HWRS 505: Vadose Zone Hydrology

Lecture 13

10/3/2023

Today: 1D transient unsaturated flow
Reading: Jury & Horton, Soil physics, Chapters 3 & 4; Pinder & Celia, Chapter 11

Review of Lecture 12

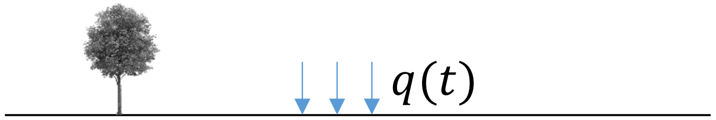
Comment on the 1D steady-state spreadsheet model

- The problems are significantly simplified because q is constant in space.
- This simplification then allows us to figure out how unsat K and $\frac{\mathrm{d}H}{\mathrm{d}z}$ or $\frac{\mathrm{d}H}{\mathrm{d}x}$ change in space.
- The scenarios are mostly synthetic, but they are useful to help us build physical intuition about unsat flow.

Transient Unsaturated Flow

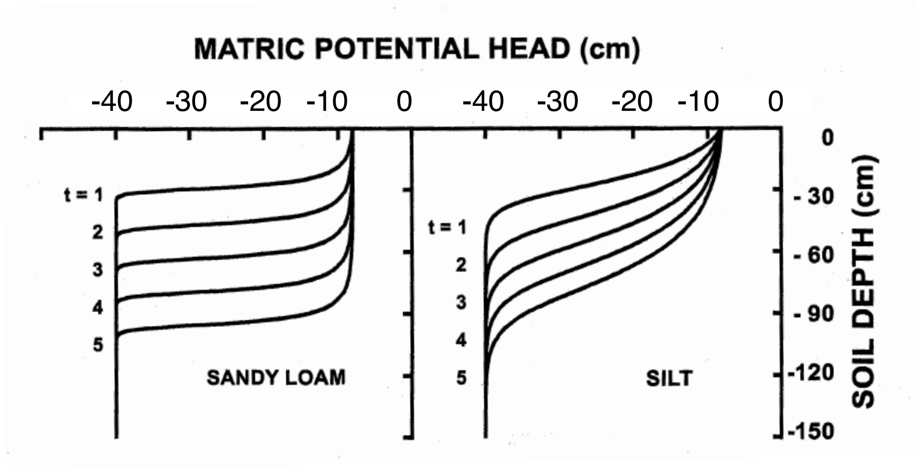
Infiltration at constant potential

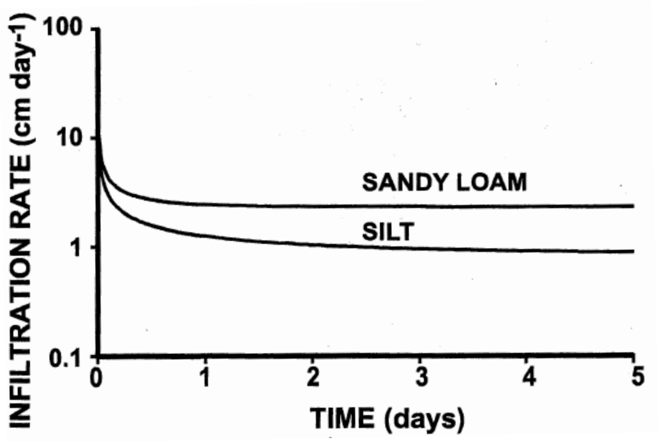
- ➢ How does the wetting front march downward?
- ➢ How does the infiltration rate q change over time?



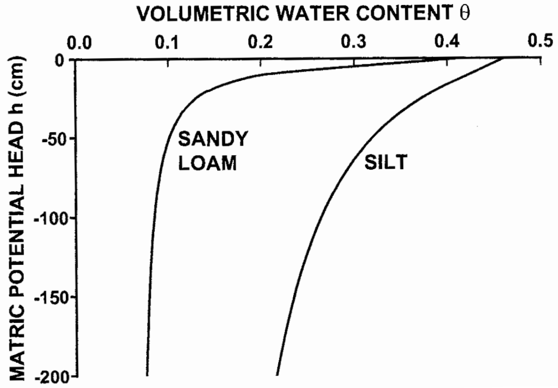
Boundary conditions:
$$h(0,t) = h_0 \ (= -8 \text{ cm})$$
$$h(-\infty,t) = h_i (= -40 \text{ cm})$$

Initial condition: $h(z,0) = h_i (= -40 \text{ cm})$



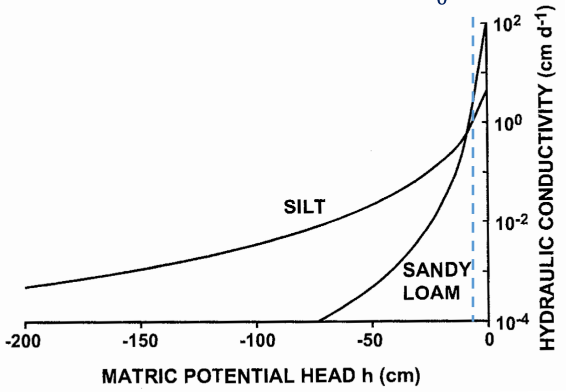


- Transition between the wet and dry zones: abrupt and narrow for sandy loam, gradual for silt.
- In both cases, wetting front moves faster at the beginning and then slows down to a more constant speed.
- Except for the beginning, the wetting front shape does not change as it moves downward.
- Infiltration rate is high at early times (capillary + gravity) and then becomes almost constant at later times (gravity only).



$K_{\text{Sandy Loam}} > K_{\text{silt}}$

$h_0 = -8$



Use the SWC and $K(h)$ to explain the above results?

Transient Unsaturated Flow

Upward flow from a water table

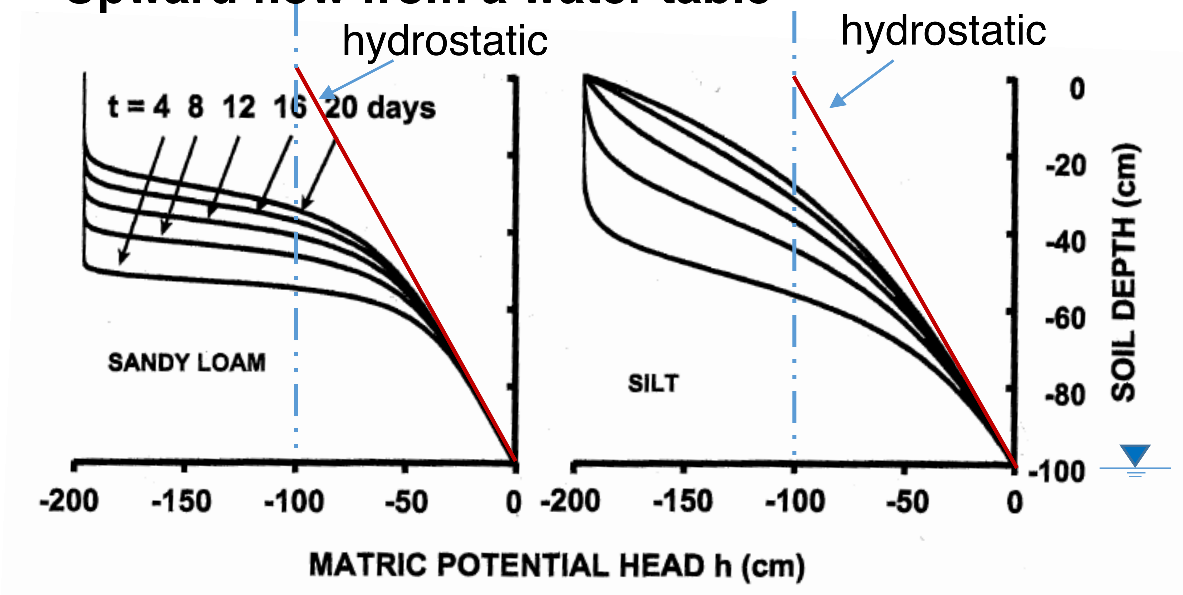
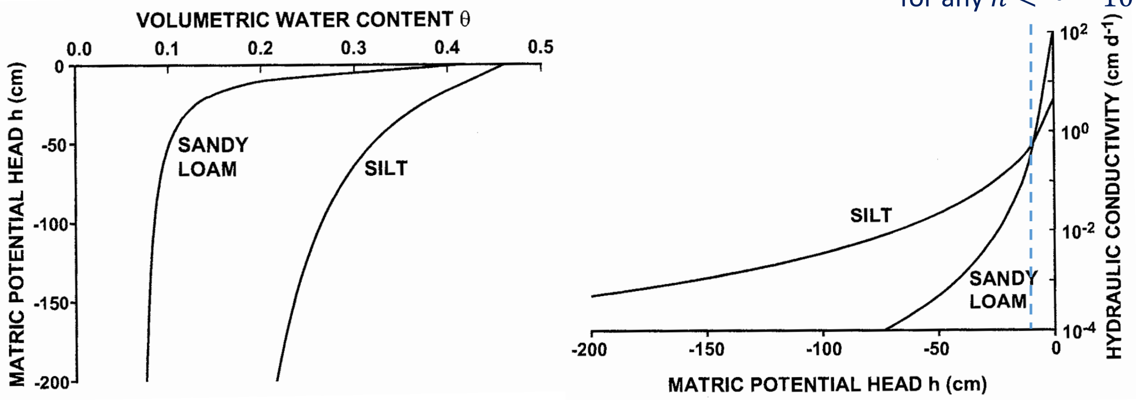


Figure 3.19 Matric potential profiles during upward flow from a water table in a sandy loam and a silt soil, each with $h_i = -200$ cm, $h(-100) = 0$, and $h(0) = -200$ cm.

- Water moves faster upward in the silt than in the sandy loam.
- Final evaporation rate at long times: 0.076 cm/day for the silt, 0.0066 cm/day for the sandy loam. => Finer-textured soils can move water upward more easily than coarse-texture soils.

$K_{\text{Sandy Loam}} < K_{\text{silt}}$

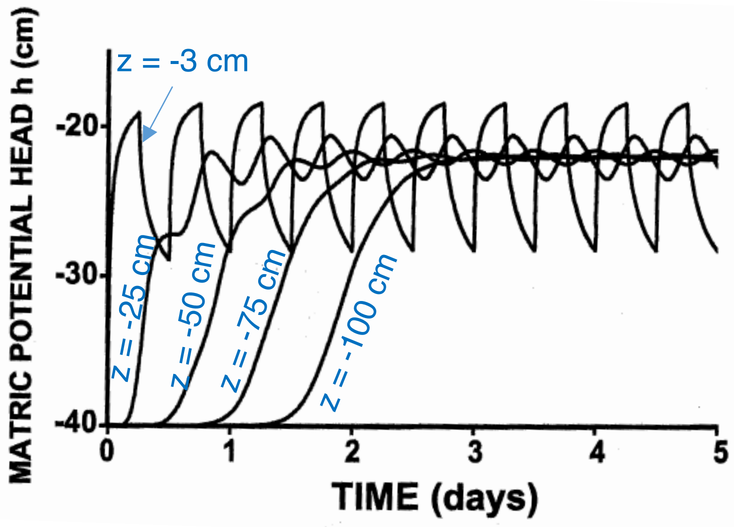
for any $h < \sim -10$ cm



Use the SWC and $K(h)$ to explain the above results?

Transient Unsaturated Horizontal Flow

Infiltration-evaporation cycles



Initial condition:
$h_i = -40$ cm

Matric potential versus time at z = -3, -25, -50, -75, -100 cm for the sandy loam soil when the surface flux is cycled every 12 h between -3 cm/day (infiltration) and 0.5 cm/day (evaporation)

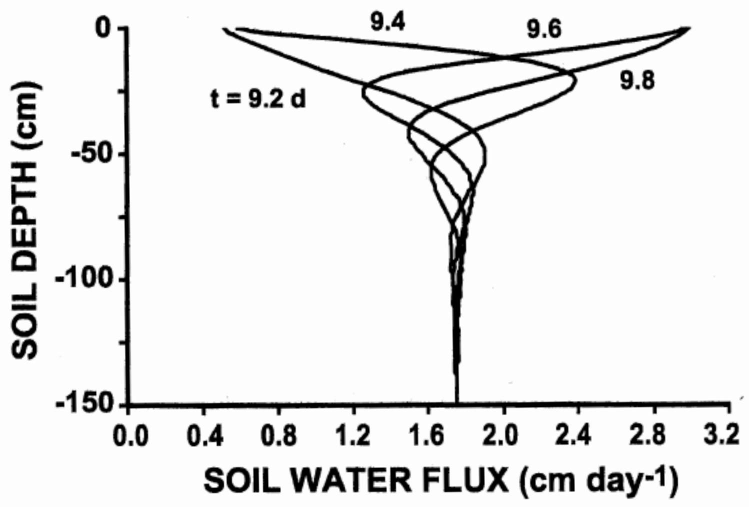


Figure 3.21 Water flux versus depth over a 1-day interval for the sandy loam soil under the conditions described in Fig. 3.20.

- The matrix potential fluctuations are large near the surface, but attenuate greatly with depth.
- Flux becomes essentially constant below 75 cm.
- The shorter the period of the cycle, the less the depth of penetration.

Field Water Content and Matrix Potential Profiles

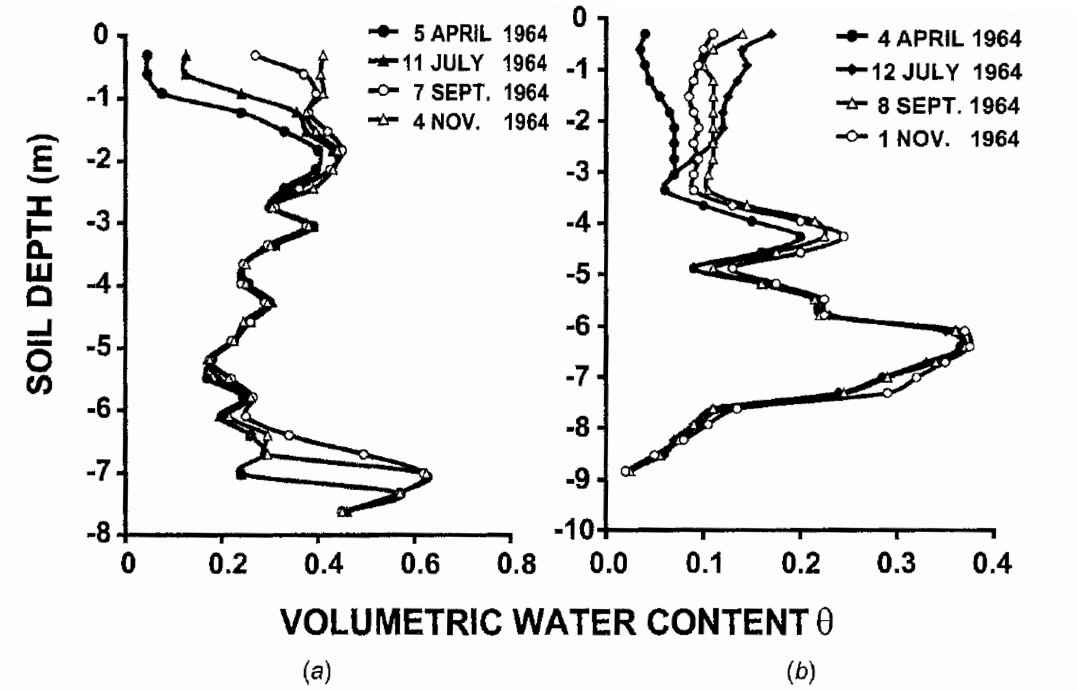


Figure 4.1 Soil water content profiles at various times during the year: (*a*) Young sand, Mount Gambier forest; (*b*) Kalangadoo sand, Penola forest. (After Holmes and Colville, 1970.)

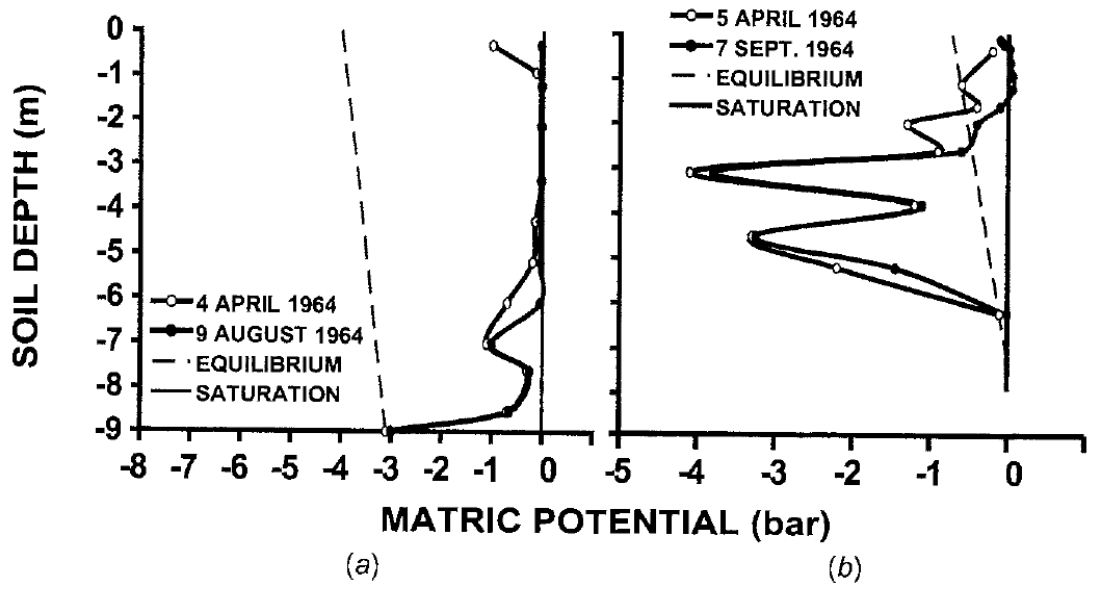


Figure 4.2 Matric potential profiles for the wettest and driest times of sampling for the sites in Fig. 4.1: (*a*) Young sand, Mount Gambier forest; (*b*) Kalangadoo sand, Penola forest. (After Holmes and Colville, 1970.)

- Fig. 4.1: Fluctuations in soil water content in response to rainfall and evaporation are very pronounced near the land surface, but diminish significantly at depths.
- Fig. 4.2: It provides an equilibrium analysis to identify water flow directions and some history of wetting and drying cycles.