

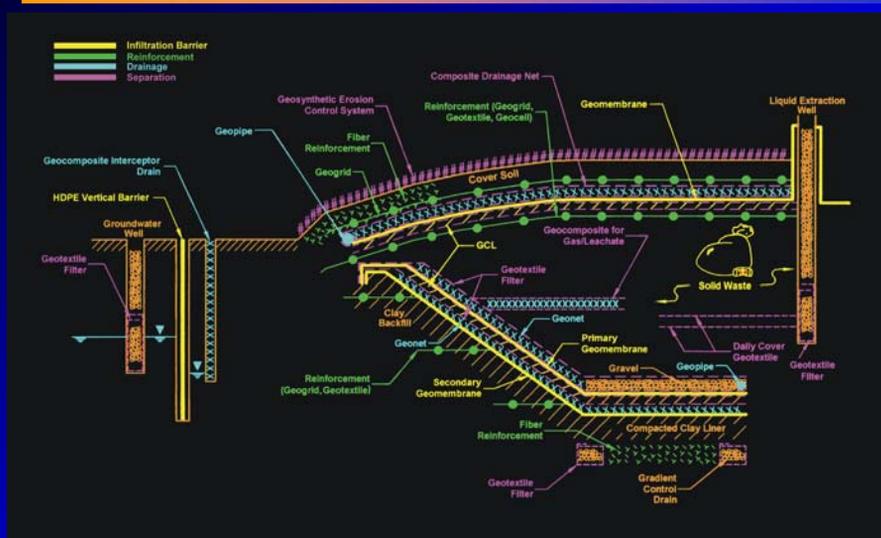
# *The Quest for Consistency among Regulatory, Design, and Post-closure Monitoring Frameworks*

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*The University of Texas at Austin*

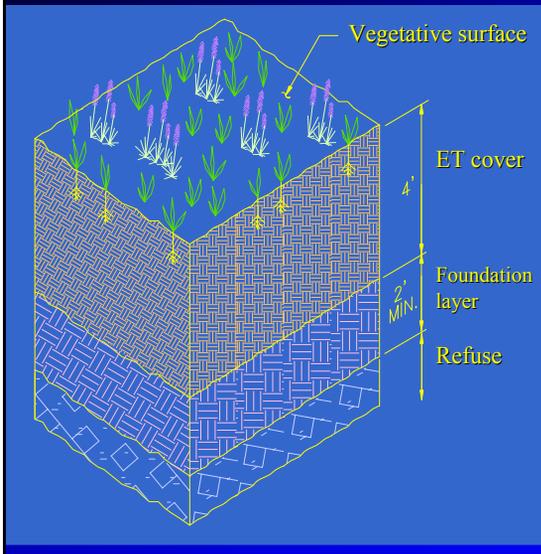


*Designing, Building, & Regulating  
Evapotranspiration (ET) Landfill Covers*  
March 10, 2004

## *What does a Modern Waste Containment Facility Look Like?*



## *What does an ET cover look like?*



### An ET cover:

- Controls percolation
- Is stable under static and seismic conditions
- Controls erosion
- Is aesthetically pleasing
- Is easy to maintain
- Is cost-effective

## *RCRA*

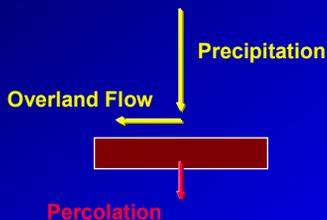
- RCRA §264 & 265 requires a prescriptive cover, which is assumed to minimize moisture migration, and a liner system. No monitoring of the cover.
- Requires ground water protection, i.e., ground water monitoring to detect problems/assess corrective actions

## *5-Year Reviews: CERCLA §121*

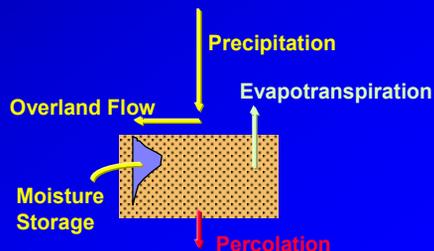
- Functioning as intended? Early indicators of potential remedy problems?
- Evaluation of the remedy and the determination of protectiveness should be based on and sufficiently supported by data observations.

## *Alternative Cover Systems for Arid Climates: Equivalence*

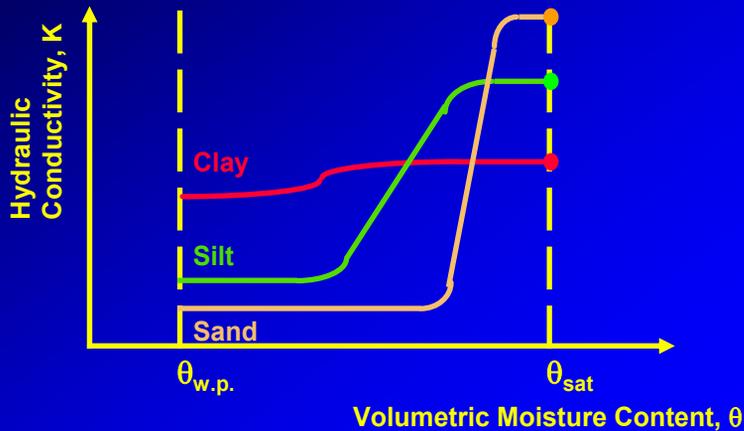
### Prescriptive Cover ("Barrier" System)



### ET cover ("Reservoir" System)



## What are the Hydraulic Properties of the ET cover Material?



## Equivalence Demonstration

- Percolation rate through the ET cover should be less than that in a prescriptive cover
- Comparative Percolation Criterion
  - $P_{ET} < MCPR \cdot P_p$
  - e.g.  $P_{ET} < P_p$  (for  $MCPR=1$ )
- Quantitative Percolation Criterion
  - $P_{ET} < MQPV$
  - e.g.  $P_{ET} < 1.3 \text{ mm/year}$

*A Comparative  
Percolation  
Criterion Case:  
OII Superfund Site*

*OII Superfund Landfill*



# OII Superfund Landfill

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- Site was originally a sand and gravel quarry
- 1948 Waste disposal initiated
- 1954 Disposal of liquids in native soil
- 1964 California buys 28 acres for Pomona Freeway (170,000 cu yards of waste in ROW)
- 1976 300,000,000 gallons liquid waste permitted
- 1978 Gas control initiated. Daily cover required
- 1983 Liquid disposal ceased
- 1984 Waste disposal ceased
- 1997 Final cover design completed
- 2000 Construction of cover system completed

## *OII Superfund Site*

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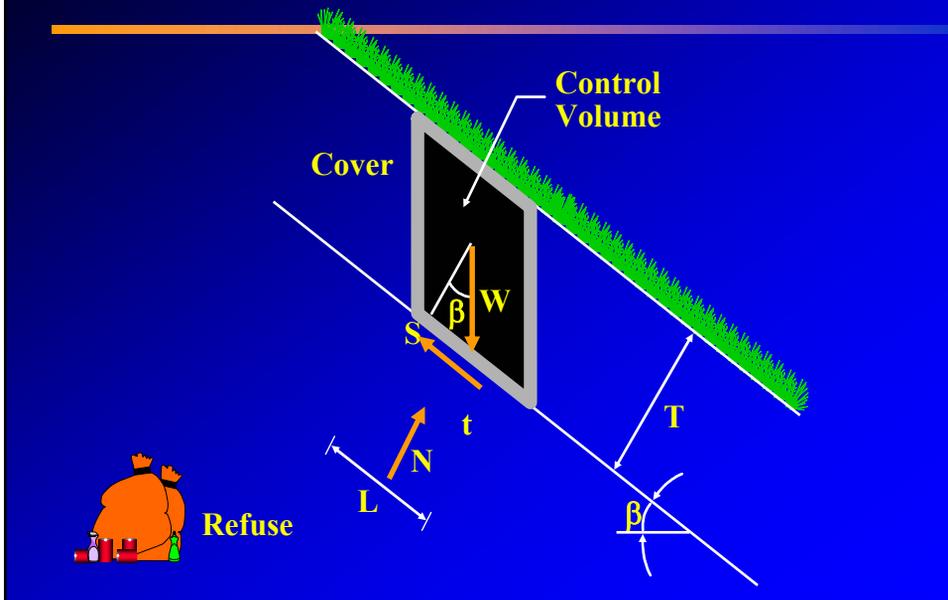
### Design considerations:

- Minimize percolation of liquids into waste
- Provide adequate stability under static and seismic conditions
- Ensure constructibility
- Account for refuse deformation response
- Provide erosion control
- Provide gas migration control

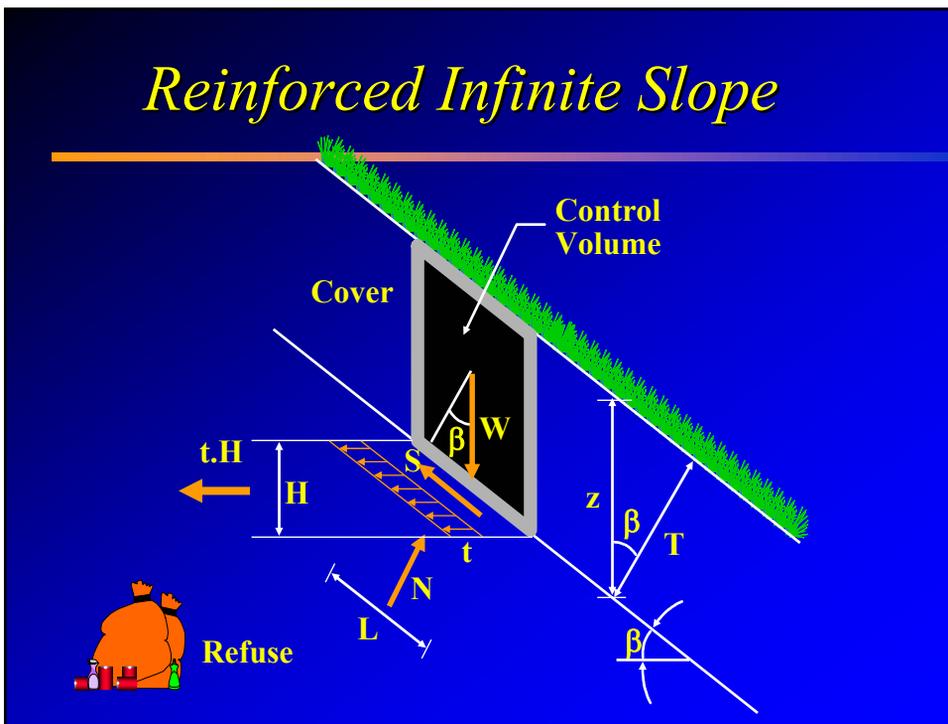
### Solution:

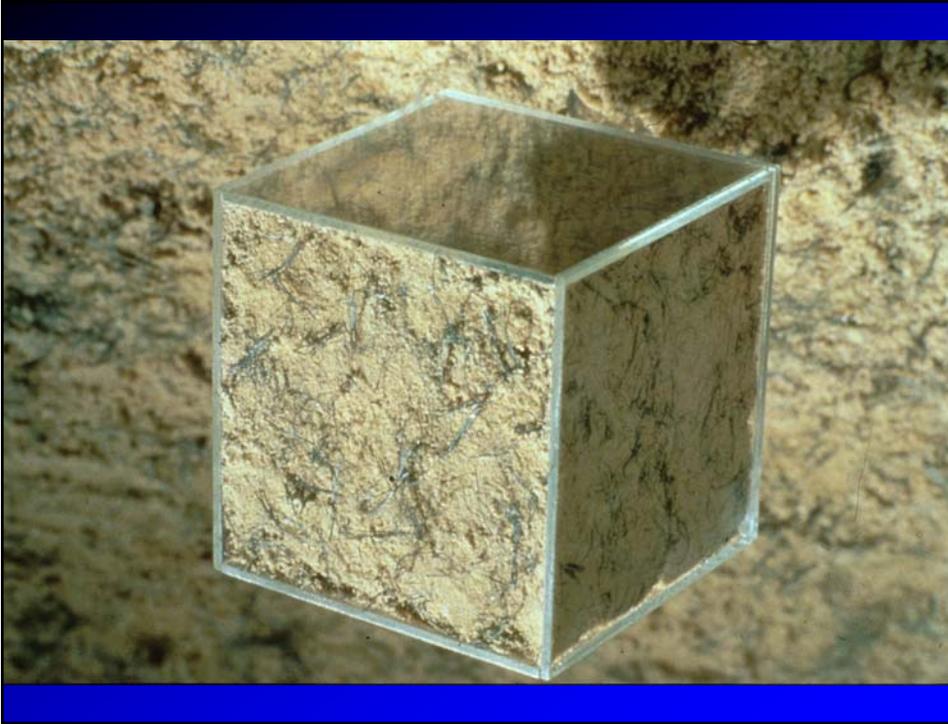
- Horizontal geogrid reinforcements anchored into solid waste
- Evapotranspirative cover system

## *Unreinforced Infinite Slope*

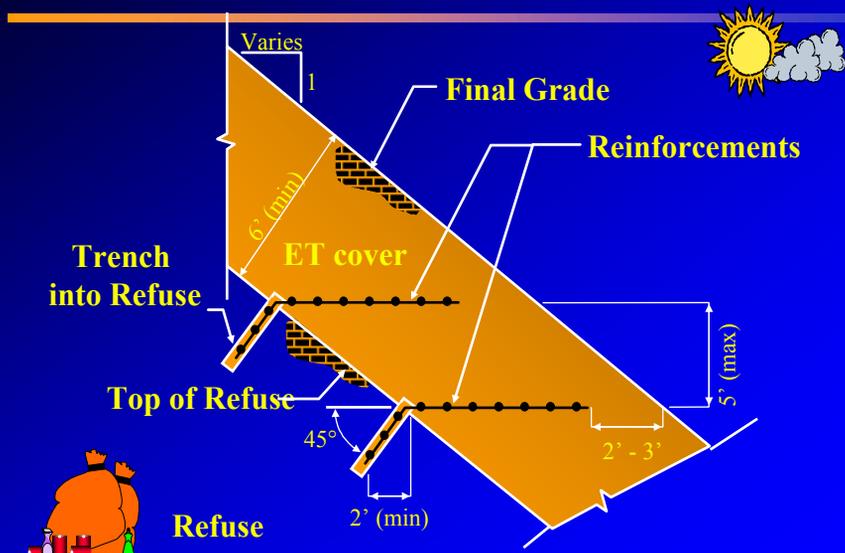


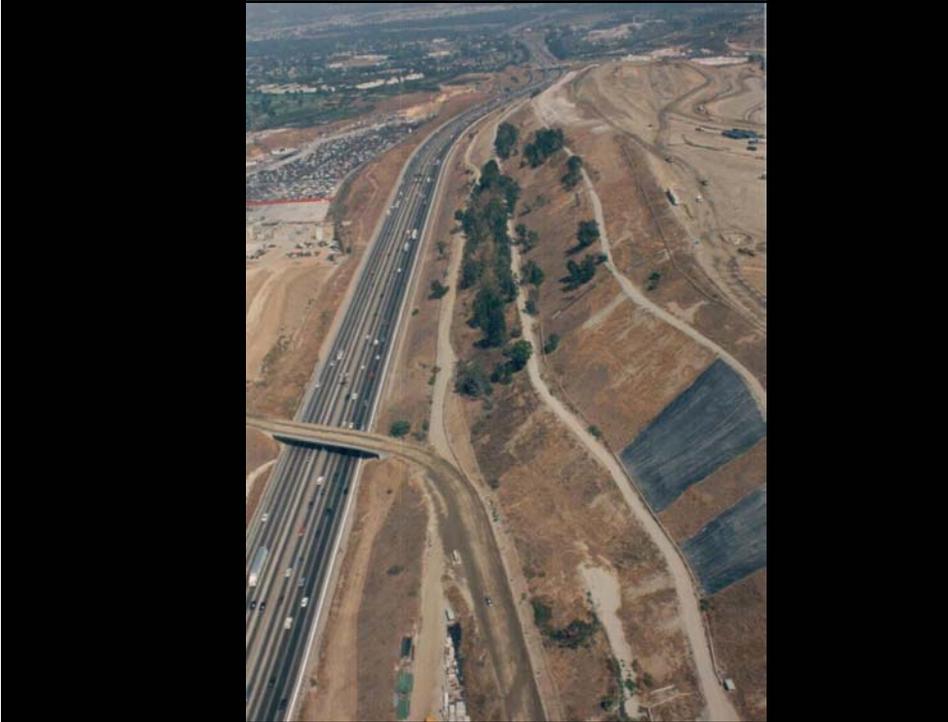
## *Reinforced Infinite Slope*





## Reinforced Veneer





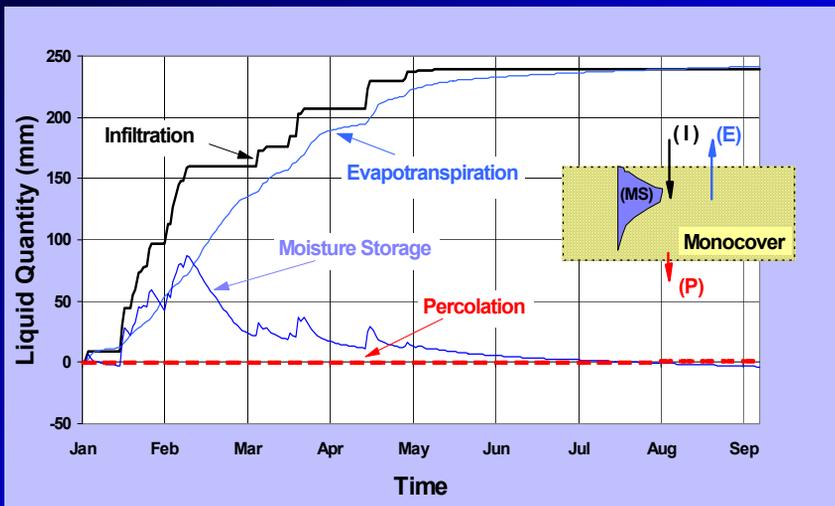
## *Equivalence Demonstration*

- Design criterion required that the percolation through the proposed ET cover be less than through the prescriptive cover.
- The prescriptive cover was defined by a consent decree as the State of California mandated prescriptive cover.
- The approach for evaluating equivalence was to compare percolation values estimated numerically through both covers when exposed to identical climatic conditions.

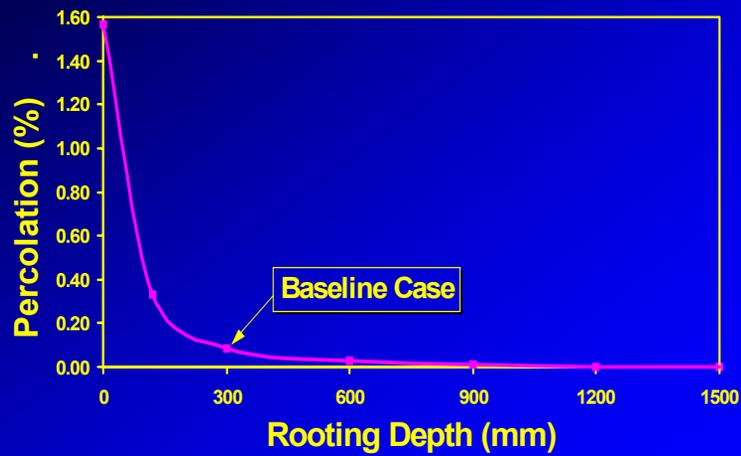
## *Phases in the Study*

- Evaluation of the performance of a Baseline ET cover
- Equivalence demonstration of generic cover
- Sensitivity evaluation of parameters governing the ET cover design
- Design
- Equivalence demonstration using soil-specific hydraulic properties

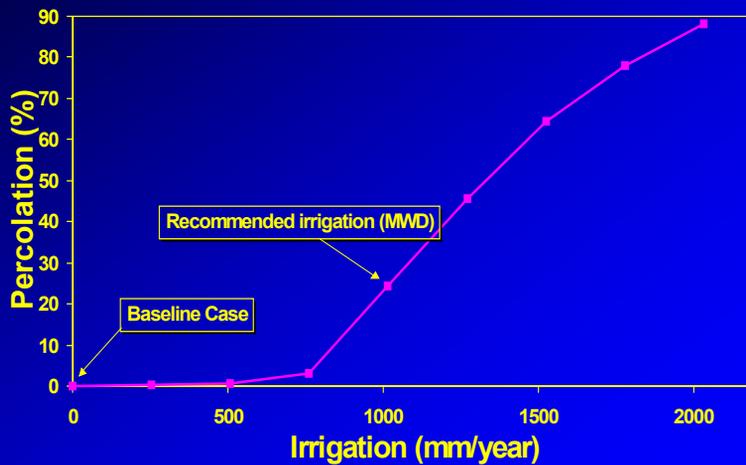
## *How does the ET cover Perform in a Wet Year?*



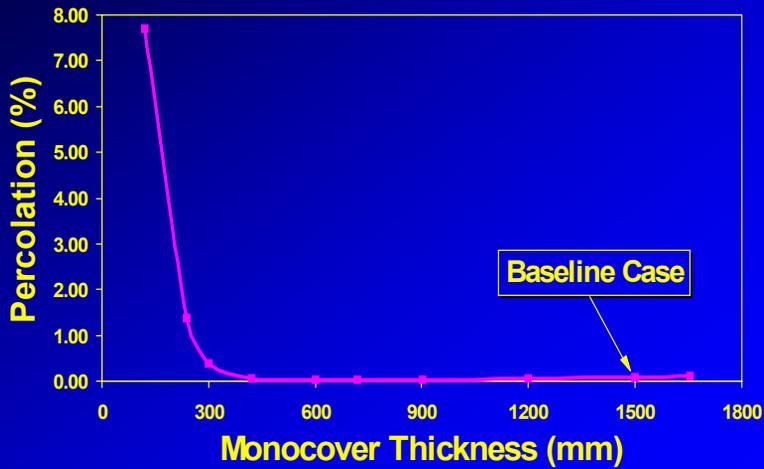
## Parametric Evaluation: Rooting Depth



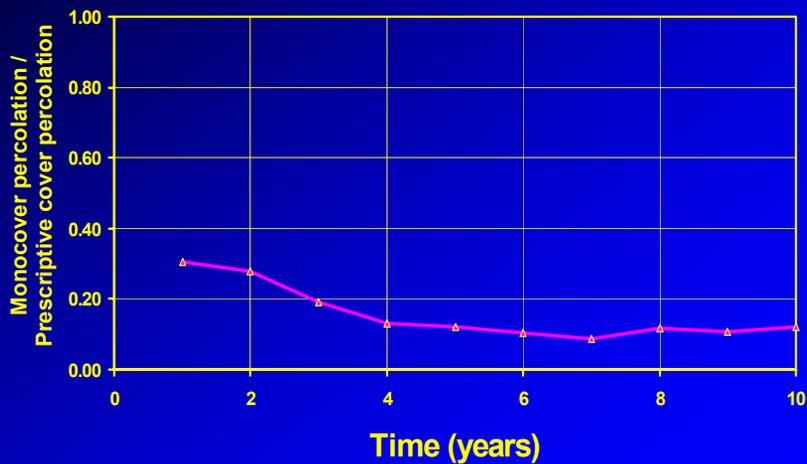
## Parametric Evaluation: Irrigation



## Parametric Evaluation: Cover Thickness



## Equivalence Demonstration



Zornberg et al. (2003). *ASCE J. Geotech. and Geoenvironmental Eng.*, 129 (5), 427-438.





## *Post-closure monitoring*

- TDR moisture monitoring systems were installed at 4 monitoring locations (one for each microclimate).
- Each monitoring location was instrumented with two sets of 4 multi-segment probes covering the upper 5 feet of the evapotranspirative cover.
- Model verification is being conducted using moisture monitoring data.

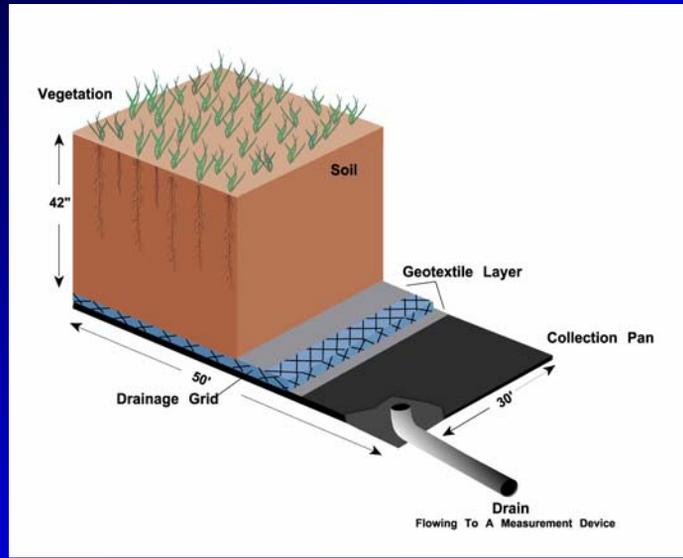
*A Quantitative  
Percolation  
Criterion Case:  
Rocky Mountain  
Arsenal*

*Equivalence Demonstration*

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- Design criterion requires that the basal percolation through the proposed ET cover be less than 1.3 mm/year
- Four test covers were constructed using different soil types and cover thickness values ranging from 42 to 60 in.
- Test covers involved lysimeters with sets of TDRs within the test area.

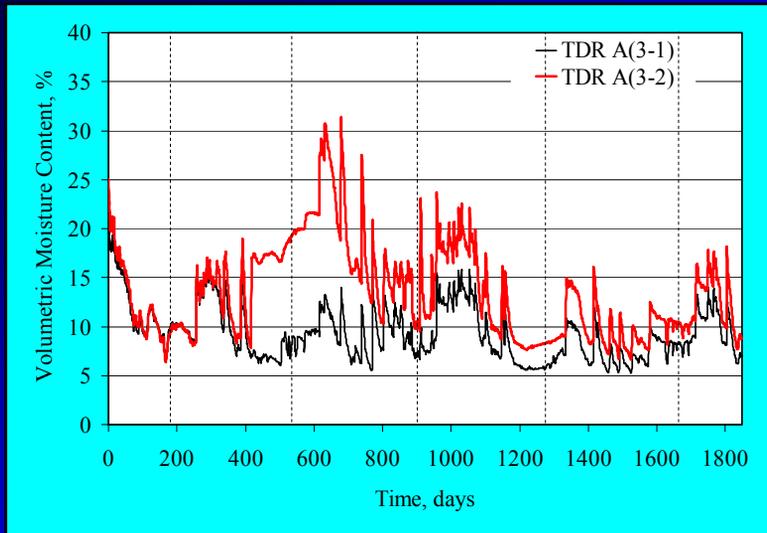
## *Typical Test Cover*



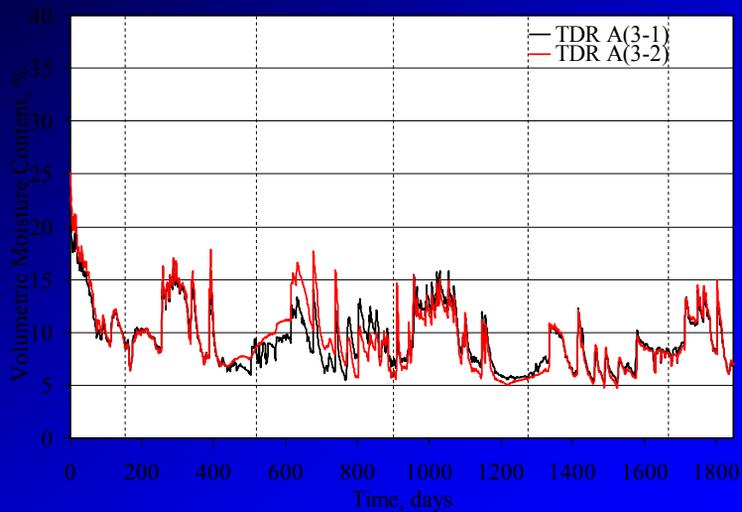
## *Phases in the Study*

- A one-year test period was conducted using a total precipitation (natural+irrigation) of 21.5 in.
- The lysimeters in all four test covers showed a basal percolation well below 1.3 mm/year.
- Borrow source characterization is under way.
- Design is under way to reproduce the storage mechanisms observed in the test plots.
- Post-closure monitoring schemes are being evaluated.

## Problems with Moisture Data



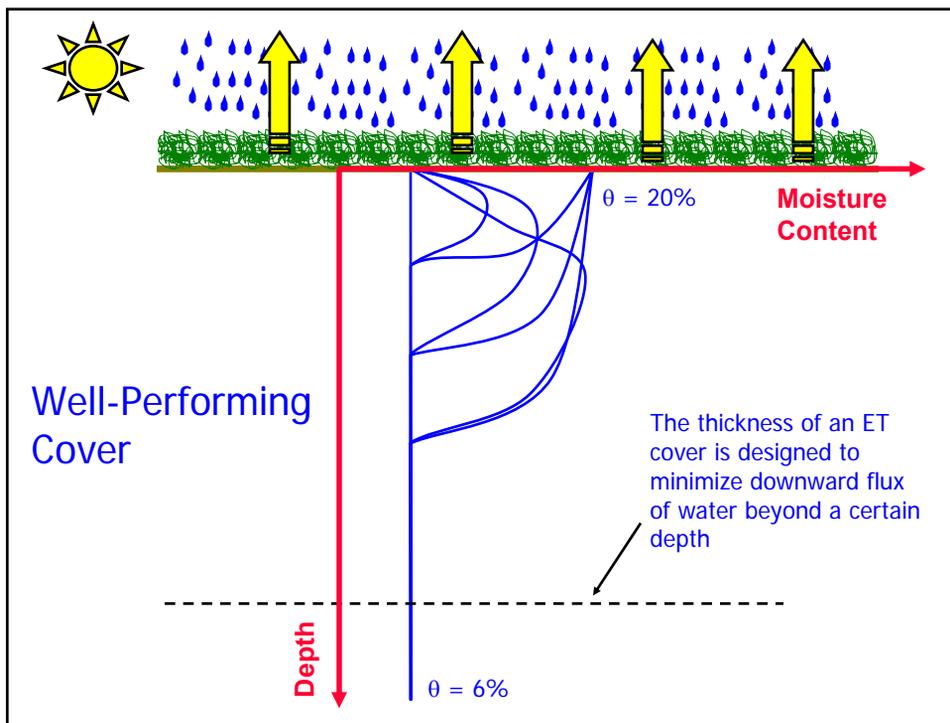
## Problems with Moisture Data: Correction

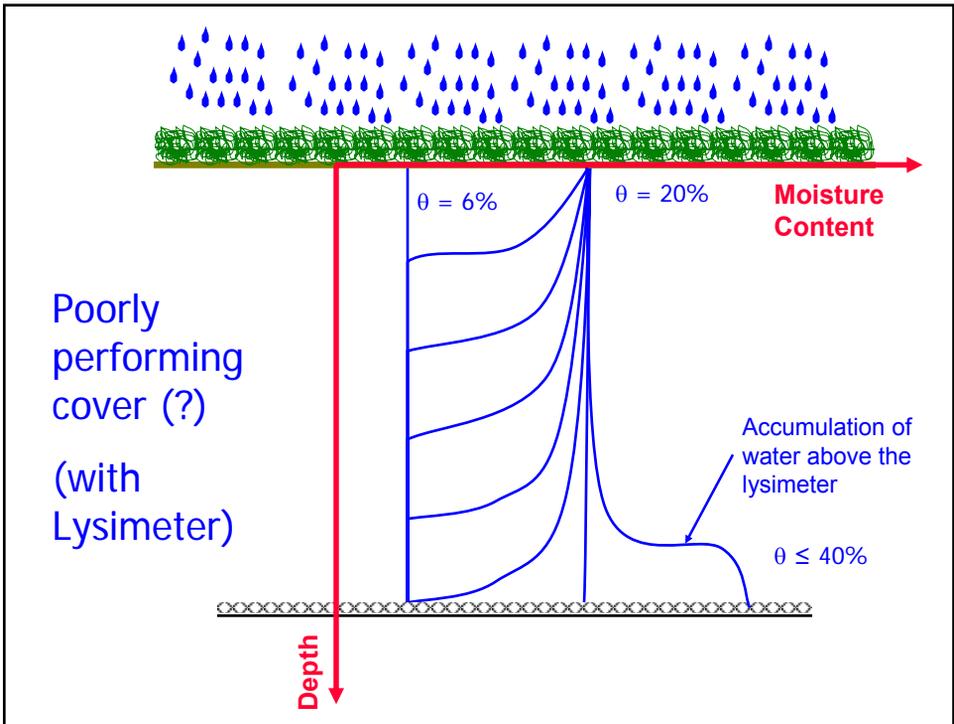
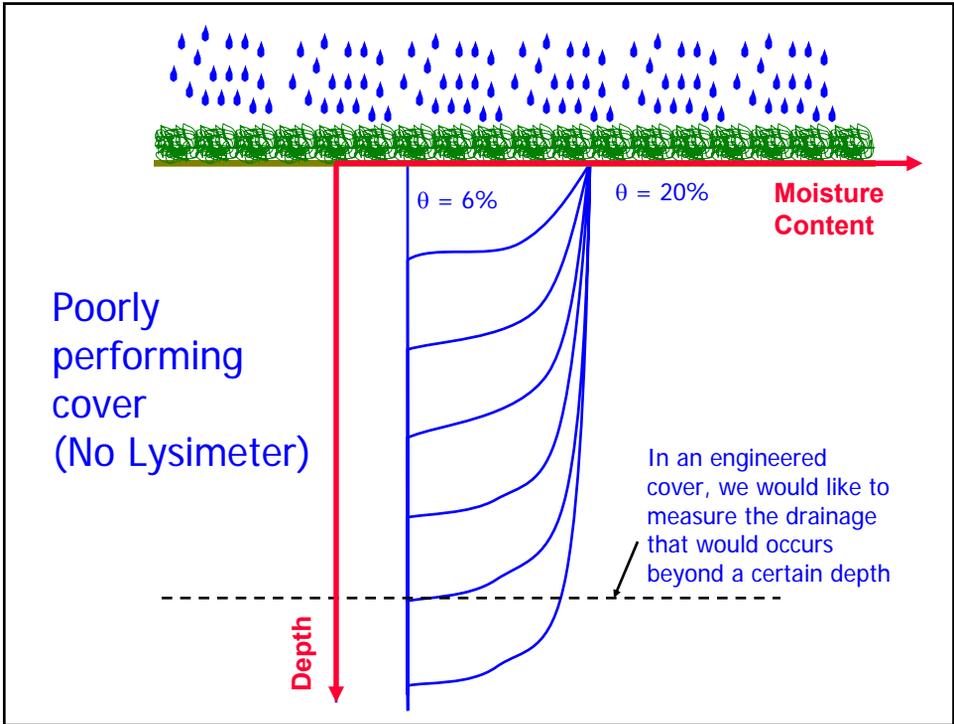


## *Lessons Learned: Capillary Break*

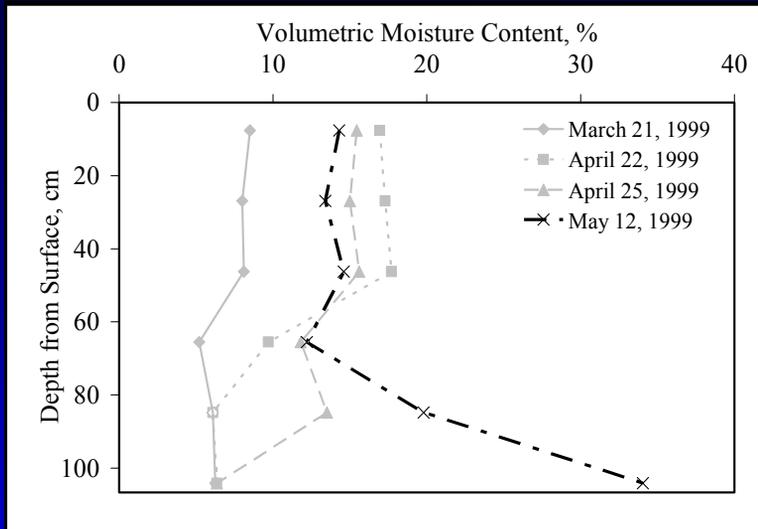
*A capillary break developed at the lysimeter interface in three of the four test plots (1999, 2001, 2003).*

*Development of a capillary break held significant volumes of liquid that would have percolated otherwise.*

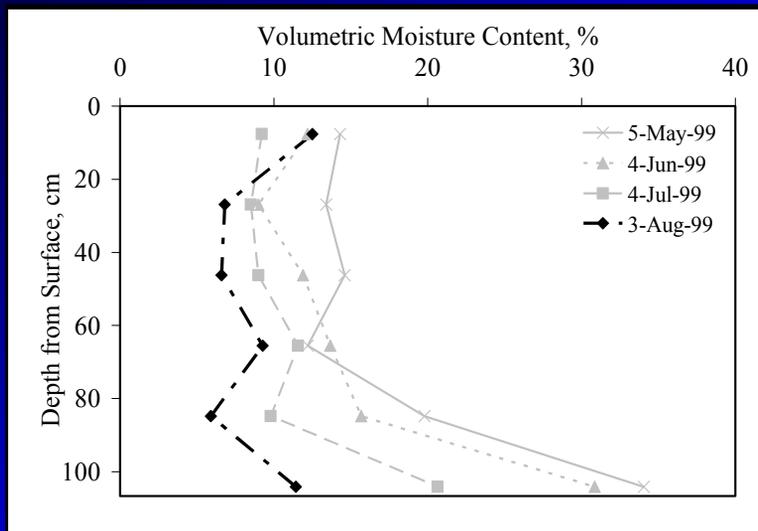




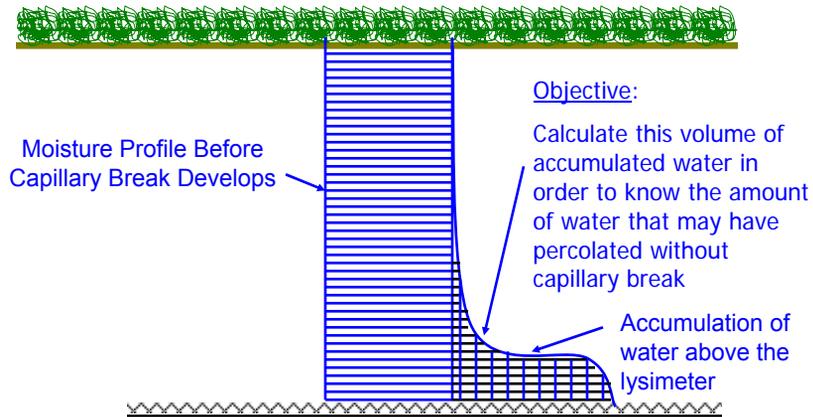
## Advance of Moisture Front in Cover A



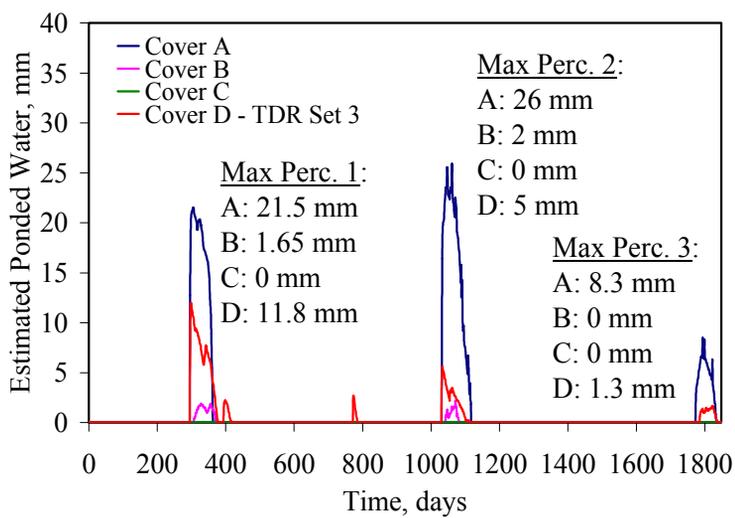
## Retreat of Moisture Front in Cover A



## Quantification of Effect of Capillary Break

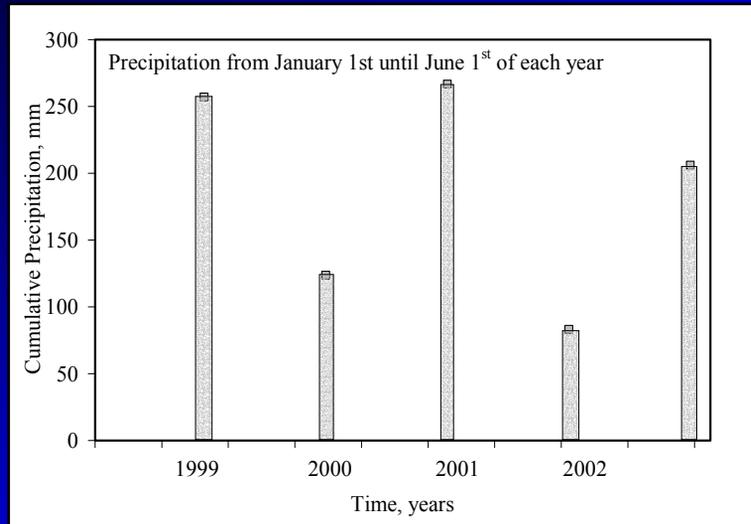


## Estimated Accumulated Water



Note: 1999 2000 2001 2002 2003

## *Understanding the data...*



## *Parameter governing design:*

- Storage capacity?
- *Effective* storage capacity?
- *Time* to exceed the effective storage capacity?

## *Capillary Break: Implications*

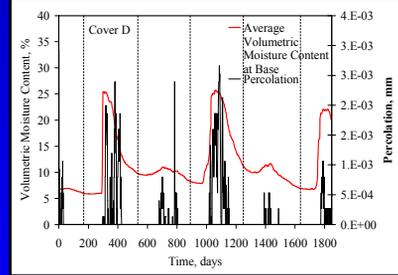
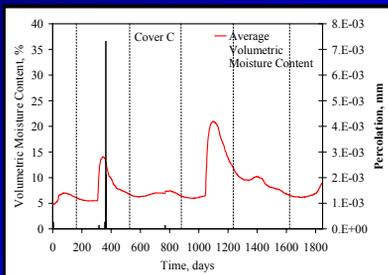
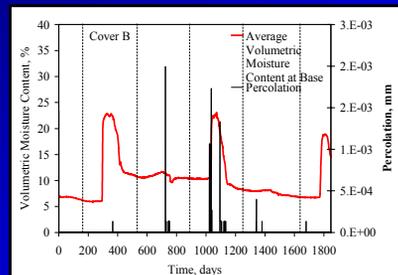
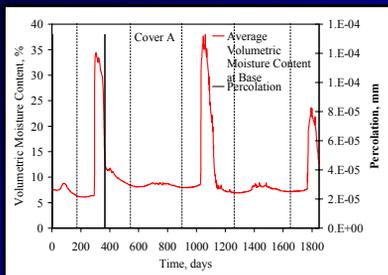
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- Development of a capillary break prevented downward migration of liquids in excess of the storage capacity of the cover
- While capillary break is beneficial, the cover was not initially designed to account for it
- To achieve equivalence, a similar capillary break should develop in the full-scale cover

## *Lessons Learned: Preferential flow*

*Due to the capillary break that developed at the interfaces, possibly only preferential flow was collected by the lysimeters*

## Correlation between Moisture at the Base and Percolation

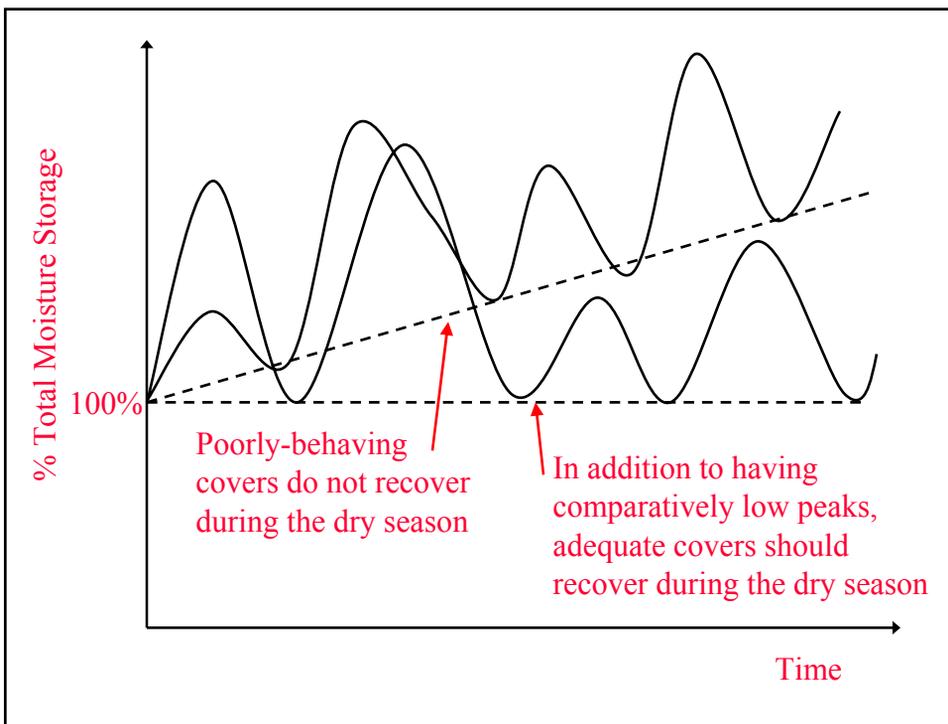


## Preferential Flow: Implications

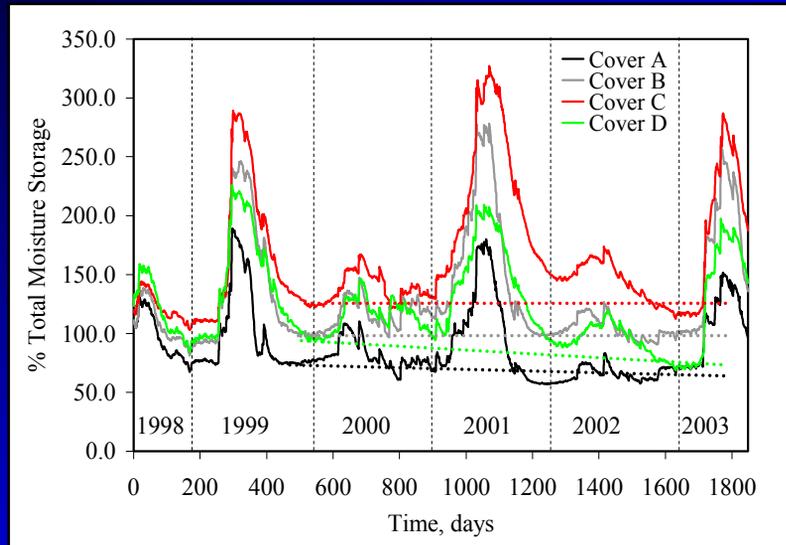
- Available data suggests that test plot lysimeters have collected only preferential flow so far
- Lysimeters have provided little insight into the cover design if uniform flow becomes a relevant mechanism (e.g. if the capillary break does not develop in the final cover)
- Lysimetry and moisture monitoring are complementary and allow evaluation of the different moisture mechanisms

## *Lessons Learned: Long-Term Trends*

*The yearly trends in the test plots indicate that the test plots have recovered their original moisture each year following the dry season.*



## *Trend in Moisture Storage in the RMA Covers*



## *Long-Term Trends: Implications*

- Evaluation of moisture storage allows assessment of the ET cover recovery during the dry season
- The different test plots showed that the covers were able to recover after the wet season

## *Post-closure monitoring: Lysimeters*

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- **Advantages:**
  - Provide direct measure of the basal flow
  - Are comparatively easy to maintain
- **Disadvantages:**
  - Change flow conditions within the system we want to monitor (capillary barrier, unconservative?)
  - Provide no information unless flux is measured (which may often mean cover failure)

## *Post-closure monitoring: Moisture probes*

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- **Advantages:**
  - Do not change flow conditions
  - Provide continuous information regarding the performance (moisture trends) within the cover
  - Allow assessment of the development of capillary break
- **Disadvantages:**
  - Do not provide direct measure of the basal flow
  - Long-term durability
  - They add cost to the monitoring program

# What is the state-of-the-practice in post-closure monitoring of ET covers?

	Site Name	Location	Contact information	Lysimeter	Moisture monitoring
1	Operating Industries, Inc. (OII)	Monterey Park, CA	NCI/Advanced Earth Sciences		X
2	Puente Hills	CA	Advanced Earth Sciences		X
3	Yucaipa	Orange County, CA	GeoSyntec Consultants		X
4	Coyote Canyon	Orange County, CA			X
5	Lopez Canyon	Los Angeles, CA	Geosyntec and City of Los Angeles		X
6	Yeremo	Los Angeles, CA			X
7	Riverside Co.	Riverside County, CA			X
8	29 Palms Marine Base	CA	URS Greiner		X
9	Potrero Hills	CA	Potrero Hills Landfill, Inc.		X
10	Chiquita Canyon	CA	Pacific Environmental Group		X
11	Needles Landfill	CA	Geologic Associates		X
12	Fairmead Landfill	CA	Madera Disposal		X
13	Rocketdyne Site	Chattsworth, CA	The IT Group, Boeing Corp.		X
14	F. R. Bowerman Landfill	CA	Geologic Associates		X
15	China Grade Landfill	Kern County, CA	Golder	X	X
16	McPherson Area Solid Waste Utility	McPherson, KS	Engineering Solutions & Design Inc.	X	
17	Nevada test site	NV	DOE	*	X
18	Ft Carson	CO	Earth Tech Environmental	X	X
19	Lakeside Reclamation Landfill	Beaverton, OR	Ecotree, Inc.		X
20	MSW Landfill	NE	Ecotree, Inc		X
21	Duvall Custodial Landfill	WA	King County Solid Waste Division		X
Total				3	20

\*: TDRs within final cover and TDR and heat dissipation probes within 8 lysimeters adjacent to the final cover

## Summary

- A comparative approach was adopted for equivalence demonstration at the OII Superfund site:
  - The ET cover design is feasible for a wide range of conditions (in southern California!)
  - Parametric evaluations showed that the parameters governing the design show a highly non-linear response
- A quantitative approach was adopted for equivalence demonstration at the Rocky Mountain Arsenal:
  - A field demonstration project indicated that the basal percolation is below 1.3 mm/year in lysimeters built using a wide range of conditions
  - Moisture retention in the lysimeters relied heavily on the development of a capillary break

## *Final Remark*

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In addition to satisfying the infiltration criterion, design and post-closure monitoring programs of an ET cover should assess not only *if* the cover is working, but also *why* the cover works as it does.

## *Acknowledgements*

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- US EPA
- Foster Wheeler, GeoSyntec Consultants
- RVO
- Kerry Guy
- John McCartney



*Thank You for  
your Attention.*