Design and Operation of Heap Leach Pads

By:

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Purpose of Presentation

- Summarize advancements made in the design and operation of heap leach pads:
  - → Design and construction of leach pads and working with operations over the last 20 years
  - → Working with difficult ore material types (saprolite, laterite, agglomerated ore, etc)
  - → Construction and operational problems in harsh environments (high rainfall, freezing temperatures, heat, etc).

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Subset of Topics Covered

- Leach Pad Configuration
- Liner System Design
- Ore Properties Testing
- Operational Considerations

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Leach Pad Configuration
General Overview

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Leach Pad Configuration

Considerations:

- Ore material properties (leaching characteristics, durability, etc.)
- Water balance
- Land availability and ground slope
- Project cost (capital and operating)

Pad Configuration Types:

- Dedicated, single use pad (“standard” leach pad)
- On/Off or Reusable Pad
- Valley Fill
- Hybrid

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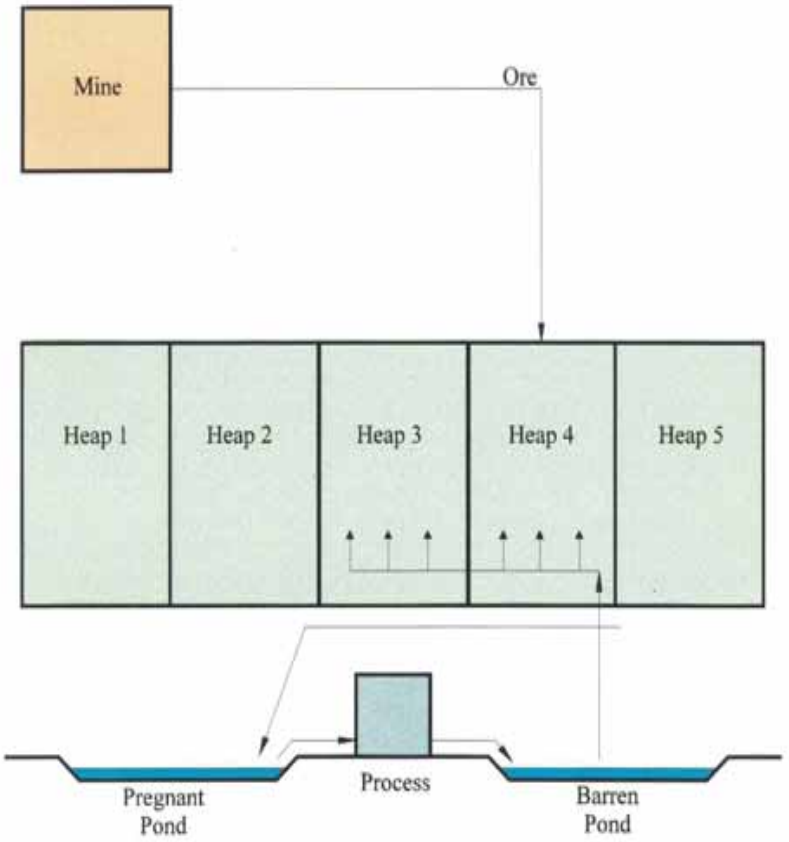
Single Use Pad



- Mine
- Prepare & Place on Pad
- Leach
- Leave in Place/Reclaim
  or
- Releach
- Place Additional Lift of Ore

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Single Use Pad

- Suitable for variable ore types and leach cycle times.
- Typically large area for leach pad. Pad area based on ore production, leaching cycle time, ore “aging”, etc.
- Flat topography to maintain geotechnical stability.
- Large storm event pond.
- Low initial capital costs.
- Incremental pad expansion costs must be considered in project cost.

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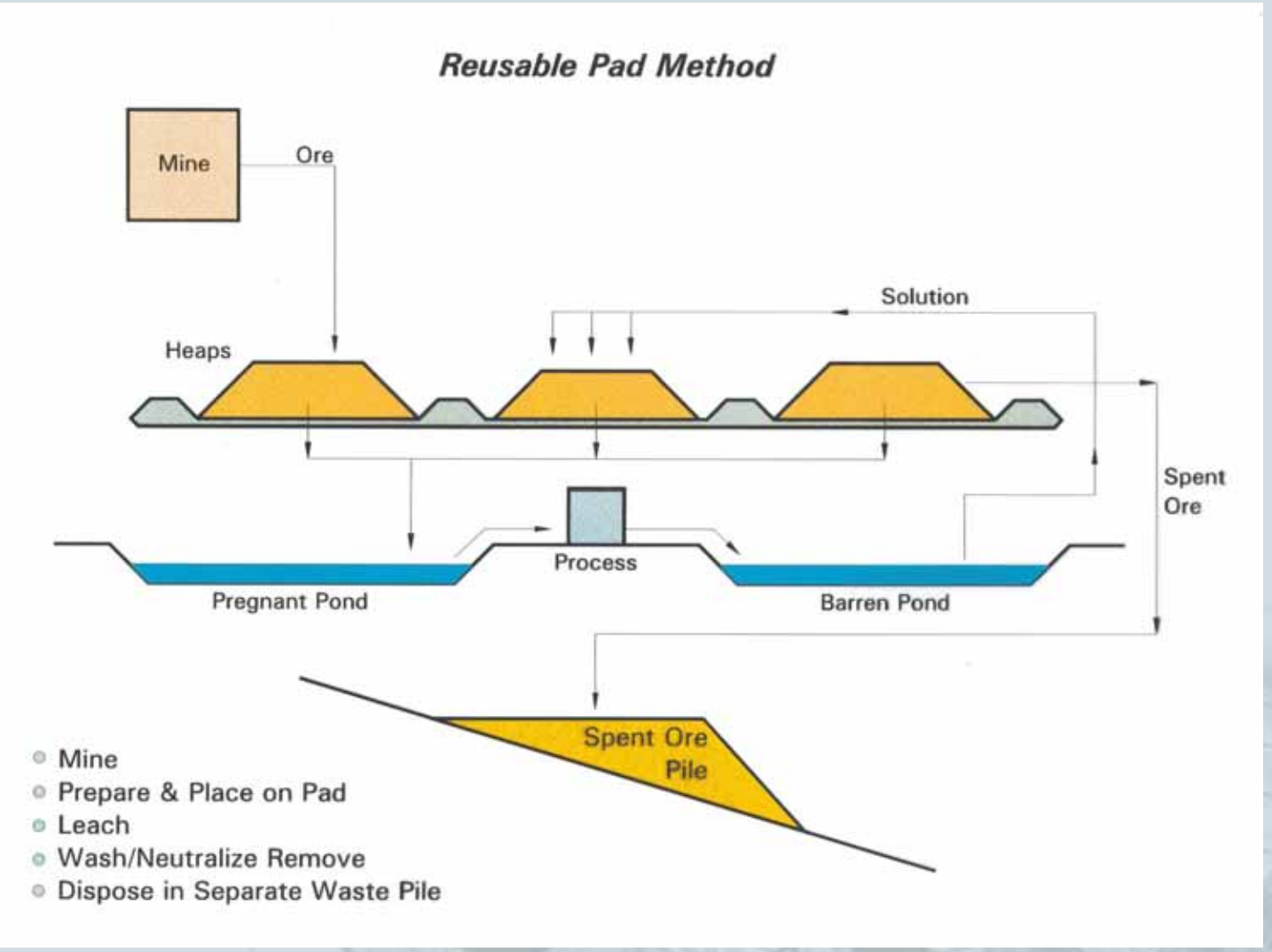
On/Off Pad


Reusable Pad Method
Mine
Ore
Solution
Heaps
Spent Ore
Process
Pregnant Pond
Barren Pond
Spent Ore Pile
Mine
Prepare & Place on Pad
Leach
Wash/Neutralize Remove
Dispose in Separate Waste Pile

On/Off Pad

- Suitable for ore with short leach cycles and consistent leaching characteristics.
- Areas with limited flat terrain.
- Requires a rinsed ore site/pad.
- Durable “high-stress” liner system.
- Practiced in wide range of climate conditions.
- Smaller storm pond.
- Costs: double handling of ore, rinsing system, rinsed ore storage.

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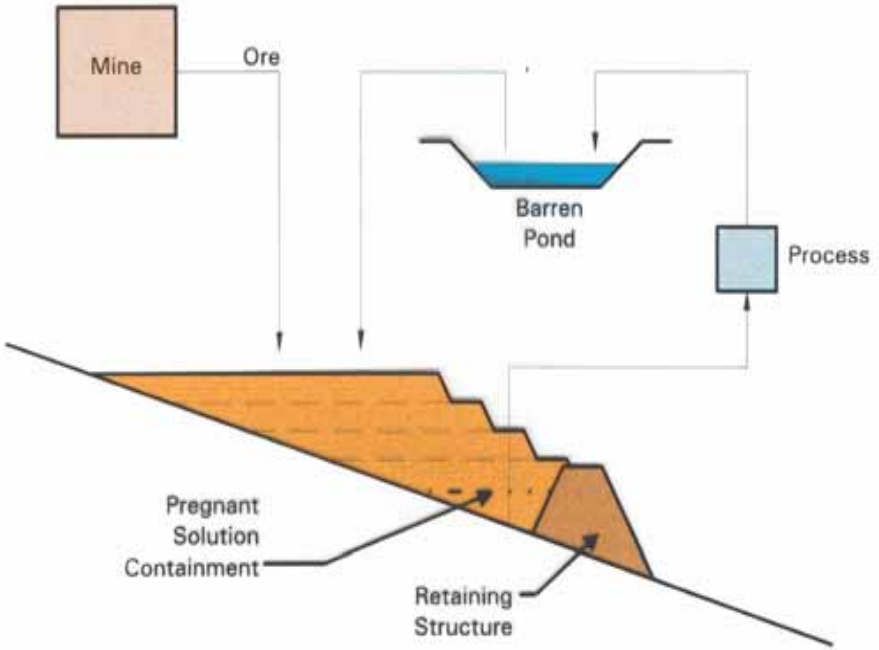
Valley Fill Pad



- Mine
- Prepare & Place in Valley
- Leach
- Cover with New Ore
- Leach
- Leave in Place

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Valley Fill Pad

- Best suited for hard, durable ore with good drainage. Can accommodate extended leach times.
- Used in steep terrain (slopes up to 40%).
- Internal solution storage reduces external pond requirements.
- Robust liner system (high hydraulic head and ore loads).
- Retaining structure for confinement of heap.
- High upfront capital cost.

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Hybrid Pads

- Combination dedicated, single use pad with partial internal solution storage
- Single use pad combined with on/off pad
- Valley fill pad with a portion used as an on/off pad
- Side-hill leach pads
- Dump leach (no liner)

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Liner System Design

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Liner Design Advancements

- Experience with geosynthetics under high loads and harsh conditions
- Operation of heap leach pads with significant ore loads (+130 m)
- Construction and operation of very large leach pads (+ 1.5 billion tonnes and covering 10 km^2 across varying foundation materials)
- Solution collection pipe performance under high ore load

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Liner Design Components

- Foundation materials
- Underliner soils
- Geomembrane liner
- Overliner materials (drainage and/or protection layers)
- Solution collection/air injection piping

Not normally considered liner design

Strong interaction between each component and the overall system.

Construction Quality Assurance program needed to achieve good liner performance

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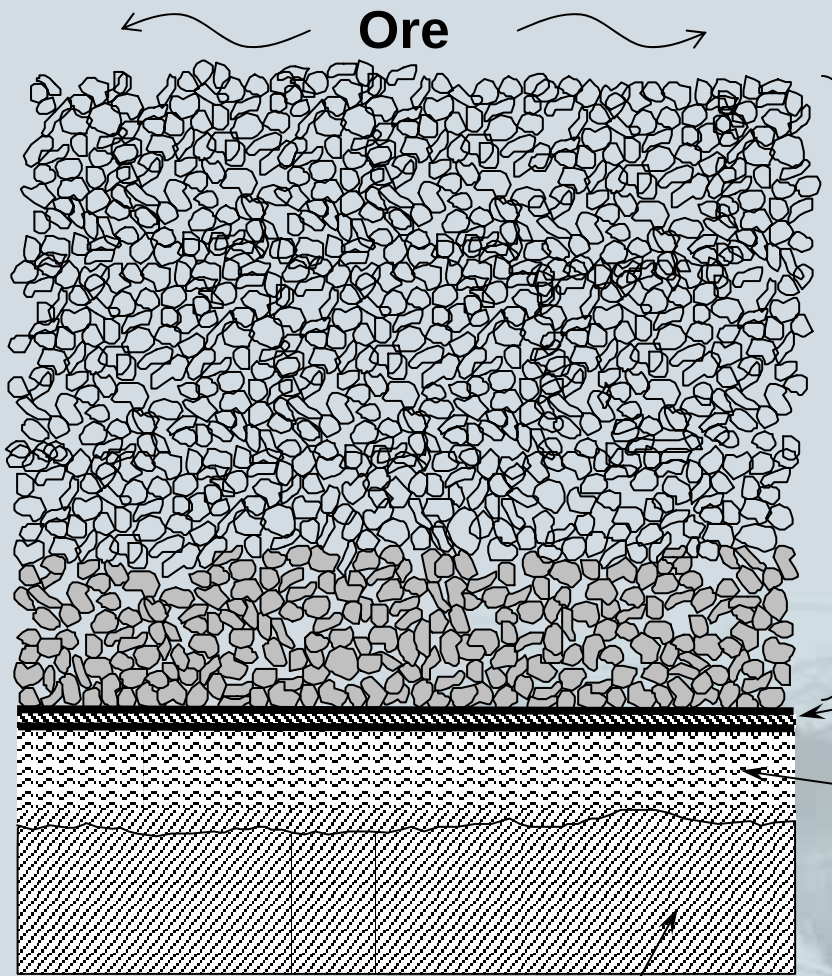
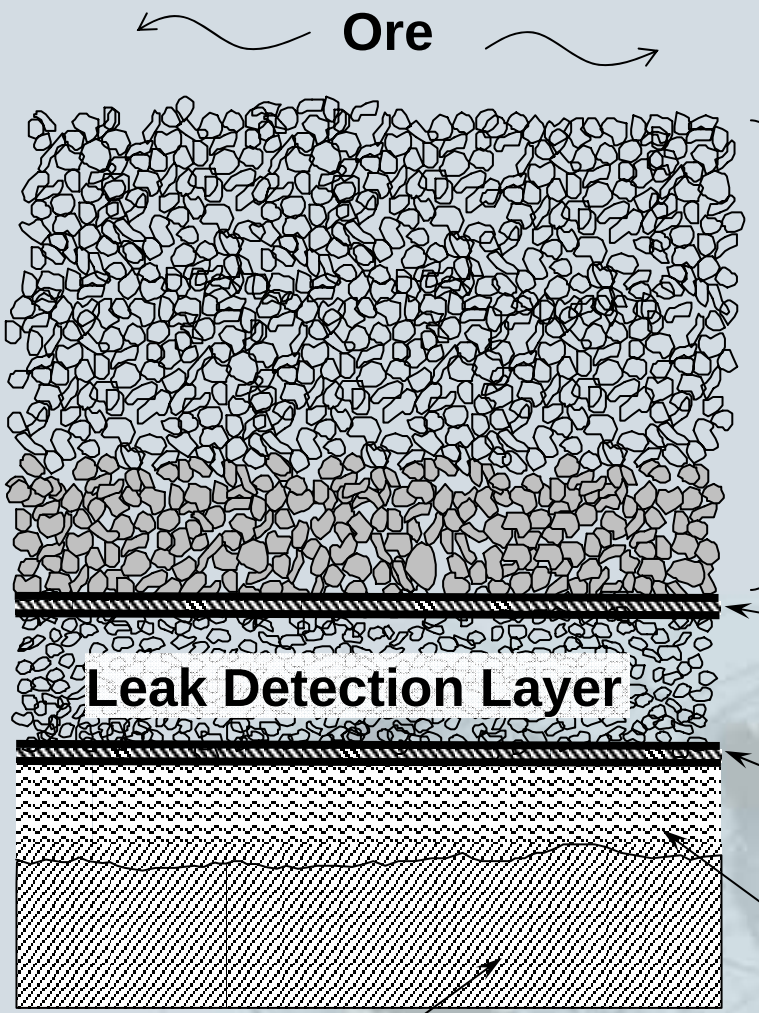
Typical Single Composite Liner



Typical Double Composite Liner



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Foundation Design Considerations

- Heap stability
- Solution drainage/recovery
- Performance of geomembrane
- Performance of solution pipes

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Underliner Design Considerations

- Seepage control
  - Environmental impact
  - Economic impact
- Interaction with geomembrane liner
- Prefer compacted native soil with a minimum saturated hydraulic conductivity of 1×10^{-8} m/s (World Bank Standard)
- Admixtures maybe considered
- Geosynthetic Clay Liner (GCL) – limited

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Underliner

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Geomembrane Considerations

- Geosynthetics preferred over other liner materials (asphalt, concrete, etc).
- Typical: HDPE, LLDPE, and PVC (smooth and textured)
- Overall seepage control (environmental & economic issues)
- Foundation settlement
- Puncture by ore load and trafficking
- Heap stability (slippage along interface)

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Geomembrane Liner Testing

- Load Testing: Compatibility of geomembrane liner with rest of liner system under anticipated ore loads
- Interface Shear: Shear strength of interface for heap stability analysis

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Geomembrane Liner Puncture

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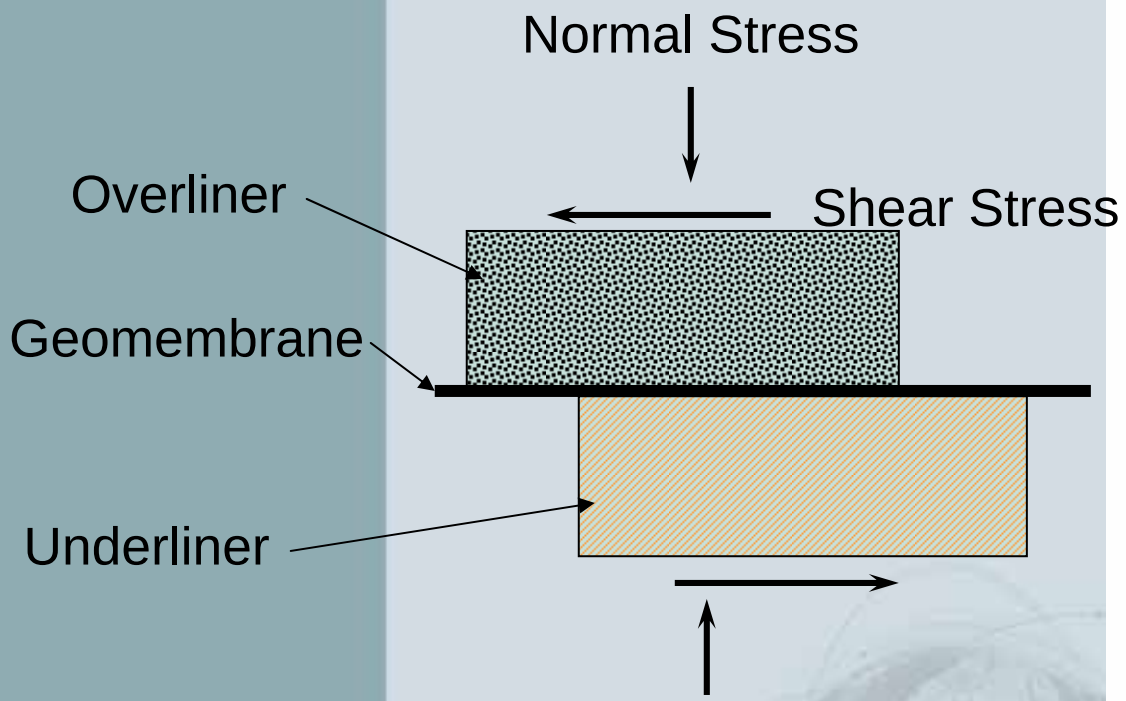
Geomembrane Interface Shear

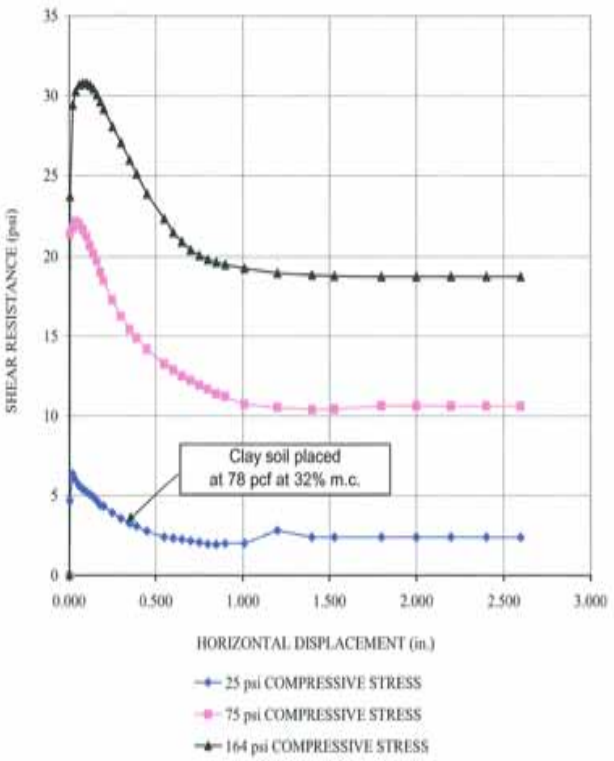


INTERFACE FRICTION TEST RESULTS
ASTM D 5321

CLIENT : GOLDER ASSOCIATES, INC.
CLIENT PROJECT : JOB NO. 043-2189
PROJECT NO. : L05156-01

INTERFACE : **SOIL LINER VS 80-MIL SMOOTH LLDPE ON SCREENED OVERLINER**
*The Soil Liner in points 2 and 3 were placed at 87 pcf at 27% m.c.

SHEAR RESISTANCE VS HORIZONTAL DISPLACEMENT



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Overliner Design Considerations

- Protect geomembrane (ore loads, mine equipment trafficking, etc)
- Medium for solution collection, air injection, etc
- Protect solution collection/ air injection piping (ore loads, mine equipment trafficking, etc)
- Prefer native free-draining sand and gravels – durable materials.
- Hydraulic properties of overliner govern solution collection pipe design.

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Overliner Placement

Note: Overliner placed directly over geomembrane and pipes

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Ore Properties Testing

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Material Test Types

- Geomechanical properties
  - Heap stability
  - Ore compression
  - Settlement
  - Ore durability
- Hydraulic properties
  - Percolation
  - Flow versus ore load
  - Draindown moisture content (water balance and inventory)
- Metallurgical testing (not covered)

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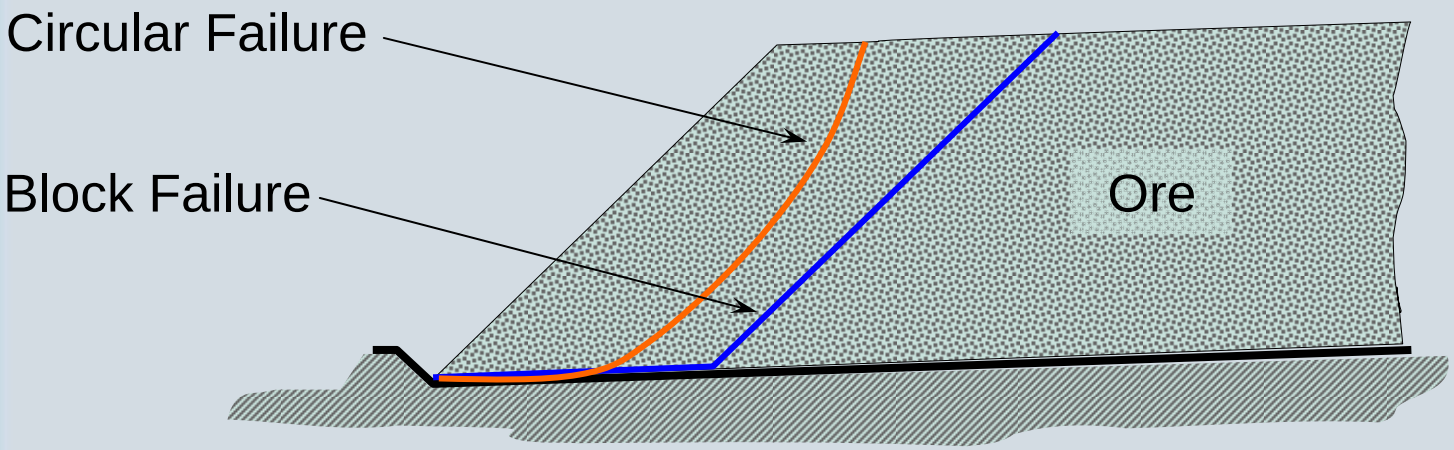
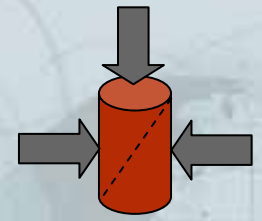
Typical Geomechanical Tests



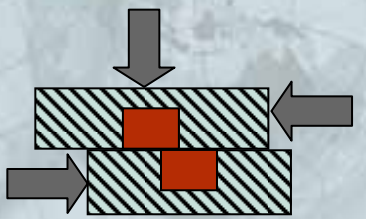
Tests simulate varying stress conditions within heap

Triaxial Compression



Unconfined Compression

Direct Shear



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Typical Hydraulic Tests

- **Column Tests**:
  - Recovery
  - Percolation rates
  - Leaching parameters (time, concentration, etc)
  - Moisture contents (drain down, leaching)
- **Load-Percolation**:
  - Sustainable percolation (unsaturated flow) under load
  - Compression of ore (settlement and density)
- **Load-Permeability:**
  - Saturated hydraulic conductivity under load
  - Ore degradation
  - Overliner characteristics

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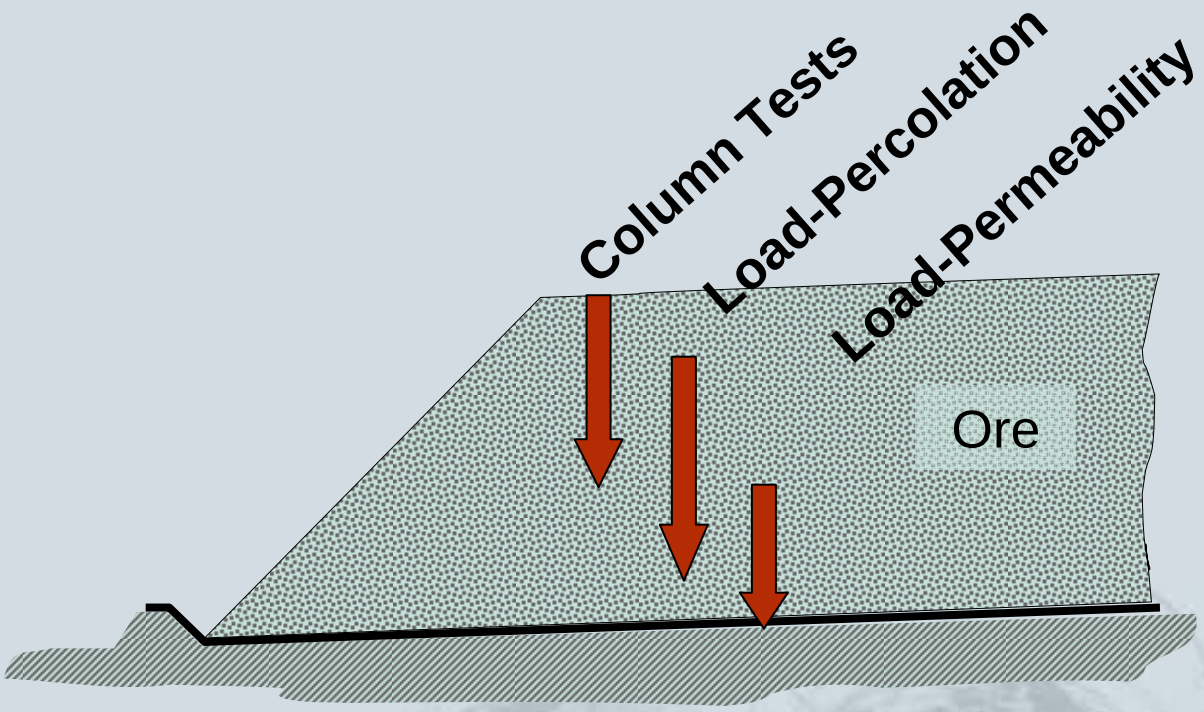
Hydraulic Testing



Tests simulate varying hydraulic conditions within heap

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Operational Considerations

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Operational Issues

- Ore stacking and scheduling
- Leach scheduling
- Chemistry control
- Water balance
- Cold or hot climate operation
- Wet or dry climate operation
- Difficult ore types:
  - Low permeability
  - Slow leaching
  - Acid consuming/generating

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Select Operational Issues

- Wet Climates
  - Positive water balance requiring storage and treatment of excess process solution.
  - Dilution of solution grade.
  - Ore heap instability due to high saturation and erosion
- Low Permeability Ore
  - Heap instability due to high saturation
  - Poor or delayed recovery
  - High inventory (lock-up in pore spaces)

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Wet Climates

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Operational Issues

Solution management/heap stability problem:

- Increase solution and storm pond sizes
  - Capital cost and land constraints
- Pump excess solutions onto the heap ("sponge" effect)
  - Does not reduce excess solution volume
- Rain Skirts / Covers
  - Capital cost
  - Operationally intensive during rainy season
- Excess solution treatment/discharge

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Rain Skirts

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Rain Skirts

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Low Permeability Ore

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Operational Issues

Heap stability & recovery problem:

- Ore agglomeration
  - Controlling agglomeration process to provide consistent product (moisture important)
- Maintain low heap height to preserve ore permeability
  - Capital cost and land constraints
- Blending with more durable ore
  - Logistics of blending and control
- Interlift liner systems
  - Capital cost
  - Operationally intensive

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Interlift Liner

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