Design Methodology for Alternative Covers

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Definition:

- An alternative cover is a soil cover consisting of one or more layers that is used in place of a conventional cover.

- Also called ET covers, water balance covers, store-and-release covers.

- Generally required to be ‘equivalent’ to conventional cover.

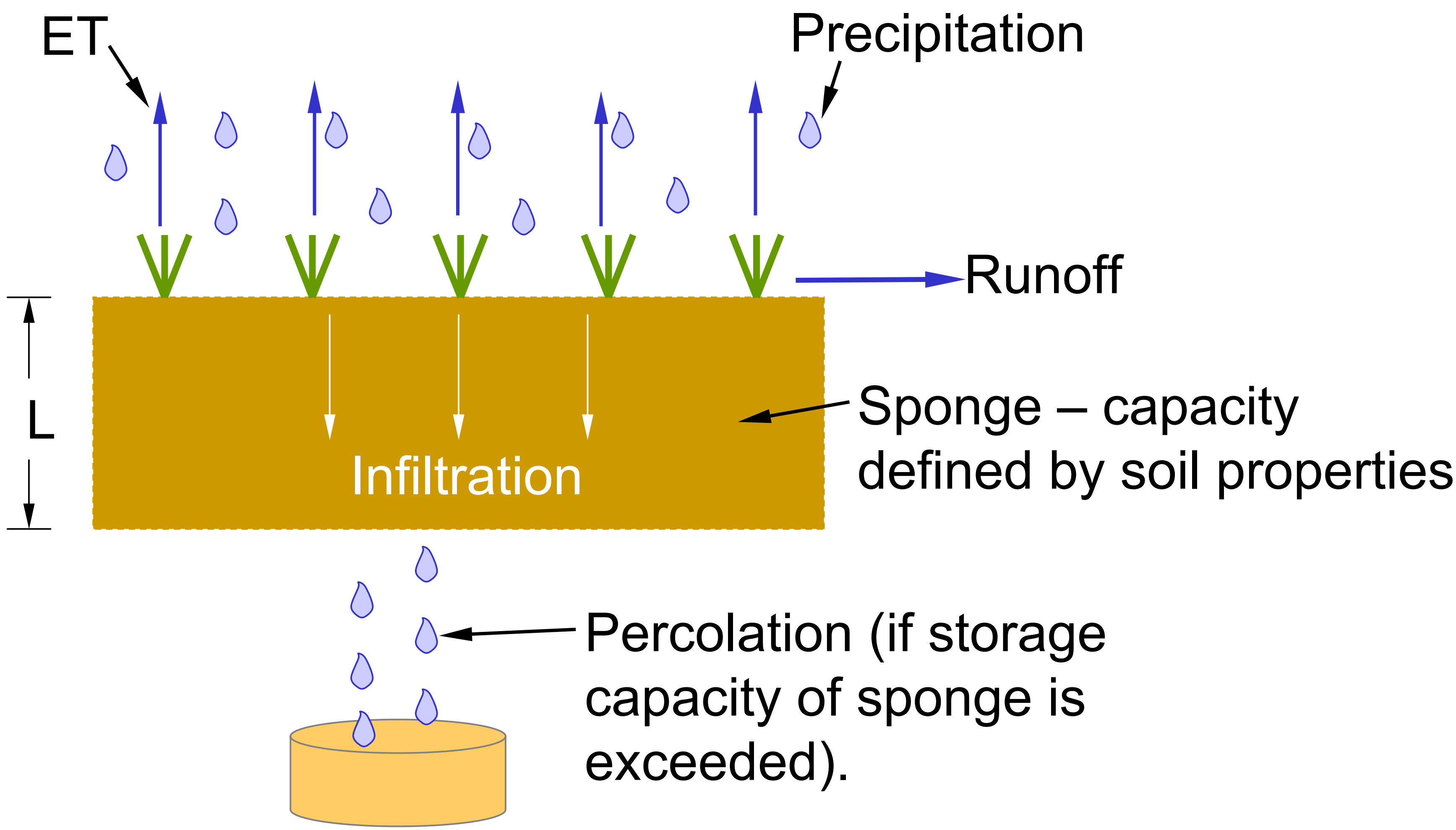
Equivalency:

- Percolation rate for alternative < conventional.

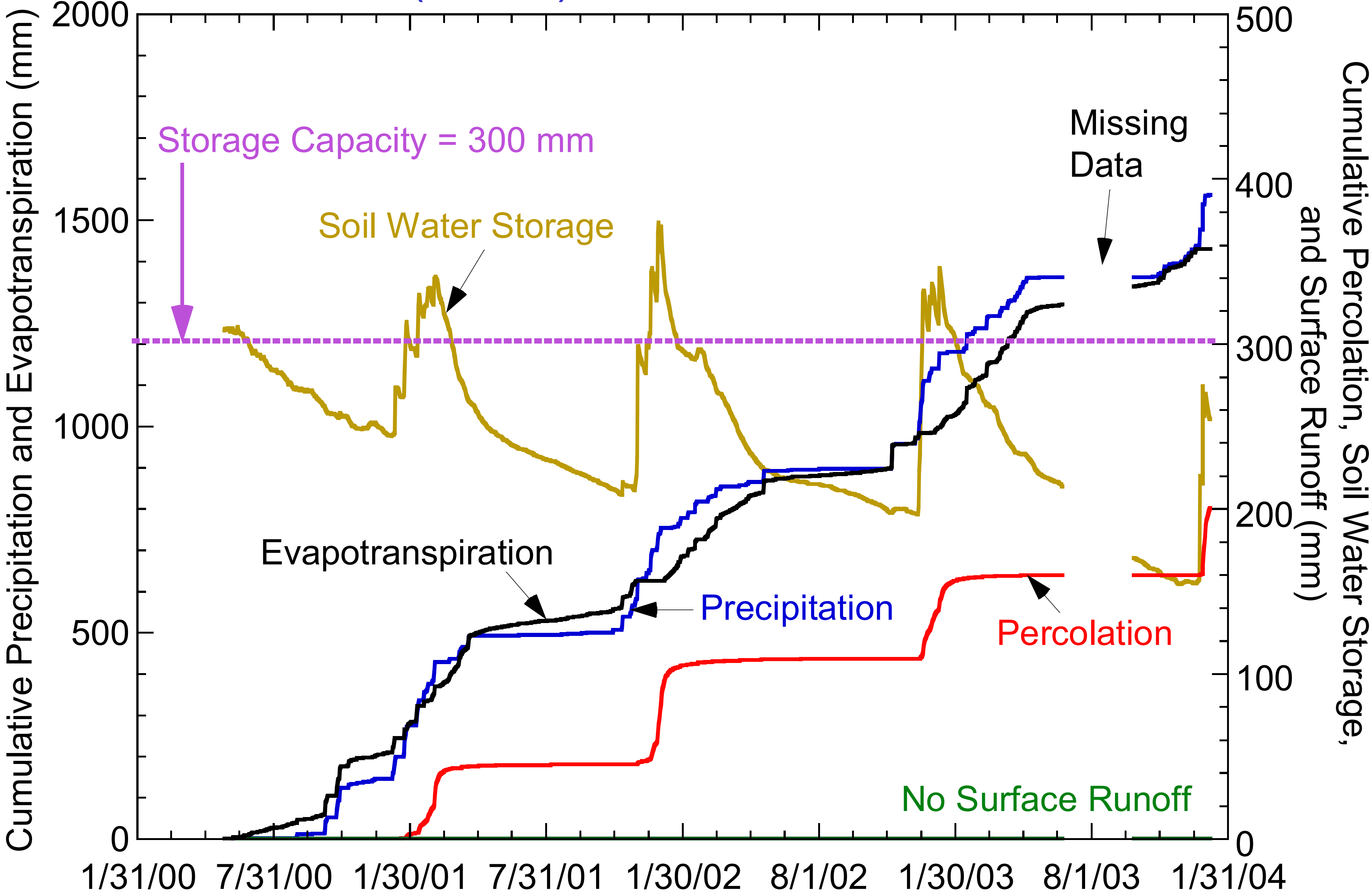
- Erosion rate for alternative < conventional.

Water Balance Principle

Balance the storage capacity of finer textured soil with the water removal capabilities of evaporation & transpiration.



USEPA's Alternative Cover Assessment Program (ACAP) Site in Marina, CA



Percolation occurs every year when storage capacity is exceeded.

Five-Step Approach

1. Site Characterization

- climatic conditions (suitable location, design record)
- available borrow soils (storage capacity)
- suitable vegetation (growing season, root depth, coverage)

2. Preliminary Design Calculations

- defining storage capacity of soils
- sizing storage layer
- monolithic cover or a capillary barrier

3. Numerical Modeling -- Session 3

- select a numerical model (UNSAT-H, HYDRUS, Vadose/W)
- design verification and refinement

4. Design Details -- Sessions 1, 3, & 5

- surface water management
- erosion, desiccation and frost effects
- biota intrusion, fire
- soil placement and re-vegetation

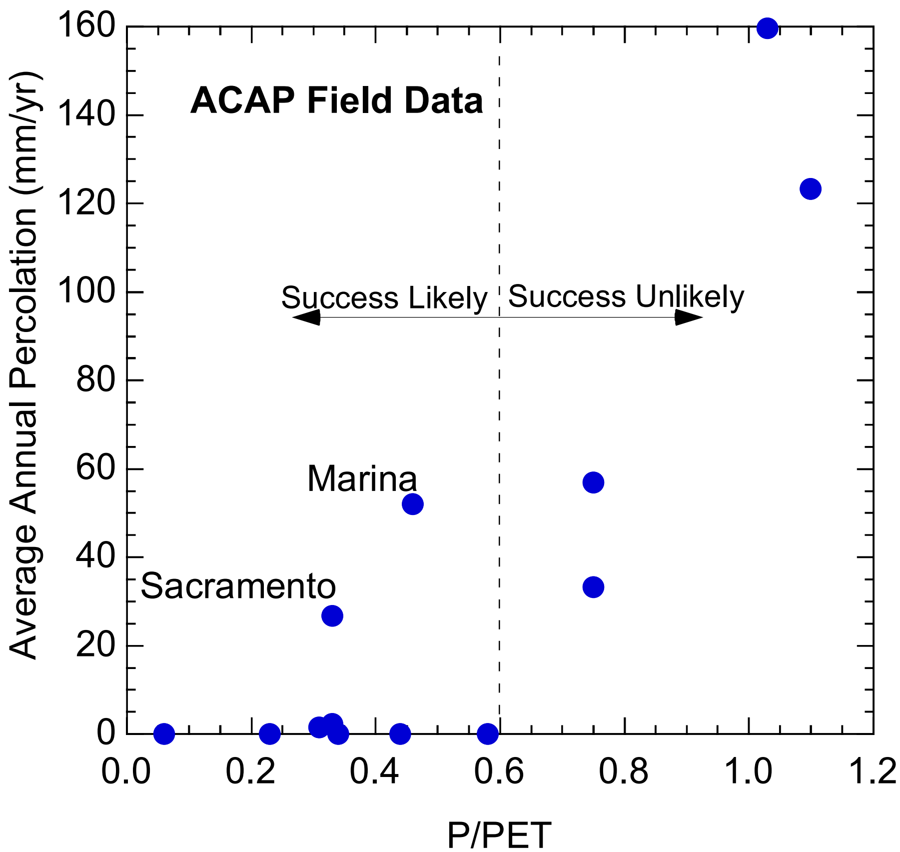
5. Performance Evaluation & Monitoring -- Session 4

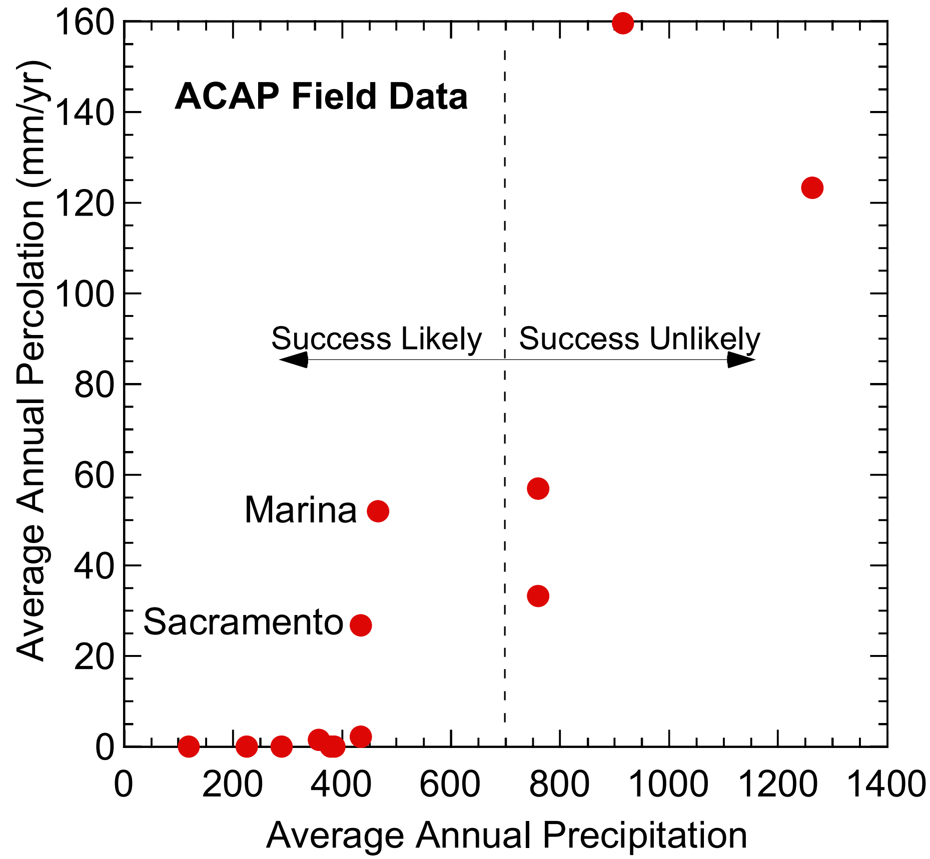
- verify that cover performs as intended
- lysimeter
- water content and matric potential sensors
- combinations of lysimeters and sensors
- data needs and evaluation criteria

Site Characterization

- climate
- soils
- vegetation

Climate

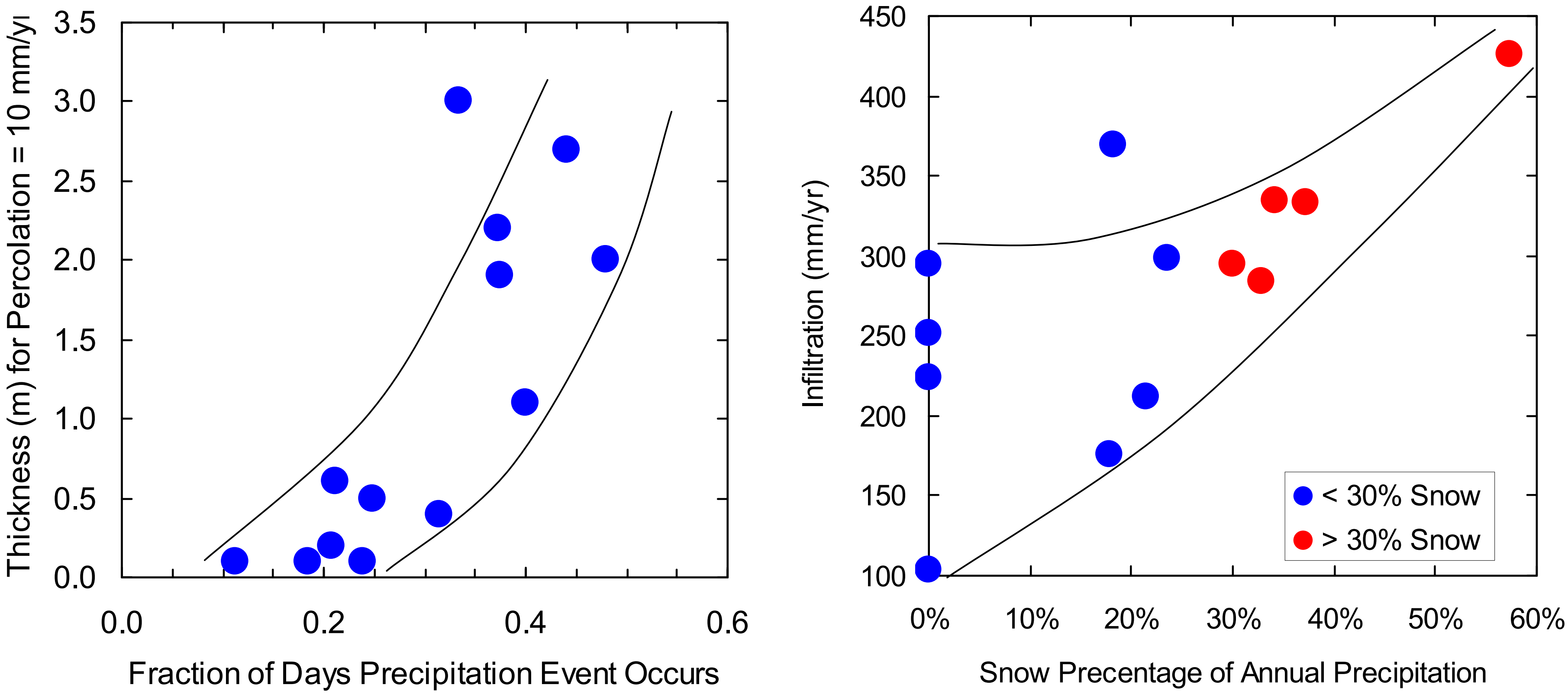




Suitable Sites: P/PET < 0.6, P < 700 mm/yr

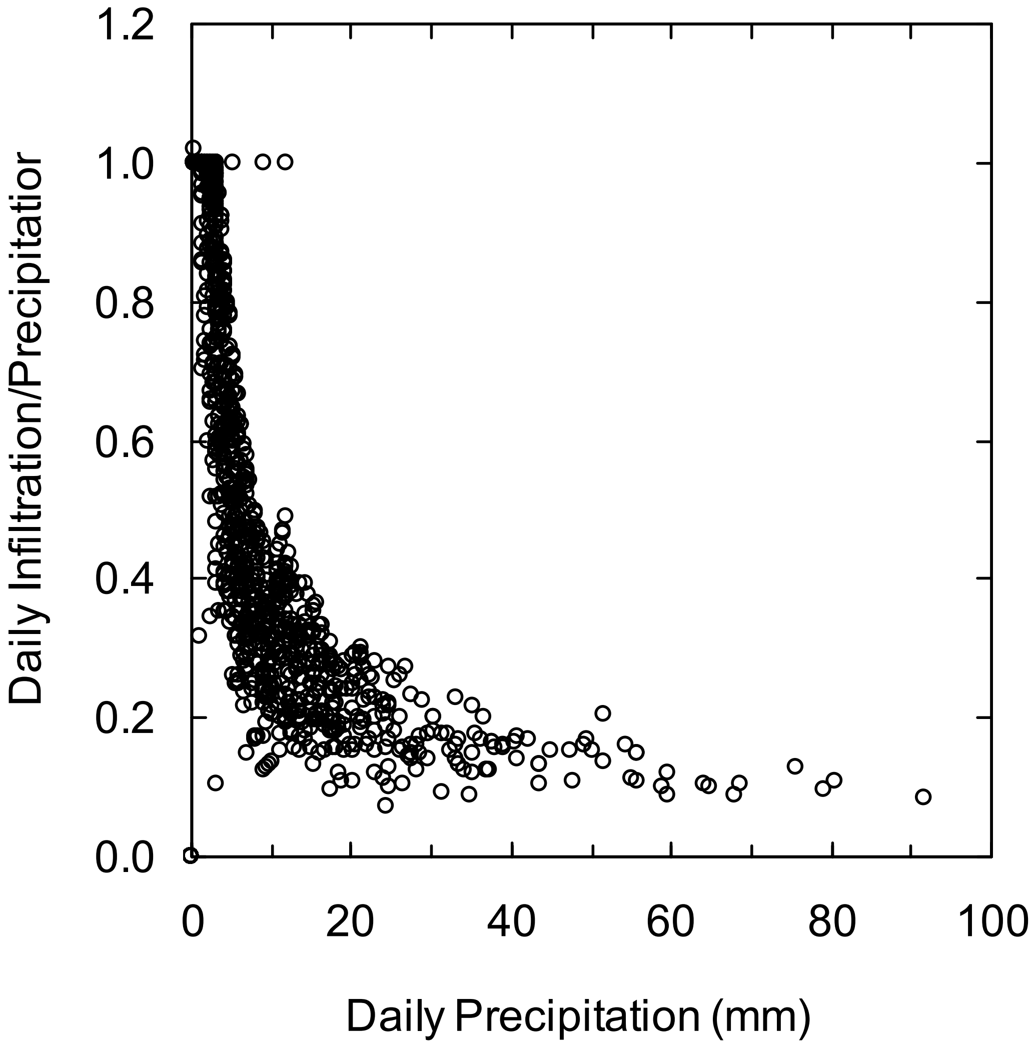
Contingent on proper cover design

Frequency & Type of Precipitation



- frequency and intensity of precipitation
- % precipitation that is snow

Precipitation Intensity

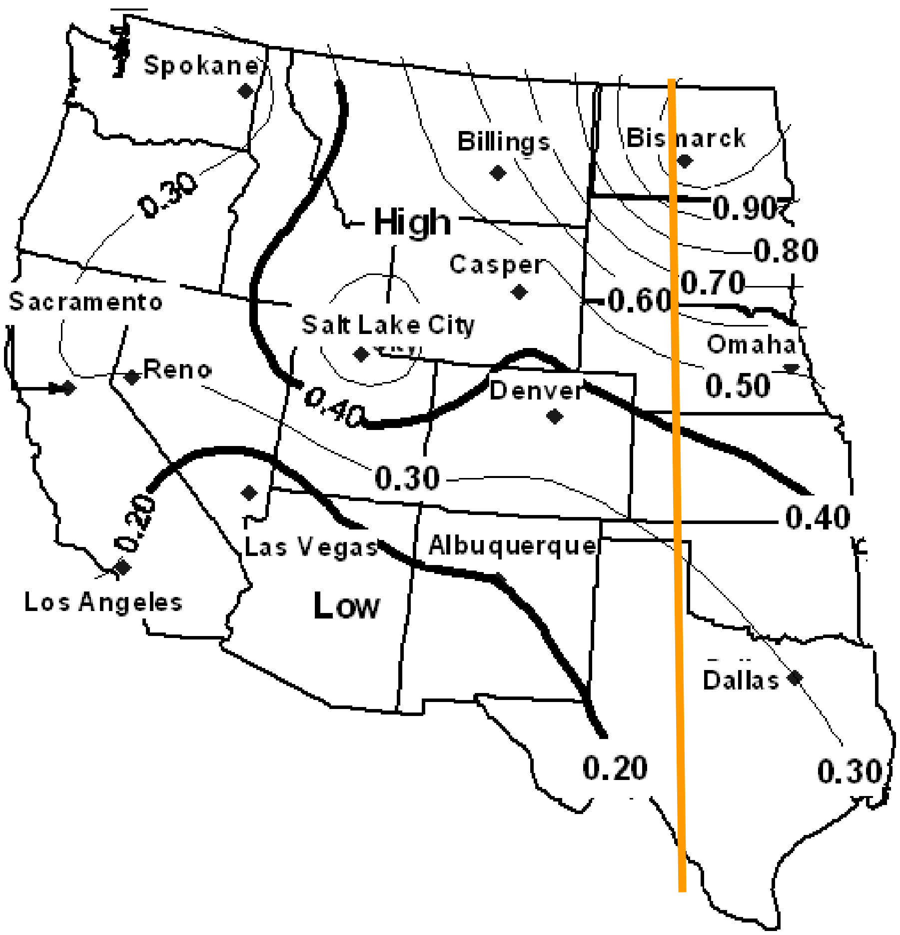


More infiltration occurs (and thicker covers are required) as the precipitation intensity decreases

More frequent and less intense precipitation events generally are MORE IMPORTANT than large thunderstorms.

Location & Climate

Cover Thickness Contours (m)
for 10 mm/yr



Climate and location are closely related

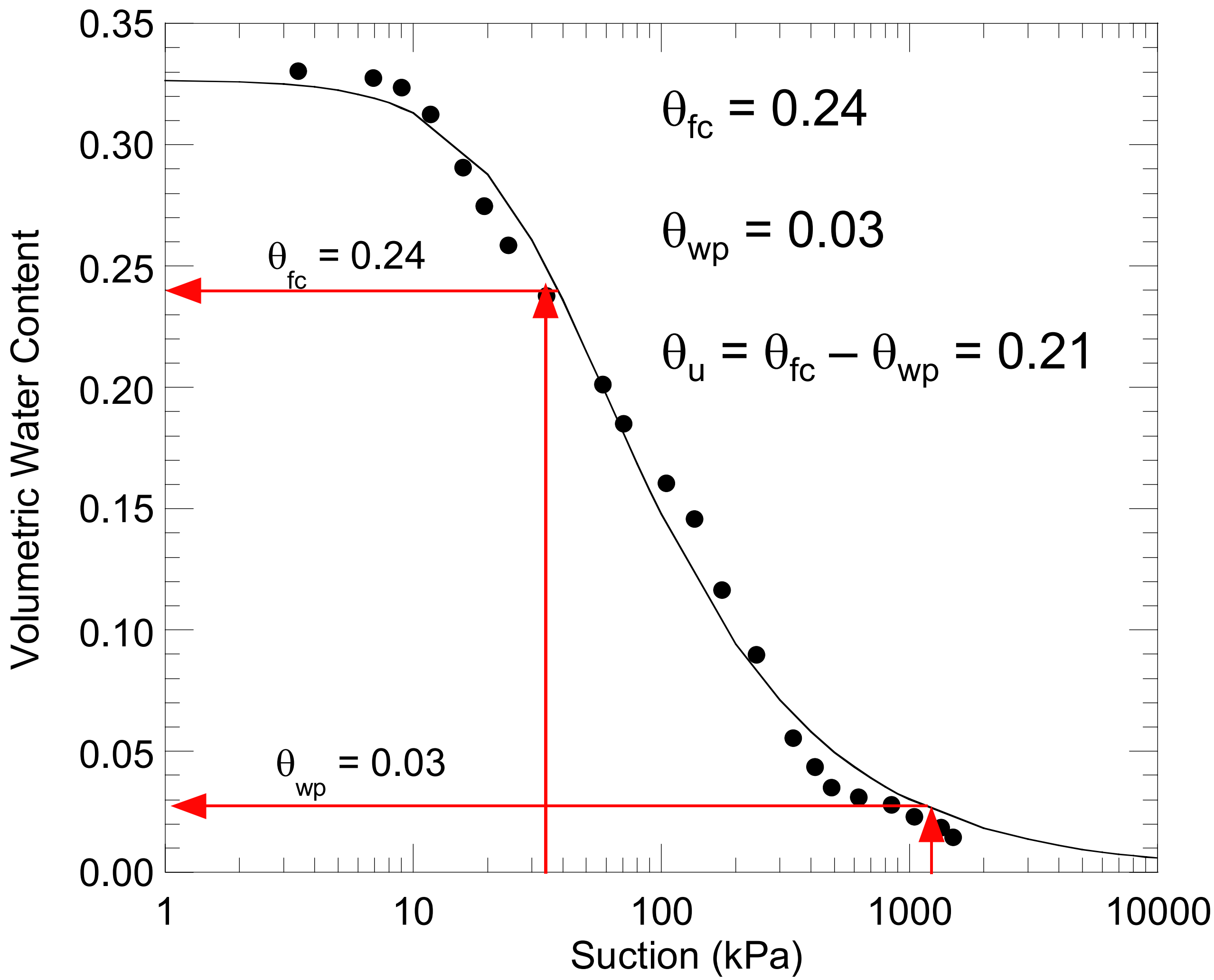
Thicker covers required in cooler and wetter regions

Soil Properties

Key Characteristics:

- Water retention characteristics (high, finer textured)
- Saturated hydraulic conductivity (low, finer textured soil)
- Shrink-swell potential (low, modest clay fines, well graded, appreciable coarse fraction)
- Erosivity (low, well graded, blend of clay and silt fines)
- Shear strength (high, well graded)
- Sufficient volume and close proximity
- Agronomic properties

Water Retention: Soil Water Characteristic Curve



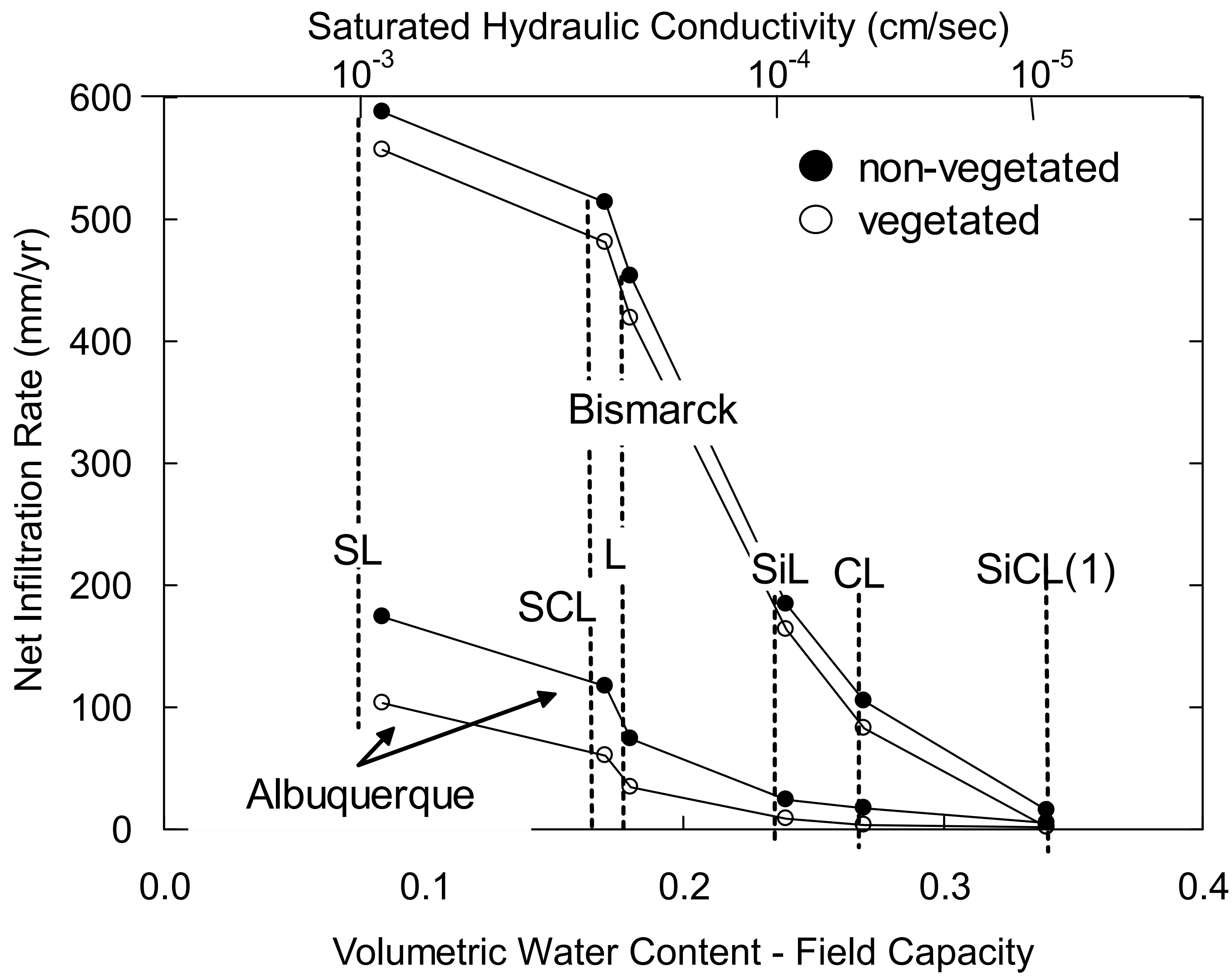
ASTM D 6836

Unit storage capacity = field capacity = θ_{fc}

Unit available storage (θ_u) = available volume per volume of soil … 1 m cover *conceptually* can store & release 210 mm.

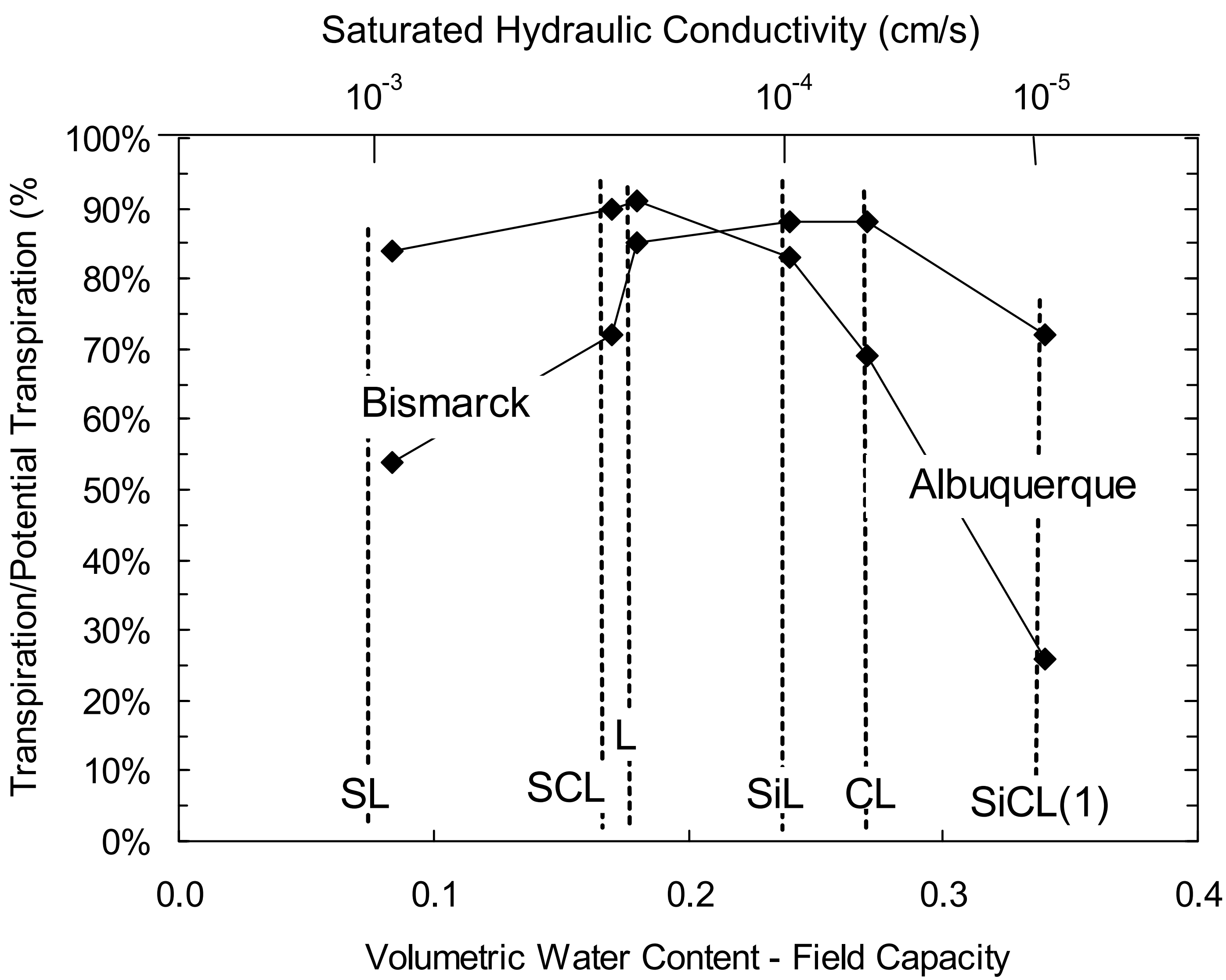
Finer-textured soils have higher θ_u than clean coarse textured soils (loamy sand - 0.3%, loam - 7%, silty clay loam - 14%)

Soils & Percolation



Finer textured covers transmit less percolation by enhancing runoff & retention

Soils & ET



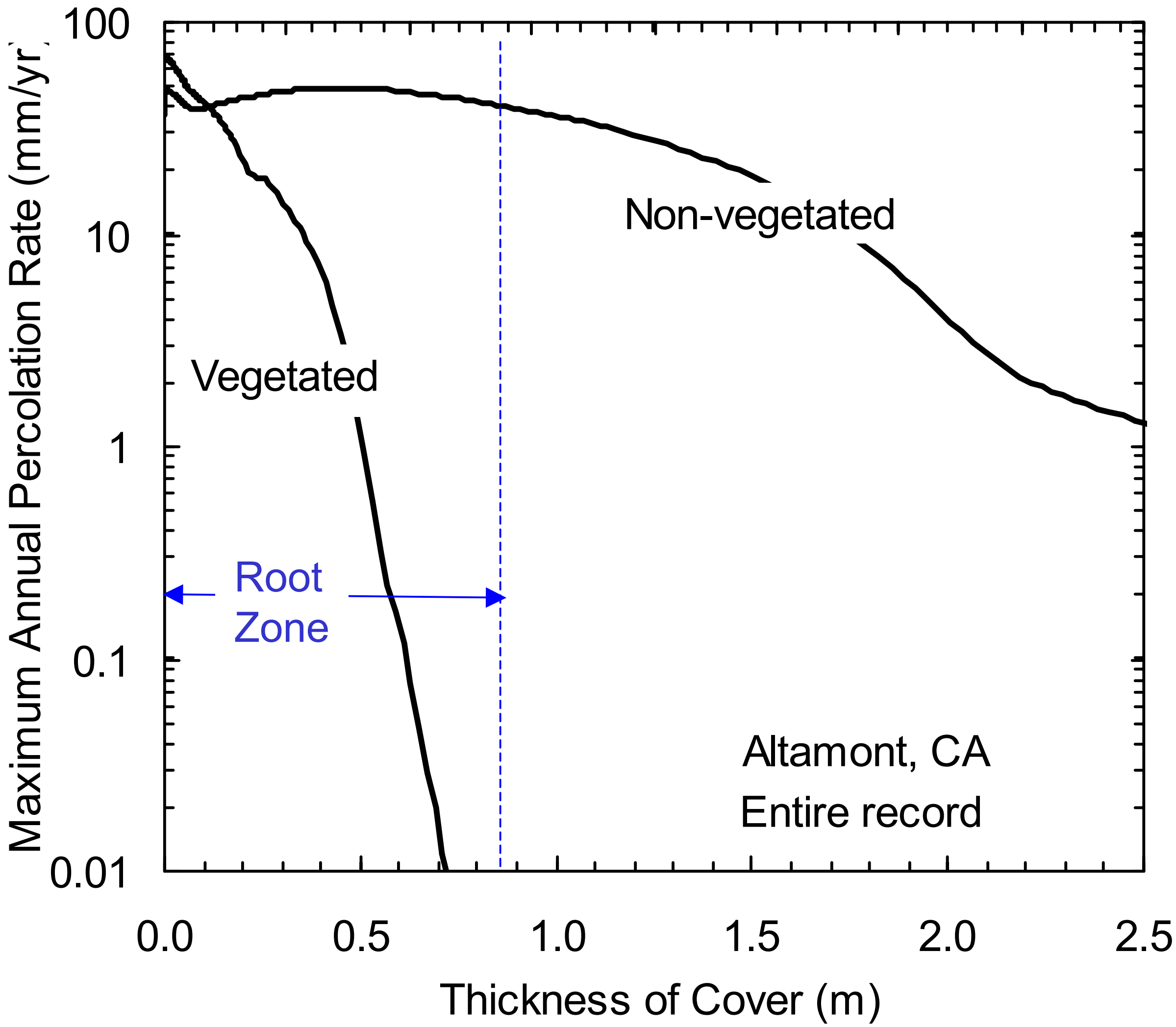
Type of cover soil affects efficiency of transpiration

Vegetation

Key Characteristics:

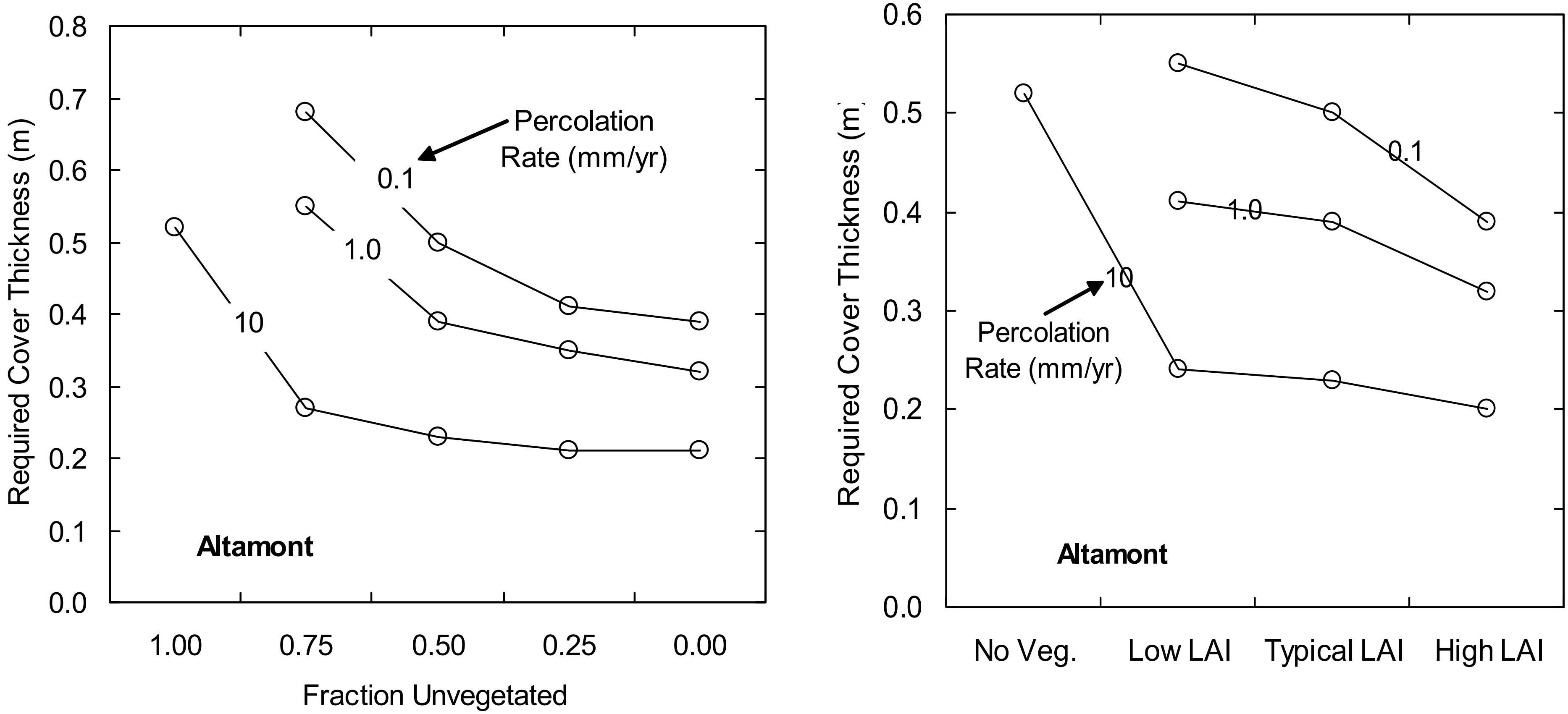
- Warm and cool seasons
- Deep and shallow rooted vegetation
- Readily established and low maintenance
- Native to location
- Disease resistant

Vegetation is Essential



- In many climates, vegetation is key to reducing percolation
- Vegetated covers generally can be thinner than non-vegetated covers relying on evaporation
- Water is removed directly from the root zone, rather than cover surface

Coverage and Density



Model predictions suggest that *having vegetation* is *more important than details* of vegetation.

Preliminary Layer Sizing & Configuration

- layer thickness
- monolithic vs. capillary barrier

Design Approach

1. Define quantity of water to store.

   - wettest year on record

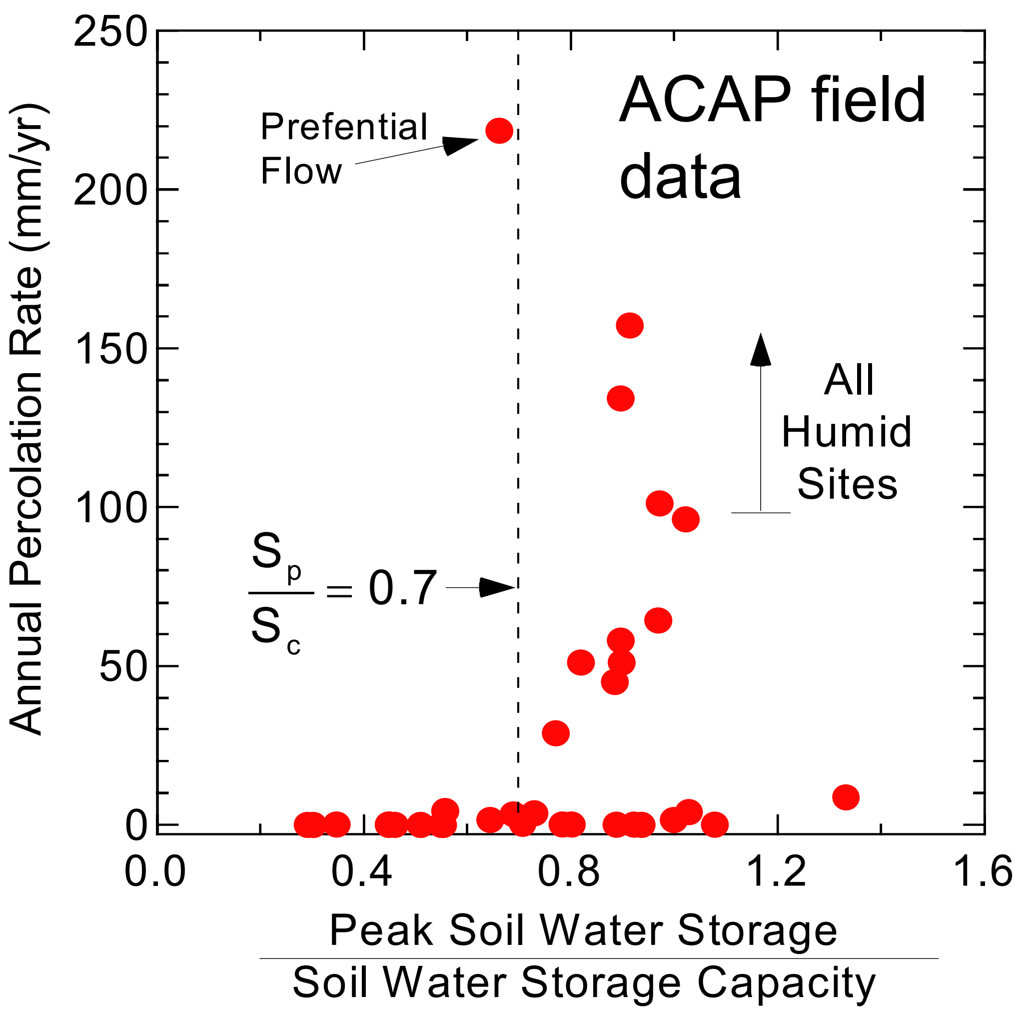
   - precipitation received outside the growing season (i.e., when ET is low), P_o

2. Select layer thickness and/or configuration to provide adequate storage

$$L \geq \frac{P_o}{F\,\theta_u}$$

F = scaling factor. Assuming runoff = 0.

Lab-to-Field Scaling



Storage capacity (S_c) of ACAP covers computed assuming $S_c = L\theta_{fc}$, where L = cover thickness.

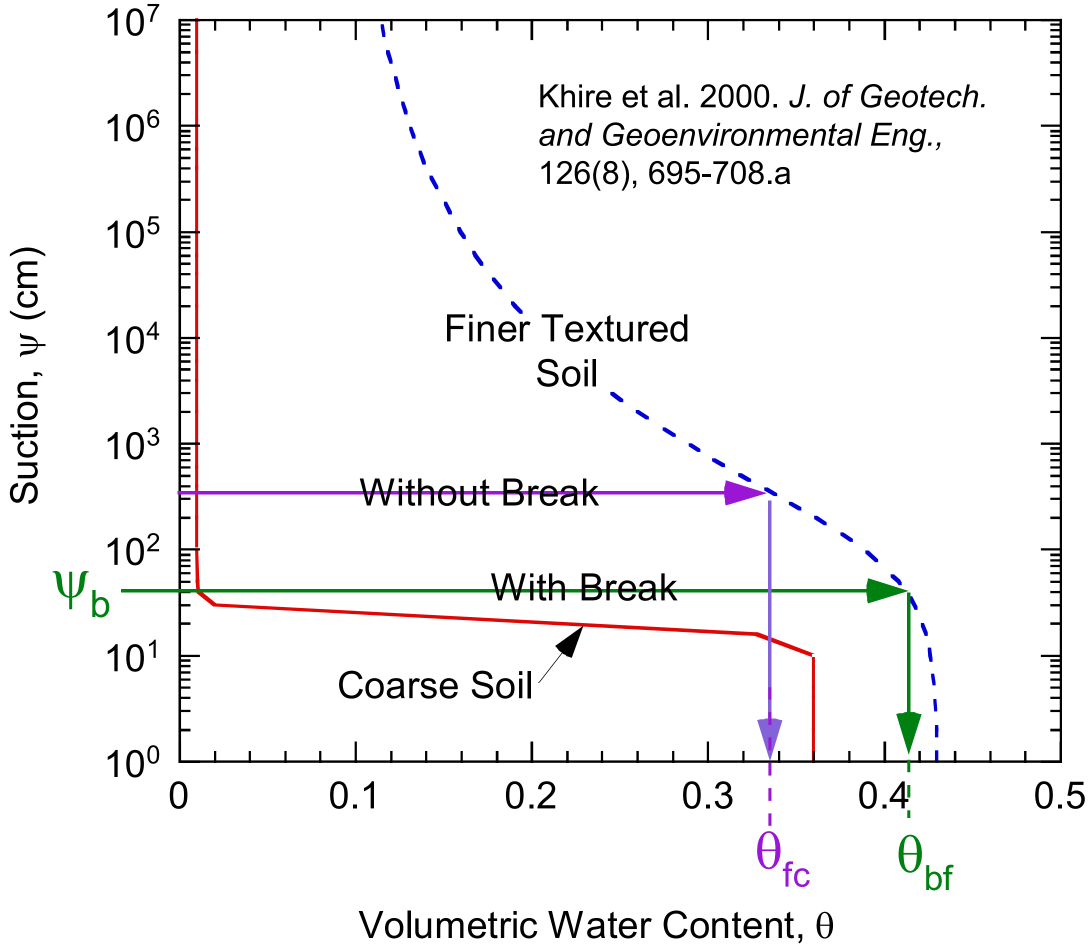
Conceptually, percolation should be negligble if peak soil water storage < storage capacity.

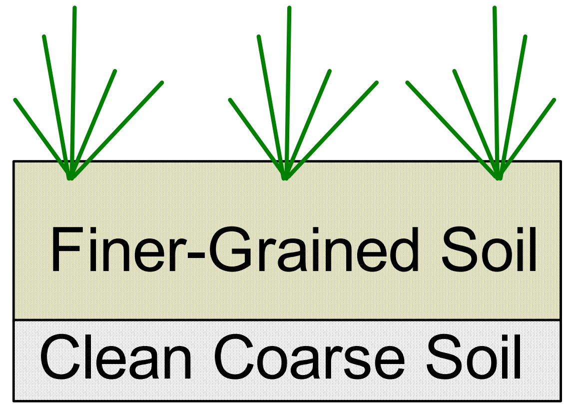
Data suggests that percolation can be appreciable at 70% θ_{fc}.

$$L \geq \frac{P_o}{0.7\ \theta_u}$$

P_o = precipitation outside the growing season.

Capillary Barrier Design





Capillary break can enhance storage capacity of the finer textured layer.

Capillary barrier effect is larger for non-plastic finer textured soils.

In this case, capillary break increases storage capacity by ~ 80 mm of water per 1 m of cover

$$S_{CB} = \int_0^L \theta(z + \psi_b)dz \approx \frac{(\theta_T + \theta_{bf})L}{2}$$

Numerical Modeling

Purpose: Numerical modeling is used to *refine the design* (make more efficent) and *check the design* (against percolation criterion).

1. Model should have been compared against field data, notably fluxes (percolation, runoff, ET)

2. Model should include a rigorous algorithm for the soil-plant-atmosphere continuum and effects of water availability on transpiration.

3. Measured parameters may need to be scaled before being used in models

Numerical Modeling (con’t.)

4. Model predictions should be checked against typical ranges observed in the field (e.g., runoff < 10% of precipitation).

5. Model predictions should be reasonably consistent with preliminary design calculations.

Summary

1. Five-step procedure for designing alternative covers intended to be equivalent to conventional covers.

2. Be *realistic* about suitability of site. Equivalent alternative covers are not practical at all sites.

3. Essential to locate a soil with sufficent storage capacity that *also satisfies* all other engineering and agronomic criteria.

Summary

4. *Account for scaling* in design calculations. Field conditions often differ from laboratory measurements.

5. Check the design using *verified* models. Use *justifiable input parameters* and check the output against field data for *reasonableness*.

6. Be prepared to verify that the design functions as intended. This criterion is characteristic of any new environmental technology, even if conventional technology is not proven to be effective.

Acknowledgements

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