WATER FLOW IN UNSATURATED SOIL - Vertical Down

The Stages in Transient Water Flow (Rao, 1992):

1. INFILTRATION:

- Water input at the soil surface (e.g., rainfall, irrigation, ponding).
- Water intake rate (infiltration rate) is controlled by the method and rate of water application and by the antecedent soil-water conditions. Runoff initiated when application exceeds intake rate.
- In early stages of infiltration, application rate controls intake rate, but in later stages soil hydraulic properties are important.

2. REDISTRIBUTION:

- Exponentially decreasing flux until unit hydraulic gradient is acheived (i.e., gravitational forces).
- This stage may last only a few hours in sandy soils but may prolong for several days in loamy soils, and for several weeks in clayey soils.

3. STATIC:

- Soil-water content is at “field capacity” value, and the soil-water flux is essentially zero.
- Water flow and losses are primarily the result of evaporation, plant root uptake.
- Presence of shallow water table or impeding layers has a dominant effect on when and if this stage is reached.

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GOVERNING EQUATIONS:

- General form:

$$\frac{\partial \theta}{\partial t} = -\frac{\partial q_z}{\partial z}$$

Assumptions:
- r , *n are constant*
- *1-D flow*

D *in water saturation with time* = D *water flow rate with space (depth)*

- Expanded form:

$$\frac{\partial \theta}{\partial t} = C(\Psi)\frac{\partial \Psi}{\partial t} = \frac{\partial}{\partial z}\left(K(\Psi)\left[\frac{\partial \Psi}{\partial z} + 1\right]\right)$$

Specific soil-water capacity, or $\frac{\partial \theta}{\partial \Psi}$ ***NONLINEAR***

D *pressure head with time*

Unsaturated Hydraulic Conductivity ***NONLINEAR***

Pressure head gradient

Gravitational gradient

- Water capacity relationship, $\theta(\Psi)$

$$\frac{\theta - \theta_r}{\theta_{sat} - \theta_r} = \left(\frac{\Psi_d}{\Psi}\right)^{\lambda}; \Psi < \Psi_d, \quad \text{and} \quad \theta = \theta_{sat}; \Psi > \Psi_d$$

Brooks-Corey Model

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What do we really want to know?

- Rate that mass of contaminant is delivered to the water table.
  - Basically, $q_z(z,t)$ and $\theta(z,t)$ [water flux and water content as function of space and time] to put into contaminant transport equations.
- Relationship between P (precipitation rate) and I (infiltration rate).

Lets examine the infiltration/redistribution process:

Important points:

<u>Static case</u>:

$\theta(z) = \theta(\psi)$ when $z = 0$ at the water table.
No flow: $\partial h/\partial z = 0$, $K(\psi) \to 0$

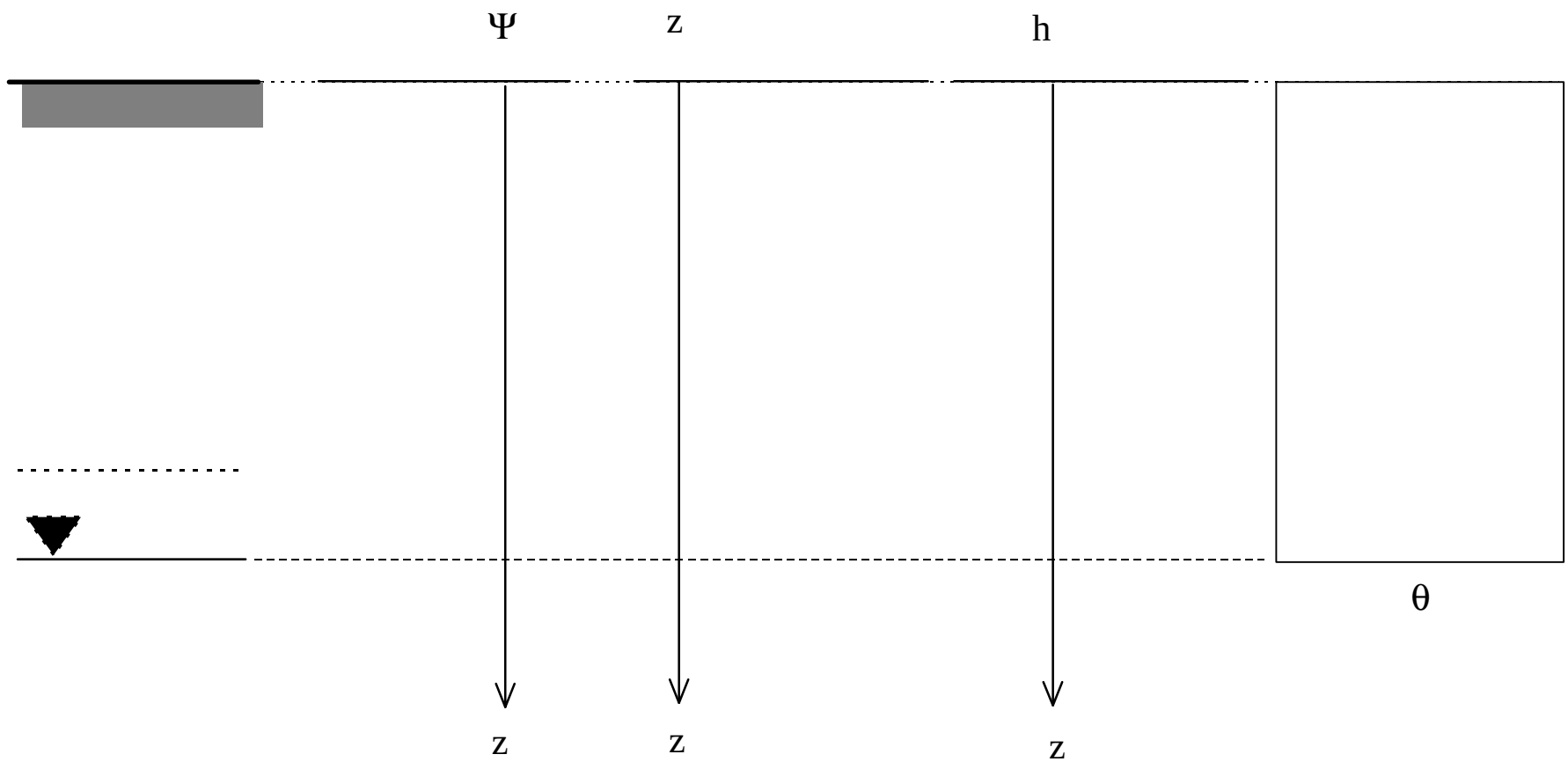
<u>Infiltration:</u>

Initially $\partial\psi/\partial z$ is very large: what limits q_z?
Later, $\partial\psi/\partial z \to 0$, what limits q_z?
What is the rate of advance of the water front?
What is the velocity of a solute traveling in the water?

<u>Redistribution:</u>

$\partial\psi/\partial z$ continues to $\to 0$.
θ decreases, so does $K(\theta)$.
Gravity gradient controls flux, but $K < K_{sat}$.

What is the long term water flux to the water table?
Why might this be inadequate?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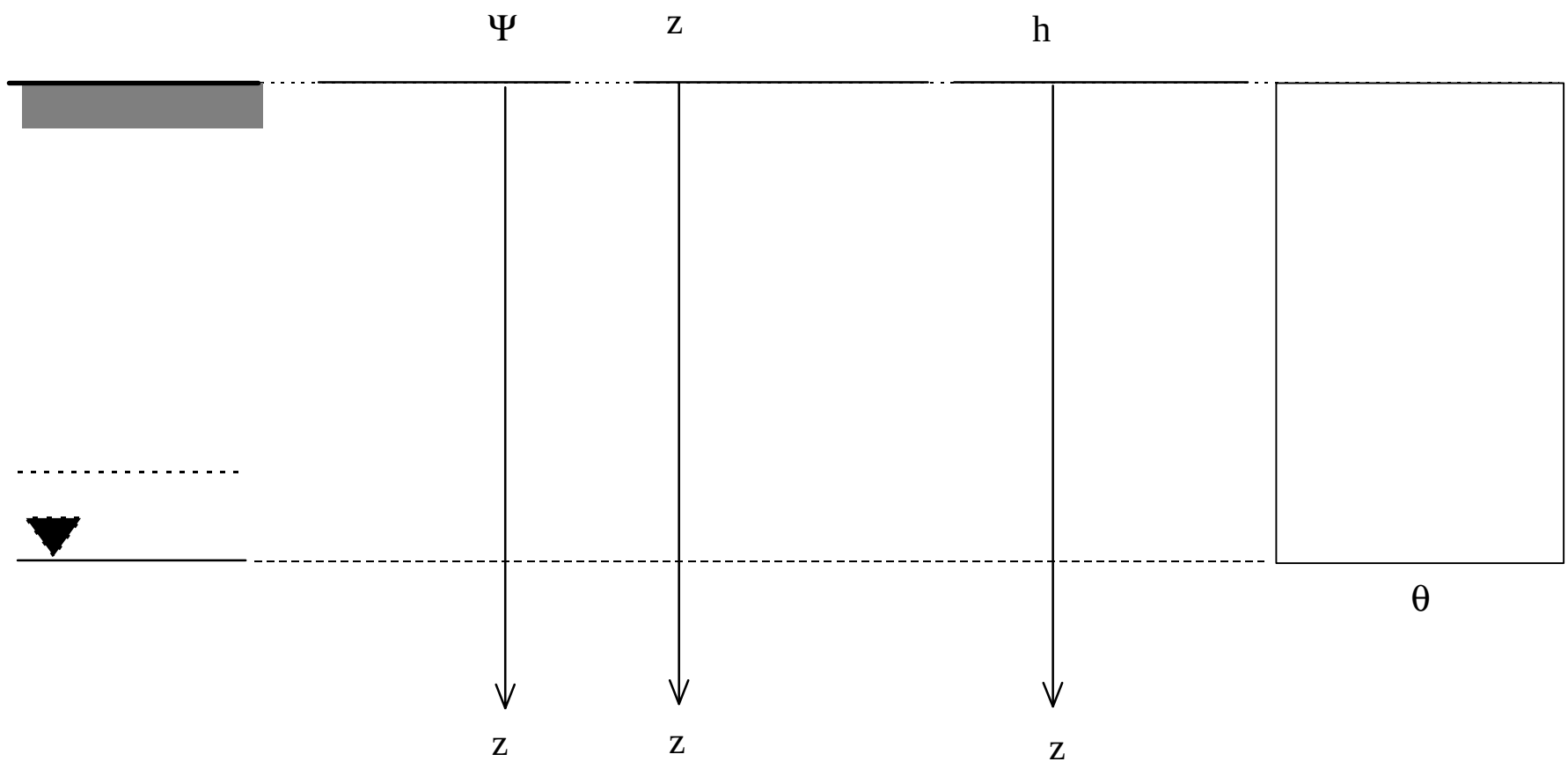
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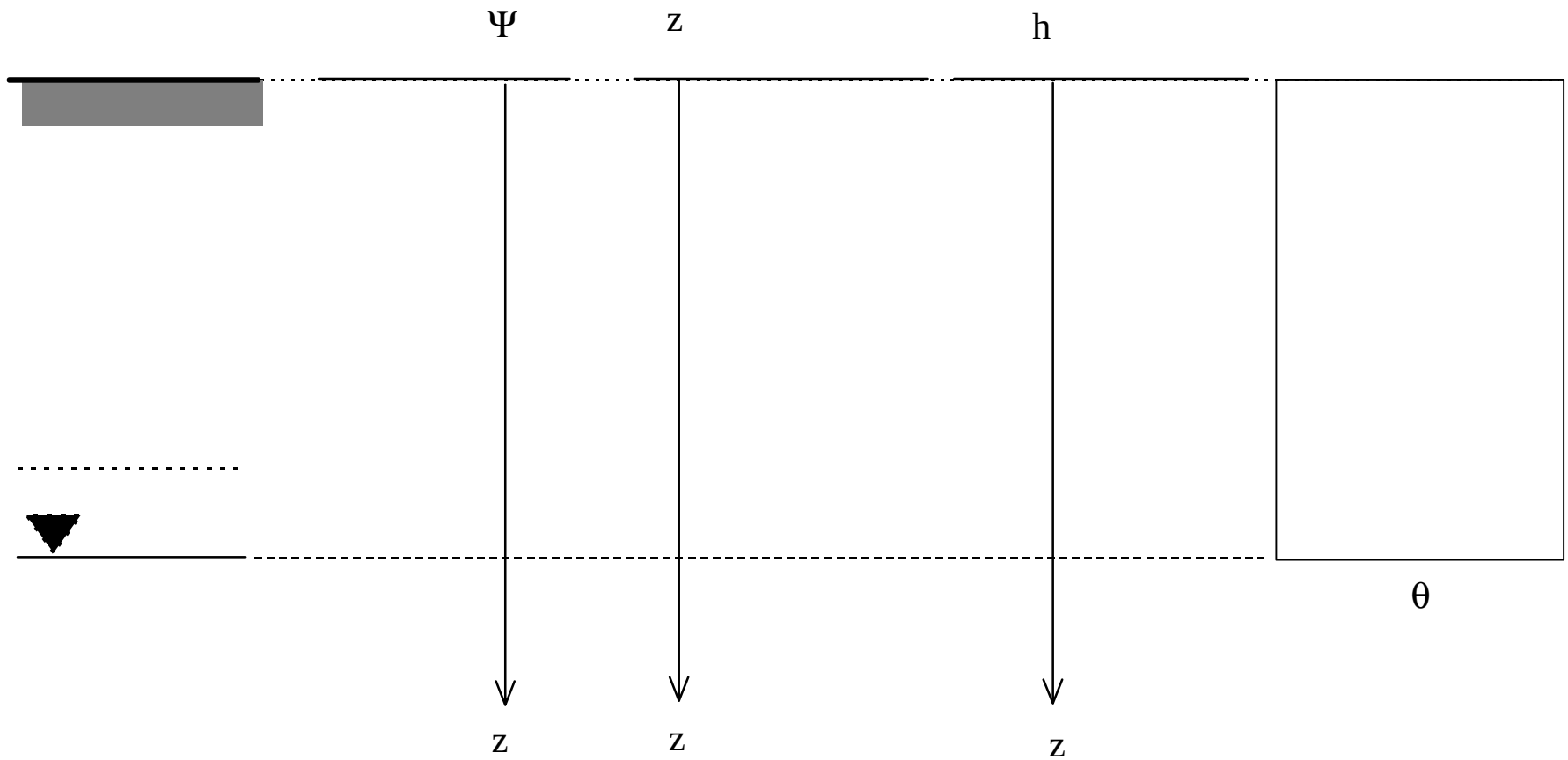
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