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Methods for Measuring Hydraulic Conductivity

OUTLINE

- Hydraulic Conductivity
  - Definition
  - Importance
- Methods
  - Saturated Hydraulic Conductivity
  - Unsaturated Hydraulic Conductivity
- Applications

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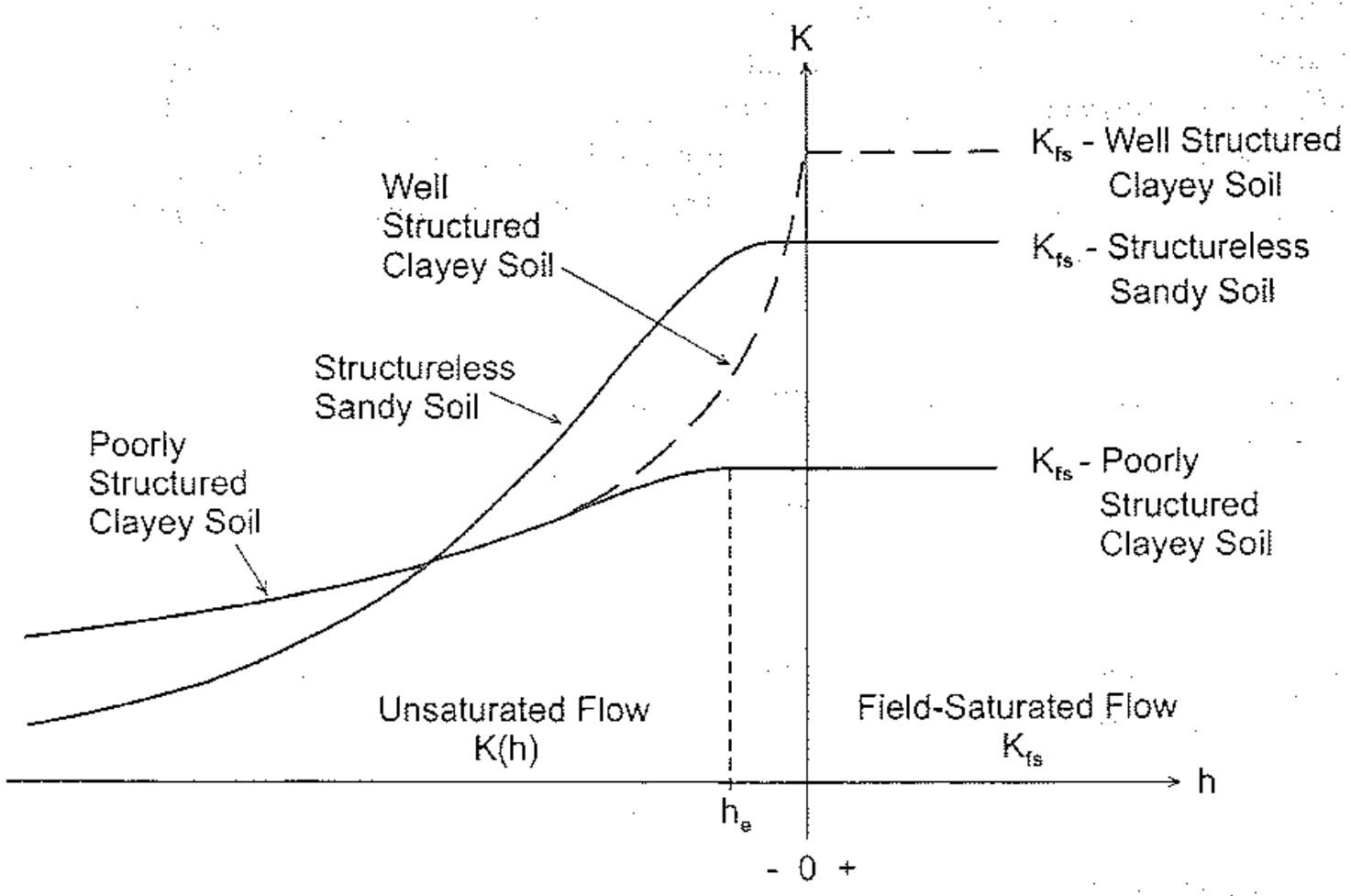
Definition

- What is Hydraulic Conductivity:
  - Ability of a porous medium to transmit water under saturated or nearly saturated conditions
- Dependent on:
  - Size distribution, roughness, tortuosity, shape and degree of interconnection of water-conducting pores

Hydraulic Conductivity Curve



Importance

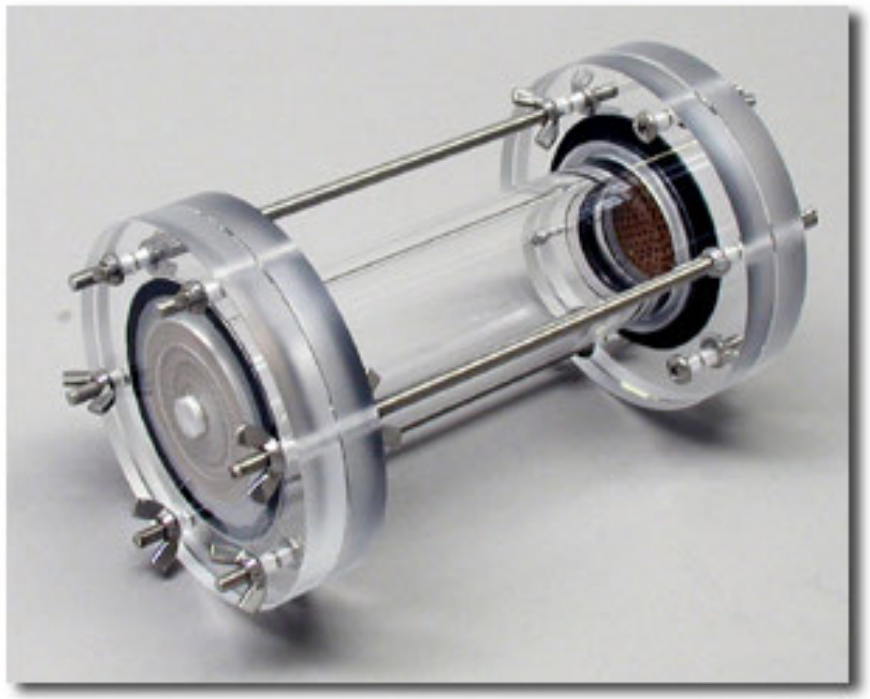
- Why do we care?
  - Hydrology Modeling
  - Agricultural decisions
  - Landfill Cover efficacy
  - Geotechnical design

METHODS

Methods – Saturated Hydraulic Conductivity (K_s or K_{fs})

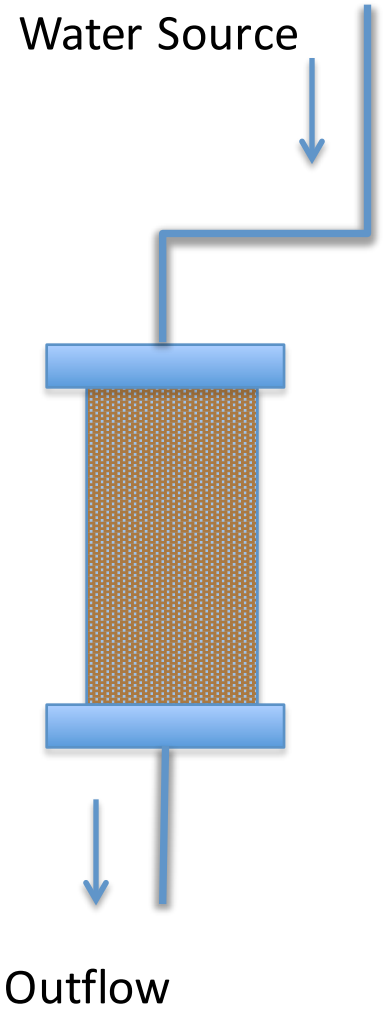
- Laboratory (K_s)
  - Flow Cells
  - KSAT
- Field (K_{fs})
  - Ring Infiltrometers
  - Borehole Permeameters
  - Pressure Infiltrometers

Flow Cells



- Constant & Falling head technique
- Measurement of Soil Cores in Lab
- Undisturbed or Disturbed samples

Flow Cells – How they work



- Water Passes through Saturated Soil Core
- Steady State flow rate is measured
- Calculations correct for pressure head

Flow Cells – Pros & Cons

Advantages

- Simple calculations
- No corrections for 3-dimensional flow
- Separate different horizons
- Multiple samples can be stored
- Fairly easy setup

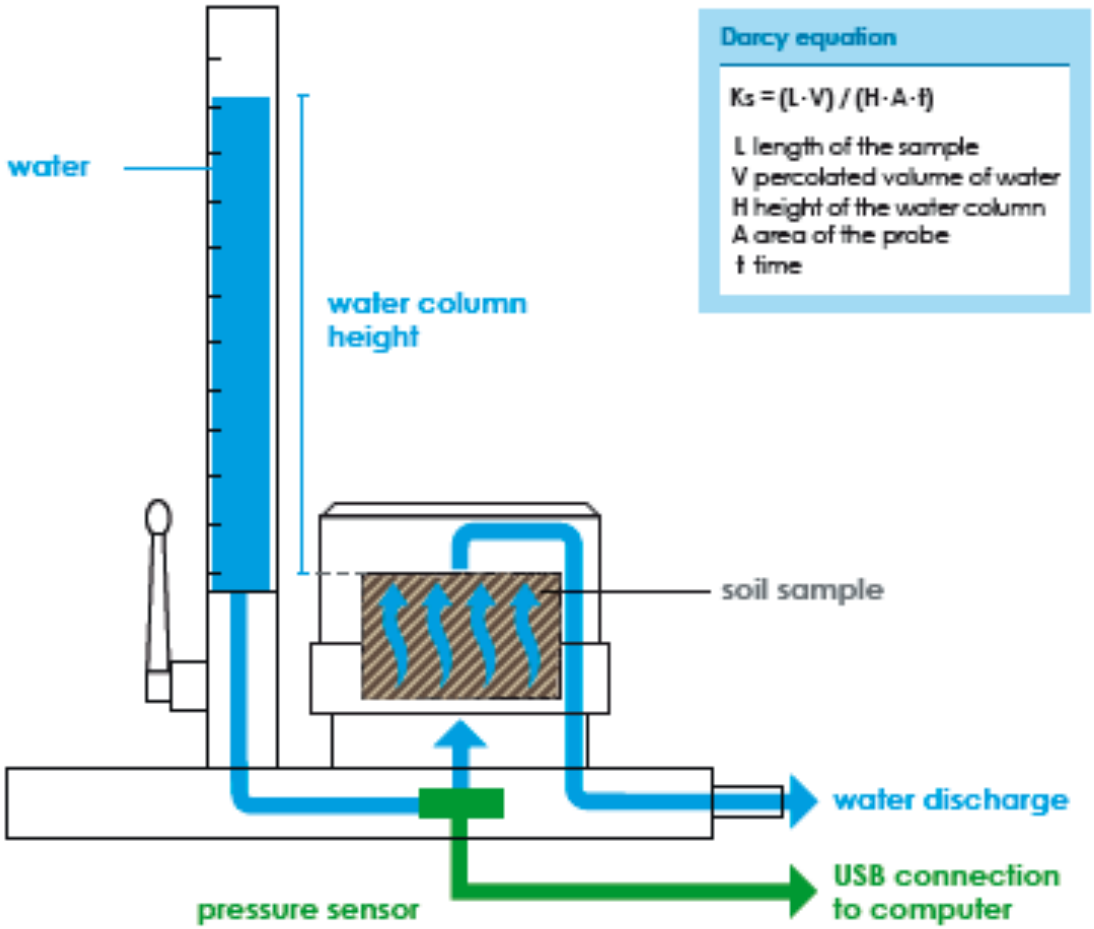
Disadvantages

- Expansive soils are confined
- Values may differ from field methods
- Requires additional equipment to automate
- Dedicated lab space
- Small surface area

UMS-KSat

- Same concept as flow cells
- Automation built into device
- Falling & Constant Head technique

KSat – How it works

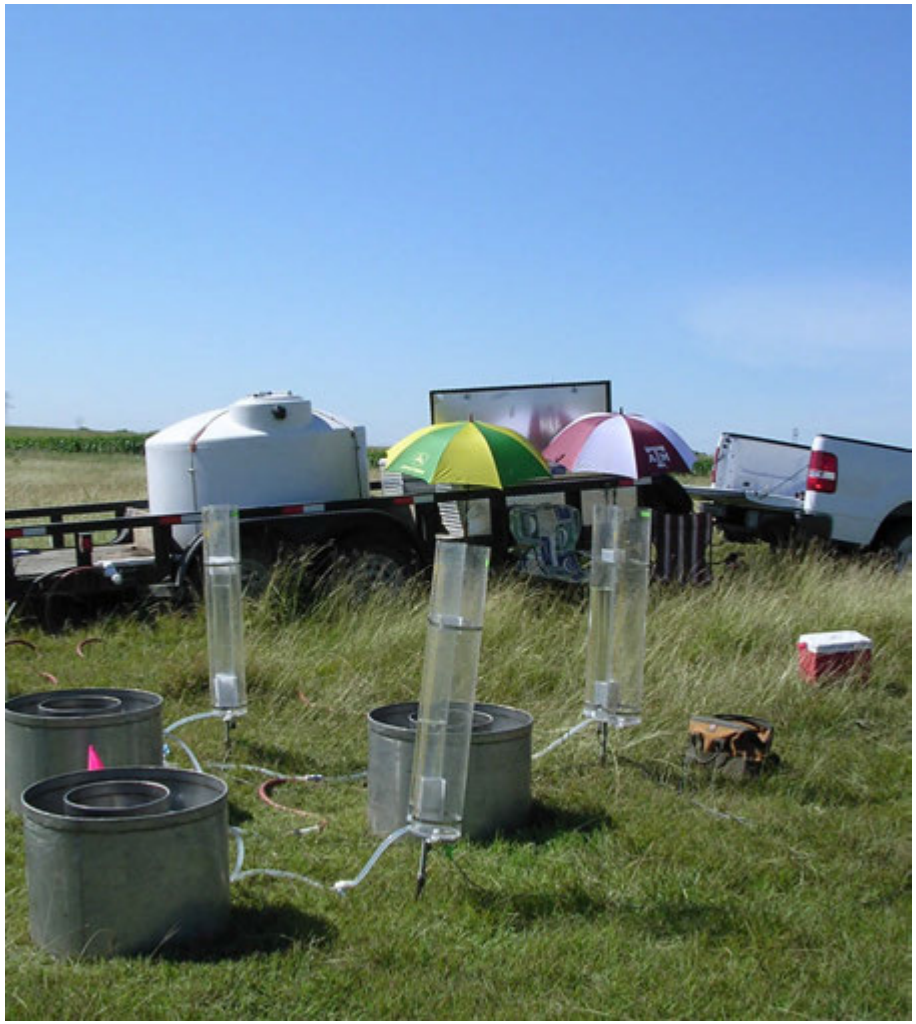


Darcy equation

$K_s = (L \cdot V) / (H \cdot A \cdot t)$

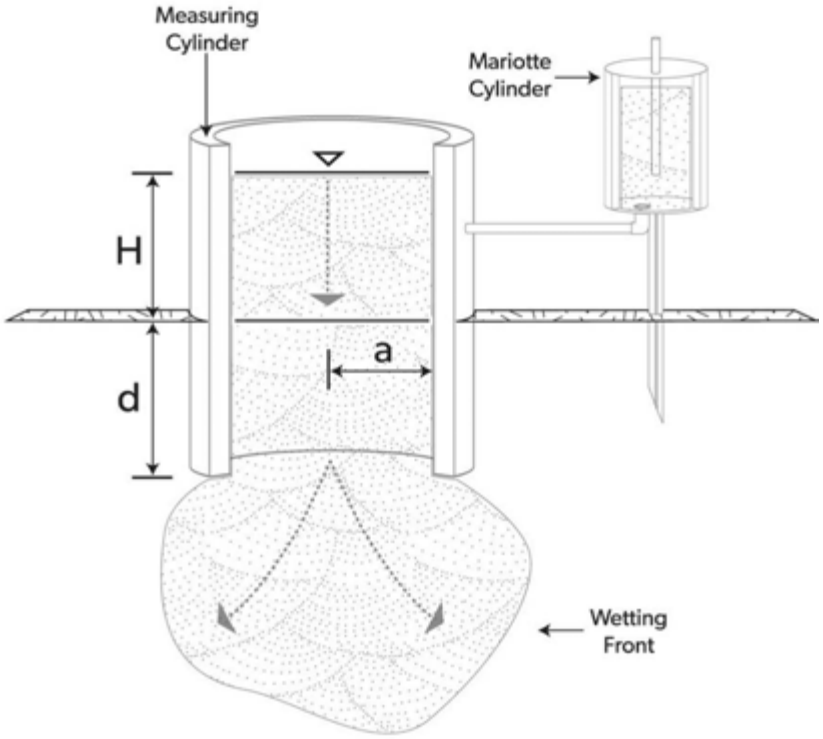
L length of the sample
V percolated volume of water
H height of the water column
A area of the probe
t time

Ring Infiltrometers



- Thin-walled open ended cylinders
- Various Cylinder Arrangements
- Constant- and falling-head techniques

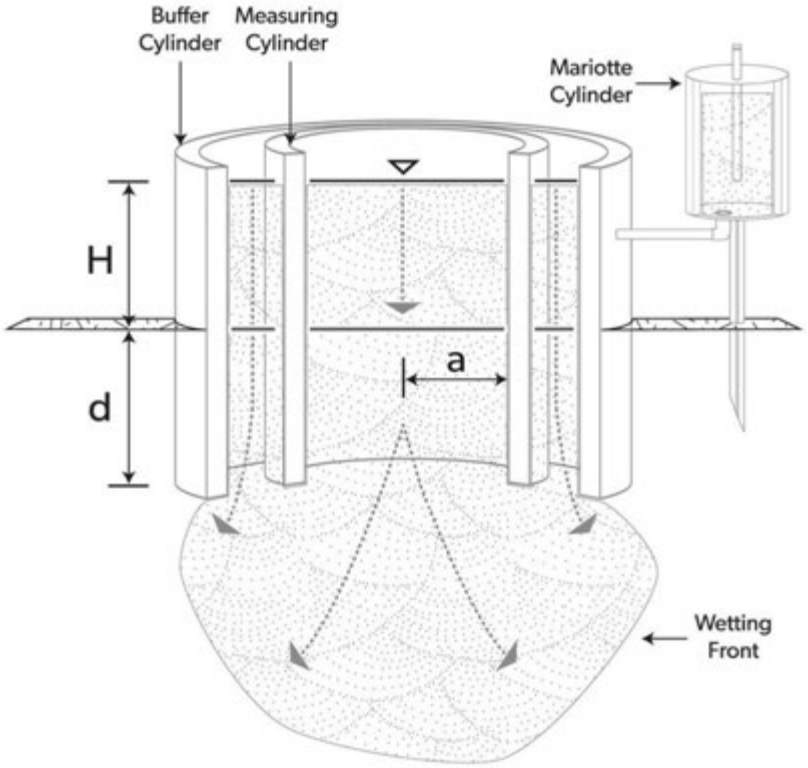
Single-Ring Infiltrometer



Single Ring Infiltrometer (Cross Section)

- Single measuring cylinder
- Diameters range from 10 to 50 cm
- Corrections are made for 3-dimensional flow

Double-Ring Infiltrometer



Double or Concentric Ring Infiltrometer (Cross Section)

- Single measuring cylinder placed inside larger buffer cylinder
- Intention of buffer cylinder is to prevent flow-divergence from measuring cylinder

Ring Infiltrometer – Pros & Cons

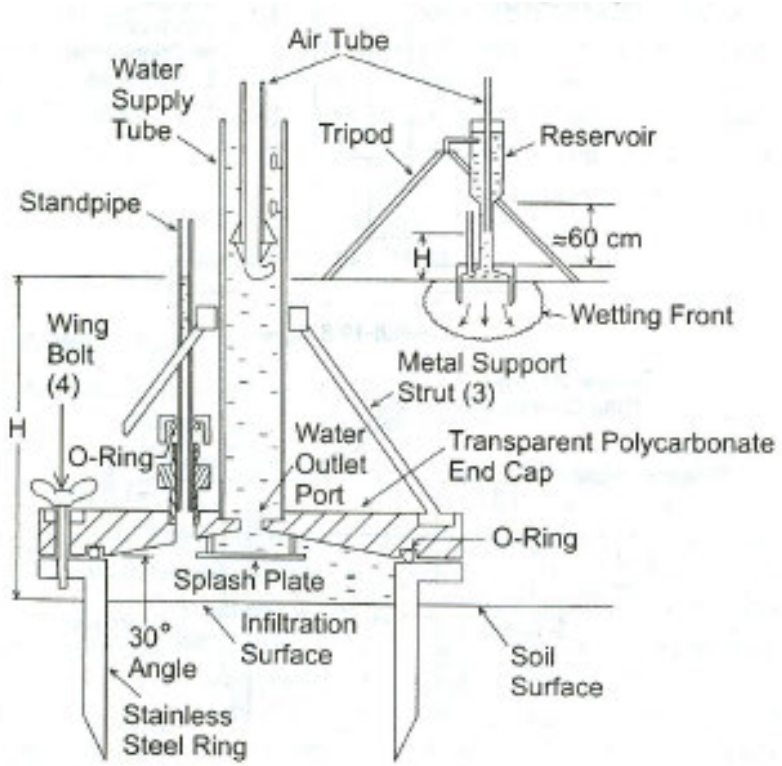
Advantages

- Larger rings encompass more spatial variability
- Results represent field conditions

Disadvantages

- Time consuming
- Requires estimation of soil properties (α) to correct for 3-dimensional flow
- Buffer cylinder often is not effective

Pressure Infiltrometer



- Similar to single-ring infiltrometer
- Analysis on Single or multiple heads
- Can also determine macroscopic capillary length parameter (α)

Pressure Infiltrometer – Pros & Cons

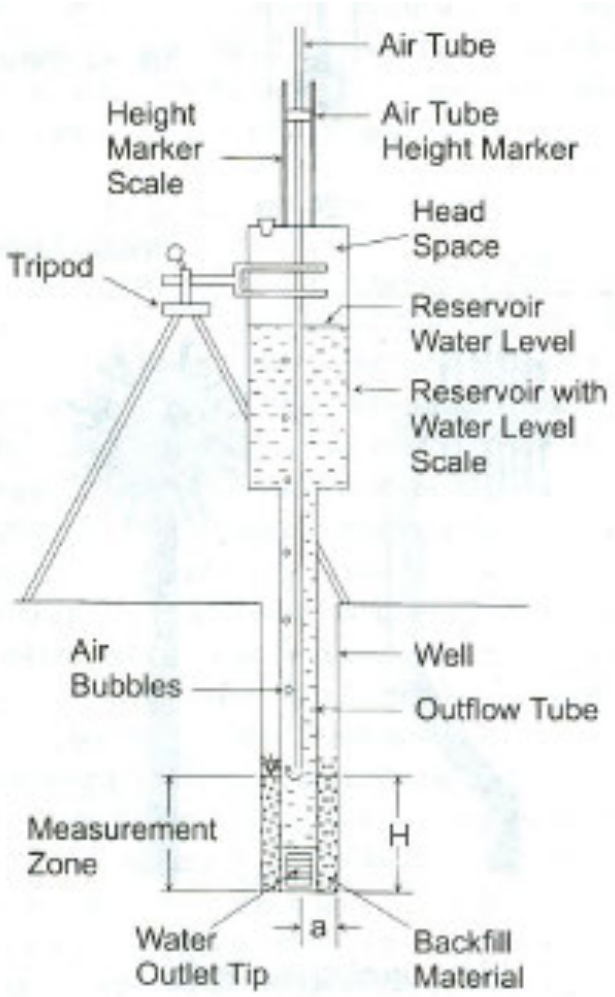
Advantages

- Measurement of (α) improves analysis of K_{fs}
- Can also be used to determine sorptivity and matric flux potential

Disadvantages

- More complex measurement apparatus
- Multiple-head technique requires more time

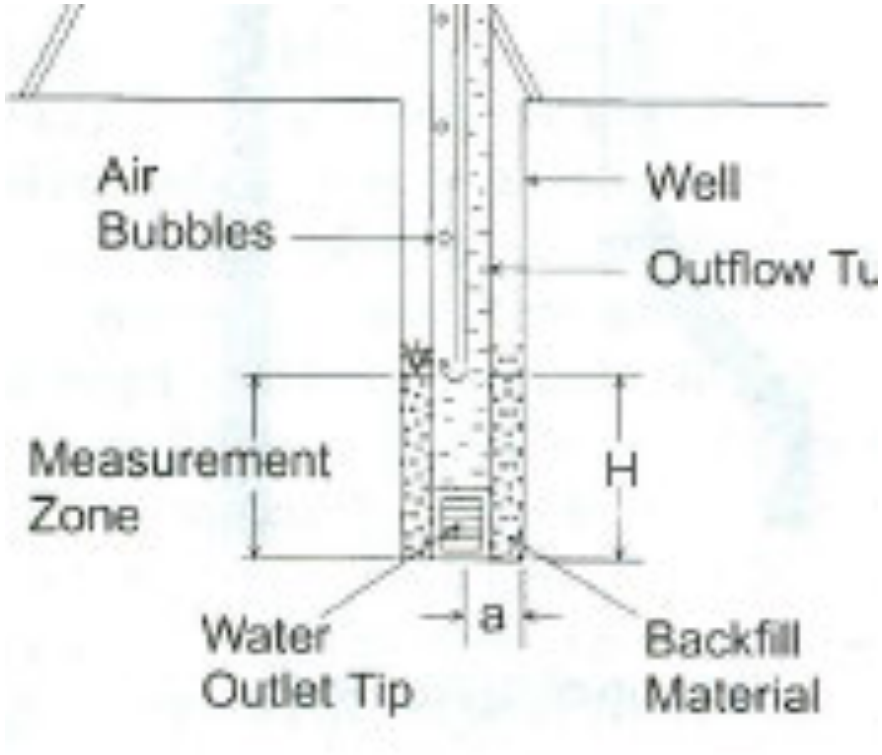
Borehole Permeameters



- Constant head method
- Several permeameter designs
- Single and Multiple Head analysis
- Can also determine α

Borehole Permeameters

- Well is augured to desired depth
- Permeameter is mounted over the well
- Marriotte bubbler maintains constant head



Borehole – Pros & Cons

Advantages

- Measurement of (α) improves analysis of K_{fs}
- Analysis of different soil layers
- Can also be used to determine sorptivity and matric flux potential

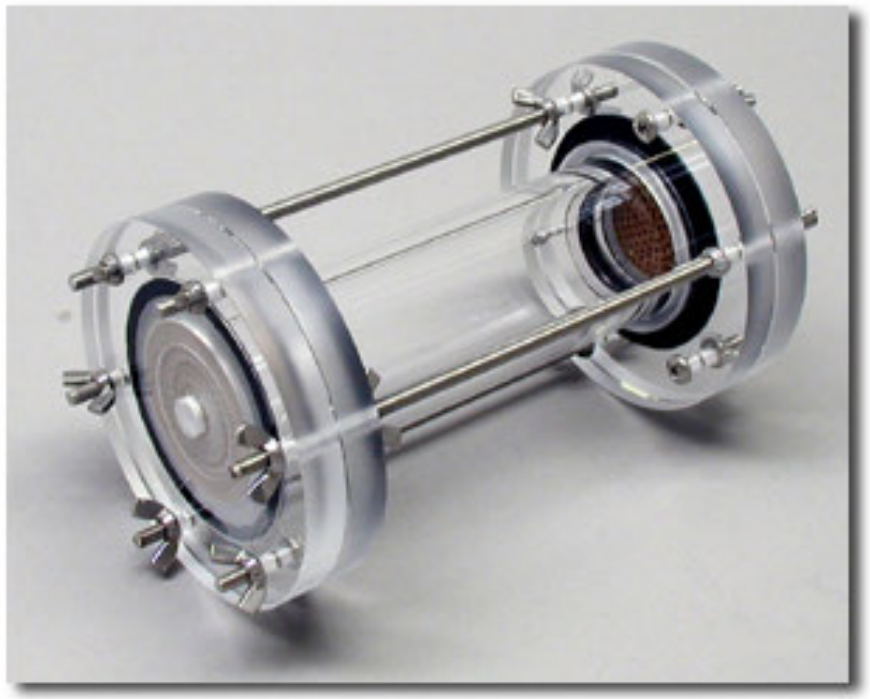
Disadvantages

- Small surface area
- Long measurement times
- Potential smearing and siltation
- No visibility in measurement site

Methods – Unsaturated Hydraulic Conductivity (K(y))

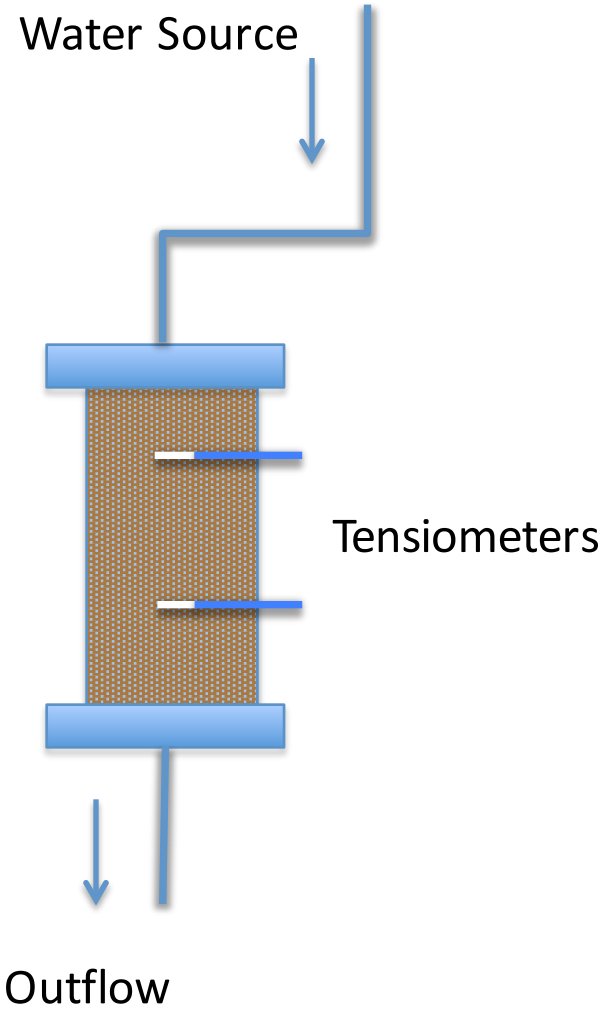
- Laboratory
  - Tempe Cells
  - Evaporation Method
- Field
  - Tension Infiltrometers

Flow Cells



- Can also be used for measuring K(ψ)
- Simultaneous water transmission & retention properties
- Requires tensiometers

Flow Cells – How they work



- Steady flow rate into column
- Flow rate maintained until both tensiometers read same suction
- Flow rate is then increased

Flow Cells – Pros & Cons

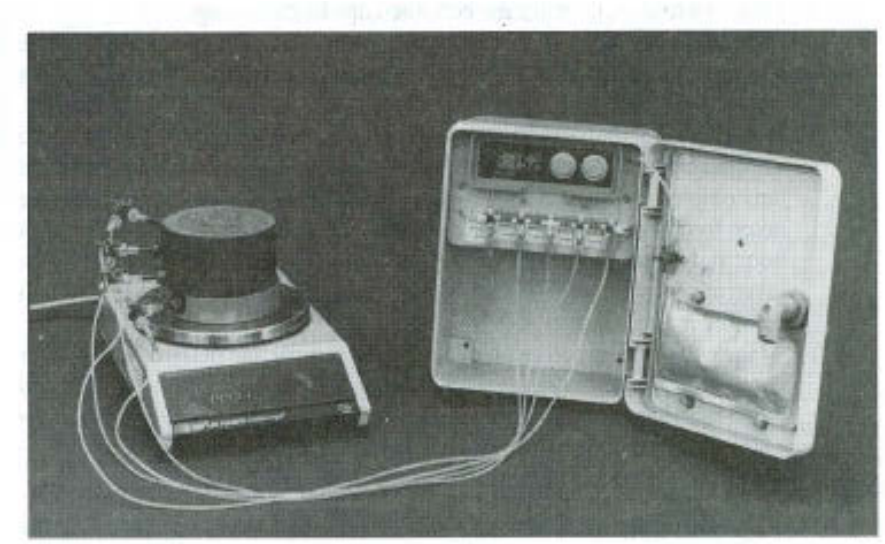
Advantages

- Simultaneous water transmission & retention properties
- Estimation of saturated and unsaturated flow parameters on same soil column

Disadvantages

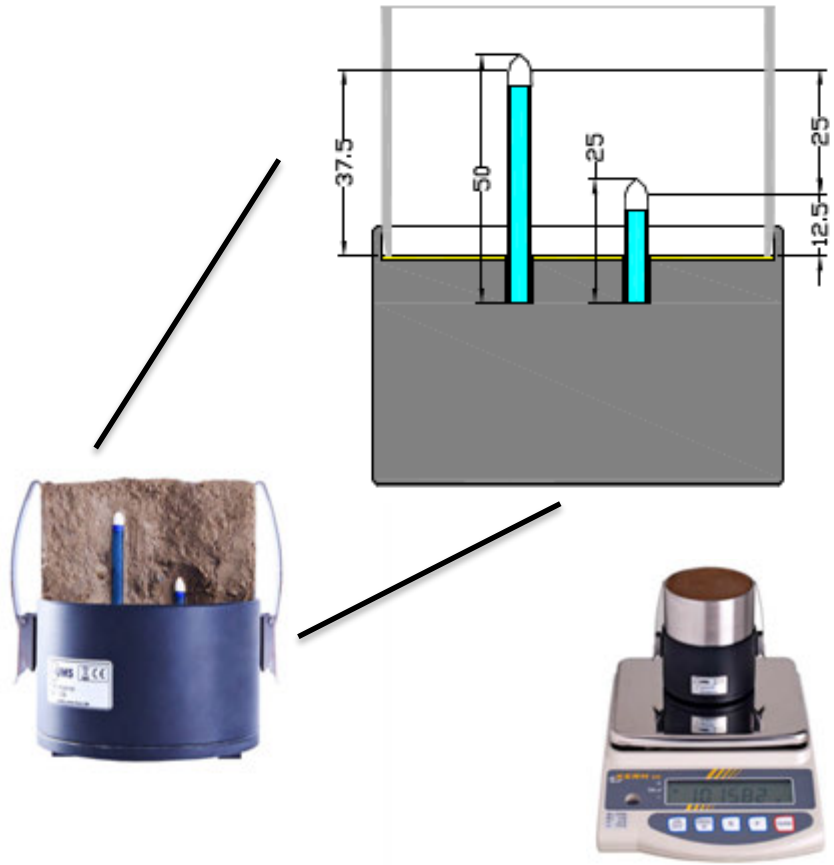
- Requires a method of maintaining a constant flow
- Complex operation

Evaporation Method



- First Introduced by Wind (1968)
- Saturated Soil Core allowed to evaporate
- Constant evaporation rate
- Simultaneous measurements of matric head

HyProp



- Simplified Wind/Schindler Evaporation Method
- Two Tensiometers at different Heights
- Calculated Using Inversion of Darcy-Equation

$$K^i(\overline{\overline{h}}^i) = -\frac{q^i}{\Delta h^i / \Delta z + 1}.$$

HyProp – Pros & Cons

Advantages

- Simultaneous water transmission & retention properties
- Automated measurement
- Good measurement resolution

Disadvantages

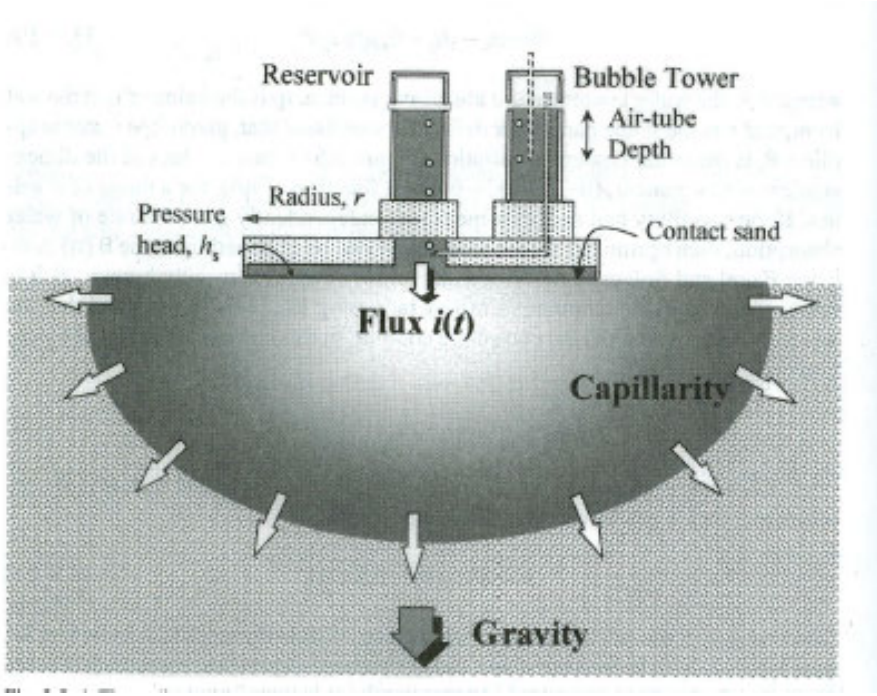
- Unreliable K(ψ) data near saturation
- Learning curve
- Only Desorption Characteristics

Tension Infiltrometers

- Infiltration under imposed suctions
- Three dimensional infiltration analysis
- Also used for determining repellency

Tension Infiltrometers

- Porous plate is placed on the soil
- Suction is controlled by bubble tower
- Analysis using transient and steady-state methods



Tension Infiltrometer – Pros & Cons

Advantages

- Controlled suction
- Larger disks account for more spatial variability
- Estimation of sorptivity and repellency

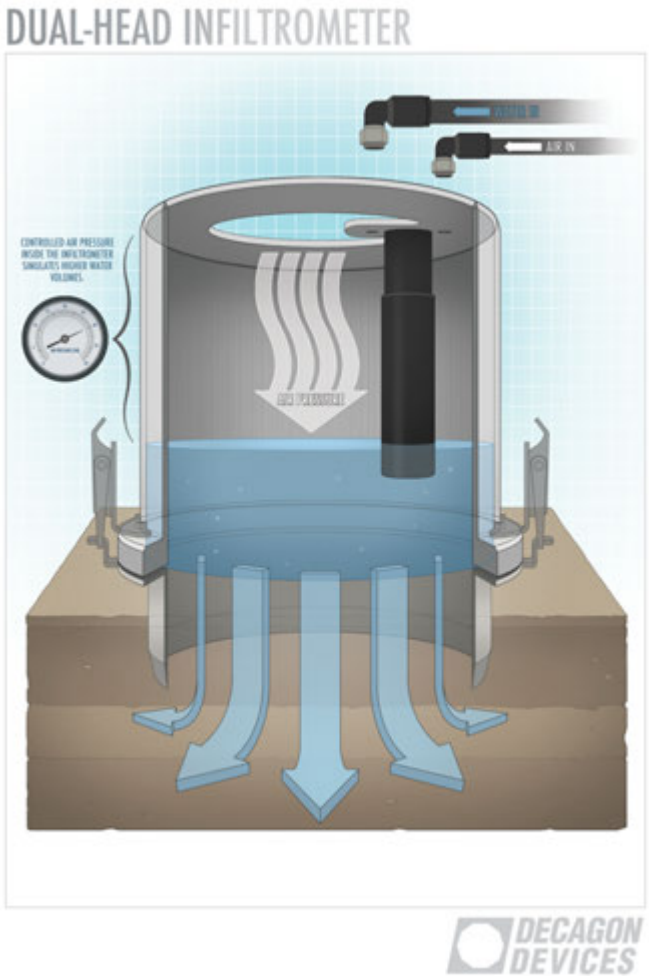
Disadvantages

- Steady-state methods are time consuming
- Requires estimation of soil properties to correct for 3-dimensional flow

DualHead Infiltrometer

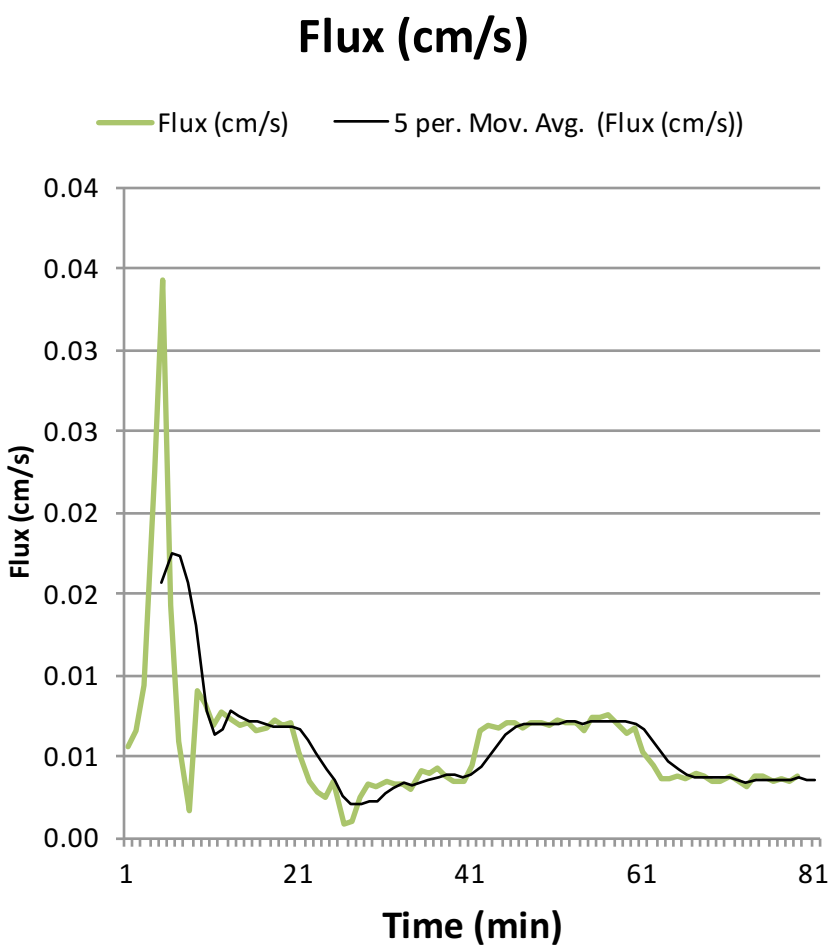
- Automated Ring Infiltrometer
- Similar to Pressure Infiltrometer
- Multiple Ponded head analysis

How It Works



- Constant Water Level
- Different pressure heads controlled by air pressure

How It Works



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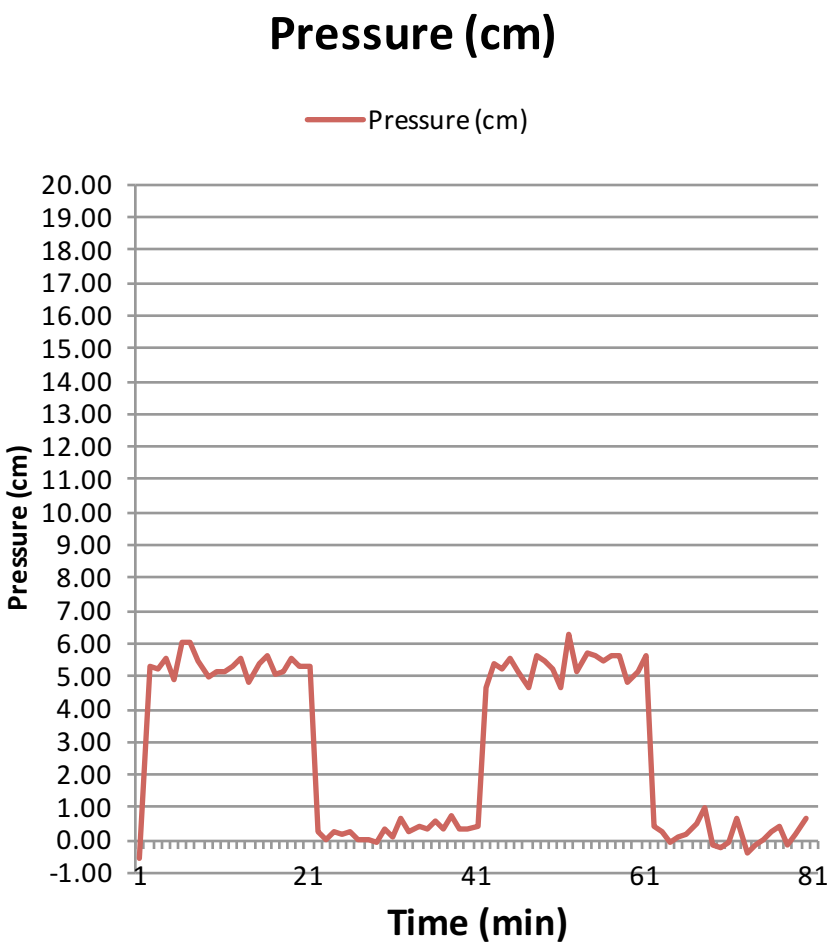
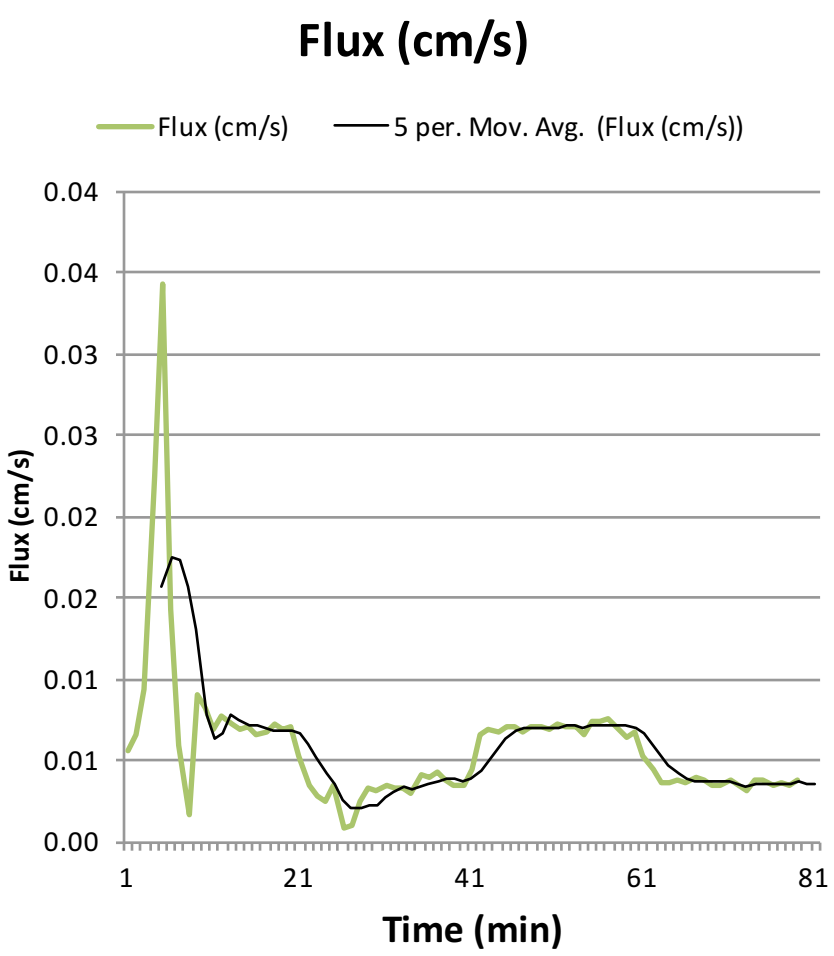
How It Works



- Constant Water Level
- Different pressure heads controlled by air pressure

How It Works



- Constant Water Level
- Different pressure heads controlled by air pressure
- Improved estimates of K_{fs}
- α directly measured

APPLICATIONS

Land-use effects

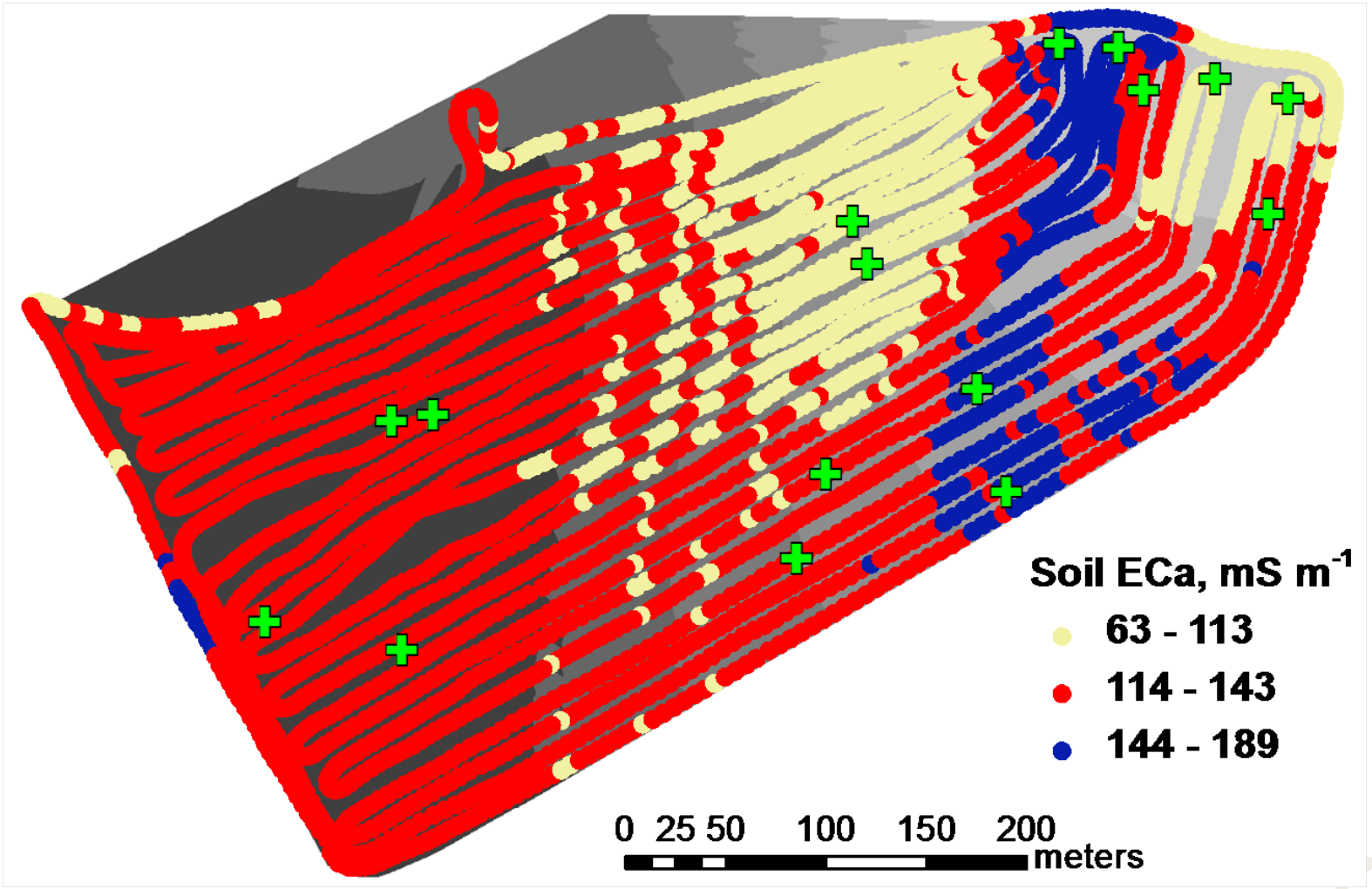
- **Comparing the effects of Landscape & Land-use on hydraulic properties of the same soil type**

Tall grass native prairie

Improved pasture—grazed

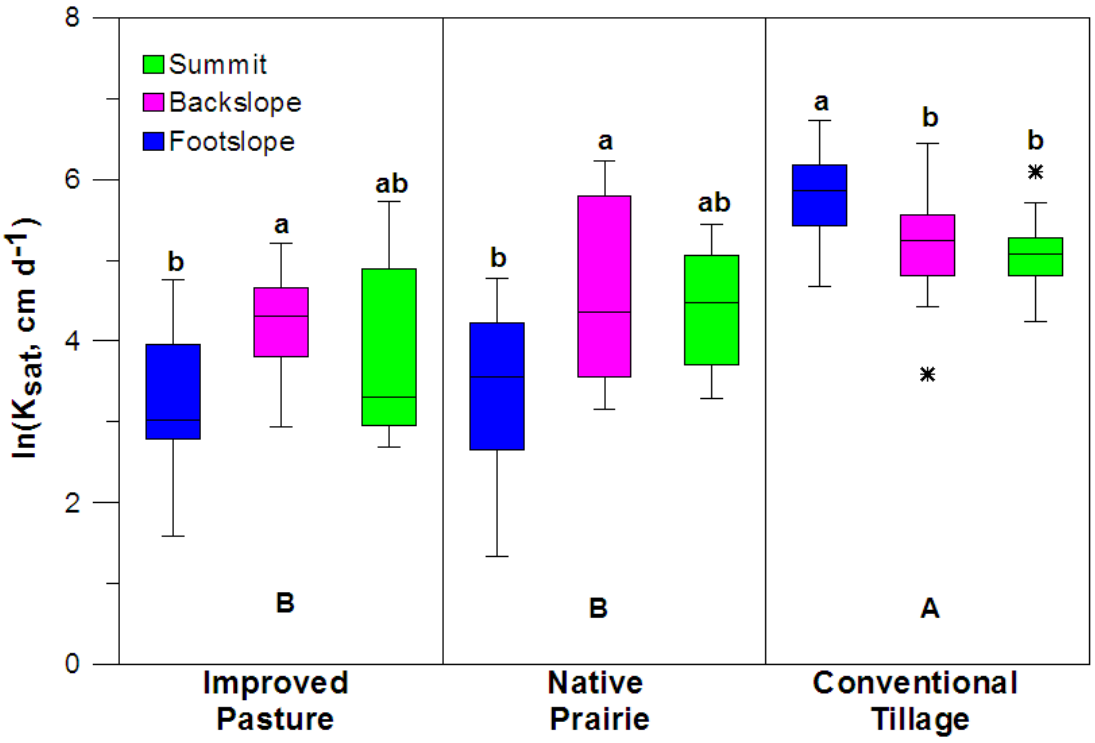
Conventional tillage (corn/corn/wheat)

Where to measure?



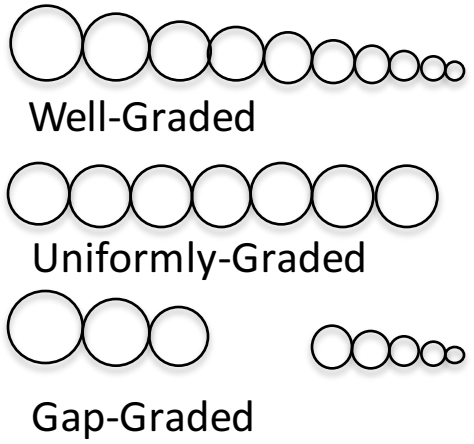
Land-use effects

- Triplicate measurements made using Double-Ring Infiltrometers



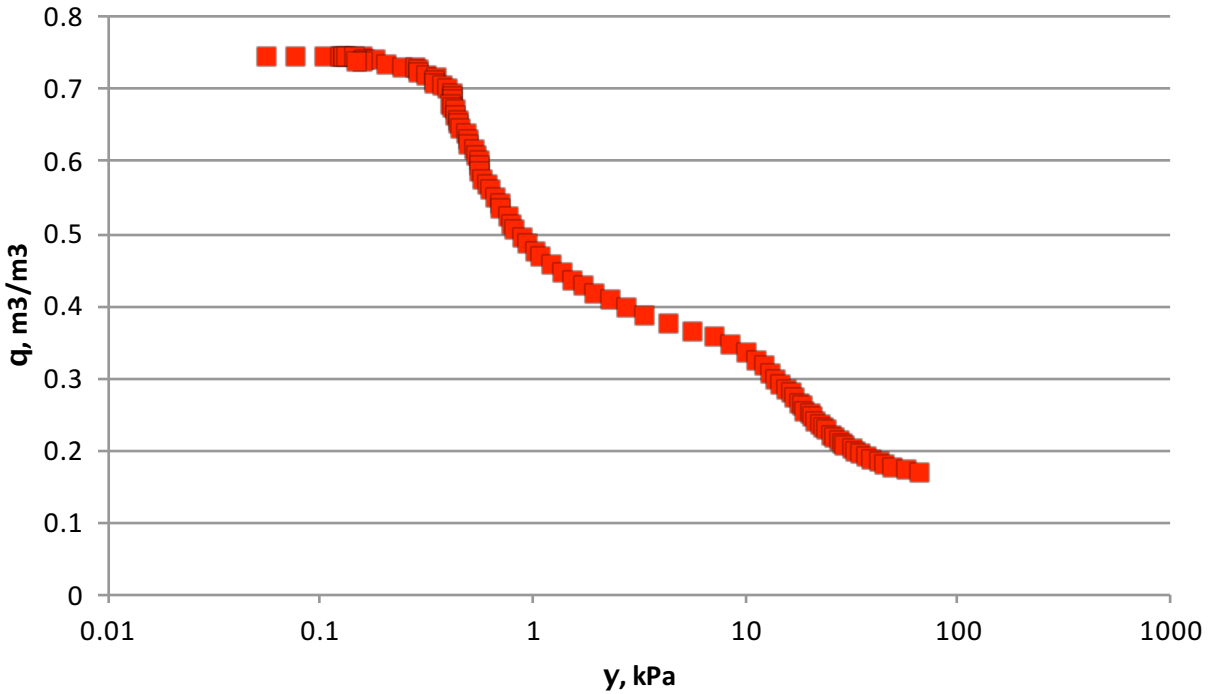
Plant Available Water

- How do hydraulic properties of soil-less substrates effects plant available water
- Many soil-less substrates are gap-graded

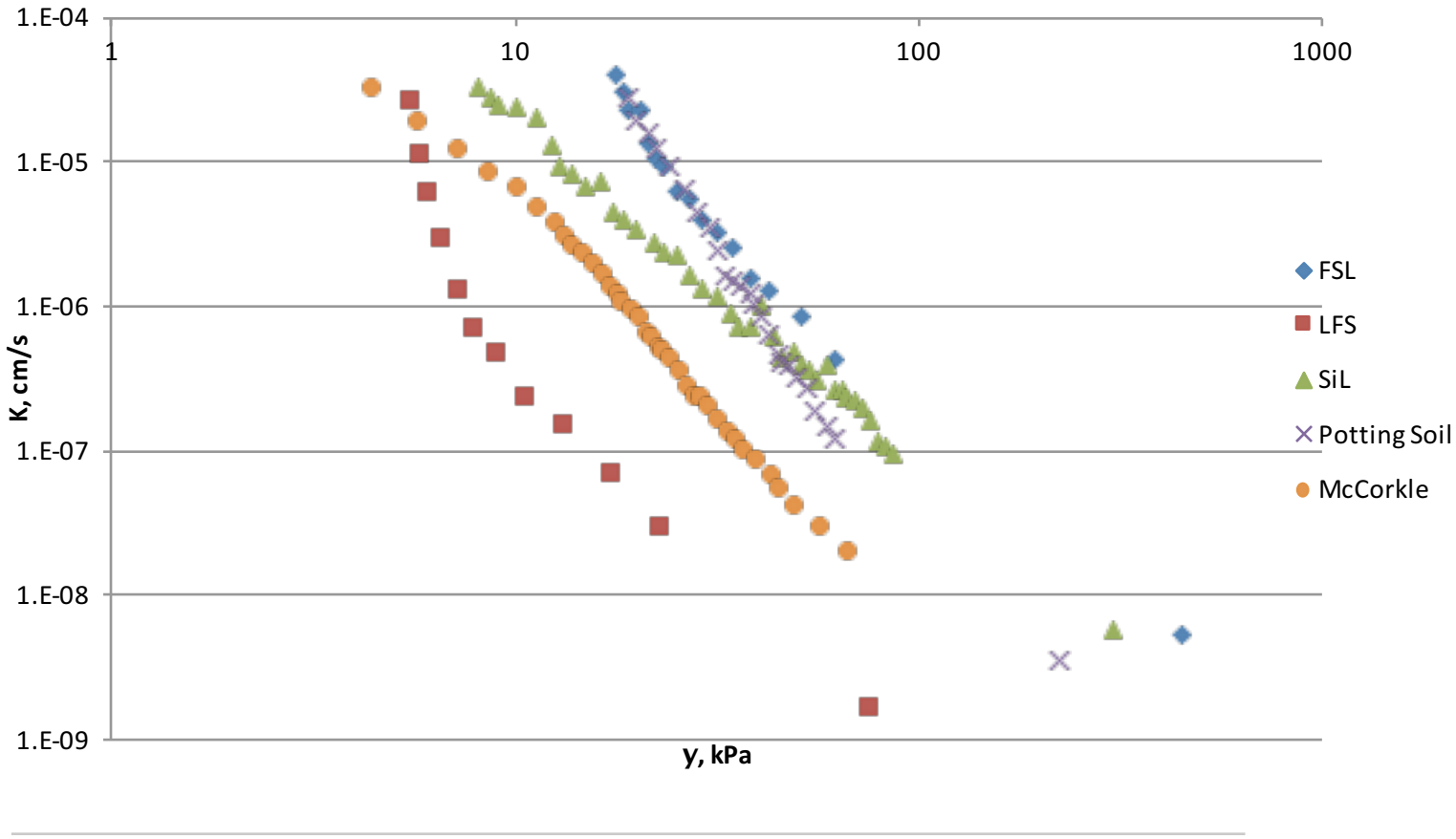


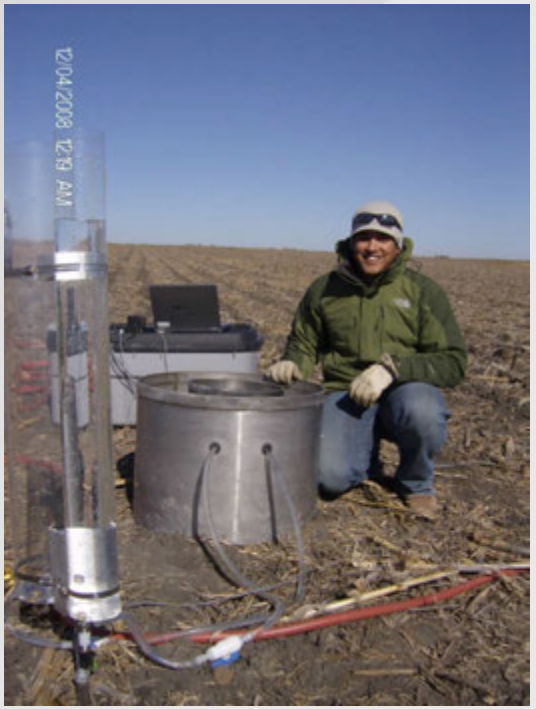
Plant Available Water

- Can Hydraulic Conductivity affect plant available water?



Plant Available Water





QUESTIONS?

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