What is Packer Testing?
Packer Testing Overview
What is a Packer?  What is Packer Testing?

• An inflatable device that isolates a segment of borehole

• “Packer Testing” refers to hydraulic tests facilitated by the use of a packer to determine hydraulic conductivity

• Wireline hydraulic packers are optimized for deep testing in conjunction with diamond core drilling
Hydraulic Wireline Packers

- Designed for core rigs
- Water inflated, no high pressure gas
- Rapidly deployed just like a core inner tube
- Retrieved via rig wireline
- No cumbersome inflation lines
- Optimized for deep testing (100m-1000m)
- No need to trip out drill rods (saves time)
Why Packer Testing?
Why Packer Testing?

Hydraulic Wireline Packer Testing is the most economical way to collect “discrete” rock hydraulic conductivity data at depths relevant to most mining operations.

In most fractured hard rock mining environments, hydraulic conductivity can be a function of depth and fracture frequency, not always rock type.

This hydraulic conductivity / depth curve is critical for the development of accurate ground water models and geotechnical design.
## Packer Testing Strategies

Decisions, Decisions....

### Packer Testing Planning Matrix

<table>
<thead>
<tr>
<th>Development Stage</th>
<th>Program Scale</th>
<th>Test Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Preliminary Drilling</td>
<td>• Multiple drill rigs</td>
<td>• Injection Test</td>
</tr>
<tr>
<td>• Pre Feas. / Feasibility</td>
<td>• Single drill rig</td>
<td>• Airlift Test</td>
</tr>
<tr>
<td>• Expansion / Infill</td>
<td>• Multiple Packers</td>
<td>• Falling Head</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Test Purpose</th>
<th>Testing Frequency</th>
<th>When to Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Pit Design (Geotech)</td>
<td>• Entire borehole</td>
<td>• Concurrent with drilling</td>
</tr>
<tr>
<td>• Dewatering Plan</td>
<td>• Selected Intervals</td>
<td>• Completion of borehole</td>
</tr>
<tr>
<td>• Groundwater Model</td>
<td>• Opportunistic</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Staffing Plan</th>
<th>Test Configuration</th>
<th>Analysis Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Consultants</td>
<td>• Single Packer</td>
<td>• Discrete zone test</td>
</tr>
<tr>
<td>• Internal Staff</td>
<td>• Double Packer</td>
<td>• Cumulative Analysis</td>
</tr>
<tr>
<td>• Drillers</td>
<td></td>
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</tbody>
</table>

Decisions, Decisions....
Types of Packer Tests

- Injection
- Withdrawal
- Falling Head
- Straddle*

* Straddle packer configuration can be used with any testing method

Graphs:
- Injection: Flow Rate vs. Pressure
- Withdrawal: Depth to Water vs. Time
- Falling Head: Depth to Water vs. Time

Legend:
- Dashed lines represent fluid movement.
Single element packer test interval are bound by the base of the packer and the bottom of the borehole.
Double (Straddle) Packer

- A straddle packer allows zones to be tested discretely
- Typically done during *Cumulative Testing*
- Test zones can be 1m or larger.
Injection (Lugeon) Testing

Injection testing involves injecting water at specified pressures and recording flow.

<table>
<thead>
<tr>
<th>Step</th>
<th>Pressure</th>
<th>Flow Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20 psi</td>
<td>4.2 L/min</td>
</tr>
<tr>
<td>2</td>
<td>40 psi</td>
<td>7.5 L/min</td>
</tr>
<tr>
<td>3</td>
<td>60 psi</td>
<td>12.1 L/min</td>
</tr>
<tr>
<td>4</td>
<td>40 psi</td>
<td>7.3 L/min</td>
</tr>
<tr>
<td>5</td>
<td>20 psi</td>
<td>4.1 L/min</td>
</tr>
</tbody>
</table>

Example data
Airlift testing involves removal of water using compressed air. Constant flow is measured, then air is turned off and water is allowed to recover. Hydraulic conductivity is determined using rising head analysis.
Falling head tests can be conducted by rapidly filling the rods with water and allowing it to drain into the formation. The resultant curve can be analyzed for hydraulic conductivity. This is typically done after an injection test for quality assurance.
Concurrent or Completion Testing?

Concurrent testing occurs during drilling
Completion testing is performed after drilling is finished

**Concurrent Testing**

**Advantages:**
- Higher quality data
- No hydraulic conductivity masking
- Hole stability less of an issue

**Disadvantages:**
- Takes longer
- Requires crew and packer during drilling (higher cost)

**Completion Testing**

**Advantages:**
- Rapid testing (more tests in shorter time)
- Less rig standby time
- Testing crew required only at hole completion

**Disadvantages:**
- Hydraulic conductivity “Masking”
- May require straddle packer to resolve any hydraulic conductivity masking
- Lower quality data

Concurrent testing is preferred, Completion testing used for special situations
Cumulative Testing

The entire hole is drilled then packer testing is performed in intervals on the way out. Measured values in upper zones may be masked by high hydraulic conductivity in lower zones.

<table>
<thead>
<tr>
<th>Interval</th>
<th>K (m/d)</th>
</tr>
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<tbody>
<tr>
<td>50-100m</td>
<td>8.0e-5</td>
</tr>
<tr>
<td>100-150m</td>
<td>1.0e-5</td>
</tr>
<tr>
<td>150-200m</td>
<td>2.3e-4</td>
</tr>
<tr>
<td>200-250m</td>
<td>5.0e-6</td>
</tr>
</tbody>
</table>
Packer Testing Program Design

Test Program Objectives

Scoping and Scaling

Logistics and Equipment

Budgeting and Cost Controls

Scheduling and Coordination

Staffing Options
Clearly defined end uses of packer testing data leads to an efficient field program that is neither too large or too small in scope.

Placing a little more effort on clearly defining and communicating data objectives is money and time well spent.

It is critical that the end users of packer testing data be involved in the field planning, i.e. groundwater modelers and geotech engineers.
Multiple drill rig advantages
- Maximizes efficiency of testing crew and equipment

Multiple packer system advantages
- Concurrent testing on multiple rigs
- Reduces risk due to equipment loss or damage
- Reduces transportation time between rigs

Additional testing personnel advantages
- Allows for sustainable day/night operations
- Continuity during shift rotations
- Collaborative problem solving
- Eliminates excessive standby when using multiple rigs

Bottom line: Redundancy reduces risk but increases costs
"Amateurs talk about tactics, but professionals study logistics. “ - Gen. Robert H. Barrow, USMC

- Complete equipment list
- Timing of personnel
- Customs delays
- Access of materials in remote sites
- Availability of materials locally
Budgeting and Cost Control

Packer testing can be expensive, but there’s no reason to take a bath.

Careful planning and an experienced project team is the key to cost control.

Adding packer testing to an existing drilling program saves money.

The highest cost component is consulting fees. Training junior staff on the packer equipment can reduce costs.

A significant and avoidable cost on many projects is standby time due to logistical delays, scheduling, and equipment issues.
Scheduling and Coordination

Drilling rate and subsurface conditions make packer testing scheduling highly uncertain.

During single rig packer testing, much of the testing crew is on standby, waiting for the borehole to advance.

Due to the 24/7 nature of drilling, testing may take place during day or night shift and is highly irregular.

Flexibility in testing methods and test interval selection can mitigate irregularities and promote efficiency.
Staffing Options

Successful Packer Testing Requires a Trained and Motivated Staff

The staffing mix is a balance between cost control and testing effectiveness

Staffing Options Include:
- Specialized Consulting Firms
- Mining Project Internal Staff
- Self Performing drillers
- Independent Experts / Trainers

Staffing Considerations:
- Day and Night Shift Operations
- Scale and Scope of Testing Activities
- Program Duration and Mobilization Costs
Conclusions

- Reliability in mine design requires the right types of data
- For deeper mine designs, this means discrete zone hydraulic conductivity data
- Hydraulic wireline packer testing is the best way to acquire this data
- Many different options can be used to obtain your data objectives and control costs
- The key is careful program planning, using experienced consultants, and keeping the big picture in mind
Thank you for attending

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Brent Johnson (Interralogic, Golden, CO)