HWRS 505: Vadose Zone Hydrology

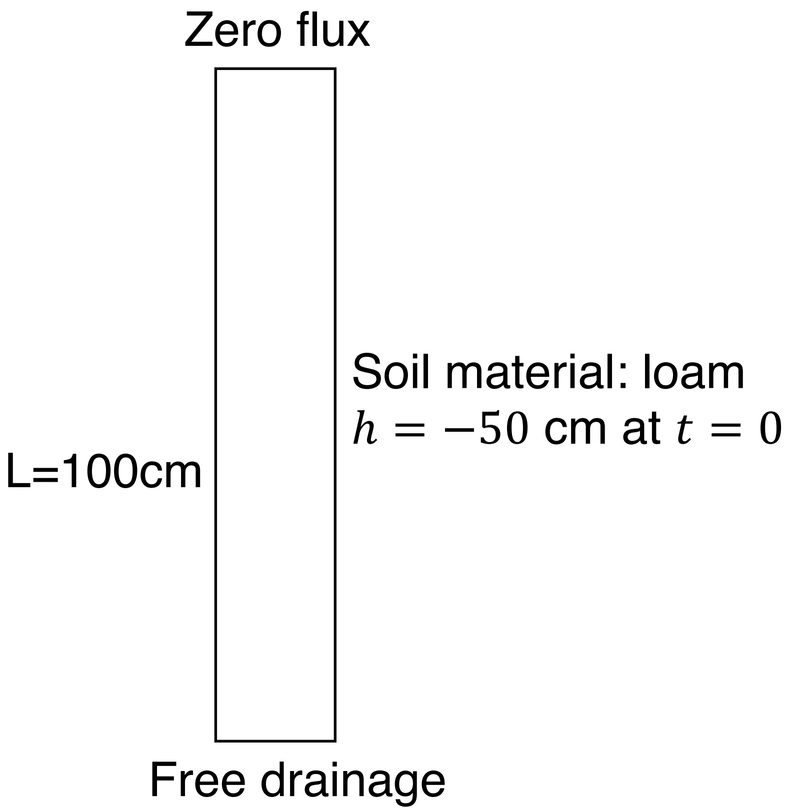
Lecture 17

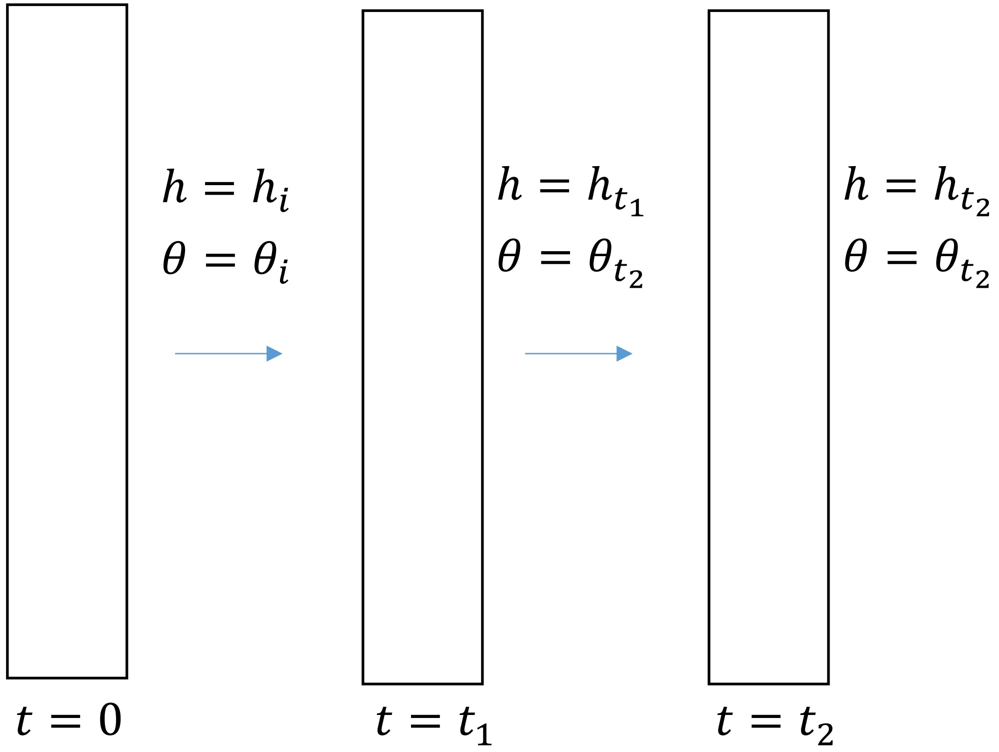
10/19/2023

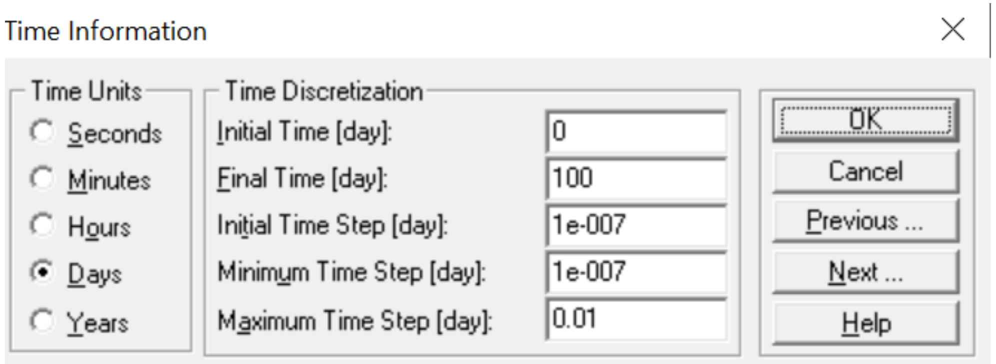
Today: 2D Transient unsaturated flow
Reading: Jury & Horton, Chapter 4

Another HYDRUS-1D exercise (will be in HW4)

Question: Is the “unit gradient” a reasonable assumption during drainage?






Time Information

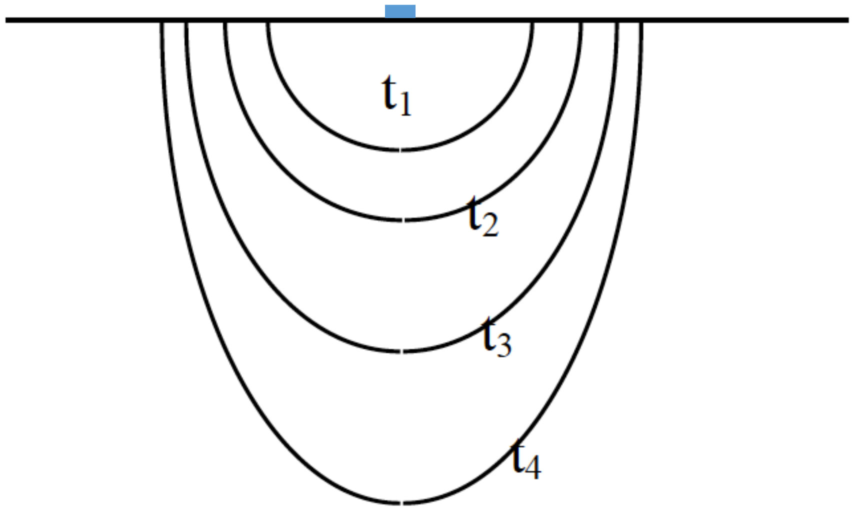
Time Units	Time Discretization	
Seconds	Initial Time [day]:	0
Minutes	Final Time [day]:	100
Hours	Initial Time Step [day]:	1e-007
Days	Minimum Time Step [day]:	1e-007
Years	Maximum Time Step [day]:	0.01

OK
Cancel
Previous ...
Next ...
Help

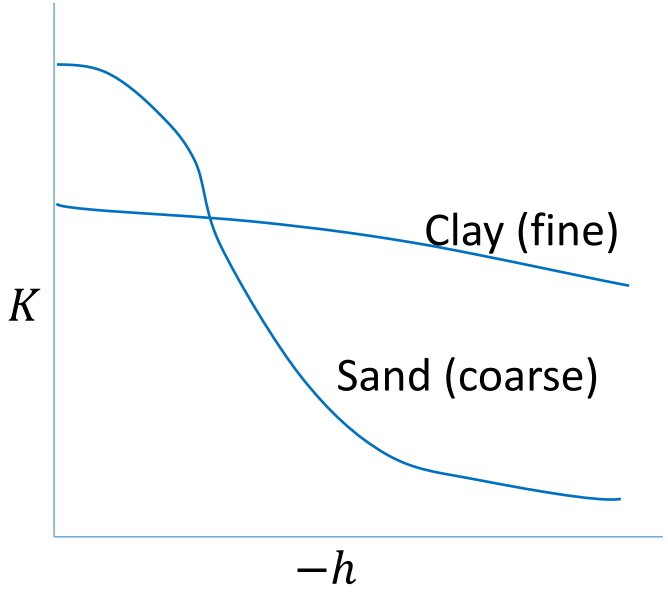
Note: “unit gradient” means flow is only driven by gravity

$$q = -K\left(\cancelto{0}{\frac{\partial h}{\partial z}} + 1\right) = -K$$

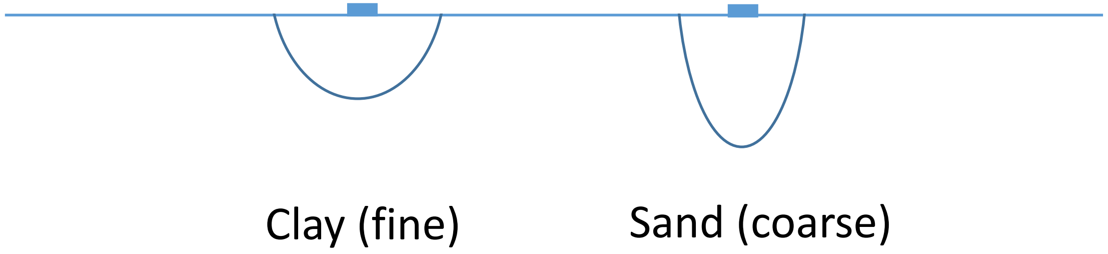
Infiltration from a Point Source



Horizontal flow: driven by capillary pressure
Vertical flow: driven by capillary pressure and gravity

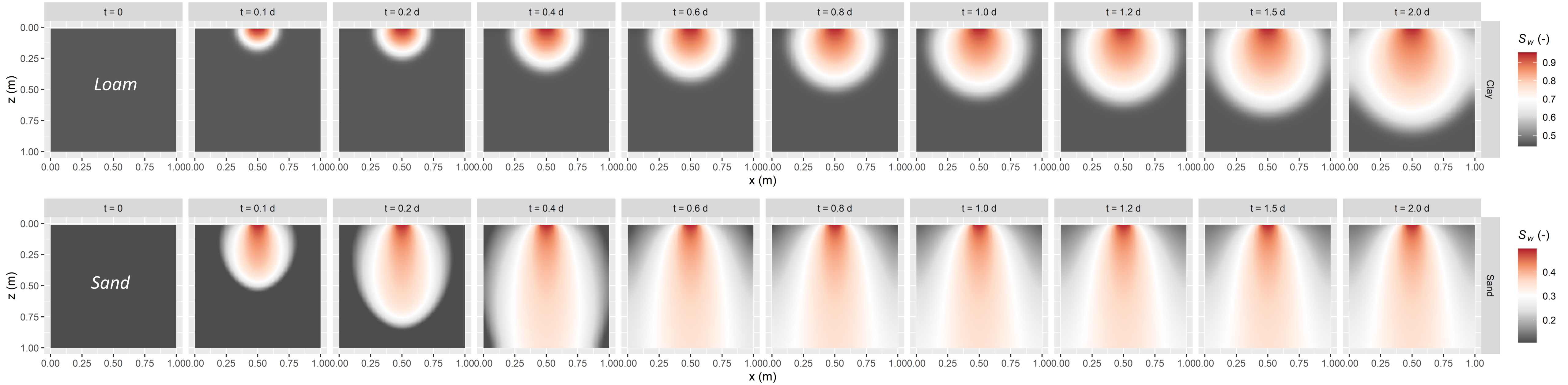


Question: How will the wetted "bulb" be different for sand and clay?

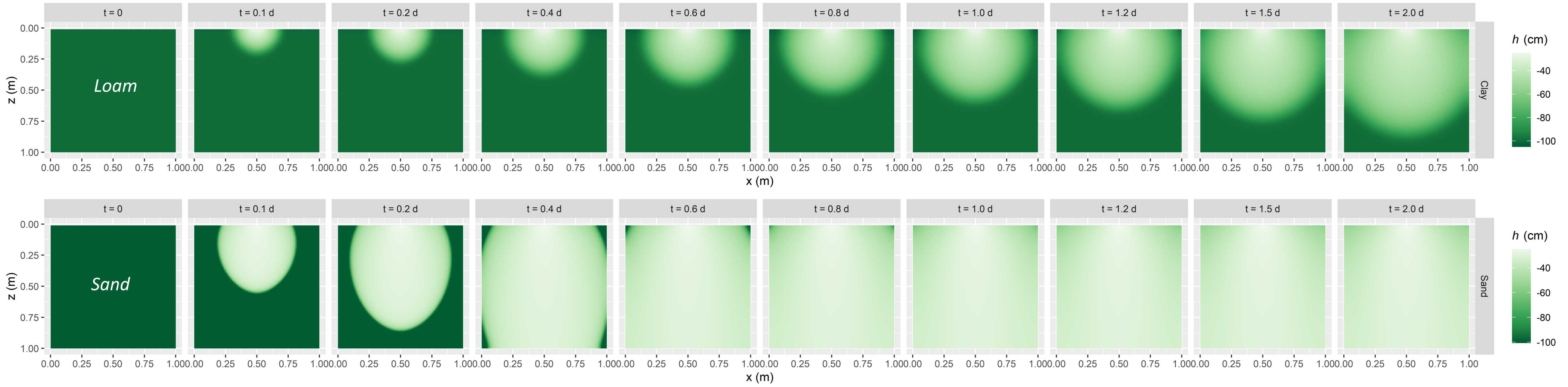


- Capillary pressure driven flow is stronger in clay

S_w

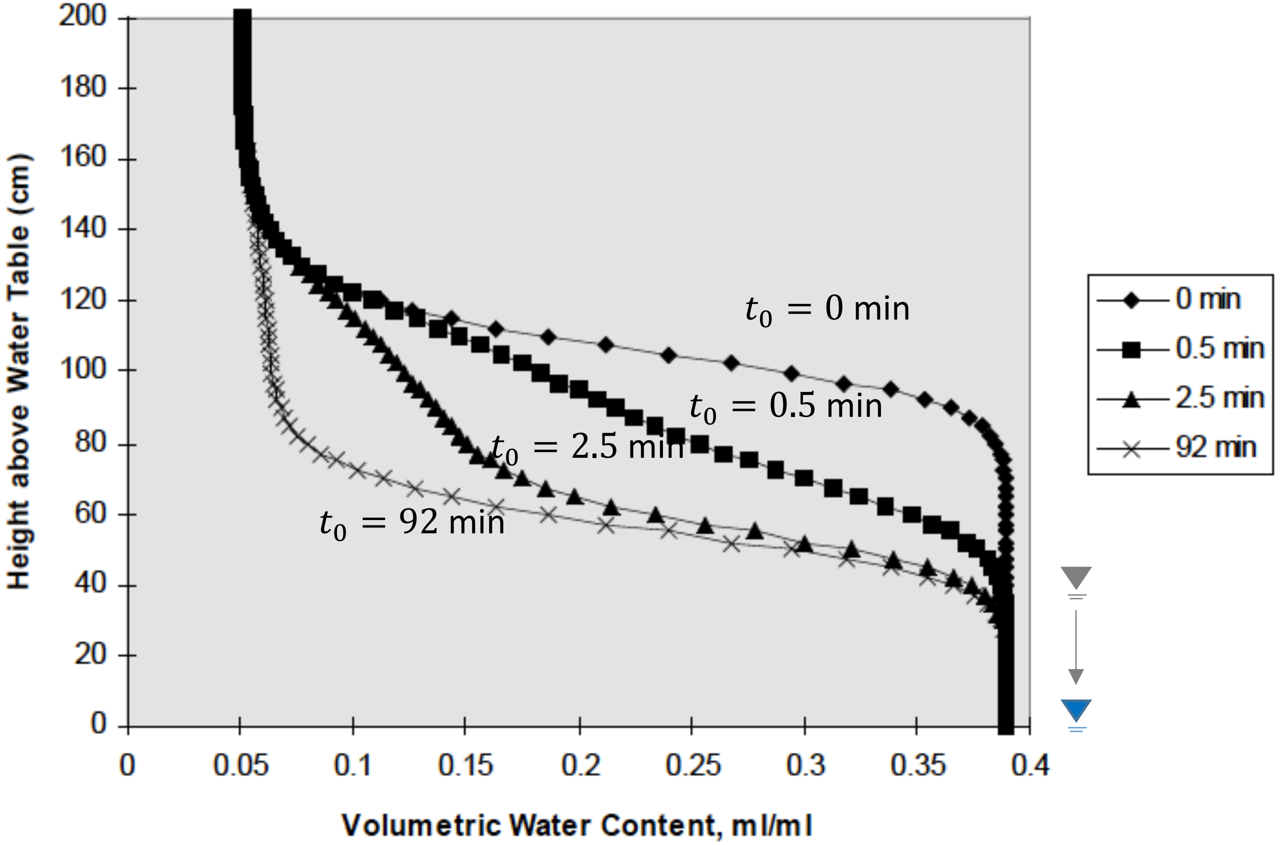

t = 0
t = 0.1 d
t = 0.2 d
t = 0.4 d
t = 0.6 d
t = 0.8 d
t = 1.0 d
t = 1.2 d
t = 1.5 d
t = 2.0 d
Loam
Sand
Clay
Sand
z (m)
x (m)
0.00
0.25
0.50
0.75
1.00
S_w (-)
0.9
0.8
0.7
0.6
0.5
S_w (-)
0.4
0.3
0.2

h


t = 0
t = 0.1 d
t = 0.2 d
t = 0.4 d
t = 0.6 d
t = 0.8 d
t = 1.0 d
t = 1.2 d
t = 1.5 d
t = 2.0 d
Loam
Sand
Clay
Sand
z (m)
x (m)
0.00
0.25
0.50
0.75
1.00
h (cm)
-40
-60
-80
-100

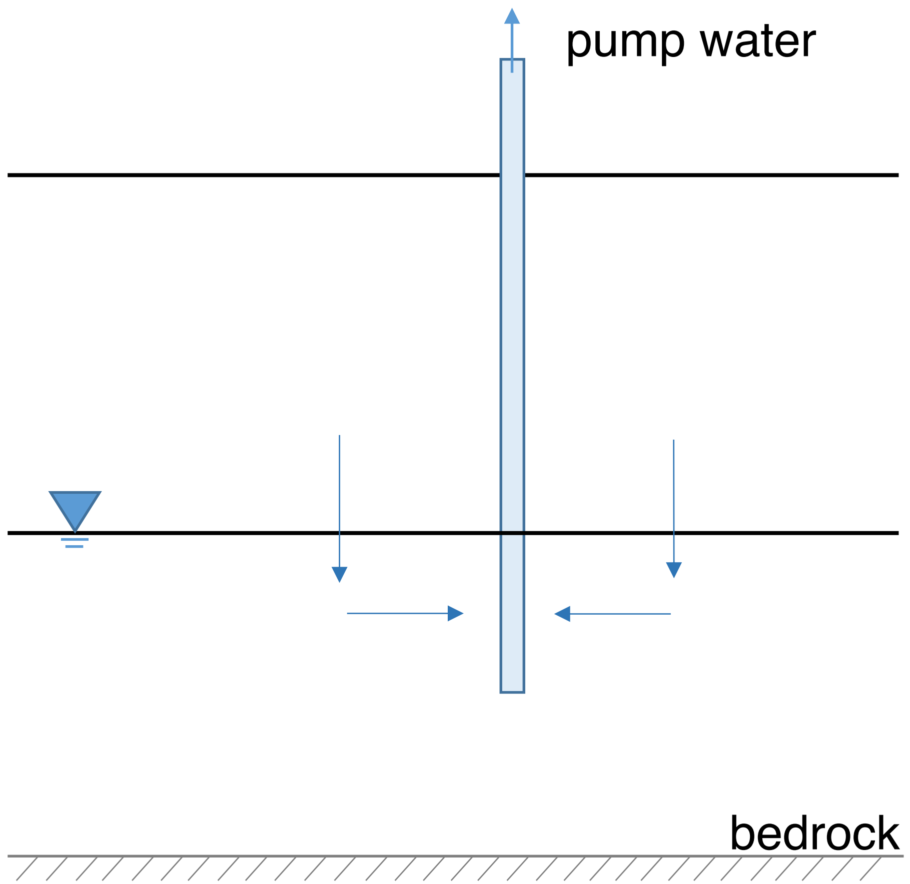
Delayed Drainage

1-D delayed drainage modeling for Borden aquifer parameters

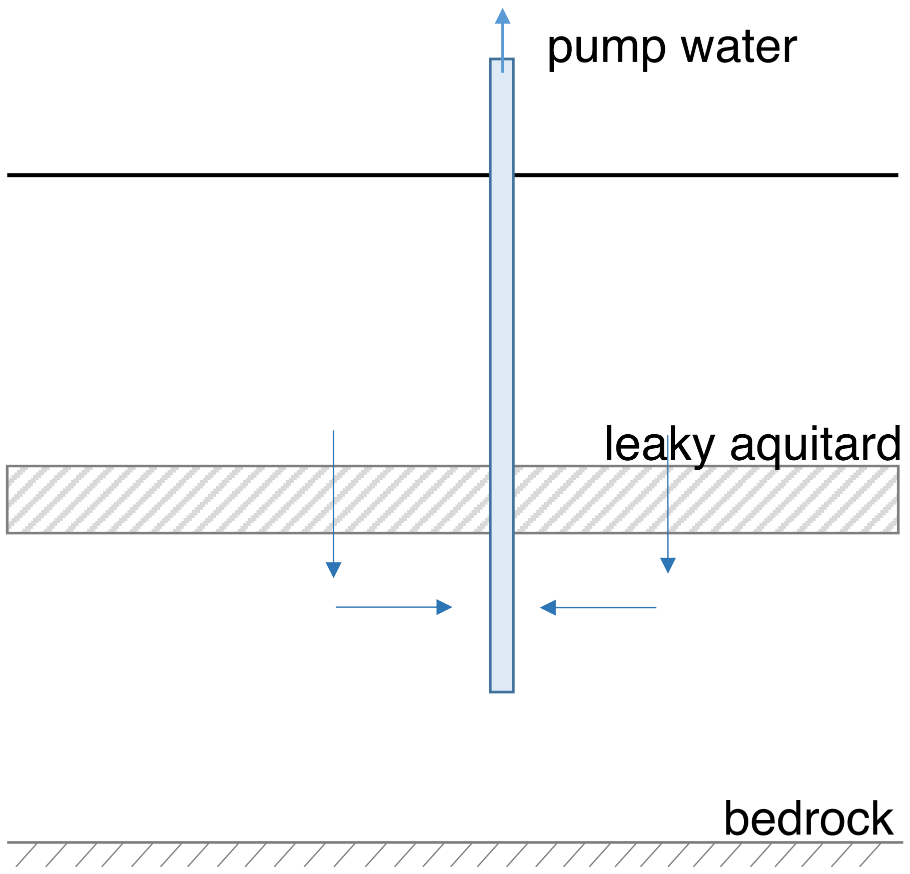


There is a time scale involved for unsaturated water to respond to change in water table

Pumping Tests: Unconfined Aquifers

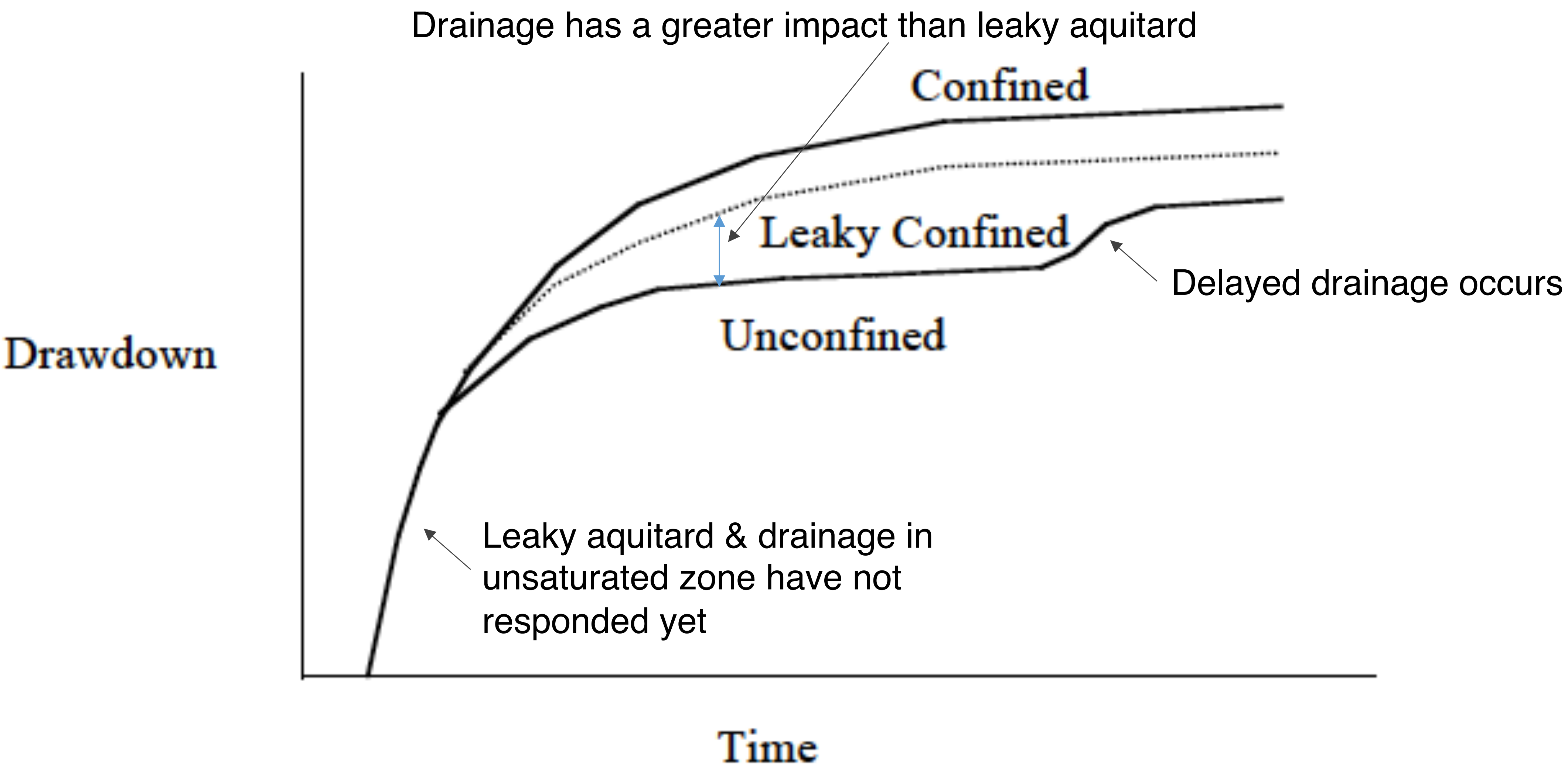


Unconfined aquifer



Confined aquifer w/ leaky aquitard

Pumping Tests: Unconfined Aquifers



Preferential flow

Preferential flow: Significantly greater than average downward movement of water through part of the soil during an infiltration or drainage event.

Three types of preferential flow: Macropore flow, funnel flow, and unstable flow.

Macropore flow

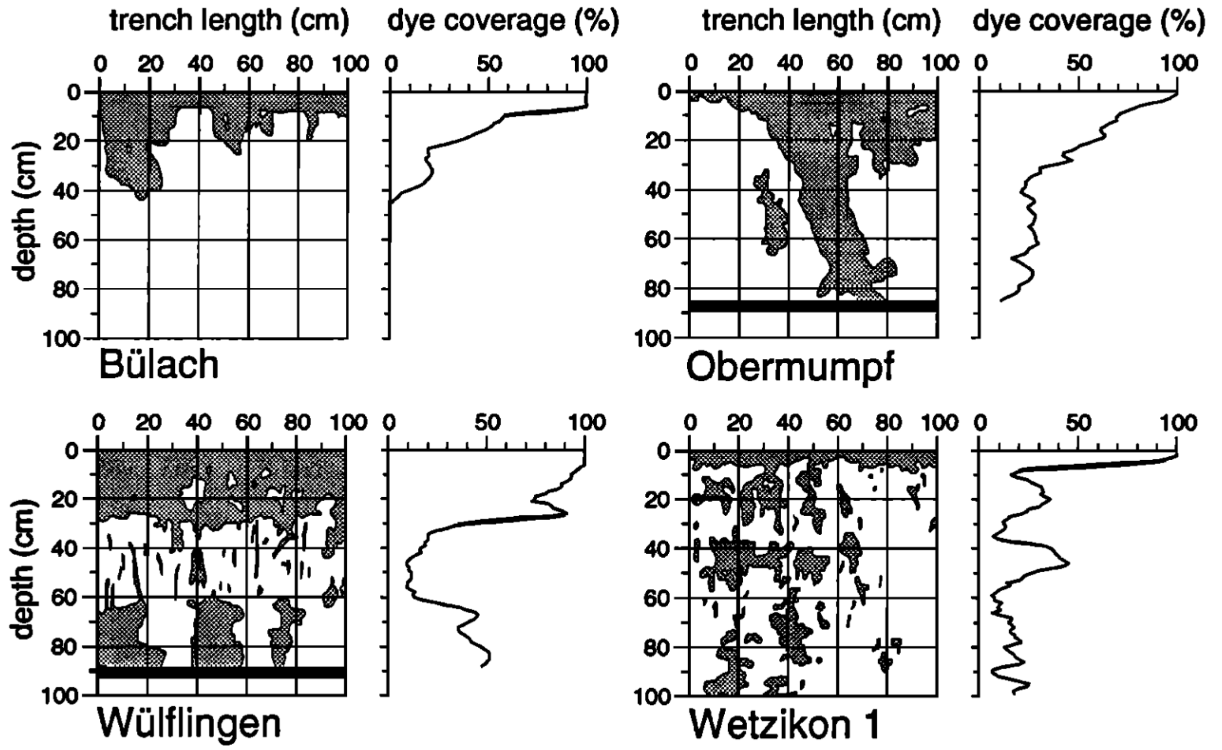


Figure 2. Vertical flow patterns of Brilliant Blue FCF and one-dimensional profiles of dye coverage after sprinkling application of 40-mm colored water in four different soils. These examples represent "wet" initial conditions. The solid bar at Obermumpf and Wülflingen indicates the maximum depth of excavation.

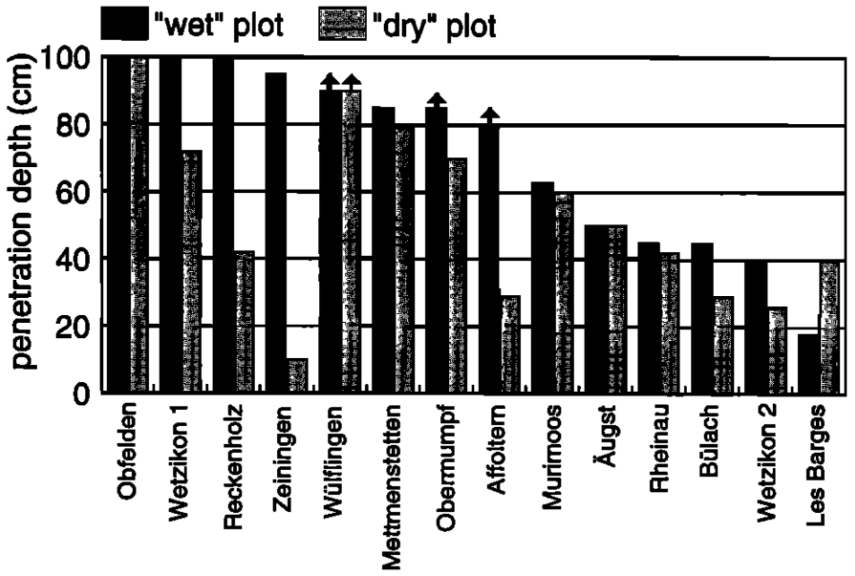
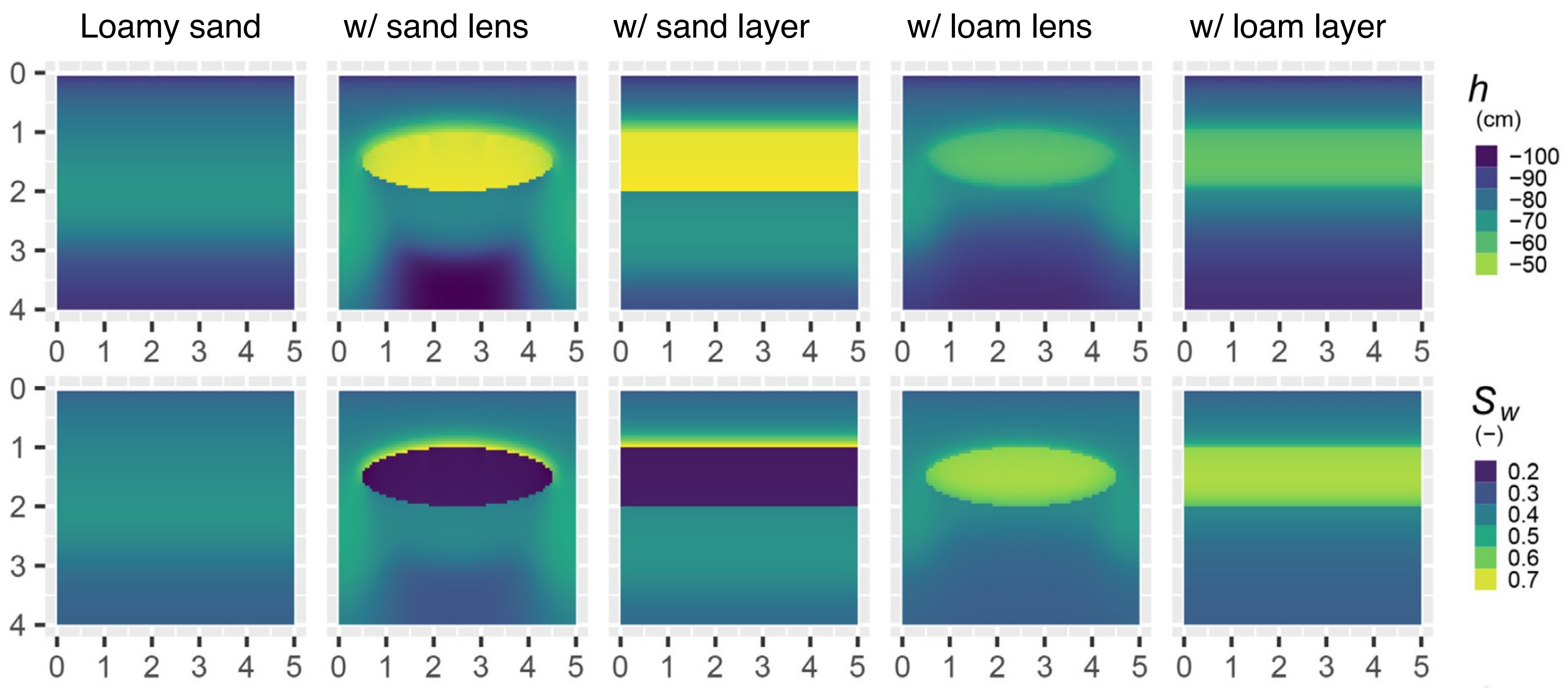


Figure 5. Maximum depth of percolation of Brilliant Blue FCF in the different soils. The sites are ranked according to the percolation depth of the "wet" plot. Big stones or erratic boulders hindered deeper excavation at the Wülflingen, Obermumpf, and Affoltern sites. However, it was expected that the dye had moved deeper than the maximum excavation depth at these sites, as indicated by the arrows.

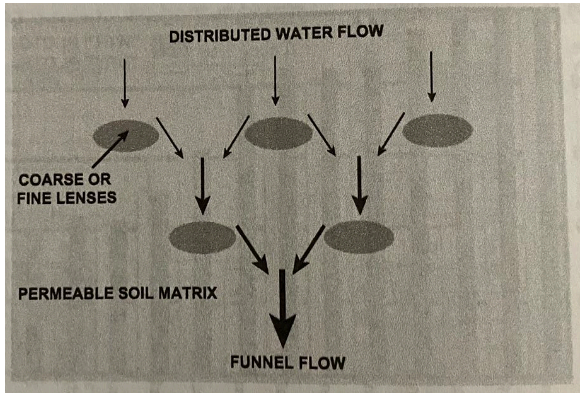
Flury et al., 1994

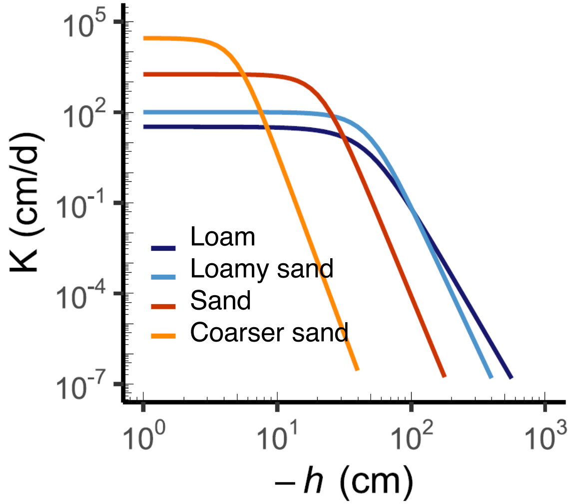
- 4 cm of water infiltration
- Channeling at various degrees observed for structured soils (moderate to extreme)
- For a uniform water content $\theta = 0.25$. Penetration should be 16 cm for 4 cm of water infiltration

Funnel flow



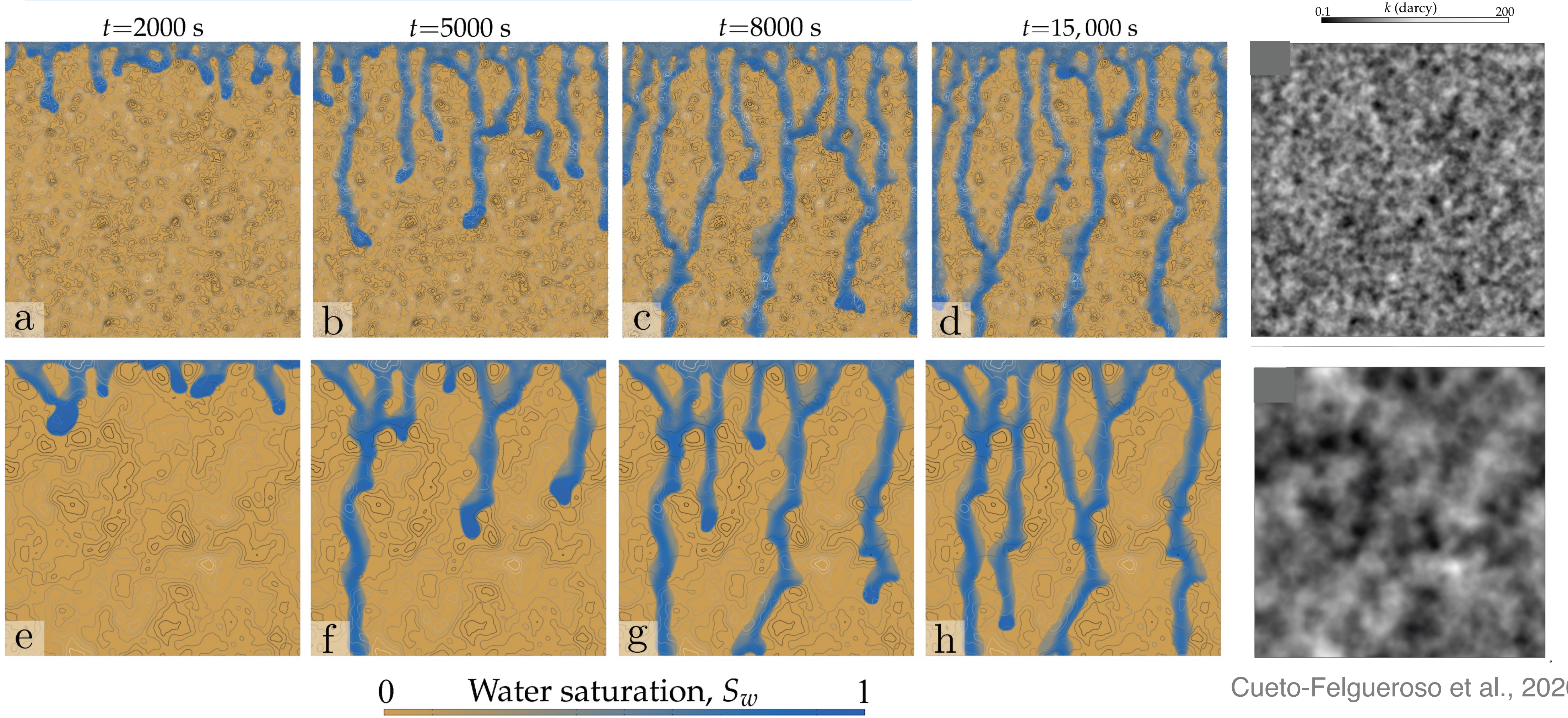
Zeng & Guo, 2021





- Both sand and loam act as a barrier for water flow in loamy sand, but the mechanisms are different.
- Sand acting as a barrier generates preferential flow on the side (the so-called “funnel flow”; Kung (1990)). See Chapter 4 of Jury & Horton.

Unstable flow



Cueto-Felgueroso et al., 2020

- Unstable flow is distinct from other forms of preferential flow. It is a flow phenomenon whose extreme flow location is not a consequence of permeability variations in the porous medium.