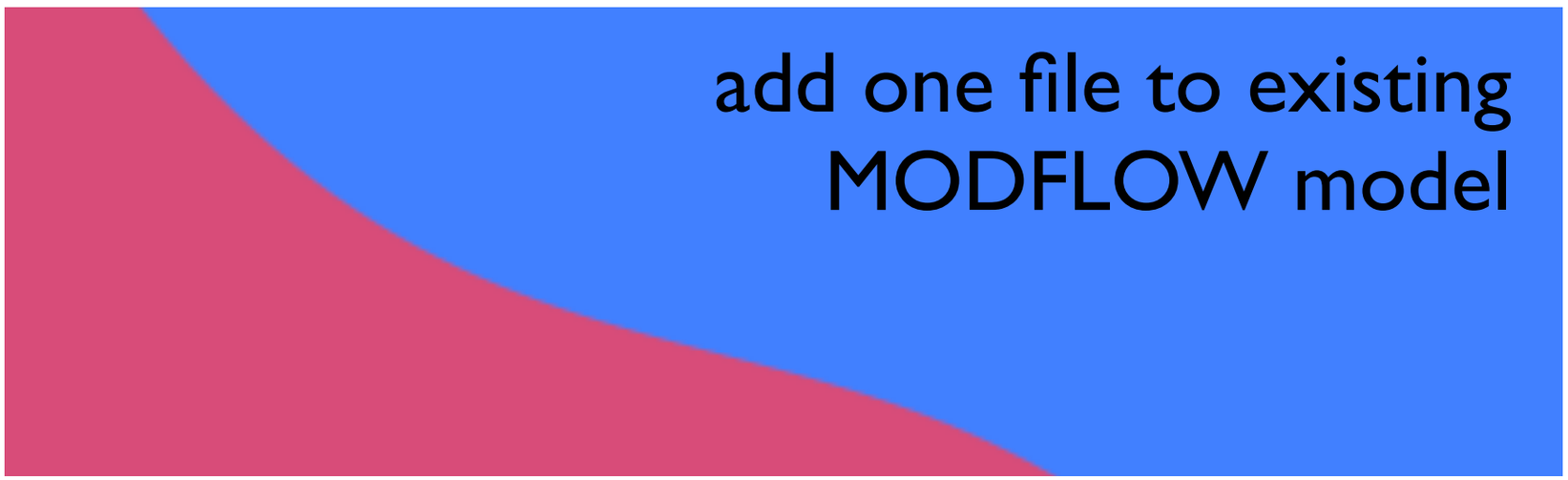


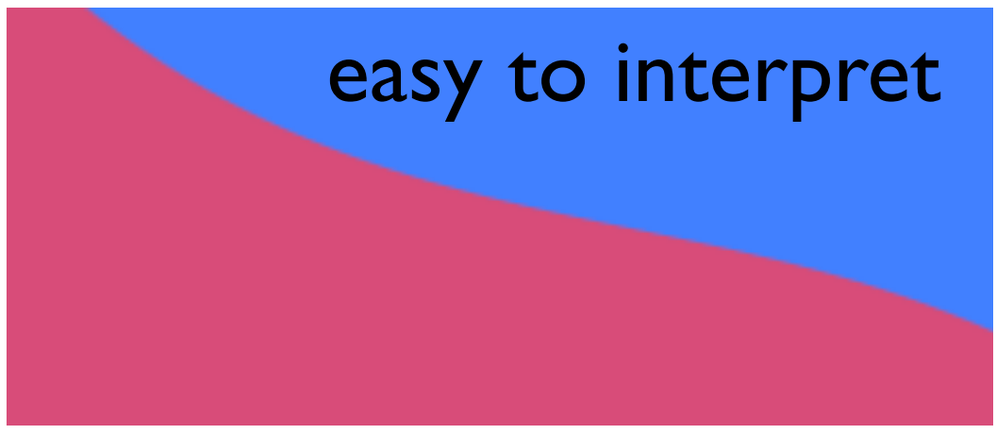






The SWI2 package for MODFLOW2005: Quick simulation of seawater intrusion on Mac or PC





SWI2 is part of MODFLOW2005

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