



Steam Enhanced NAPL Recovery at a Former Manufacturing Site in Canada: Challenges and Solutions

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Agenda

Site History and Objectives

Assessment & Modeling Effort

Installation and Operational Challenges

Heating Response and Mass Recovery

Ongoing Efforts

Take Away and Conclusion

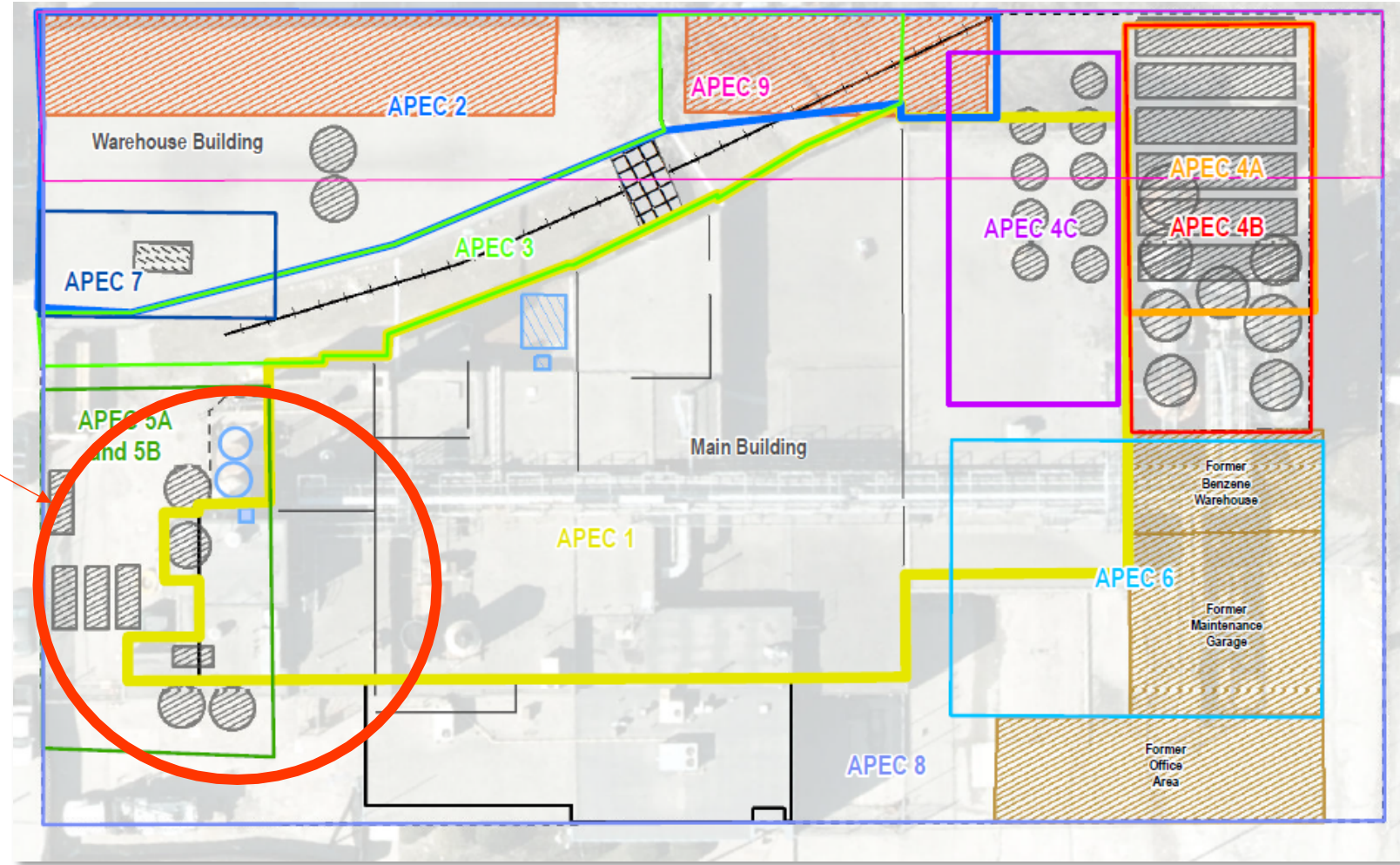


Site History and Objectives

Site History



- History of chemical processing, storage, and manufacturing both onsite and on adjacent properties
- 12 Areas of Potential Environmental Concern (APECs), often overlapping
- **LNAPL discovered at significant apparent thickness (up to 1.5m) in existing monitoring wells**



Left: Above ground infrastructure in one area of the Site

Right: Plan view of the Site identifying APECs

Contaminants of Concern in Soil and Groundwater

The following exceeded the MECP Table 3 Site Condition Standards at the Site.

Soil:

Groundwater:

- Acenaphthylene - Acetone - Anthracene - Benz[a]anthracene - Benzene - Benzo[a]pyrene - Benzo[b]fluoranthene - Boron (hot water soluble) - Cadmium - Cobalt - Copper - Dibenz[a,h]anthracene - Dichlorobenzene, 1,2- - Dichloroethane, 1,2- - Dichloroethylene, 1,2-trans-	- Ethylbenzene - Indeno[1,2,3-cd]pyrene - Lead - Methyl ethyl ketone - Methylene chloride - Mercury - Naphthalene - PHC F1 - PHC F2 - PHC F3 - Toluene - Trichloroethylene - Vinyl chloride - Xylene mixture - Zinc	- Acenaphthene - Acenaphthylene - Anthracene - Benzene - Chloroform - Dichlorobenzene, 1,4- - Dichloroethane, 1,1- - Dichloroethane, 1,2- - Dichloroethylene, 1,2-cis- - Dichloroethylene, 1,2-trans- - Dichloropropane, 1,2- - Ethylbenzene - Hexane	- Mercury - Naphthalene - PHC F1 - PHC F2 - PHC F3 - PHC F4 - Tetrachloroethylene - Trichloroethylene - Vinyl chloride (present and future condition) - Xylene mixture - Zinc
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- Petroleum Hydrocarbons
- Volatile Organic Compounds
- Semi-Volatile Organic Compounds
- Metals

Objectives



- Help the client meet their corporate objectives (listing property)
- Protect the environment and local receptors
- Integrate safely with existing and planned site operations
- Source zone removal of hydrocarbon NAPL and dissolved & vapor phase mass to the extent practical & within financial constraints



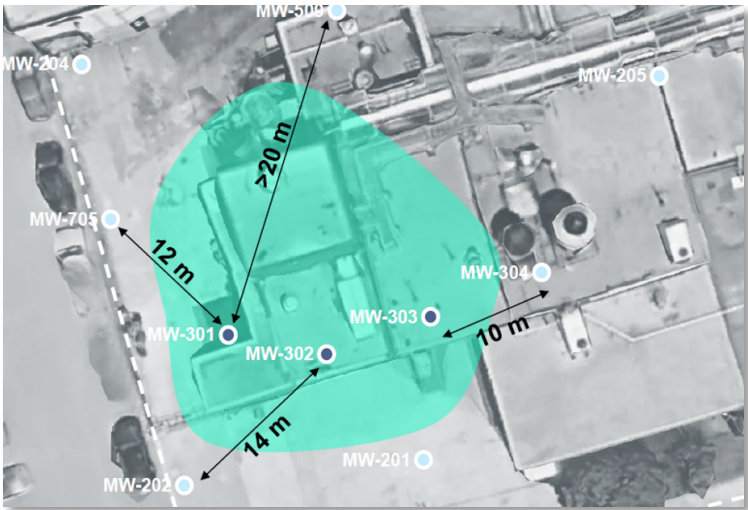
Currently for sale



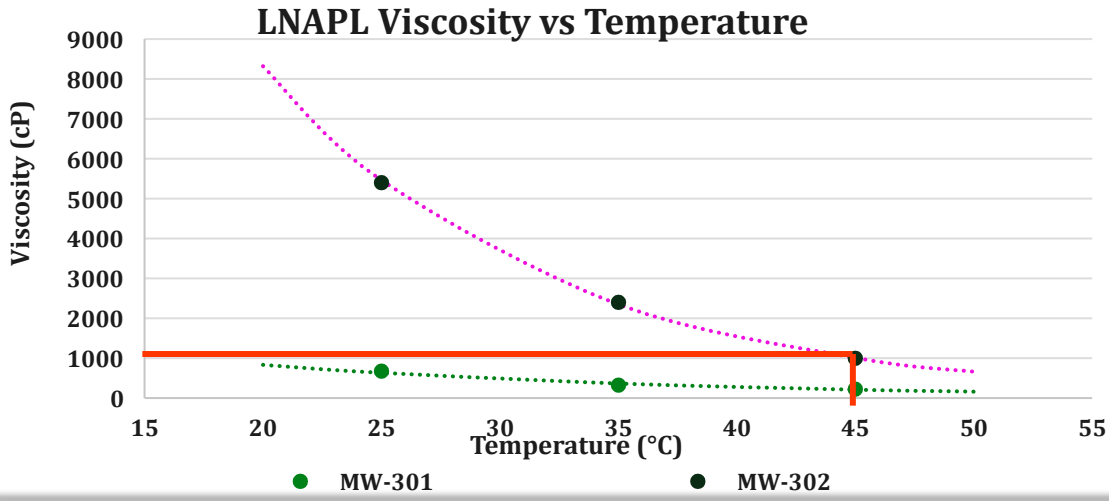
Assessment and Modeling Efforts

Site Profiling

Depth (m BGS)	Texture	Hydraulic Conductivity (cm/s)
0.0-4.6	Granular Soil (silt and gravel), backfill materials including fill and construction and demolition materials	$\sim 3.0 \times 10^{-4}$ cm/s
4.6-8.2	Hard, brown, silt with varying amounts of clay and clasts, turning grey in colour	$\sim 5 \times 10^{-6}$ cm/s
8.2-15.2	Grey silt till with find sand and fine gravel	$\sim 6 \times 10^{-6}$ cm/s



Groundwater: 2.5-4 m BGS

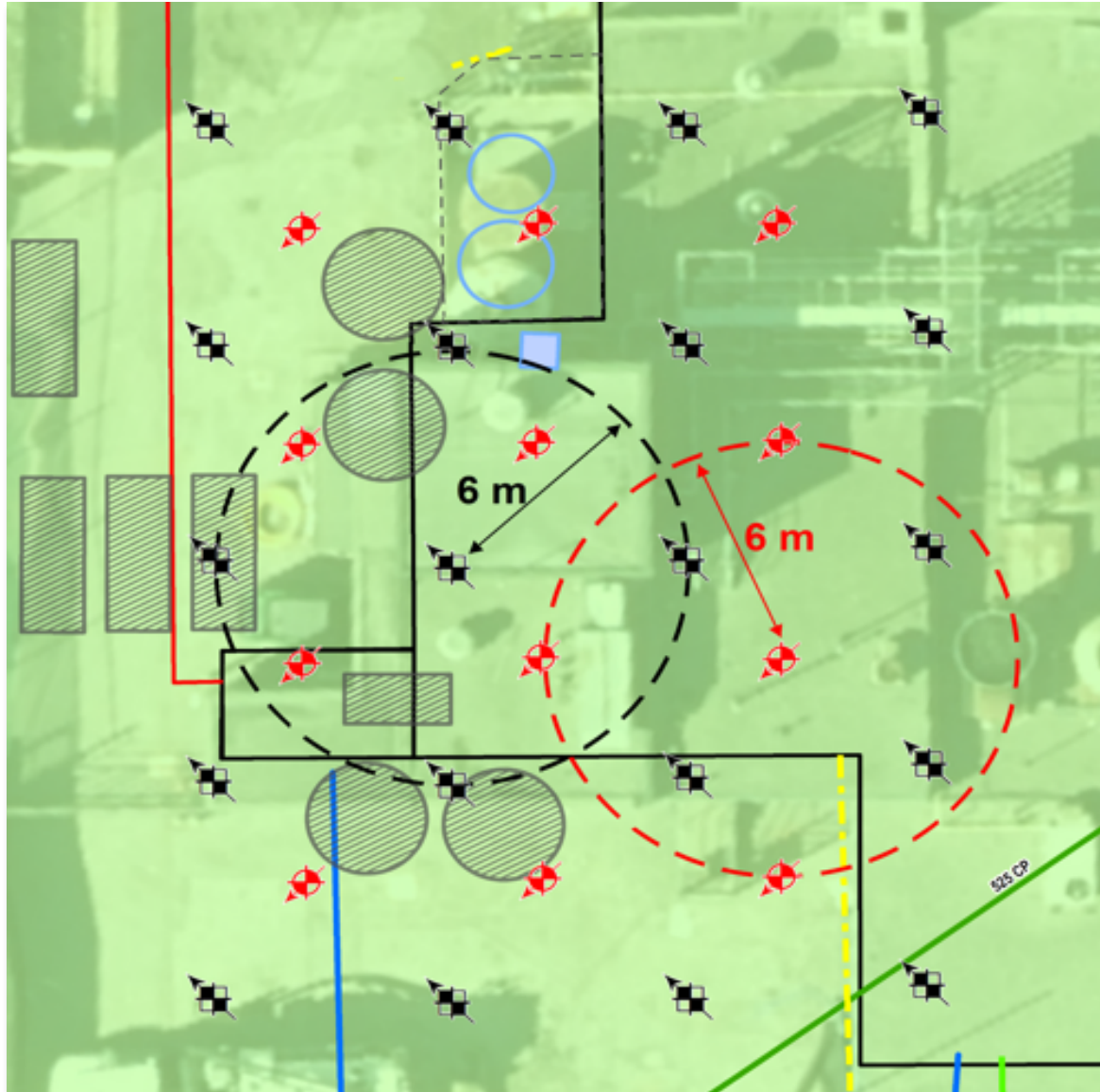


Remedial Options Appraisal

Excavation  Multi-Phase Extraction 

In Situ Thermal Remediation 

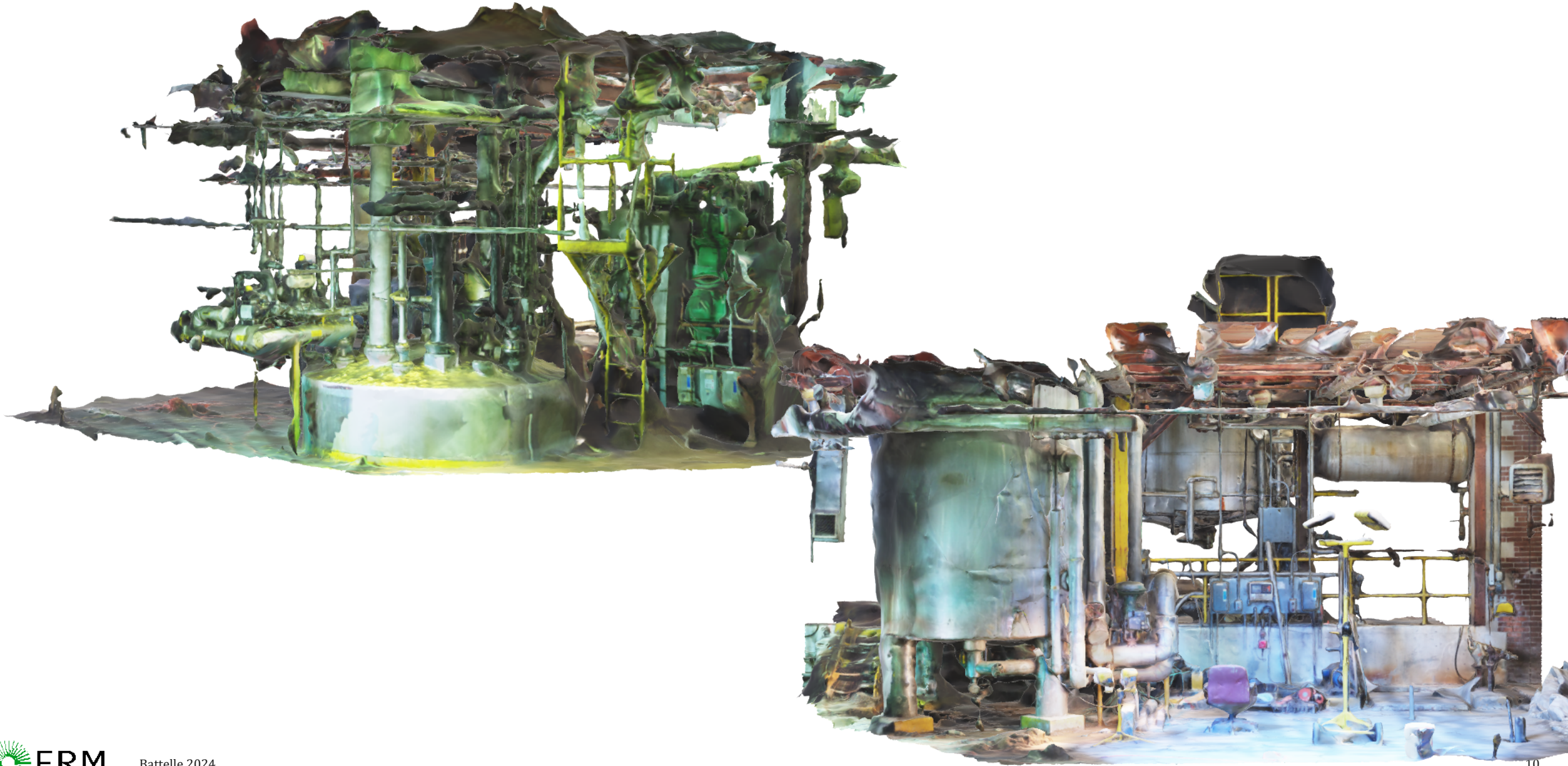
Modeling Using PetraSim™ Software – Ideal Steam Well Layout



Treatment Volume:
30 m x 30 m x 4.5 m

-  Dual phase extraction wells (20)
-  Steam injection wells (12)

Existing Infrastructure



COVID Closed the Border

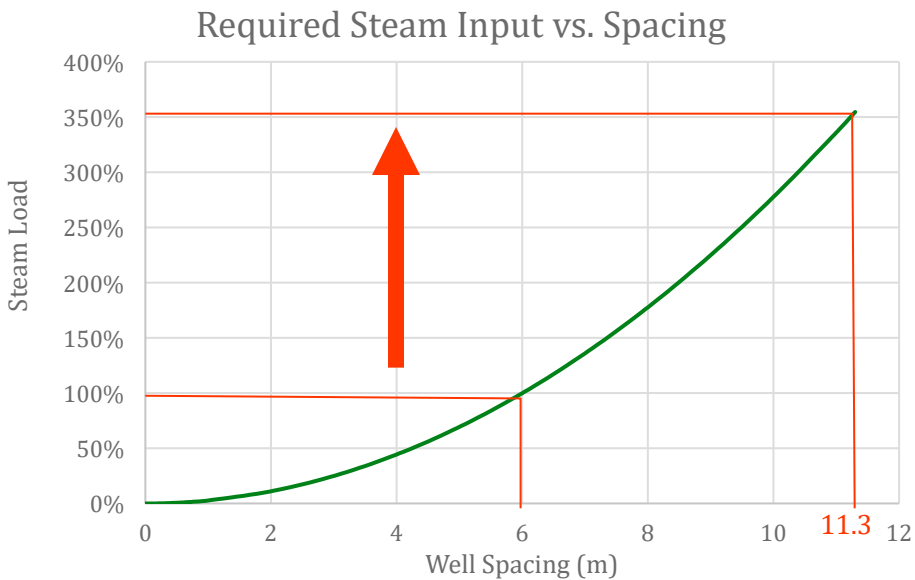


Battelle 2024

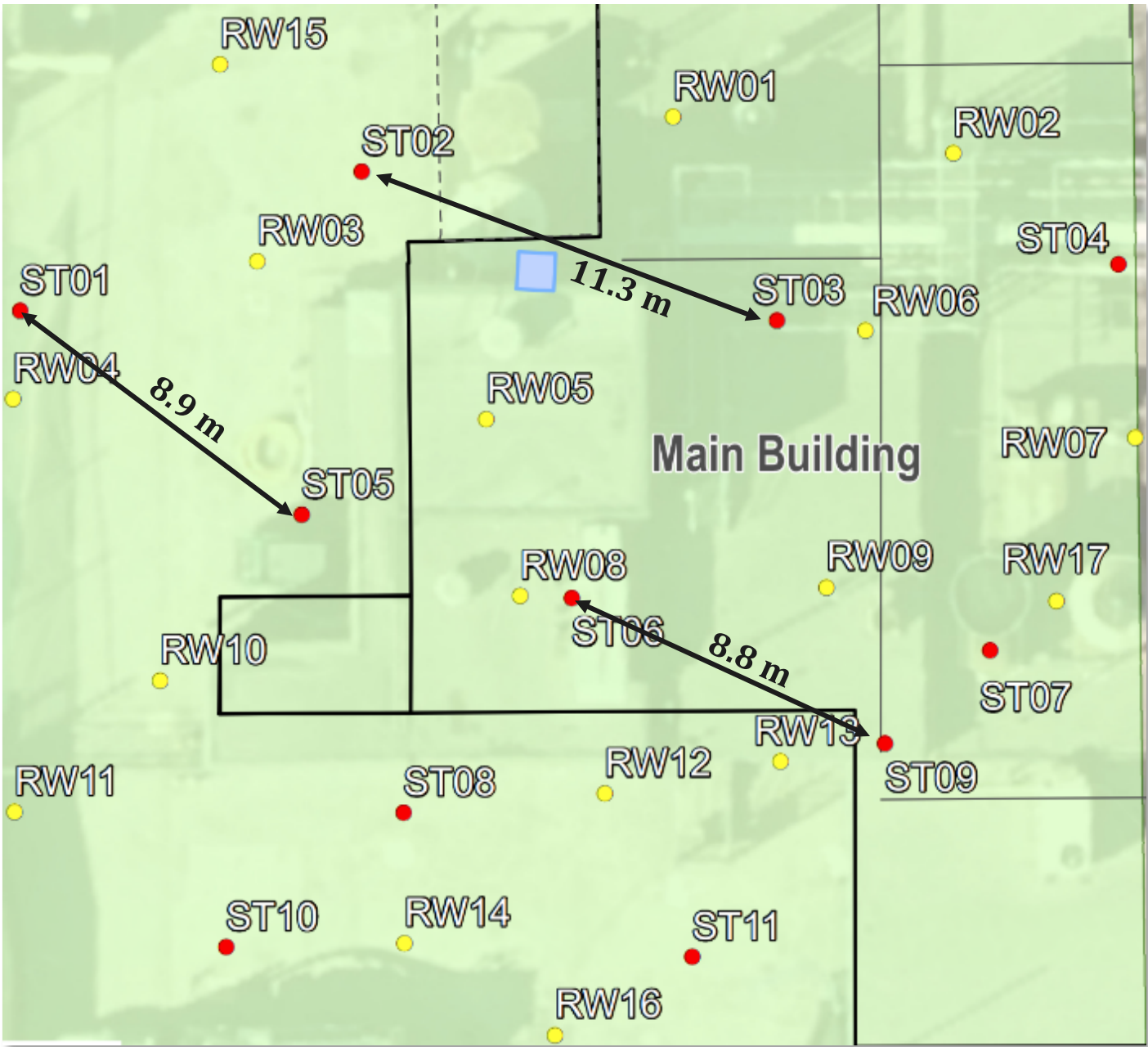
Revised Well Spacing

11 Steam injection wells

17 Dual phase extraction wells



Design temperature could be uniformly achieved in 12 weeks





Challenges Associated with Installation & Operations

Utility Challenges & Safety!

ERM Subsurface clearance waivers:

- 21 - Pre-clearance
- 5 - Management of change

Zero reportable incidents!!!



Rebar identified during GPR scanning



Clearance of holes by soft dig methods to 5 ft BGS



Drilling in tight quarters

Gas Lines & Weather



Left: Gas line which had to be re-routed for ISTR
Top: Developing MPE wells
Bottom: Lifting boiler up and over building



Operational Challenges

- Steam excursions
- Product
- Uptime
- Racoons



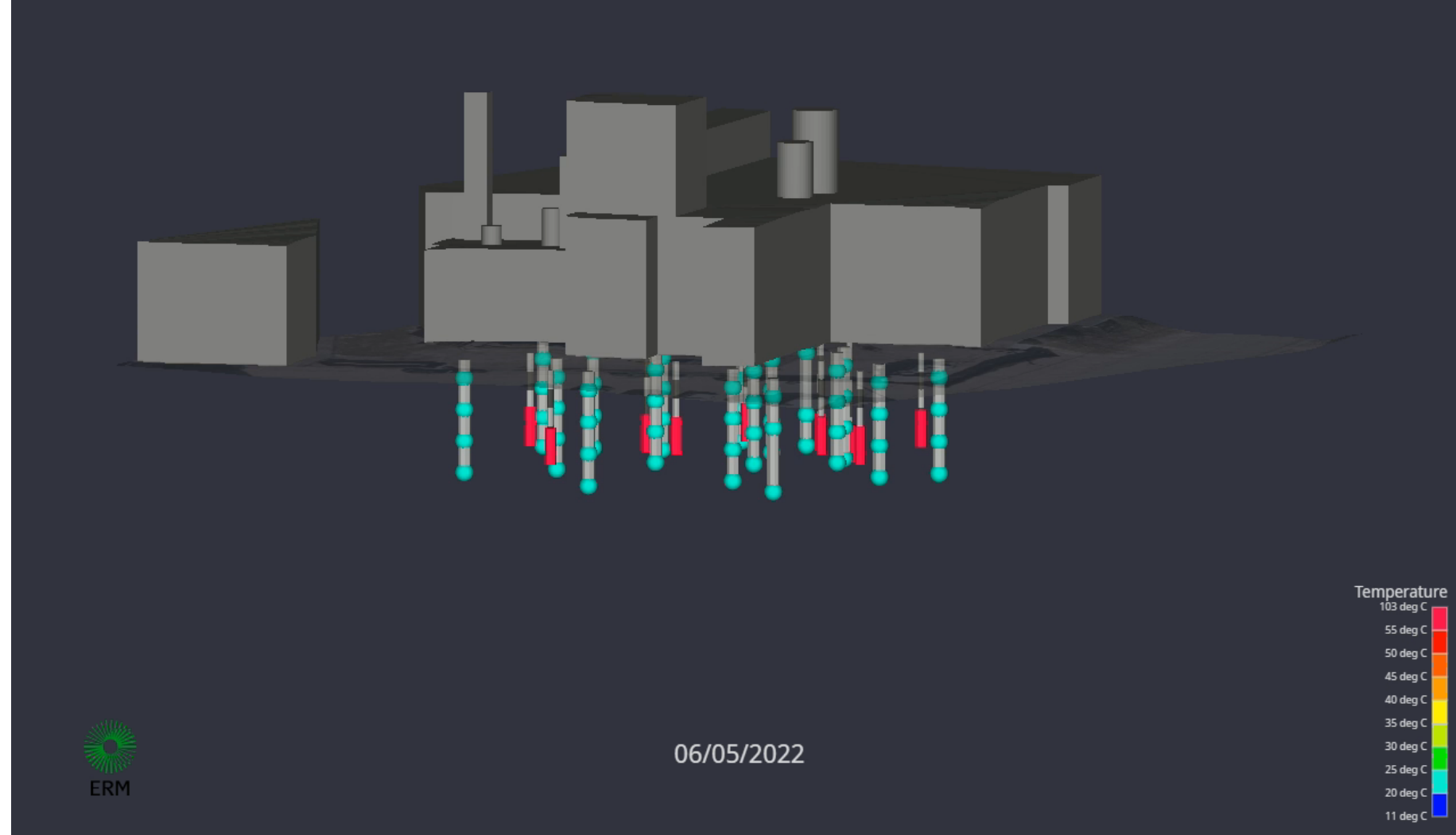


Thermal Response and Mass Recovery

Thermal Response at the Site

Steam injection

- Start - June 6th, 2022
- End - Sept 7th, 2022
- 93 days (13 weeks)
- Average rate was 335 kg/hr.
- Total mass 747,100 kg

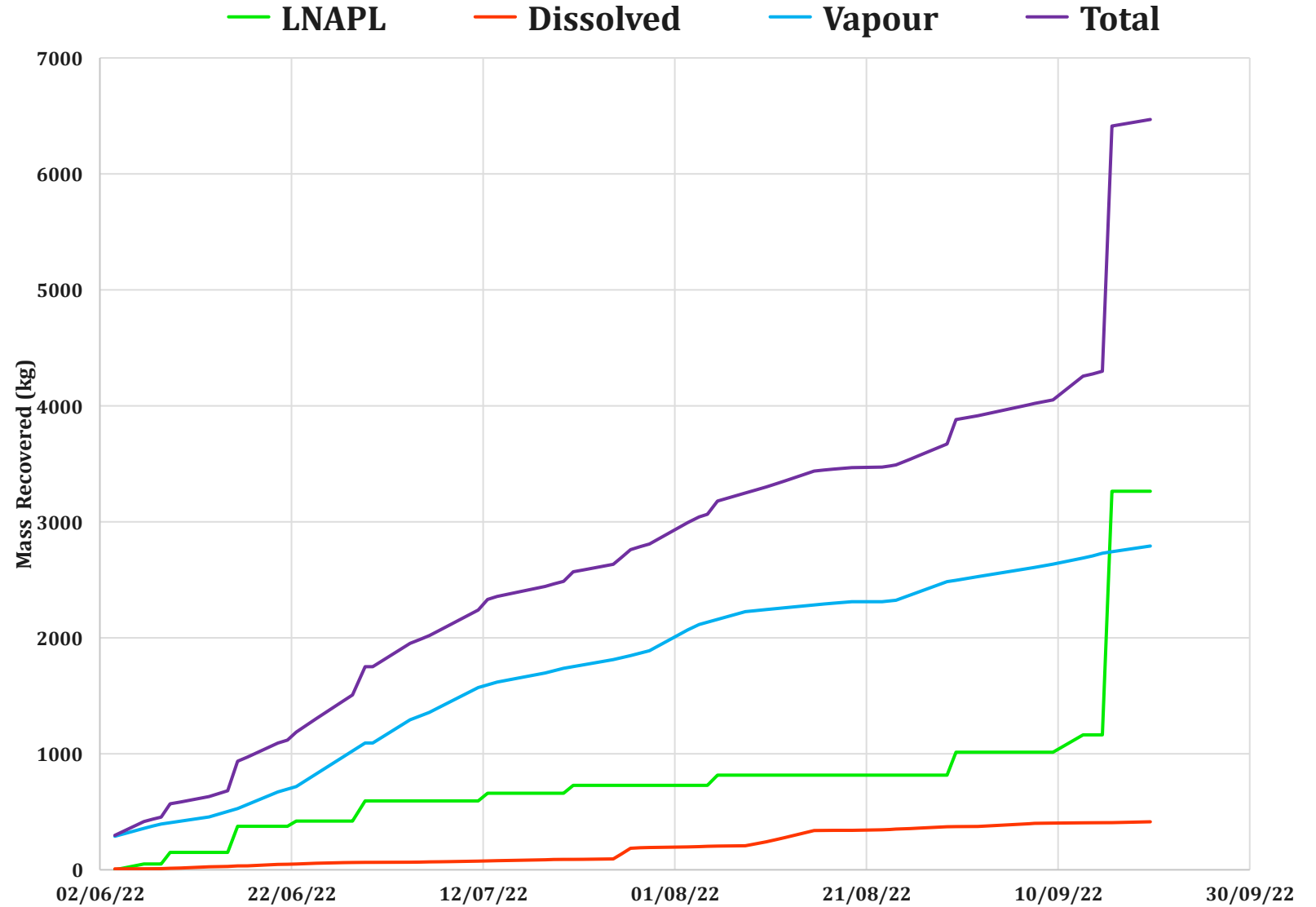


Mass Removal

Approximately 3,300 kg (3,600 L) of **LNAPL** product was recovered.

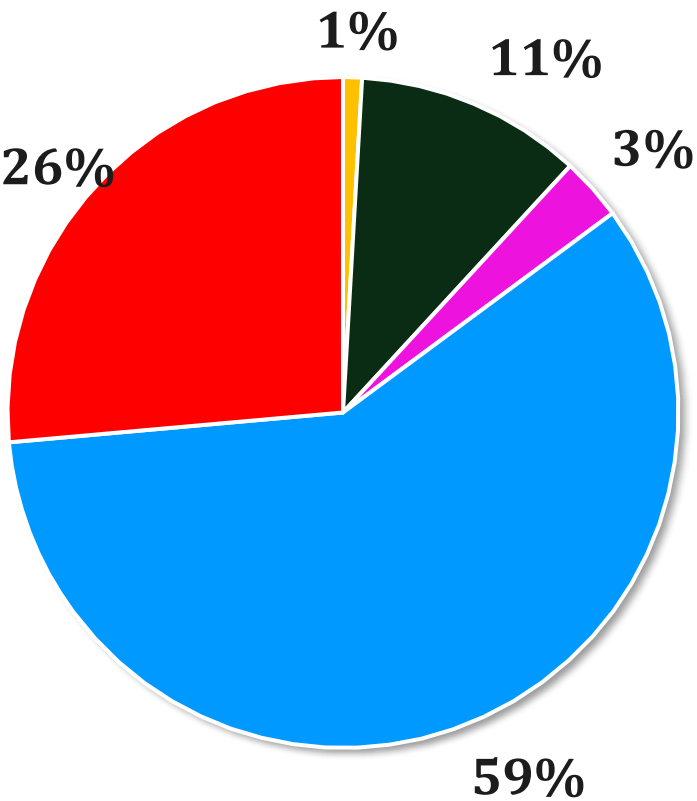
Approximately 3,200 kg of mass was recovered by the MPE system in **vapour** and **dissolved** phases.

Total mass recovered:
~6,500 kg

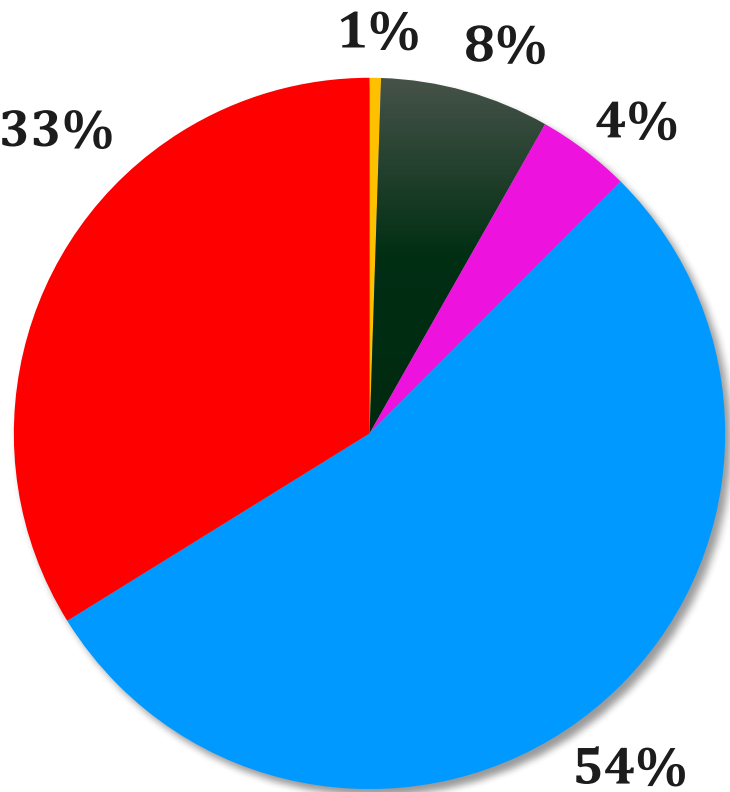


Contaminant Stream Speciation

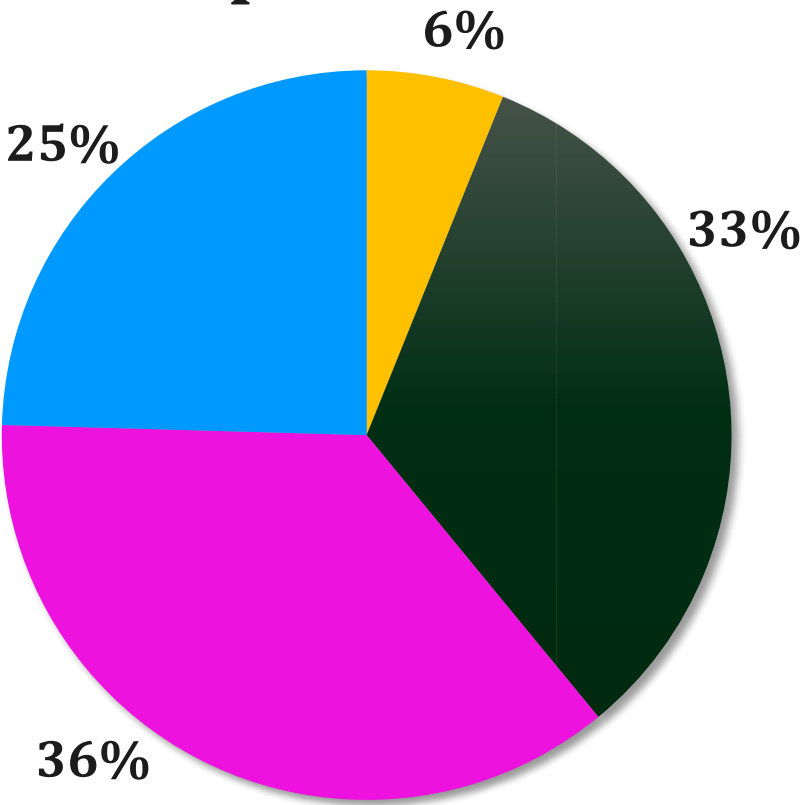
LNAPL



Dissolved Phase



Vapor Phase



■ VOCs ■ BTEX ■ PHC F1 (C6-C10) - BTEX ■ PHC F2 (C10-C16) ■ PHC F3 (C16-C34)

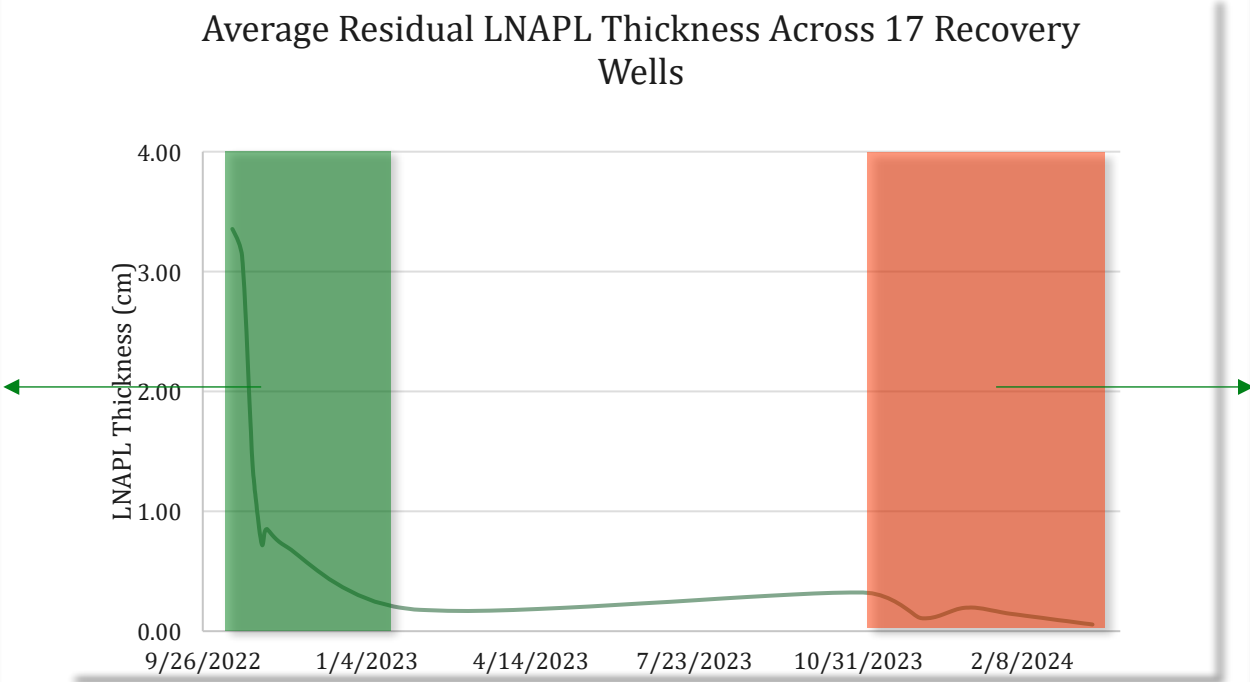


Ongoing Efforts

Continued Recovery of NAPL – Post Steam



Heated LNAPL recovered



Average (calculated) LNAPL thicknesses in the recovery wells as a result of 2 rounds of post thermal manual retrieval

ORIGINAL LNAPL THICKNESSES OF UP TO 150 CM!



Passive NAPL collection from the wells occurring on a monthly frequency.



Conclusion and Takeaway Message

Takeaway

Objectives

- Help the client meet their corporate objectives (sale of property) ✓
- Protect the environment and local receptors ✓
- Integrate safely with existing and planned site operations ✓
- Remove LNAPL and dissolved & soil vapor phase mass to the extent practical within financial constraints ?

Could have included

- Asymptotic mass removal
- Time at temperature
- Soil sampling results
- **Economic & Environmental Sustainability**

Alternate shut down criteria may have achieved greater recovery

Conclusions

1. Multiple challenges overcome related to
 - Dynamic spacing
 - Preferential pathways & excursions
 - External variables (weather, Covid)
2. No health and safety incidents reported
3. 6,500 kg of mass recovered in 13 weeks
4. Greater than 99.8% reduction in max apparent product thickness
5. Greater focus on conceptual model development and specification of shut down criteria may have resulted in complete removal of source zone NAPL... at greater cost

Steam enhanced LNAPL recovery was successfully applied at a moderately permeable Site



Thank you

Additional thanks to:

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