Differential Settlement and its Importance on the Performance of Cover Systems at Radiological Waste Disposal Facilities

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Workshop on Engineered Barrier Performance Related to Low-Level Radioactive Waste, Decommissioning, and Uranium Mill Tailings Facilities

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Workshop

Engineered Barrier Performance Related to Low-Level Radioactive Waste, Decommissioning, and Uranium Mill Tailings Facilities

Session 3

Experience with Monitoring Devices and Systems Used to Measure Performance

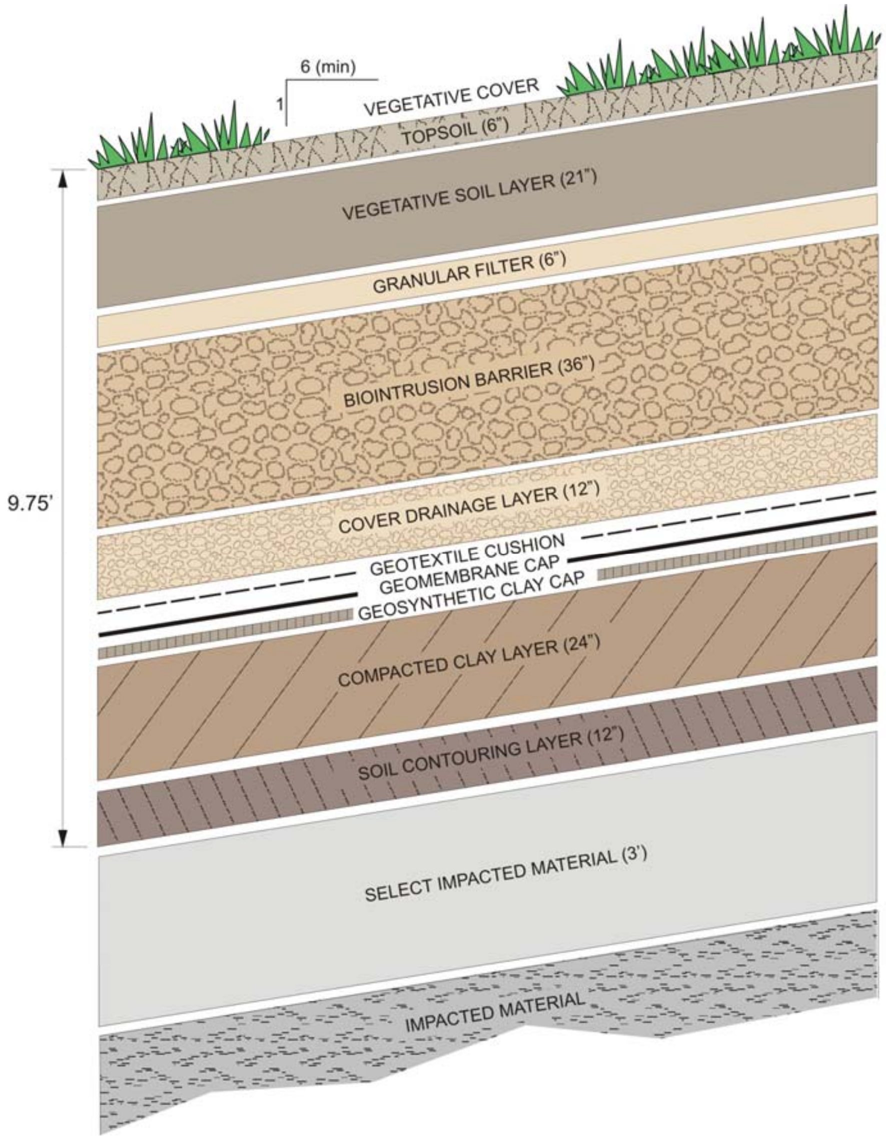
Presentation

Differential Settlement and its Importance on the Performance of Cover Systems at Radiological Waste Disposal Facilities

Differential Settlement and its Importance on the Performance of Cover Systems at Radiological Waste Disposal Facilities

- Engineered Cover Systems
  - Components
  - Soils and Geosynthetic Material Characteristics
- Differential Settlement
  - Settlement Mechanisms
  - DOE-specific Issues
- Monitoring Devices and Systems
  - Types of Devices and Systems
  - Experience
- Recommendations for DOE Facilities
  - Monitoring and Reporting
  - Rehabilitation

Final Cover at the Fernald OSDF



Note: Soil components comprise > 12 feet

Soil and Geosynthetic Materials

Low Permeability Soil Components

- Performance Expectations
  - Hydraulic barrier
  - Support vegetation
  - Radiological barrier
- Reality
  - Properties are often controlled during construction
  - Clays crack in extension at small strain
  - Desiccation cracking is *de facto* reality in clay
  - Cover systems compress (not extend) upon settlement
  - Fine-grained soil erodes relatively easily
  - Soils (and wastes) are compressible

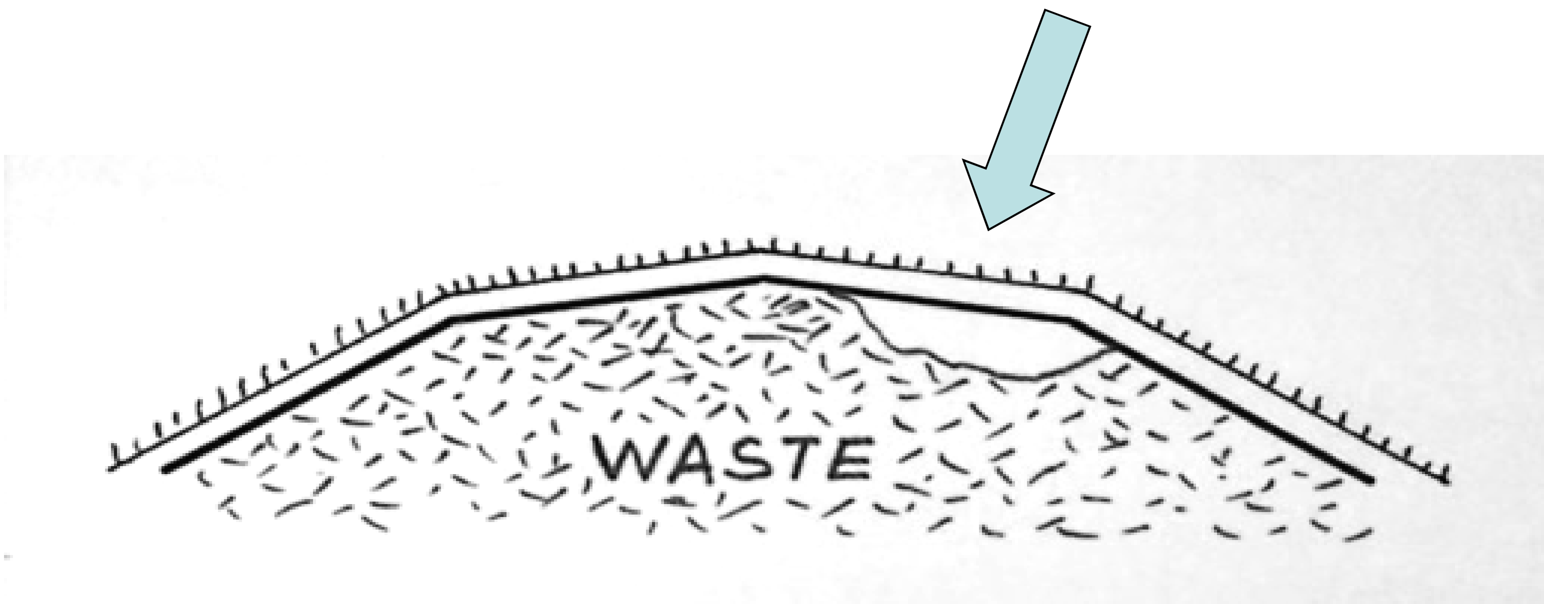
Waste Compressibility

- Mechanisms of waste compression that can lead to total and differential settlement
  - Mechanical Compression – compression of soil and waste due to loading
  - Raveling – Internal erosion of soil due to water and/or migration of soil due to large voids
  - Physico-chemical Changes – degradation of waste and subsequent mass loss
  - Biomechanical Changes – biological decomposition of waste
- Waste (and surrounding soil) compression leads to total and differential settlement

Waste Settlement and Differential Settlement

(admittedly worst case)

- Settlement is not uniform because waste may not be uniform
- Therefore, localized subsidence and differential settlement can occur



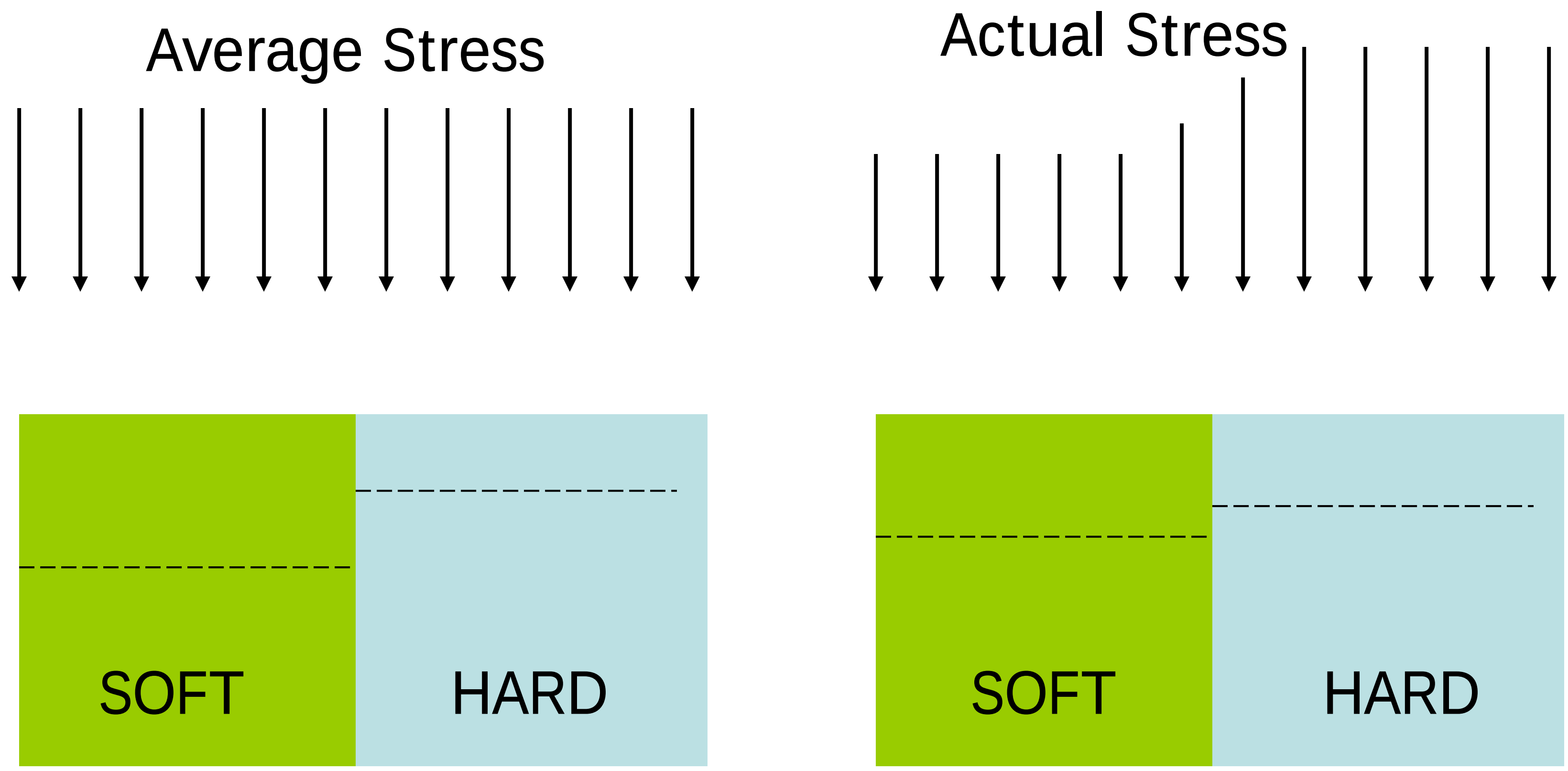
Waste may not be uniform

Often Includes (Temporarily) Stiff Inclusions

DOE-Related Issues

- Extreme conditions as shown on previous slides may be just that…extreme examples
  – Old facilities
  – Uncontrolled trench disposal practices
  – Compromised covers and raveling conditions
- Can likely be controlled at new facilities
  – Monitored waste placement
  – Waste placement plans

Concept of Stress Redistribution



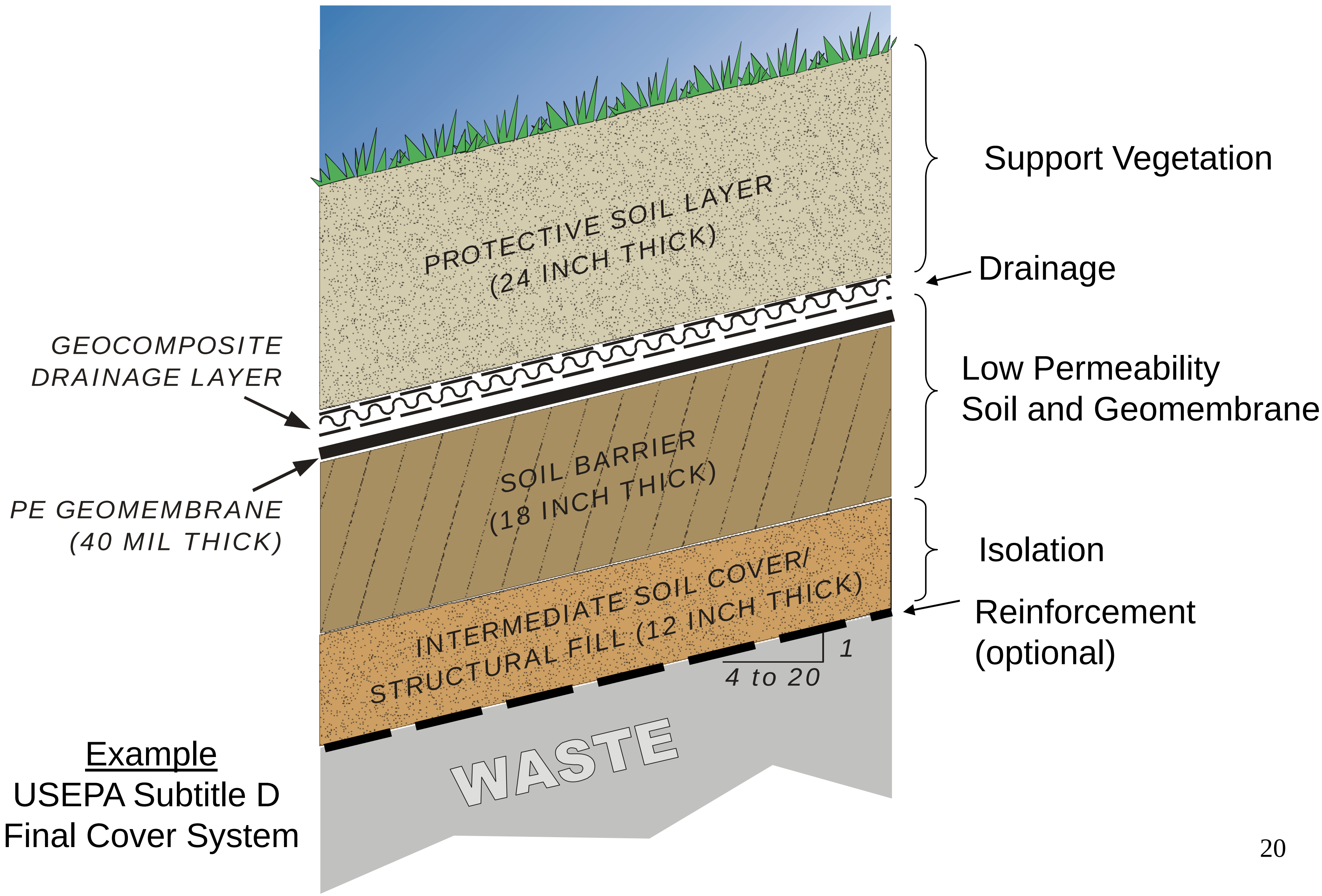
Mother Nature does not like abrupt changes in material properties and will redistribute stress in direct response to materials stiffness

Cracks due to Differential Settlement

Waste Compressibility for DOE

- Mechanisms of waste compression that can lead to total and differential settlement
  - Mechanical compression – likely for DOE
  - Raveling – problematic for old DOE facilities
  - Physico-chemical changes – not likely
  - Biomechanical changes – not likely
- For DOE facilities, may have different concerns and mechanisms when considering old versus new facilities

Performance Aspects of Cover System Components

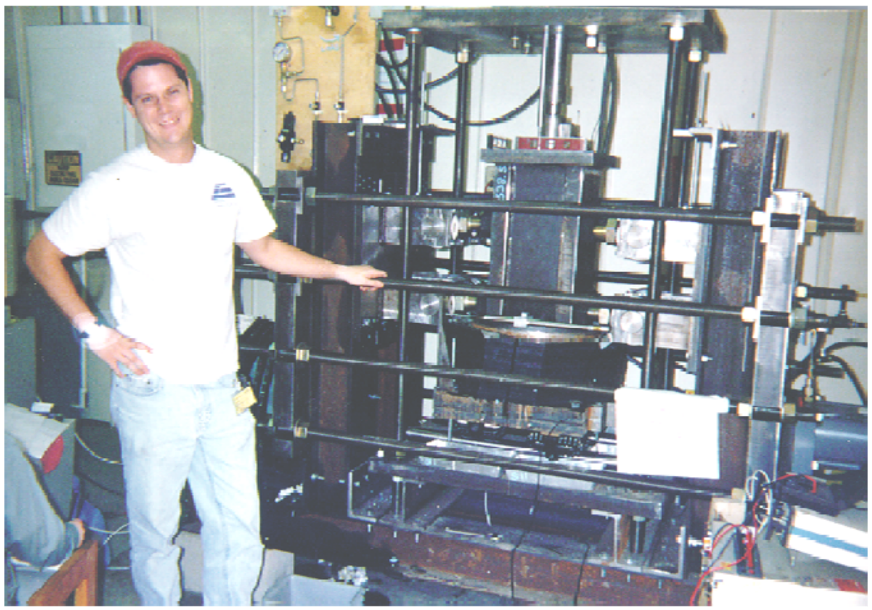


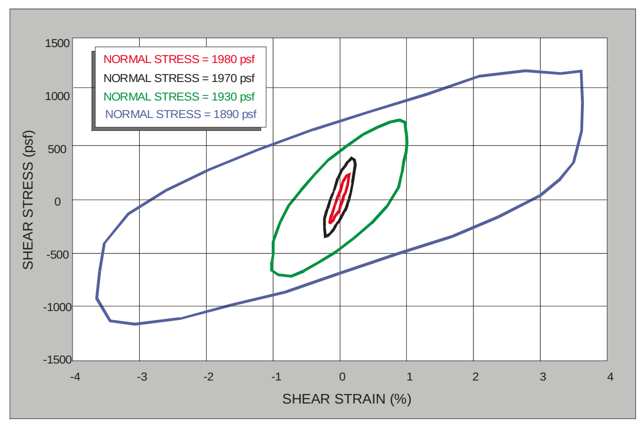
<u>Example</u>
USEPA Subtitle D
Final Cover System

Properties and Measurements

- How to Assess Properties
  - Laboratory tests
  - Performance monitoring and back calculation
  - Monitored large test fill
- Candidate Field Monitoring Concepts/Devices
  - Visual inspection
  - Aerial survey
  - Settlement plates
  - Buried settlement plates
  - Hydraulic sensors
  - Instrumented geotextiles

Large-Scale Testing of Waste

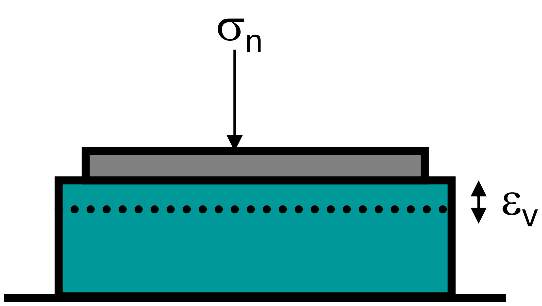




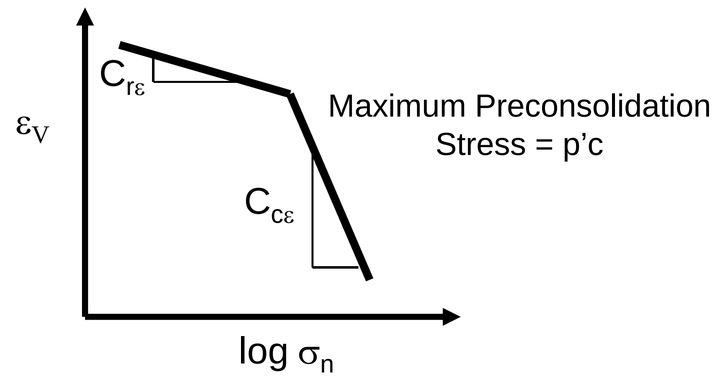
CYCLIC SIMPLE SHEAR TEST RESULTS FOR WASTE SAMPLE

Waste Compressibility

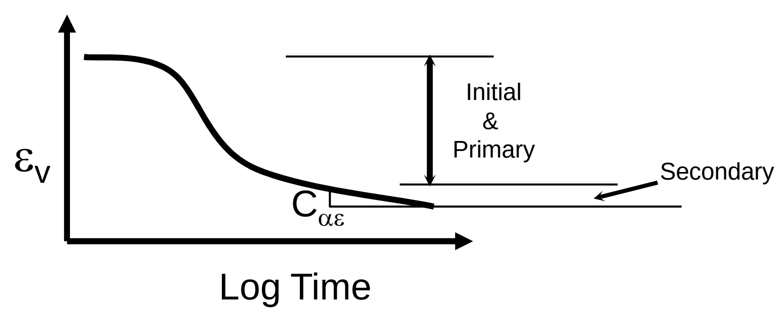
(mechanical… but with time can be physico-chemical and biological)



Primary Compression ($C_{c\varepsilon}$, $C_{r\varepsilon}$)



Secondary Compression ($C_{\alpha\in}$)



Monitoring Devices

- Visual inspection
  - Probably best for DOE
  - Evidence of erosion and “bowl shapes”
- Aerial survey
  - Excellent, except for resolution
  - Provides general assessment
- Settlement plates and surface monitoring points
  - Best, low-cost solution
  - Need to be where there is movement!

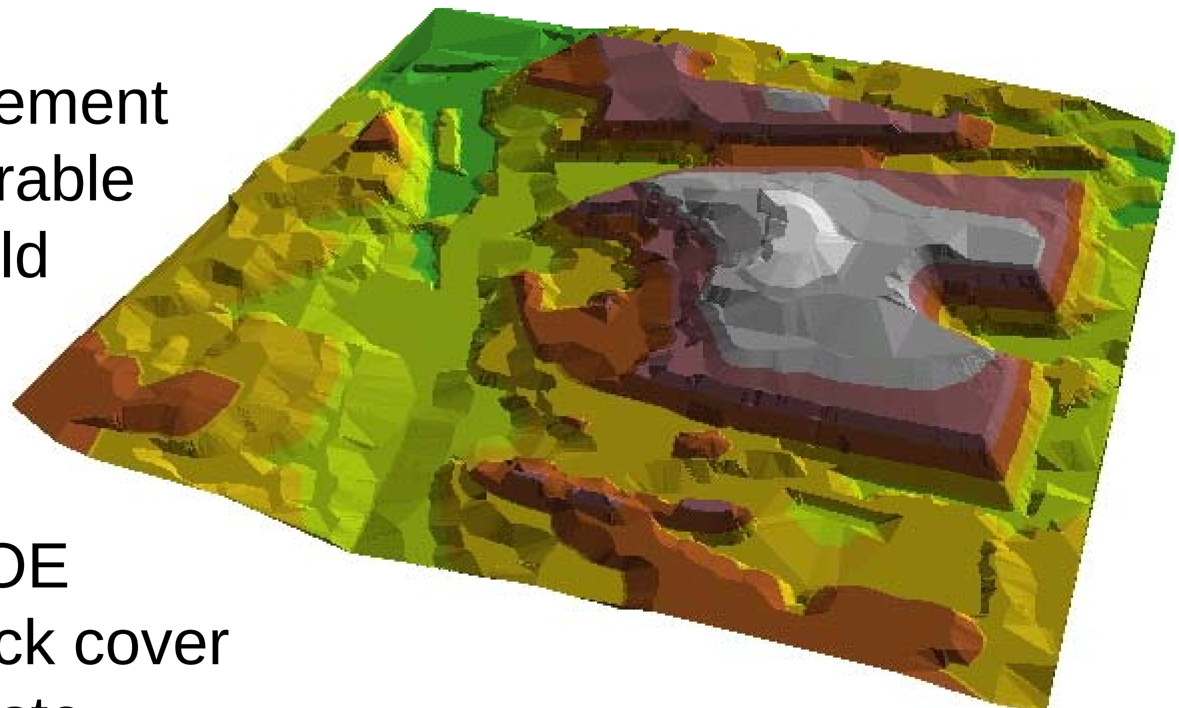
Riser Pipe and Surface Settlement Plate

Monitoring Devices

- Buried settlement plates
  - Can help assess variations with depth
  - Help assess effects of age
- Hydraulic sensors
  - Good for automated monitoring
  - Good for "profiling"
- Instrumented geotextiles
  - May be helpful in long-term study
  - Potential for automated profiling

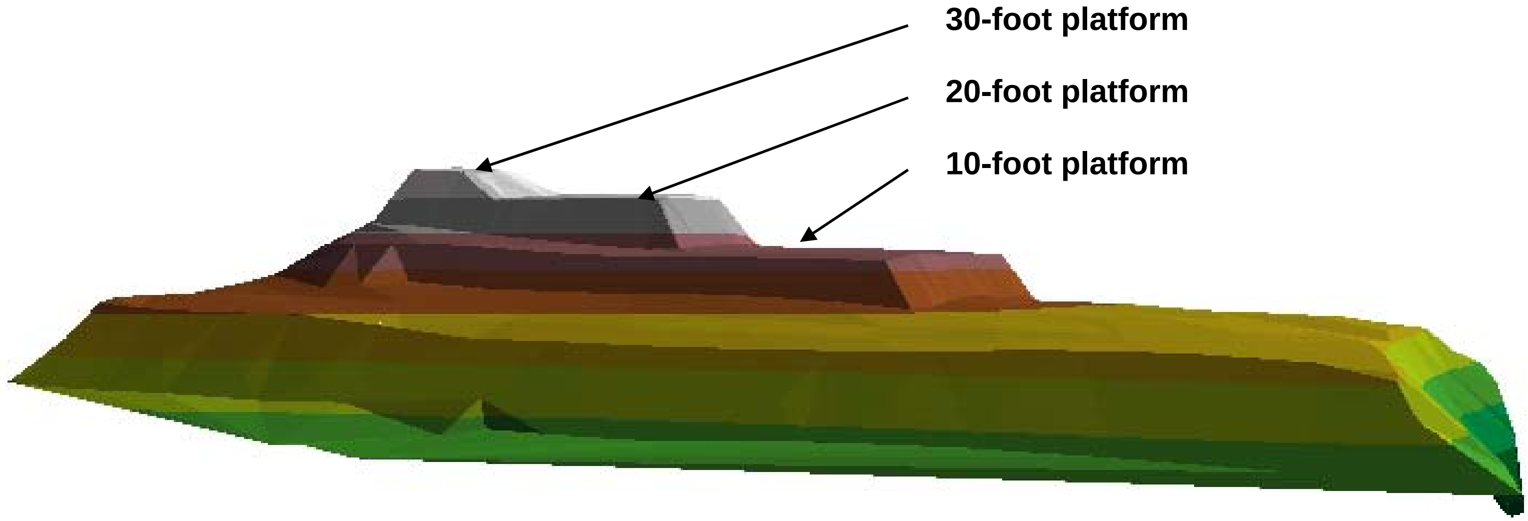
Instrumented Test Fill - MSW

- Vertical and Lateral Expansion of South Shelby Landfill, Memphis, TN
- New Waste Placement Causes Considerable Settlements of Old (Unlined) Waste



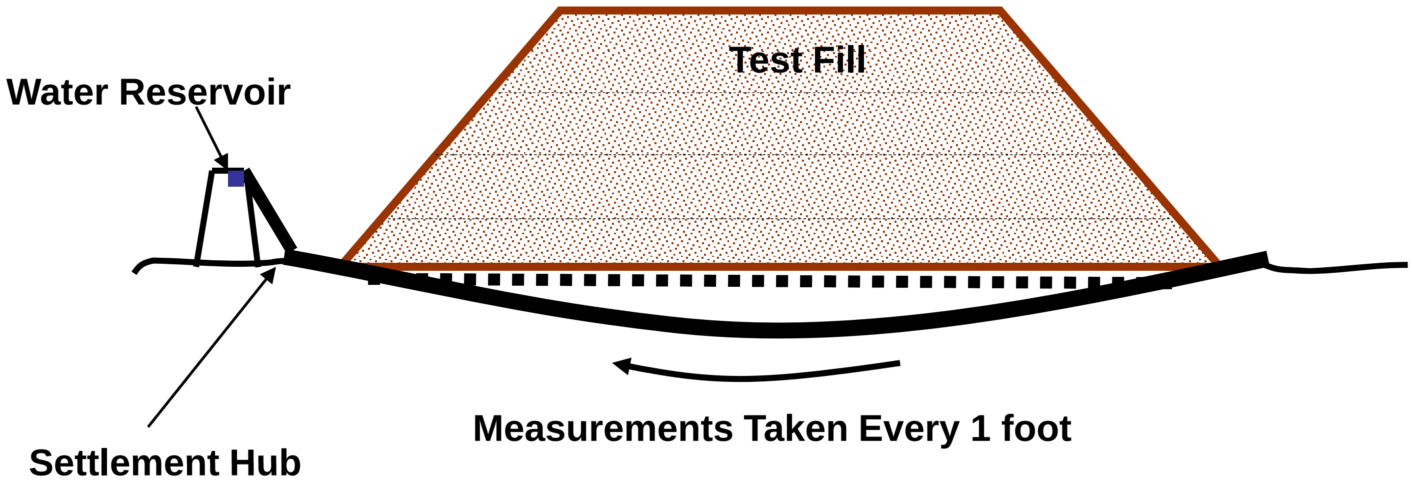
- Analogous to DOE placement of thick cover over existing waste

3D View of Test Fill

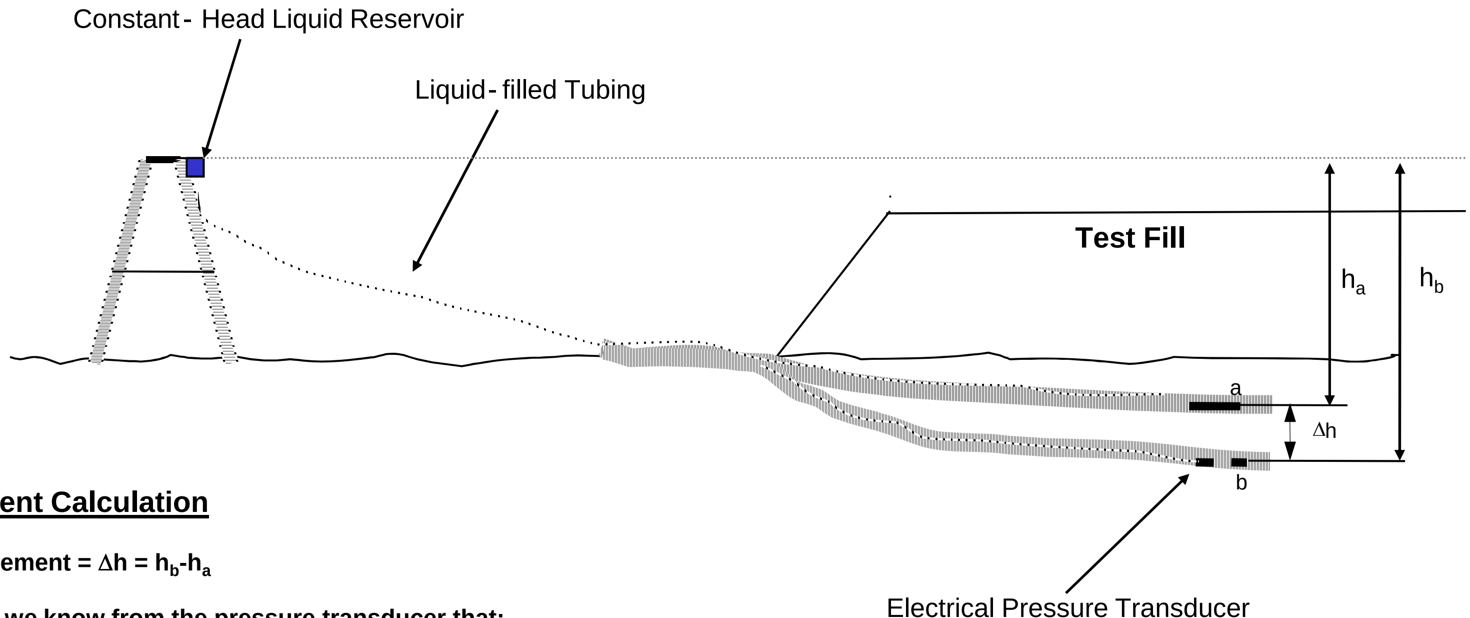


View of Test Fill

Settlement Profiler Schematic



Settlement Profiler System



Settlement Calculation

Settlement = $\Delta h = h_b - h_a$

But, we know from the pressure transducer that:

$$u_b - u_a = \gamma_w h_b - \gamma_w h_a$$
$$= \gamma_w (h_b - h_a)$$
$$= \gamma_w (\Delta h)$$

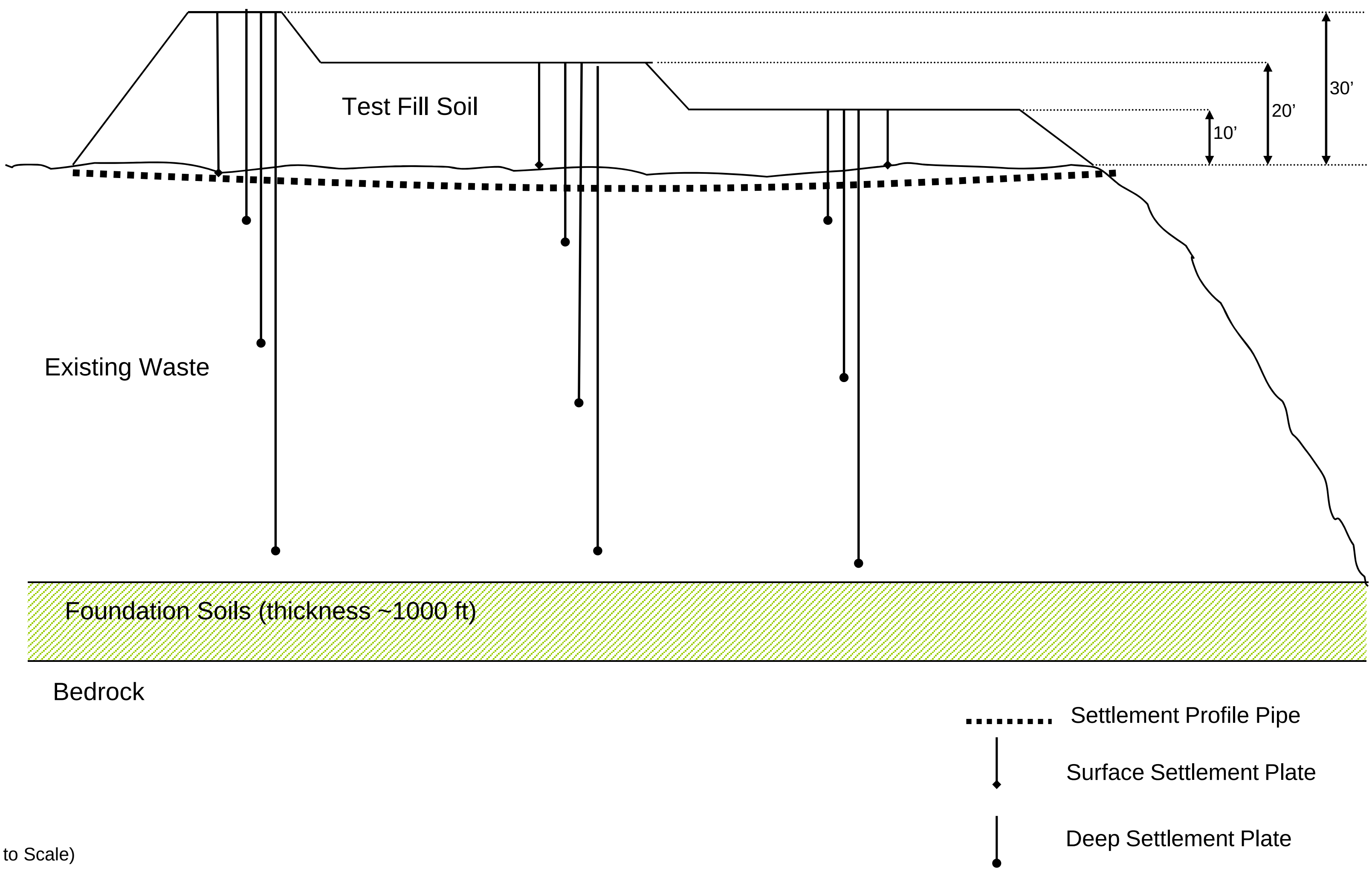
Therefore,

$$\Delta h = (u_b - u_a)/\gamma_w$$

Transducer Position Before Fill Placement (Output = $u_a = h_a\gamma_w$)

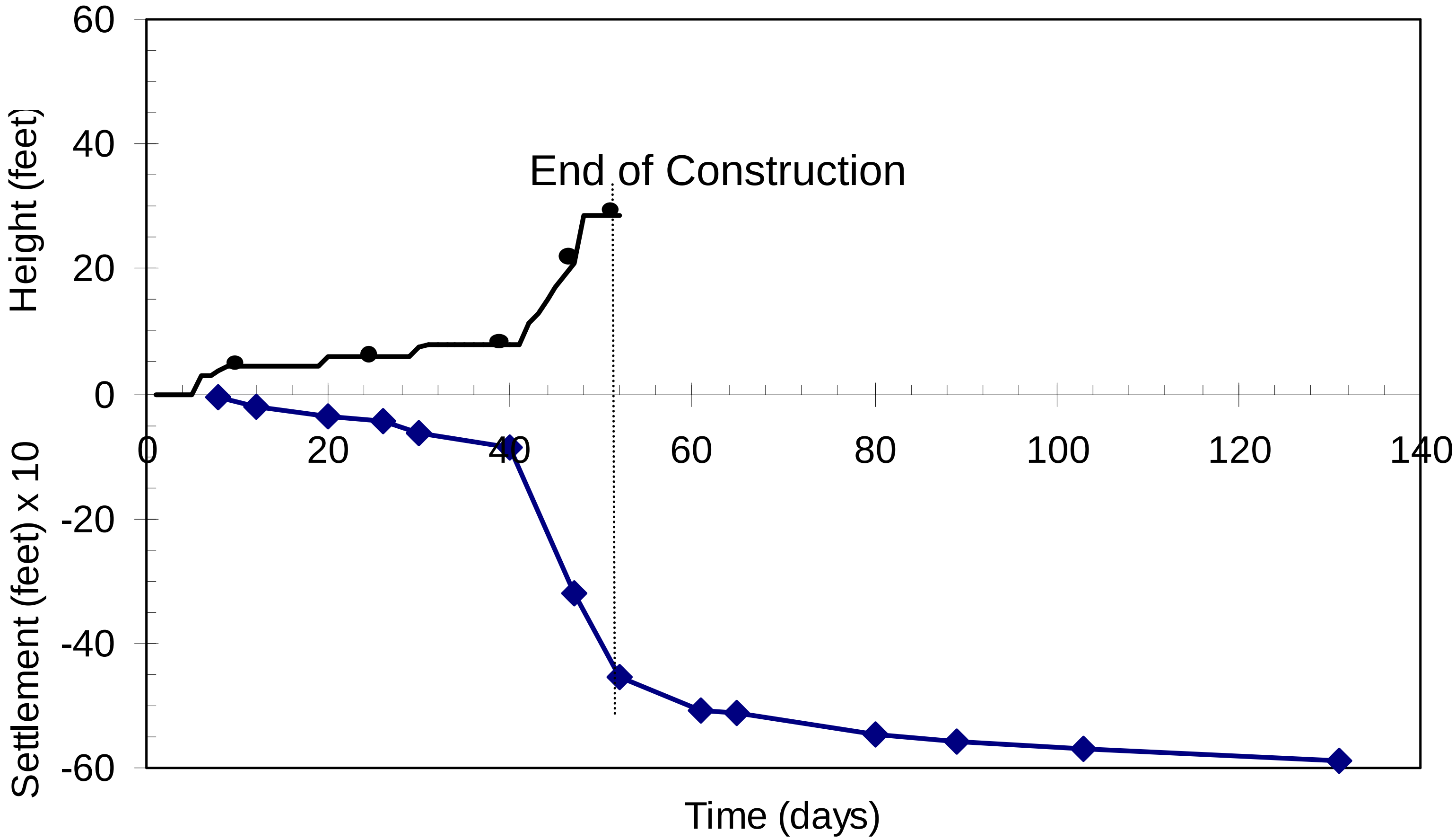
Transducer Position After Fill Placement (Output = $u_b = h_b\gamma_w$)

Longitudinal Cross-Section

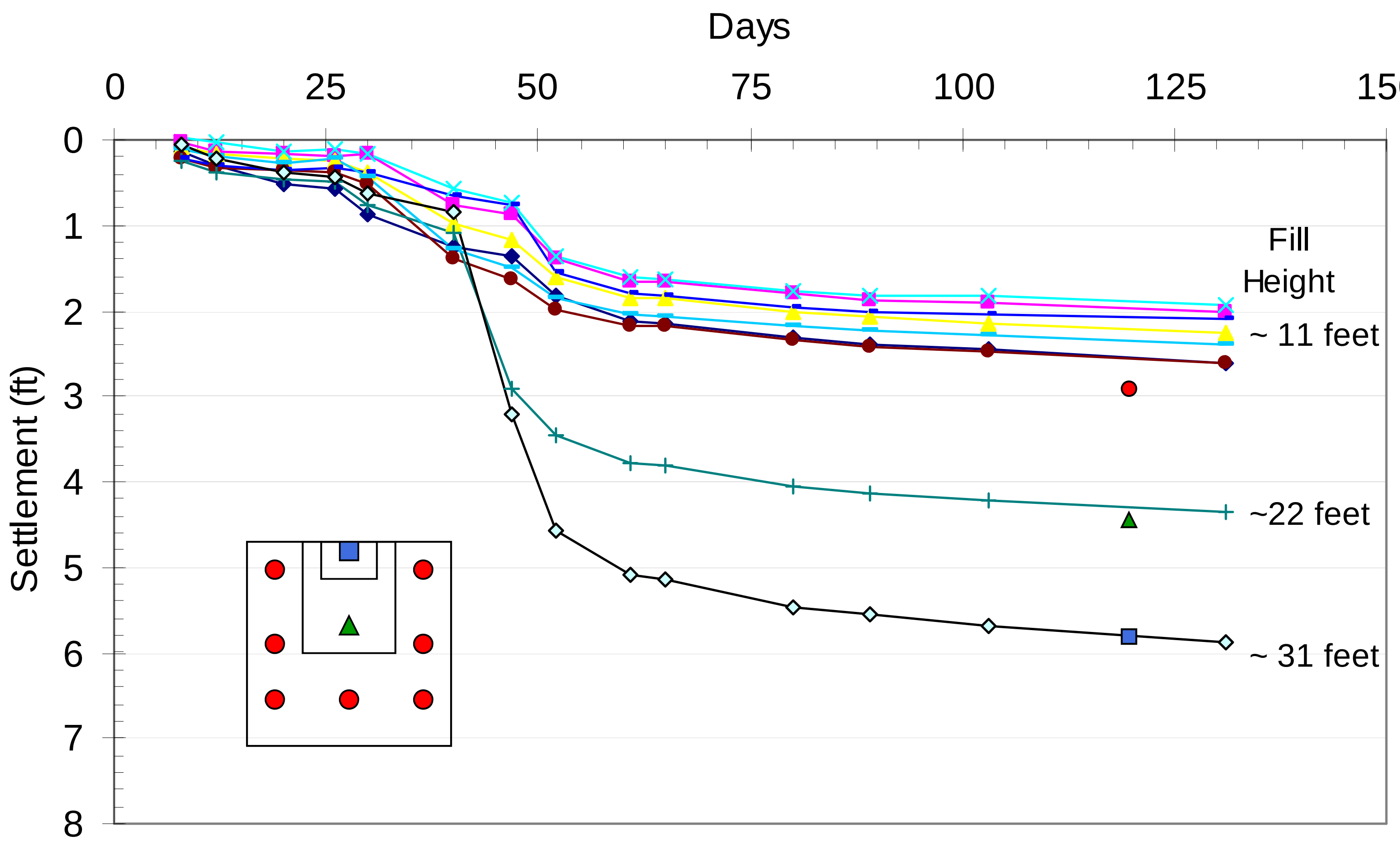


(Not to Scale)

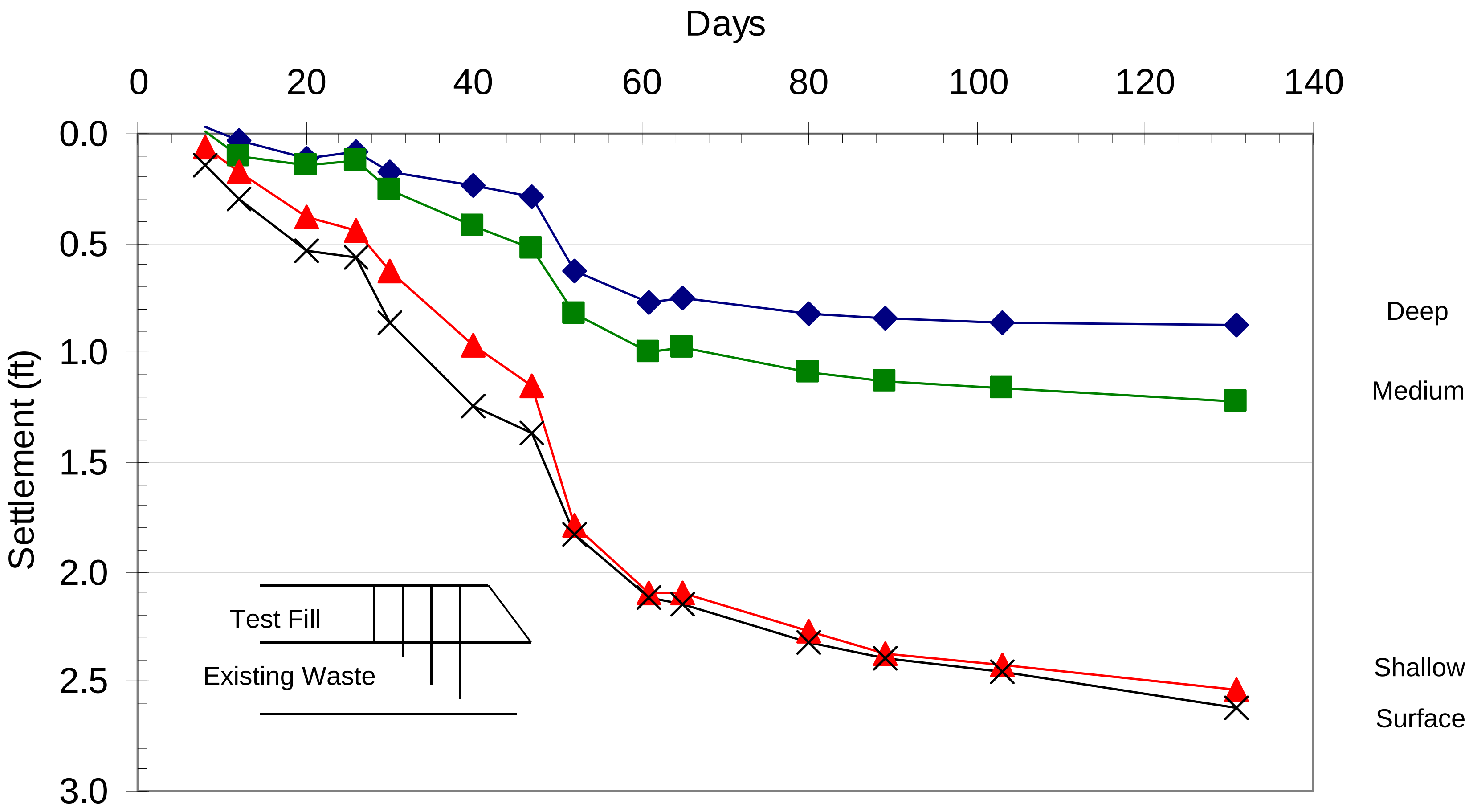
Surface Settlement Plate



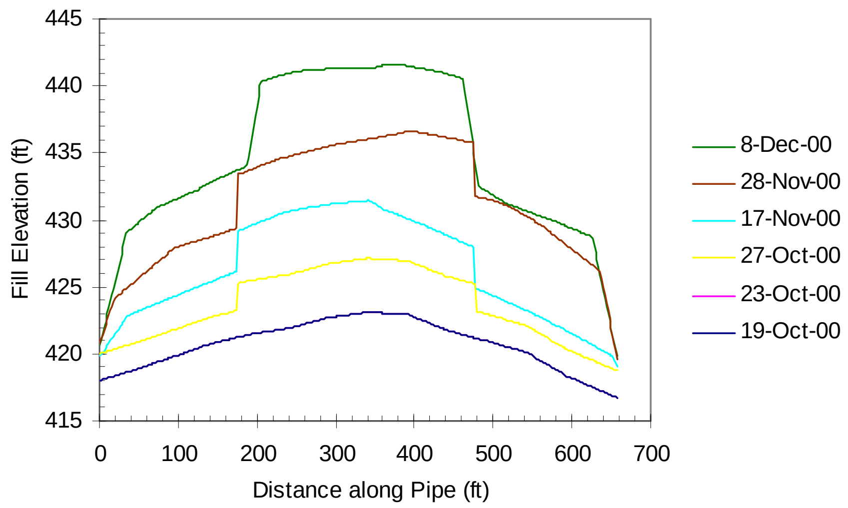
Surface Settlement Plates

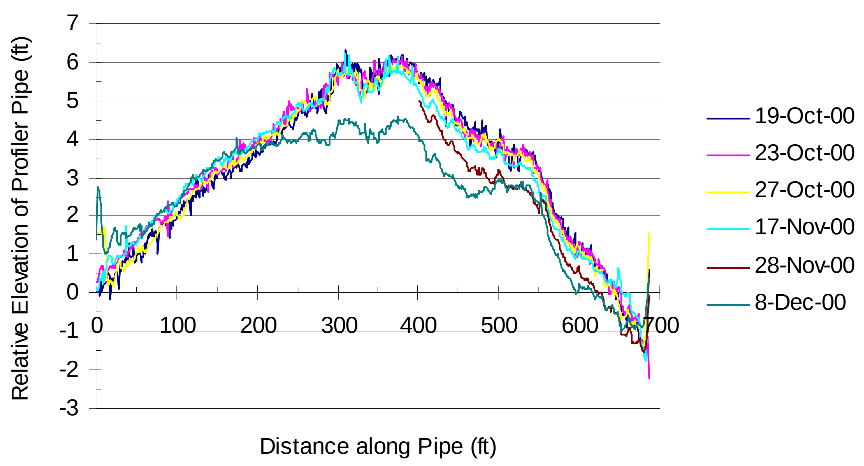


Settlement Profile with Depth

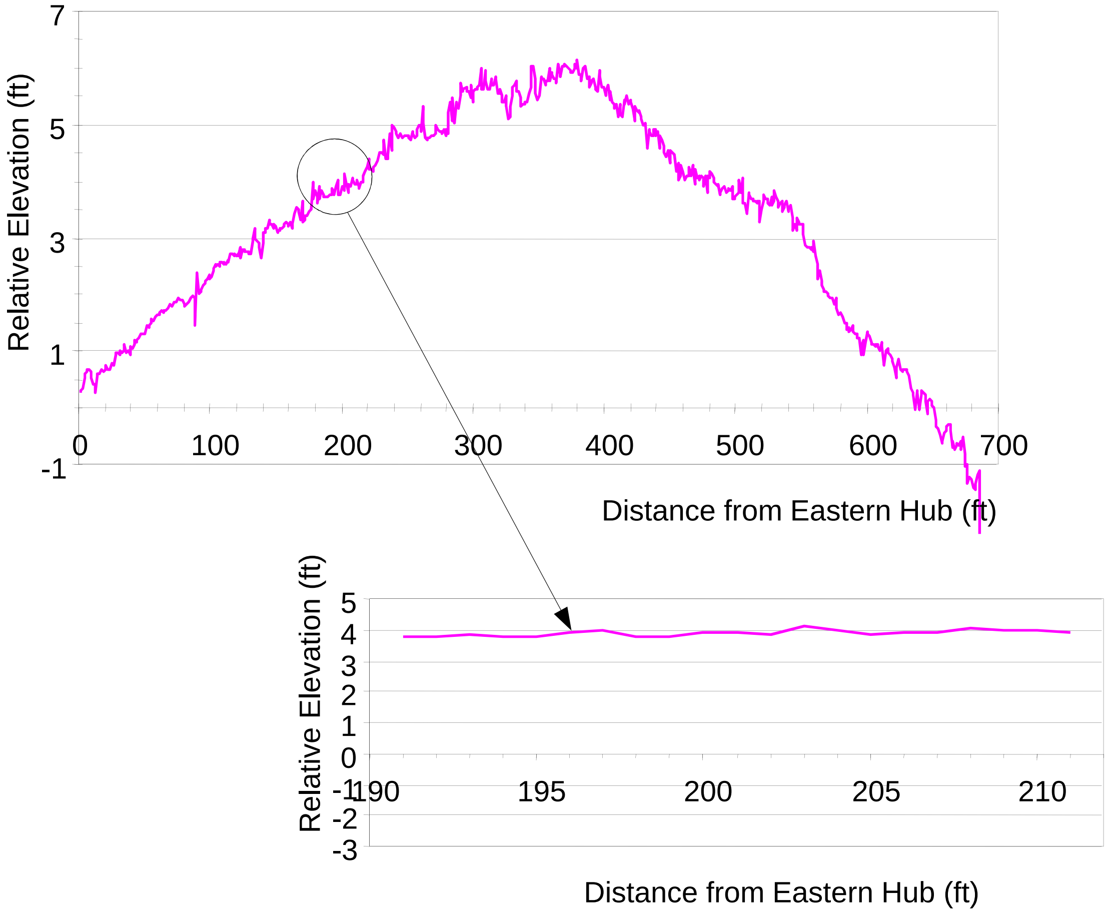


Settlement Profiler Results





Settlement Profiler Results

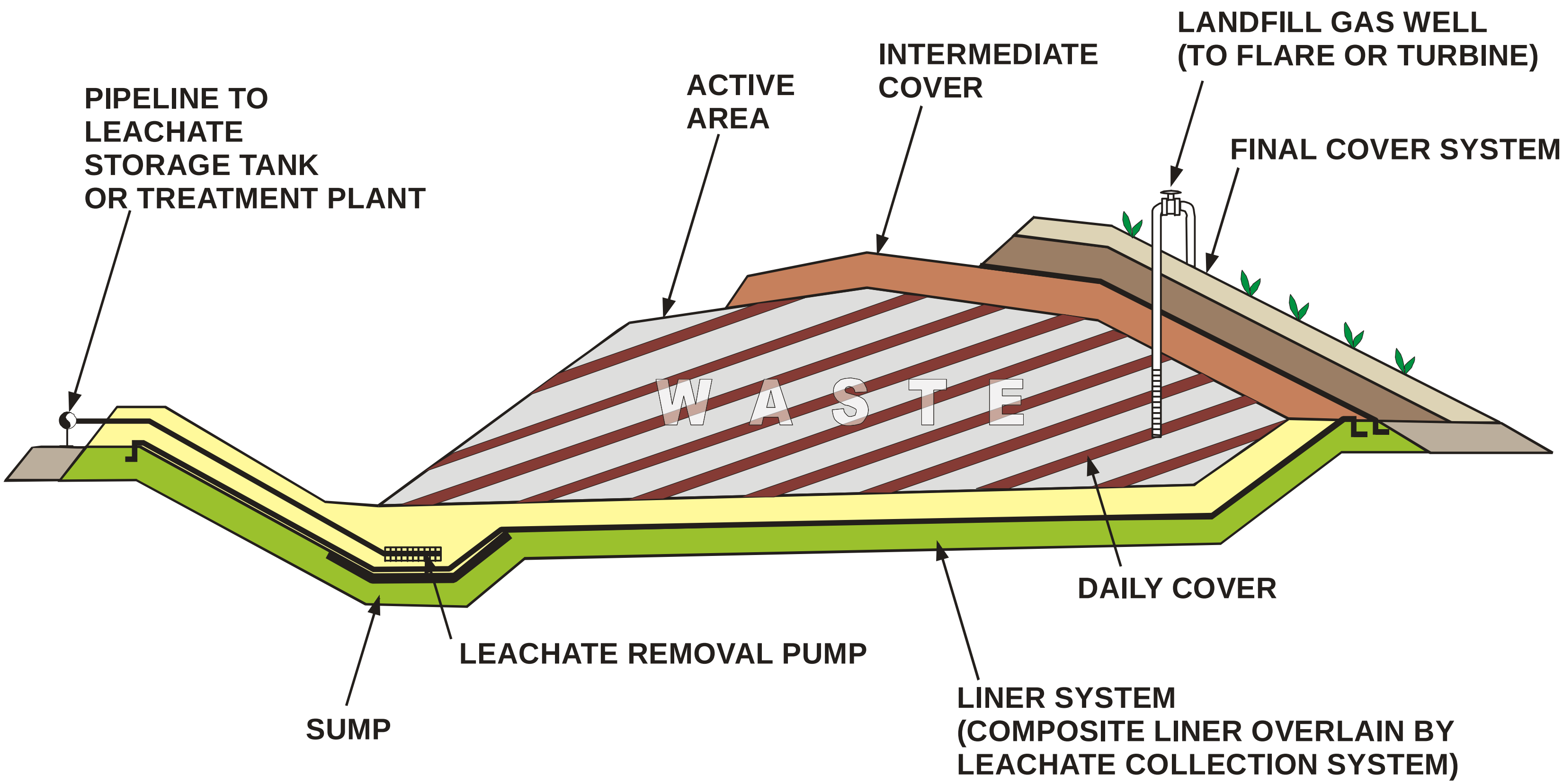


Implications to DOE Sites

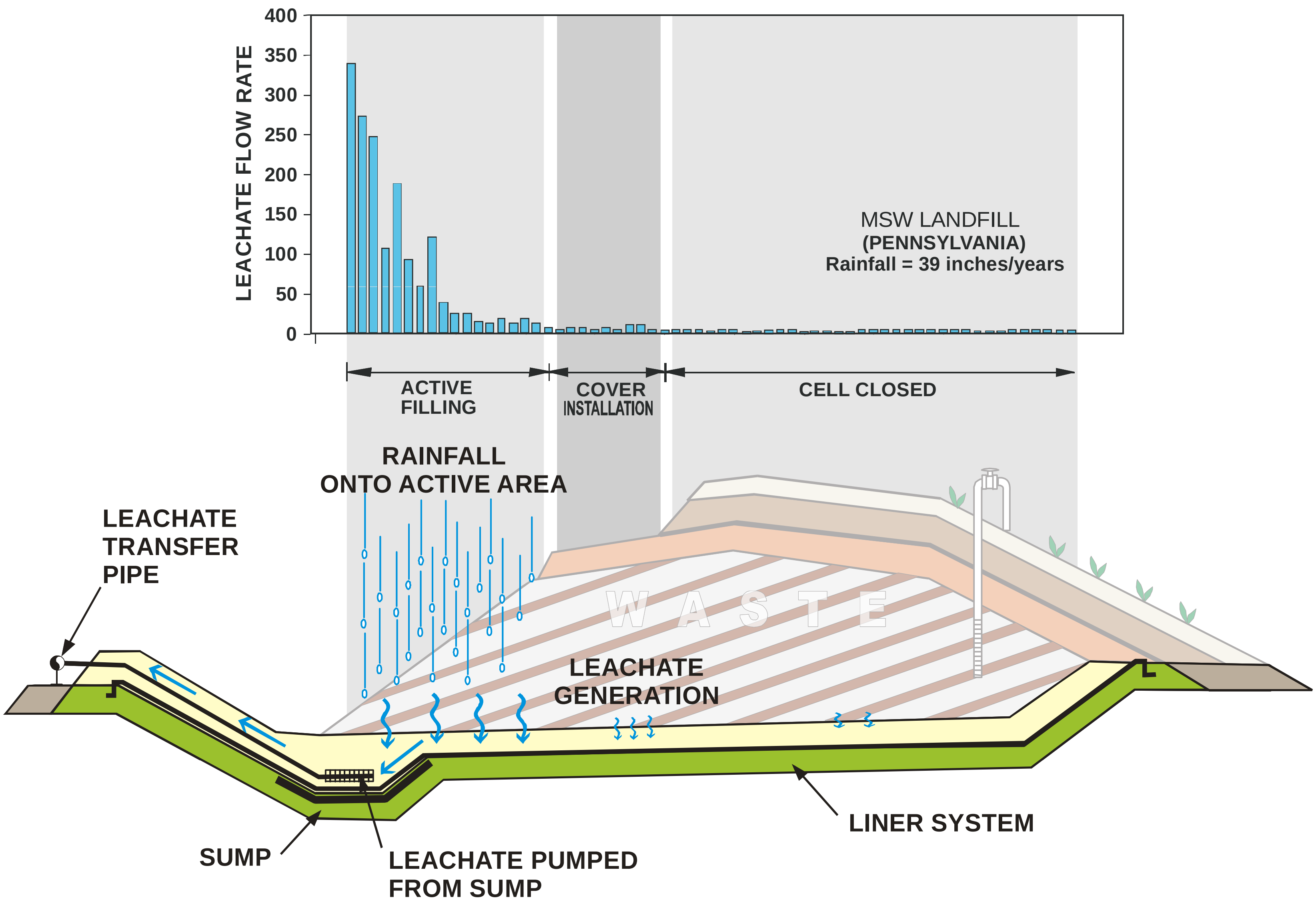
- In the absence of raveling and the introduction of water, differential settlement is NOT a major problem
- Most of the settlement is due to application of load
- Time-dependent settlements are small and relatively uniform
- Monitoring requirements are relatively simple

Liner System and Cover System

(example for Subtitle D MSW)

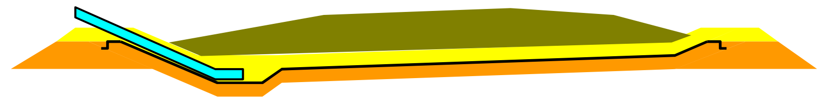


Leachate Generation Rates

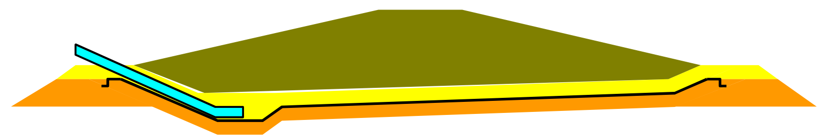


Generalized MSW Leachate Generation Rates – Rainfall Factor

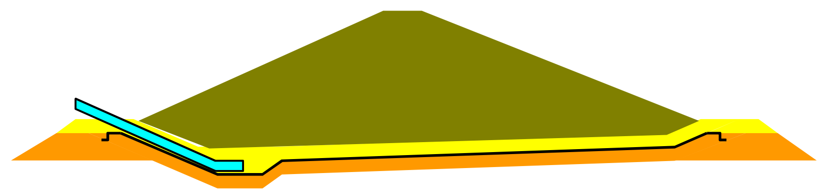
1000 – 2000 gpad
(30 to 60% of rainfall)



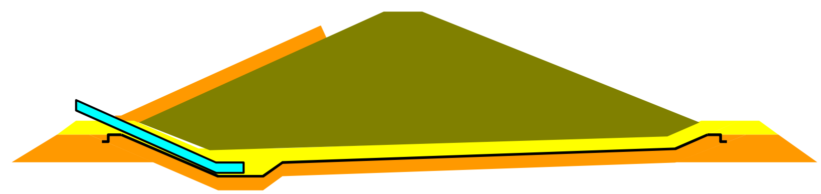
300 – 600 gpad
(10 to 20% of rainfall)



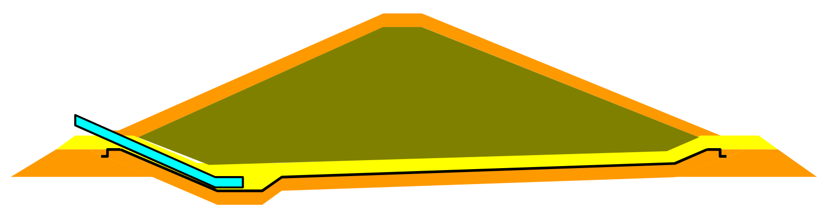
100 – 200 gpad
(3 to 6% of rainfall)



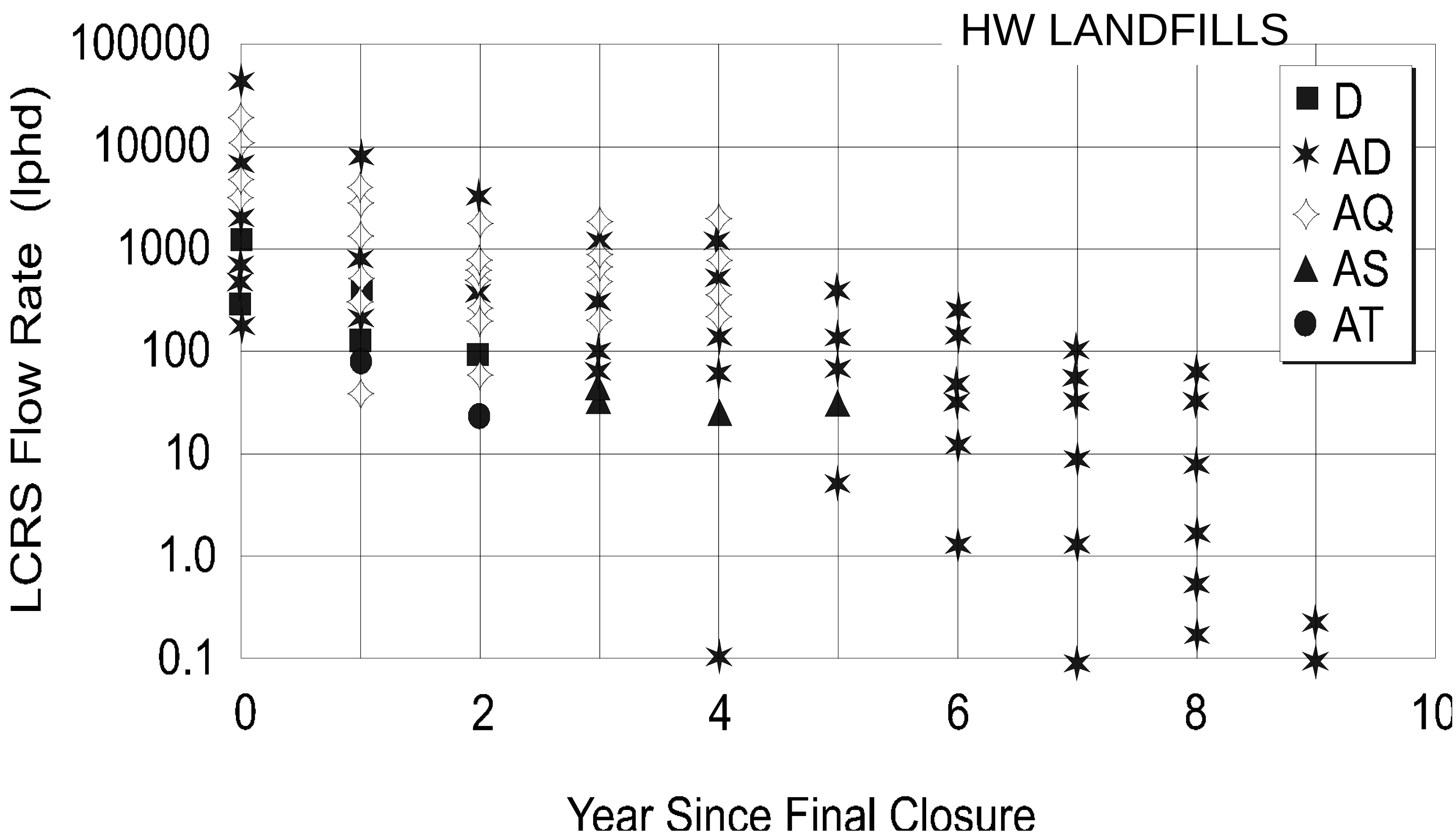
20 – 40 gpad
(0.6 to 1.2% of rainfall)



10 – 20 gpad
(0.3 to 0.6% of rainfall)



Influence of Time after Closure on Leachate Generation Rate



Recommendations

- Monitor Performance of Existing Facilities
  - Seems that "data" includes visual assessment
  - Limited quantitative data
  - Summary report of problems may exist
    - Visual reports
    - Settlement plates
    - Leachate generation rate
- Report Findings
  - Identify forum for presentation of monitoring results
  - Report performance of rehabilitation measures

Design Challenges and Solutions

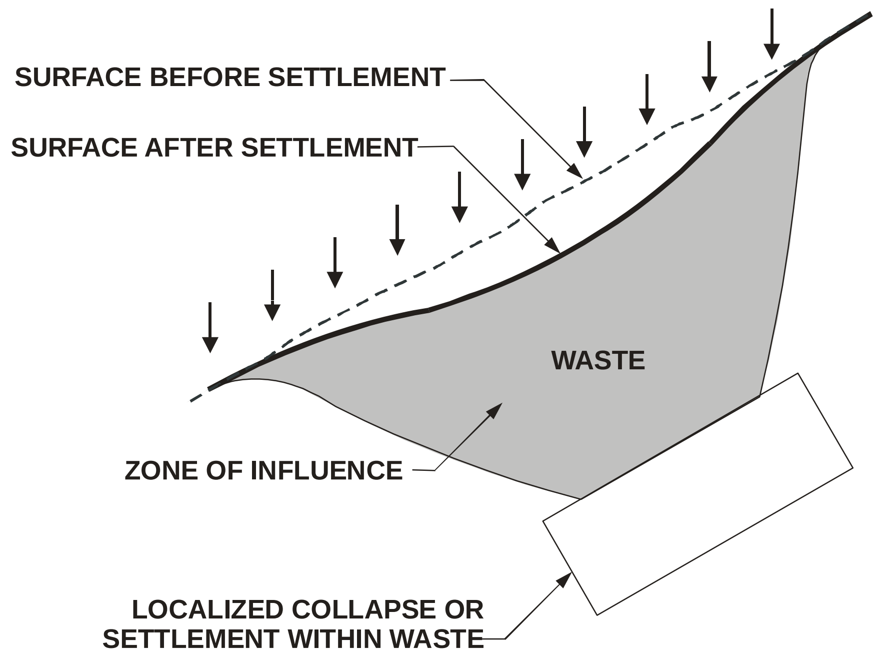
Issue – Differential Settlements

- Differential settlements along liner resulting from waste variability and local soft or hard spots (e.g., collapsing void...the "rusted refrigerator") may impair the liquid containment capability of the leachate collection system and/or cause localized settlements that result in the ponding of liquids or excessive liner system strain.

Solution

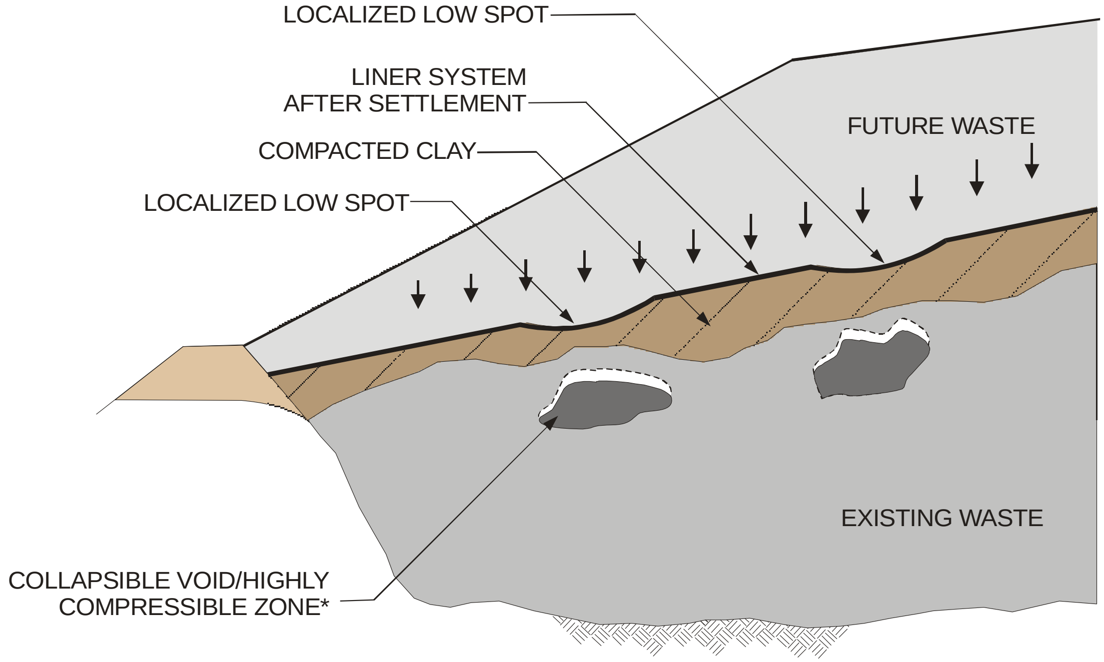
- Assess actual site conditions to avoid "worst case" analyses. Incorporate high stiffness geosynthetic reinforcement in the liner system or subbase and/or construct a foundation "buffer layer" between liner system and existing waste. Also, ground improvement techniques (e.g., deep dynamic compaction) can be used to minimize near-surface heterogeneities.
- Analytical procedures are available to select appropriate reinforcement properties (e.g., strength, stiffness) or minimum thickness buffer layer.

Design Challenges and Solutions "Rusted Refrigerator" Scenario



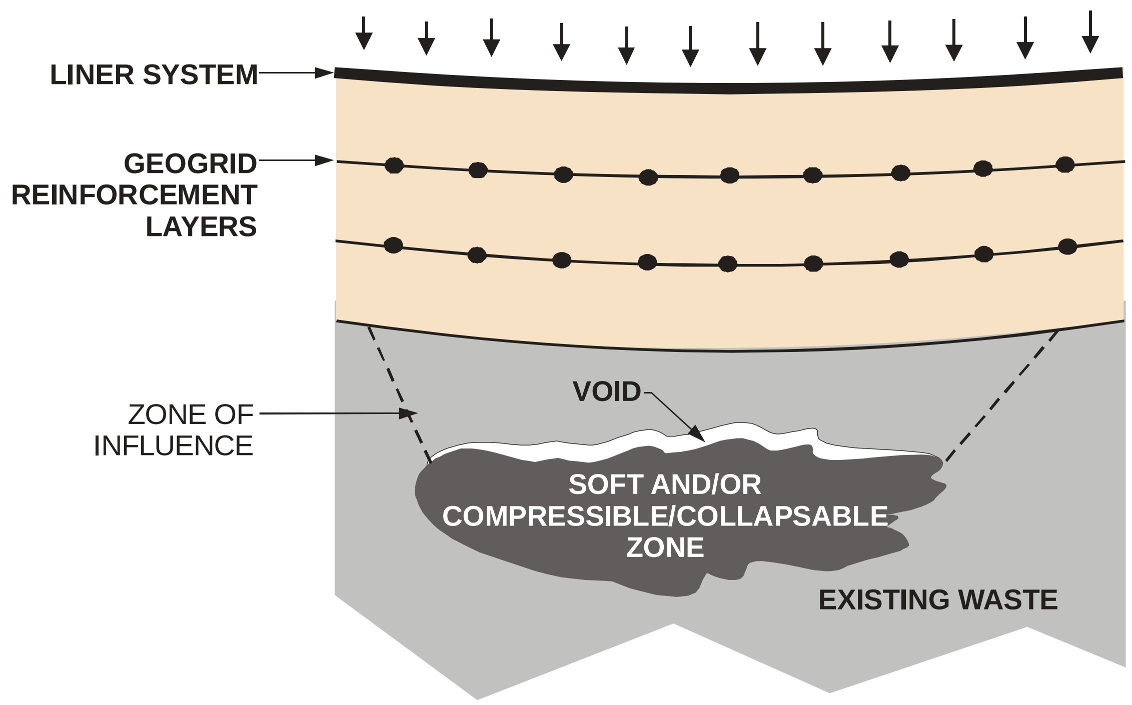
"SLOPE AREA"

Design Challenges and Solutions
Compressible Void

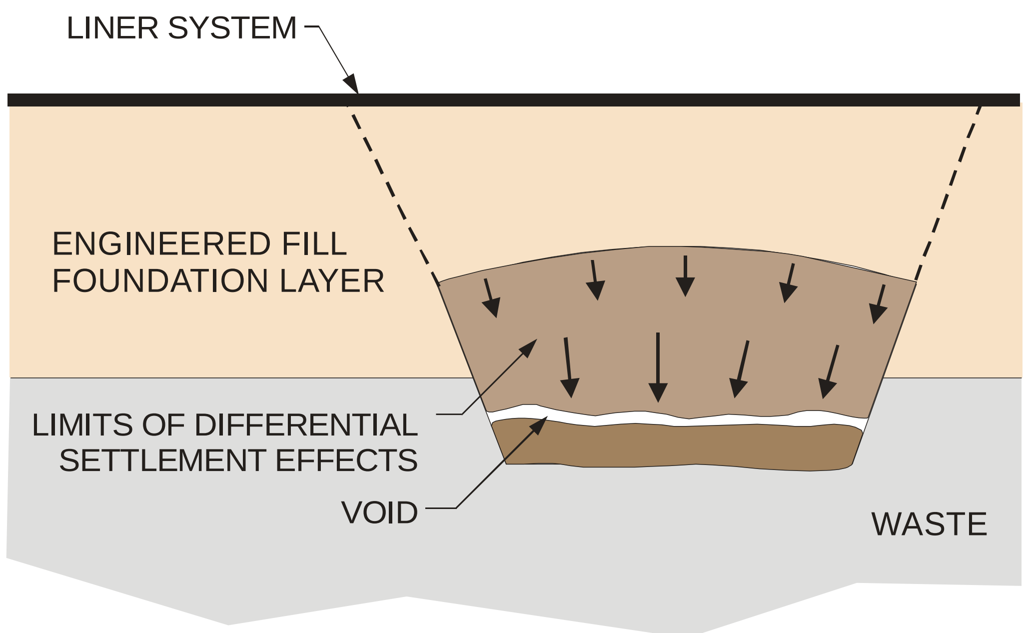


* DIFFERENTIAL SETTLEMENT MAY ALSO RESULT FROM HETEROGENEOUS NATURE OF WASTE

Design Challenges and Solutions Geosynthetic Reinforcement



Design Challenges and Solutions
Buffer Soil



Design Challenges and Solutions Deep Dynamic Compaction