Closing the Loop in In-Situ Remediation

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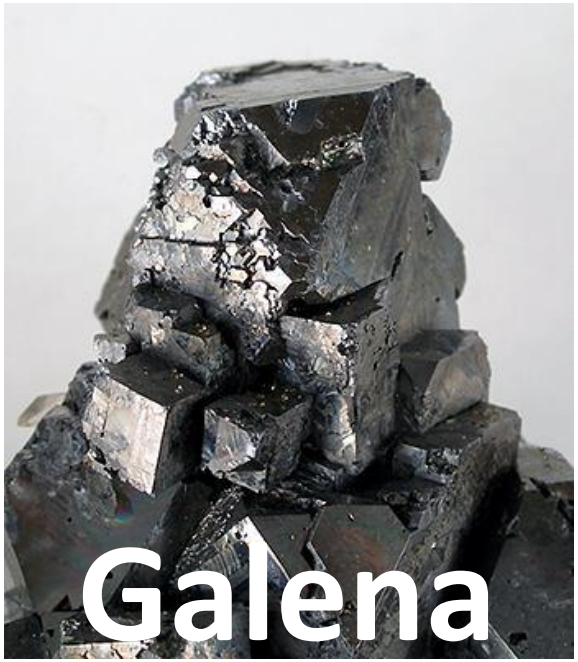
Overview

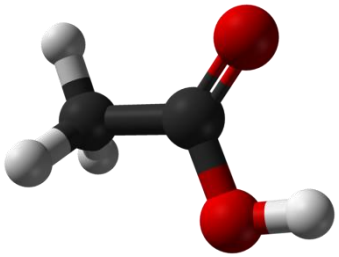
- History & site description
- Conceptual model
- Conductivity measurements
- Site measurements
- Conclusions

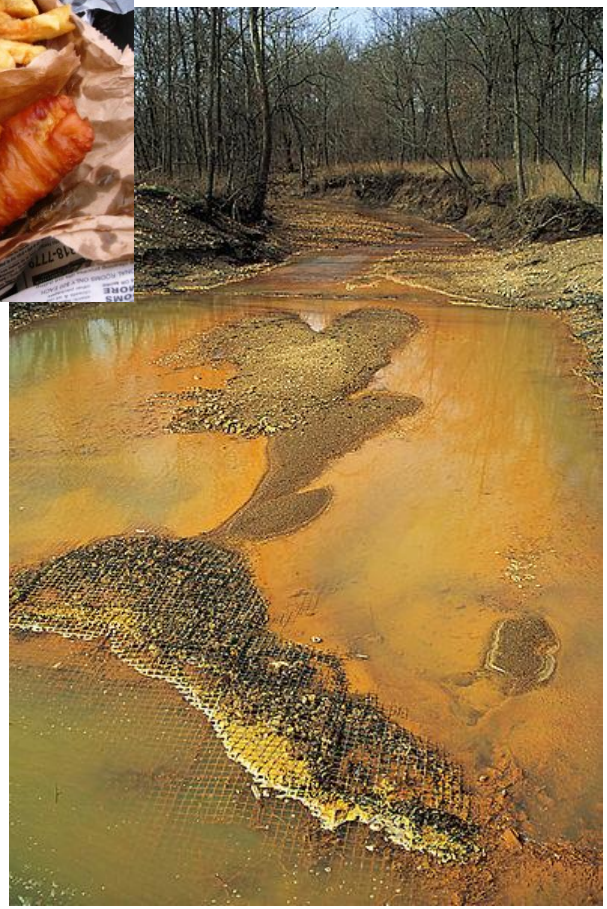
Yava Mine Site



In-Situ Leach Mining

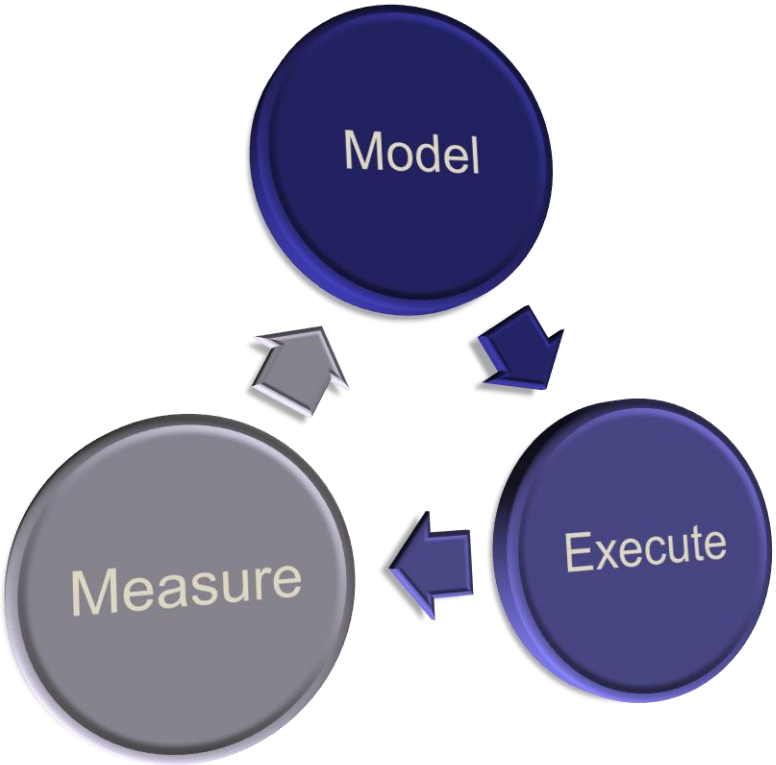
- Acetic acid: CH_3COOH



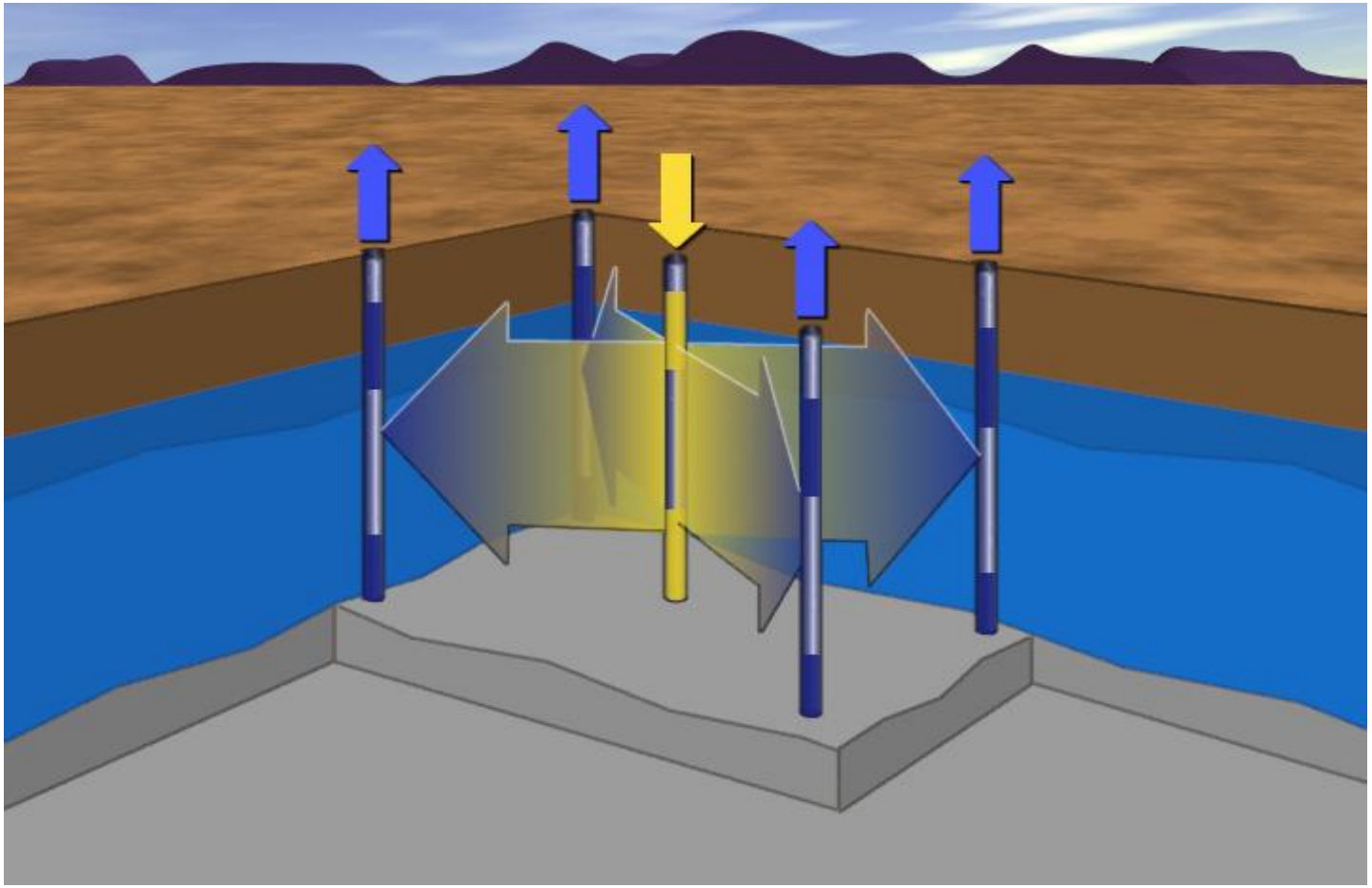


- No environmental impact
- No acid rock drainage
- No land disturbances

ISLM process

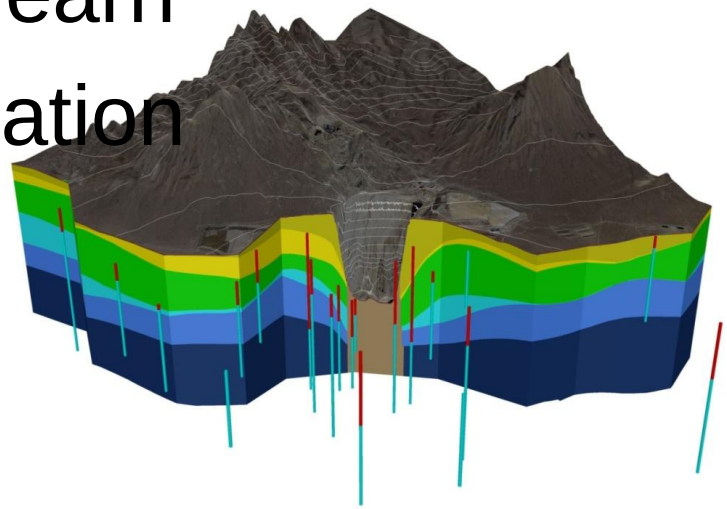


ISLM Conceptual Model

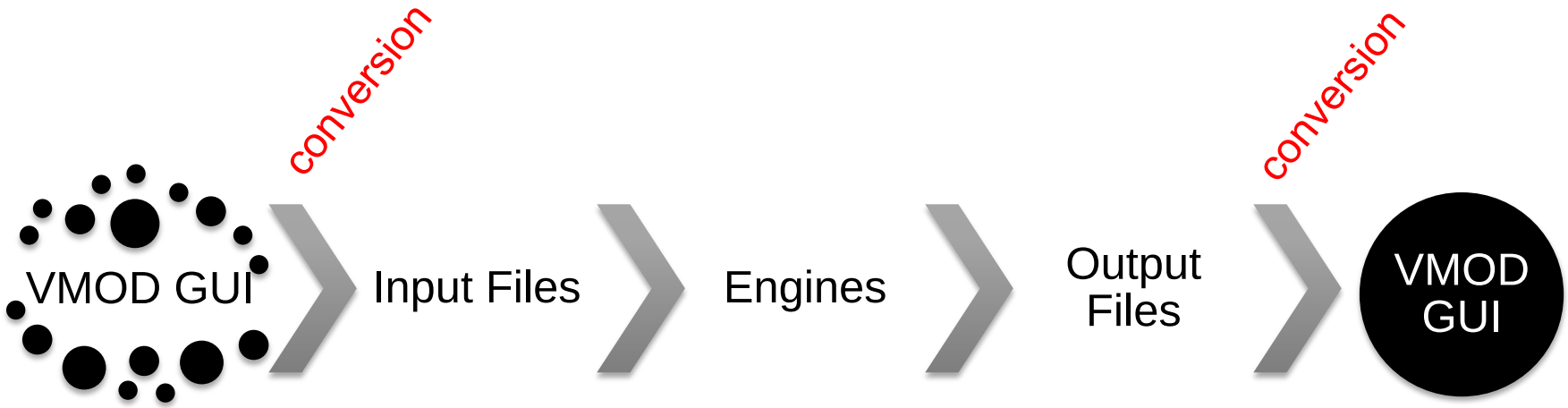


Visual MODFLOW

- Industry-standard for 3D Groundwater Flow, Heat, and Contaminant Transport Modeling
- Very flexible and easy to learn
- Enhanced 2D/3D Visualization



Visual MODFLOW – Workflow



- Tables
- Forms
- Visualization

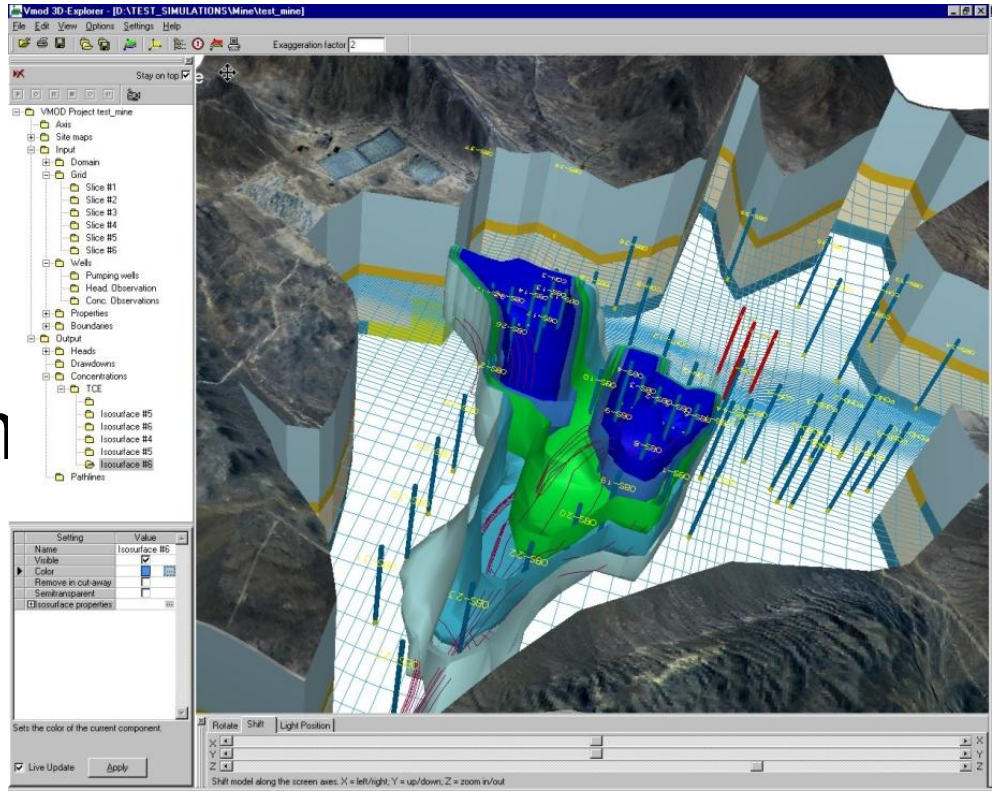
- (text)

- (text, binary)

- Color maps
- Animations

Visual MODFLOW - Applications

- Pump & Treat
- Reactive Wall
- Reactive Barrier
- Natural Attenuation
- Biodegradation

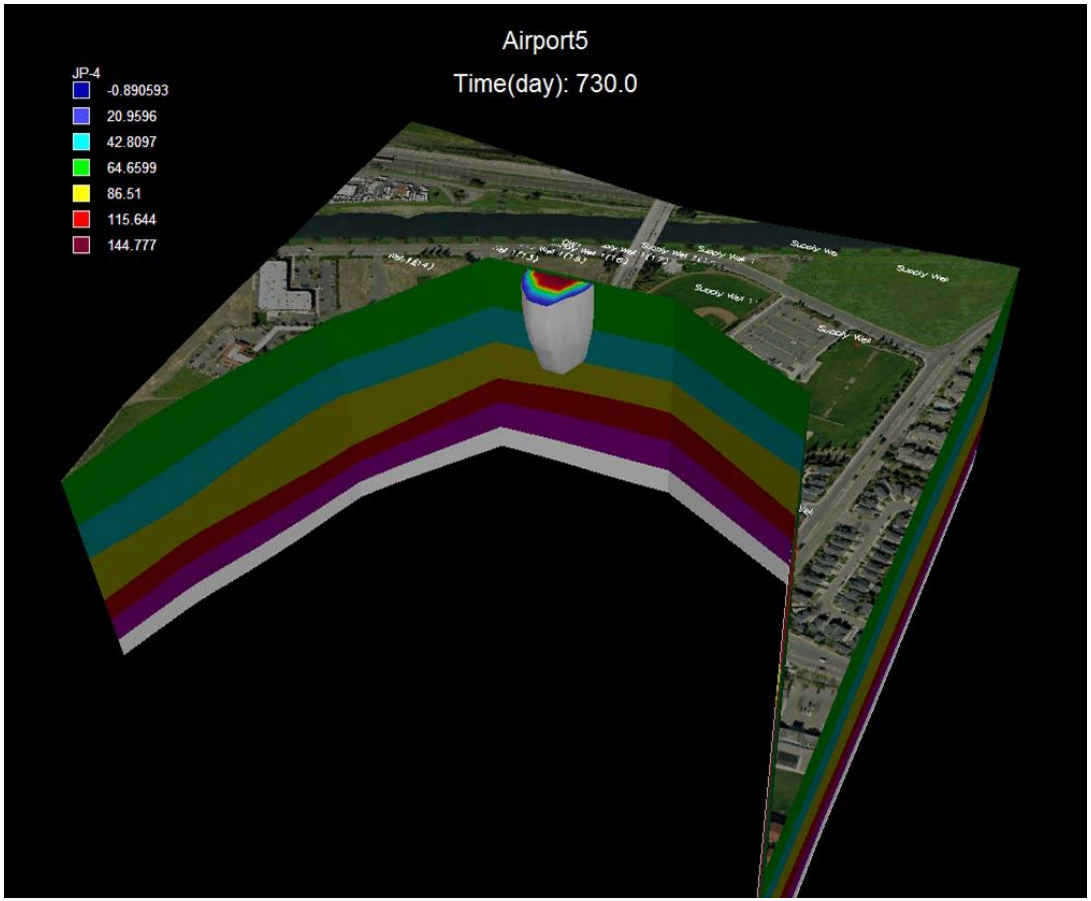


3D Plume Migration

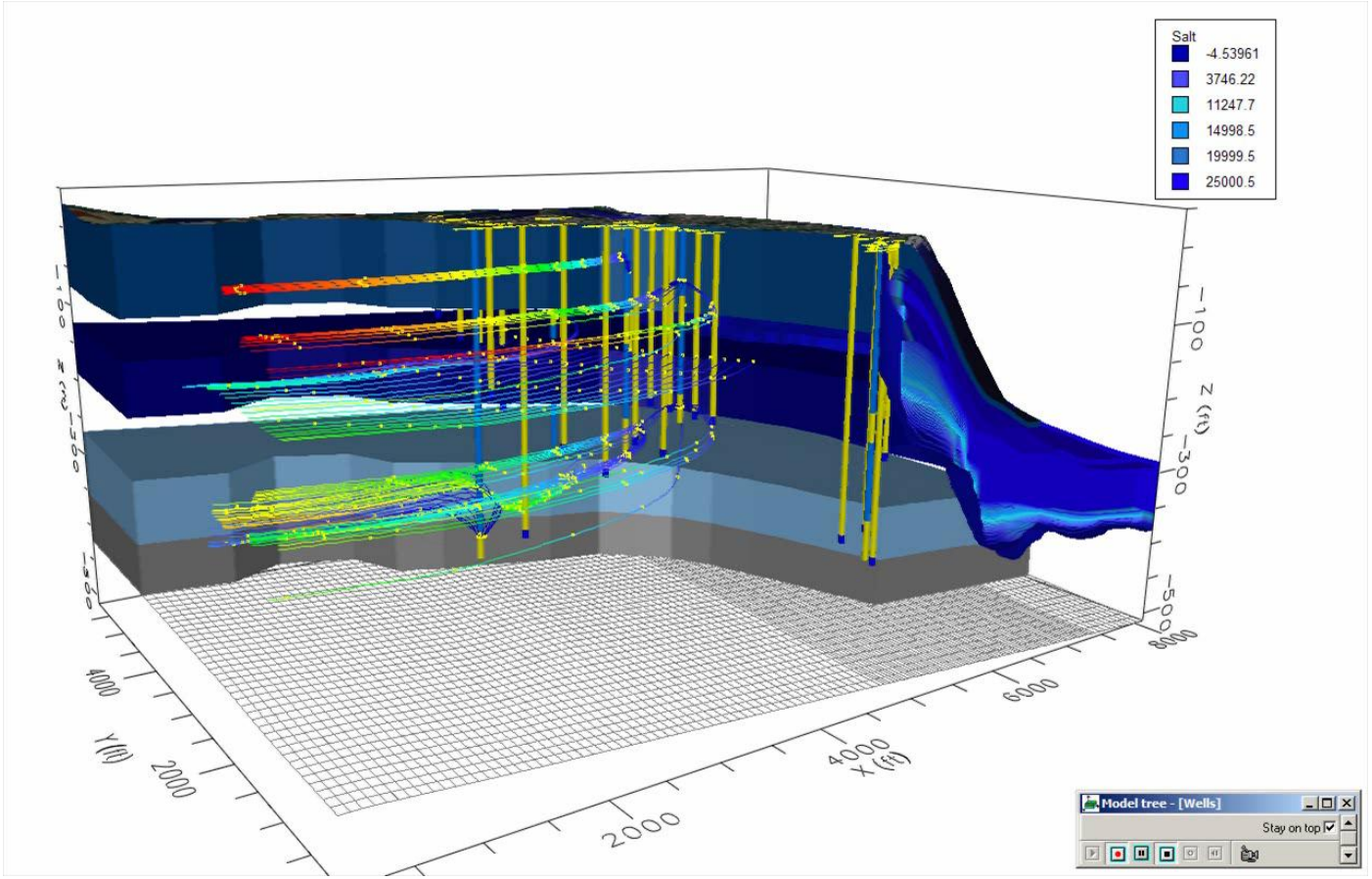
Visual MODFLOW - Engines

- Support of various contamination engines:
  - MT3DMS/MT3D99
  - RT3D
  - PHT3D = MT3DMS + PHREEQC

Demo

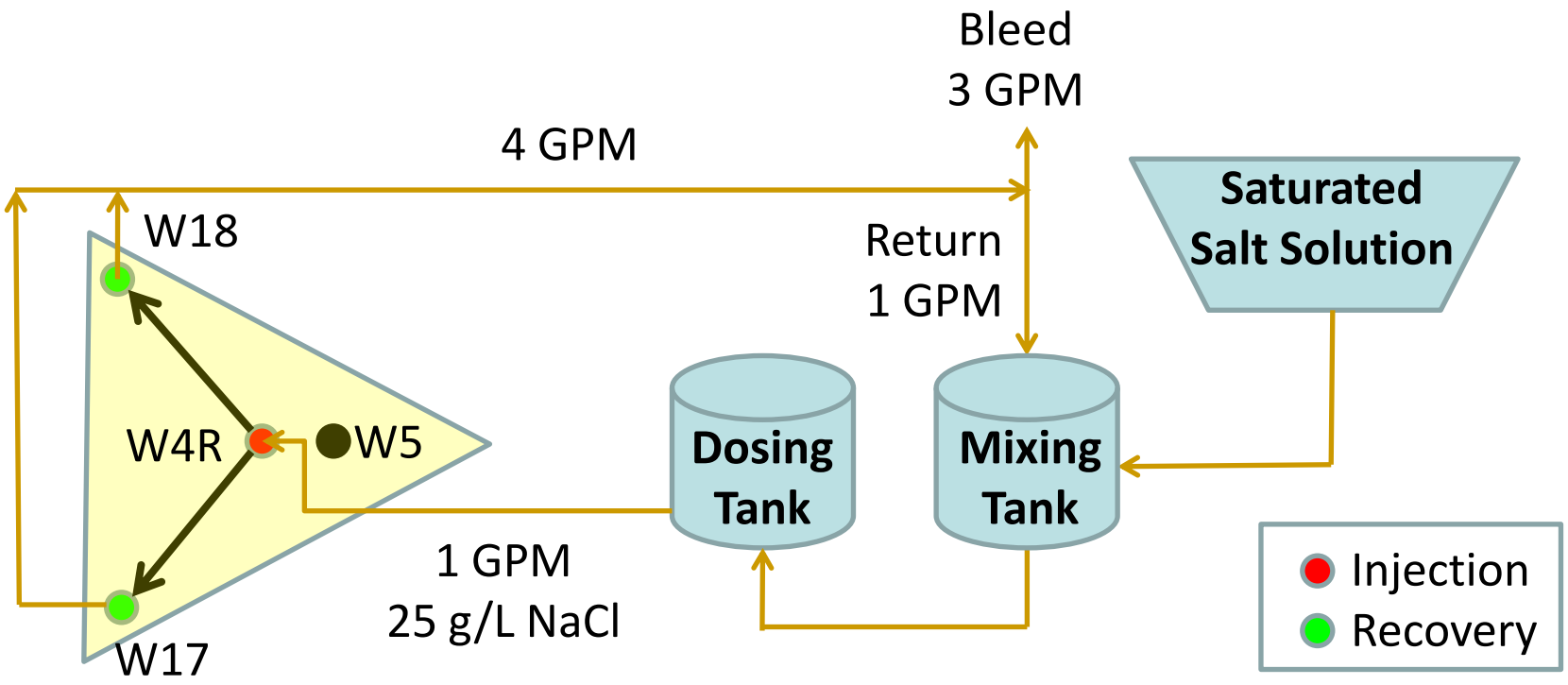

Airport5
Time(day): 730.0
JP-4
-0.890593
20.9596
42.8097
64.6599
86.51
115.644
144.777

Demo


Salt
-4.53961
3746.22
11247.7
14998.5
19999.5
25000.5
Z (ft)
-100
-300
-500
X (ft)
2000
4000
6000
8000
Y (ft)
2000
4000
Model tree - [Wells]
Stay on top

Tracer Test Setup

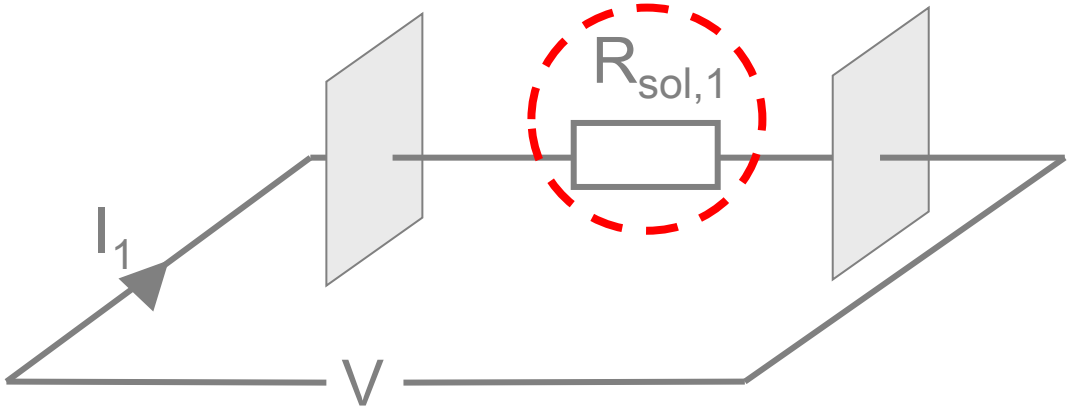
Tracer Test Setup



Electrical Conductivity (EC)

- Measure of ion activity
  - Concentration
  - Type of ion
  - Charge of ion
  - Temperature (≈ 2% per °C)
- $EC_{NaCl} / EC_{KMnO4} \approx 2.3$

How to measure EC



Ohm's Law:

$$V = I \times R$$

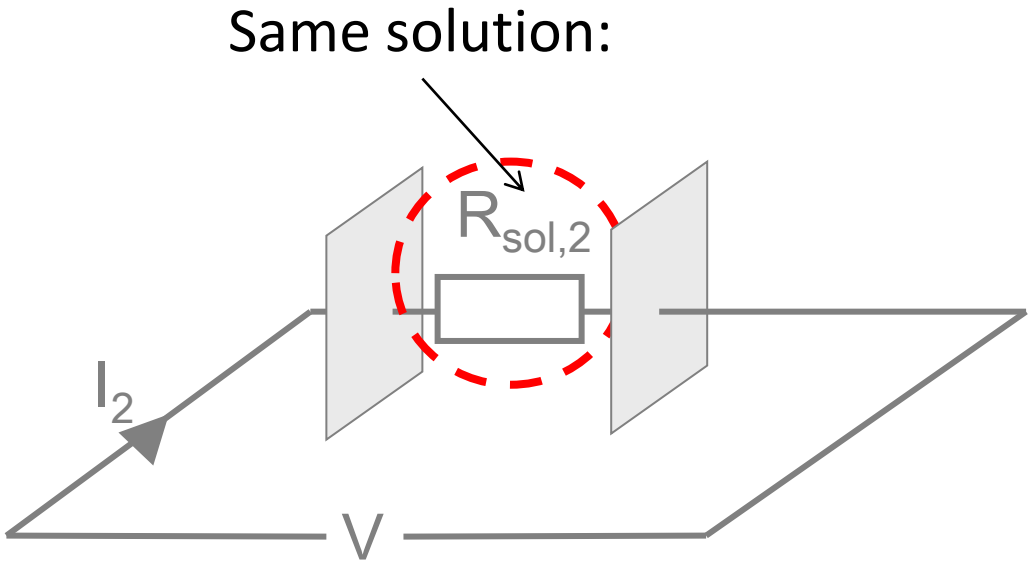
Conductance:

$$G = \frac{1}{R}$$

Measured Conductance:

$$G_{sol,1} = \frac{I_1}{V}$$

How to measure EC



Same solution:

$$R_{sol,2} < R_{sol,1}$$

$$G_{sol,2} > G_{sol,1}$$

Measured Conductance:

$$G_{sol,2} = \frac{I_2}{V}$$

Conductivity:

$$EC = G \times K_{cell}$$

Cell constant:

$$K_{cell} = \frac{d}{A}$$

Specific conductivity

- Conductivity at a specific temperature:

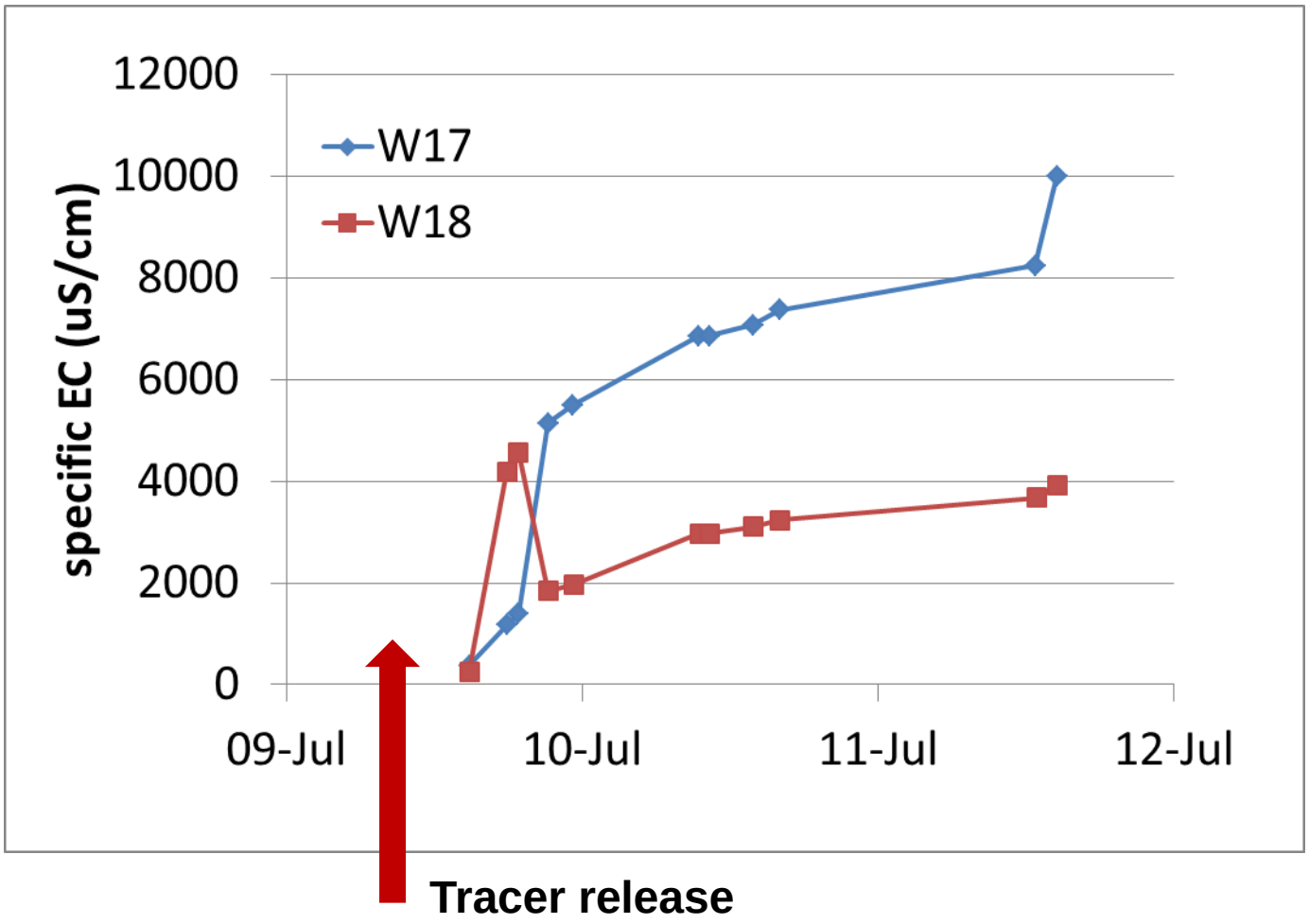
$$EC_{Tref} = \frac{1}{1 + \Theta(T - T_{ref})} EC$$

- Θ = temperature coefficient ≈ 2 %/°C

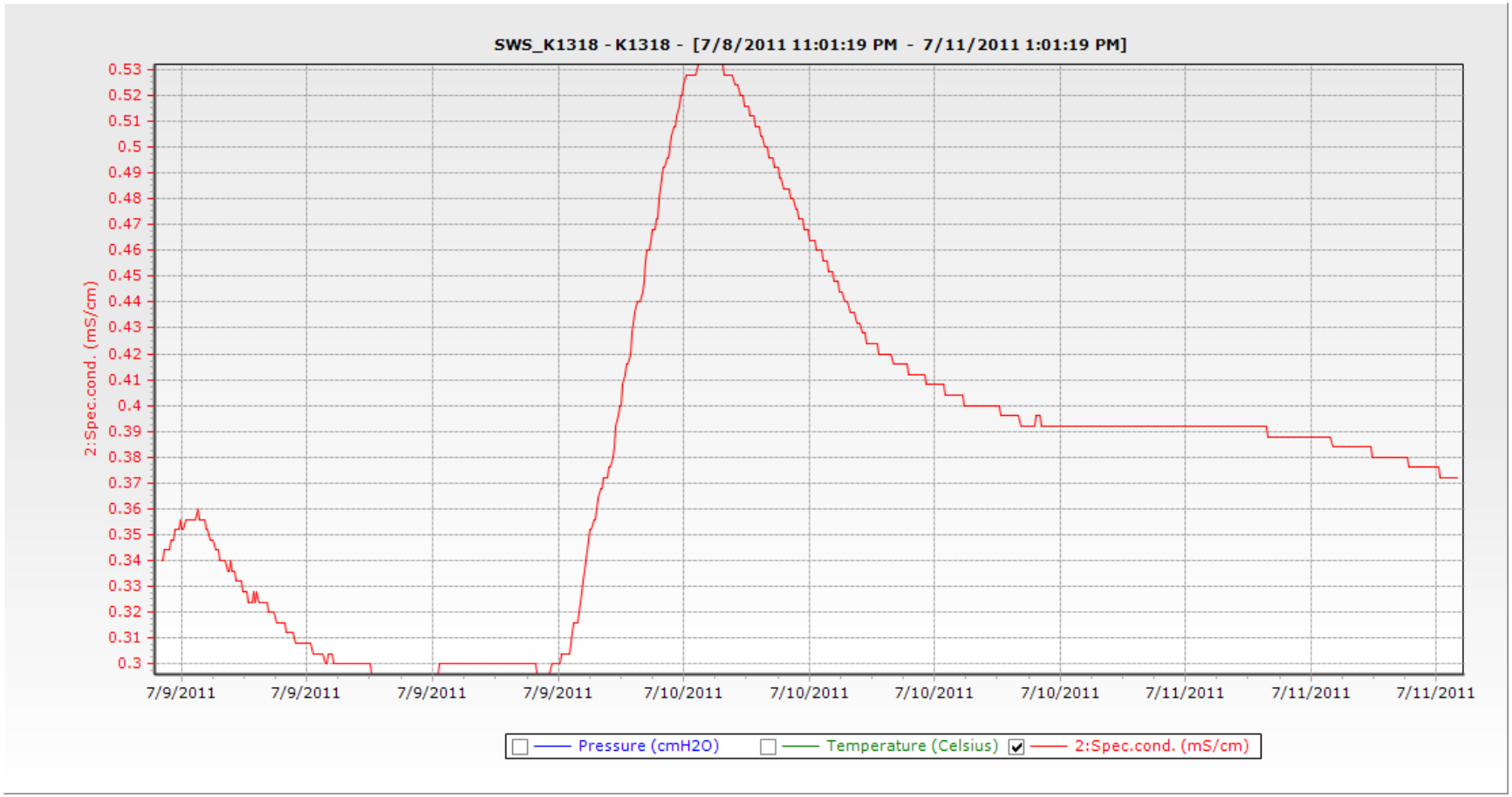
CTD-Diver

- Inert ceramic housing
- Compact size
- Range: 0 to 120 mS/cm
- 4-electrode sensor

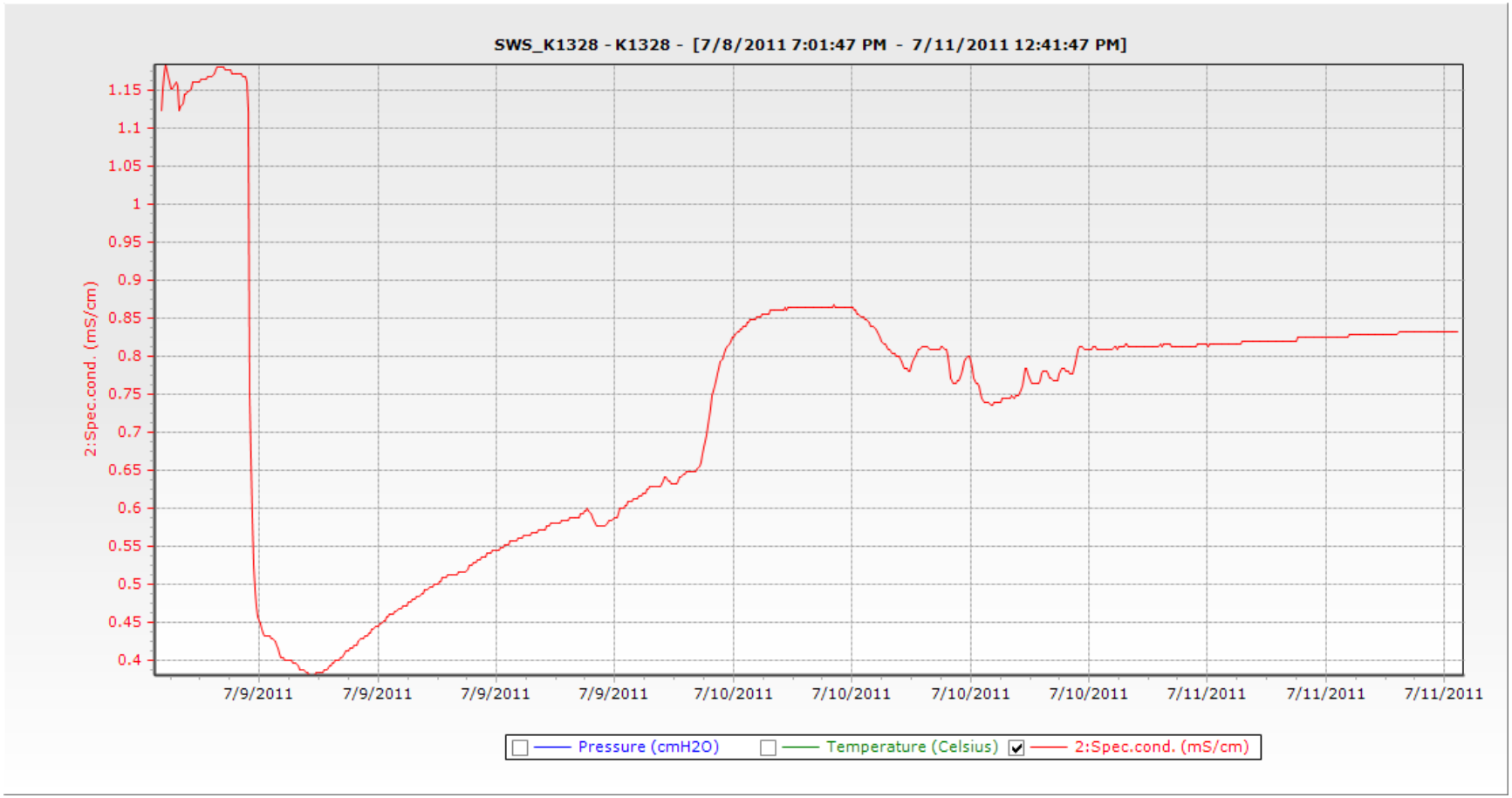
Results: Recovery wells



Results: Recovery Well W17



Results Well W5



Yava Conclusions

- Break through occurred fast due fractures
- Distribution of tracer not as wide as expected
- Regulators were impressed with CTD-Diver

Final Conclusions

- Parallels between ISLM and remediation
- Visual modeling is a powerful tool
- Use conductivity monitoring