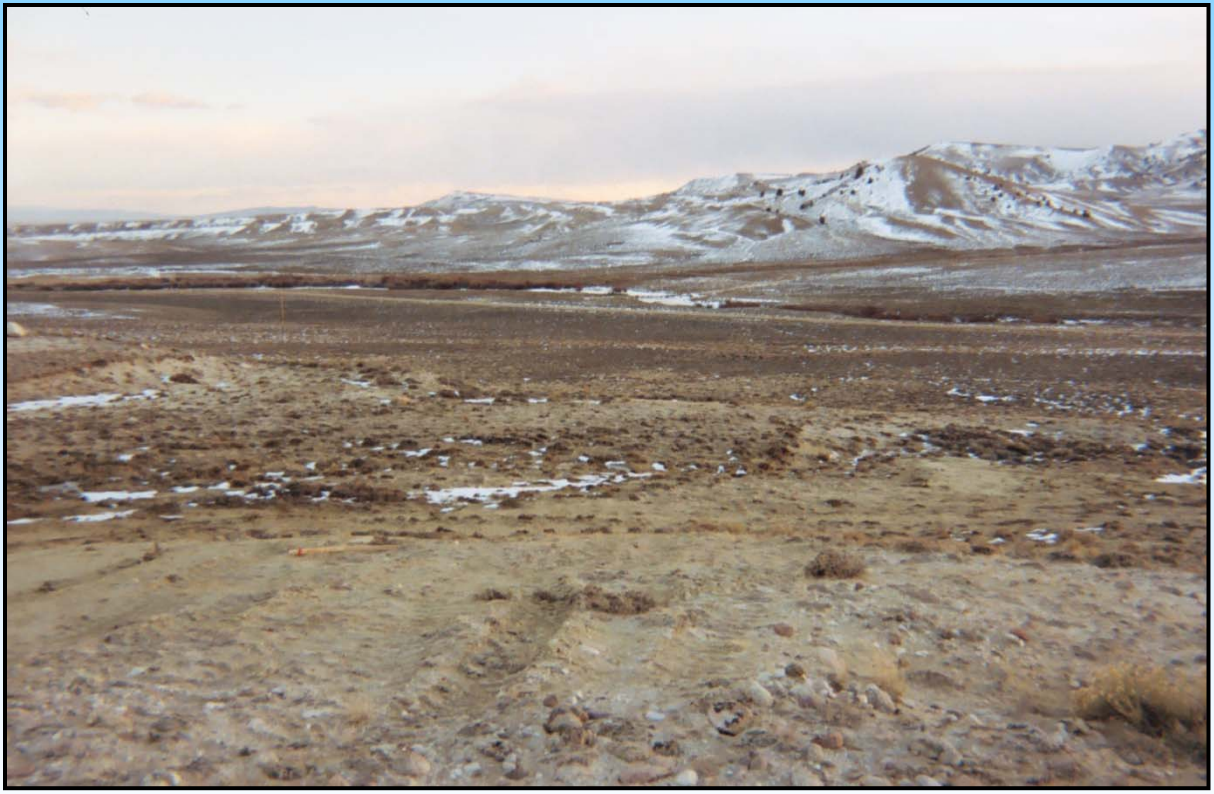
Optimization of ISR Injection and Extraction Systems

Presented by:

Shawn Leppert

Leppert Associates



NRC/NMA Uranium Recovery Workshop

July 1-2, 2009
Denver, Colorado

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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

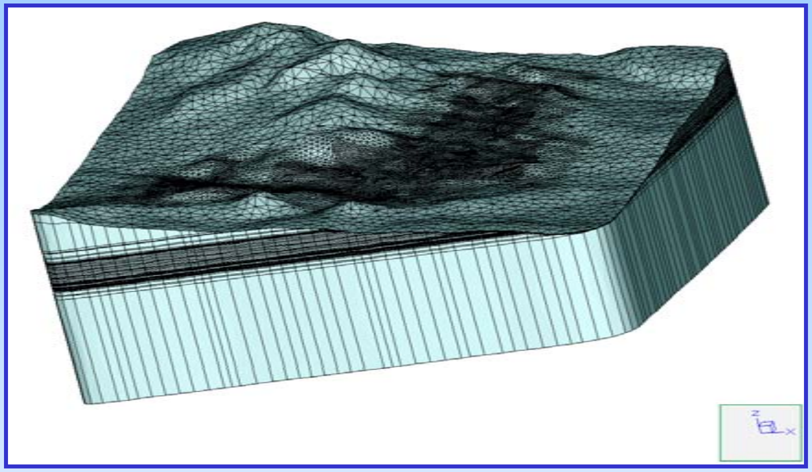
- **Substantial Site Surface and Subsurface Data**
- **Fluid Hydraulics are Predictable**
- **Uncertain Shallow Geology (even with a large number of geologic logs)**

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

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**

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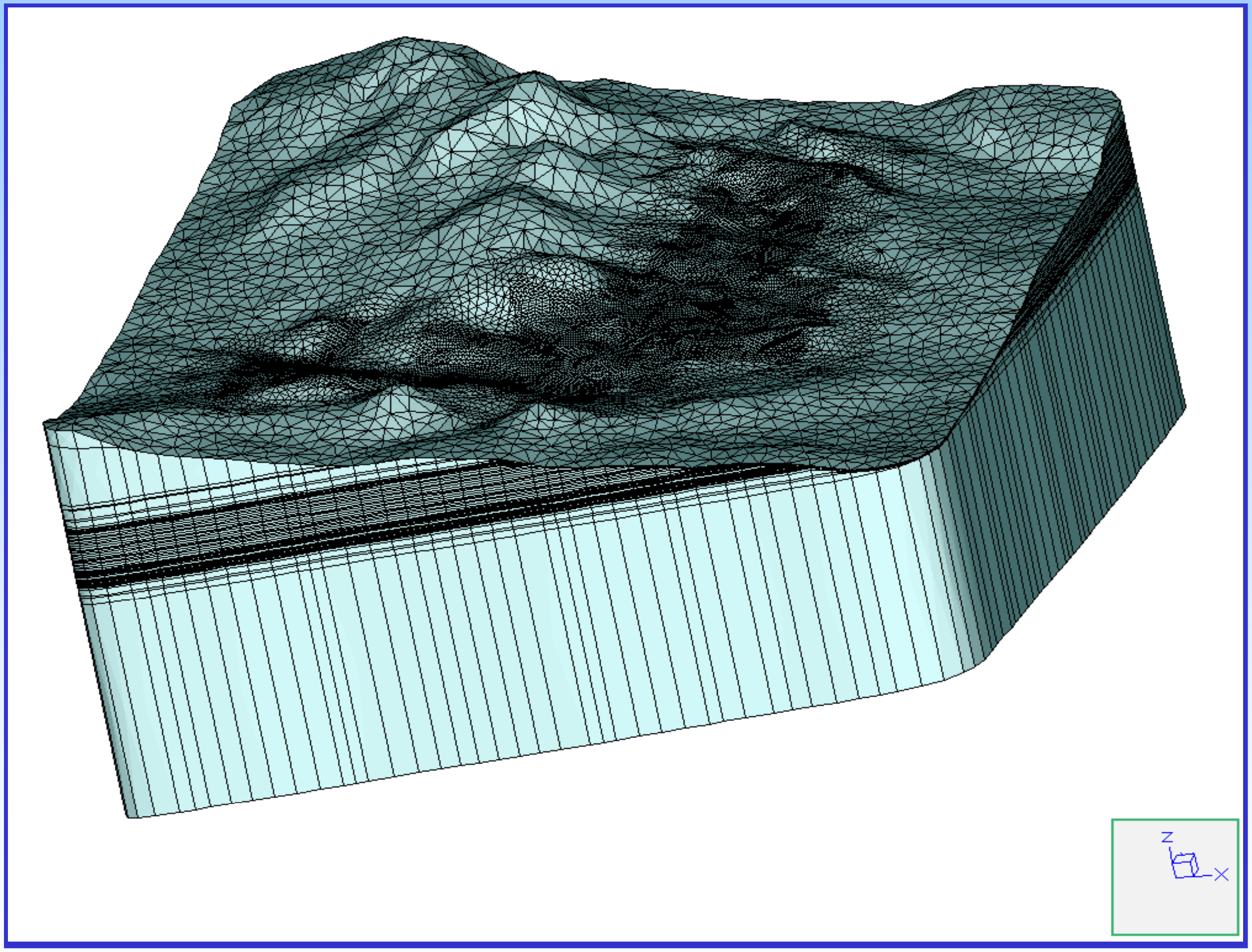
FEFLOW Model Development

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



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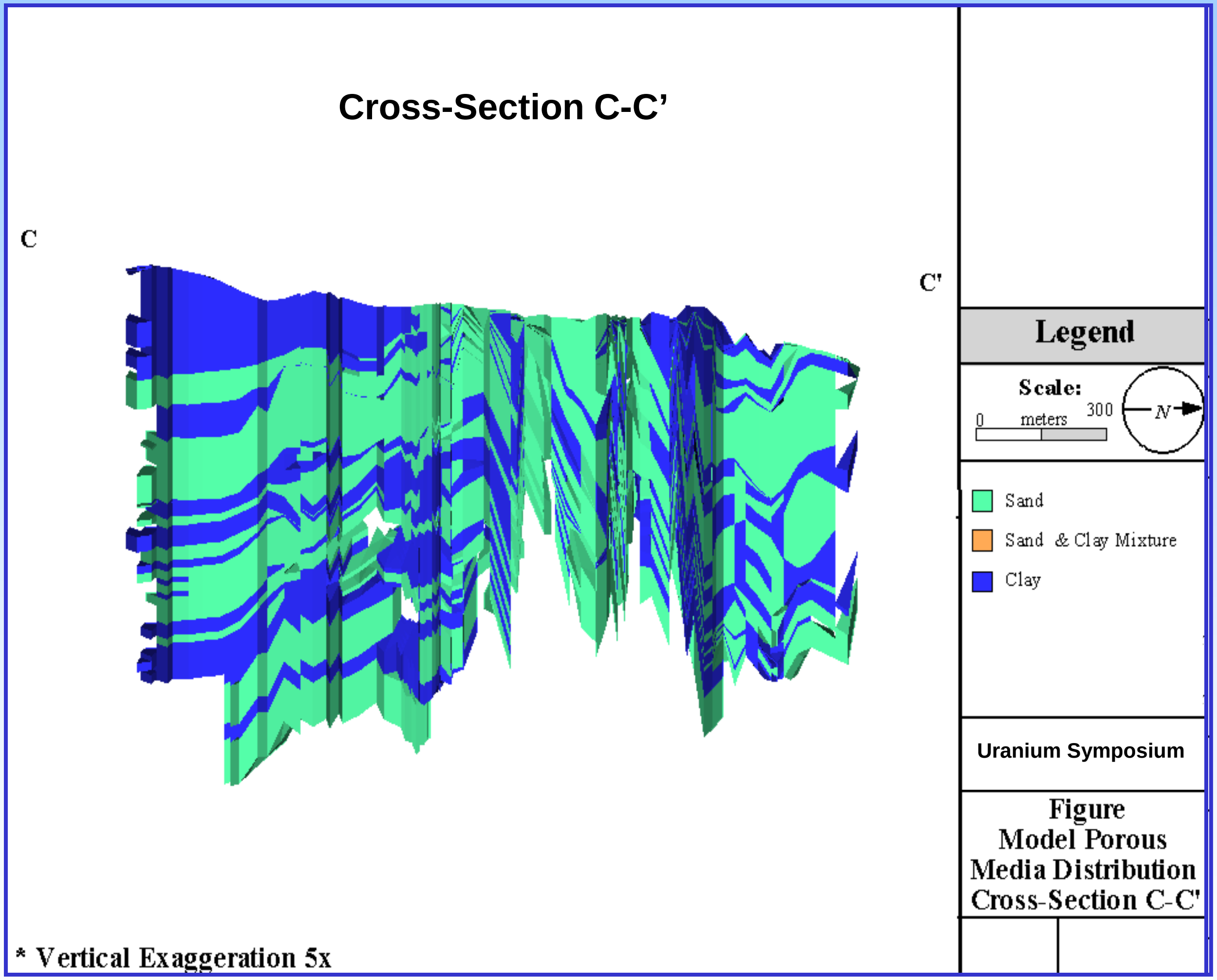

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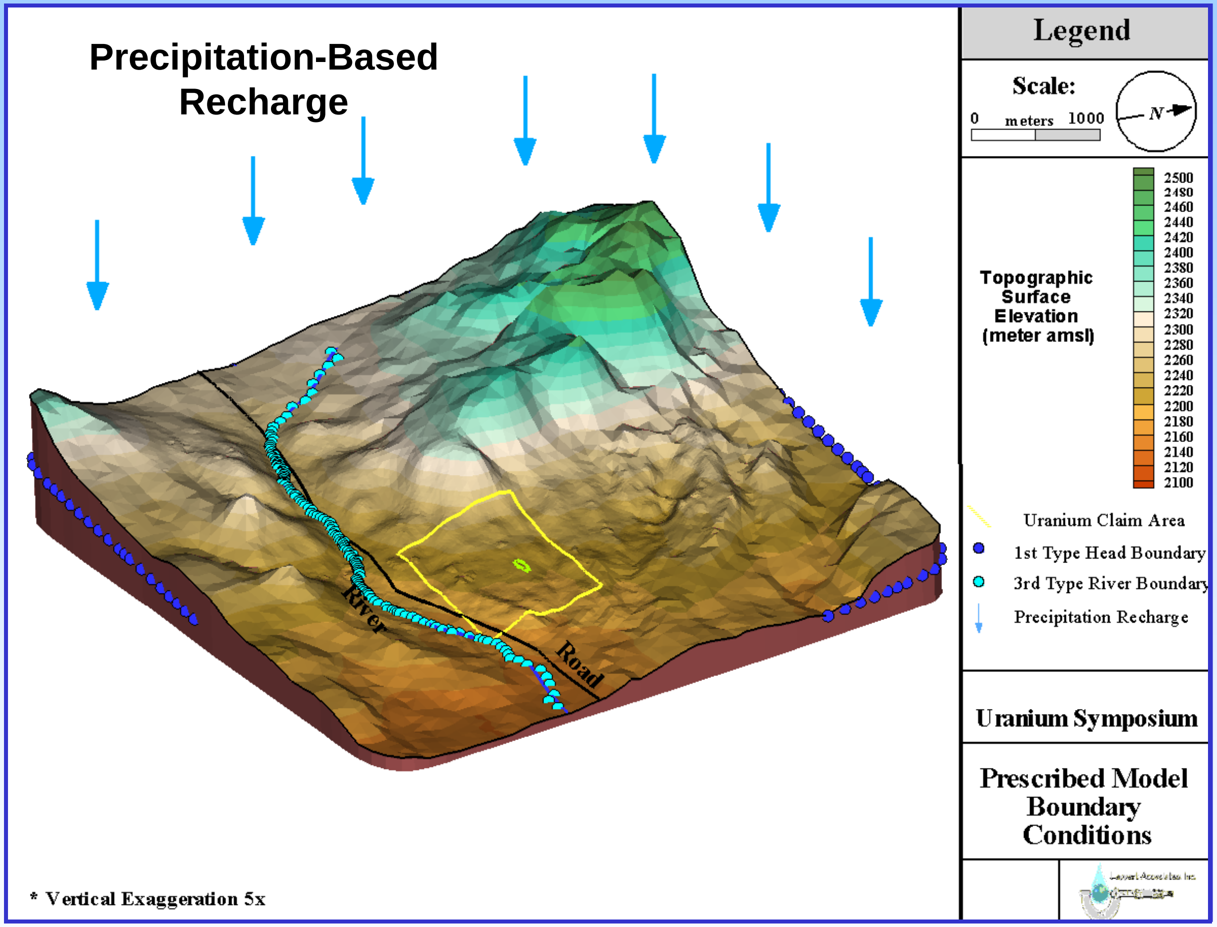
  - Lateral Flow
  - Precipitation Recharge
  - Local Creek



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- ***Hydraulic Boundaries***
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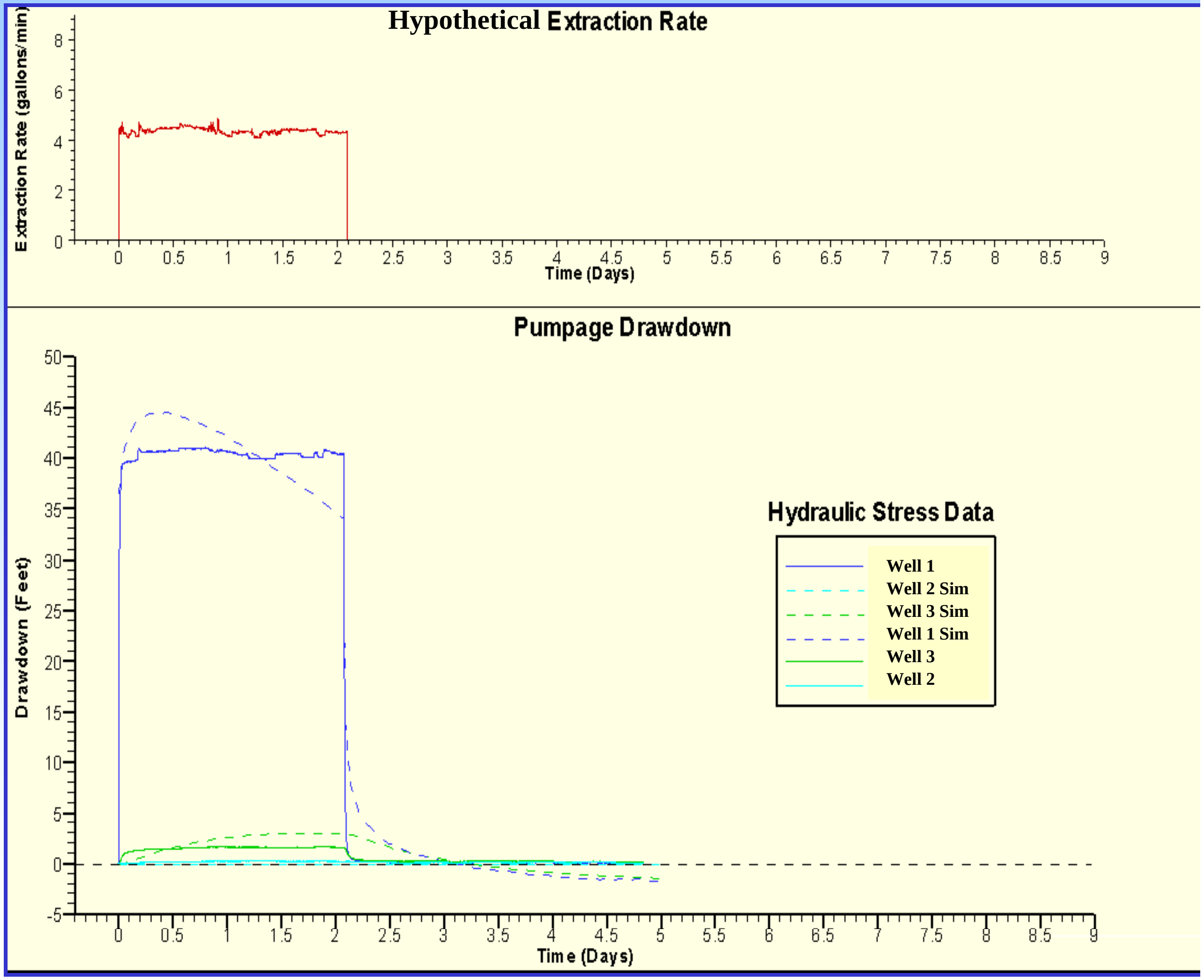
  - **Local Creek**
- ***Calibration***
  - **Target – Hydraulic Heads**
  - **Hydraulic Stress Tests**
  - **Parameter Estimation**



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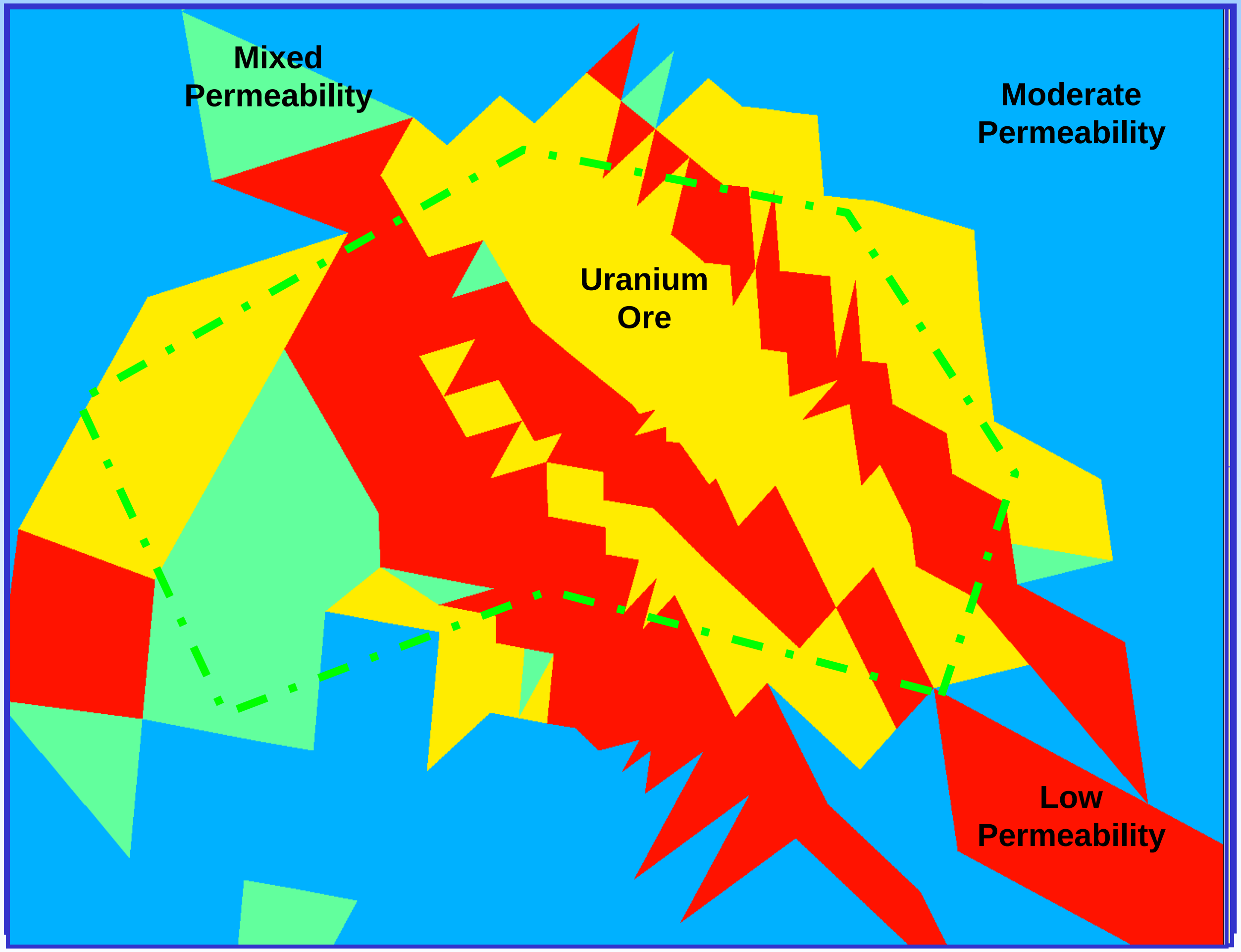
Lixiviant Delivery/Recovery System Design

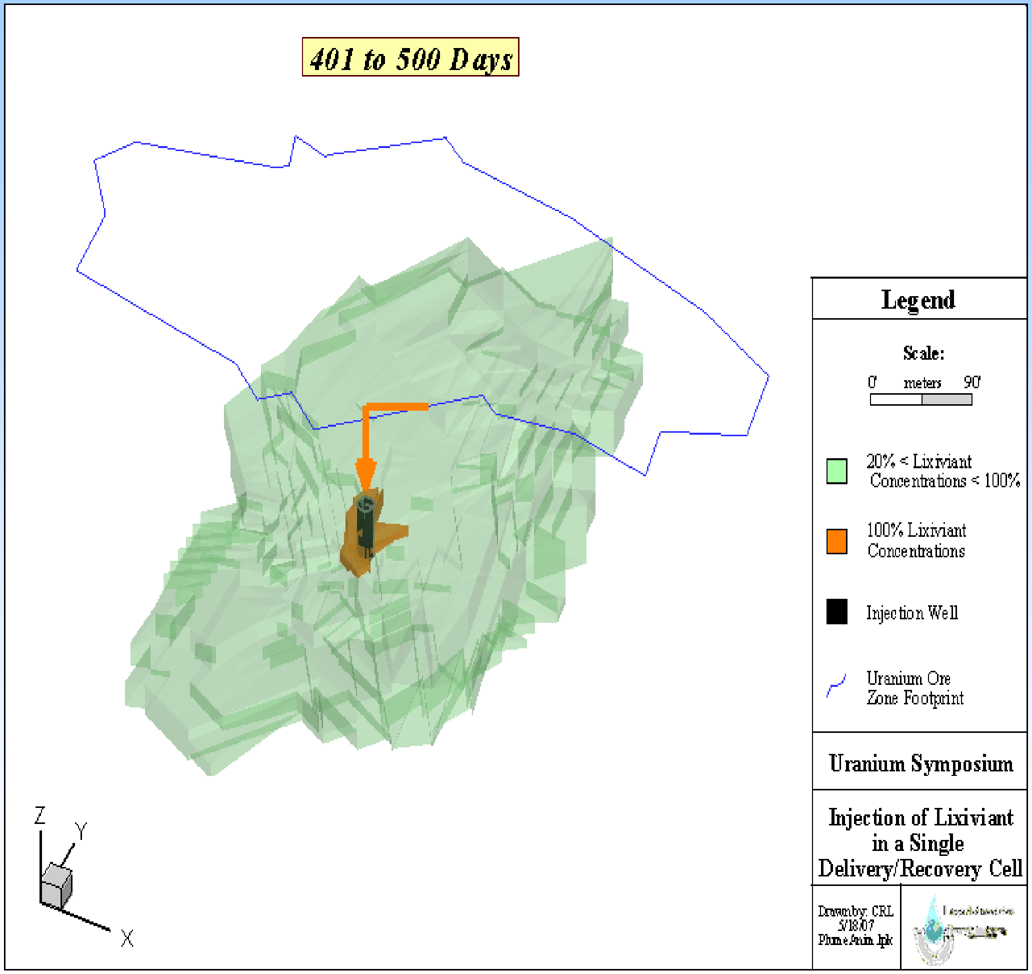
Ore Body Scenario



Lixiviant Delivery/Recovery System Design

Ore Body Scenario

Examine the Injection



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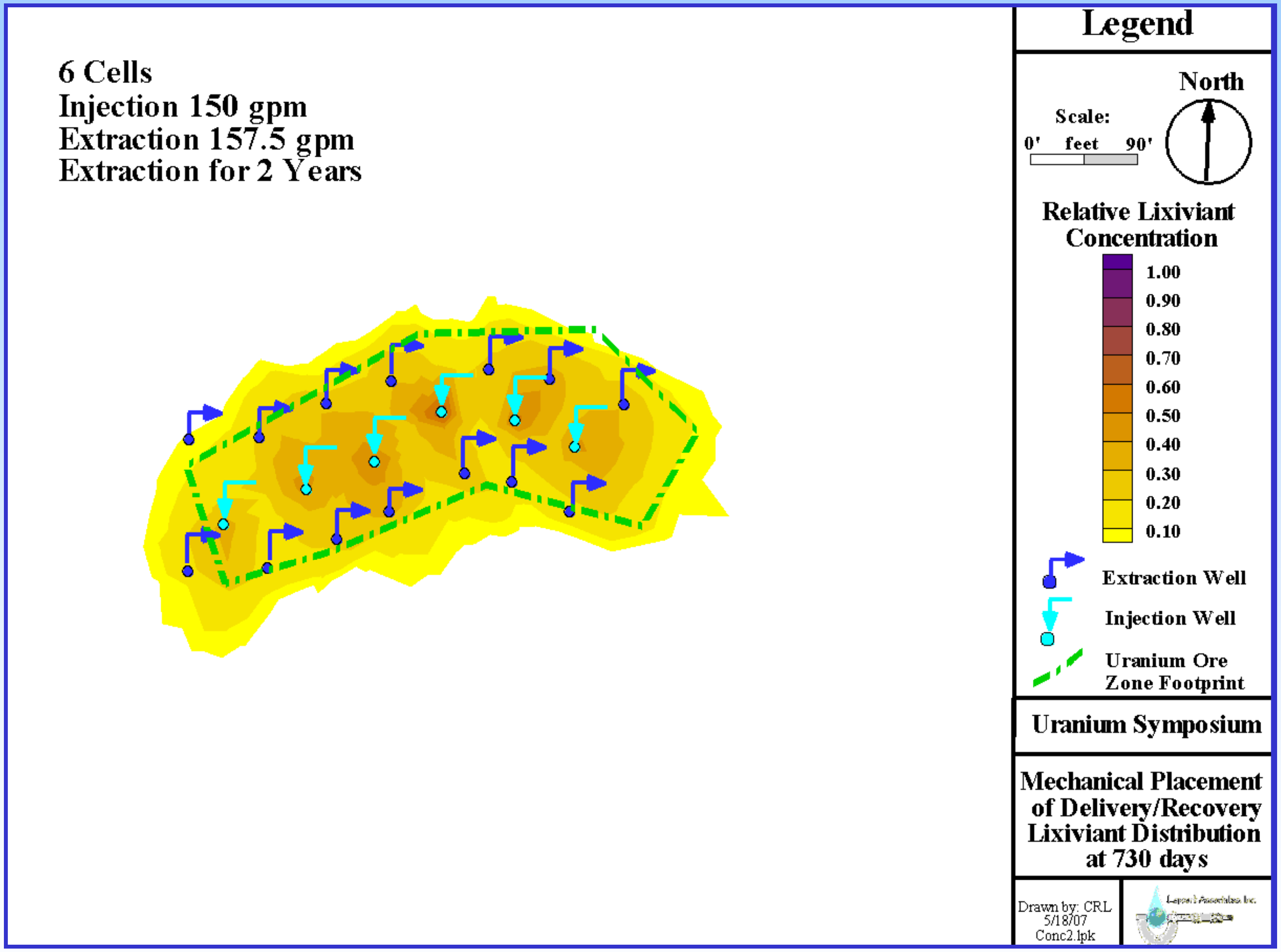
Lixiviant Delivery/Recovery System Design

Ore Body Scenario

Examine the Injection

Mechanical Design



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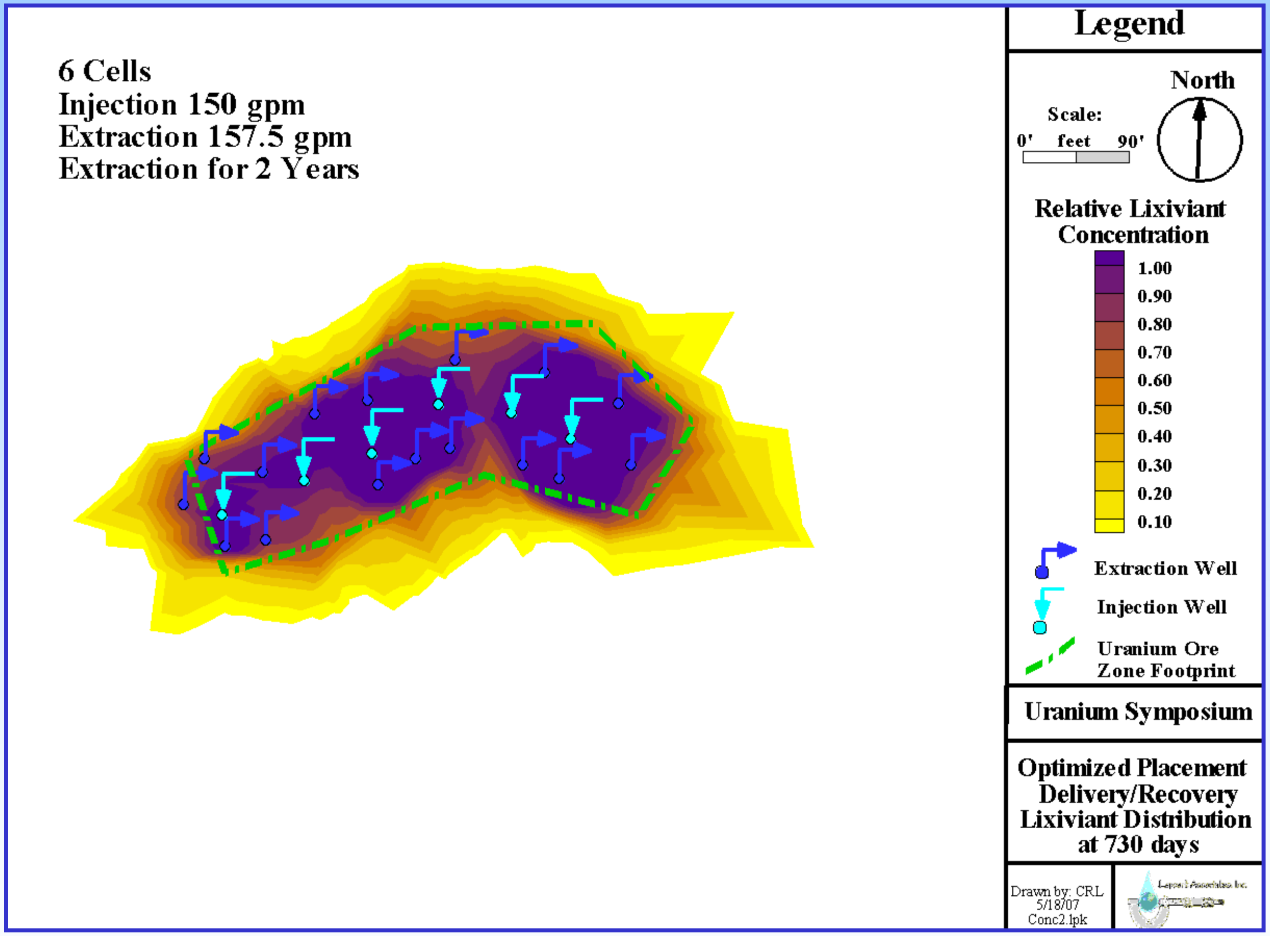
Lixiviant Delivery/Recovery System Design

Ore Body Scenario

Examine the Injection

Mechanical Design

Optimized Design



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Lixiviant Delivery/Recovery System Design

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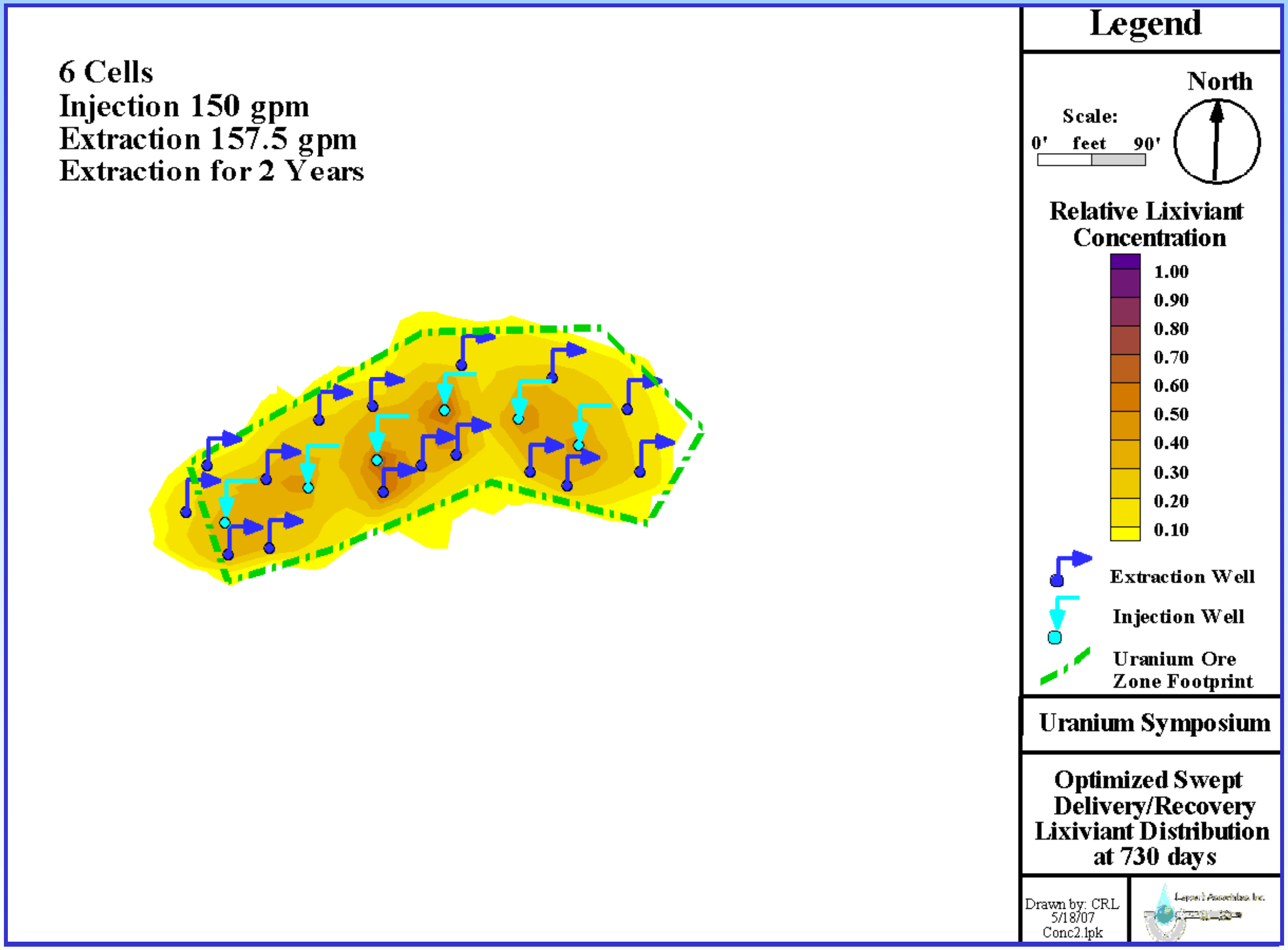
Examine the Injection

Mechanical Design

Optimized Design

Sweeping Design



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Lixiviant Delivery/Recovery System Design

Ore Body Scenario

Examine the Injection

Mechanical Design

Optimized Design

Sweeping Design

Scenario Comparison

Comparison Criteria

(1) Volume of Ore Zone having a Lixiviant Saturation >50%

- **Maximize Delivery**
- **Favorable if the Lixiviant is Controlled**

(2) Average Residence Time of Lixiviant

- **Maximize Recovery … Minimize Residence Time**

(3) Volume of Lixiviant Remaining after ½ Year of Clean-Water Injection/Extraction

- **Minimize Restoration Activities**

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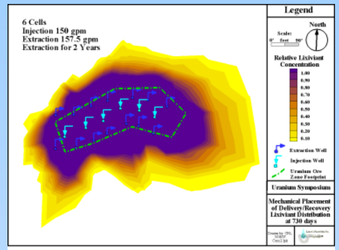

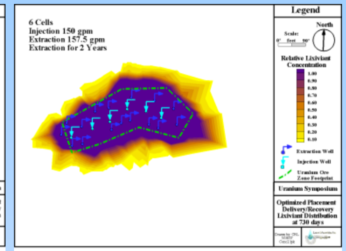

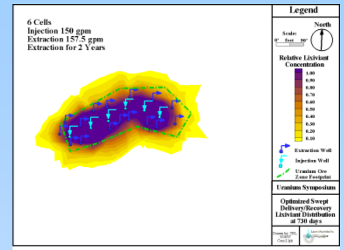

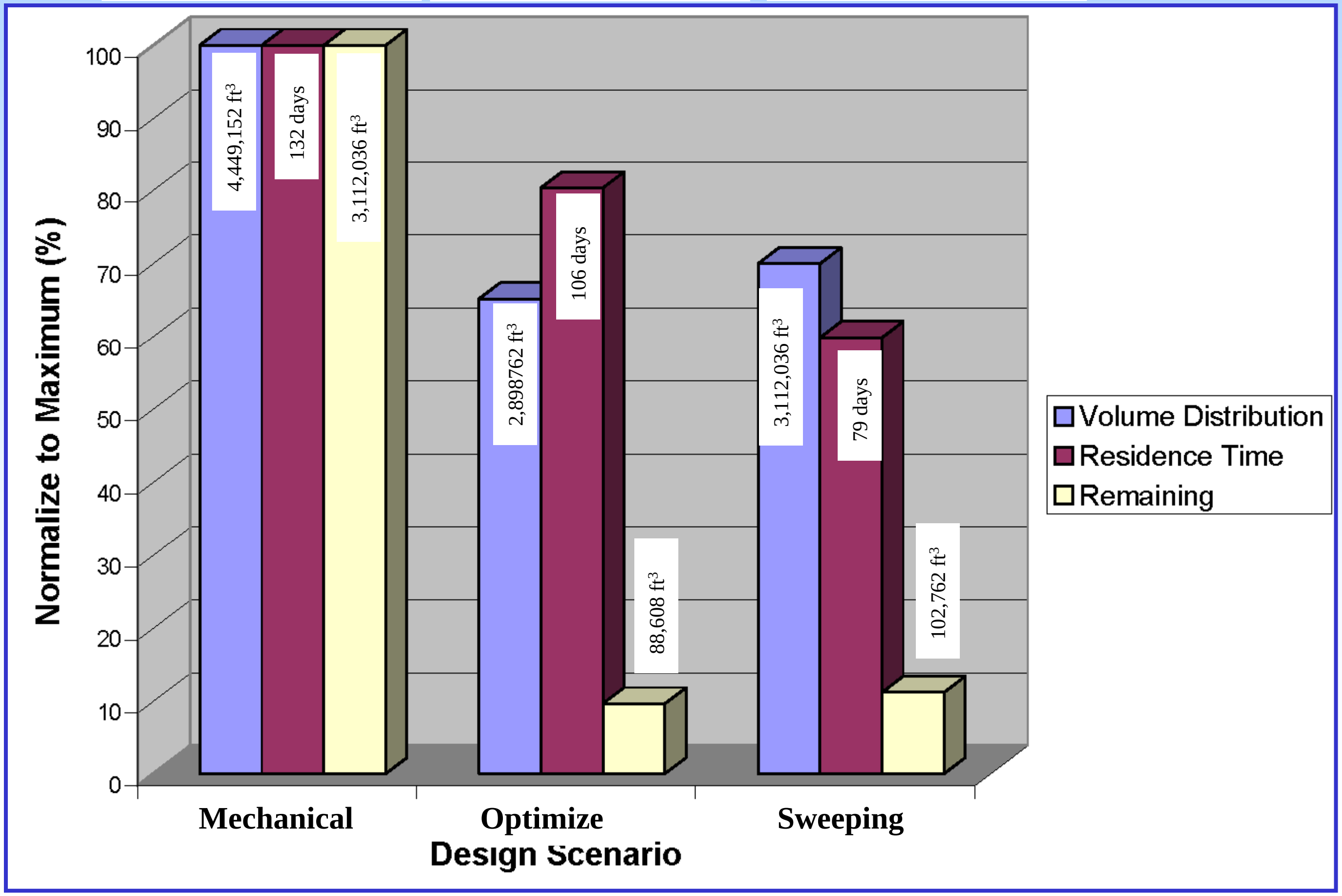

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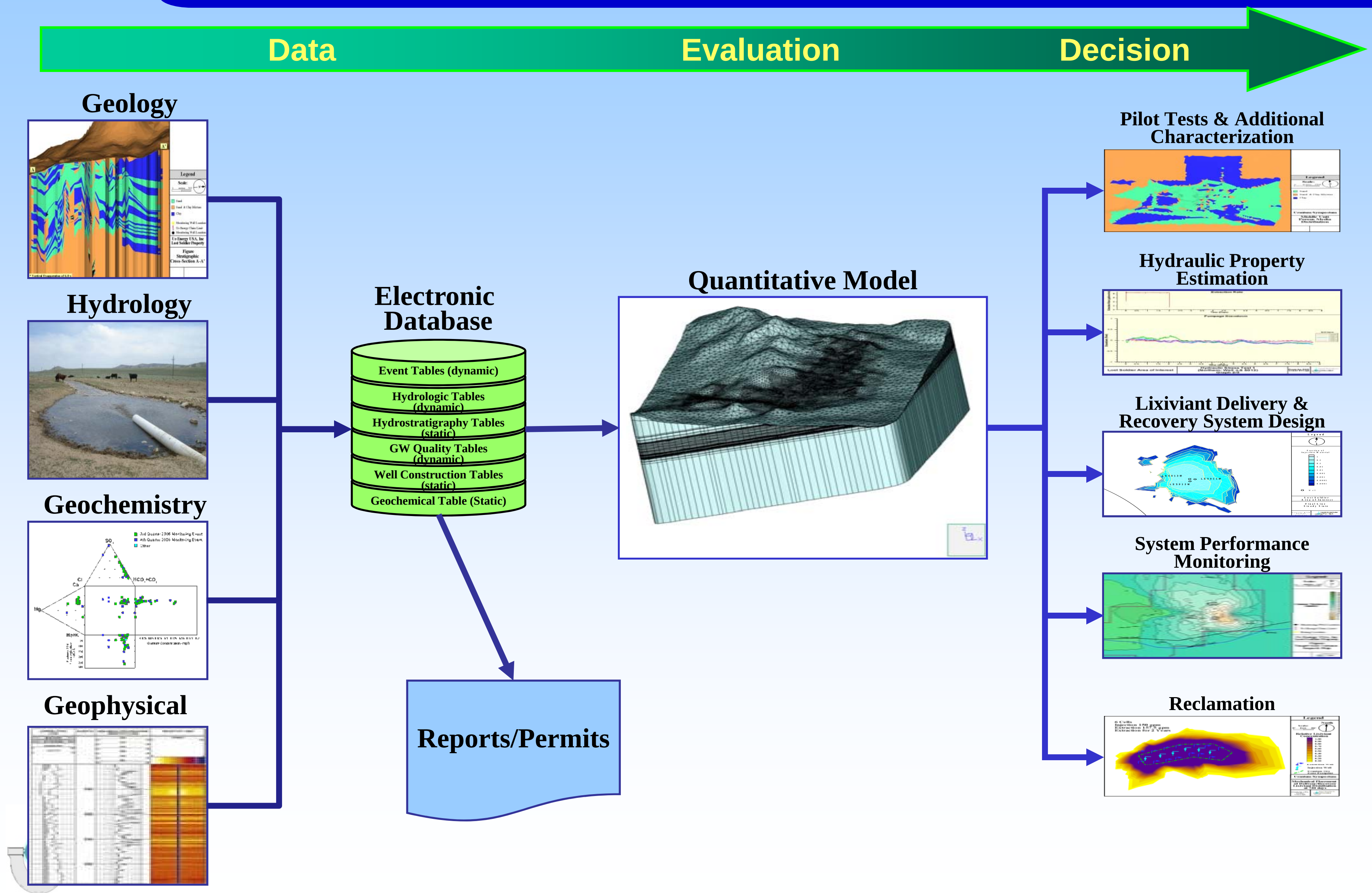
Quantitative Hydrogeologic Decision Framework



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 the 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**

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End

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