

# EVAPOTRANSPIRATION SURFACE BARRIER CONCEPTS AND DESIGN

Citizens Advisory Board Meeting

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*Idaho Dept. of Environmental Quality*

# GOALS AND OBJECTIVES

- Short History of Cover Design
- Principles of ET Covers
- Proof of Concept/Examples
- Design Criteria and Conceptual Design for SDA
- Why the Cover Will Work



# HISTORY OF COVER DESIGN

- Traditional RCRA Low Permeability “Barrier” Concept
- Performance Criteria and Design in Regulations
- Performance Over Time
- Evolution Towards the ET Design (Solid Waste Landfill Regulations and Acceptability of Alternative Designs)

# PERFORMANCE CRITERIA

- Depends on the Presence/Absence of a Liner (RCRA Subtitle D)
- Can be Prescriptive (specific minimum thicknesses of layers) or Performance Based
- Performance is Typically Tied to Material Properties
- Expressed as conductivity, amount of percolation per year, or vaguer terms like “minimize infiltration”



# HISTORY OF COVER DESIGN

- Traditional RCRA Low Permeability “Barrier” Concept

## *RCRA Subtitle D Cap*

-For non-hazardous waste landfills. Cover design is a function of the bottom liner system or natural subsoils present.

-Cover specifications:

- the material must have a permeability no greater than 0.36 inches/day ( $1\text{E}-5$  cm/sec), or equivalent permeability of any bottom liner or natural subsoils present, whichever is less.

- Infiltration layer  $\geq$  18 inches of earthen material.

- Erosion control layer at least 6 inches of earthen material capable of sustaining native plant growth.

-All covers should be designed to prevent the "bathtub" effect.

# HISTORY OF COVER DESIGN

- Traditional RCRA Low Permeability “Barrier” Concept

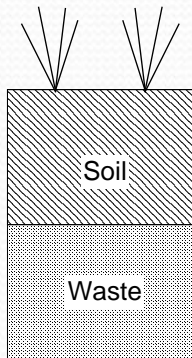
## *RCRA Subtitle C Cap (Composite Design)*

- A multilayered landfill cap baseline design for hazardous waste applications.
- Upper vegetative (topsoil) layer, a drainage layer, a geomembrane and a low permeability layer
- Low Permeability layer often consists of a synthetic liner over 2 feet of compacted clay.

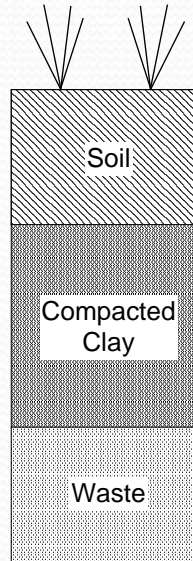


# RCRA BARRIER DESIGN

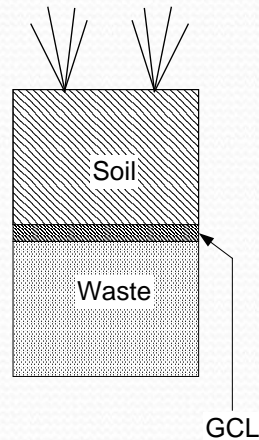
Simple  
Soil  
Cover



Compacted  
Clay  
Cover

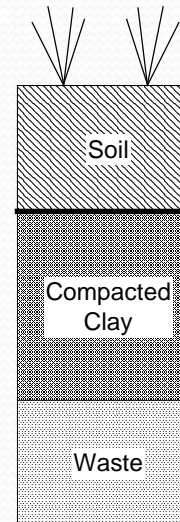


Geosynthetic  
Clay Liner  
(GCL)  
Cover

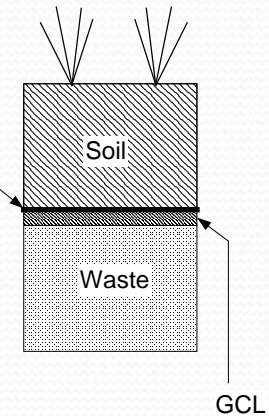


Composite Covers

Composite with  
Clay Barrier



Composite with  
GCL



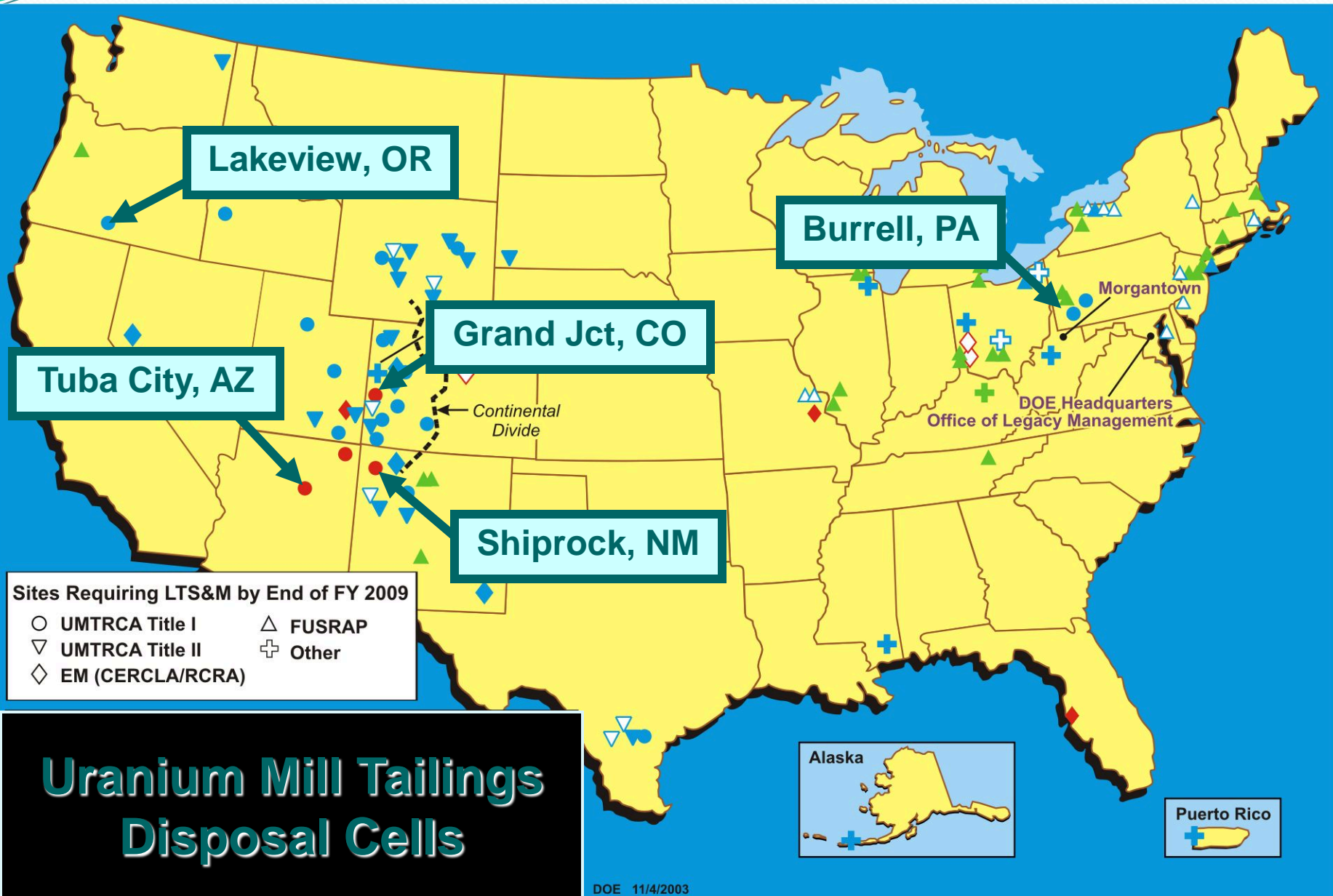
Geomembrane  
(GM)

# PERFORMANCE OVER TIME

- Uranium Mill Tailings Radiation Control Act (UMTRCA) Cover Assessment
- Solid Waste Landfill Experience



# Performance of UMTRCA Conventional Covers



# PERFORMANCE OVER TIME

- UMTRCA Cover Assessment

Most UMTRCA sites use engineered covers for *long-term* containment of radionuclides and metals in landfill disposal cells

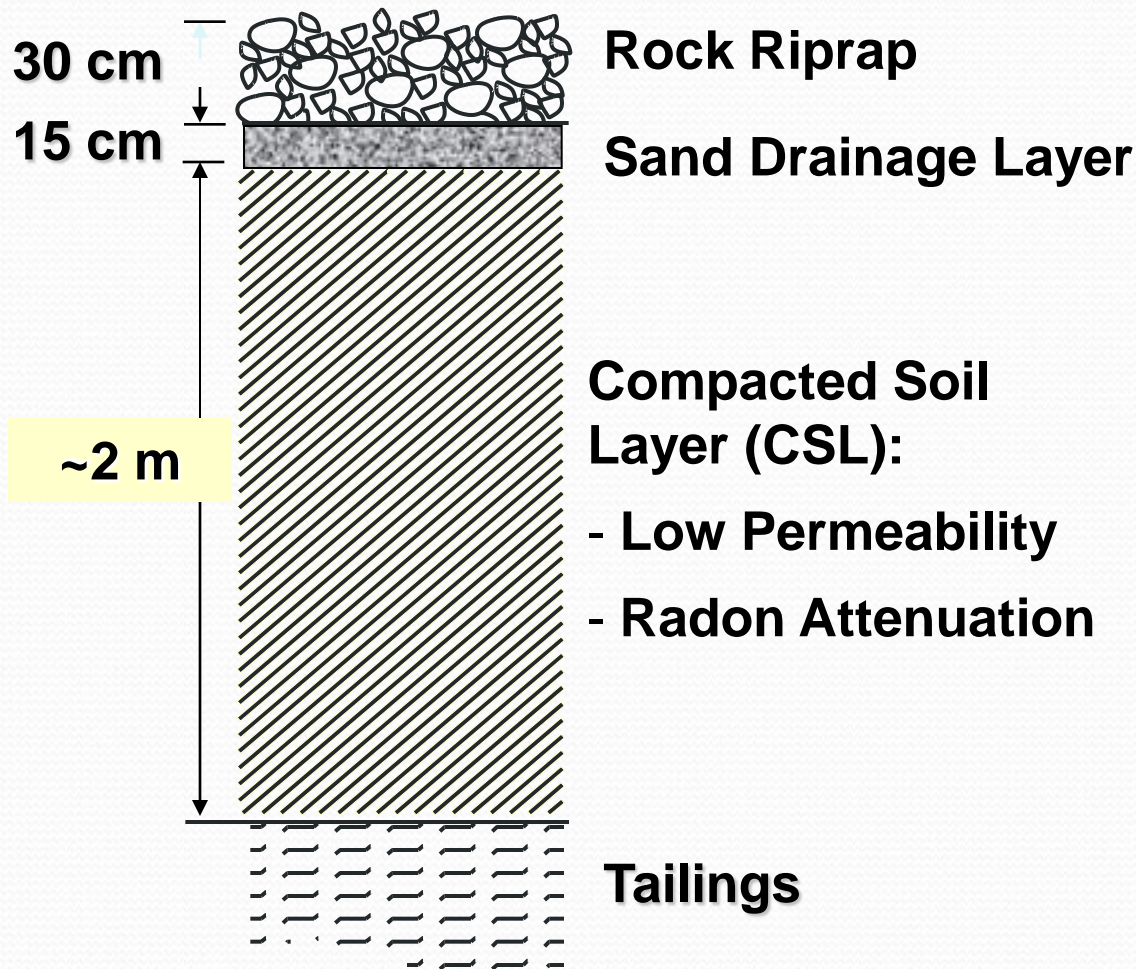
## Cover *Design* Standards

- Radon Flux  $< 20 \text{ pCi/m}^2/\text{s}$
- Saturated Hydraulic Conductivity  
 $K_{\text{sat}} < 0.0003 \text{ feet/day or}$
- Drainage flux from cover  $< 0.1 \text{ inches/year}$
- Longevity: 200 – 1000 years



# PERFORMANCE OVER TIME

- UMTRCA Cover Assessment



# PERFORMANCE OVER TIME

Barriers Can Be Compromised by:

- Root Penetration
- Freeze-Thaw
- Drying
- Organisms
- Rock Riprap fostered development of unwanted vegetation
- Conductivity was increased 100-1000x greater than design criteria

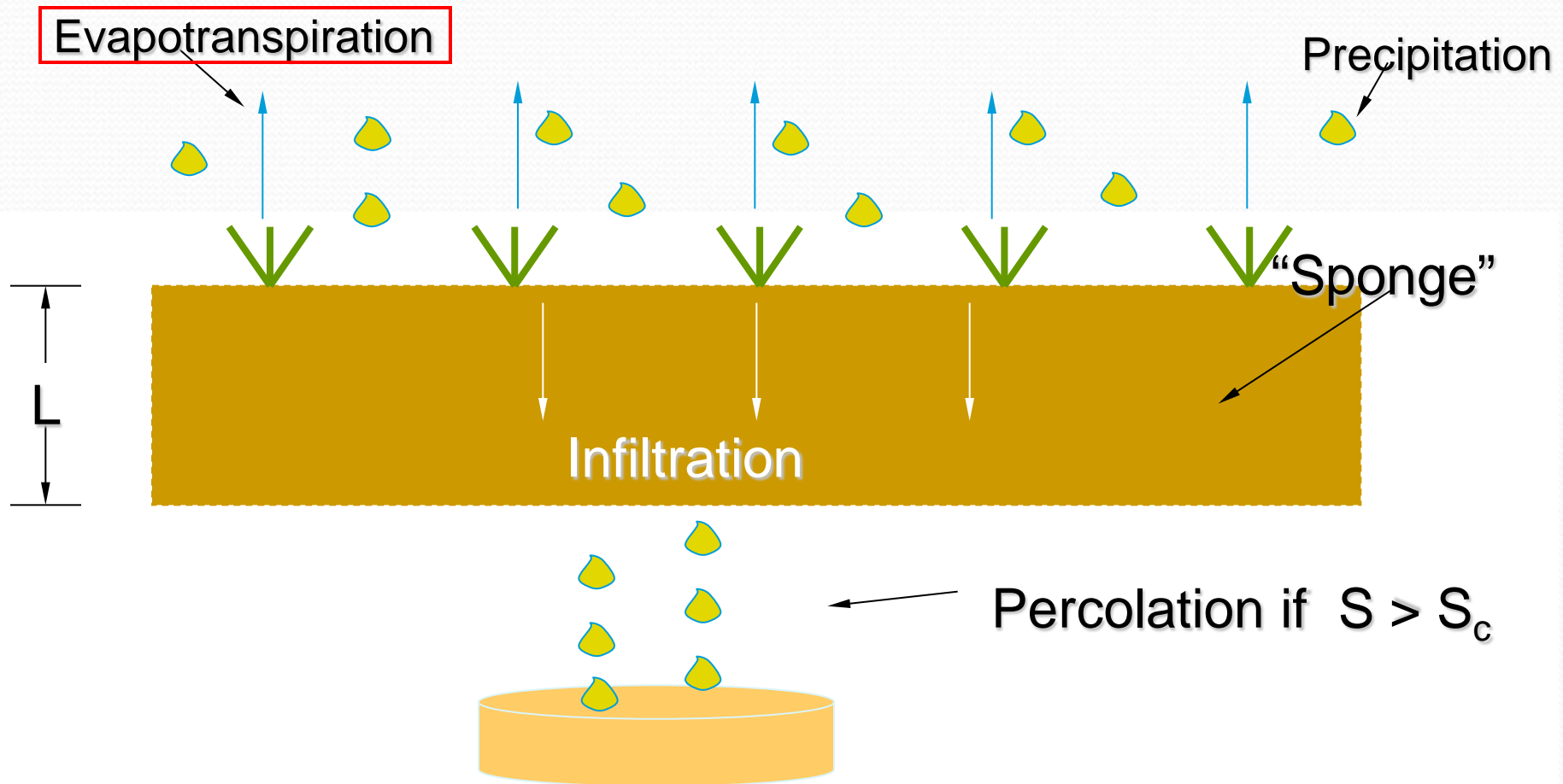
As a result of these issues alternative designs began to be developed and tested



# ET COVER PRINCIPLES

- Based on Ecosystem Water Balance Concepts
- Principles of Soil Water Storage, Release and Movement

# SURFACE BARRIER WATER BALANCE



$S$  = soil water storage  
 $S_c$  = soil water storage capacity



# FACTORS AFFECTING STORAGE AND RELEASE FROM SOILS

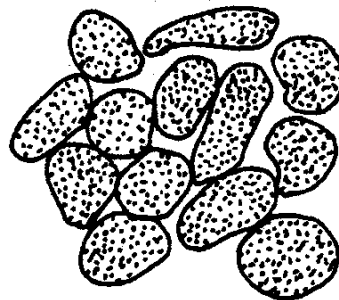
- Water Retention Characteristics of Soils
- Layering
- Meteorological Conditions (Amount, Timing, Form of Precipitation, Temperature)
- Vegetation (Transpiration)
- Soil and Surface Cover (Evaporation)

# IMPORTANT SOIL PROPERTIES FOR WATER STORAGE AND RELEASE

- Porosity and Pore Size Distribution
- Water Holding Capacity (Clay = Silt Loam >> Sandy Loam)
- Conductivity



Clay



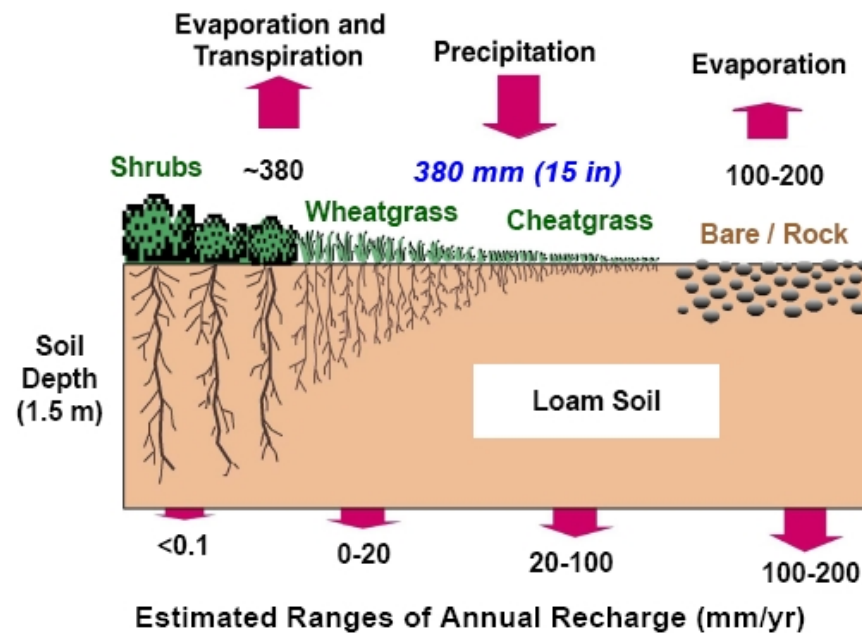
Sand



# EVAPOTRANSPIRATION

- Evaporation controlled by soil and climate
- Transpiration controlled by soil, climate, and vegetation
- Most Water Evaporated From Upper Foot of Soil
- Transpiration accounts for the bulk of ET

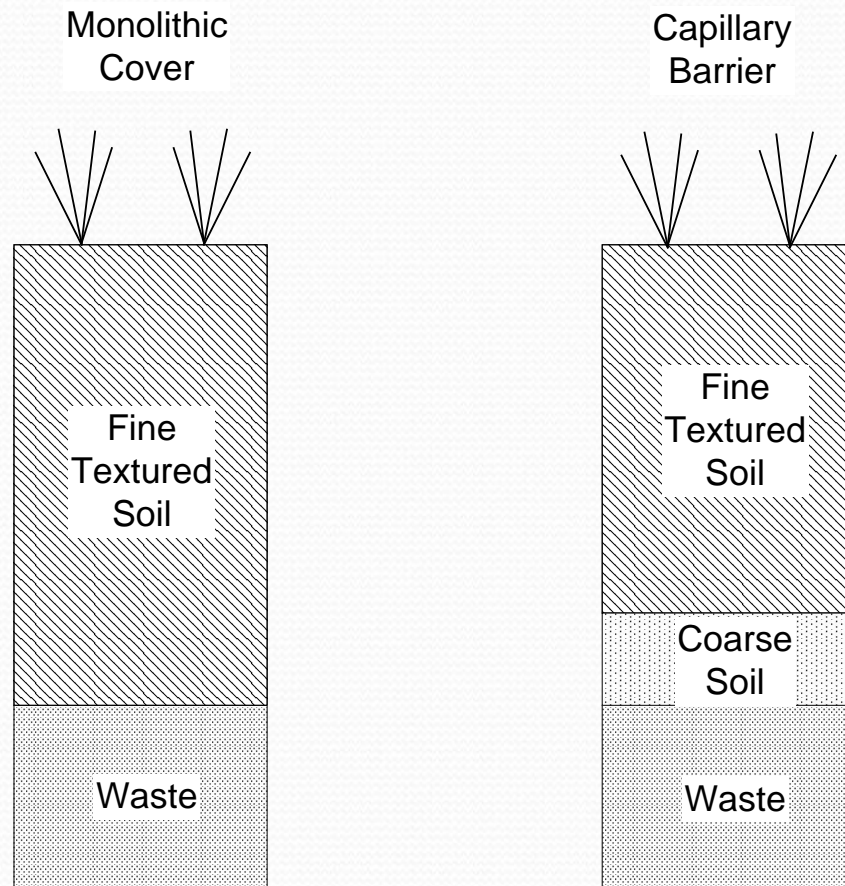
## Cover Water Balance: Role of Plants



(GW Gee)

# ET COVER VARIETIES

- Two Basic Types: Monolithic and Capillary Barrier

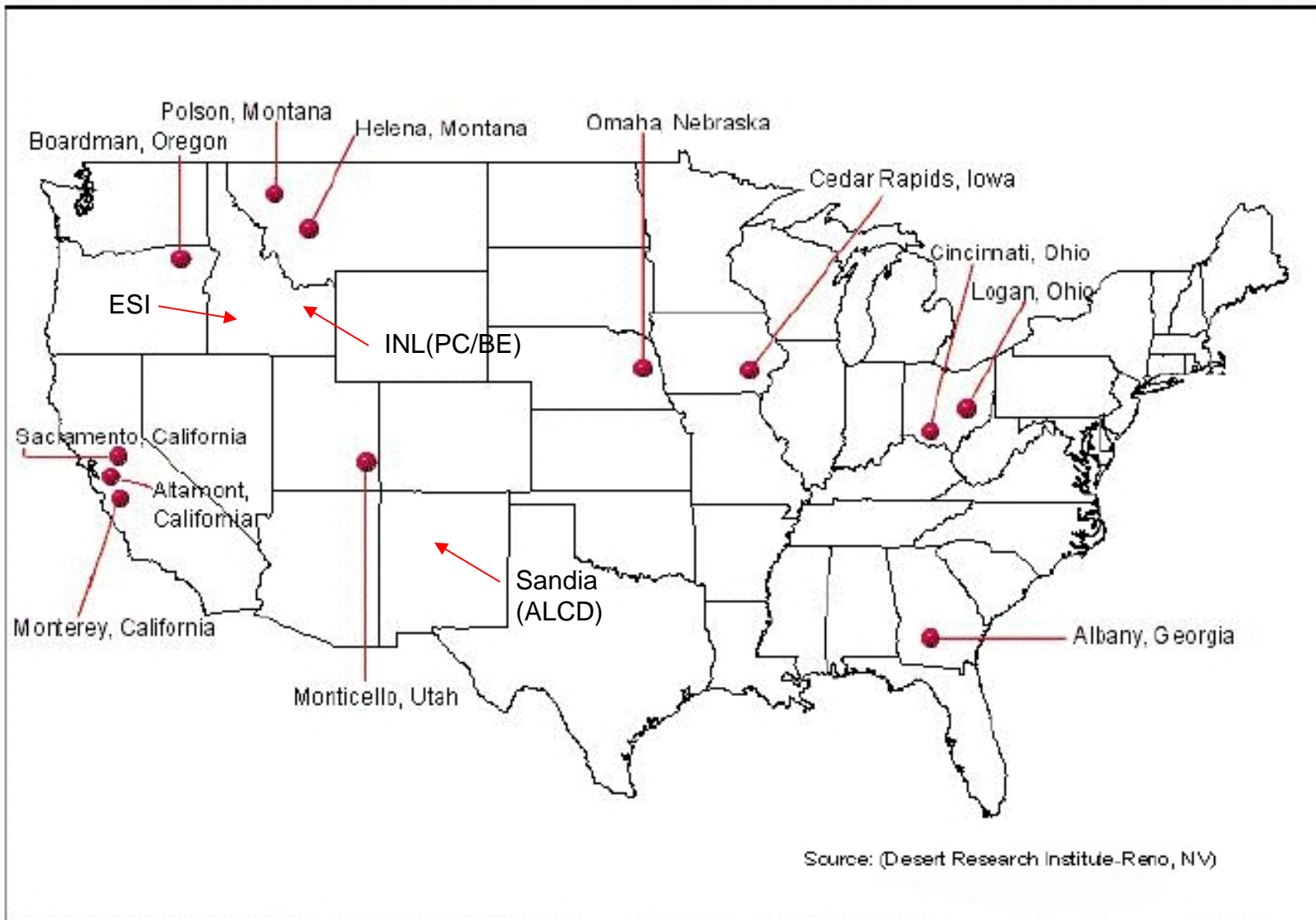




# ET COVER CONCEPT VALIDATION

- ACAP (Alternative Cover Assessment Program)
- SANDIA Lab (Alternative Landfill Cover Demonstration)
- UMTRA (Monticello, Utah)
- INL (Protective Cap/Biobarrier Experiment and Engineered Barrier Test Facility)
- US Ecology (Southwest Idaho)
- Simplot (Smoky Canyon Mine) SE Idaho Phosphate
- Primary goals of these studies are to demonstrate equivalence to conventional covers and provide design guidance for specific cover components

# ACAP/OTHER FIELD SITES



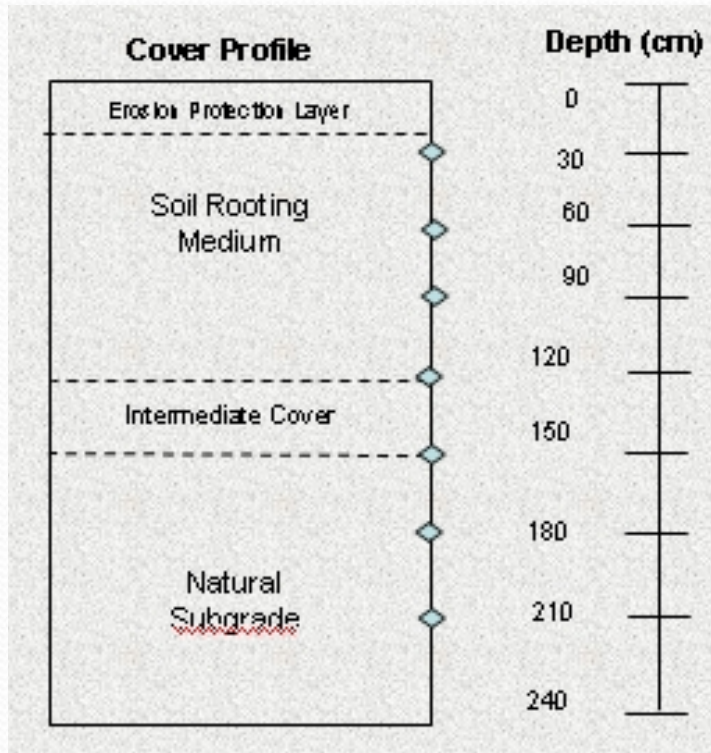


# ET COVER CONCEPT VALIDATION

- ACAP (Alternative Cover Assessment Program)
  - 11 Field Sites
  - 10 Conventional Covers (3 Compacted Soil, 7 Composite)
  - 14 Alternative Covers (8 Monolithic, 6 Capillary Barrier)
  - Percolation from Conventional *Composite* Covers in Arid Areas Averaged 0.06 inches/year vs. 0.09 inches/year for ET Covers. Demonstrates equivalence in performance.
  - Site Specific Design is Critical and Use of a Conservative Estimate of Storage Capacity of Soils is Important

# ET COVER CONCEPT VALIDATION

- US Ecology (Southwest Idaho- Grandview)

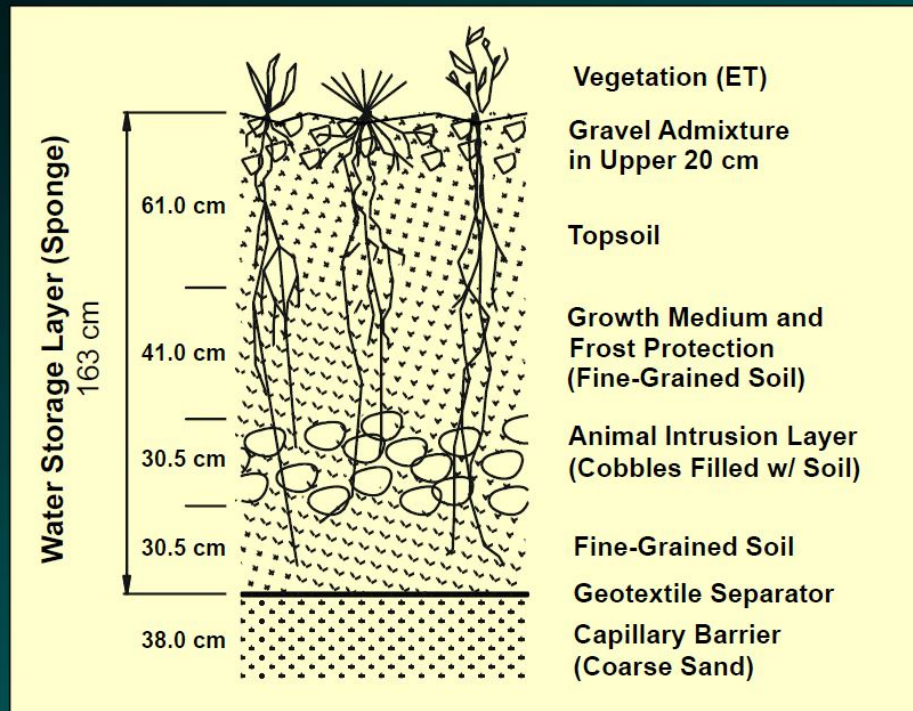


During the five years of the demonstration infiltration did not appear to move below about 24 inches. Annual percolation was estimated at 0.00007 inches. Average annual precipitation was 5.9 inches.



# ET COVER CONCEPT VALIDATION

## Monticello Alternative Cover Design: ET / Capillary Barrier



Utilized a 7.5 Ac lysimeter. During the six years of the demonstration average annual percolation was 0.02 inches. Average annual precipitation was 15.4 inches.



# ET COVER CONCEPT VALIDATION

- SANDIA Lab (Alternative Landfill Cover Demonstration)





# ET COVER CONCEPT VALIDATION

- SANDIA Lab (Alternative Landfill Cover Demonstration)
  - Six different cover types were tested (3 conventional, 2 capillary barrier, 1 monolithic)
  - The measurement and demonstration period lasted from 1997-2002 and annual avg. precipitation was 9.7 inches
  - Average annual percolation was greatest for the Subtitle D cover (0.05 inches/year) and least for the ET Cover, Anisotropic Barrier, and Subtitle C cover (0.002 inches/year)
  - The GCL cover (variant of the Subtitle C) and Capillary Barrier cover were intermediate in percolation (0.02 and 0.006 inches/year)

# ET COVER CONCEPT VALIDATION

- INL (Engineered Barrier Test Facility and the Protective Cap/Biobarrier Experiment)
  - EBTF tested Monolith and Capillary Barrier designs to evaluate effects of extreme wetting and disturbance (lack of vegetation) on percolation and recovery of function. Operated 1996-1999
  - PCBE evaluated 4 cover designs (3 ET covers and 1 RCRA design), 2 vegetative types (native and crested wheatgrass), and 3 precipitation regimes (ambient, summer wet, and fall/spring wet). 1994-2006



# ENGINEERED BARRIER TEST FACILITY

- Monolith (9.8 feet soil) and Capillary Barrier (5.2 feet of soil over a 3 foot biobarrier/break
- Capillary Barrier designs stored more water, allowed more evaporation, and produced less drainage than Monolith designs
- Snowmelt following irrigations overloaded storage capacity of all designs
- Within two years of breakthrough Capillary Barrier design function was restored.

# PROTECTIVE CAP/BIOBARRIER

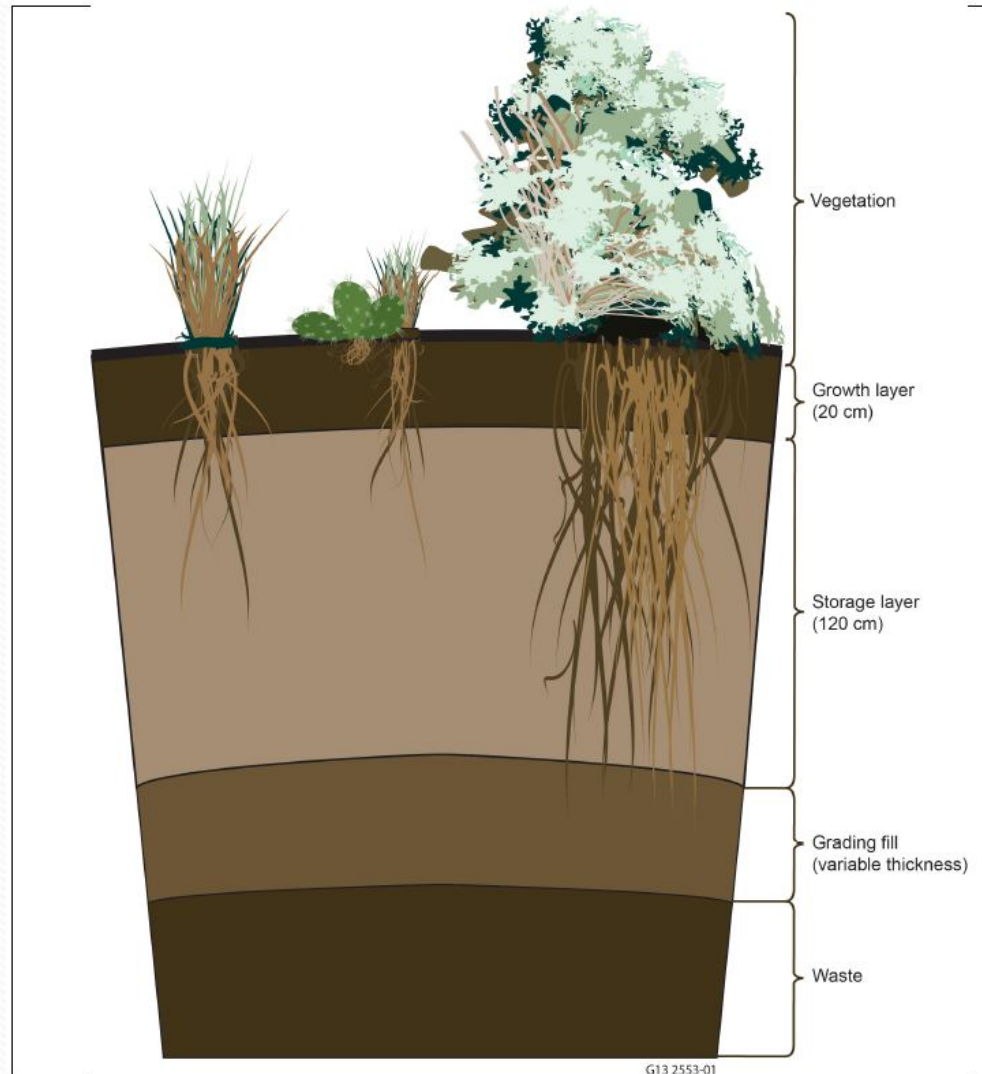
- Percolation through the bottom of caps was not measured directly
- 6.5 foot thick Monolith had most frequent and highest water accumulation at base
- Capillary barrier with deep biobarrier and native vegetation had best performance
- Relationships between vegetation, precipitation, and ET are complex when trying to predict performance



# DESIGN CRITERIA FOR THE SDA

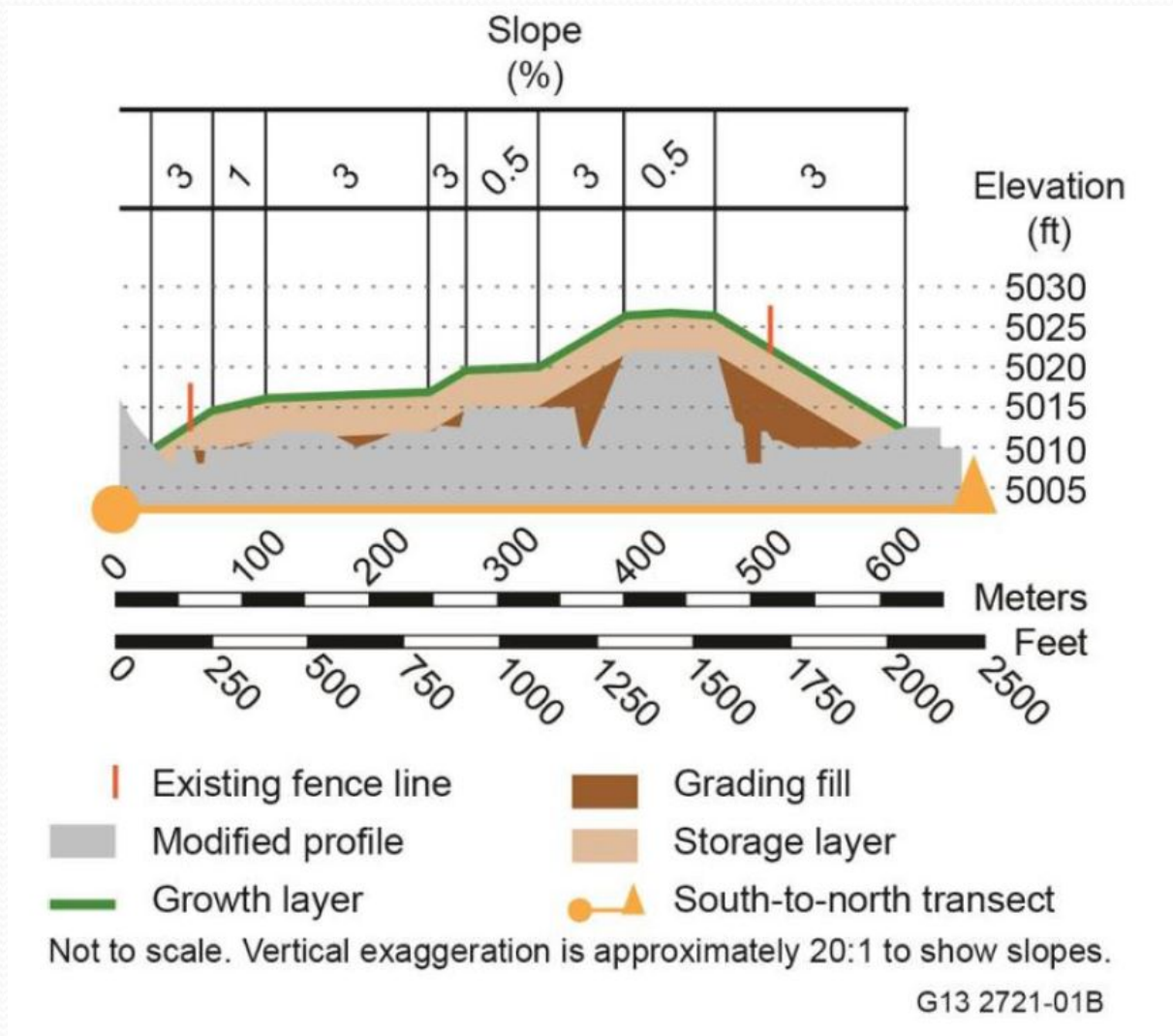
- Limit Moisture Infiltration (< 0.4 inches/year on avg.)
- Longevity (1000 years)
- Conformability to Differential Subsidence
- Biointrusion
- Erosion Resistance(Wind and Water)

# CONCEPTUAL DESIGN FOR THE SDA



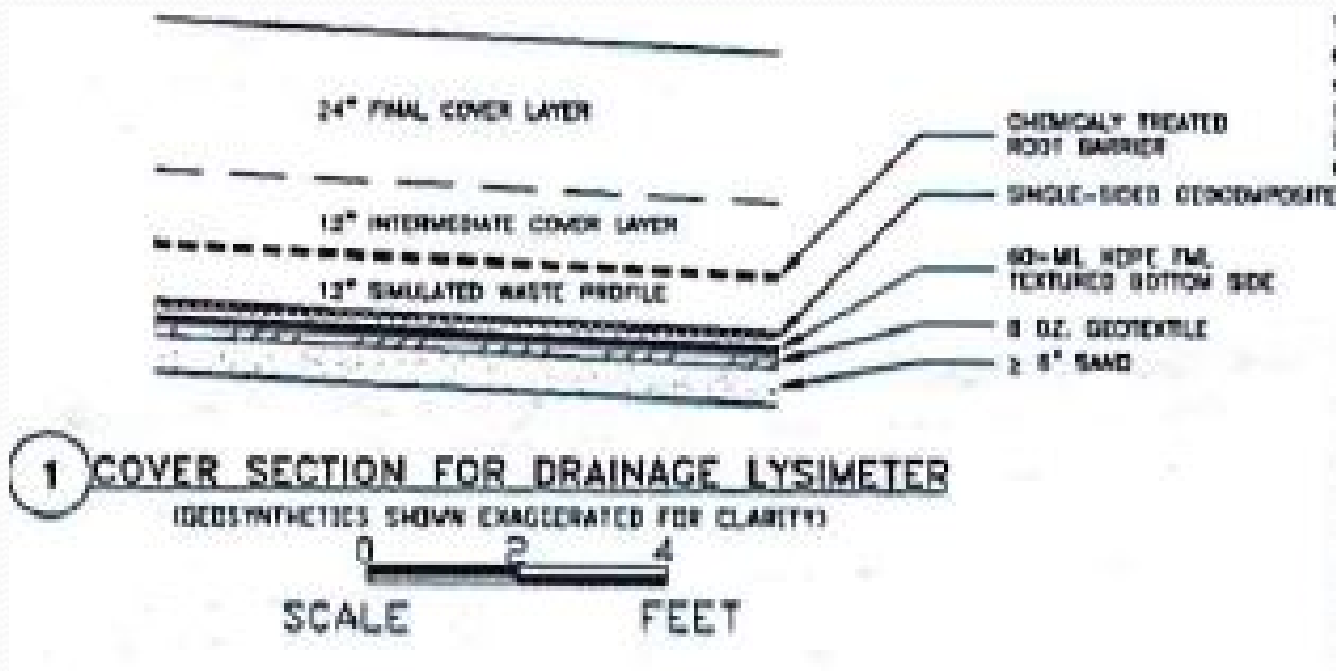


# CONCEPTUAL DESIGN FOR THE SDA



# ET COVER VERIFICATION

- US Ecology (LLRW Beatty, Nevada)



A monolithic ET type cover has been approved as a final cover design with a monitoring requirement for a lysimeter. Avg. annual precipitation is 6 inches.



# WHY IT WILL WORK?

- Limited Number of Layers- Simplicity
- Sufficient Water Storage Capacity for Design Conditions
- Sustain Long Term Performance with Low Maintenance and Easy Repairability
- Low Erosion Potential
- Demonstrated Proof of Concept/Verification of Performance with Monitoring
- Natural Analog/Recovery from Disturbance