Introduction to Water Balance Covers

by

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Categories of Engineered Final Covers

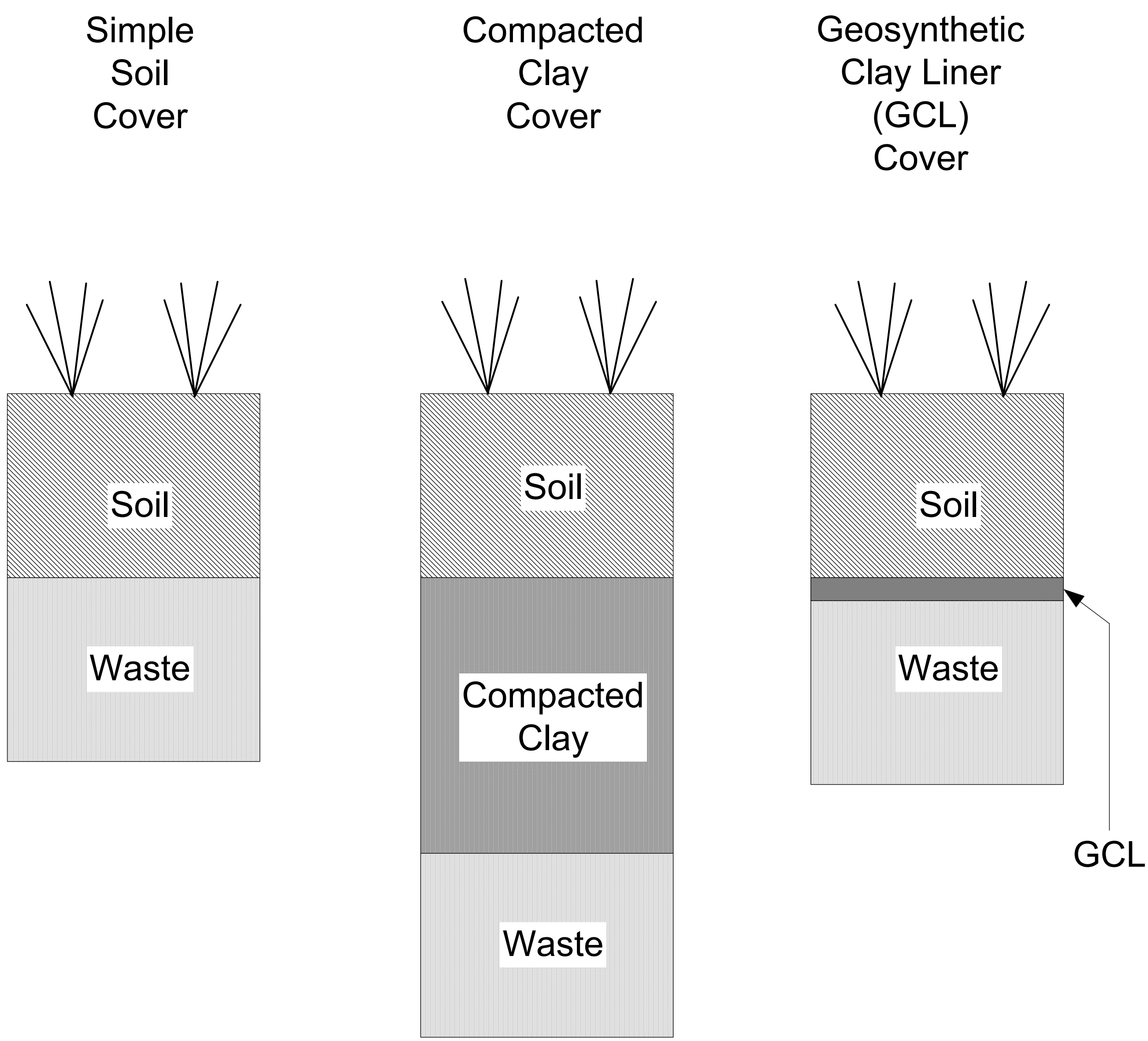
Conventional covers – cover designs where a barrier layer (clay, plastic, etc.) having low saturated hydraulic conductivity is the primary impediment to leakage and gas flow. Also called prescriptive covers or resistive covers.

clay covers, GCL covers, composite covers

Water balance covers – cover designs where leakage is controlled by balancing the water storage capacity of unsaturated finer-textured soils and the ability of plants and the atmosphere to extract water stored in the soil. Also known as *alternative covers, evapotranspiration (ET) covers, store-and-release covers*. Often designed to transmit equal or less percolation than conventional resistive cover required in regulations ("equivalent"), but may also be designed to transmit a specified percolation rate.

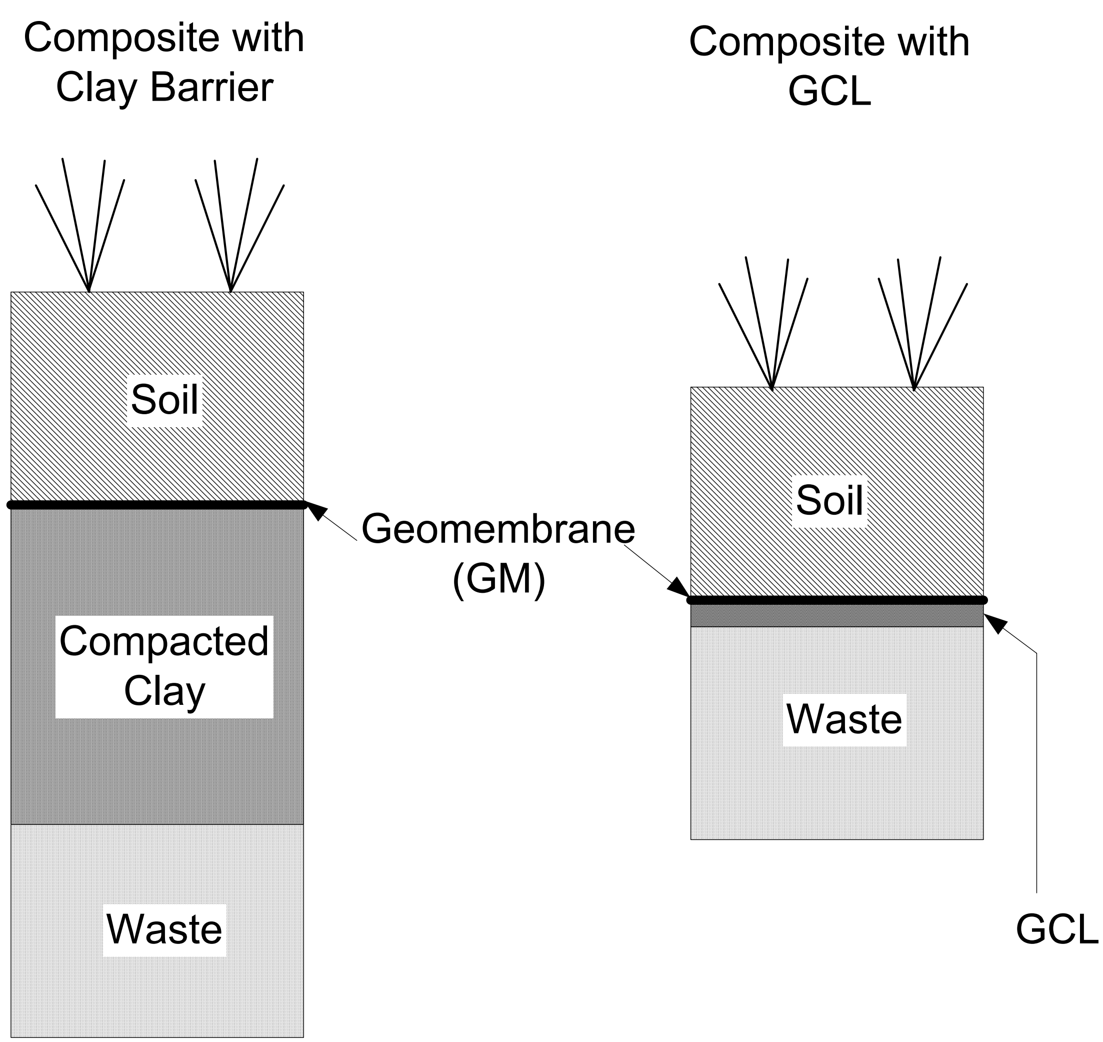
monolithic covers, capillary barriers

Conventional Covers with Earthen Barriers

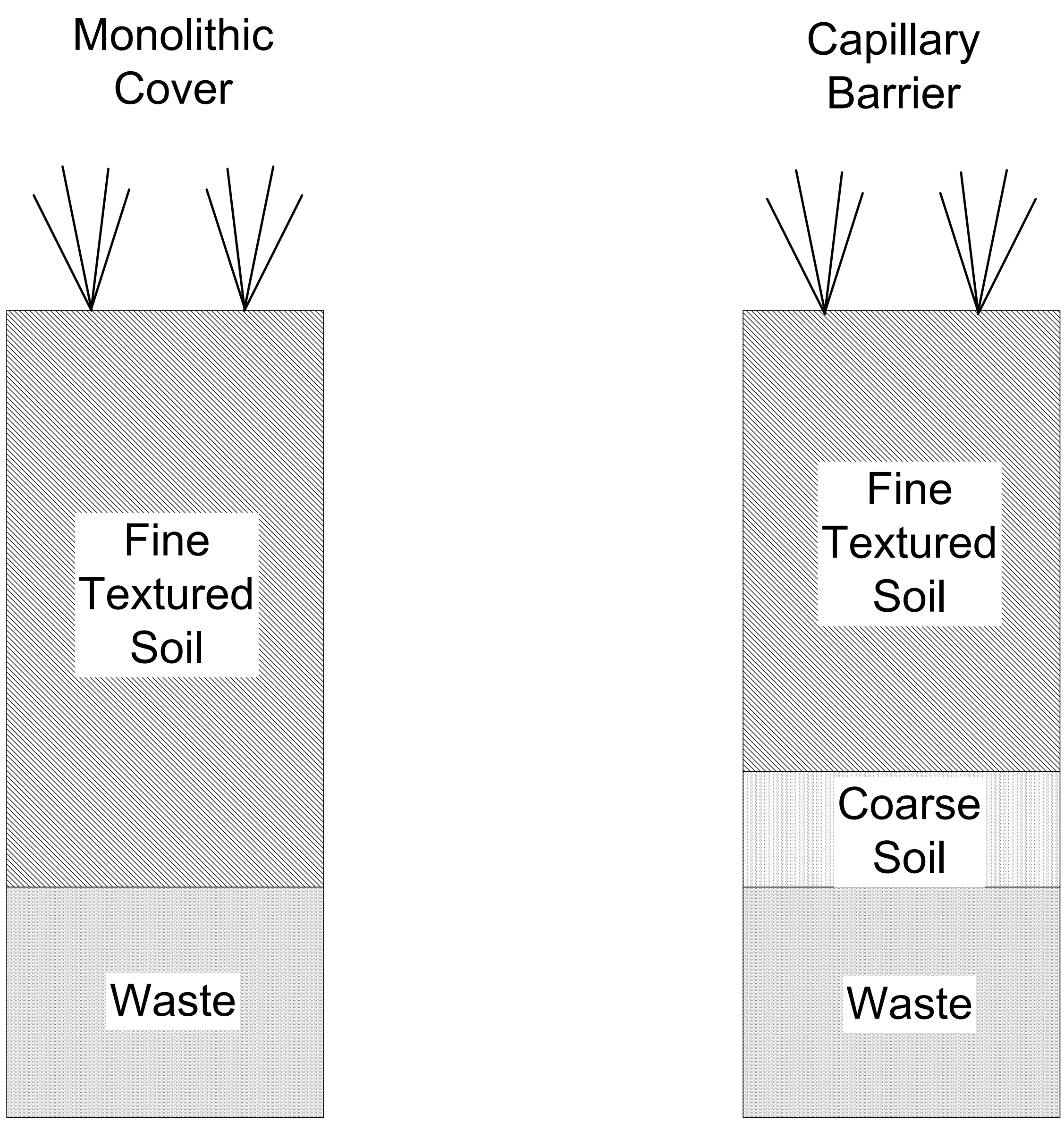


Conventional Covers with Composite Barriers

Composite Covers



Water Balance Covers



Infiltration vs. Percolation

Infiltration – flow of water into the soil by crossing the soil surface (i.e., soil-atmosphere boundary). Units of volume/area-time, or length-time (e.g., mm/yr).

Percolation – flow of water within the soil profile, or for covers, flow of water from the base of the cover and into the underlying waste. Units of volume/area-time, or length-time (e.g., mm/yr). Sometimes referred to as drainage.

Applications for Water Balance Covers

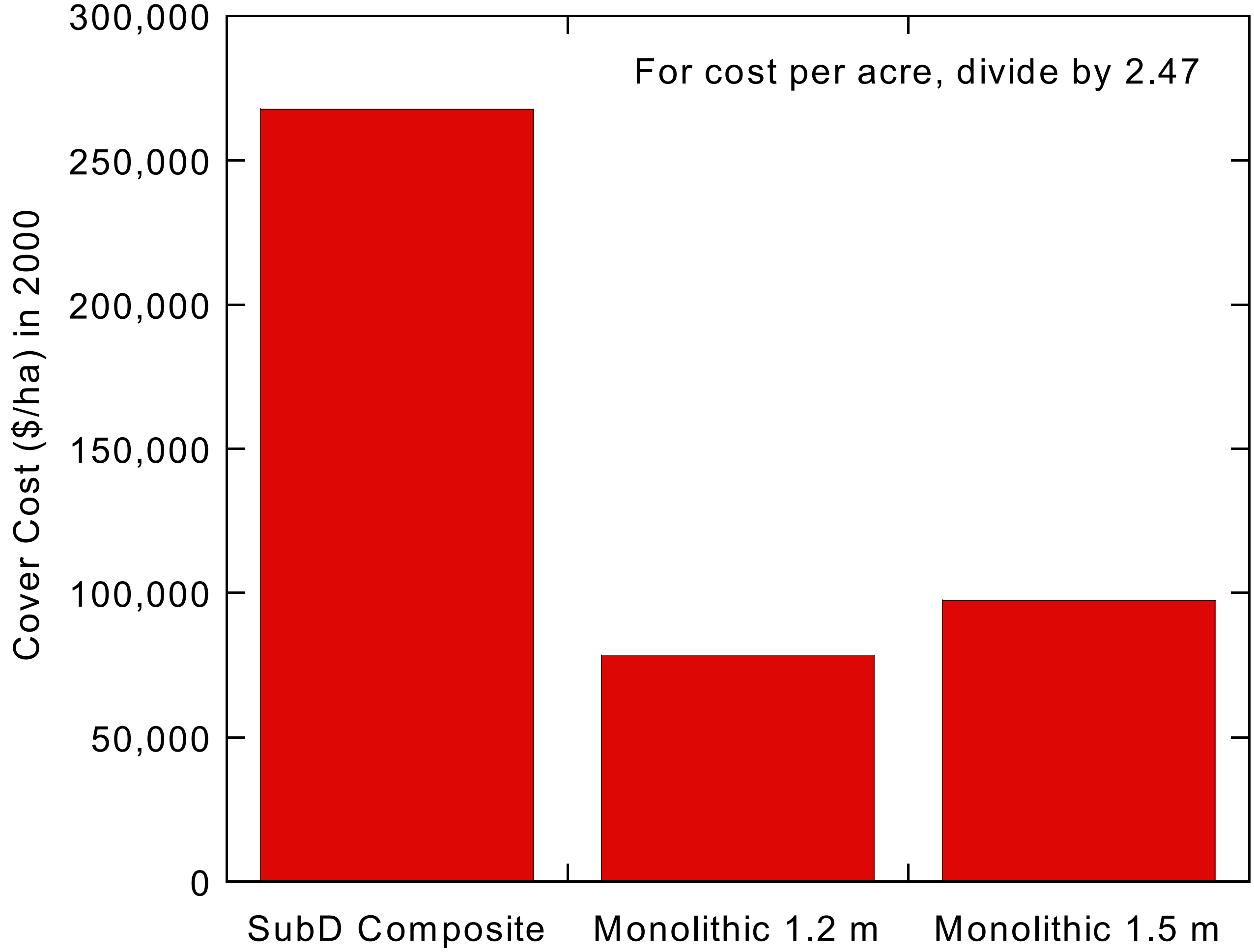
- Replace clay caps & composite caps (RCRA C & D) for solid waste landfills or similar facilities following the same or comparable regulations (e.g., Superfund CAMUs following RCRA ARARs, mine waste repositories).

- Caps for bioreactor landfills where specific water input is desired (i.e., controlled flow cap)

- Significant cost savings (~$50 to $75k per acre) relative to prescriptive caps.

- Employ natural materials and principles and thus fit well with nature.

Example of Potential Cost Savings



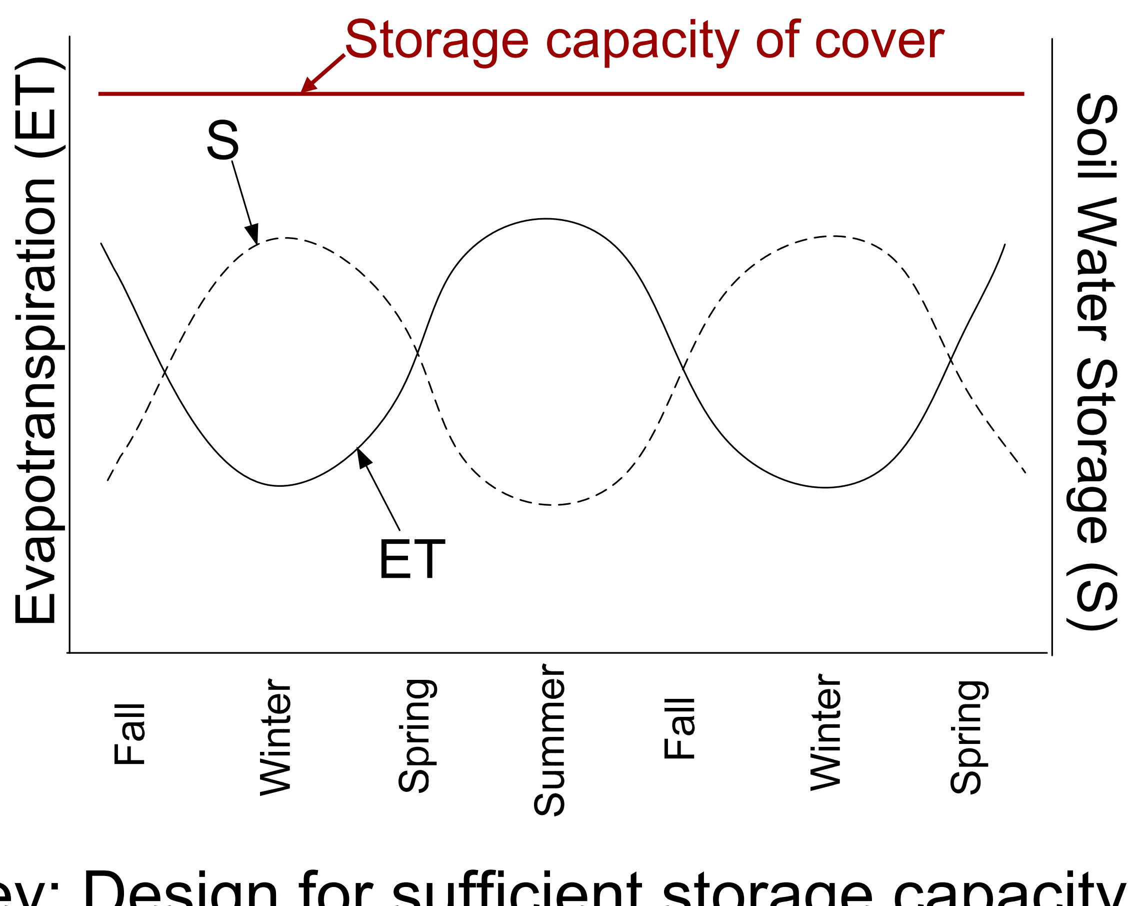
Subtitle D composite for this site consists of 450 mm of fine-grained soil with saturated hydraulic conductivity < 10^{-5} cm/s, 1 mm geomembrane, drainage layer, and 300 mm surface layer.

> 64% cost savings with water balance cover

How Do Water Balance Covers Work?

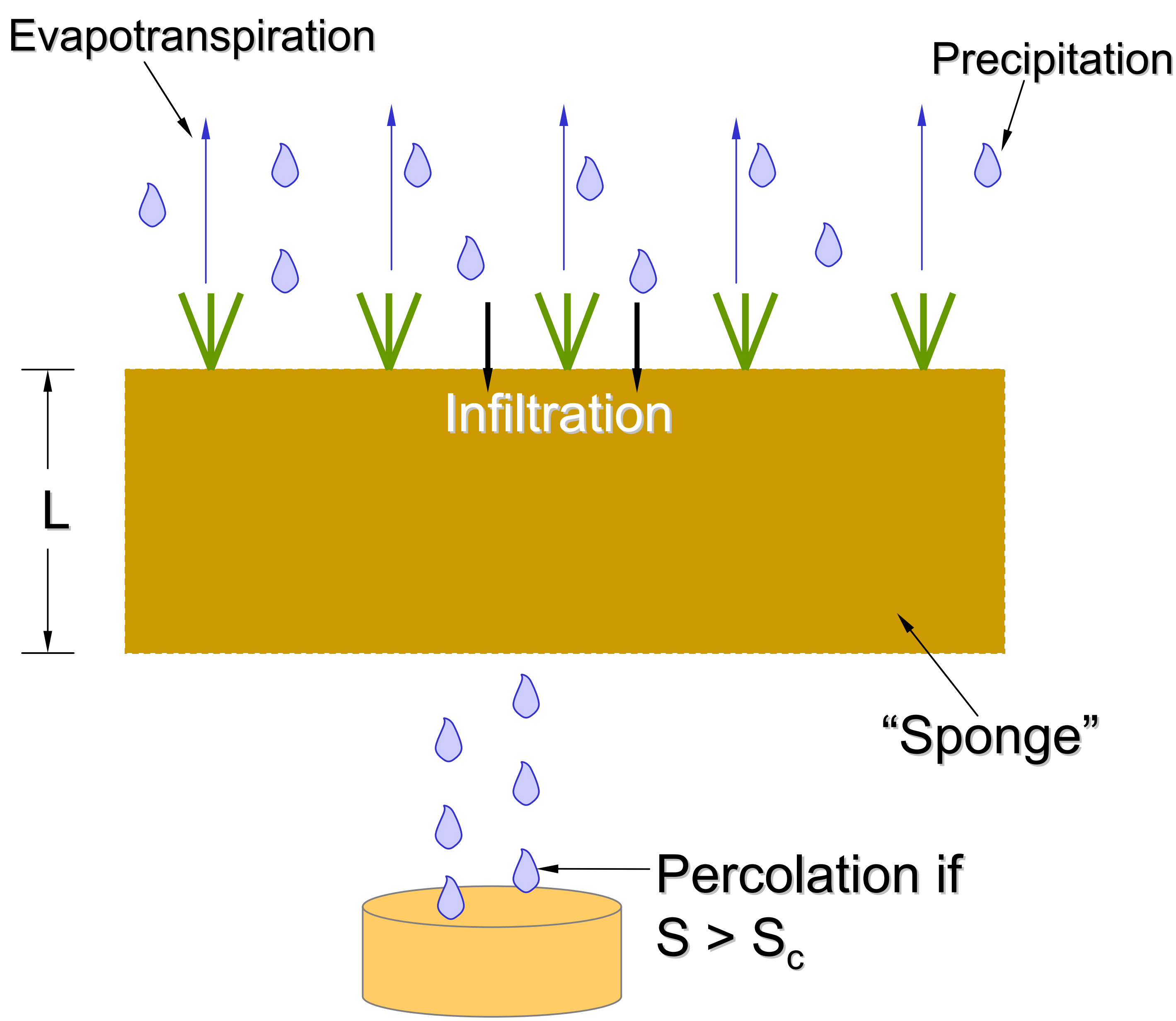
Rely on the natural water storage capacity of finer textured soils.

Reply on the water removal capabilities of evaporation and transpiration.



Key: Design for sufficient storage capacity to retain water that accumulates during periods with low ET with *limited or desired* percolation.

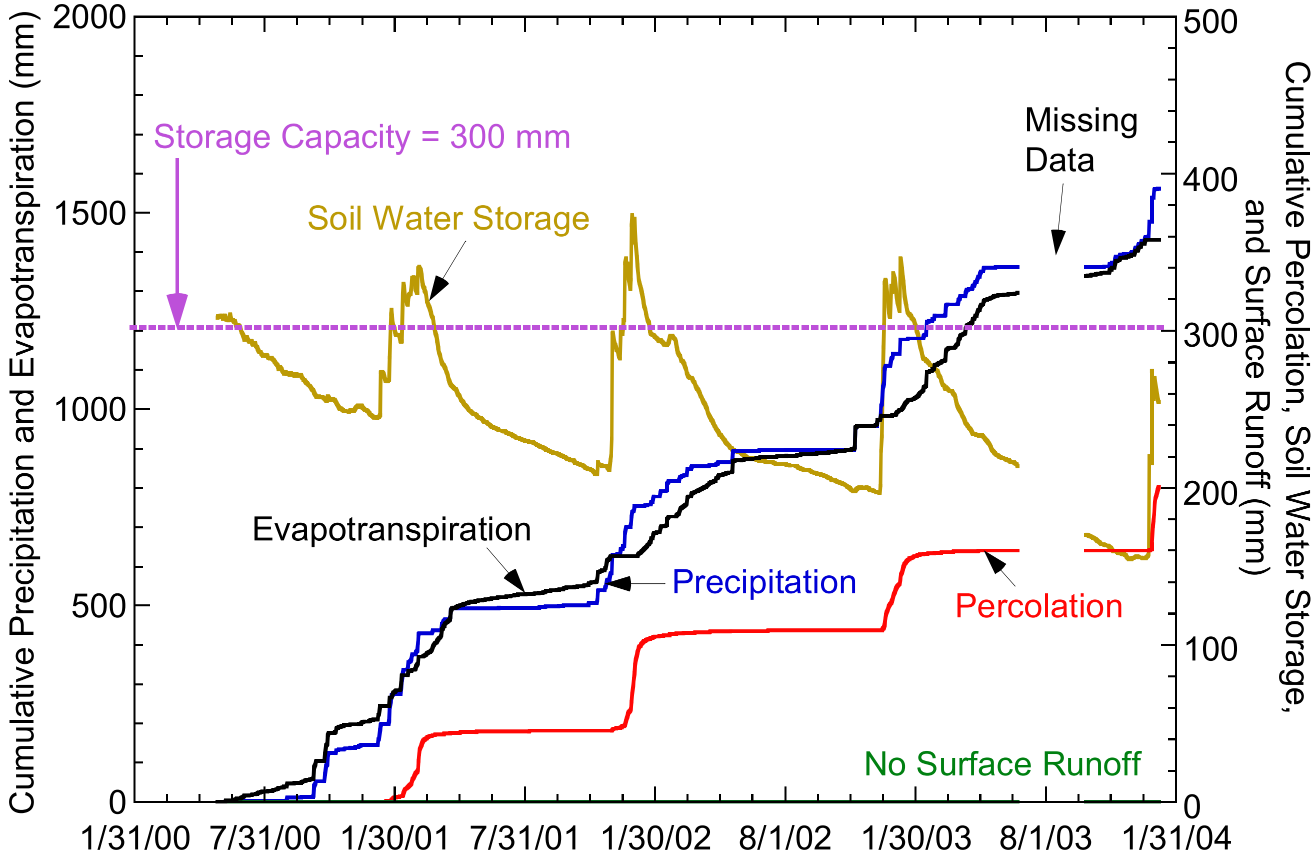
Sponge Concept



S = soil water storage

S_c = soil water storage capacity

Field Data - Site in Marina, CA

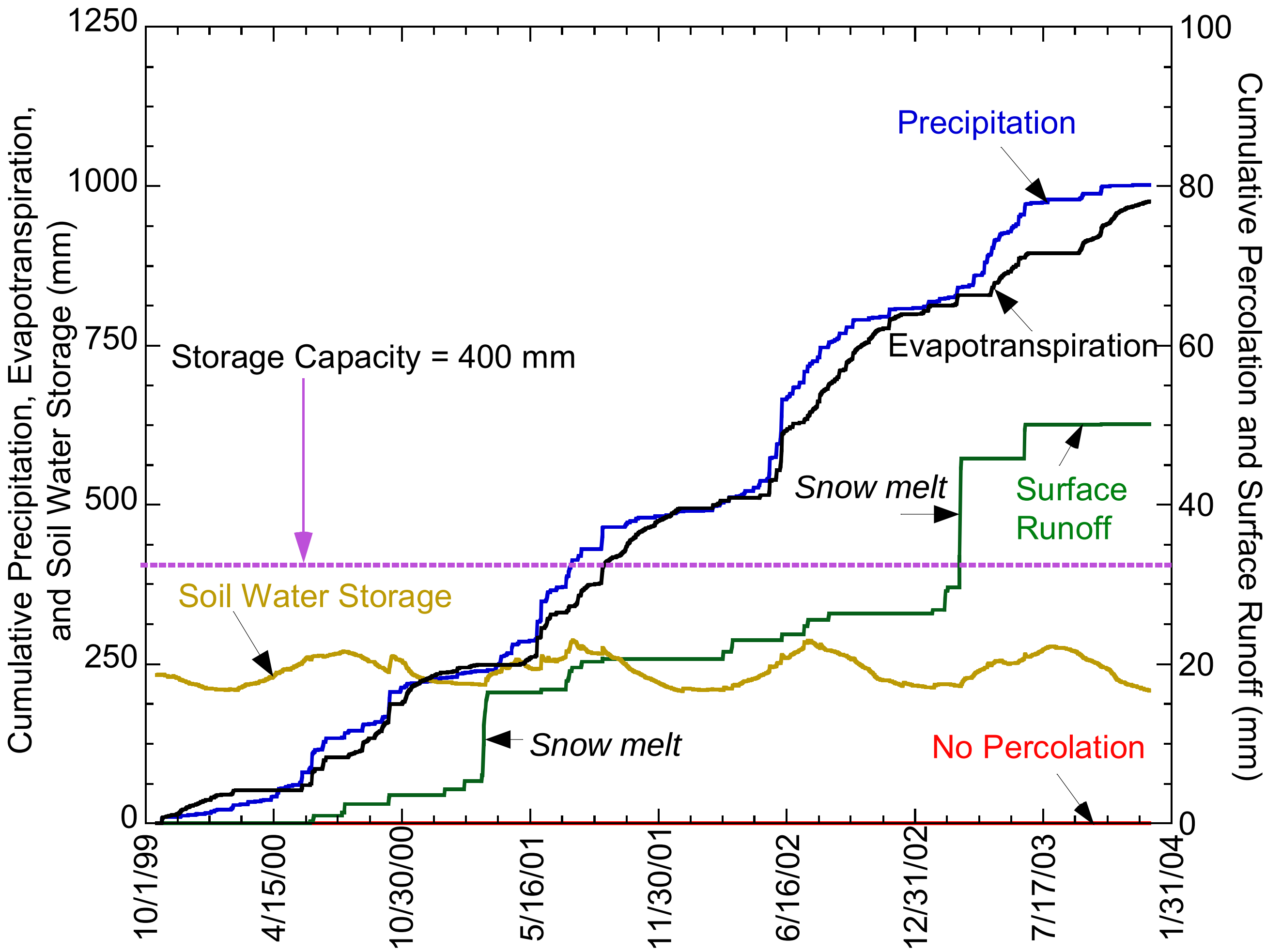


Data from USEPA's Alternative Cover Assessment Program (ACAP)

Soil water storage is seasonal. Withdrawal of water increased as plants matured

Storage capacity ~ 300 mm. Percolation occurs every year, when storage capacity is exceeded.

Field Data - Site in Helena, MT



Data from USEPA's Alternative Cover Assessment Program (ACAP)

Storage capacity ~ 400 mm. No percolation has occurred because storage capacity has not been exceeded.

Key Design Questions

- What is the design objective?
- How much water must be stored?
- How much water can be stored … what is the *storage capacity*?
- How much water can be removed … or how *dry* does the cover become?

Design Criteria

- Acceptable percolation

  regulatory driven (e.g., 1-3 mm/yr, equivalency)

  performance driven (e.g., acceptable percolation into waste to ensure minimal risk)

- Bathtub principle – cover shall not leak more than the base liner. Not realized in practice when profiles are matched.

- Acceptable gas flux (LFG, oxygen)

- Regulatory acceptance – will the agency accept the design?

- Sustainable for expected lifetime or maintenance period – life cycle cost?

- Acceptable capital cost?

- Congruent and consistent with surroundings and future land use?

Part 258 Municipal Solid Waste (MSW) Landfills Subpart F Closure and Post-Closure Care

258.60 - Closure Criteria

"… all MSWLF units must install a final cover system that is designed to minimize infiltration and erosion."

258.60 (b)(1)&(2) - Provision for Alternatives

- an infiltration layer that provides equivalent reduction in infiltration *as specified above*

- erosion layer that provides equivalent protection from wind and water erosion as specified above

What does "minimize" mean?

Infiltration:

- No quantitative criterion in federal and most state regulations. Infiltration is 'defined' by percolation from a cover with prescribed material properties … note: infiltration in Subtitle D really is *percolation.*
- Have "permeability" less than or equal to the permeability of any bottom liner system, or natural sub-soils present, or ≤ 10^{-5} cm/s (bathtub criteria). ????
- Infiltration layer of at least 18 in of earthen material

Erosion:

- Erosion layer ≤ 6 in thick that can sustain vegetation

MSW Bottom Liner Systems & Corresponding Conventional Covers

(USEPA CFR40 Amendments)

No Liner

- 6 in erosion layer
- 18 in having $K_s \leq 10^{-5}$ cm/s

Compacted Soil Liners
(clay liners with $K_s \leq 10^{-6}$ or 10^{-7} cm/s)

- 6 in erosion layer
- 18 in having $K_s \leq 10^{-6}$ or 10^{-7} cm/s

Composite Liners
(geomembrane over clay barrier)

- 6 in. erosion layer
- Geomembrane
- 18 in. having Ksat $\leq 10^{-5}$ cm/s

Note: Subtitle D requires a cover ≥ 24-in thick. Water balance cover thickness driven by performance criteria.

Percolation Criteria for Cover Designs Requiring Equivalency

(from ACAP evaluation criteria)

Type of Barrier in Conventional Cover	Equivalent Percolation Rate	
	Humid Climate	Semi-Arid or Arid Climate
No Barrier or Clay Barrier	30 mm/yr 200 mm/yr?	10 mm/yr 20 mm/yr?
Composite Barrier	3 mm/yr 5 mm/yr?	

Do not *necessarily* apply to designs based on other performance criteria (e.g., performance driven percolation rate or risk-based design).

Which regions are practical for water balance covers?

As an 'equivalent' replacement of RCRA C & D caps with geomembranes:

Regions where precipitation << potential evapotranspiration (semi-arid regions)

Better in regions where snowpack is minimal.

Regions with wet summers rather than wet winters

As a replacement of RCRA D caps with clay barriers:

If comparison is based on *observed performance*, equivalency practical in most regions of N. America.

Design Philosophy

RCRA or Conventional Designs

- regulatory engineering
- construct what is stated in regulations
- methods & materials requirements
- no quantitative performance criterion

Water Balance Cover Design

- determine performance criterion (e.g., percolation ≤ prescriptive cover)
- select layering to meet a quantitative performance criterion
- analyze to ensure alternative cover meets performance criterion

Note: WBC design philosophy generally requires more upfront costs for design work and laboratory analyses.

Issues for the Site Owner

Cost:

- WBC design costs higher
- WBC construction may cost less
- Long-term maintenance

Performance:

- Regulatory requirements – equivalency?
- Performance criteria depend on type of waste and regulatory setting (RCRA C or D)

Permitting:

- WBCs require more regulatory interaction
- Regulatory acceptance and knowledge highly variable
- Well-defined prescriptive design vs. site-specific flexible design process; requires more time and effort.

Issues for the Designer

- Feasibility study
  - Initial site assessment
  - Performance criteria, success likely?
  - Economic analysis
- Design selection and validation
  - Potential designs
  - How do they function?
  - Possible failure modes?
- Site characterization
  - Soil properties – different from other engineering projects
  - Plants – water balance & erosion control
  - Climate – details make the difference
- Modeling for evaluation and prediction
- Construction: can this cover be built?

Issues for the Regulator

- Change in Philosophy:
  - Conventional: materials & methods approach is comfortable and straightforward to evaluate.
  - WBC: site specific performance-based design makes evaluation difficult.
- Performance Evaluation:
  - Do WBCs work in this state/region?
  - How to demonstrate satisfactory design?
- Site Characterization:
  - Required design parameters & methods
  - Site-specific data vs. literature values
- Modeling and Performance Prediction:
  - Which models should be used?
  - What are reasonable input parameters?
  - What is the accuracy of our predictive capability?
- Monitoring and long-term maintenance

Issue for Everybody: Are Water Balance Covers for Every Site? … No

- Performance: Suitability must be assessed on site-by-site basis using rational principles based in science and engineering. In some cases, meeting performance goals may not be possible/practical with a water balance cover.

- Cost: Costs are generally, but not always, lower than for conventional cover. Must consider design/permitting, capital, and O&M costs.

- Logistics: More hurdles to jump in the approval process.