DOE Experience with Cover Degradation Processes, Design Improvements, and Renovation for Uranium Mill Tailings

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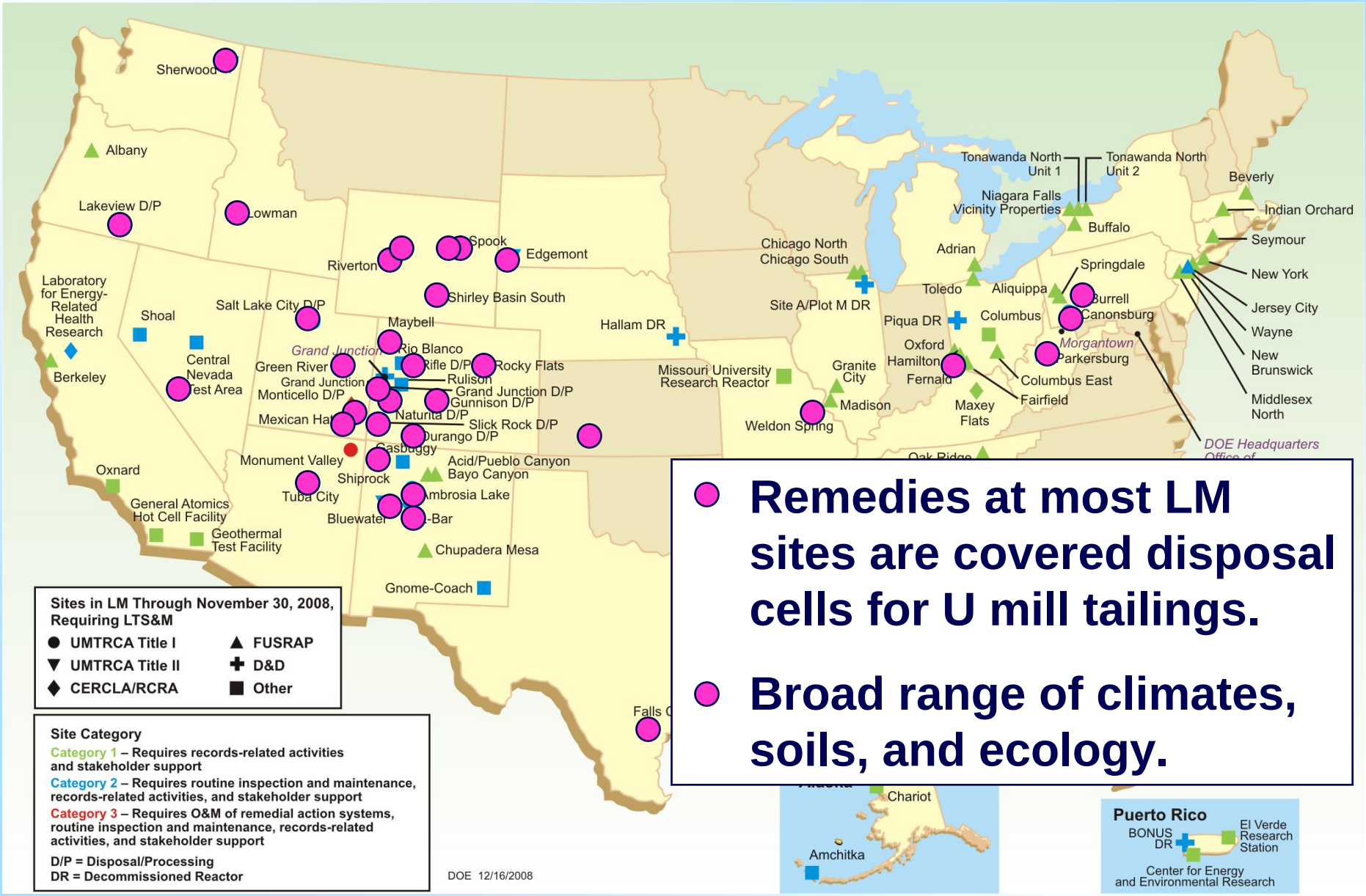
NRC Workshop on Engineered Barrier Performance

August 3-5, 2010

U.S. DEPARTMENT OF ENERGY | Office of Legacy Management

U.S. Department of Energy
Office of Legacy Management (LM) Sites



- **Remedies at most LM sites are covered disposal cells for U mill tailings.**
- **Broad range of climates, soils, and ecology.**

Presentation Topics

- Uranium tailings cover degradation processes for different climates and ecology
- Historical improvements in uranium mill tailings covers to minimize degradation
- Cover renovation – improving sustainability by accommodating degradation processes
- Summary of responses to Session 2 questions

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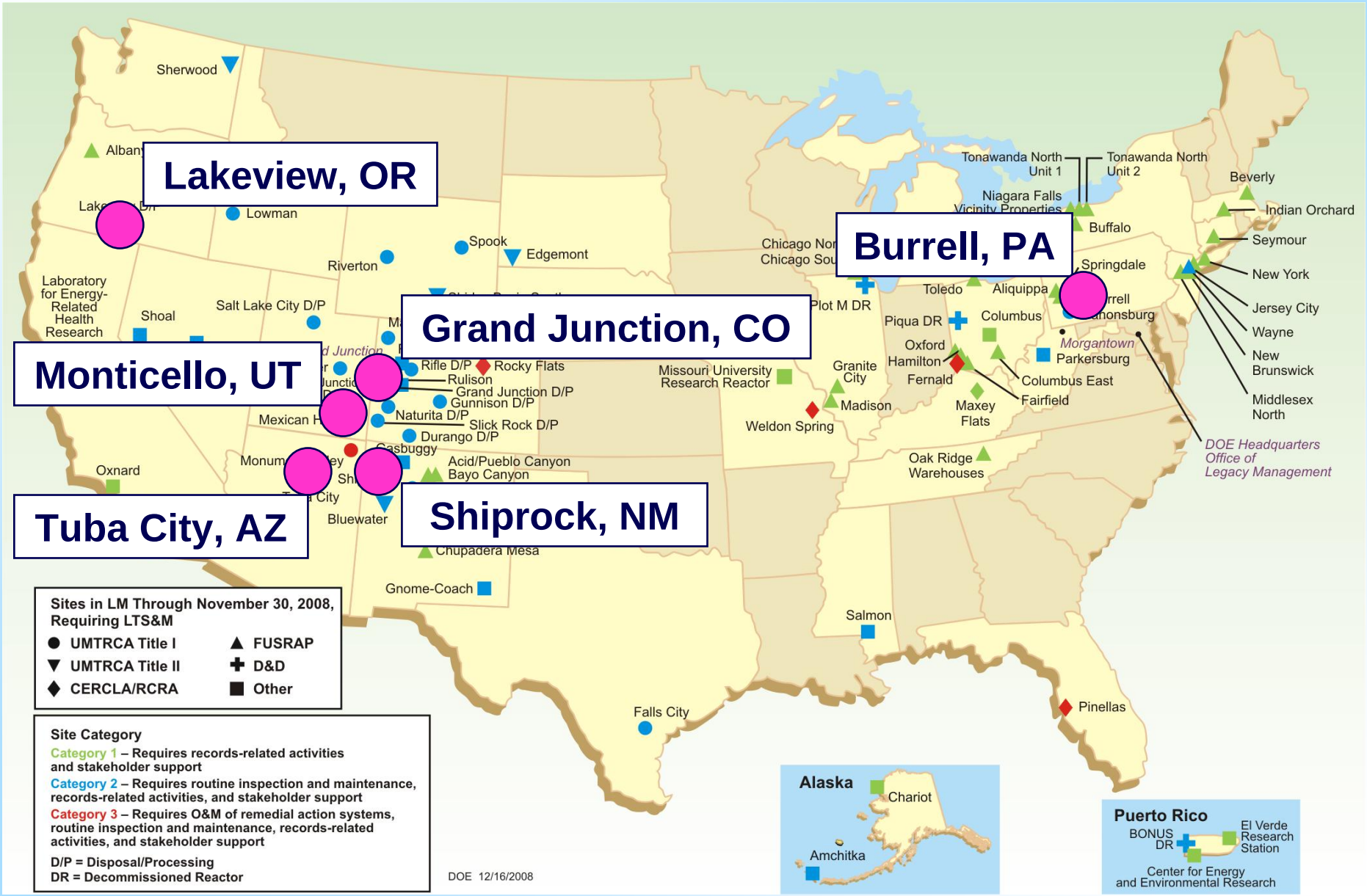
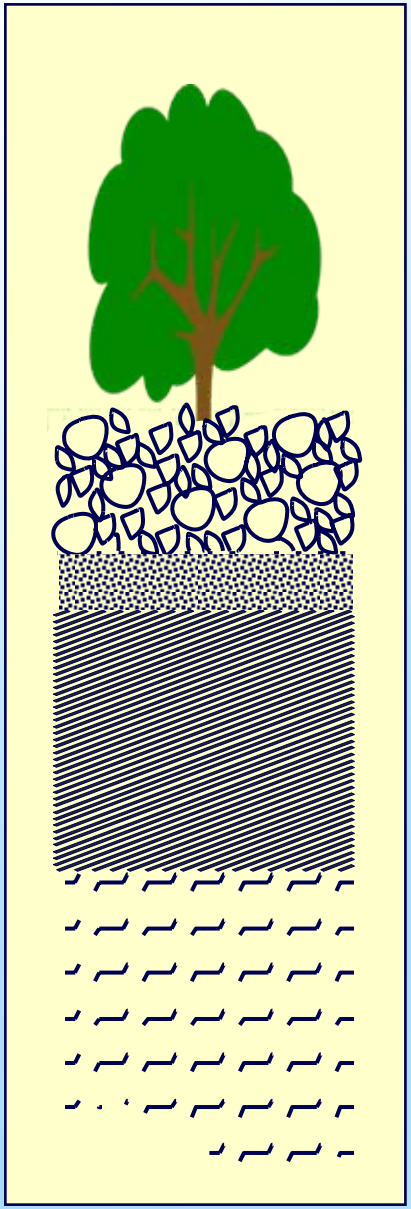
U Tailings Cover Degradation Case Studies



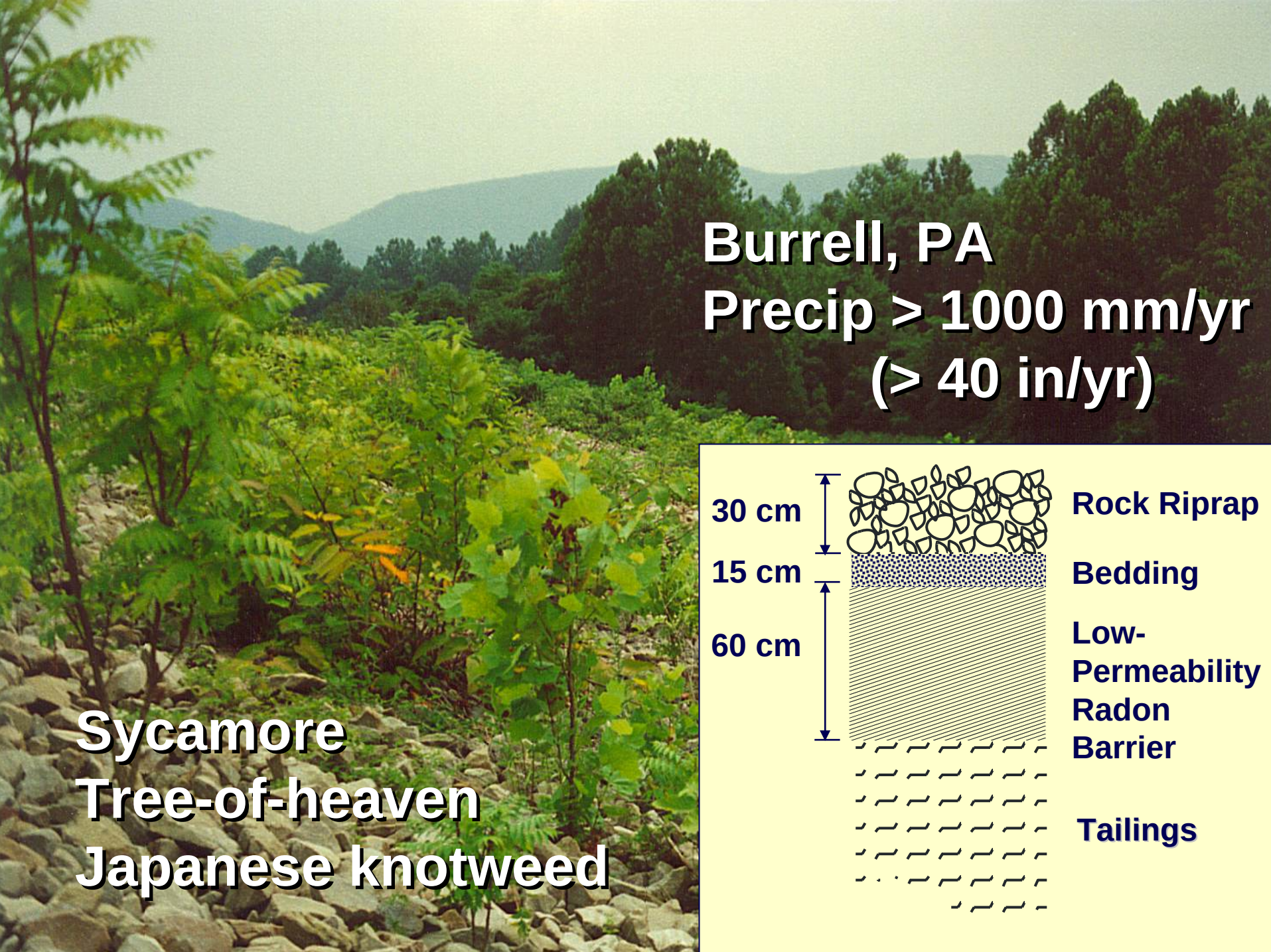
Cover Degradation Processes and Performance



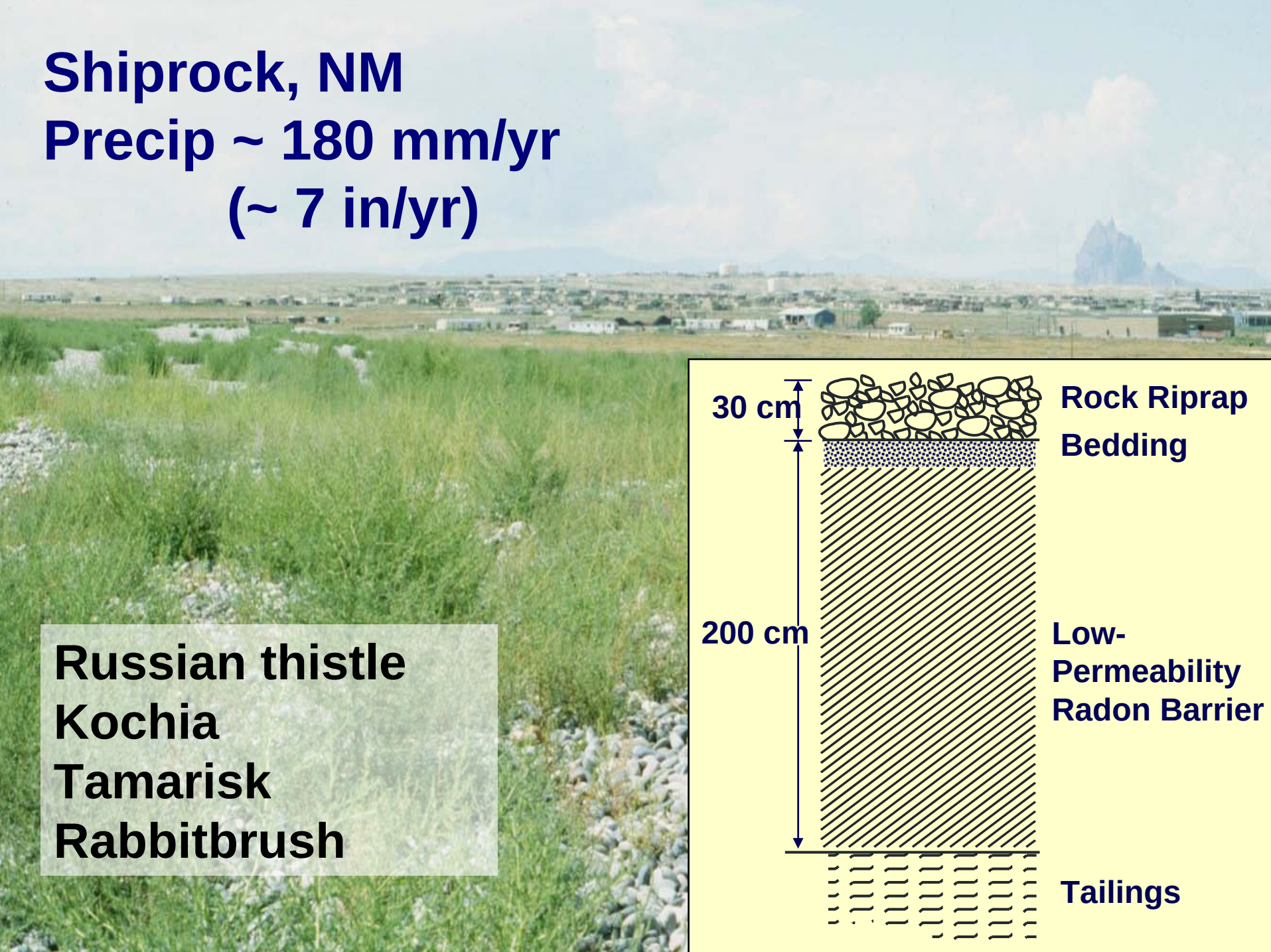
Lesson 1:

Rock covers can increase water storage and create habitat for deep-rooted woody plants for broad range of climates and ecology

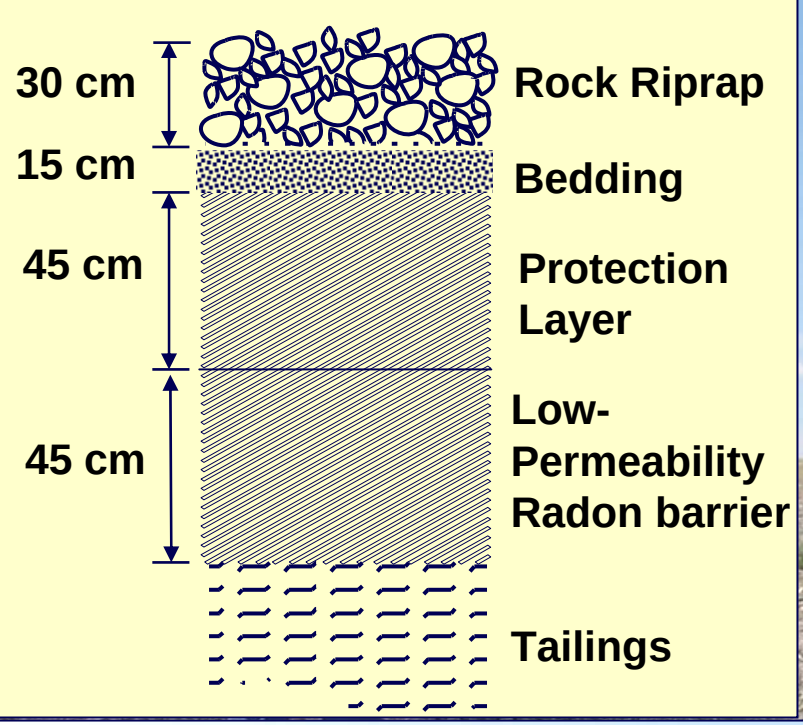
Accumulation of water in the bedding layer and low-permeability radon barrier favors germination and establishment of shrubs and trees.


Burrell, PA
Precip > 1000 mm/yr
(> 40 in/yr)
30 cm
15 cm
60 cm
Rock Riprap
Bedding
Low-Permeability Radon Barrier
Tailings
Sycamore
Tree-of-heaven
Japanese knotweed

Shiprock, NM
Precip ~ 180 mm/yr
(~ 7 in/yr)



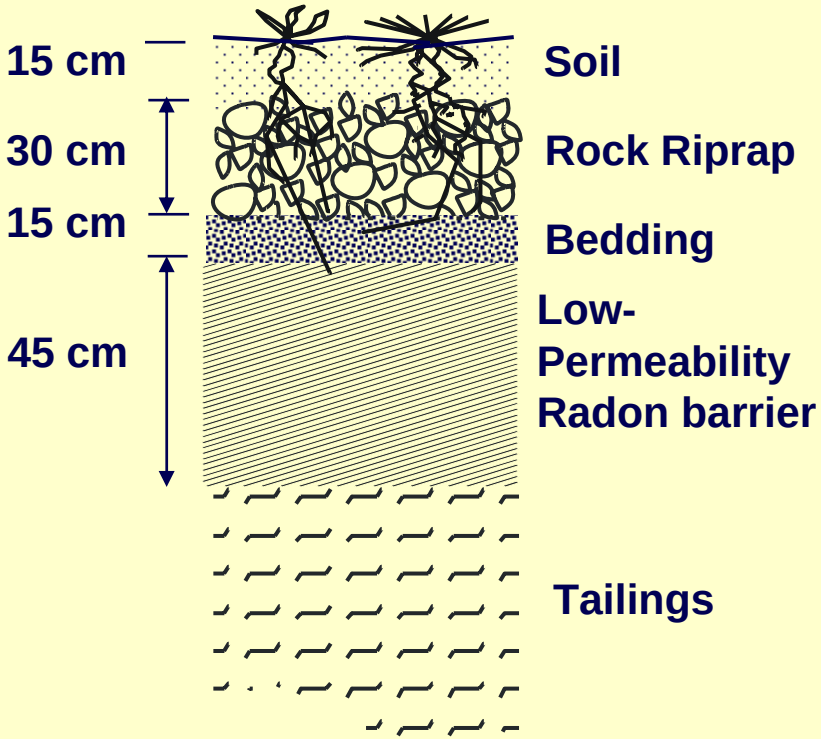
Russian thistle
Kochia
Tamarisk
Rabbitbrush



Grand Junction, CO
Precip < 200 mm/yr
(< 8 in/yr)

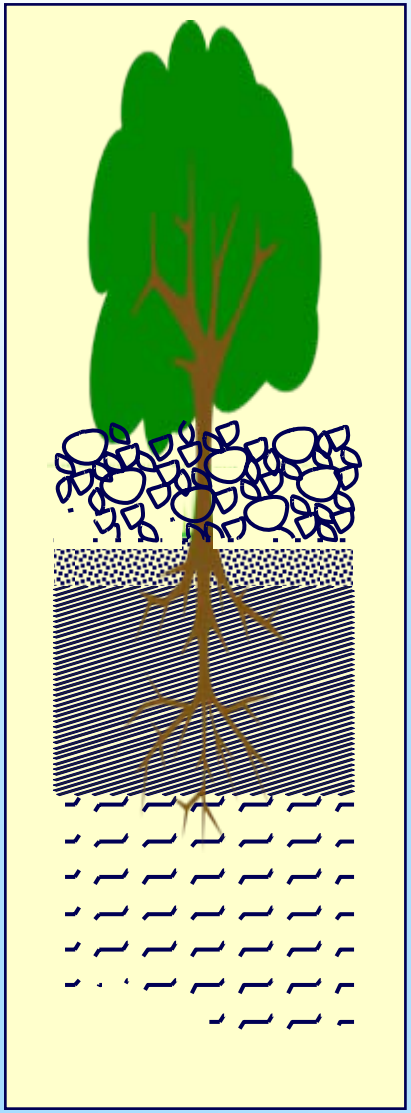
Fourwing Saltbush
Shadscale
Spiny Hopsage
Rabbitbrush
Halogeton

Lakeview, OR
Precip ~ 380 mm/yr
(15 in/yr)



Rabbitbrush
Sagebrush
Bitterbrush

Cover Degradation Processes and Performance



Lesson 2:

Roots of woody plants can penetrate compacted soil layers overlying tailings

Plant roots were excavated at several sites to determine rooting depths.

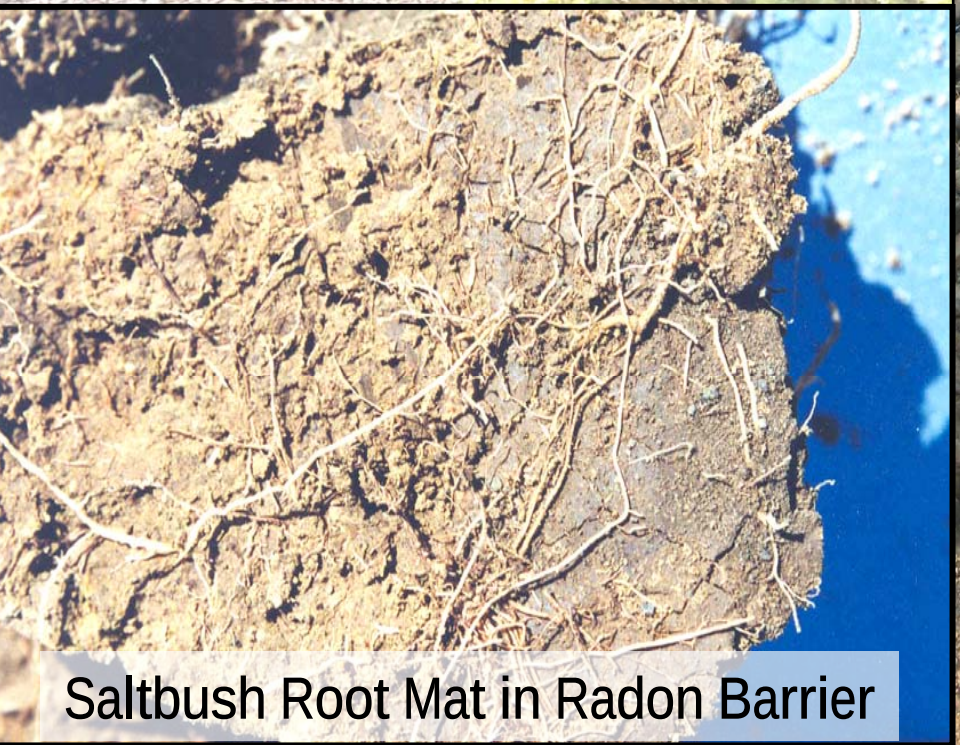
- Primary roots extend vertically through rock and bedding layers and then branch laterally at the radon barrier surface
- Secondary and tertiary roots extend vertically in the radon barrier as root mats following soil structural planes

Lakeview, OR
Sagebrush

Test Dye and Sagebrush Roots in Radon Barrier

Grand Junction, CO
Fourwing Saltbush

Grand Junction, CO
Fourwing Saltbush

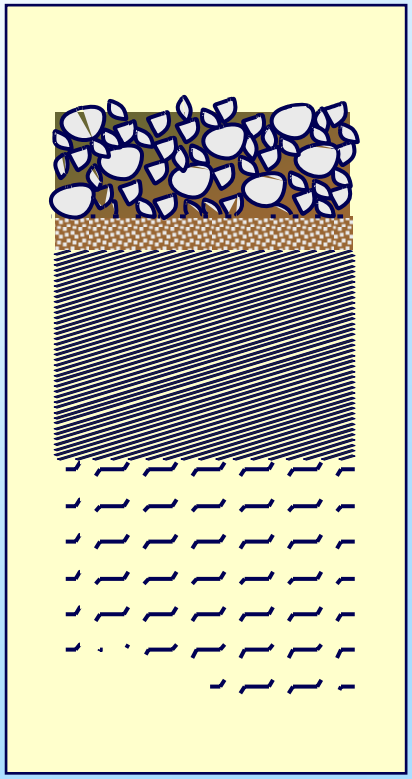


Saltbush Root Mat in Radon Barrier

Burrell, PA
Japanese knotweed

Burrell, PA
Japanese knotweed

Cover Degradation Processes and Performance



Lesson 3:

Windblown dust in West and organic litter in East creating soils in rock and drainage layers

- Soil development in rock enhances plant habitat and drives plant succession
- Soil development in drainage layer may limit lateral shedding of precipitation

Grand Junction Cover

Dust has filled the basalt riprap layer on leeward side of the cover

Cover Degradation Processes and Performance

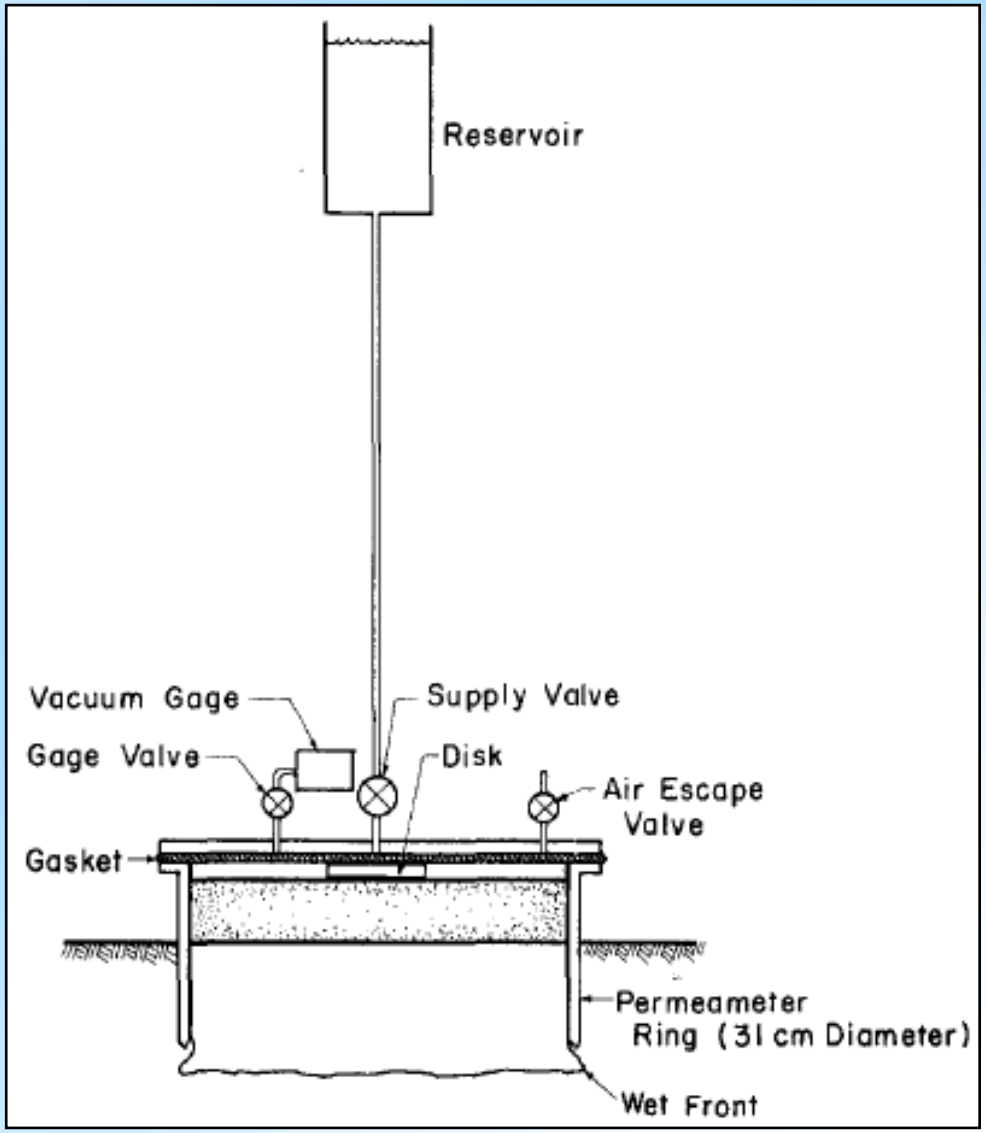
Lesson 4:

Root intrusion and soil development increase the K_{SAT} of the CSL

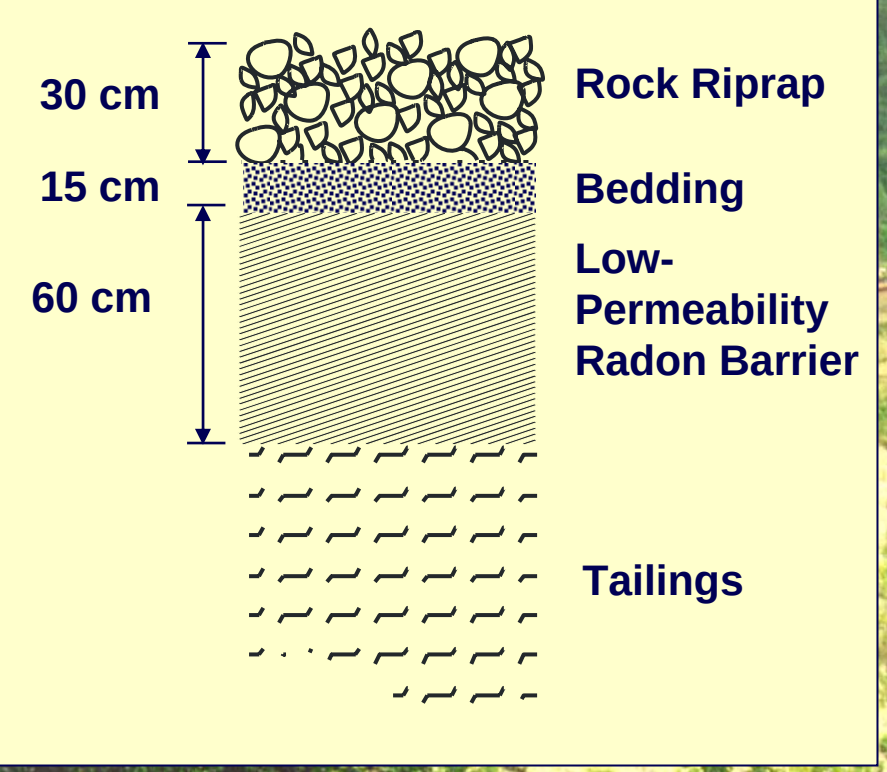
***Target* saturated hydraulic conductivity (K_{SAT}):**

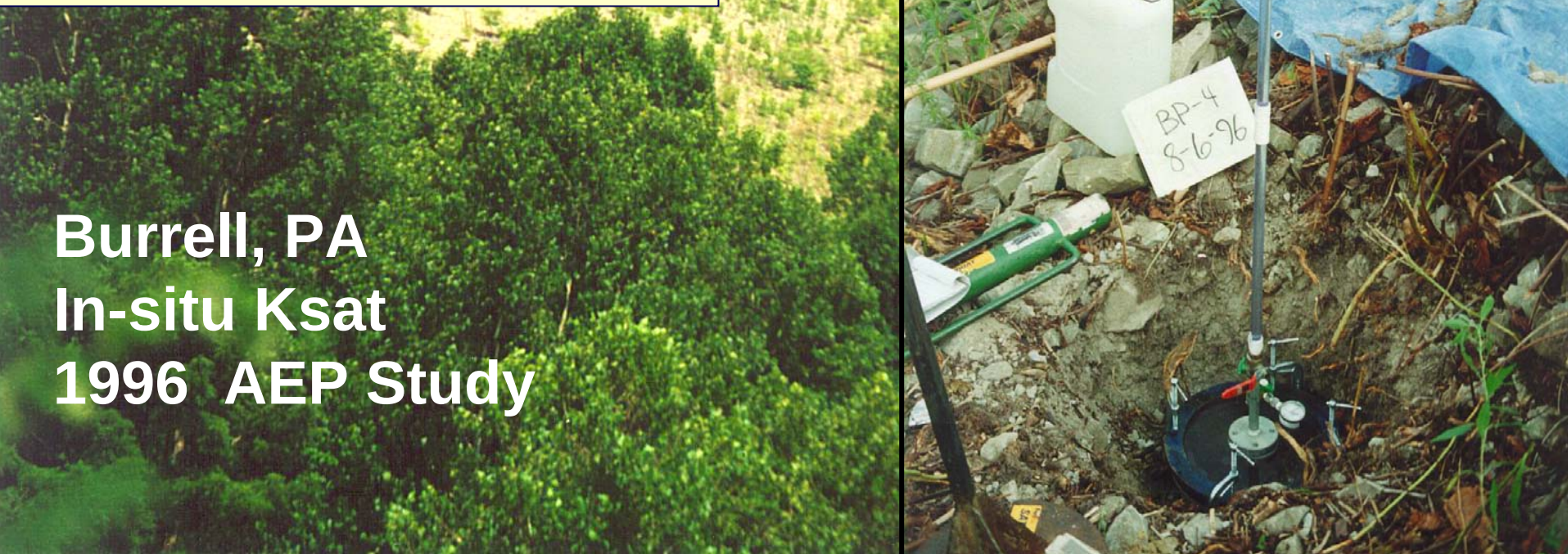
Ksat ≤ $1x10^{-9}$ m/s

In situ Ksat measured using air-entry permeameters (AEPs)



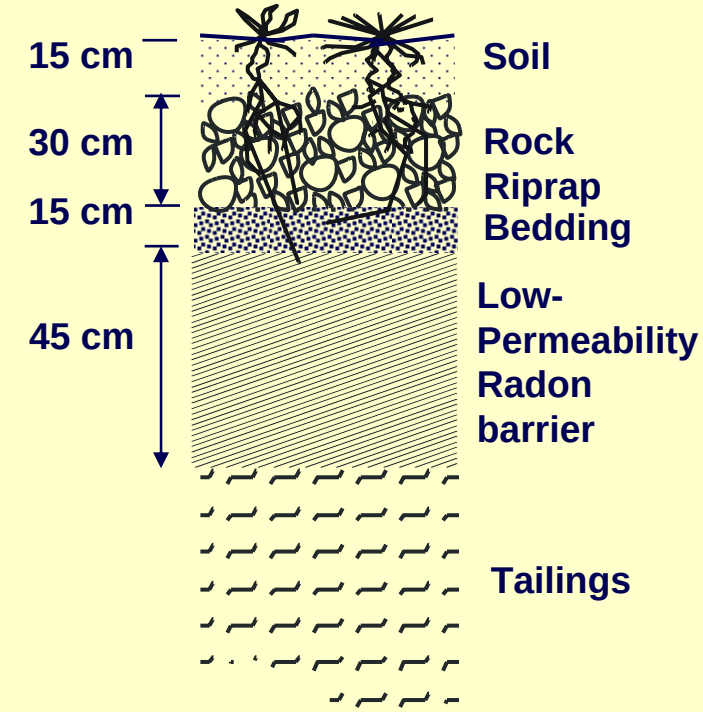
D.B. Stephens Air-Entry Permeameter



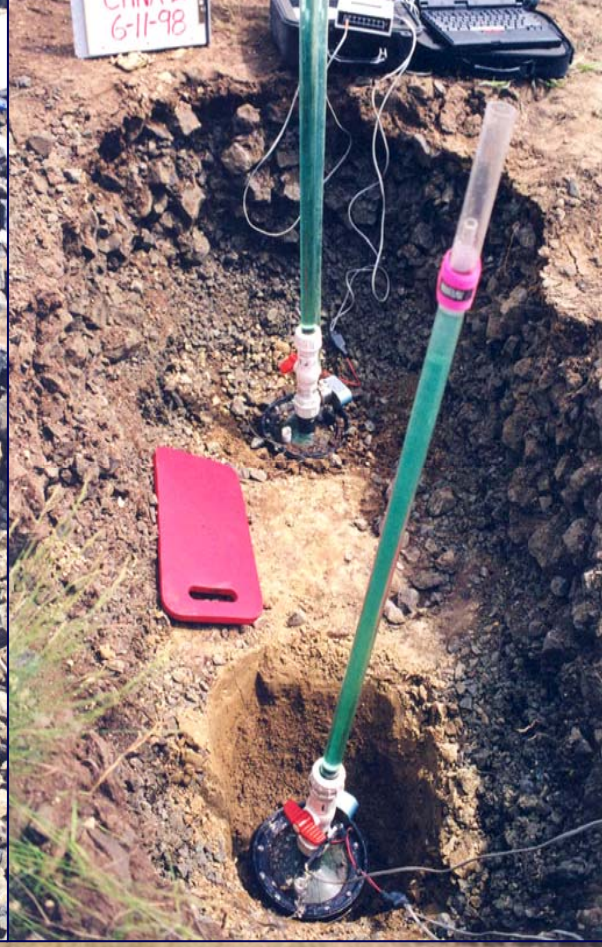


Burrell, PA
In-situ Ksat
1996 AEP Study

Lakeview, OR
In-situ Ksat
1998 AEP Study

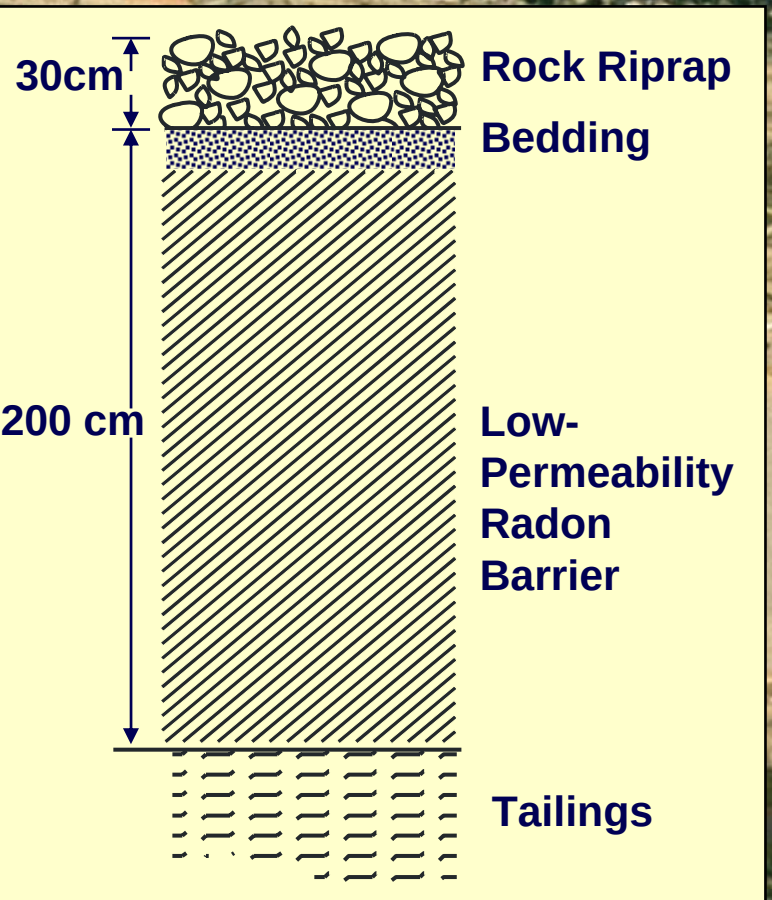


Manual AEP on side slope

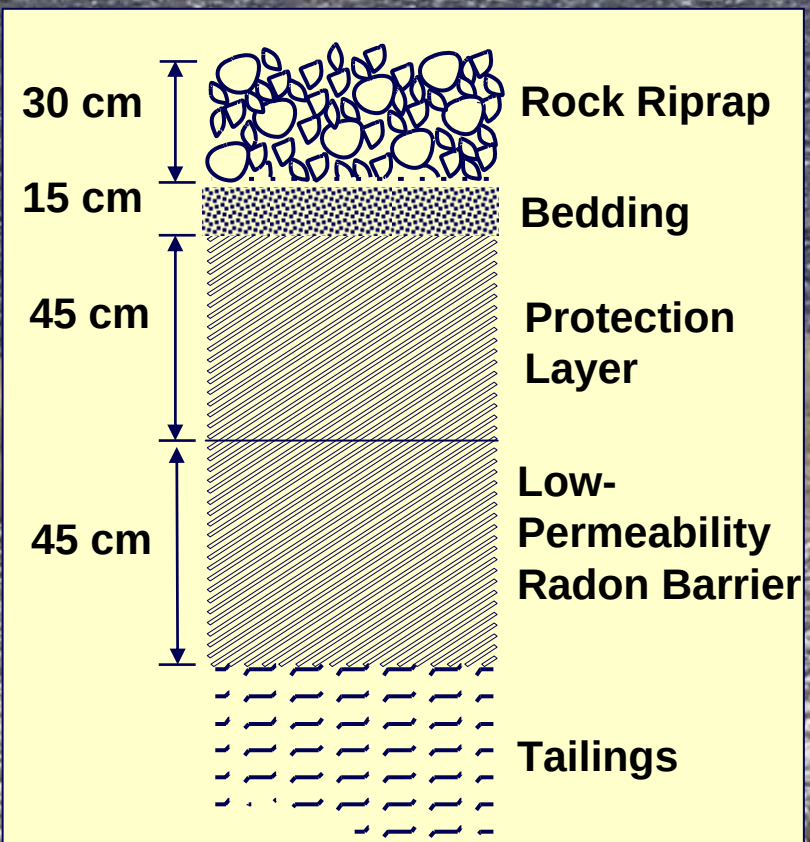


Automated AEPs on topslope

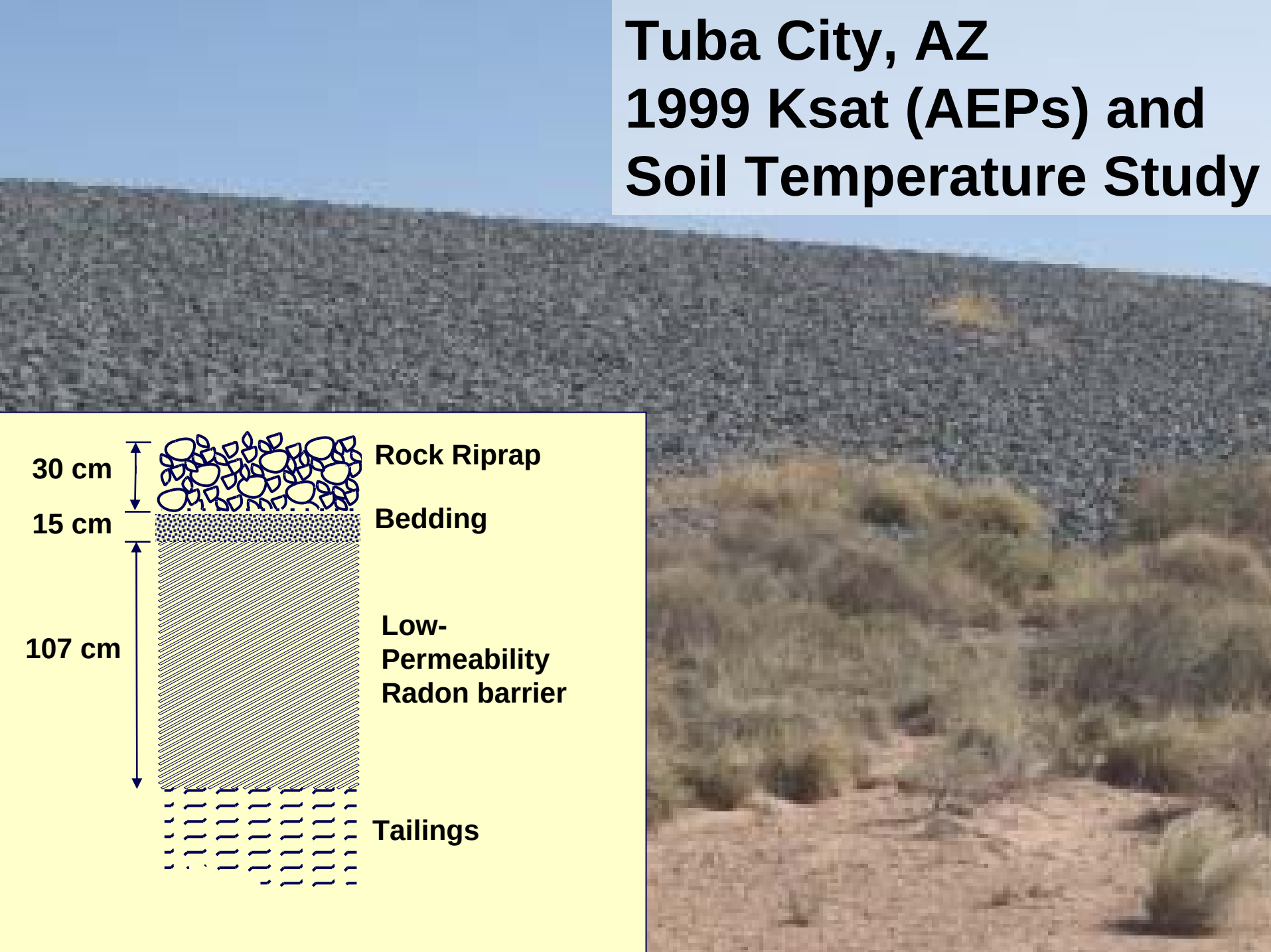
Shiprock, NM
In-situ Ksat
1999 AEP Study



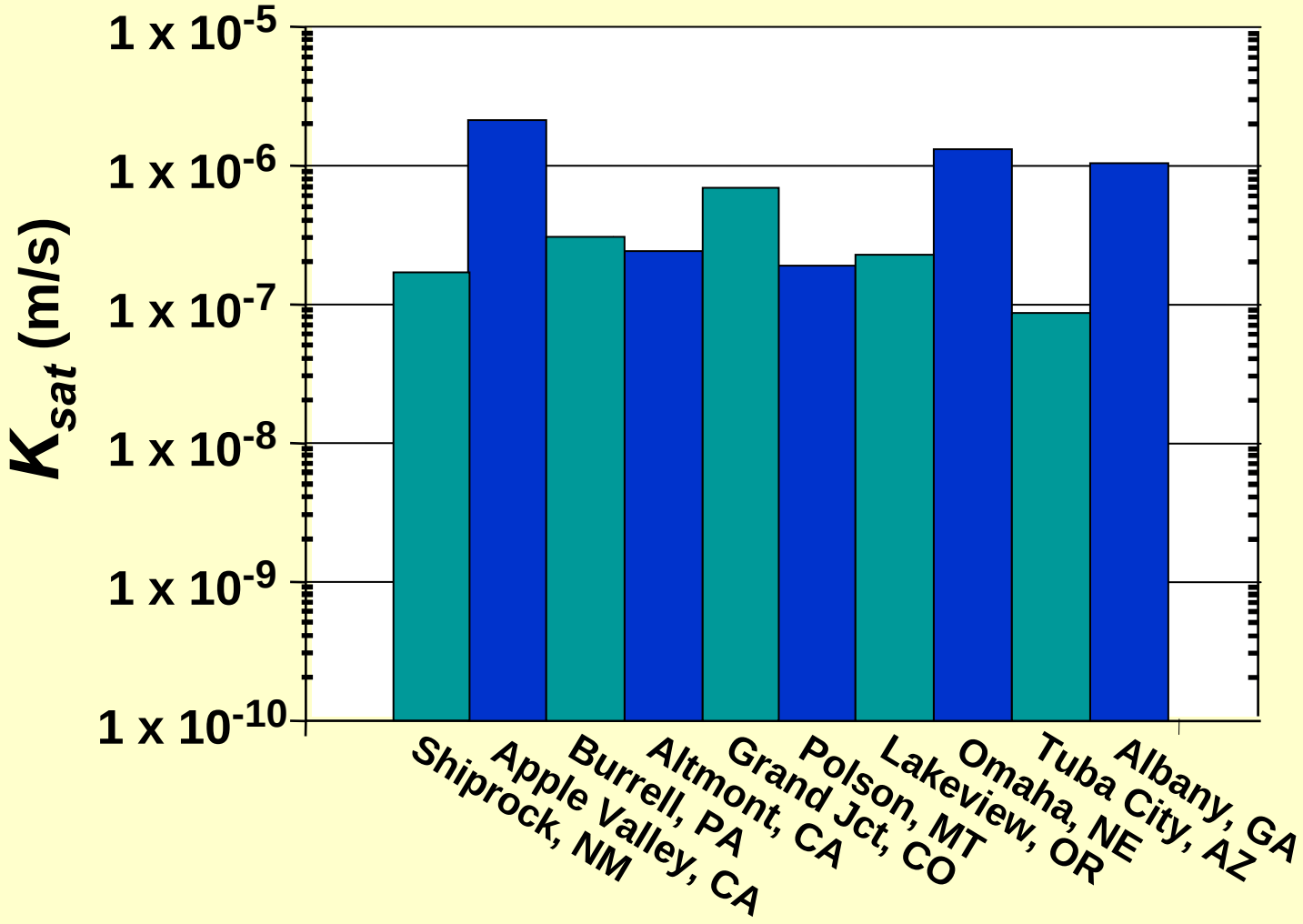
Grand Junction, CO
In-situ Ksat
2005 AEP Tests



Tuba City, AZ
1999 Ksat (AEPs) and Soil Temperature Study



CSL K_{sat} Means



Lesson 5:

Different types of soil development processes may be causing preferential flow and high Ksat in CSLs:

- **Soil structure developing faster than expected**
- **Plant roots and burrowing animals**
- **Freeze-thaw cracking and desiccation**
- ***Borrow soil structure retained after construction***

Test dye shows structural planes

Roots follow structural planes

Lesson 6:

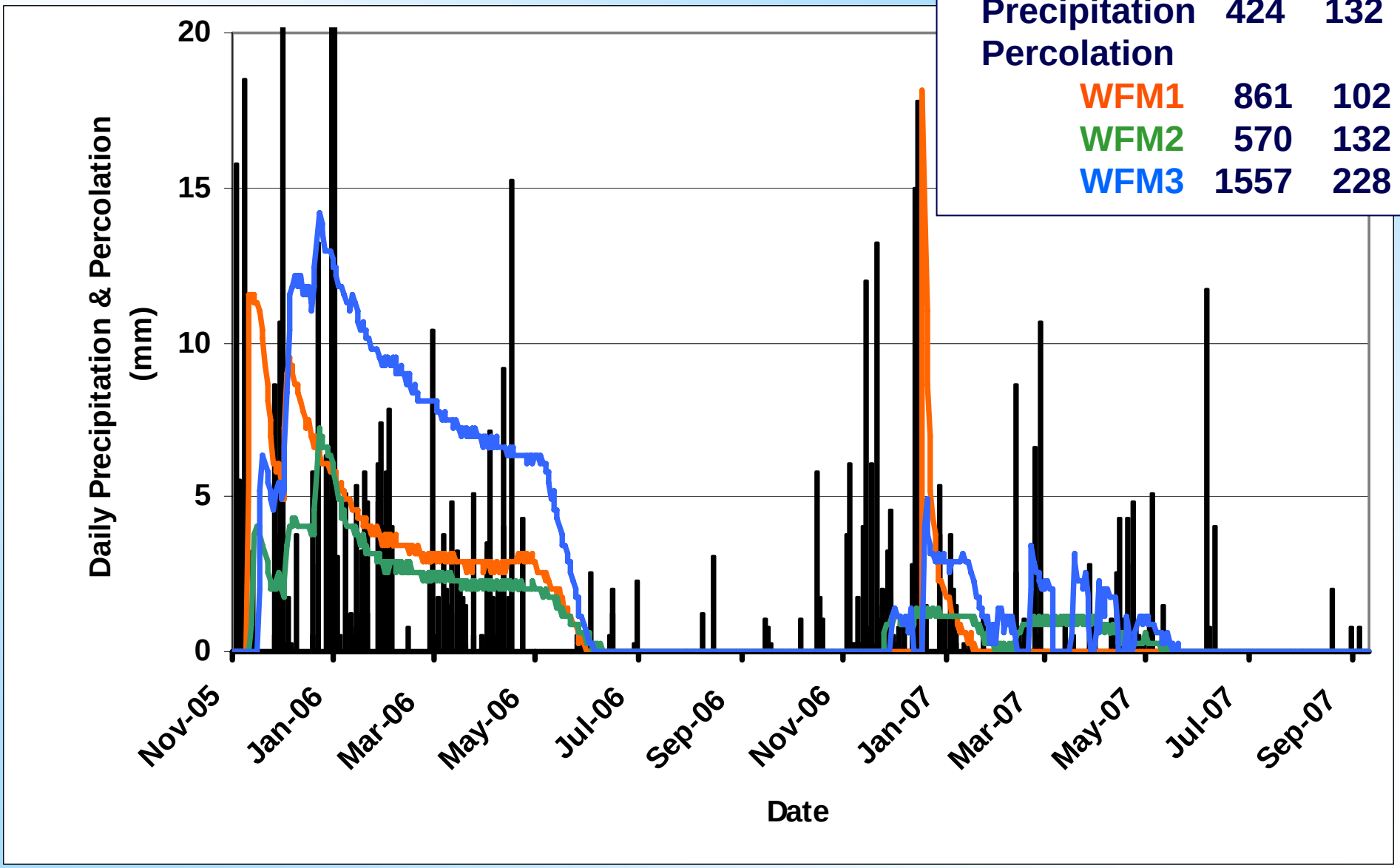
High saturated hydraulic conductivity (Ksat) *may* cause significant percolation through the cover

Lakeview, Fall 2005

Water fluxmeters Installed below CSL

Lakeview Water Flux Meter Results
(November 2005 – September 2007)

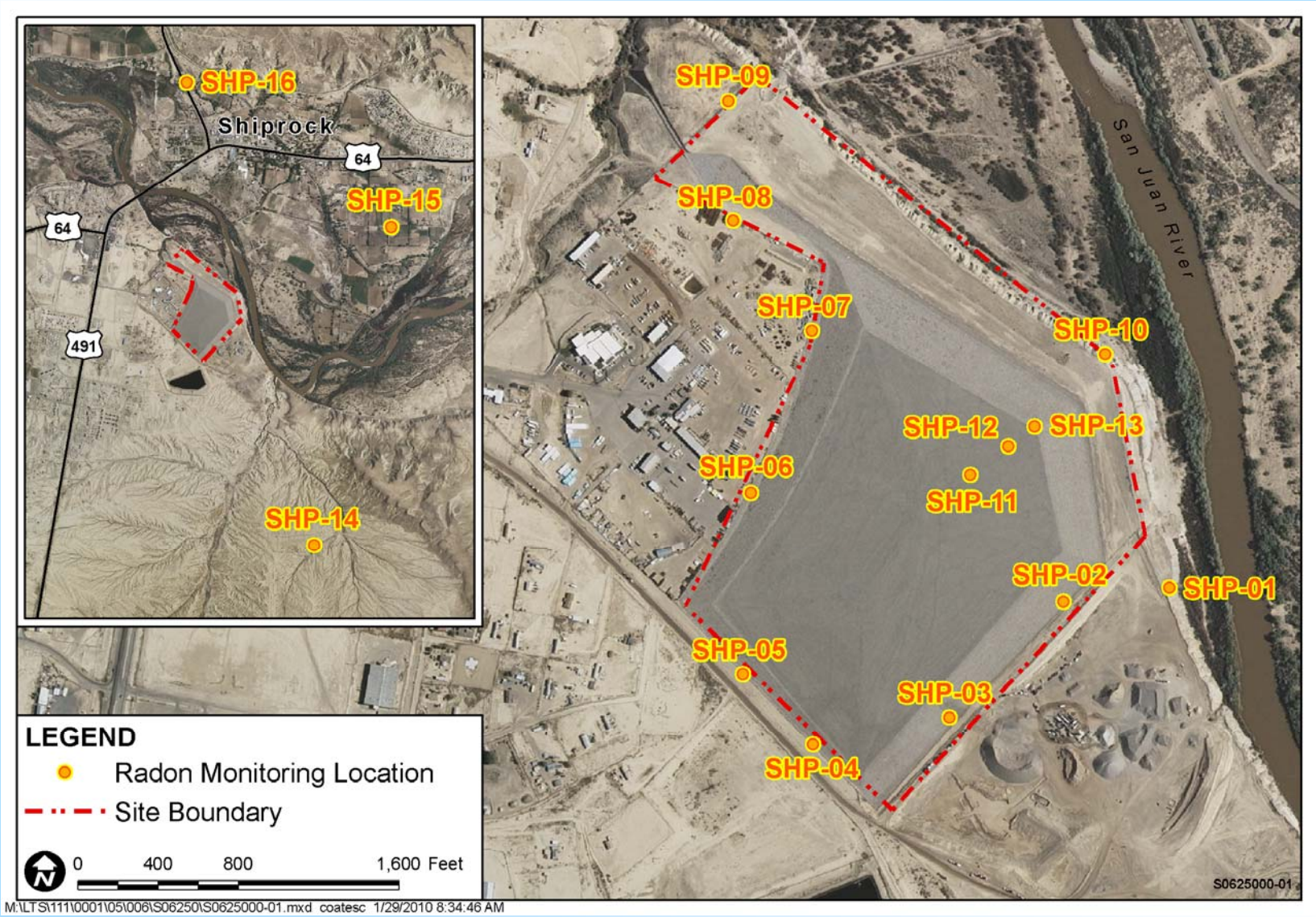
Totals (mm)	05-06	06-07
Precipitation	424	132
Percolation		
WFM1	861	102
WFM2	570	132
WFM3	1557	228



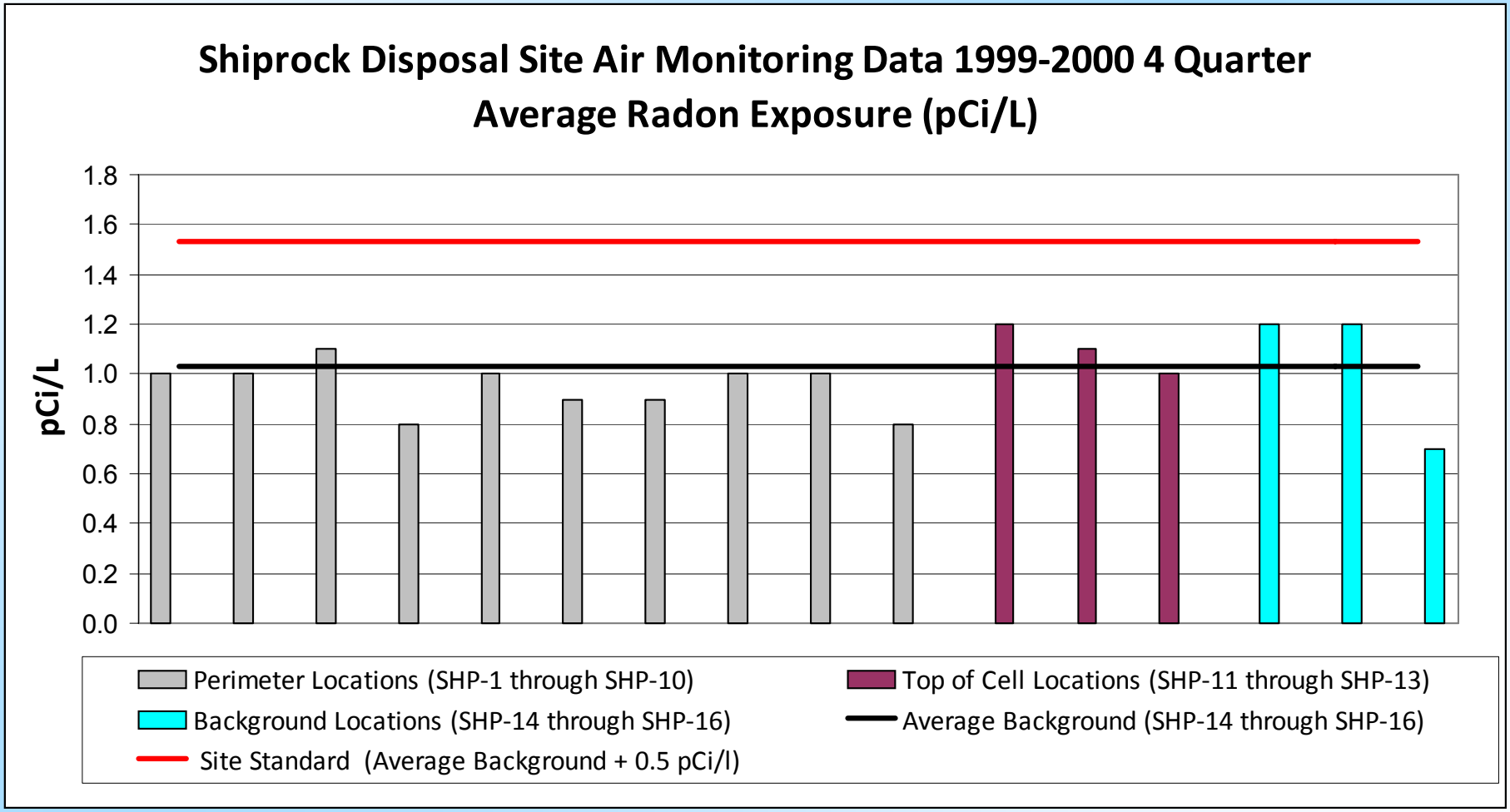
Effects of Degradation Processes on Radon Attenuation and Biouptake

- DOE LM has not directly measured effects of root intrusion and soil development on radon attenuation or biouptake.
- DOE monitored radon on and around disposal cells with Radtrak cup air samplers at Shiprock, Lakeview, and Grand Junction.
- At all sites radon was below the 40 CFR 192.02(b)(2) standard (average background +0.5 or +3.0 pCi/L).

Shiprock, NM Radon Monitoring



Shiprock, NM


Shiprock Disposal Site Air Monitoring Data 1999-2000 4 Quarter
Average Radon Exposure (pCi/L)
pCi/L
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Perimeter Locations (SHP-1 through SHP-10)
Top of Cell Locations (SHP-11 through SHP-13)
Background Locations (SHP-14 through SHP-16)
Average Background (SHP-14 through SHP-16)
Site Standard (Average Background + 0.5 pCi/l)

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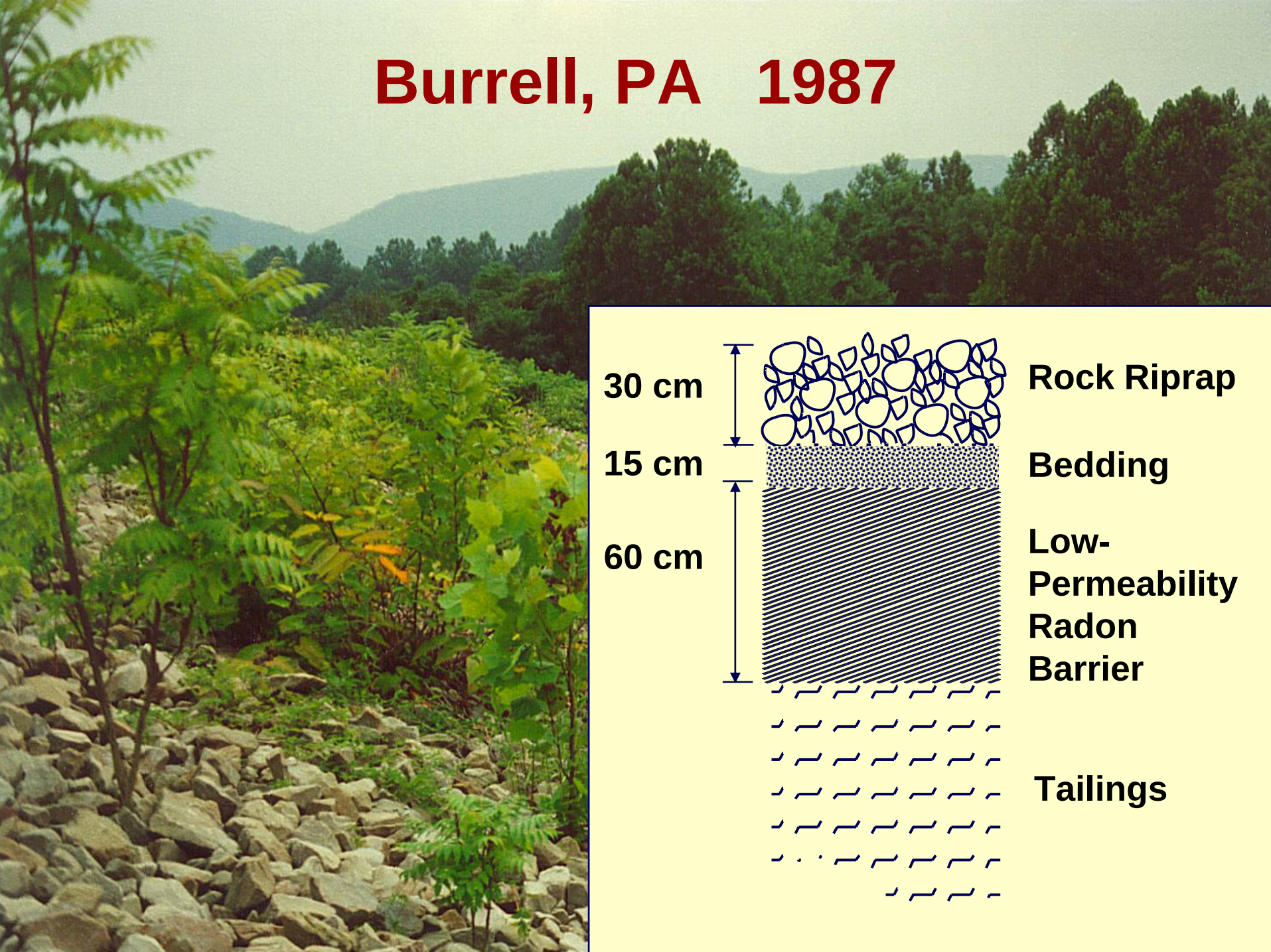
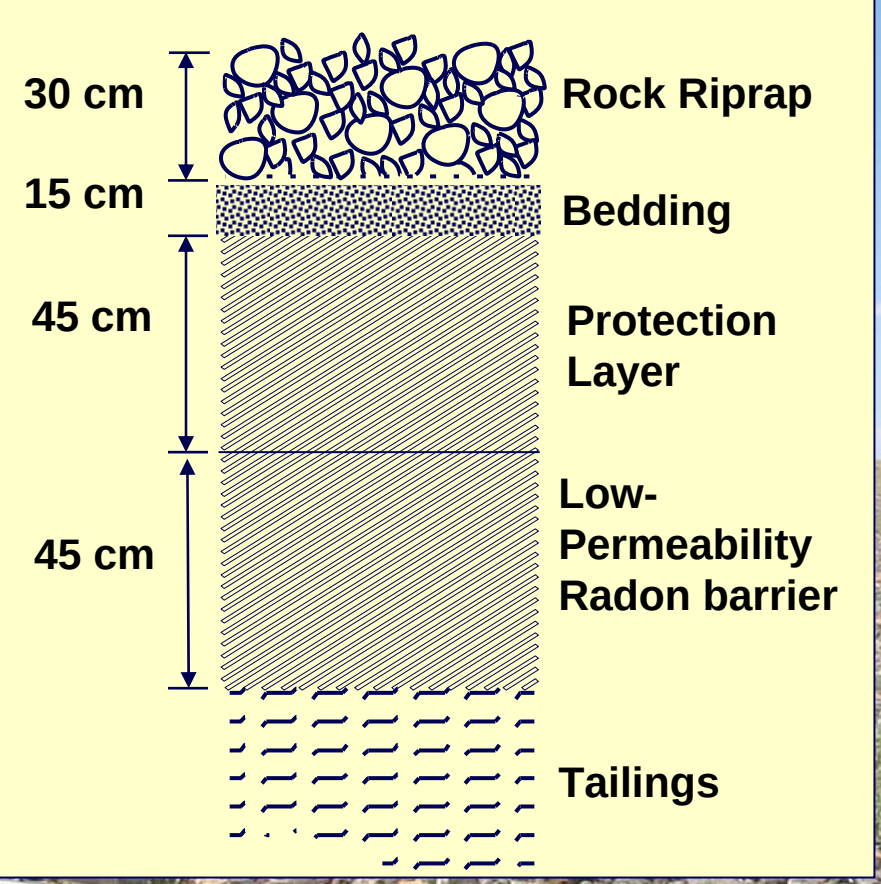
Burrell, PA 1987

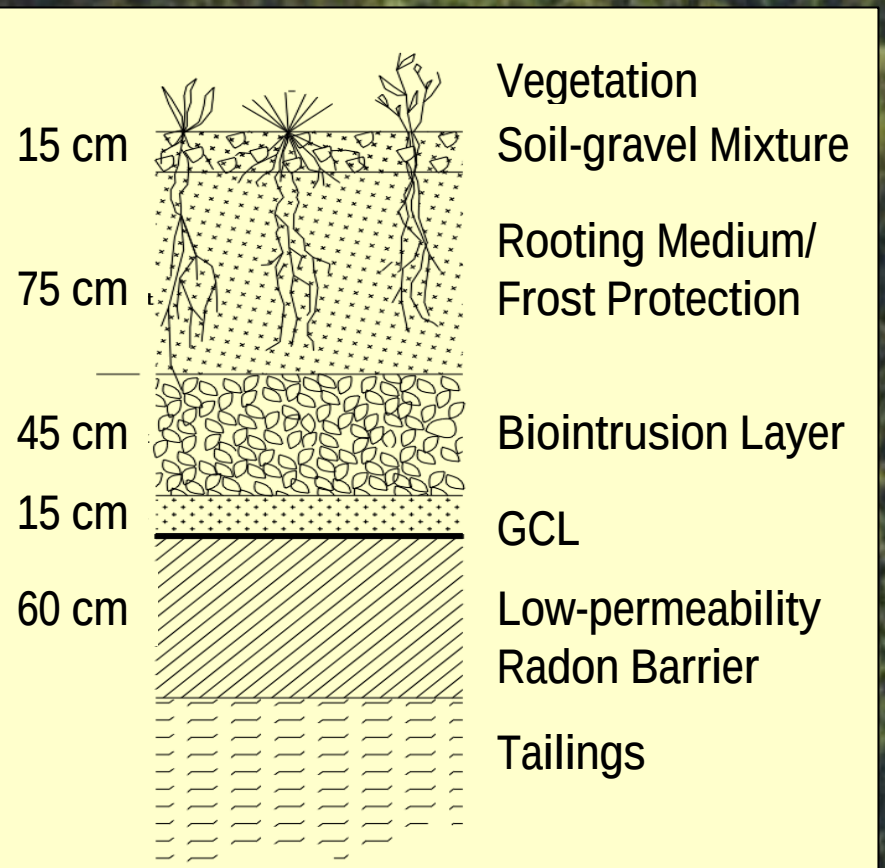


Grand Junction, CO
1994



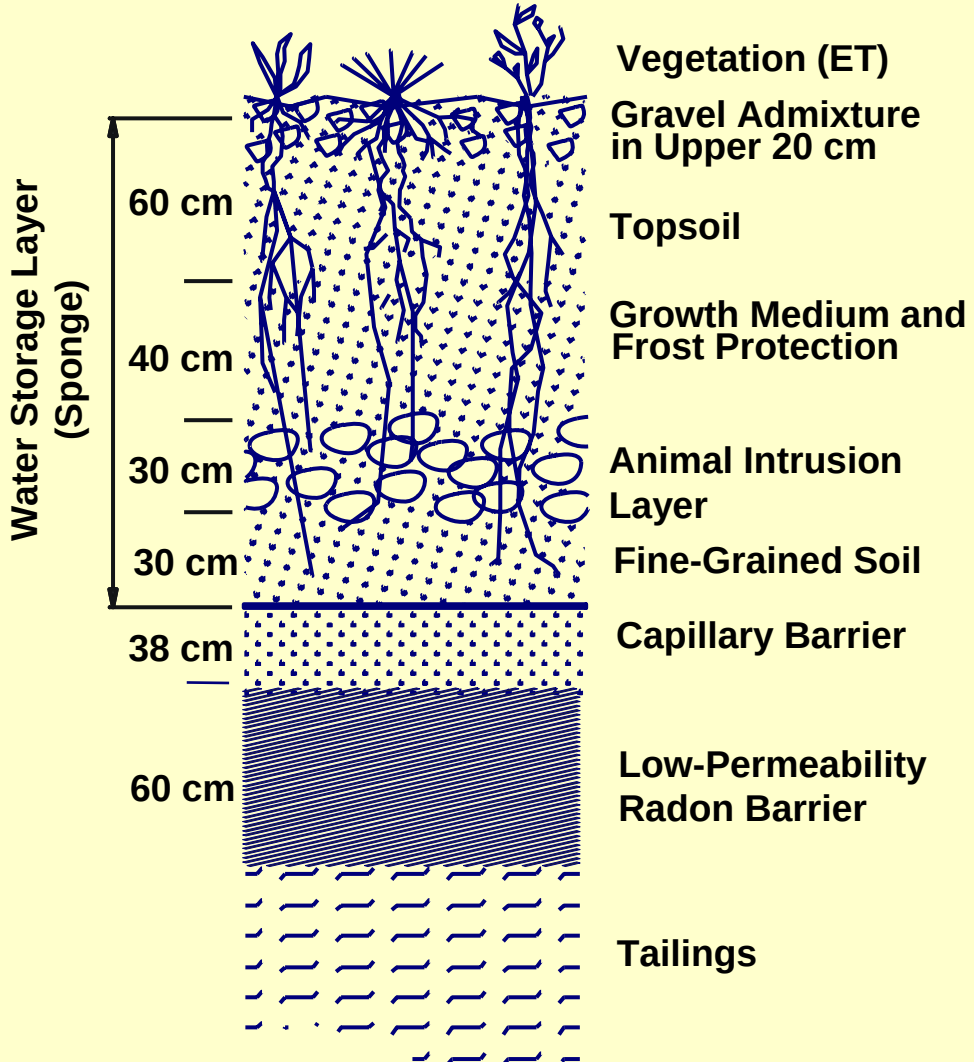
Protection layer to control freeze-thaw and desiccation cracking of low-permeability radon barrier from frost

Durango, CO 1992



- Vegetation
- Soil-gravel mixture
- Rooting Medium
- Biointrusion Layer
- Geosynthetic Clay Liner

Monticello, UT 2000



- Water balance cover – "ET cover"
- Designed to accommodate degradation processes
- Preserved soil edaphic properties
- Mimicked native plant community
- Water storage layer designed for possible wetter climate
- Animal intrusion layer
- Capillary barrier: (enhances water storage)

Root Growth and Soil Development in Monticello Water Balance Cover

Soil Hydraulic Properties

Soil block monoliths

2-Stage Borehole Infiltrometer

Sealed Double-Ring Infiltrometer

Monticello Root and Soil Development Study Highlights

- Greater-than-expected soil structural development 7 years after construction
- Soil structure development related to
  - An increase in saturated hydraulic conductivity, but also, greater soil water storage capacity
  - Improved habitat for sagebrush (deeper water = deeper roots)
  - An increase in leaf area index
- Overall, soil development had little influence on the performance of the water balance cover as measured in a 3-ha embedded lysimeter

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Shrub encroachment and soil development may be the *solution*, not the *problem*!

Without intervention, natural "degradation" processes may eventually transform conventional low-permeability covers into ET-type covers.

LTSM Options:

- **Control plant growth**
- **Let plants grow**
- **Accelerate soil development and ecological succession**

Cover Renovation!

Grand Junction, Colorado

Cover Renovation Research

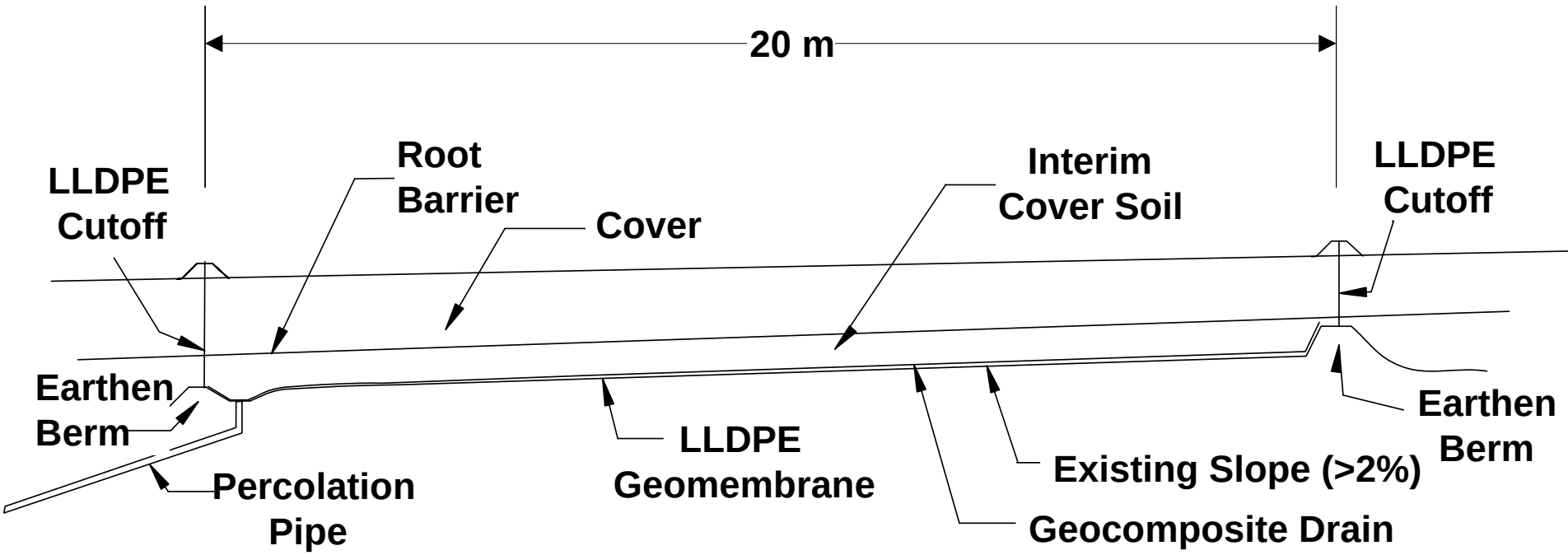
Goal: **Transform conventional covers into ET covers**

- **Reduce soil bulk density (compaction)**
- **Increase soil water storage capacity**
- **Blend soil and rock to imitate natural analogs (Session 5)**
- **Enhance establishment of favorable vegetation**

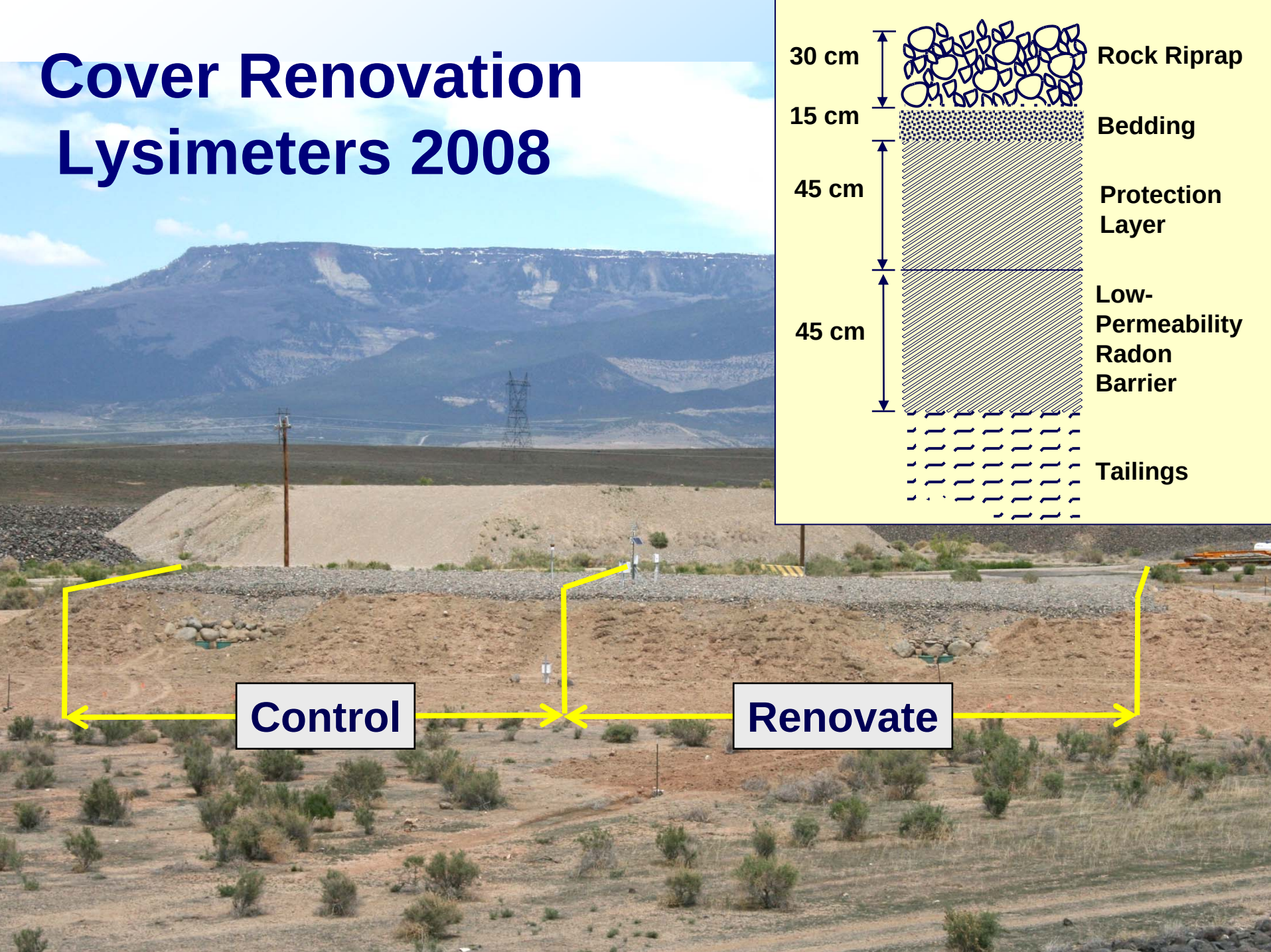
Test: **Construct pair of large drainage lysimeters, identical to actual cover, and compare water balance of existing and renovated designs**

Renovation Concept: **Rip the rock, drainage, and protection layers on the contour, and transplant native shrubs in rip rows**

RECAP Lysimeter Cross Section



Cover Renovation Lysimeters 2008



Cover Renovation Test Pad - 2010

Treatments

Ripping

1. Ripping depth
2. Rip row spacing
3. Rip tine flanges (soil-rock mixing)

Revegetation

1. Species composition
2. Seeding vs transplants
3. Soil amendments

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Responses to Session 2 Questions

- Rock covers can increase soil water storage and create habitat for woody plants
- Root intrusion and soil development can increase the saturated hydraulic conductivity of the low-permeability radon barrier
- Different soil development processes may be causing preferential flow in the low-permeability radon barriers
  - Soil structure developing faster than expected
  - Intrusion by plant roots (and burrowing animals)
  - Freeze-thaw cracking and desiccation
  - Retention of borrow soil structure after construction
- Higher-than-expected saturated conductivity *may* cause significant percolation through low-permeability covers
- Root growth and soil development had little effect on the performance of the Monticello water balance cover

Responses to Session 2 Questions

- Cover designs for uranium mill tailings have evolved in response to evidence of degradation processes
- DOE is currently investigating cover renovation—enhancing the natural transformation of conventional low-permeability covers into water balance or ET covers
- Results of radon monitoring surrounding selected disposal cells shows that sites are in compliance with the standard
- DOE has not directly measured effects of cover degradation processes on radon flux and biouptake
- Renovation could dry cover soils and potentially increase radon flux
- Cover renovation research will address effects on radon attenuation, biouptake, and erosion where applicable