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Sustainable and Rapid Remediation of VOCs and SVOCs Using Gas Thermal Remediation

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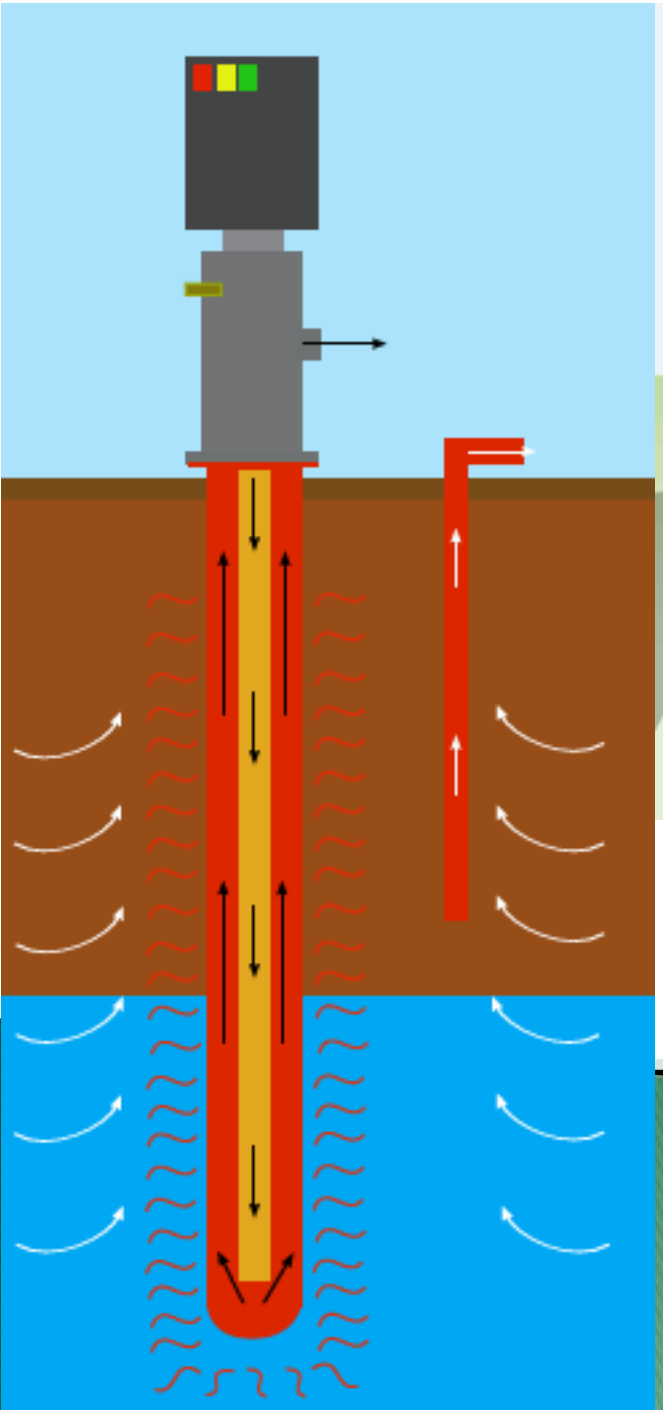
Summary

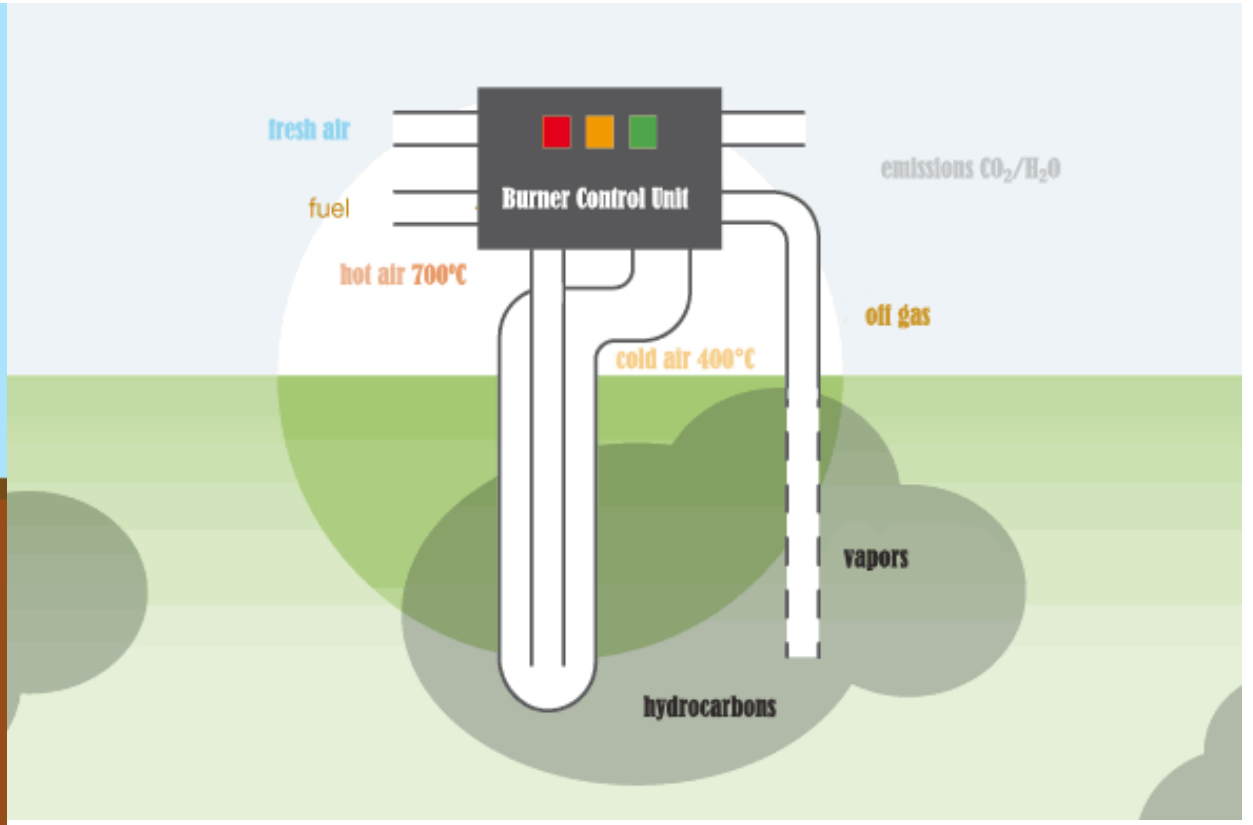
Gas Thermal Remediation (GTR) Primer with Example of Canadian Project

LNAPL / DNAPL Extraction

Liquid Fuels & Sustainable Reuse

Reuses of Residual Heat



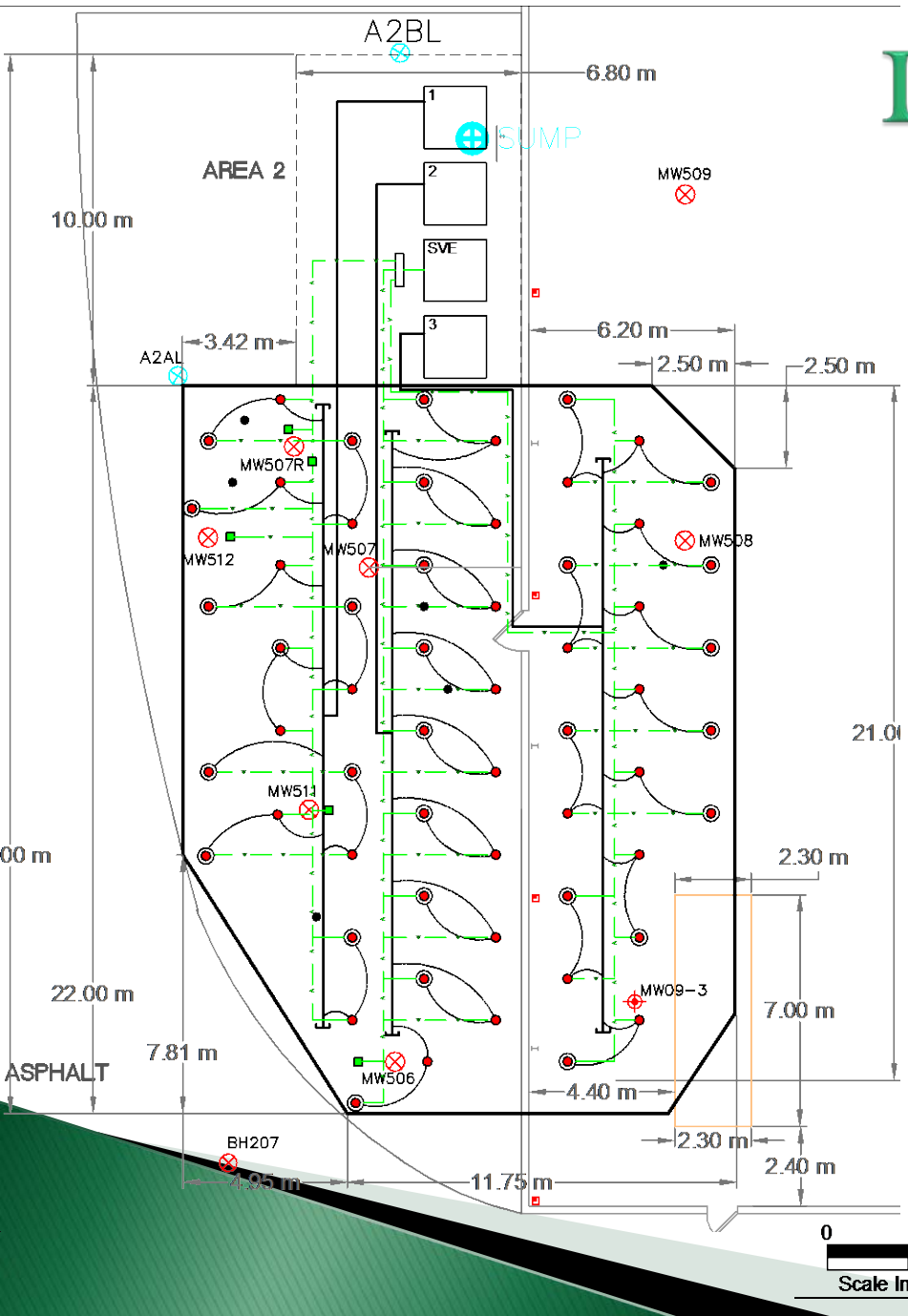


Generalized Depiction of Fuel-Operated Thermal Conduction Heater Systems Used by GEO.

Primer: Canadian Project

- Partially Inside and Outside Active Manufacturing Facility.
- TTZ: 1,100 ft^2 to an average depth of 18 ft bgs.
- Silt and Silty Clay with GW beginning at 9 ft bgs.
- CVOC contaminants exhibited maximum concentrations of TCA = 640 ug/L, DCA = 320 ug/L, TCE = 1.6 ug/L, 1,1-DCE = 1.6 ug/L.
- Treatment Goal: CVOC mass reduction of 90%.

Layout of Project



- 59 Heating Wells (2.5 m well spacing)
- 59 Co-Located Vapor Extraction Wells
- 7 Vapor Extraction Wells
- Existing Natural Gas Connection (to Heating Wells) and Existing Electrical Connection (to SVE)
- 7 TPMPs

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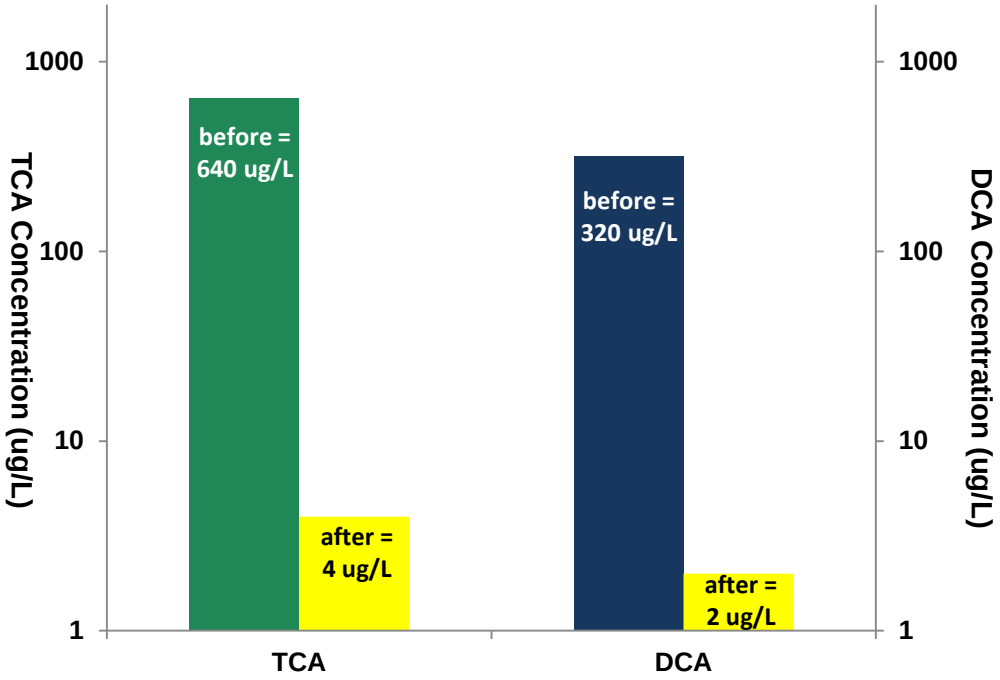

Results

- 100°C reached in all zones and depths within 84 days of system start.
- 98% reduction in CVOCs from groundwater achieved (goal = 90%)

Lessons Learned

- Hydrolysis of TCA is powerful in-situ reduction mechanism
- Shipping, customs clearance, permitting (U.S. to Canada) should be started directly after design is approved

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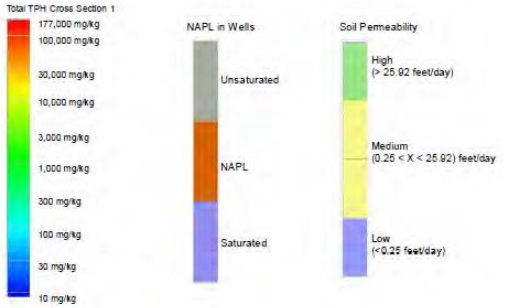
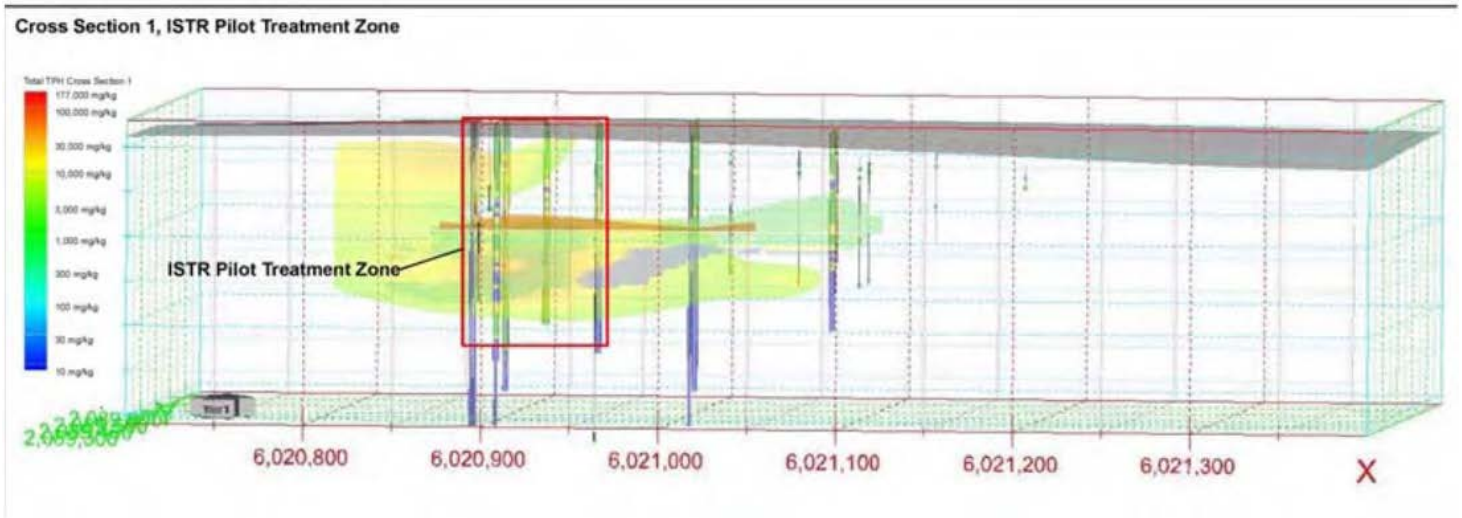
Case: NAPL Extraction / Elimination

Boring	Depth (ft bgs)	Total NAPL (%PV)	Mobile NAPL (%PV)	Total TPH (mg/kg)	Total PCB (µg/kg)	Total DCB (µg/kg)
IR03B429	10	8.74	0	1,757	720	900
	15	16.03	2.29	13,130	3000	NS
	23	2.44	0	4,449	950	246
IR03B426	16	26.55	5.27	48,110	94000	23400
	18.5	4.84	0	1,180	87	NS
	22	2.45	0	7,701	120000	64000
IR03B430	14	7.71	0	9,472	330000	NS
	16	1.71	0	14,097	5000	36200
	20	4.23	0	1,051	2900	NS
IR03B425	15	21.72	3.2	27,074	28000	NS
	18	11.13	0.17	31,076	15000	NS
	20	5.57	0	861	3000	10010
IR03B427	13	4.45	0	9,453	2800	2360
	15	2.41	0	6,324	920	NS
	21	7.8	0	15	10	105
IR03B428	13	33.28	9	1,831	580	NS
	15	3.36	0.12	22,920	32000	32500
	22	9.36	0.73	2,773	8100	12400
IR03B431	19	13.79	0	12,839	350	ND
IR03B432A	20	7.36	0	18,139	860	327
IR03B433	15	9.99	0	12,061	280	NS

GTR pilot study was conducted at San Francisco Bay to aggressively remove mobile NAPL that potentially may threaten bay area.





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Treatment Area and Goal

GTR heated the subsurface to mobilize and extract NAPL from the subsurface. The remediation goal was measured as a reduction in average total NAPL saturation in soil to levels below residual saturation.

Item	Value	Units
Treatment area	1,900	sq ft
Upper depth of treatment	5	ft bgs
Lower depth of treatment	20	ft bgs
Treatment volume	1,056	yds^3
Heated volume	1,760	yds^3

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Well Layout

Well Type	Depth (ft)	#
Heater Wells	25	46
Multi-phase Extraction Wells	20	14
Horizontal Vapor Extraction Wells	200	3
Co-Located Vapor Extraction Wells	5	46
Reinjection Wells	20	7
Temperature and Pressure Monitoring Points	20	14

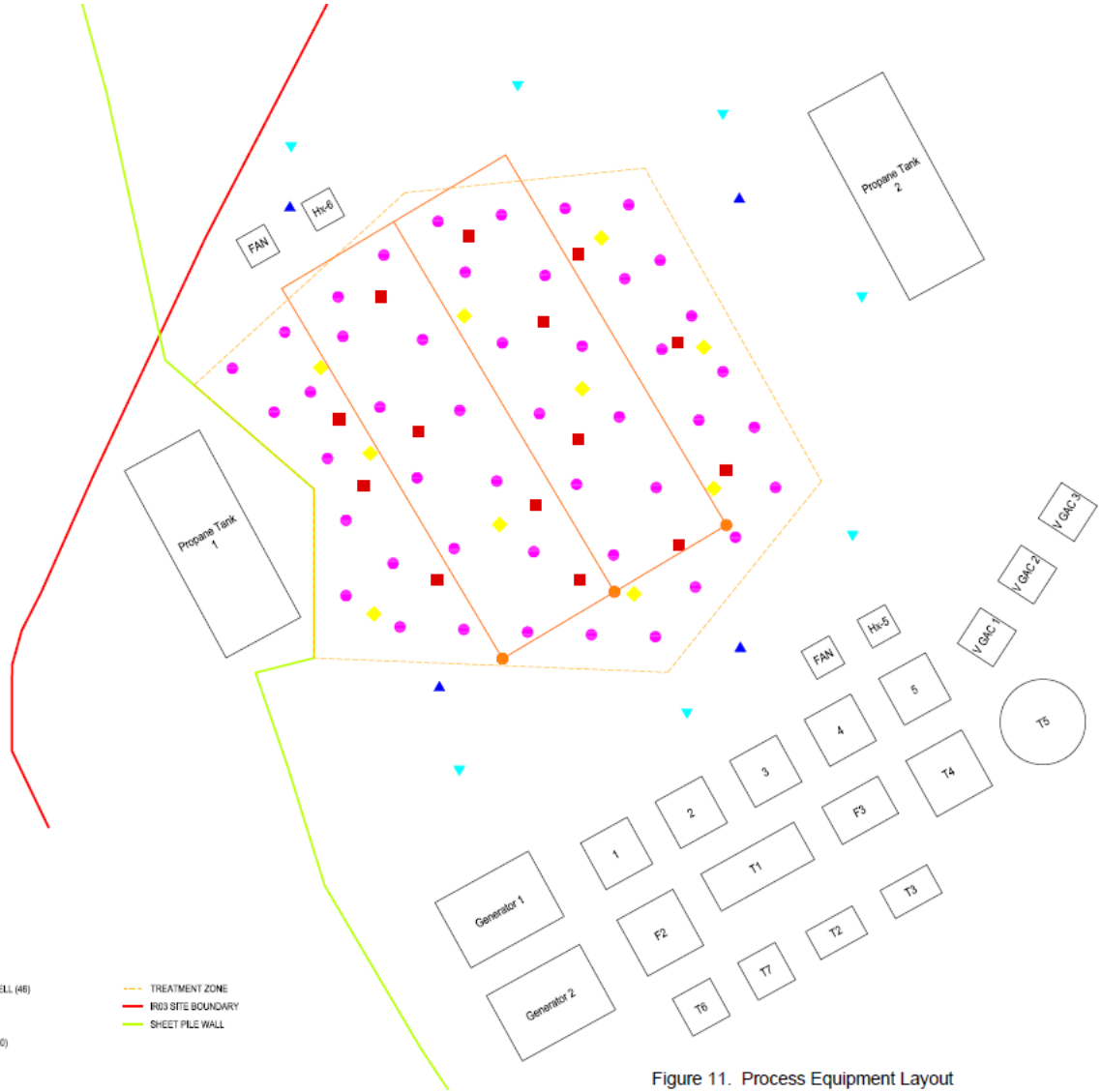

Figure 11. Process Equipment Layout

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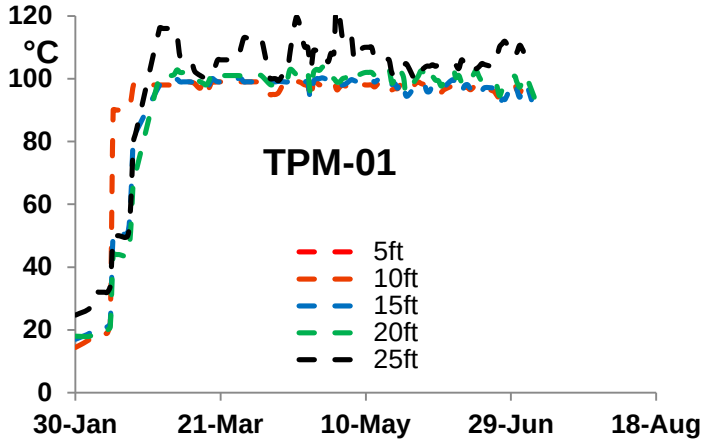
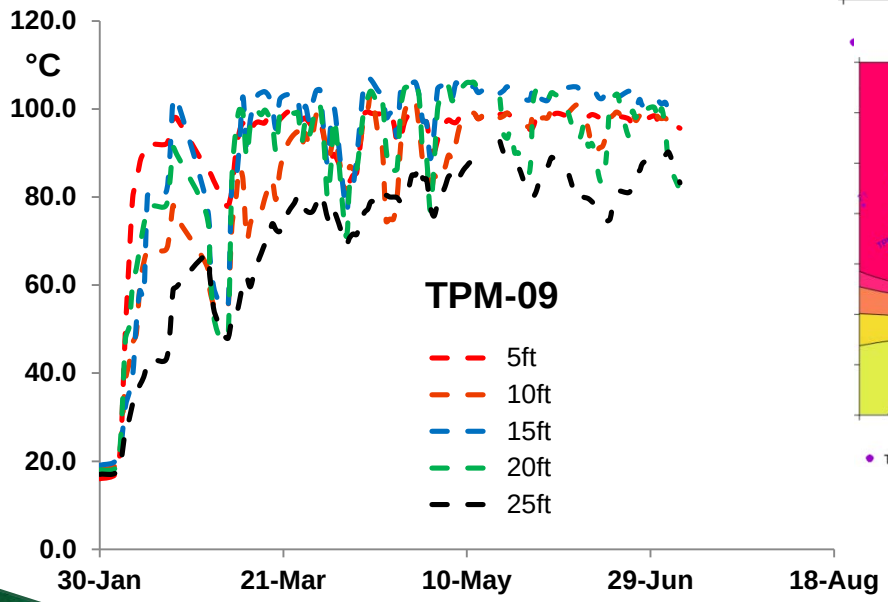
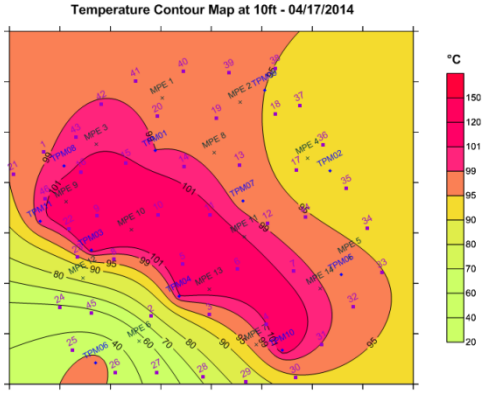
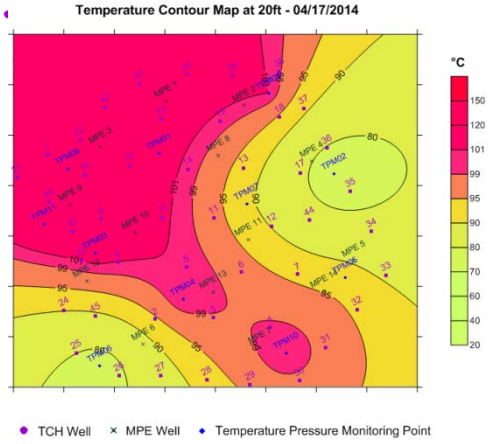
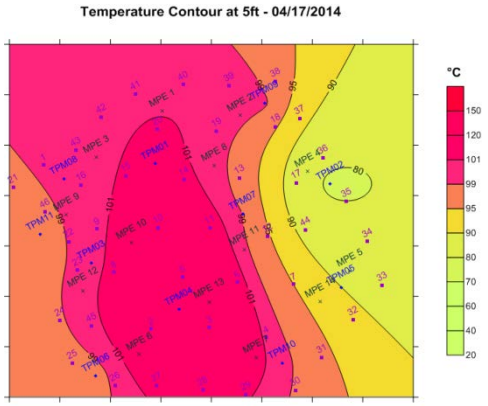
Subsurface Temperature Evolution

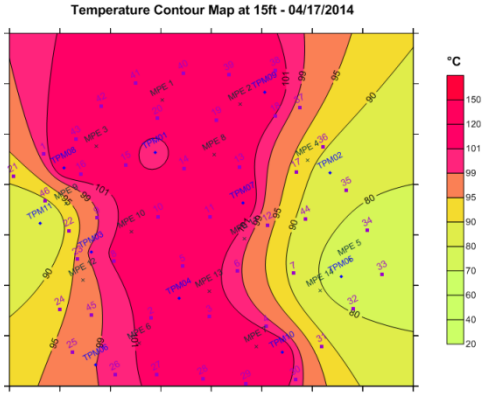


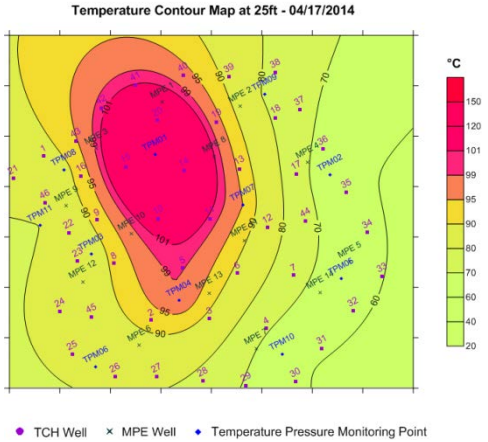












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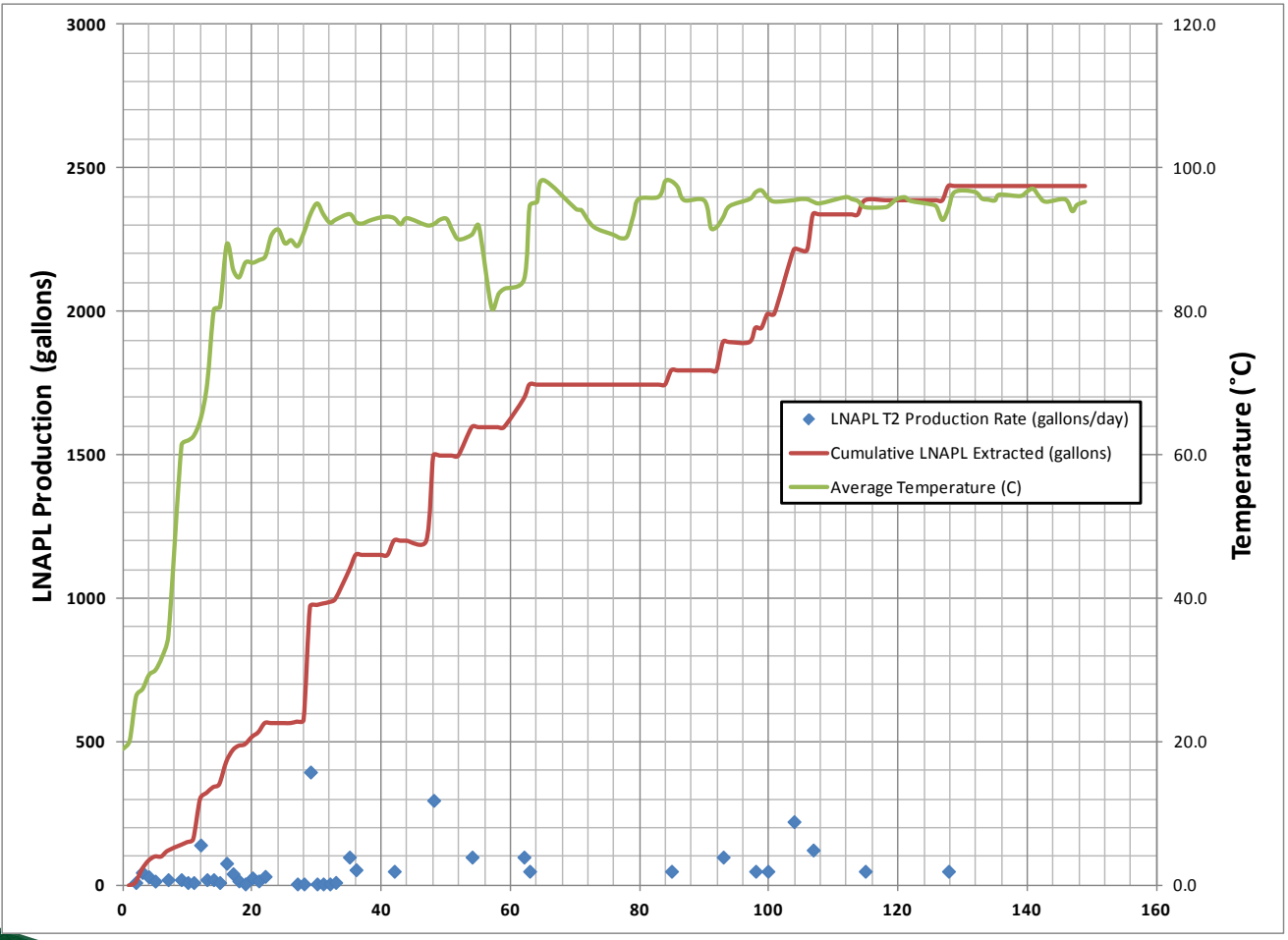
NAPL Extraction Data



The estimated LNAPLs on site was 2,400 Gallon.

After 100 days of heating, collected LNAPLs was >2,400 Gallon.

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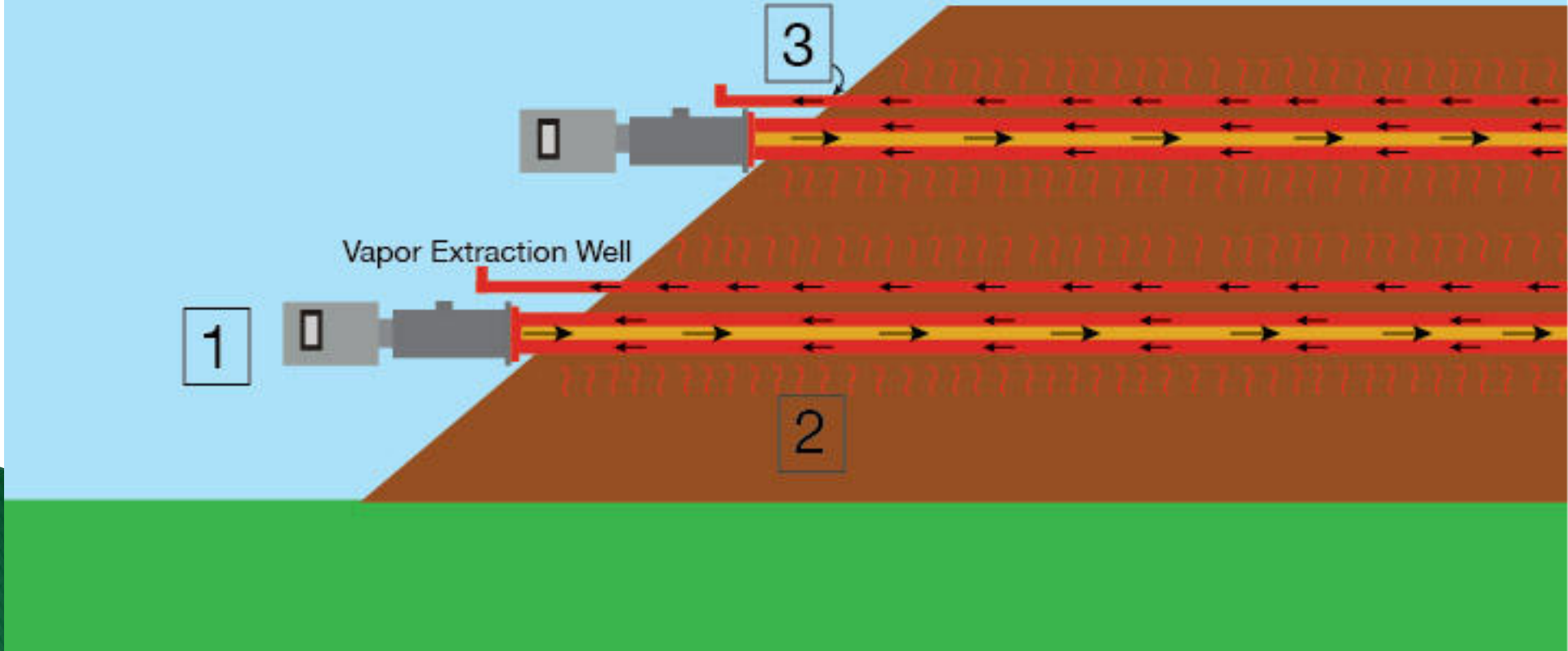
GTR | Gas Thermal Remediation

How Ex Situ GTR™ Works

1) GTR and SVE wells are placed within the soil pile during construction at approximately 2-3 meters apart.

2) GTR wells heat the soil resulting in the destruction of non volatile COCs and or the volatilization and extraction of water, VOCs and SVOCs.

3) Volatile COCs are removed from the pile by vacuum extraction wells for treatment.



Diesel Ethanol Natural Gas Propane

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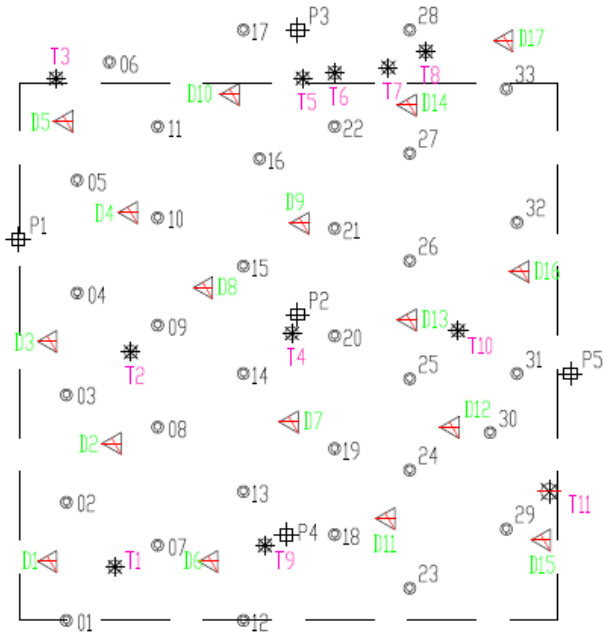
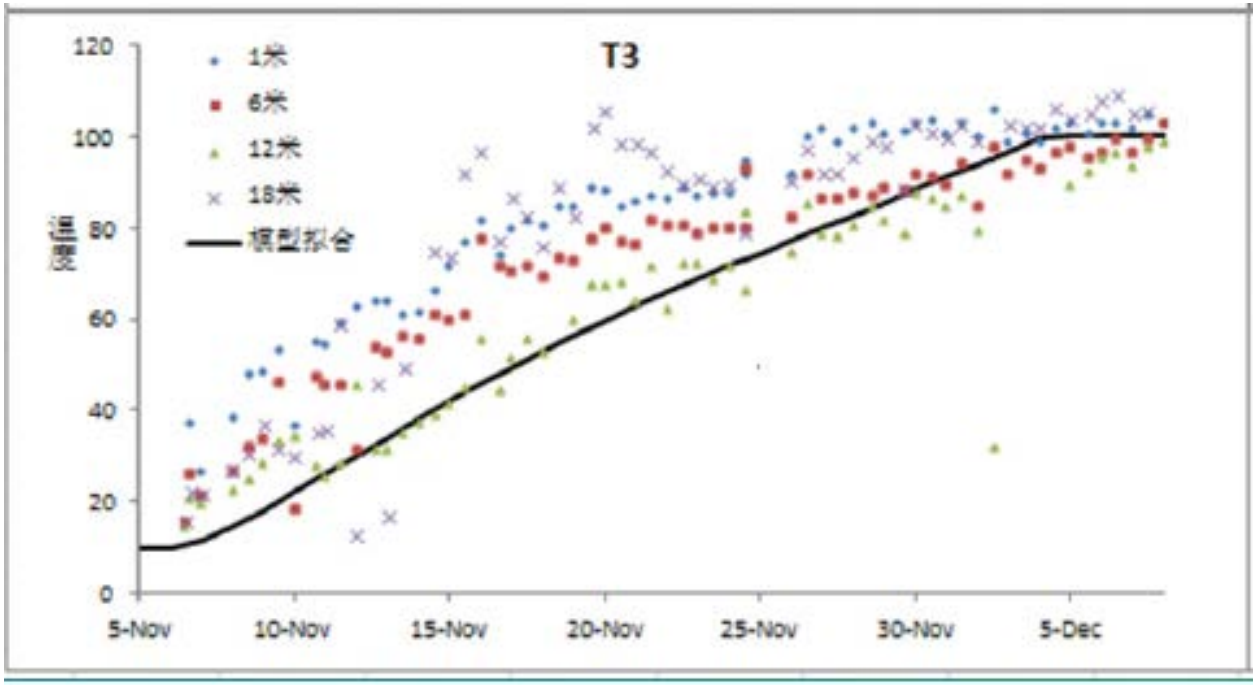
Case: Sustainability; Reuse of Residual Heat

- Area: 1,080 ft^2 Depth: surface to 60 ft bgs
- Target Treatment Temperature: 100°C
- No. Heater Wells: 33 No. Extraction Wells: 17
- No. Temperature & Pressure Monitoring Points: 11
- Primary Contaminants: Naphthalene, Benzene
- Lithology: Clay, Groundwater encountered at 5 ft bgs
- Setting: Former industrial area

Layout and Temperature Profile





- Remedial Goals:
  - Benzene: < 2 mg/kg
  - Chlorobenzene: < 1.5 mg/kg
  - Naphthalene: < 10 mg/kg

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Case: Results

	Budgeted	Actual	% Benefit
NAPL extracted	900 liters	**1,120 liters**	**24.4%**
Duration to 100°C	45 days	**33 days**	**33.3%**

COC	-3m			-9m		
	before	after	removal rate	before	after	removal rate
Benzene	**1.51**	**<0.05**	**100%**	**42.69**	**<0.05**	**100%**
Naphthalene				**>100**	**5.53**	**95%**

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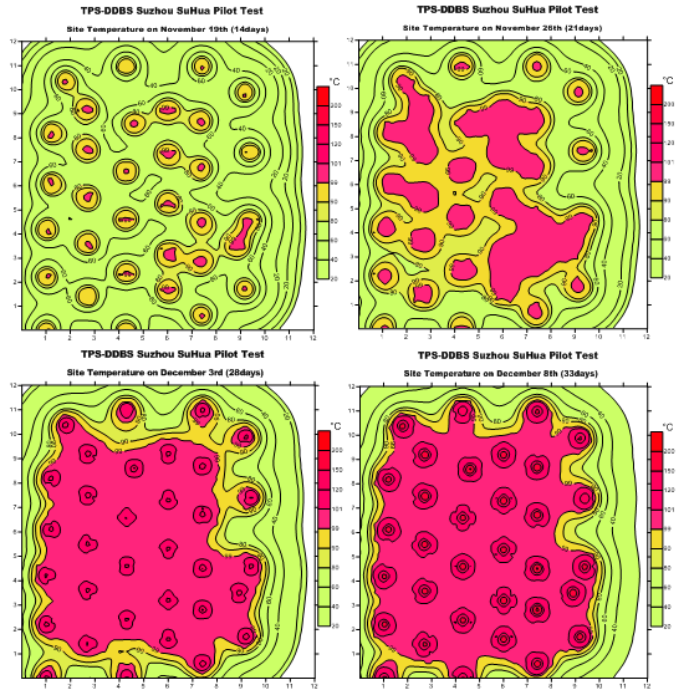

Results (cont.)

- Hot water injection heated down gradient plume, with the goal of enhancing bioremediation efforts.
- Remedial goals attained and exceeded at all confirmation sampling locations within 60 days of ISTD system operation.

修复前土壤 | 修复后土壤

Soil Before Soil After

修复前地下水 修复后地下水

Water Before(with NAPL) Water After

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Summary

GTR© Gas Thermal Remediation

1. Achieves soil temperatures from **50°C to >325°C**
2. Effective in both **in situ** and **ex situ** configurations
3. Ability to use liquid fuels [like **diesel**] or natural gas enhances feasibility for “remote” oil/gas operations.
4. Recovered LNAPLs may be used to fuel the GTR heaters, creating an **onsite reuse** for extracted hydrocarbons.
5. Reuse of heat may be used for ancillary remedial efforts.
6. **Proven in Canada**… and about 12 other countries.

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Questions?

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