Optimization of ISR
Injection and Extraction Systems

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A Uranium Mine Prospect

**Opportunity** – Uranium Ore has been Delineated within a Fluvial Deposits

- Found within water-bearing geologic units 100+ feet below ground surface
- Data indicate the uranium is potentially present in mineable quantities

**Challenge** - Can the Uranium Ore be Extracted Cost Effectively Using Hydraulic Methods; if so How?

- Understand the subsurface setting ➔ Geology, Hydrology, & Geochemistry
- Maximize the Extraction of Uranium Ore ➔ Efficient Lixiviant Delivery/Recovery
- Minimize Environmental Liability ➔ Placement of Monitoring Network
- Minimize Required Restoration ➔ Tight Control of Lixiviant Distribution

**Contributing Factors**

- Substantial Site Surface and Subsurface Data
- Fluid Hydraulics are Predictable
- Uncertain Shallow Geology (even with a large number of geologic logs)

**Solution** – Develop A Regimented Quantitative Decision Framework

Site Specific Information has been Modified to Protect Its Propriety Nature
Quantitative Analysis as a Part of the Regimented Decision Framework

A Hydraulic Simulator Integrates Hydrogeologic and Hydrogeochemical Data into a Dynamic Decision Framework

The Decision Framework can Evolve as an Understanding of the Subsurface Increases

Quantitative Analysis Tools Have Advanced Since the Last ISR Mine Permitted Wells Tested, Accepted and Practicable

- Explicit Water Table Emulation
- Dynamic Front Generation
- Telescopic Mesh Refinement
- Faulting/Fracturing
- Finite-Element Surface Representation
- Accurate Extraction/Injection Well Simulation
- Direct Simulation of Separate Liquids
- Coupling with Geochemical Model
FEFLOW Model Development

- **Finite-Element Mesh**
  - Telescopic Mesh
  - 54 Layers, 55 Surfaces
  - Total of 1,050,408 Elements
FEFLOW Model Development

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- **Porous Media Property Distribution**
  - Geology Defined by Logs
  - Very Fine Grained Media
  - Fine Grained Media

*Vertical Exaggeration 5x*
FEFLOW Model Development

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- **Hydraulic Boundaries**
  - Lateral Flow
  - Precipitation Recharge
  - Local Creek

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- **Calibration**
  - Target – Hydraulic Heads
  - Hydraulic Stress Tests
  - Parameter Estimation
Lixiviant Delivery/Recovery System Design

Ore Body Scenario

- Mixed Permeability
- Moderate Permeability
- Low Permeability
- Uranium Ore
Lixiviant Delivery/Recovery System Design

Ore Body Scenario

Examine the Injection

401 to 500 Days

Legend

Scale:

20% < Lixiviant Concentration < 100%

100% Lixiviant Concentration

Injection Well

Uranium Ore Zone Footprint

Uranium Symposium

Injection of Lixiviant in a Single Delivery/Recovery Cell
Lixiviant Delivery/Recovery System Design

Ore Body Scenario

Examine the Injection

Mechanical Design

6 Cells
Injection 150 gpm
Extraction 157.5 gpm
Extraction for 2 Years

Legend

Relative Lixiviant Concentration

Scale:
0’ feet 90’

North

Extraction Well
Injection Well
Uranium Ore Zone Footprint

Uranium Symposium

Mechanical Placement of Delivery/Recovery Lixiviant Distribution at 730 days

Drawn by: CRL
CRL61807
CRL61807
Lixiviant Delivery/Recovery System Design

Ore Body Scenario

Examine the Injection

Mechanical Design

Optimized Design

6 Cells
Injection 150 gpm
Extraction 157.5 gpm
Extraction for 2 Years
Lixiviant Delivery/Recovery System Design

Ore Body Scenario

Examine the Injection

Mechanical Design

Optimized Design

Sweeping Design

6 Cells
Injection 150 gpm
Extraction 157.5 gpm
Extraction for 2 Years

Legend
Scale:
0’ feet 90’

Relative Lixiviant Concentration

Extraction Well
Injection Well
Uranium Ore Zone Footprint

Optimized Swept Delivery/Recovery Lixiviant Distribution at 730 days

Diagram by CRL 51807 06/03/10
## Comparison Criteria

### Ore Body Scenario

#### Examine the Injection

1. **Volume of Ore Zone having a Lixiviant Saturation >50%**
   - Maximize Delivery
   - Favorable if the Lixiviant is Controlled

### Mechanical Design

#### Optimized Design

2. **Average Residence Time of Lixiviant**
   - Maximize Recovery … Minimize Residence Time

#### Sweeping Design

3. **Volume of Lixiviant Remaining after ½ Year of Clean-Water Injection/Extraction**
   - Minimize Restoration Activities

### Scenario Comparison
Lixiviant Delivery/Recovery System Design

Ore Body Scenario

Examine the Injection

Mechanical Design

Optimized Design

Sweeping Design

Scenario Comparison

### Mechanical Design

- **Volume Distribution**: 3,112,036 ft³
- **Residence Time**: 13 days
- **Total**: 6,224,072 ft³

### Optimized Design

- **Volume Distribution**: 2,899,762 ft³
- **Residence Time**: 106 days
- **Total**: 3,112,036 ft³

### Sweeping Design

- **Volume Distribution**: 88,698 ft³
- **Residence Time**: 79 days
- **Total**: 102,762 ft³

**Comparison**:

- **Mechanical**: 88,608 ft³
- **Optimized**: 102,762 ft³
- **Sweeping**: 88,698 ft³

*Note: The bar chart compares the volume distribution and residence time for each design scenario.*
Conclusions

Demonstrated how the Quantitative Decision Framework can be used to Assist in the Design of a Hydraulic Lixiviant Delivery and Recovery System

- Comparison of three design alternatives using three quantitative design criteria
- Optimize the design to maximize its efficiency
- Design a system that will control the lixiviant so as to require only minor restoration efforts

One can Infer How the Decision Framework can Assist in the other Challenges

- Develop a thorough understanding of the subsurface setting
- Place an effective subsurface monitoring network
End