Thermal Remediation in Low-Permeability Materials

USEPA/TAIWAN EPA TECHNICAL EXCHANGE

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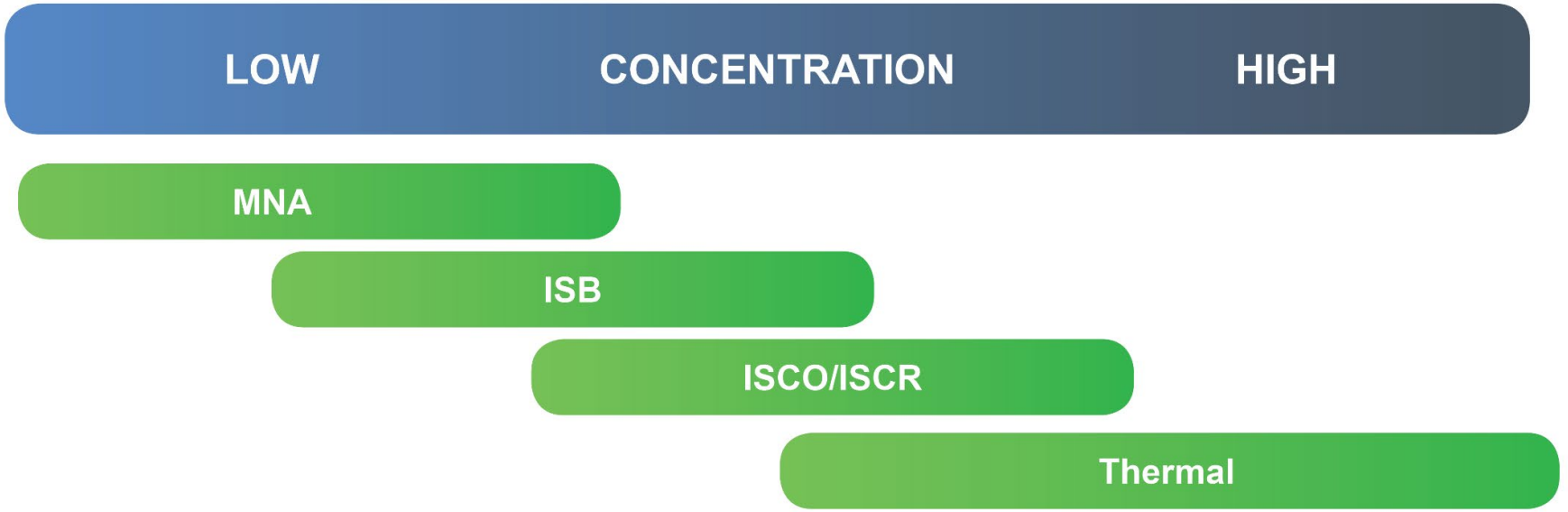
What is Thermal Remediation?

- Source zone technology – sweet spot
- Employs heat to volatize chemicals
- Chemical and steam vapors are:
  - Captured by vacuum
  - Brought to the surface
  - Treated before discharge
- Multiple Heating Methods:
  - Thermal Conduction Heating (TCH)
  - Electrical Resistance Heating (ERH)
  - Steam Enhanced Extraction (SEE)

Thermal Remedies Utilized for High Mass



Applications and Key Points

- Dry Cleaners
- Chemical Spills
- Redevelopment Sites
- MGP Sites
- Chemical Facilities

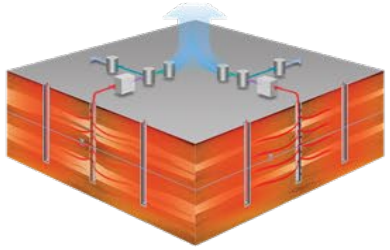
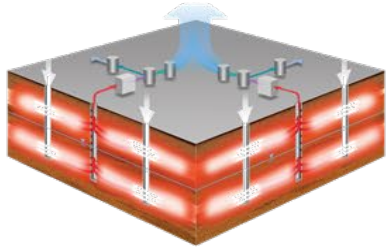
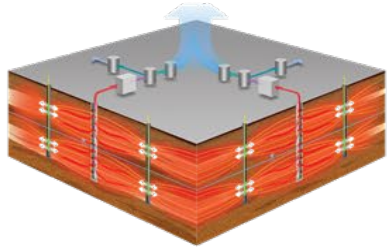
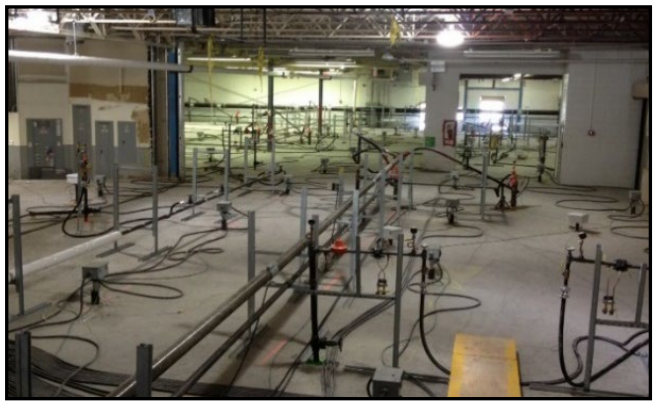
- In-situ
- No excavation
- No landfilling

Before - Syracuse, NY

After - Syracuse, NY

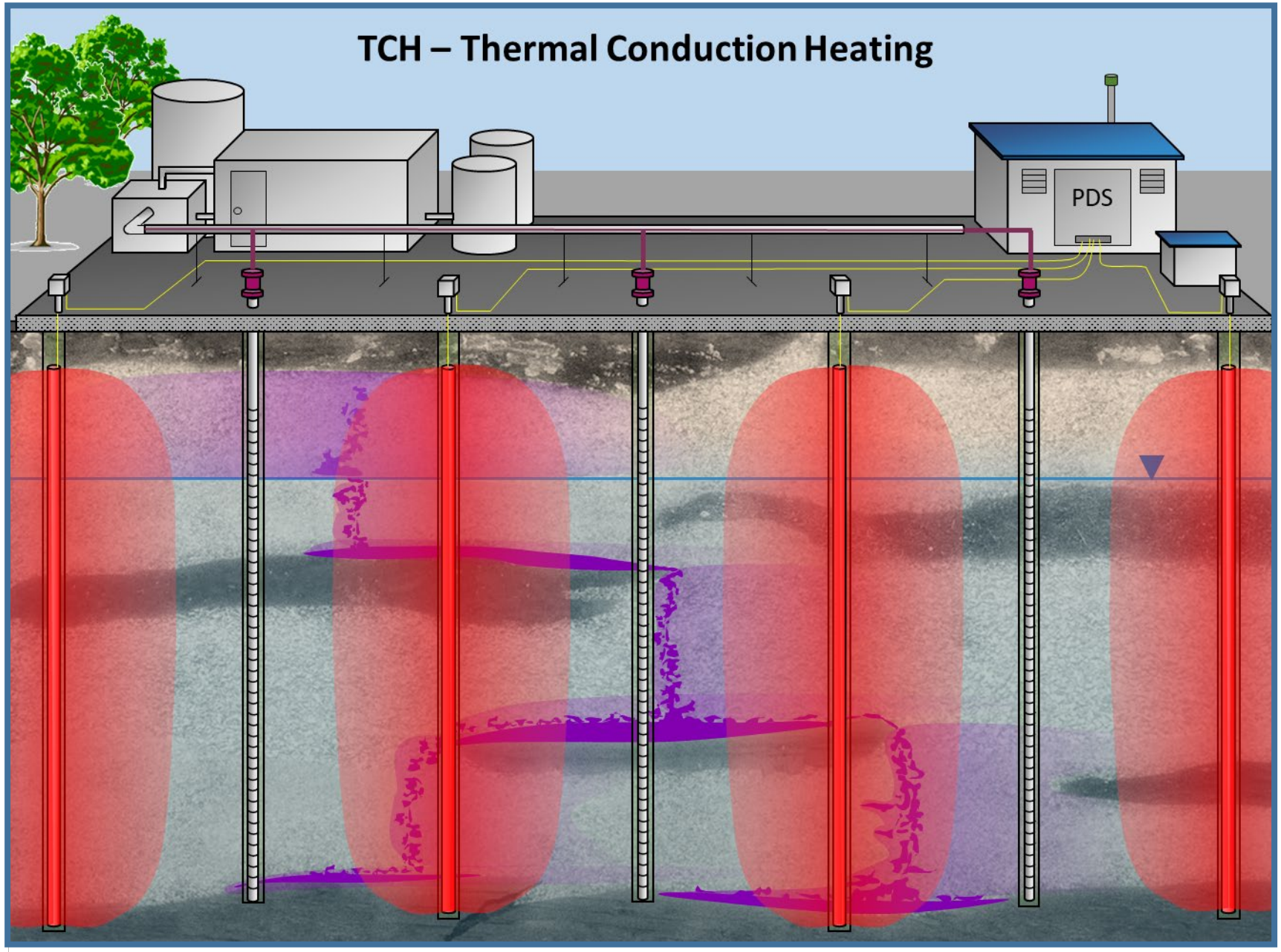
Technologies

ISTR Technologies

Thermal Conduction Heating (TCH / ISTD)	Steam Enhanced Extraction (SEE)	Electrical Resistance Heating (ERH)
		
		

Overview of Heating Technologies

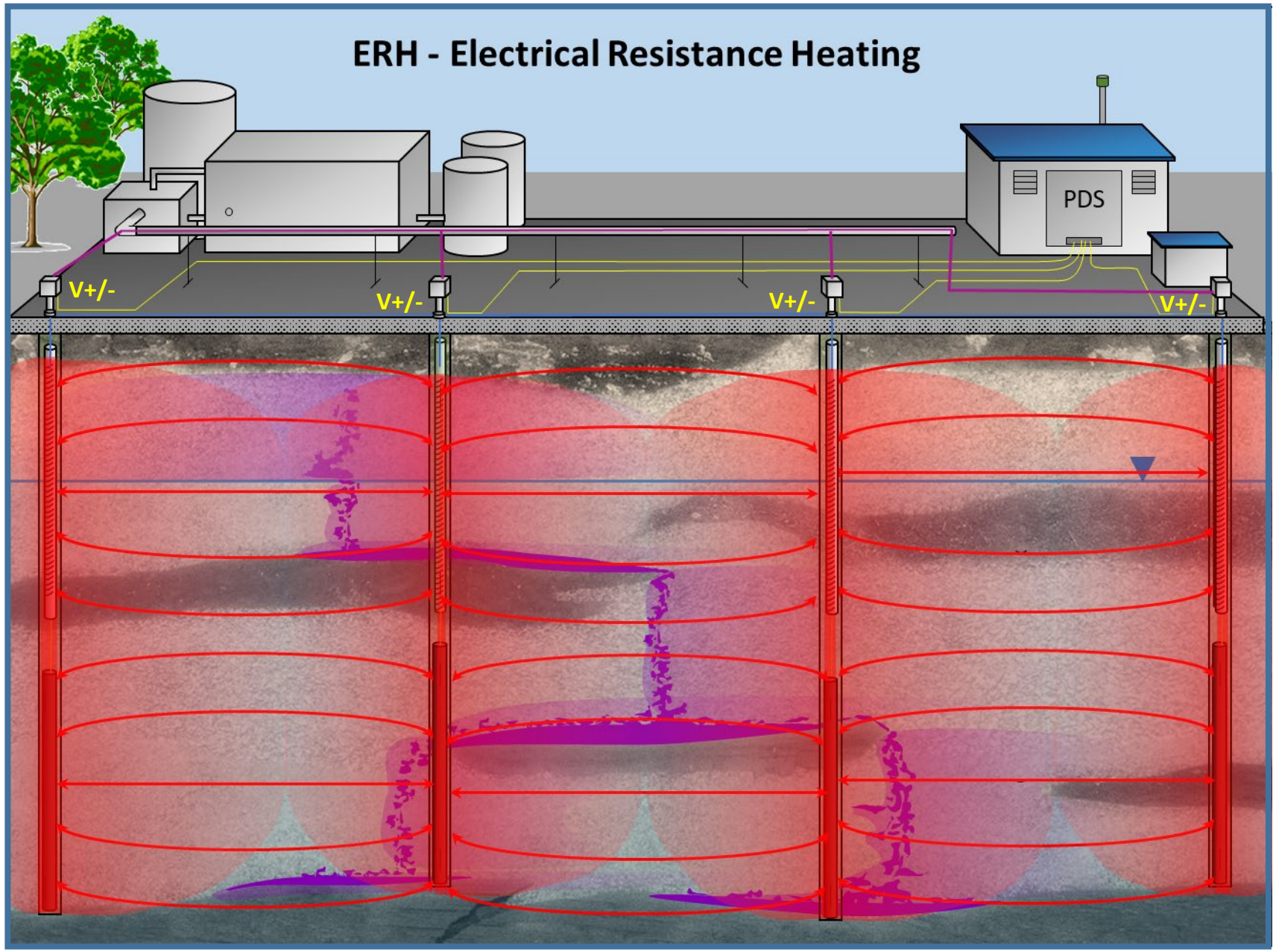
TCH



TCH Wellfield

Overview of Heating Technologies

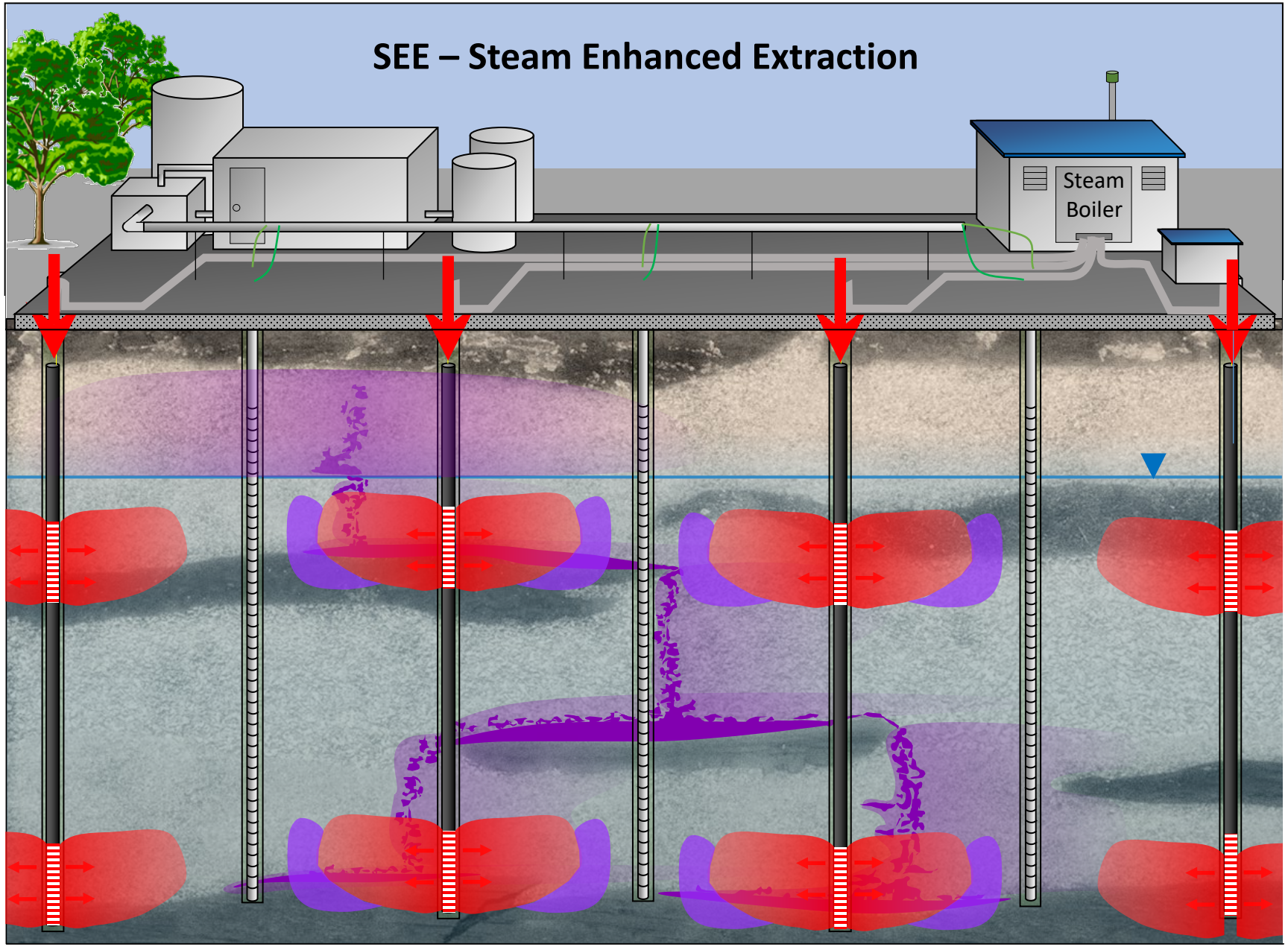
ERH



ERH Wellfield

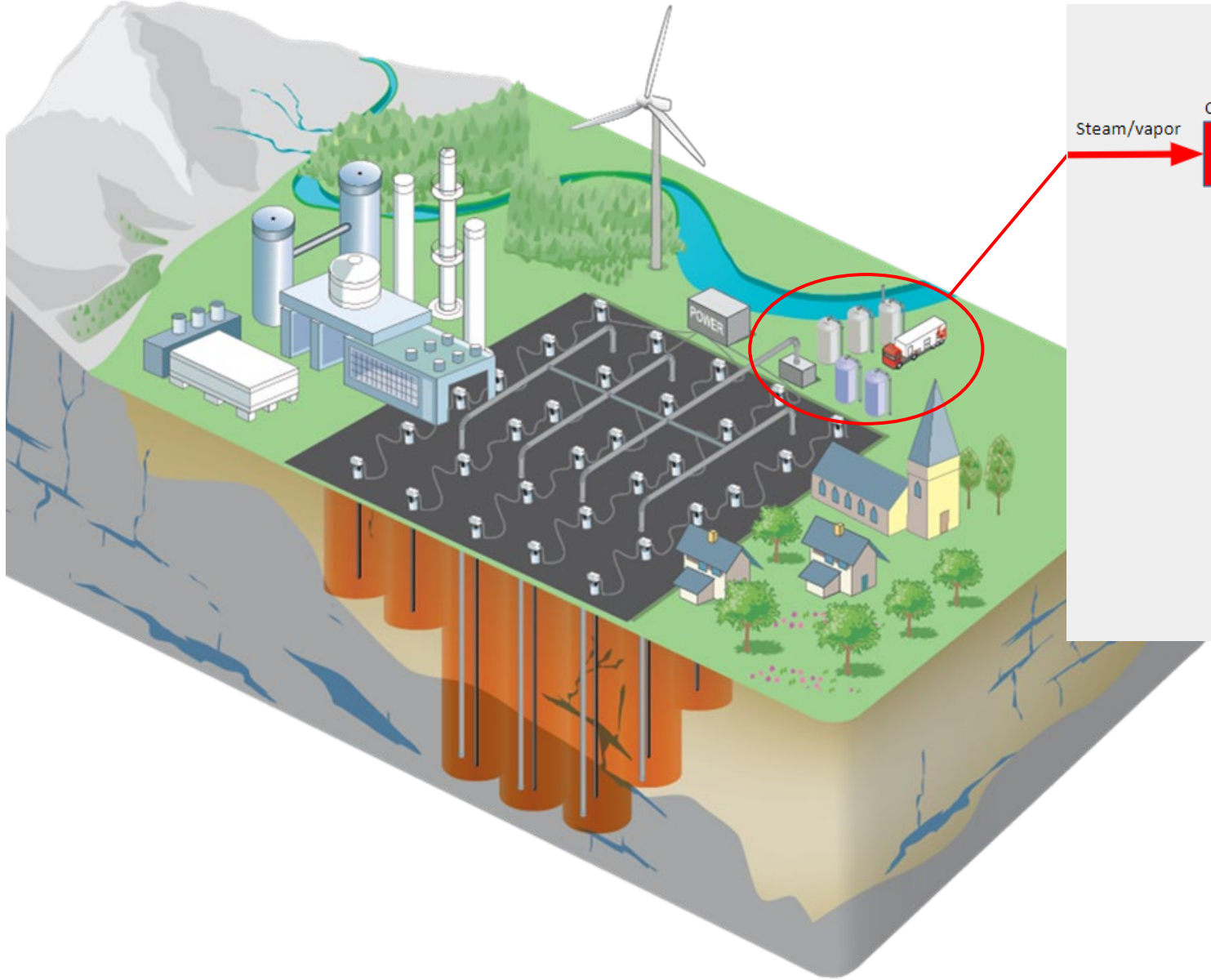
Overview of Heating Technologies

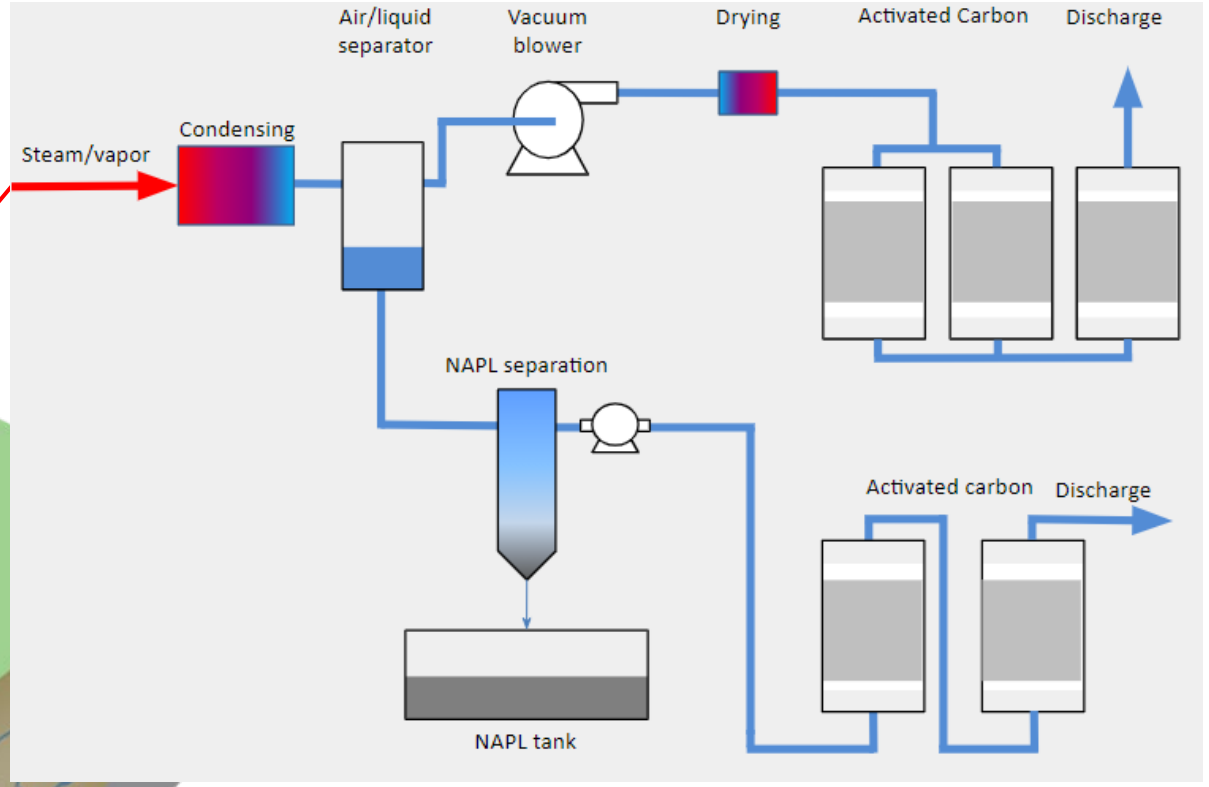
SEE



SEE Wellfield

Conceptual Schematic of Thermal System

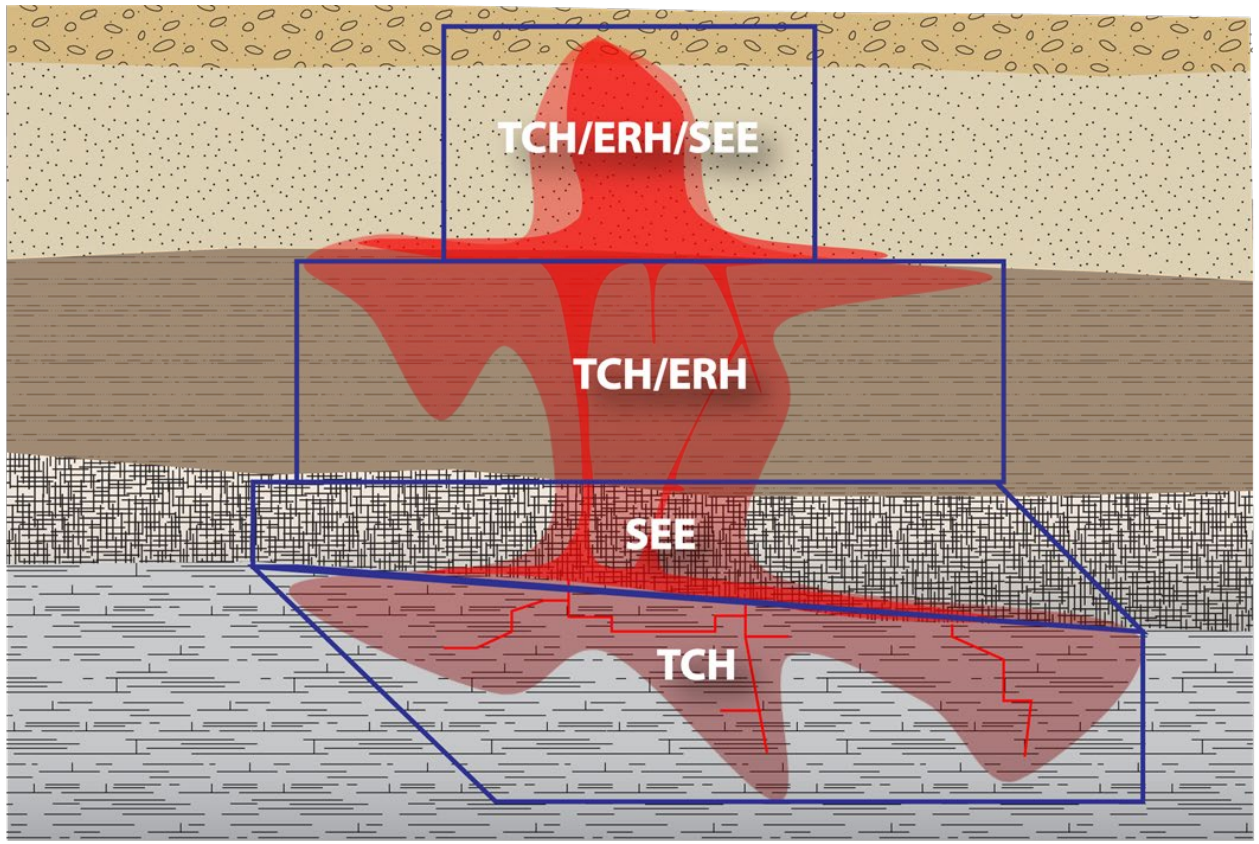




BASIC ELEMENTS

- Heating source
- Extraction network
- Treatment system

Technologies Applicable in Low-Permeability Material



TCH ✓

ERH ✓

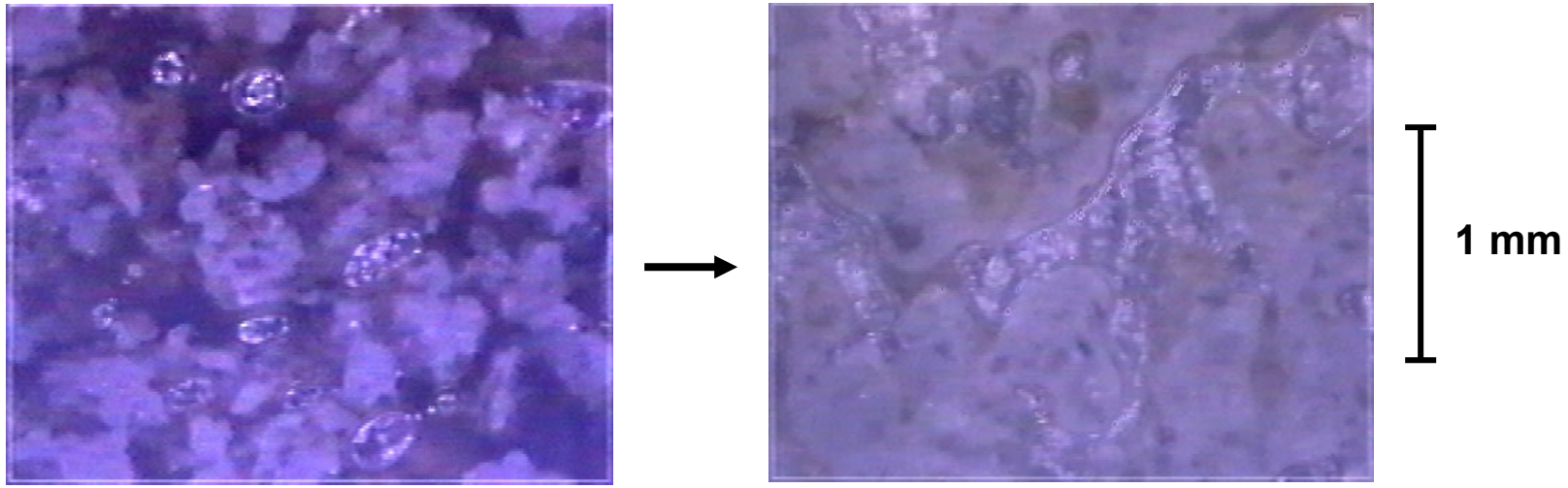
SEE ✗

Depending on specific site geology/hydrogeology, combinations of heating methods can be utilized.

Removal Mechanisms

Removal Mechanism - Boiling

Add heat ⇒ change state of chemicals from liquid to vapor

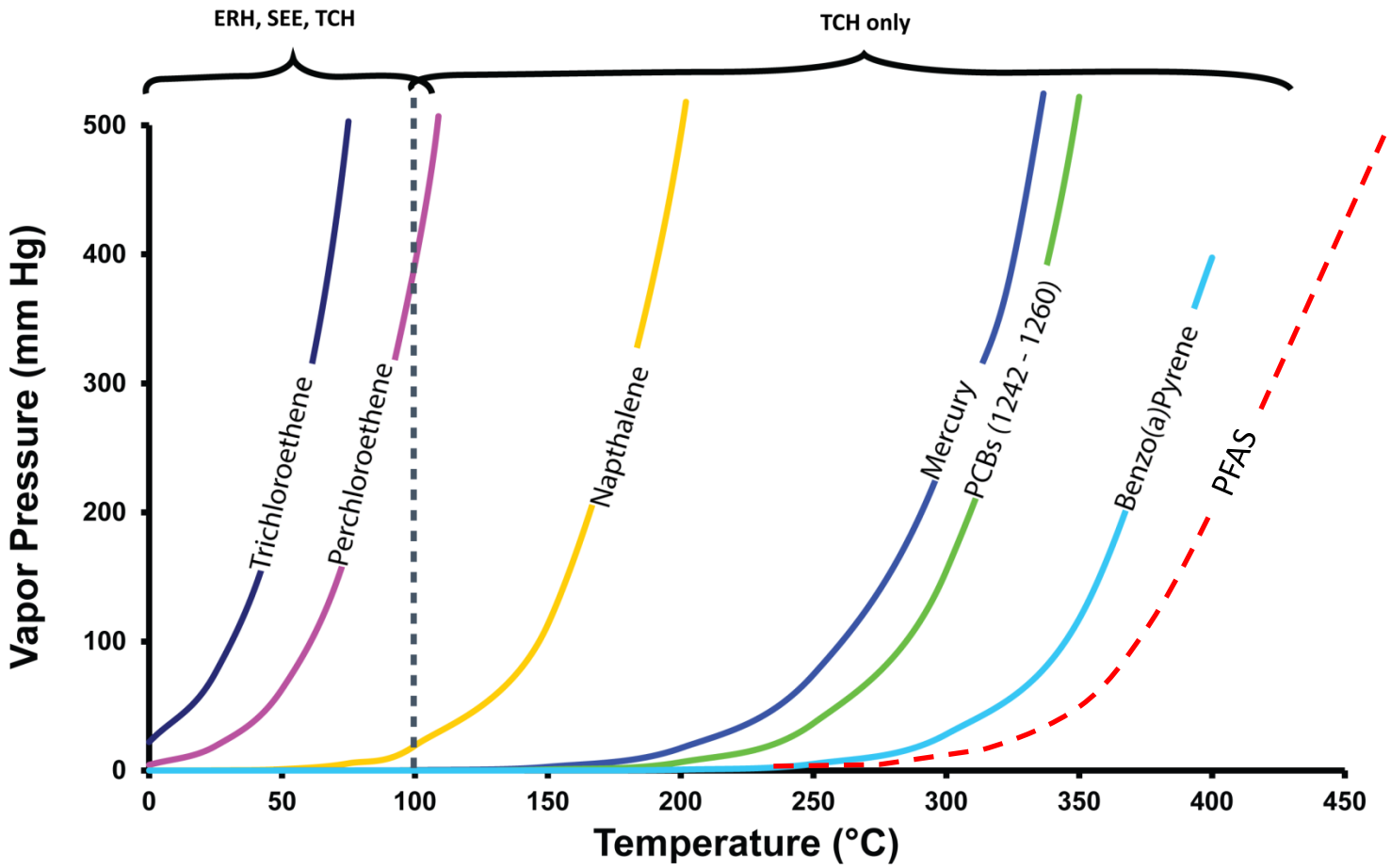


[Udell et al. 1999; Alameda Point SEE demonstration]

Heat transfer occurs about 10,000 times faster than aqueous diffusion in porous media

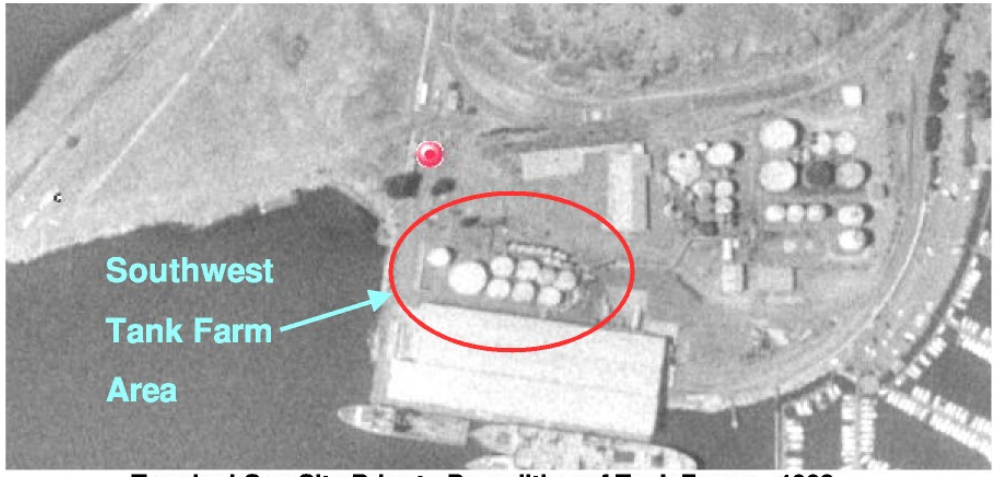
Removal Mechanism - Volatilization

Volatilization is main removal mechanism in Low-Permeability Material



Low Permeability Bay Mud Case

Contaminant Source



Terminal One Site Prior to Demolition of Tank Farms - 1993

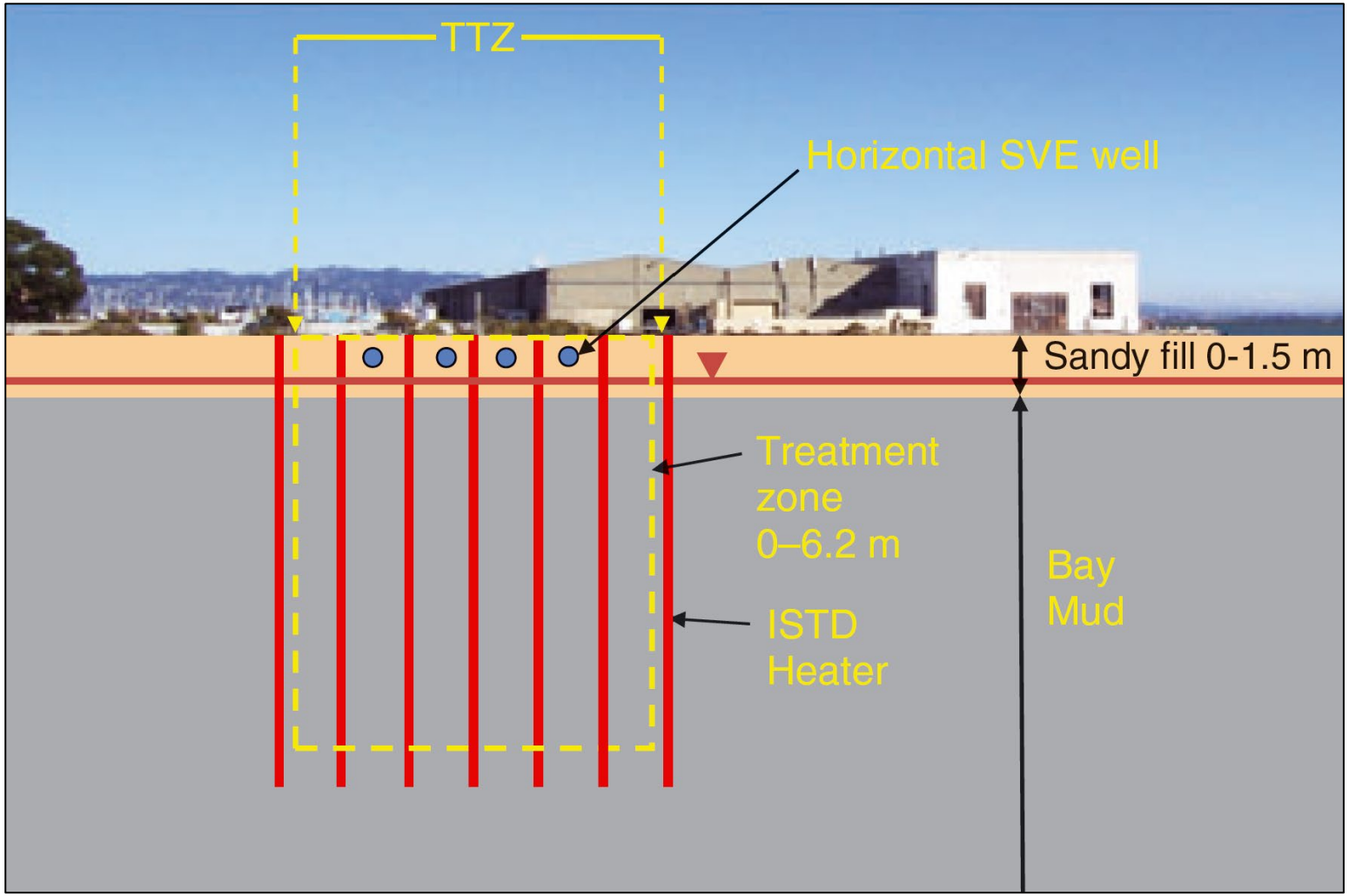
Terminal One Site Post Demolition of Tank Farms - 2004

Treatment Zone Location

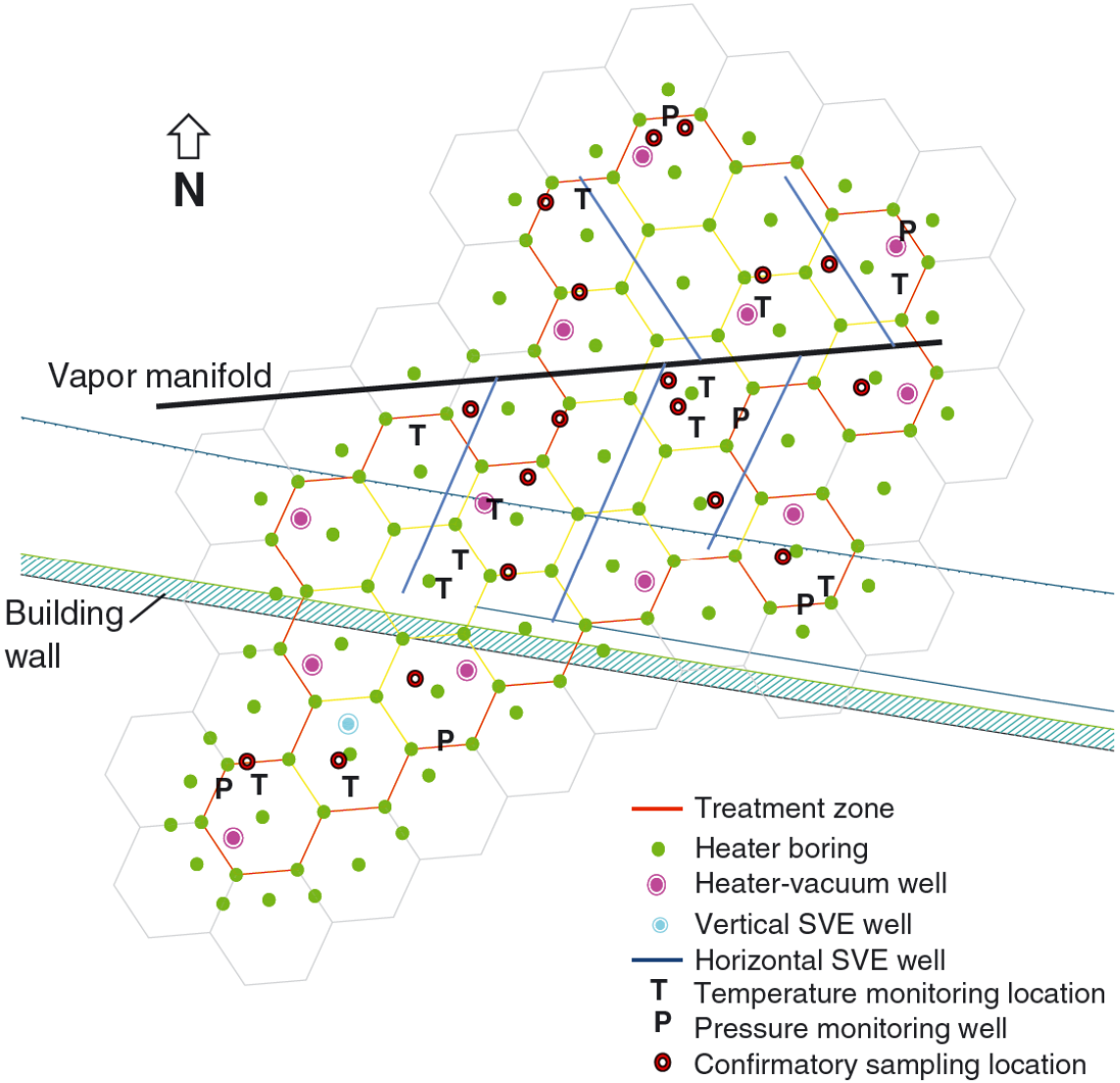
Site Key Parameters

- Contaminants: CVOCs, PCE, TCE, DCE and VC
- Up to 2.700 mg/kg PCE concentrations
- NAPL present in bay mud
- Treatment area: 836 m2
- Treatment volume: 5.097 m3
- Remedial goals:
  - PCE: 2,0 mg/kg
  - TCE: 2,0 mg/kg
  - DCE: 17,0 mg/kg
  - VC: 0,23 mg/kg

Cross Section

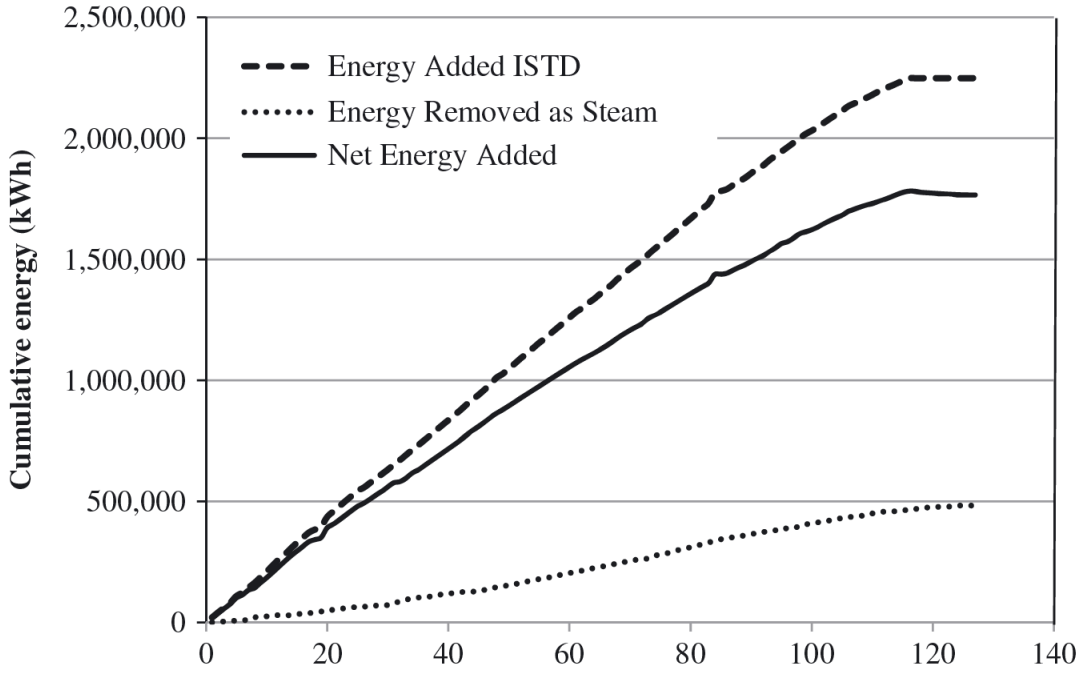


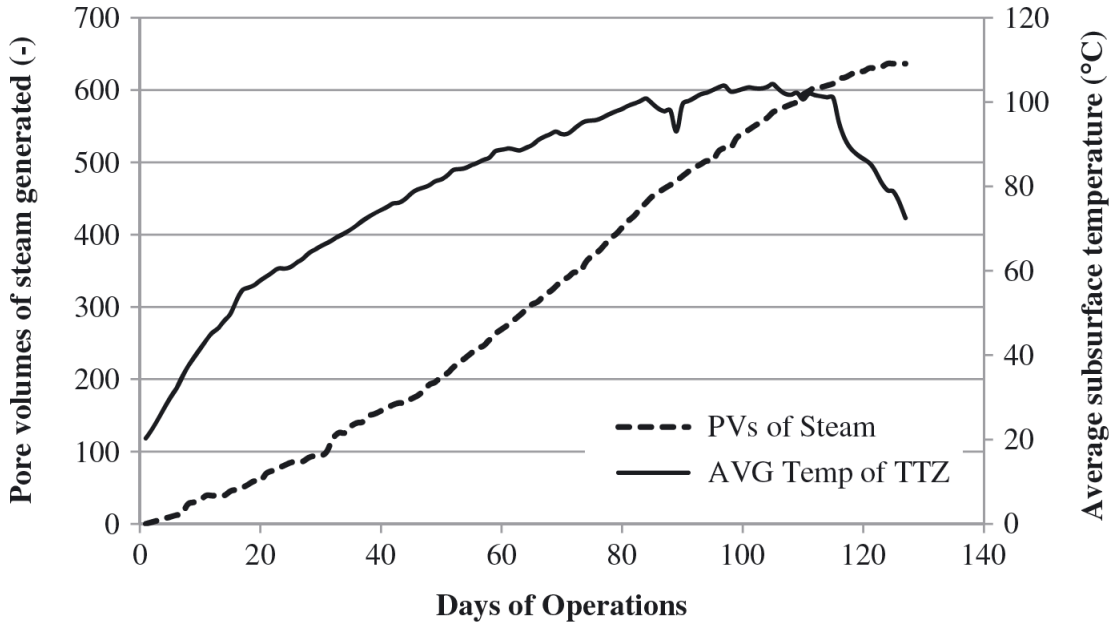
Wellfield Layout



- 126 heater borings
- 12 combined heater and extraction wells
- 5 shallow extraction wells in void space below building
- 5 horizontal extraction wells
- 17 temperature and pressure monitoring points
- Insulated vapor cover

Operational Parameters





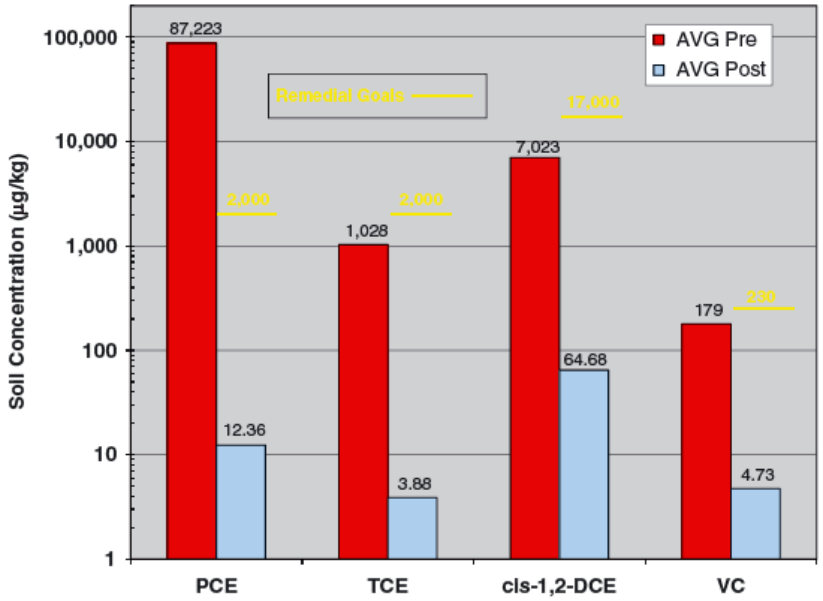
- 110 days of heating followed by 17 days of post treatment extraction (127 days total)
- 2.200.000 kWh of energy added
- 428 kWh/m^3 (330 kWh/m^3 more typical)

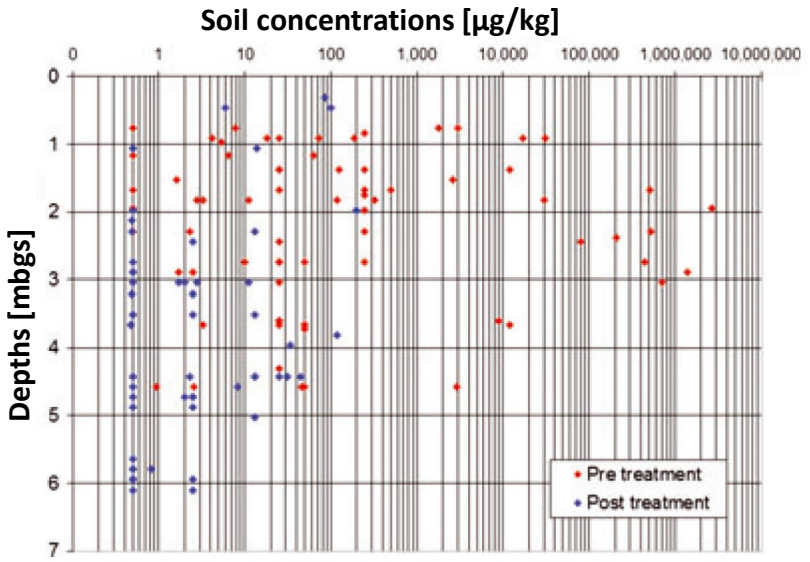
- Average temperature above 100 C
- 636 pore volumes of steam
- 2,820 kg of contaminants removed

Results - Soil

Soil Sample Data from Before and After ISTD Implementation. Percent Reduction Was Estimated Based on the Listed Concentrations

		PCE (µg/kg)	TCE (µg/kg)	*cis*-1,2-DCE (µg/kg)	VC (µg/kg)
Remedial goals		2000	2000	17,000	230
AVG	AVG Pre	87,223	1,028	7	179
	AVG Post	12.36	3.88	64.68	4.73
	No. of samples	54	64	41	63
	% Reduction AVG Pre to Post	99.99%	99.62%	99.08%	97.36%
MAX	Max pre	2,700,000	33,000	87,000	3300
	Max post	200	100	1,500	24
	% Reduction max pre to post	99.99%	99.70%	98.28%	99.27%





Post treatment bay mud still wet or moist (41% boil off)

Wellfield

Wellfield Infrastructure

Conclusions

- Thermal can be performed in all geologies from permeable sand and gravels, tight silt and clays and saprolite as well as fractured and competent bedrock systems.
- In low-permeable materials only TCH and ERH are effective.
- Reduction of > 99% are typically achieved for VOC contaminations
- Typically, thermal remedy duration between 4 and 6 months for VOCs

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