Mine Design - Dewatering

The Importance of Dewatering in Mine Design

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Case Study:

- Hydrogeology work flow for a Feasibility Study
- Expectations vs. Findings
- Relationship between the Technical Economic Model and dewatering work

May 17, 2018

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Goal: Advance Nb project to Feasibility Level in 10 months

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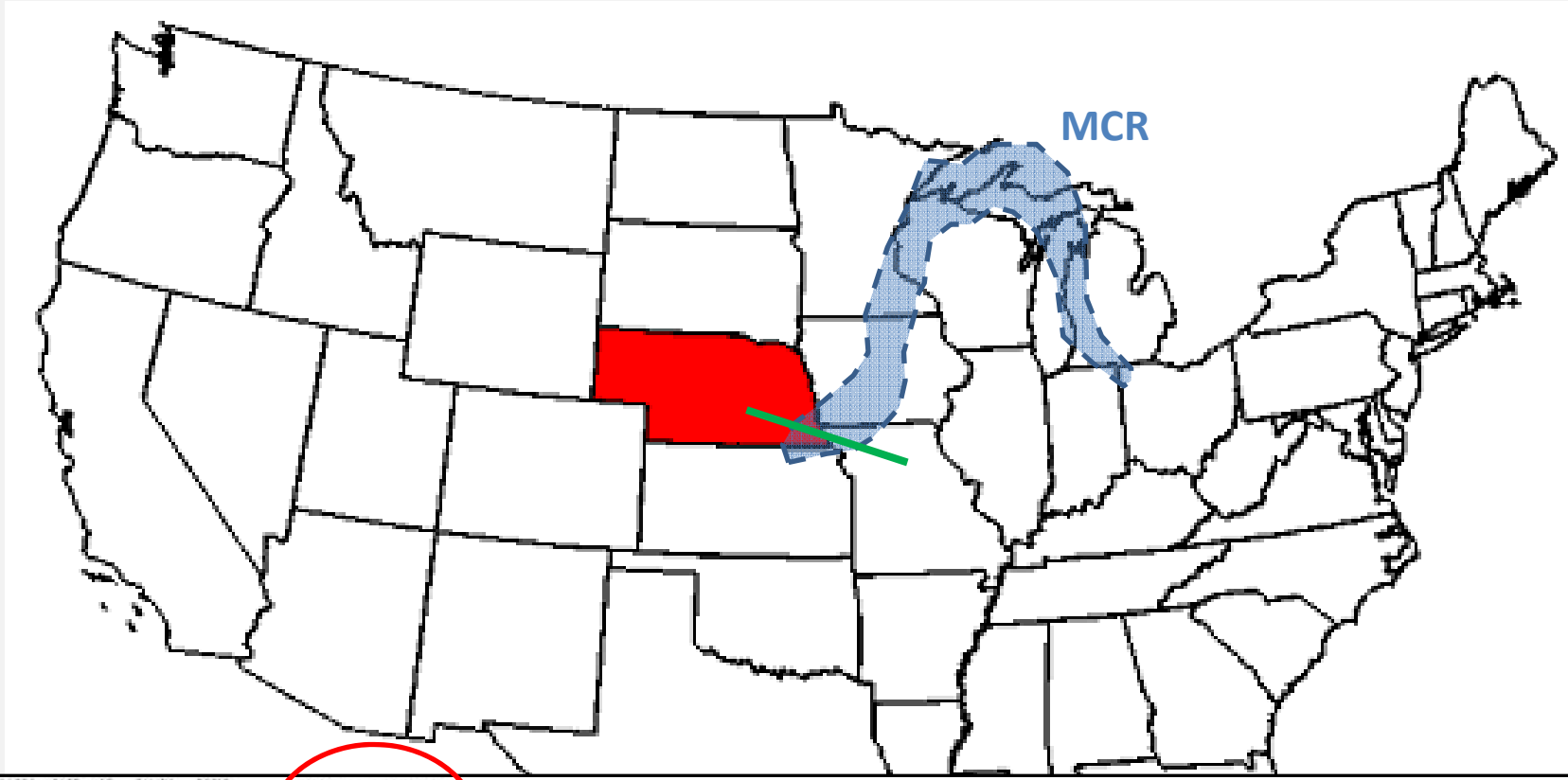

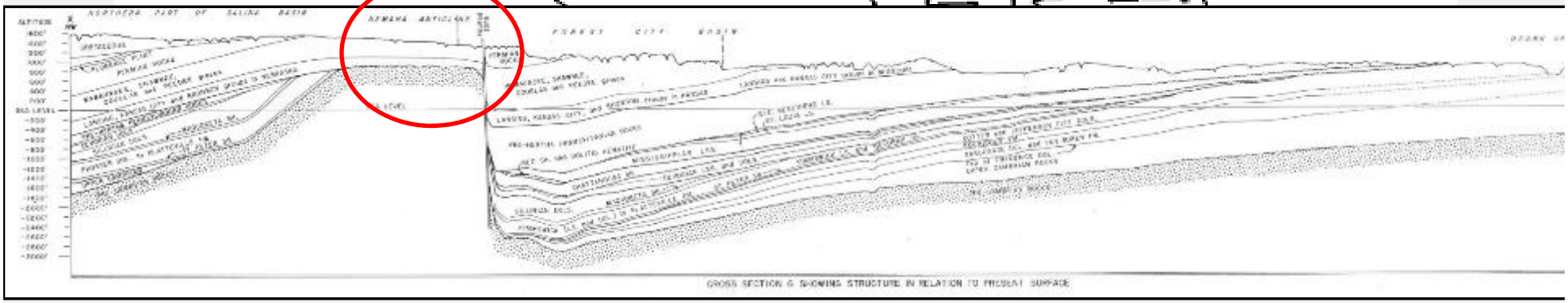

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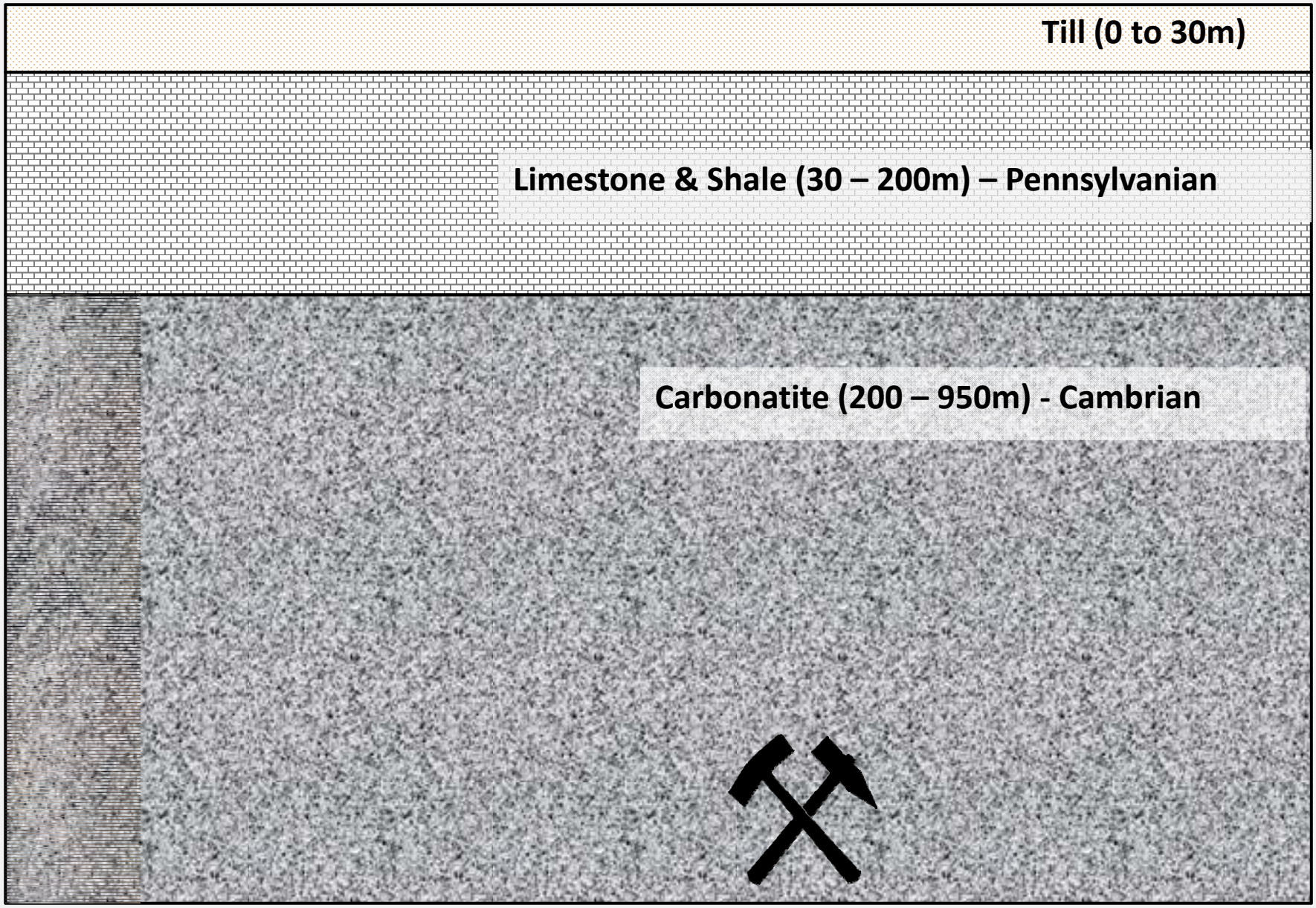

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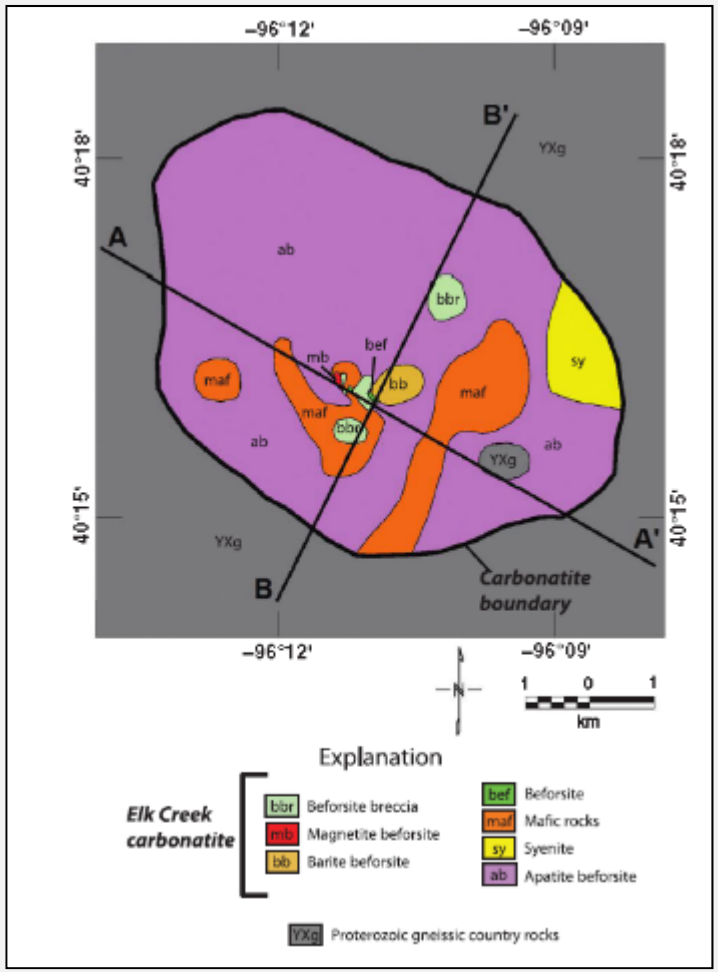
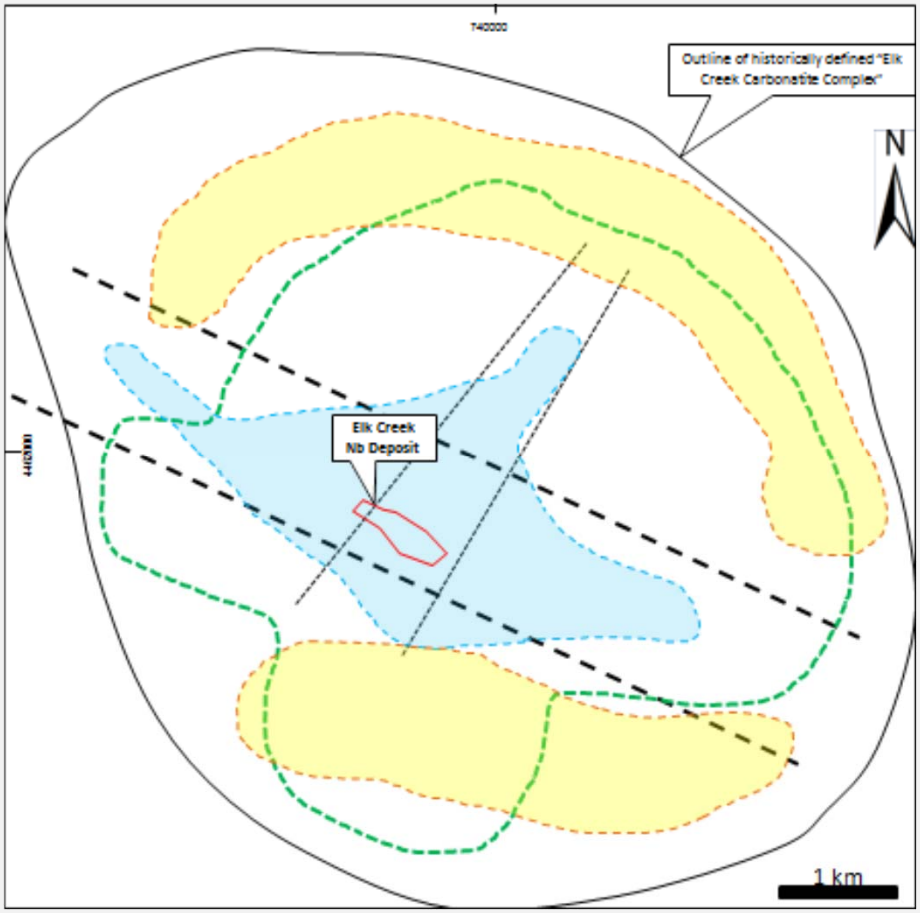
Geology beneath Mississippian Limestone:





Geological map outline of the project area (provided by the client). Syenite (yellow); Beforsite (blue). Deposit outline in green. Dotted straight lines are magnetic lineaments. **From Elk Creek Structural Report**.

Drenth B., 2014. **Geophysical Expression of a buried niobium and rare earth element deposit: The Elk Creek carbonatite, Nebraska, USA**

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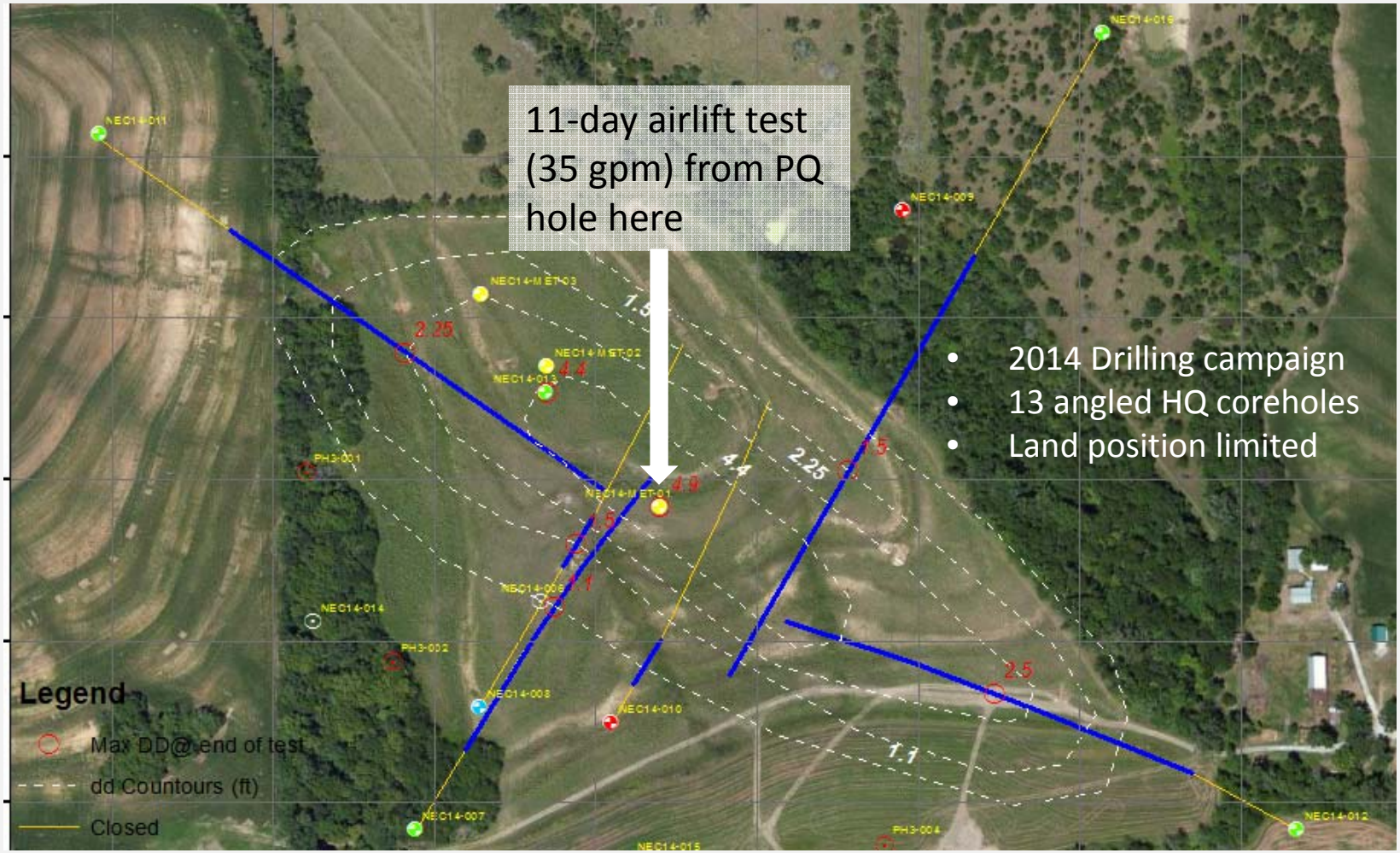
2014 Field Program:



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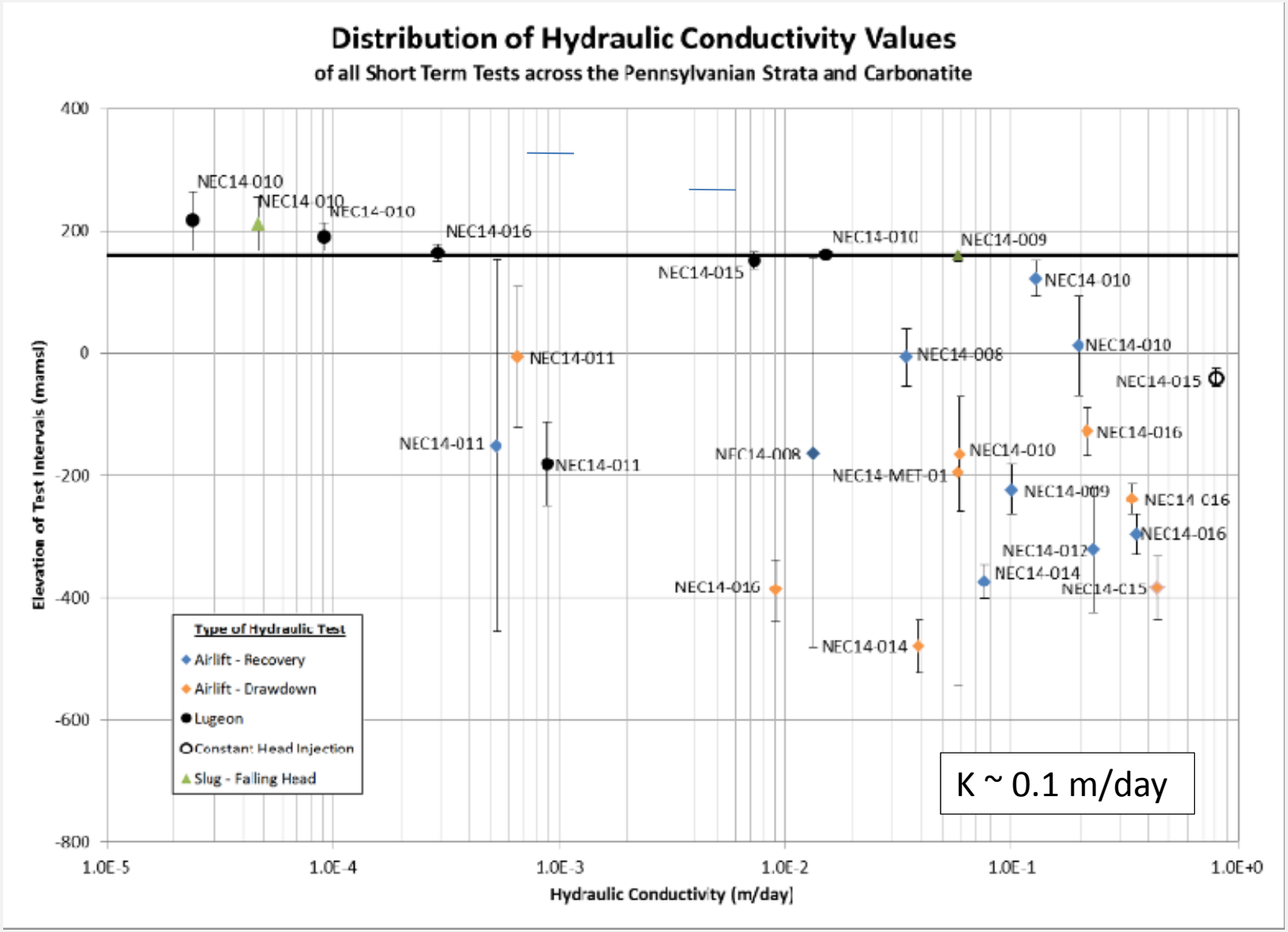

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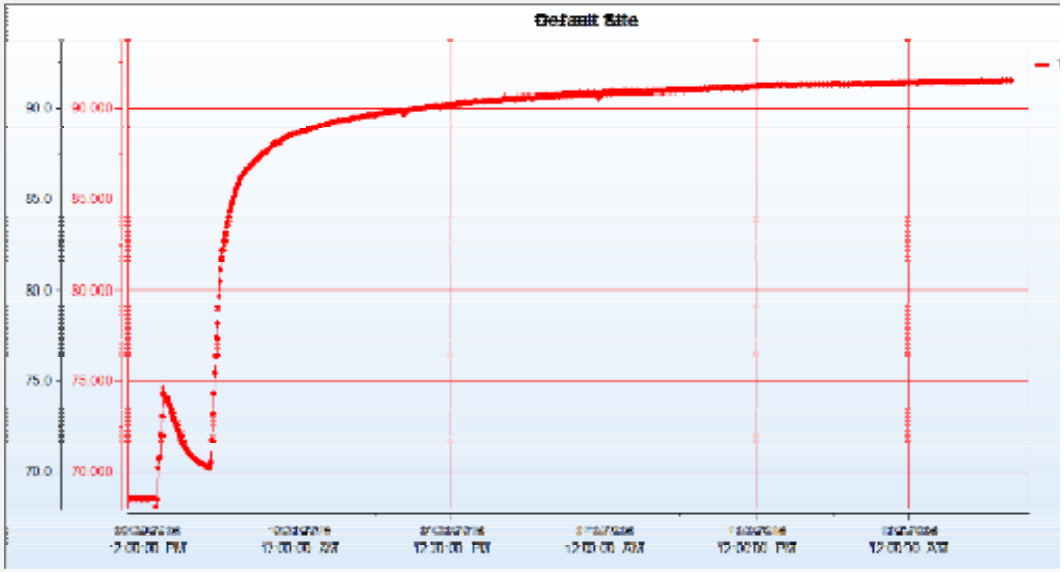
	Aqueous concentration (mg/l)				
drill hole	**Chloride**	**Iron (total)**	**Sodium (total)**	**Sulfate**	**Comment**
NEC14-006	755	15.6	597	320	full open borehole
NEC14-007	5200	10.65	3733	1670	full open borehole
NEC14-008	3520	0.46	2350	736	shallow completion
NEC14-014	10300	7.85	6158	1410	Packer-isolated - deep
NEC14-015	10500	4.34	5937	1400	Packer-isolated - deep
Met-01	10300	1.57	7357	1400	open borehole after 5 days of pumping.



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Conclusions after ~5 months of Field Work :

- Water Levels are consistently low in carbonatite
  - ✓ In equilibrium with something distant.
  - ✓ Connection to larger system?
- Hydraulic Conductivity values are relatively high to total depth of the deposit (850m)
  - ✓ Lots of water
- Water is brackish
  - ✓ Water management problem

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Can we proceed with the FS?

Uncertainties:

1. **Defensible carbonatite parameters (Short term Q)**
   - Is $K_{carbonatite}$ > 0.1 m/day?
   - Storage?

2. **Role of the Granite (Long term Q)**

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- Risk 1: Overestimate costs to actively dewater the mine
  - ✓ CAPEX for drilling, well network, piping
  - ✓ O&M for electricity

- Risk 2: Overestimate water management costs
  - ✓ Cl and Na content of water elevated
  - ✓ Discharge issues or Treatment costs?

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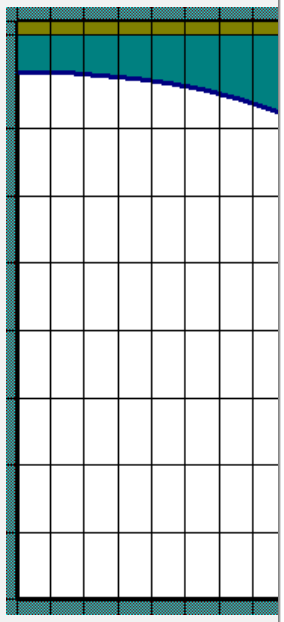
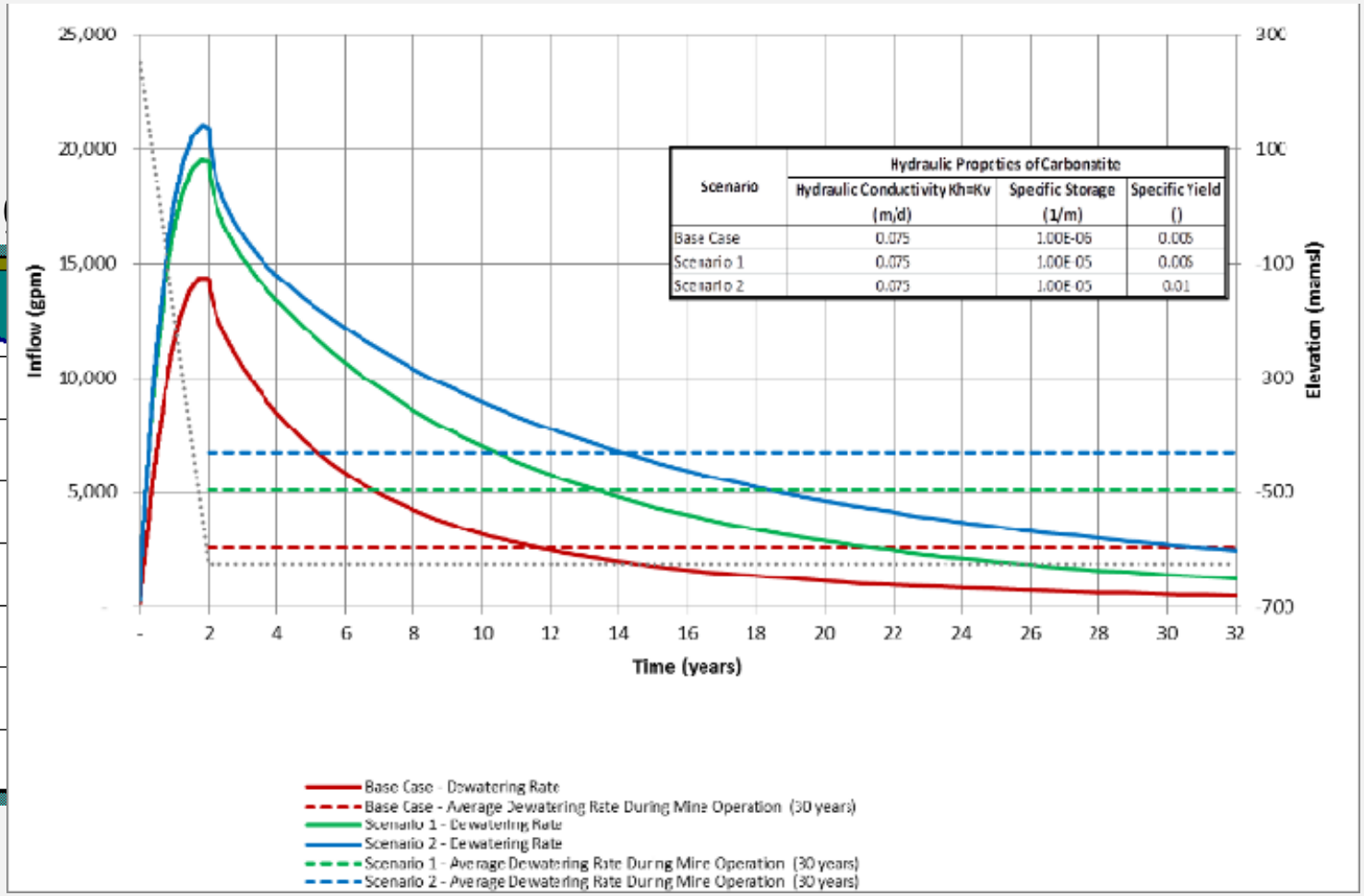
Options:

- Modelin





- Return to the field

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Impose a larger stress - Look for boundary effects

- Drill and install a test well. Conduct a long term test at a much higher rate (500 gpm) for 30 days.
- Conduct additional drilling lateral to the deposit – piezometers to monitor response from test
- Cost/Schedule?
  - ✓ 850-m deep 6-inch well
  - ✓ 2 deep, hybrid piezometer/VWP strings away from deposit
  - ✓ technical labor and oversight, including 30-day test
  - ✓ Schedule – 5 months

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What to do with the water: (500 gpm, 30-day)?

- DISCHARGE (Elk Creek)
- TRUCK (lagoons)
- TREAT (discharge to Elk Creek - **NPDES**)
- STORE & RE-INJECT (construct lined ponds, **UIC**)

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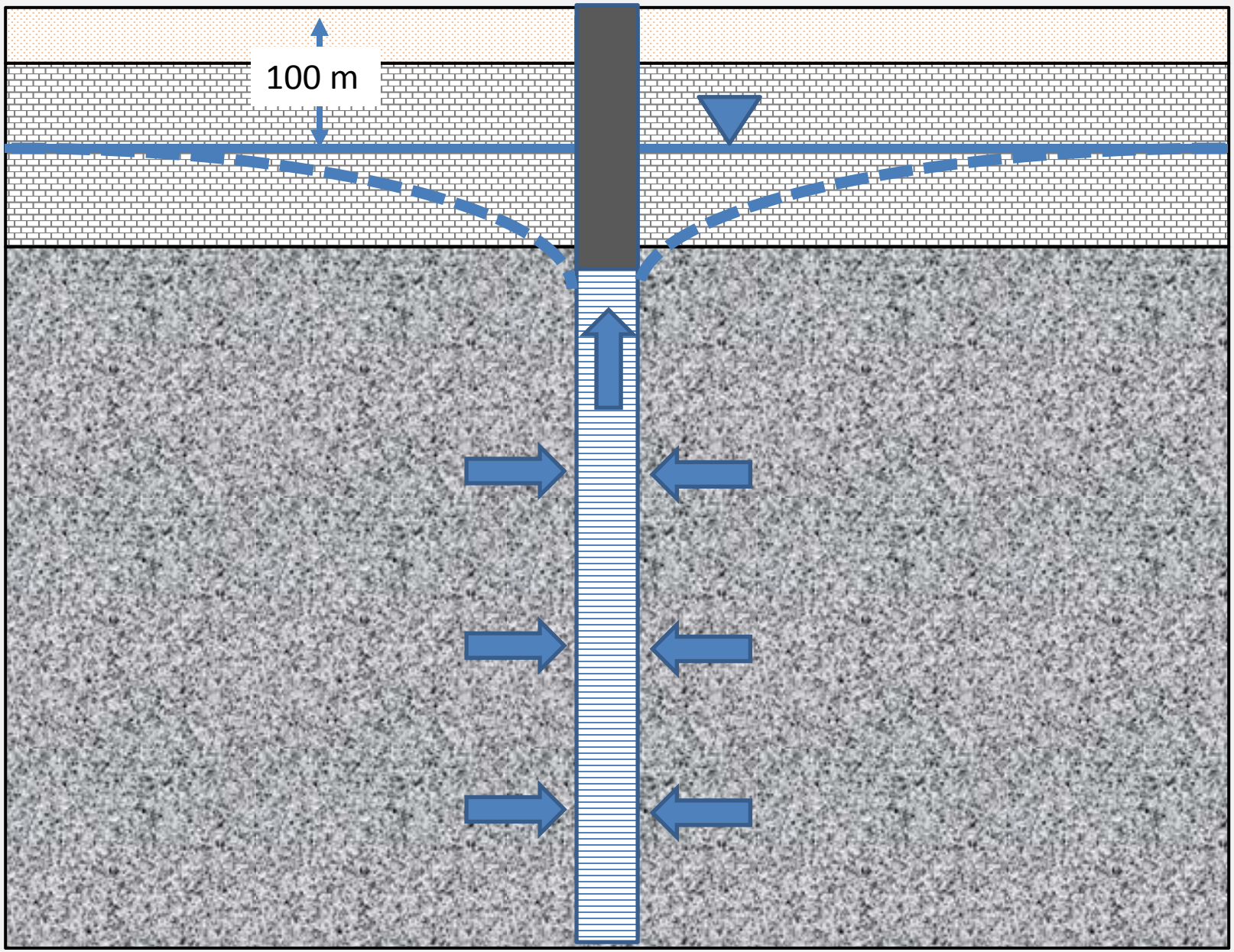

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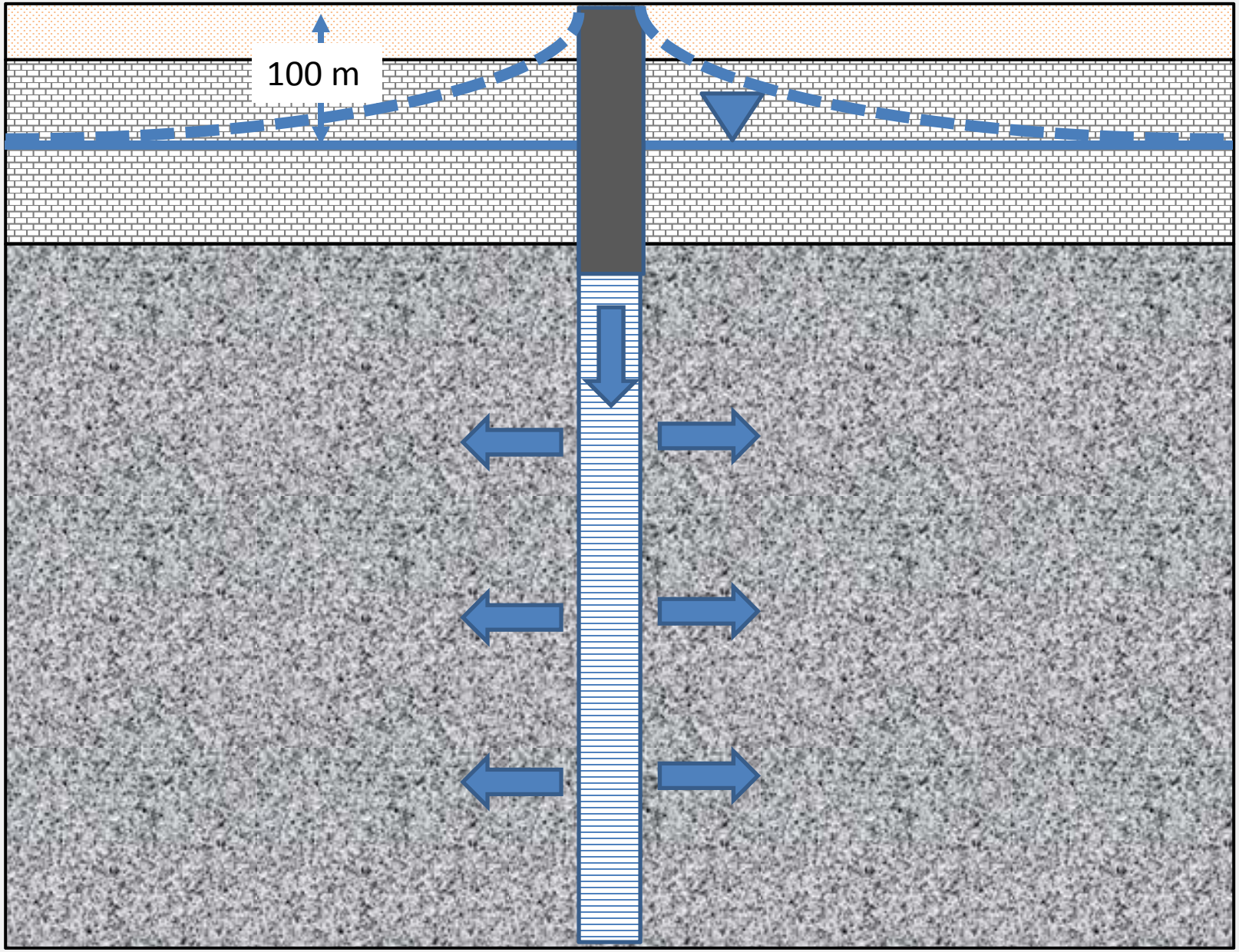

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Senior Water Rights

Engineered Reservoir – Todd Creek

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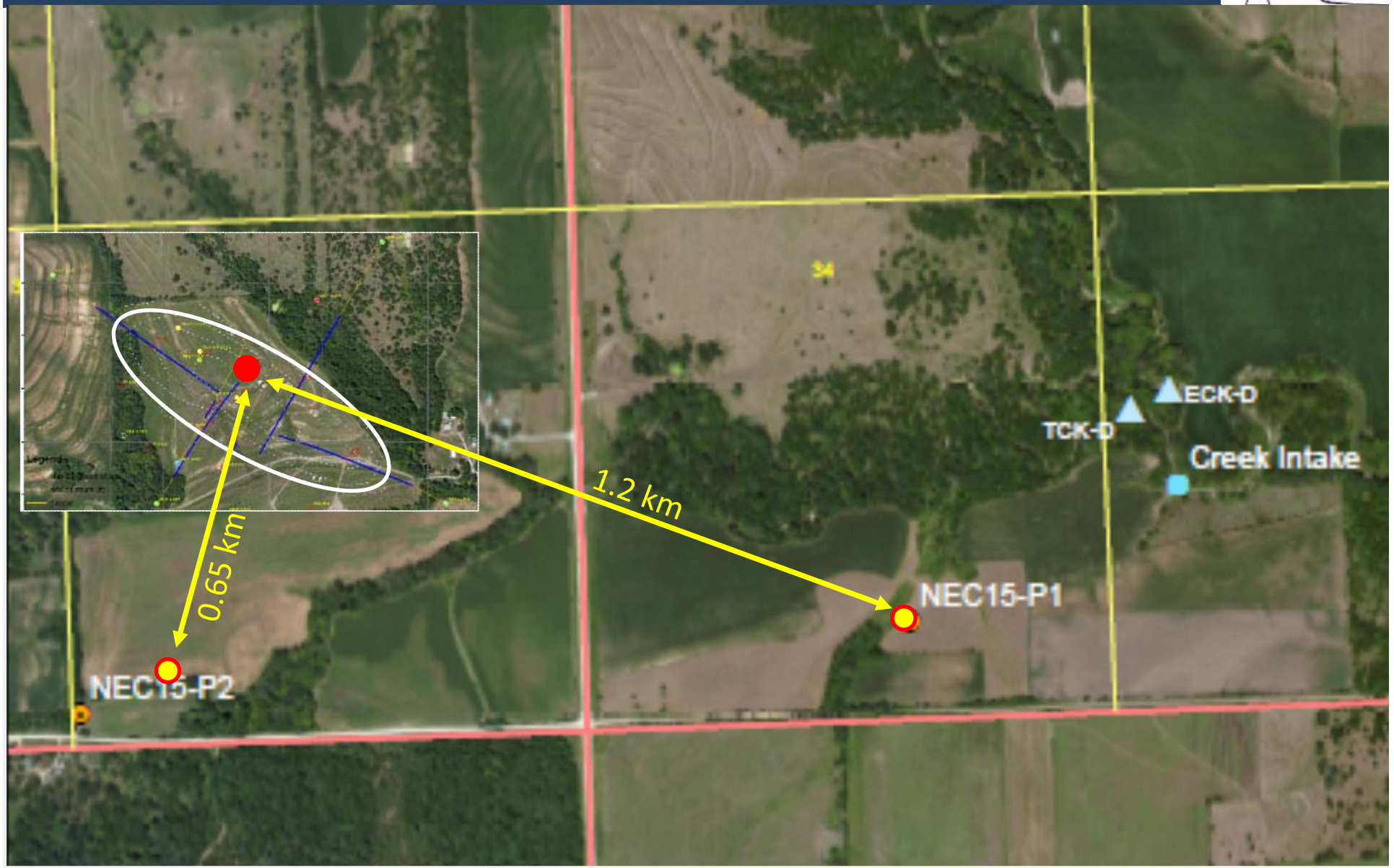

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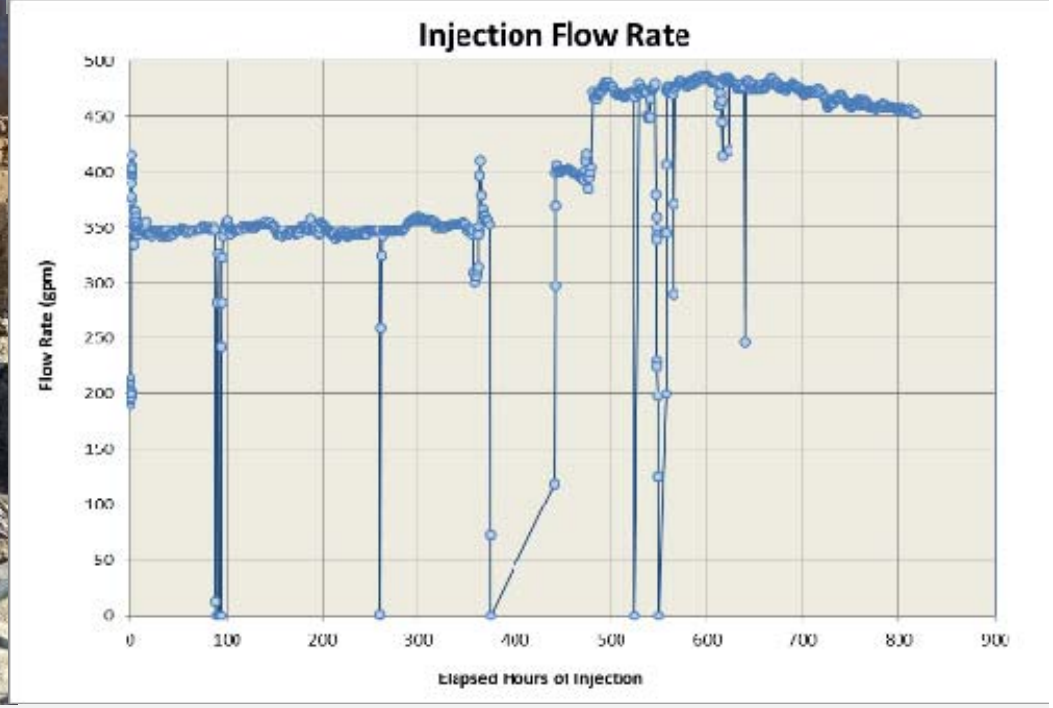

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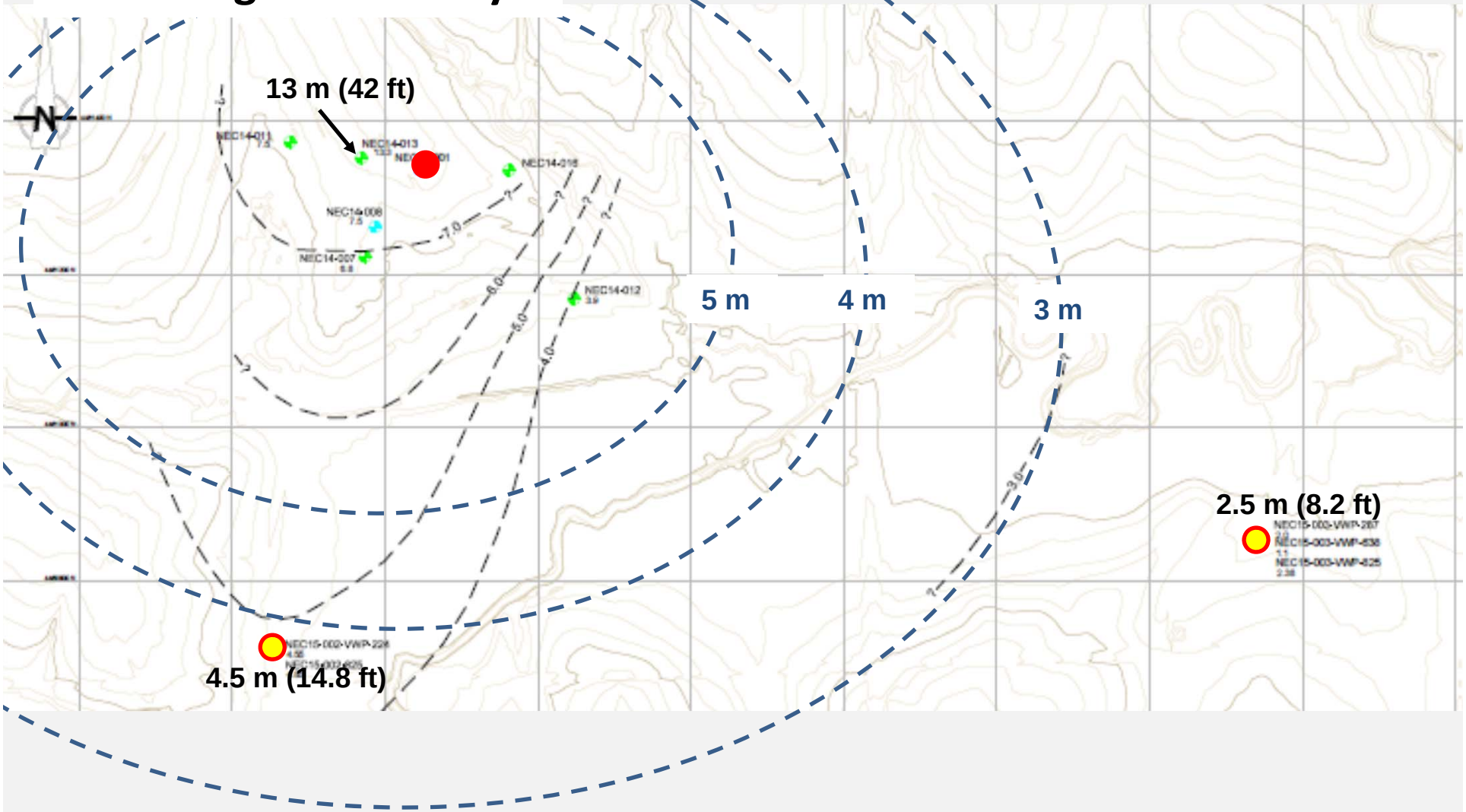
Mounding after 30 days:



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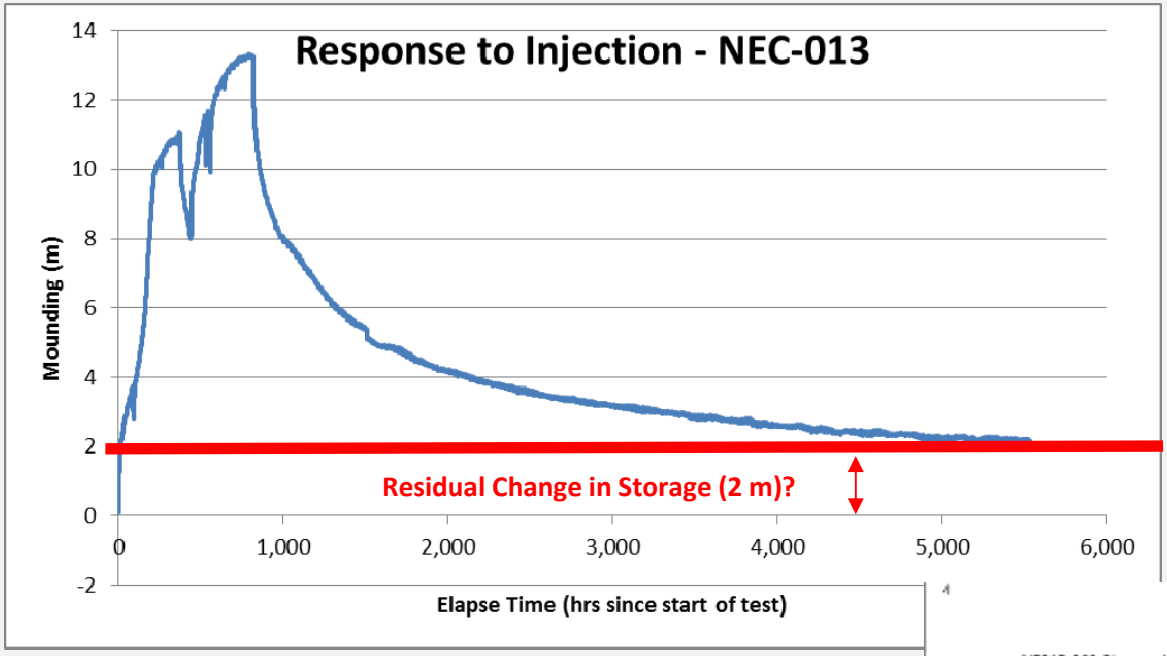

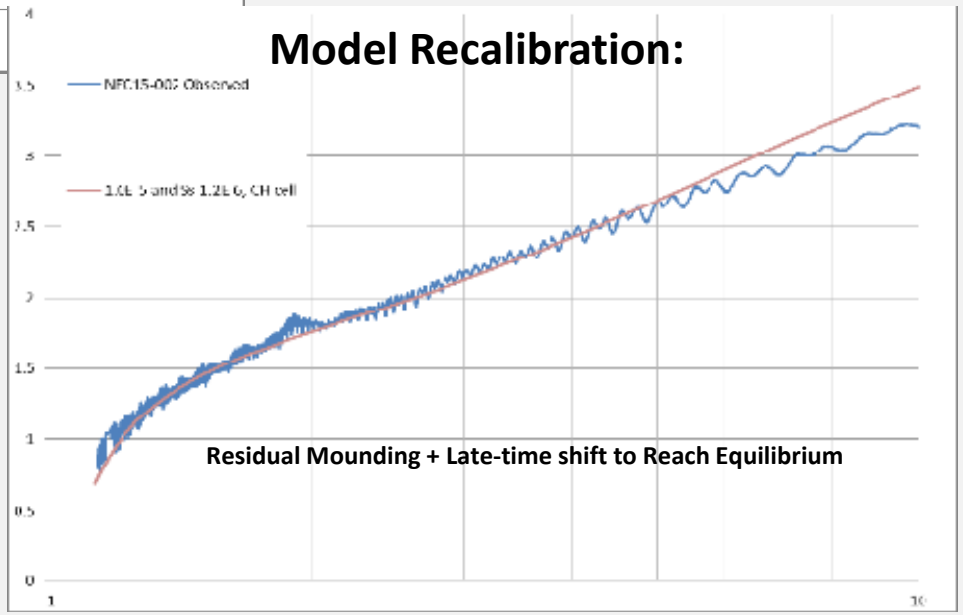

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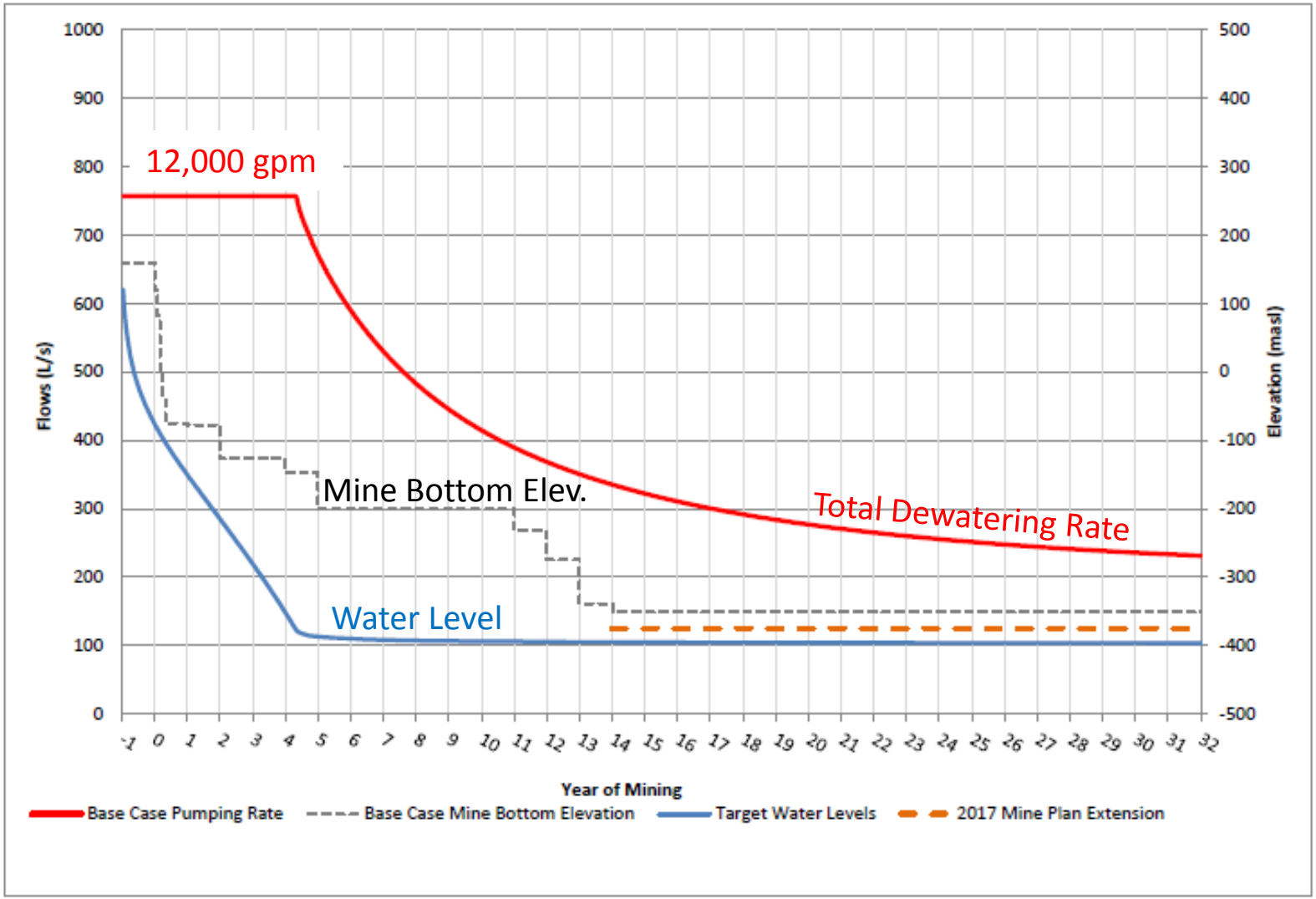

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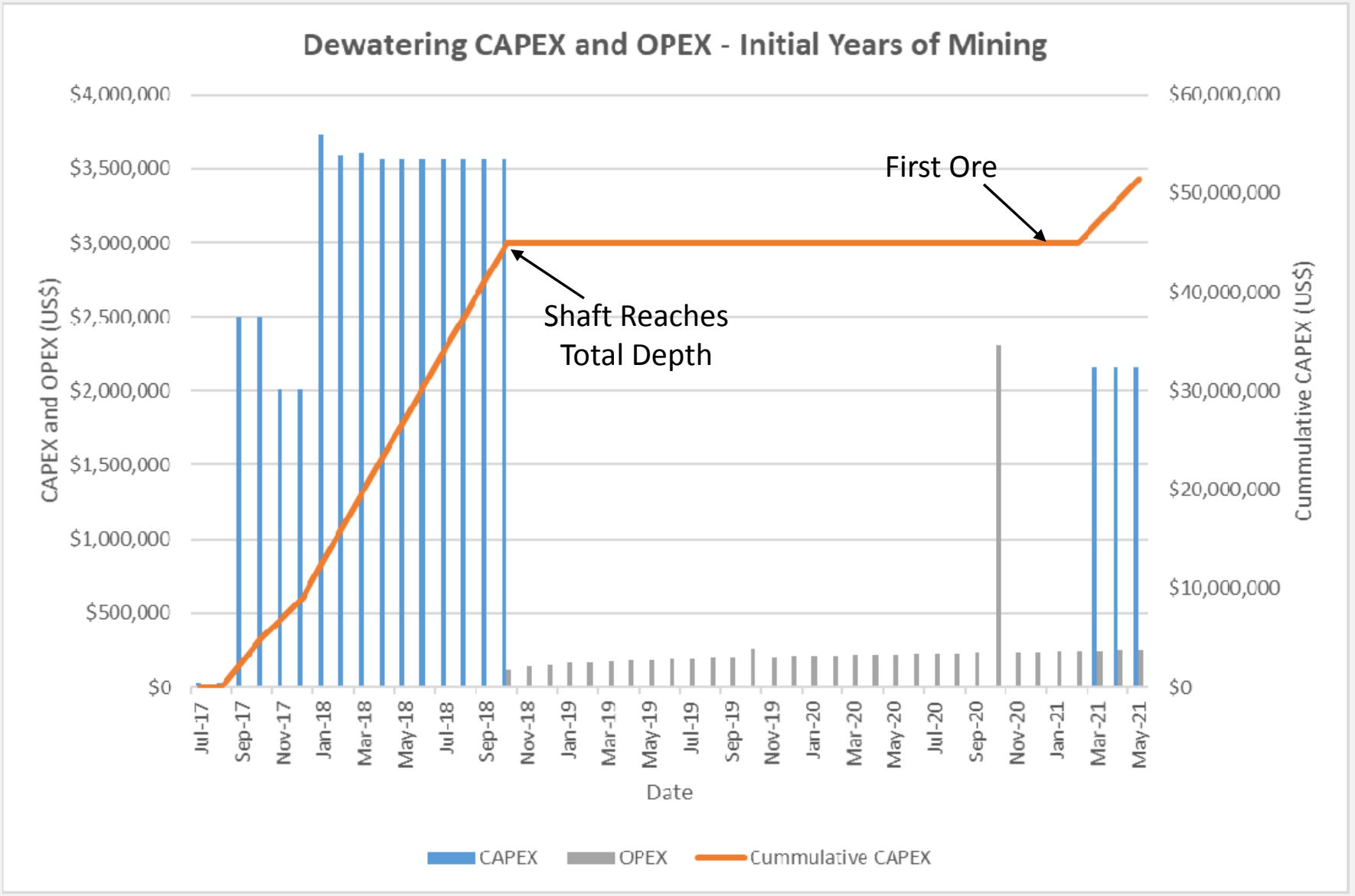

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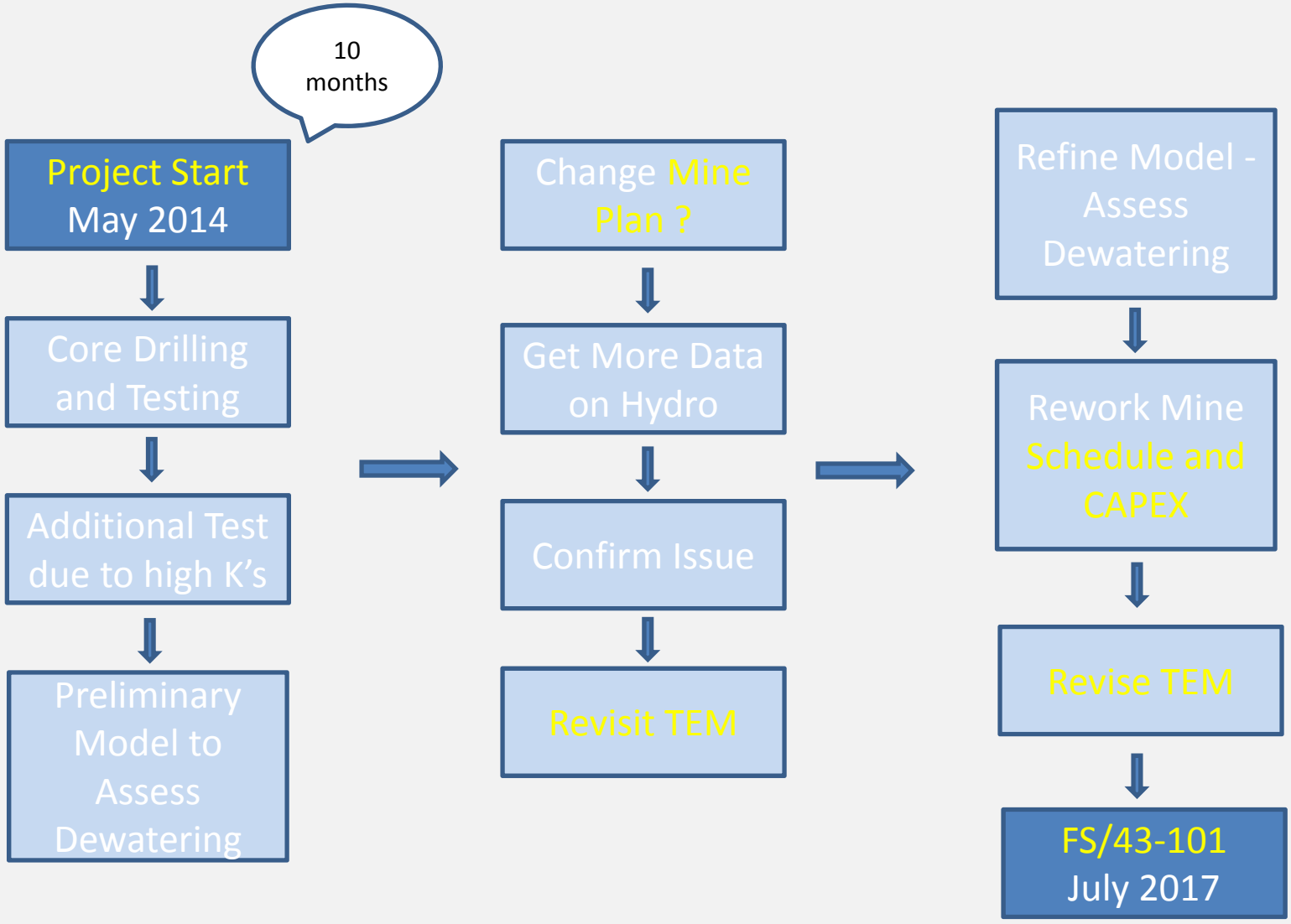

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Take Home:

1. If geology is complex or rock is transmissive, we need time to figure out the hydrogeology

2. A good groundwater model is essential for evaluating alternatives and limiting uncertainty

3. Water issues can have a significant impact on the TEM

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Special Thanks:
Data Collection: Geoff Baldwin (SRK)
Modeling: Vladimir Ugorets (SRK)
Scott Honan (Elk Creek Developments)
Trevor Mills (Elk Creek Developments)

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Field Program II - Objectives:

- Decrease the significant uncertainty in active dewatering rates (LOM)
- Improve understanding of Carbonatite parameters
- Improve understanding of the perimeter (granite) – controls inflow to the mine from 5-30 years