Evapotranspiration (ET)
Landfill Covers

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Current Practice

- Long-term waste storage in place or warehousing
- Objective: Keep it dry to prevent leaching

Similar to storing antique cars for decades

Requires a good landfill cover
Conventional Landfill Cover

“Impermeable Barrier” Concept

- Cover Soil
- Drainage
- Clay Barrier
- Gas Collection
- Foundation
- Waste

\[ K < 1 \times 10^{-7} \text{ cm/sec} \]
Conventional Cover Leakage

- **Clay barriers**
  - Leak and crack \( (\text{Elsberry, Miller and Mishra and Dwyer, 98 & 99}) \)
  - Likely to leak \( (\text{Suter et al., 93}) \)
  - Leak 6 to 8 inches/year (Germany) \( (\text{Melchoir, 97}) \)

- **Geomembrane or Plastic**
  - Leak \( (\text{Bass, 85, Brown, 86}) \)
  - Poor seams leak \( (\text{Jayawickrama, 88}) \)

- **Composite barriers – The best**
  - Leak \( (\text{Dwyer, 98 & 99}) \)
  - Leak .05 -.14 inches/year (Germany) \( (\text{Melchoir, 97}) \)
Conventional Cover Performance

- Appears to be satisfactory
- Therefore, some leakage appears to be acceptable

How much leakage is acceptable?

Suggest: 0.2 in./yr. (5 mm/yr.)
What is the State of Cover Technology?

- Conventional cover attributes:
  - Expensive to build - up to $570,000/acre
  - High maintenance cost
  - May require future replacement

- Is there a better landfill cover?
  - Vegetative covers?
    - Self renewing – natural cover, but
    - Some vegetative covers have failed
Vegetative Cover Failures: Why?

- Insufficient soil depth - (1)
  - Inadequate water storage capacity
  - Can not support healthy plants

- High soil density
  - Results in low water holding capacity
  - Causes poor or no root growth

[conclusion from data in paper – (2)]

- Anderson (1997)
- Warren et al. (1996)
Root Growth – Soil Strength

Effect of soil bulk density ($B_d$) on root growth

From: Sharpley & Williams, 1990, pp. 56-57

From: Mitretek Systems, Innovative Technology in the Public Interest™
Persistence of Soil Compaction

- Wadsworth trail (Minnesota), wagon tracks can still be seen

- After 100 years of disuse (with grass cover and freeze-thaw action) the trail had:
  - Greater bulk density
  - Poor soil structure
  - Poor plant growth

Sharratt, Voorhees, McIntosh and Lemme
Evapotranspiration (ET) Cover

Nomenclature

- **Failures** are associated with “Vegetative Cover”
- **Use** “ET Cover”
  - to describe correctly designed and constructed vegetative covers
ET Landfill Cover

No barrier Layer
Field Verification of ET Concept

Alberta
Sask.
Manitoba

< 4 years
8 years
long term
precipitation, inches
Short-term Experiments

- One or more treatments similar to ET cover at each site
- *No water movement below grass roots*

< 4 years

Precipitation inches
Mineland Experiment

- Covers similar to an ET cover
- 8 years – *No water movement below grass roots*

![Diagram of Texas with a label indicating 35 inches]
Long-term Measurements

- **33-years** - Pawnee National Grasslands (Colo. State. Univ. & USDA)
- **Centuries** - Bushland, TX (USDA)

No water movement below roots of native grass
Saline Seep Region

• 12,000 years - *No water movement below roots of native grass*

Soil Salt Content

Field Verification of ET Concept

Alberta  Sask.  Manitoba

< 4 years
8 years
long term
precipitation, inches
Extrapolation

- Model required to extrapolate from proven sites
- Environmental Policy Integrated Climate (EPIC) model contains comprehensive models for:
  - Climate
  - Soil
  - Plants
  - Hydrology (including soil water balance)
- Operates on a daily time step
- Capable of modeling thousands of years
Geographic Application for ET Covers

Generally Effective

Site Specific
Requirements for Success of ET Covers

• Adequate soil water holding capacity
  – soil depth and plant-available water holding capacity
• Adequate plant nutrition (CEC, pH etc.)
• Rapid and prolific root growth
  – Soil temperature
  – Plant health
  – Soil water content
  – Soil strength
    • Particle size distribution
    • Soil chemistry and water content
    • Soil bulk density
Design Criteria for Critical Event on an ET Cover

● **Objective:**
  – Control percolation through the landfill

● **Cover design requires adequate:**
  – Soil thickness to store water
  – Root growth rate to extract water stored as a result of the design storm event

● **Evaluate ET cover application at each site**
  – Use models and measured data
Critical Event

Field Capacity

Soil Water

Wilting Point

Precipitation

Available Storage

Mar. | April | May | June
ET Cover –
Protectiveness Potential

● Natural system - less prone to failure
● More protective of human health and environment because it is less prone to failure
● Minimum design and construction time
● Long life
Construction Cost Avoidance
-- Potential of ET Cover

- Estimates for one landfill in a semiarid climate
  - save $212 to $247k per acre

- Conservative estimate (most of country)
  - save $150 to $200k per acre

- Potential Air Force cost avoidance
  - $500 to $750 million
Conclusions

● ET cover has potential for:
  – Improved protection of human health and environment
  – Large cost savings

● ET cover technology is proven and available