Managing Remediation Risk Through Multi-Criteria Decision Making

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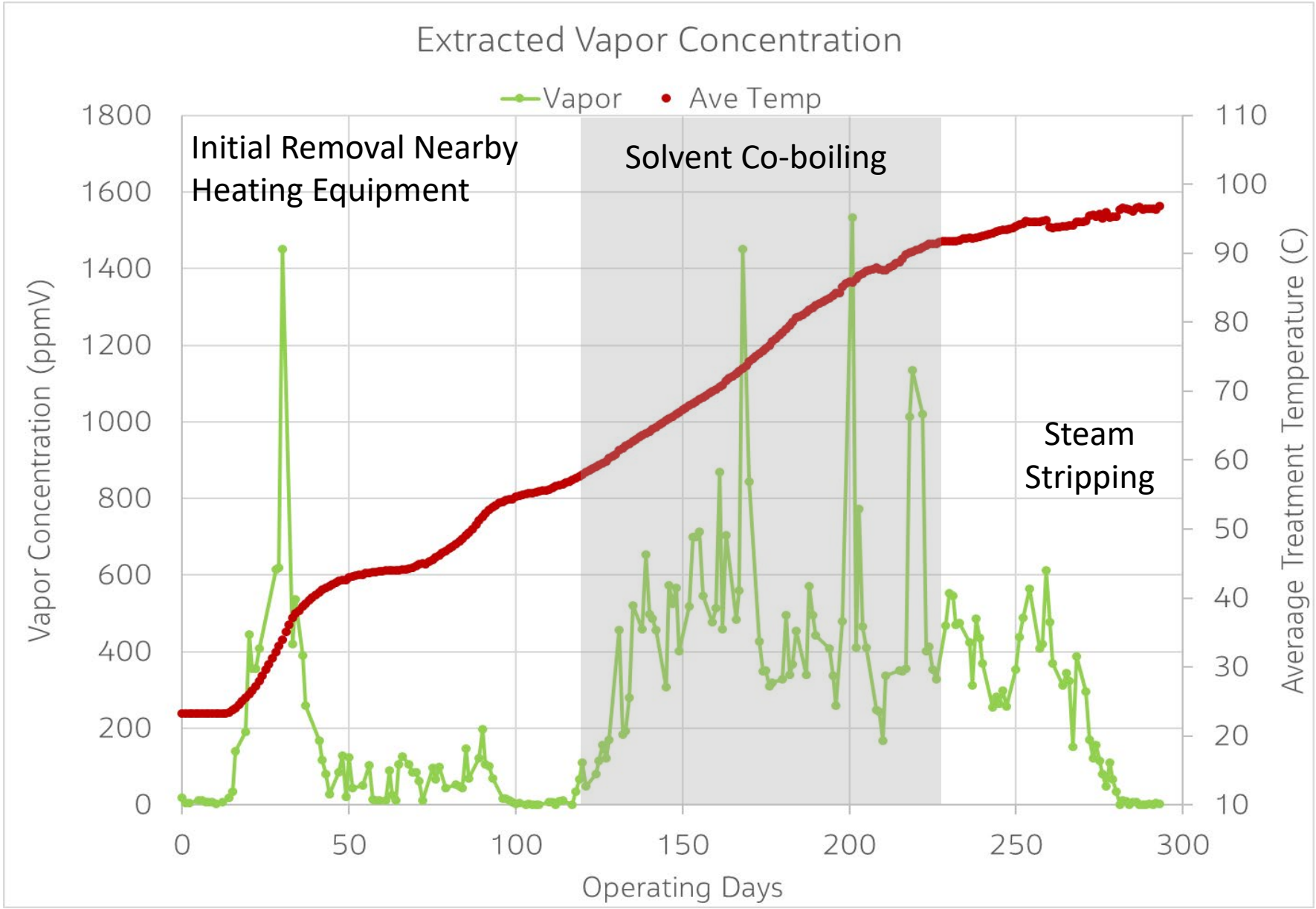
Jacobs

How it Works

Typical response to subsurface heating



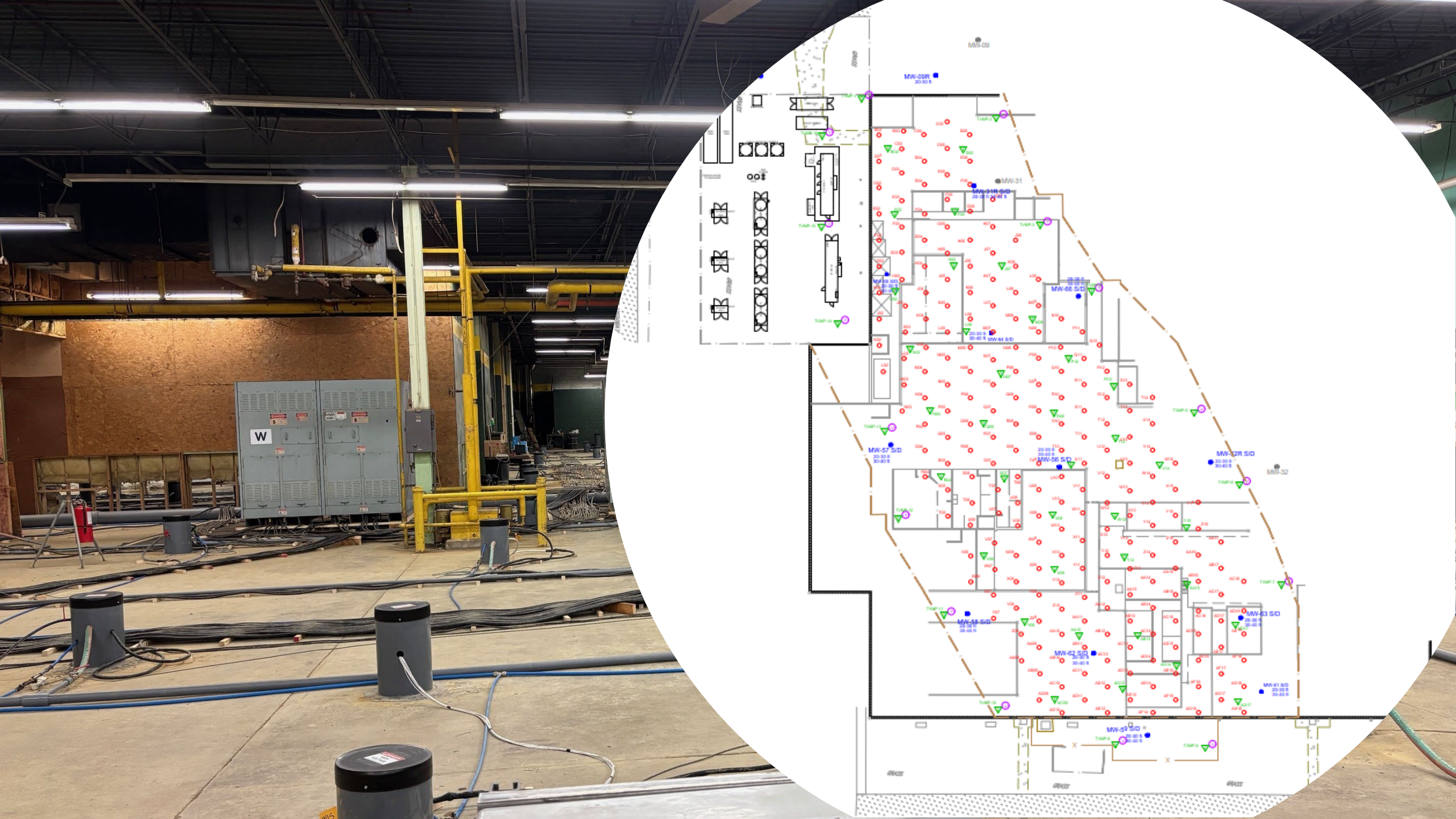
Flexible Decision Criteria Reduces Risk

- Multiple lines of evidence couples direct measurement of contaminant recovery, subsurface temperature and energy input to:
  - Demonstrate that the practical (and technical) capacity of ISTT to remove contaminants from soil or groundwater has been reached
  - Demonstrate when additional thermal energy input or extended system operation will not yield a significant reduction in soil and groundwater contaminants
- Ideally suited for sites where contamination mass is unknown or exhibits a high degree of spatial variability
- Provides greatest cost efficiency in ISTT system operation

Arrowhead Superfund Site

- 227 Dual stacked bored electrodes
  - Co-located wetting and vapor extraction
- 36 Temperature monitoring points
- 16 Pressure/Temperature monitoring points
- 27 Groundwater monitoring wells
  - 14 – (Shallow) screened ~ 30 ft bgs
  - 13 – (Deep) screened ~ 40 ft bgs

- Performance
  - 185 operation days
  - ~3,500 pounds contaminants removed
  - ~11.9 M kWh delivered to the subsurface
  - ~1.95 M gallons of steam condensate treated

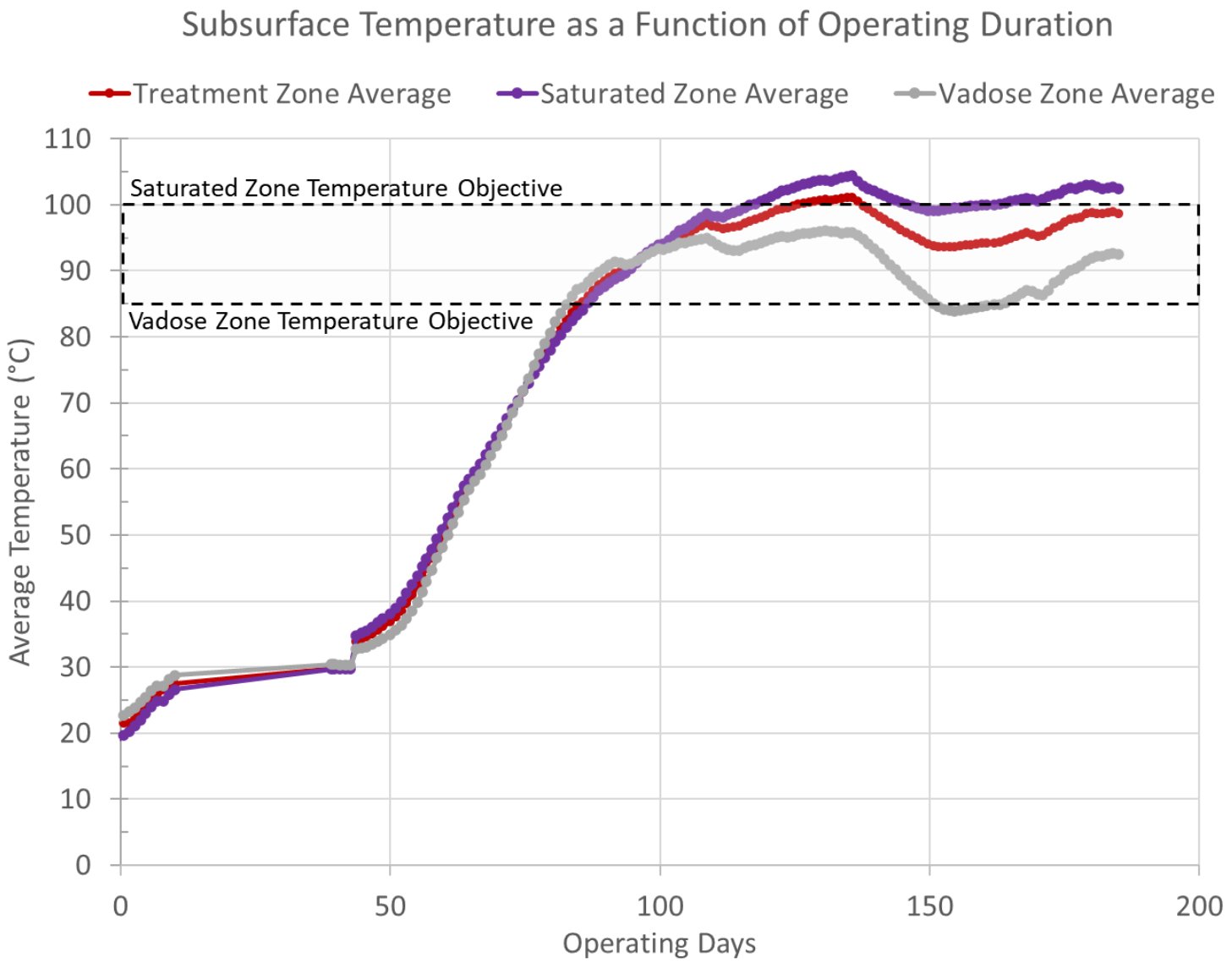

W
MW-09
MW-09R
MW-31
MW-86 S/D
MW-57 S/D
MW-56 S/D
MW-42R S/D
MW-32
MW-63 S/D
MW-61 S/D
MW-59 S/D

Thermal Treatment Objectives

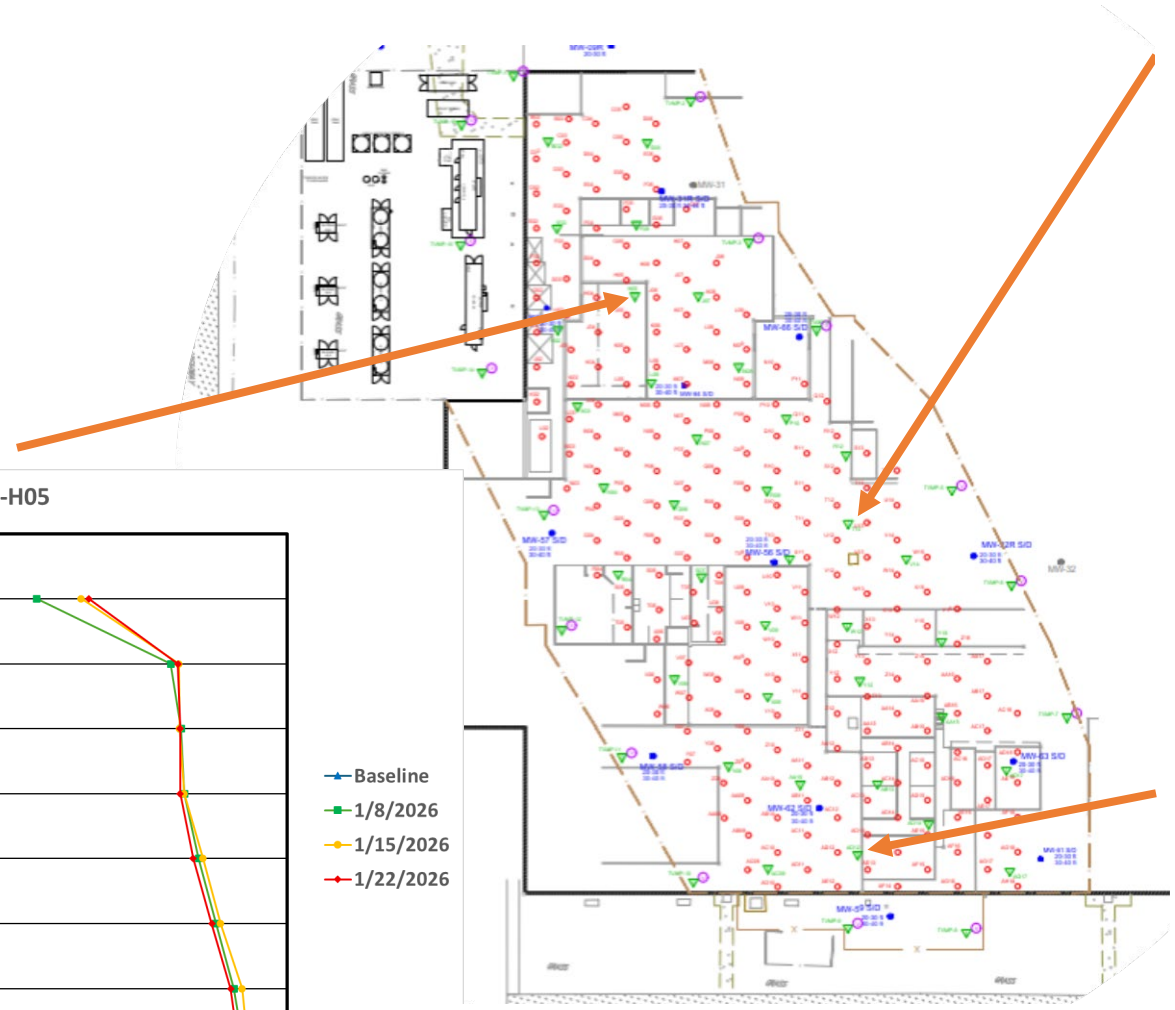
- Apply electrical resistance heating (ERH) in the thermal treatment zone to remove subsurface contaminants.
- Heat unsaturated soil to a minimum temperature of 85°C
- Heat saturated soil above 100°C to promote steam stripping
- Capture, convey and treat extracted contaminants
- Document hydraulic and pneumatic control of treatment zone
- Demonstrate treatment endpoint using multiple lines of evidence

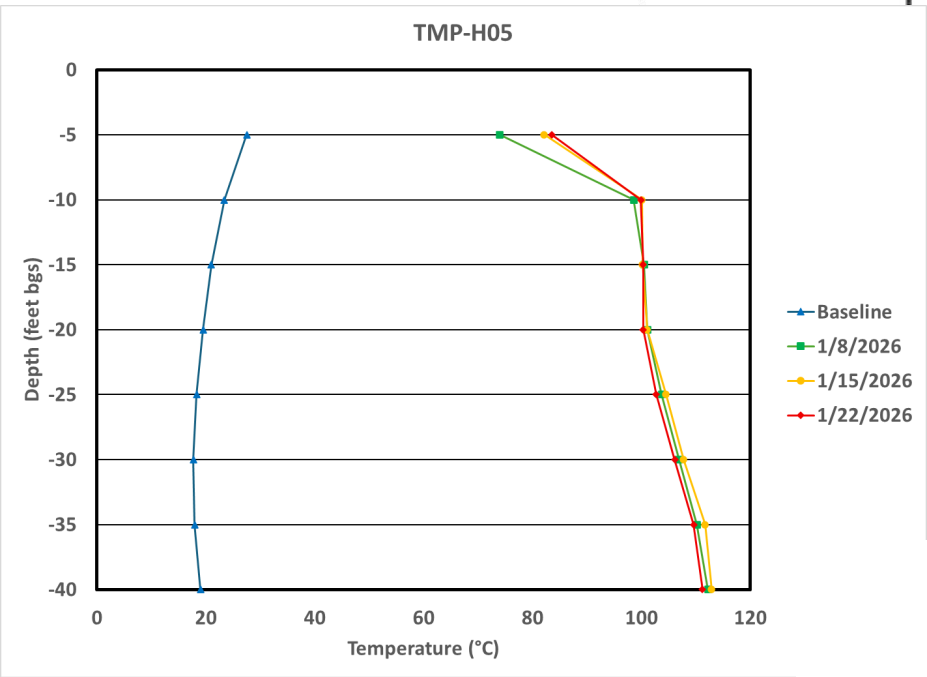
Heating Observations

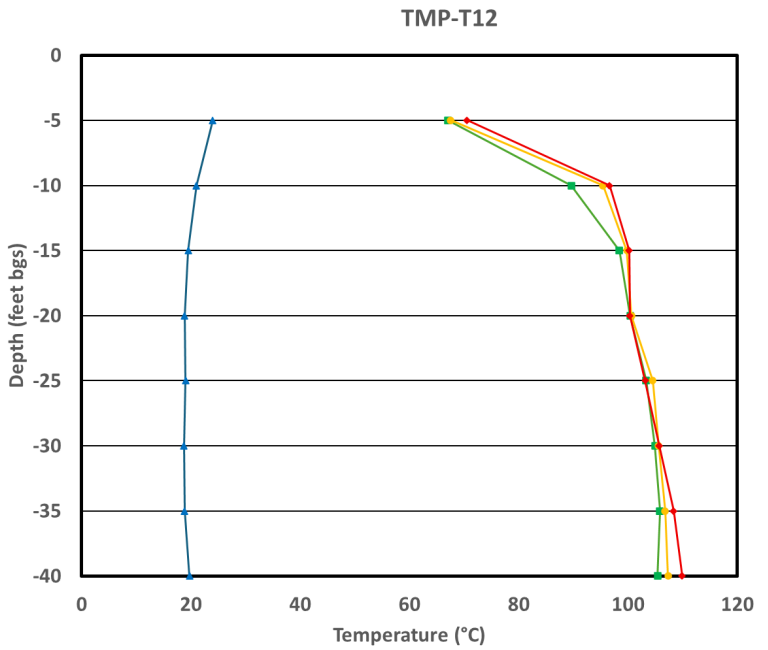
- ERH system installed
- Vadose zone > 85°C
- Steam stripping

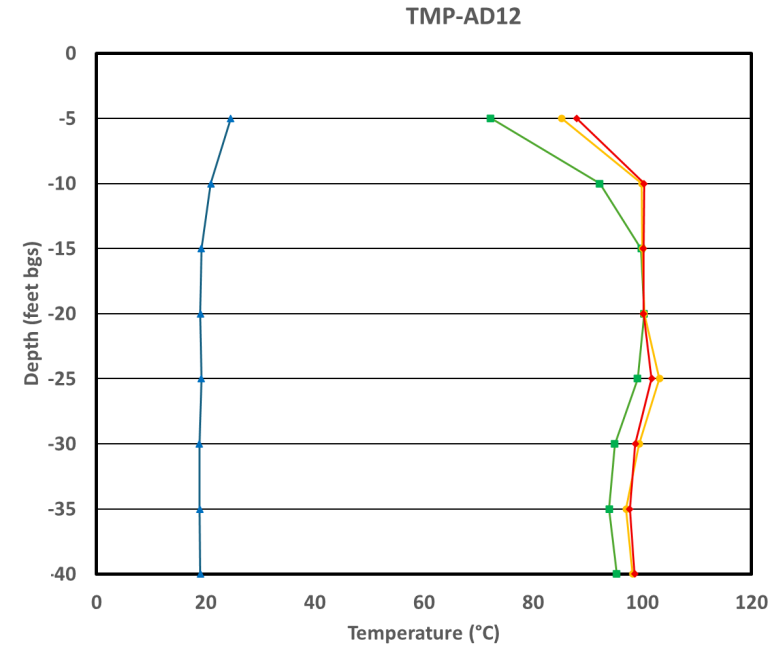


Uniform Temperature Distributions Observed



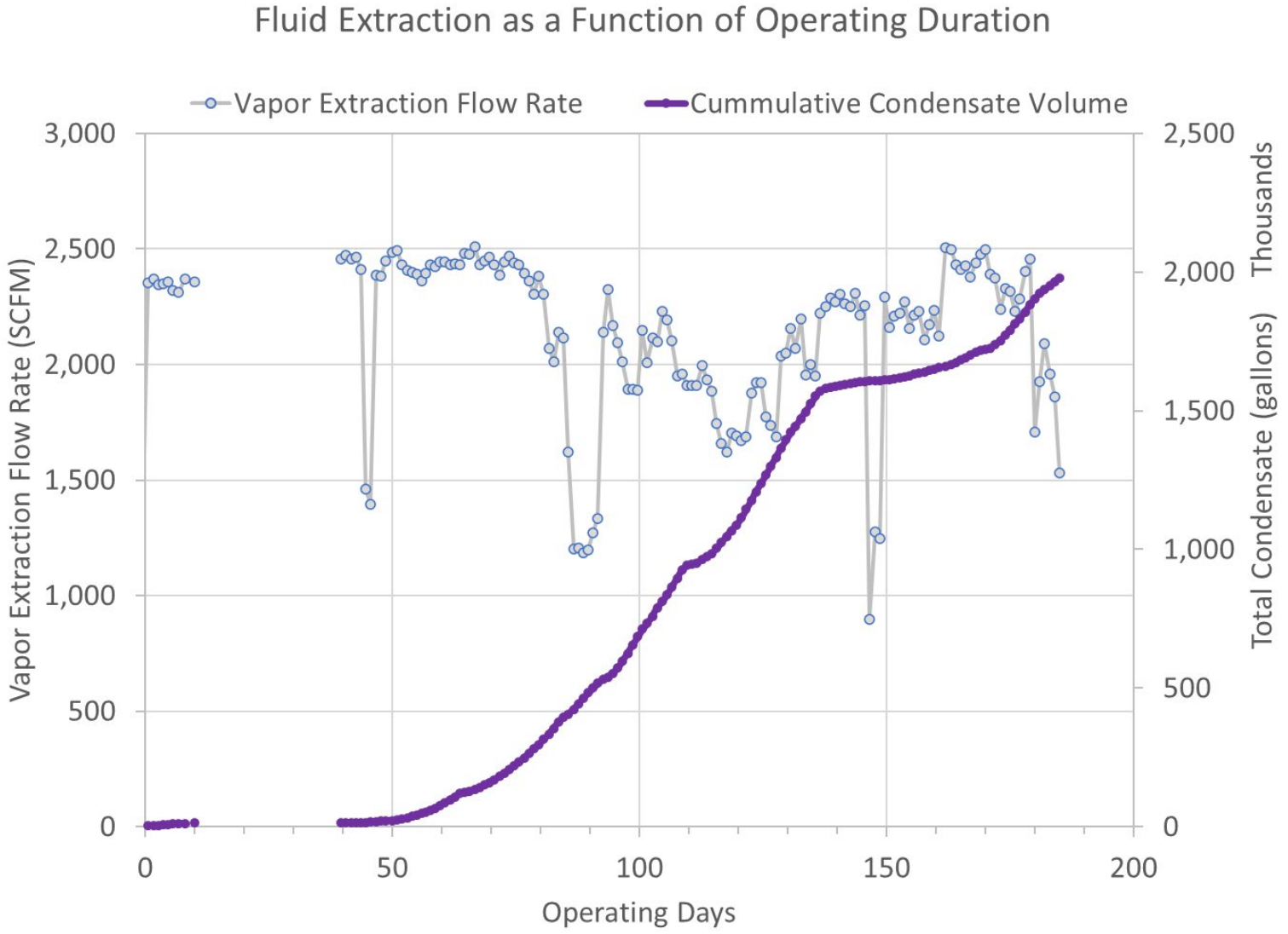






Extraction Observations

- Continuous vapor extraction
- Condensate recovery
- Extraction maintained throughout operations*



Diminishing Returns – Evaluation Criteria

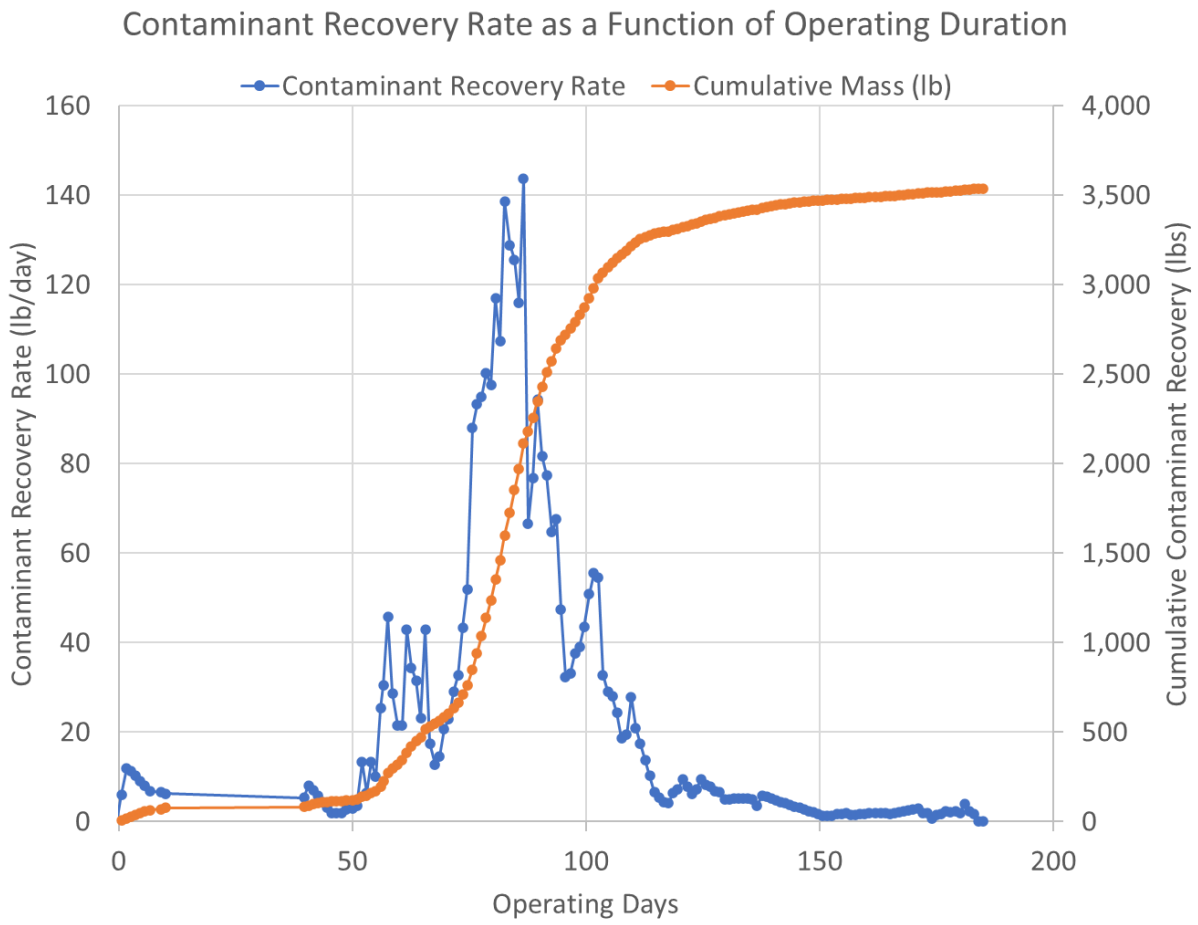
Three criteria for ISTT system performance were evaluated:

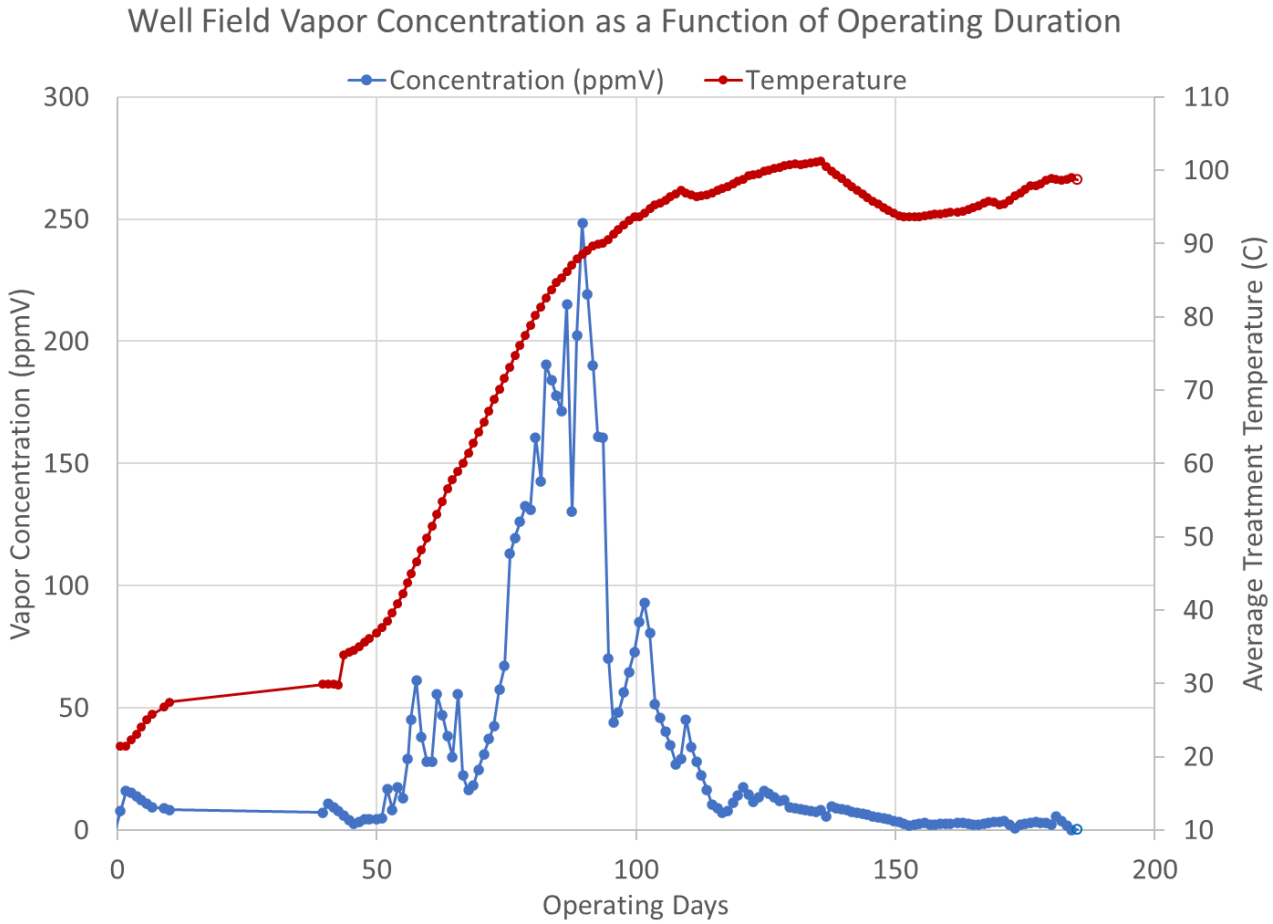
(1) Has treatment of the source area using ISTT has reached an asymptotic rate of COC recovery?

(2) Will continued energy input alter COC mass removal rate?

(3) Does extended operation of the ISTT system offer further benefit in COC mass reduction?

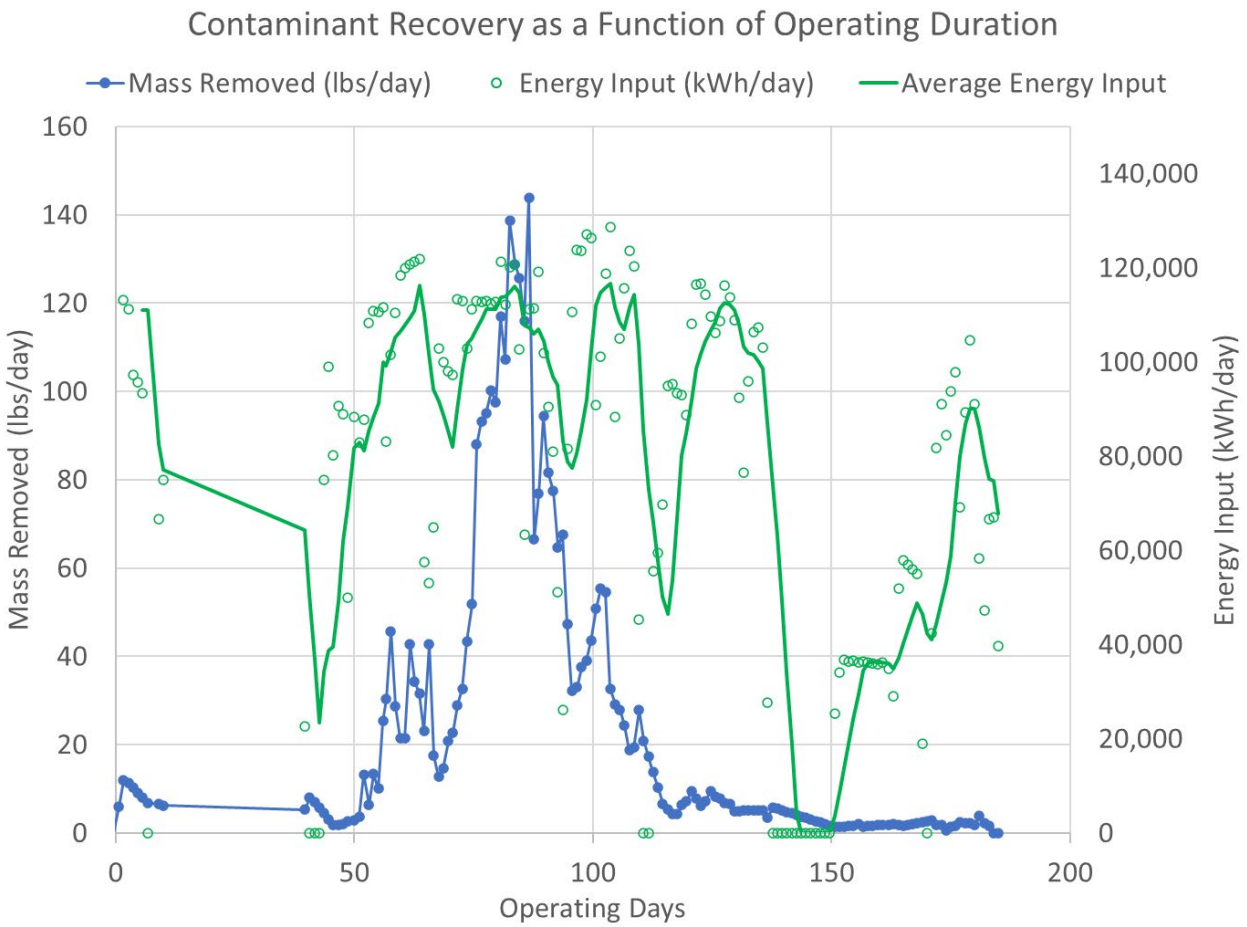
Contaminant Recovery has Decreased with Time

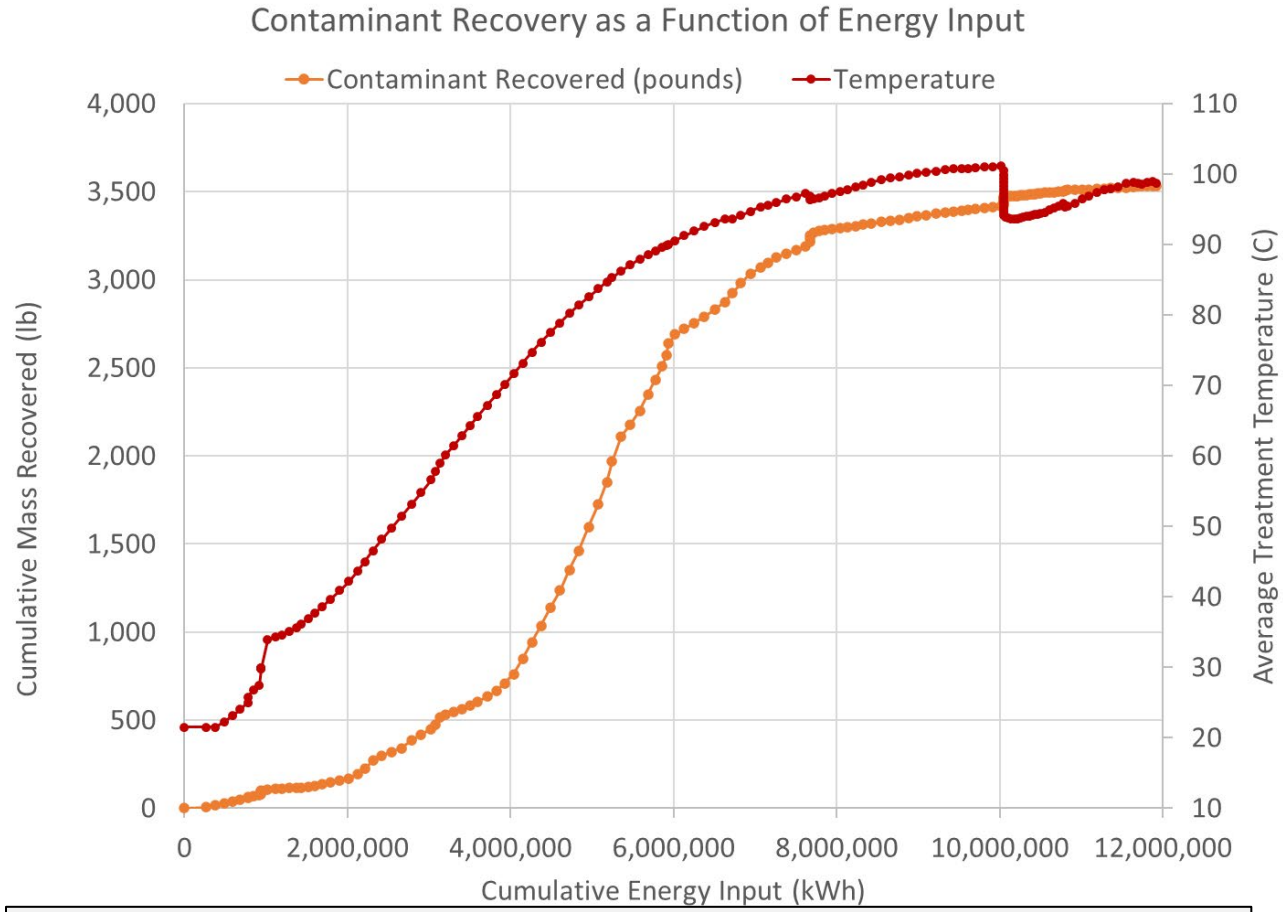




Key Point: With increasing time the total mass recovered had plateaued even though heating was maintained at target temperature

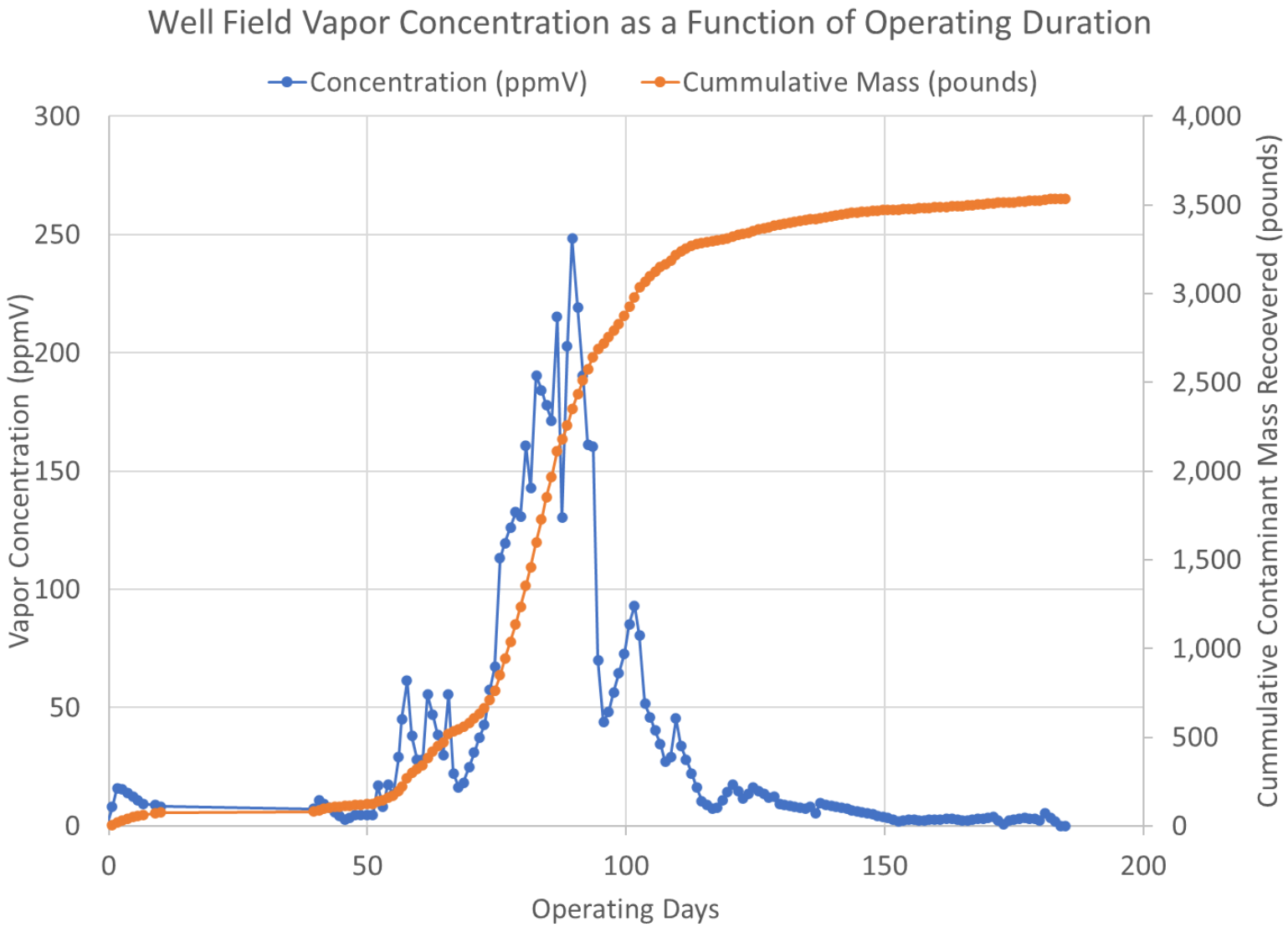
Energy Input Does Not Change Mass Removal Rate





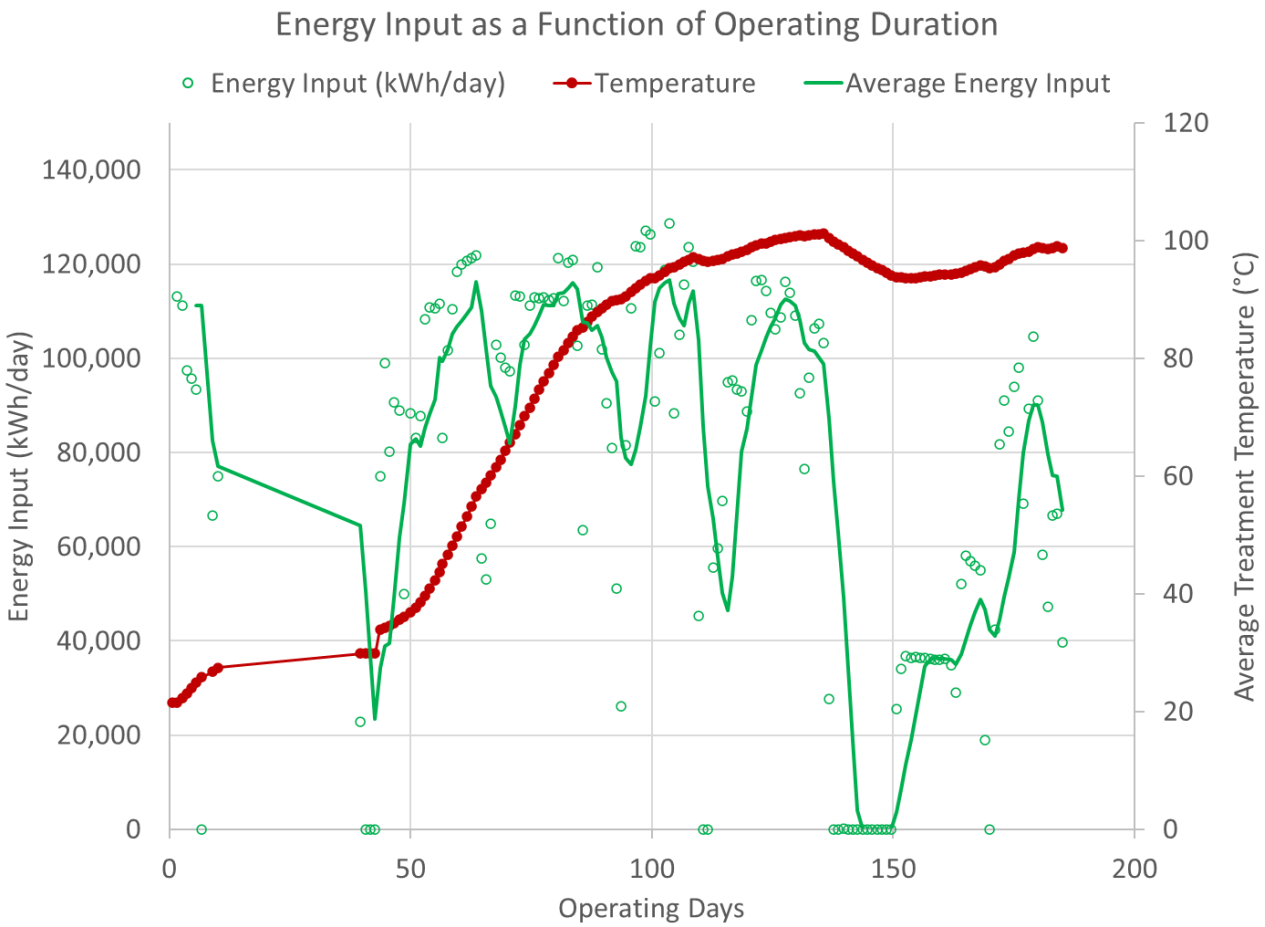
Key Point: Continued energy input (heating) would not significantly increase the rate or total contaminant mass removed by the thermal treatment system.

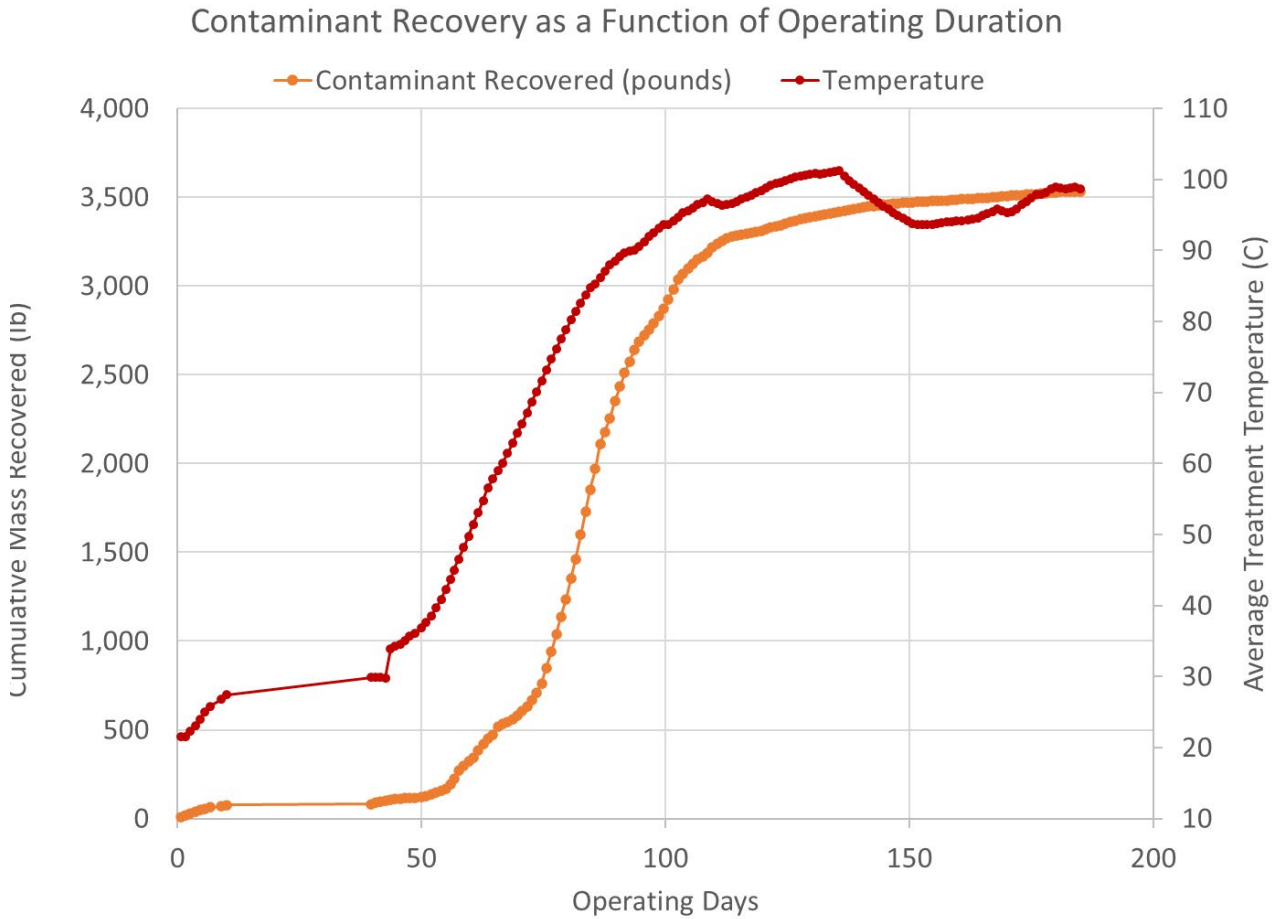
Extracted Vapor Observations



Key Point: Vapor treatment sytem inlet concentrations have declined, and vapor phase recovery was a minor contribution to total mass removed.

Continued Heating Provides No Further Benefit

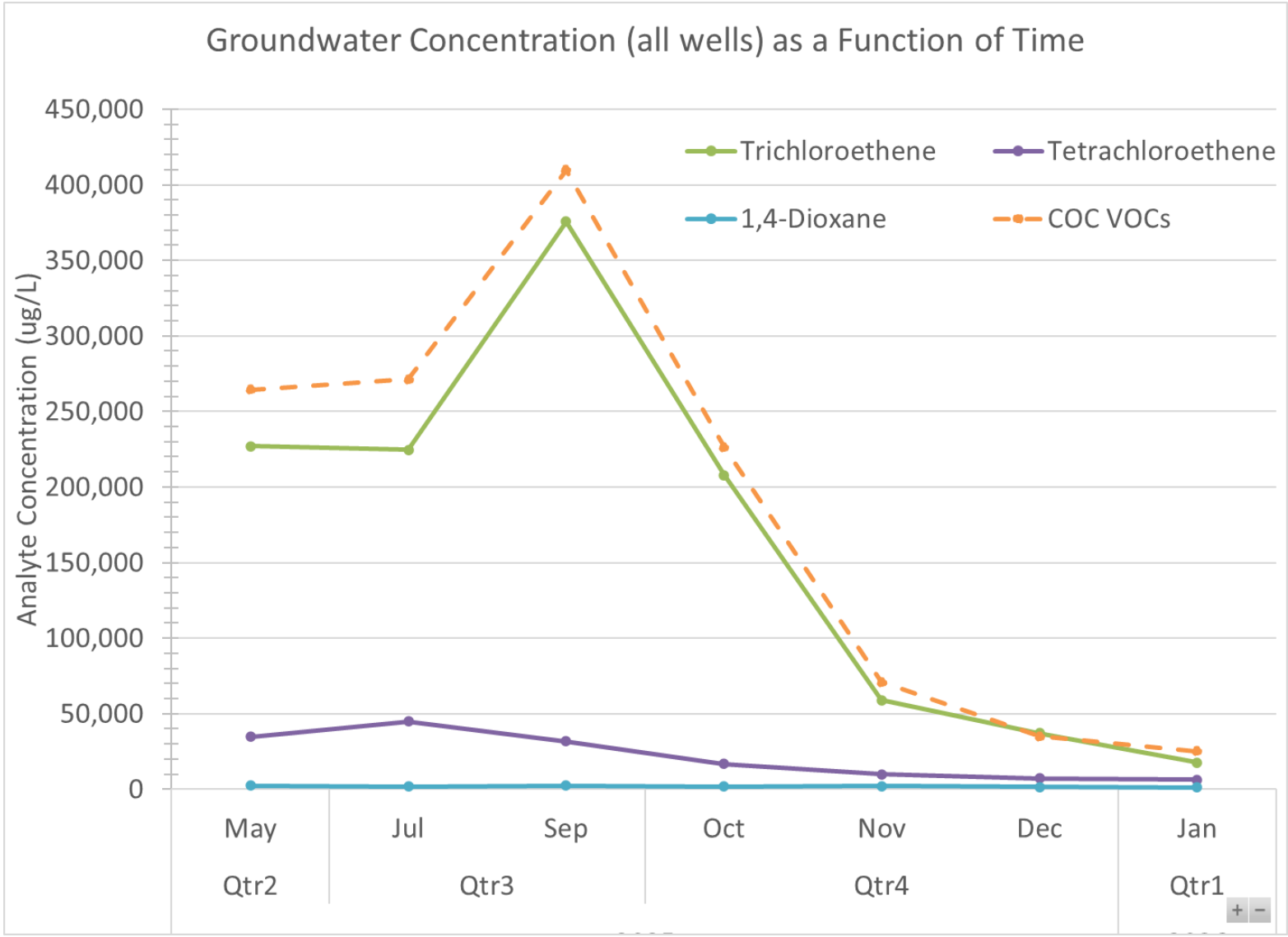




Key Point: Despite favorable temperatures, monitoring data indicates the contaminant reservoir is depleted and the physical capacity of the ISTT system to remove contaminants from the subsurface has been reached.

What About Groundwater ?

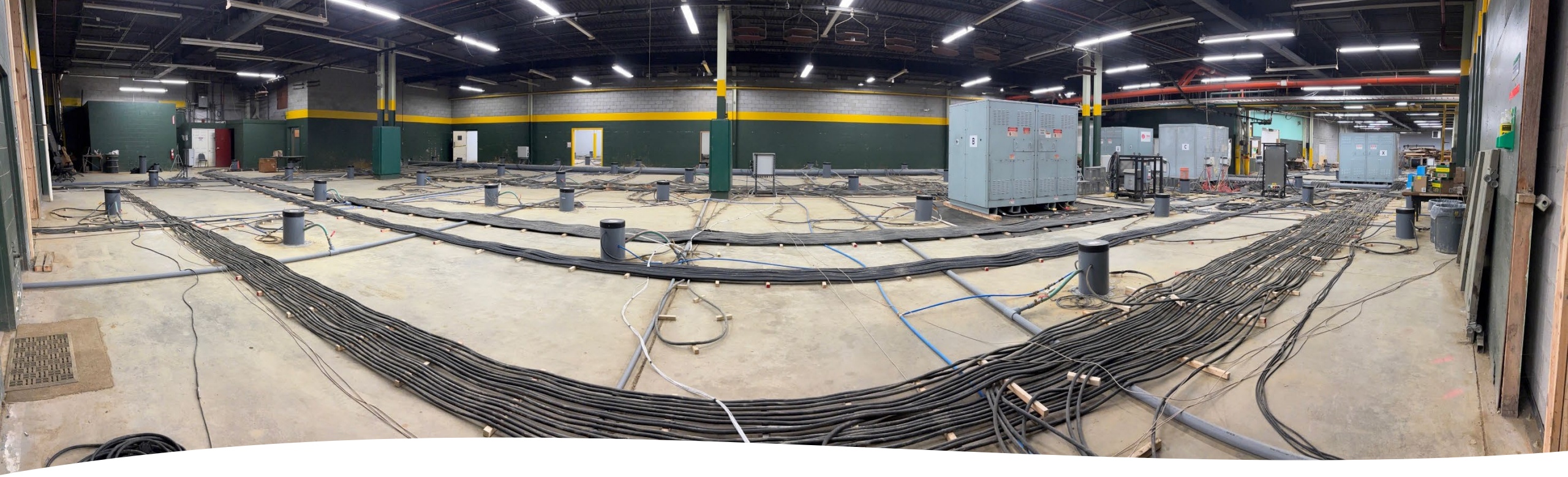
- Significant decreases observed in all monitoring locations
- Samples could not be obtained from all wells due to steam presence
- Decreasing concentration trends correlate with decreasing mass recovery



Closing Thoughts

- ISTT endpoint determination was successfully demonstrated for the Arrowhead Superfund Site using multi-criteria decision making
- Data necessary for endpoint determination was obtained by simple tools common to ISTT system performance monitoring practices
- Early planning and stakeholder engagement was key to mutual and undisputed agreement for endpoint demonstration
- Energy input was beneficial in reinforcing operational endpoint demonstration
  - Energy (or power) metrics can be adapted to contract or support endpoint definition

- When considering your own ISTT applications it's never too early to develop and discuss the framework for endpoint determination and system shutdown



Acknowledgements

- Travis Barbier – USEPA Region 3 Remedial Project Manager
- William Lindsay – Virginia Department of Environmental Quality
- HGL – Remedial Design Contractor
- Thermal Remediation Services (TRS)
- Scott Pratt – Jacobs Project Manager

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