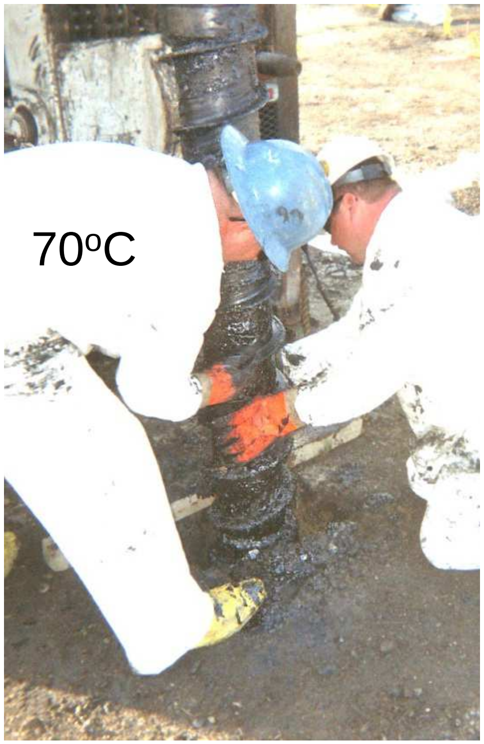
Thermal remediation of LNAPL



Level 1

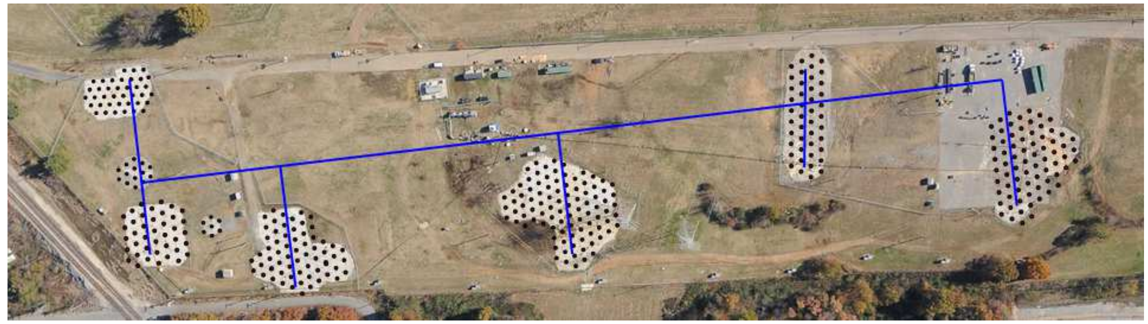
Level 2

Level 3

Gorm Heron, Jim Galligan, Steffen Nielsen
TerraTherm, Inc.

In Situ Thermal Treatment

1. Size
   - Many boreholes
   - More than 5,000 ft^2
   - More than 3,000 cy
   - Deeper than 10 ft



2. Organics, mass
   - Source areas
   - We love CVOCs
   - Large mass – DNAPL
   - Heavy decon

3. Driver

Visalia Pole Yard -SEE

Creosote DNAPL to +140 ft depth

Alluvial sands and gravels with clays

Both LNAPL and DNAPL

160,000 gallons removed from subsurface

Superfund Site delisted

UC Berkeley – LLNL - SCE

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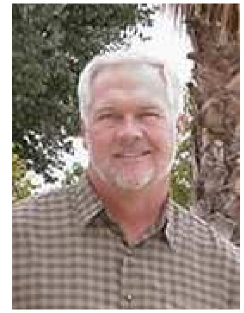
The Visalia design team leaders

Kent Udell

Robin Newmark

Roger Aines



Hank Sowers

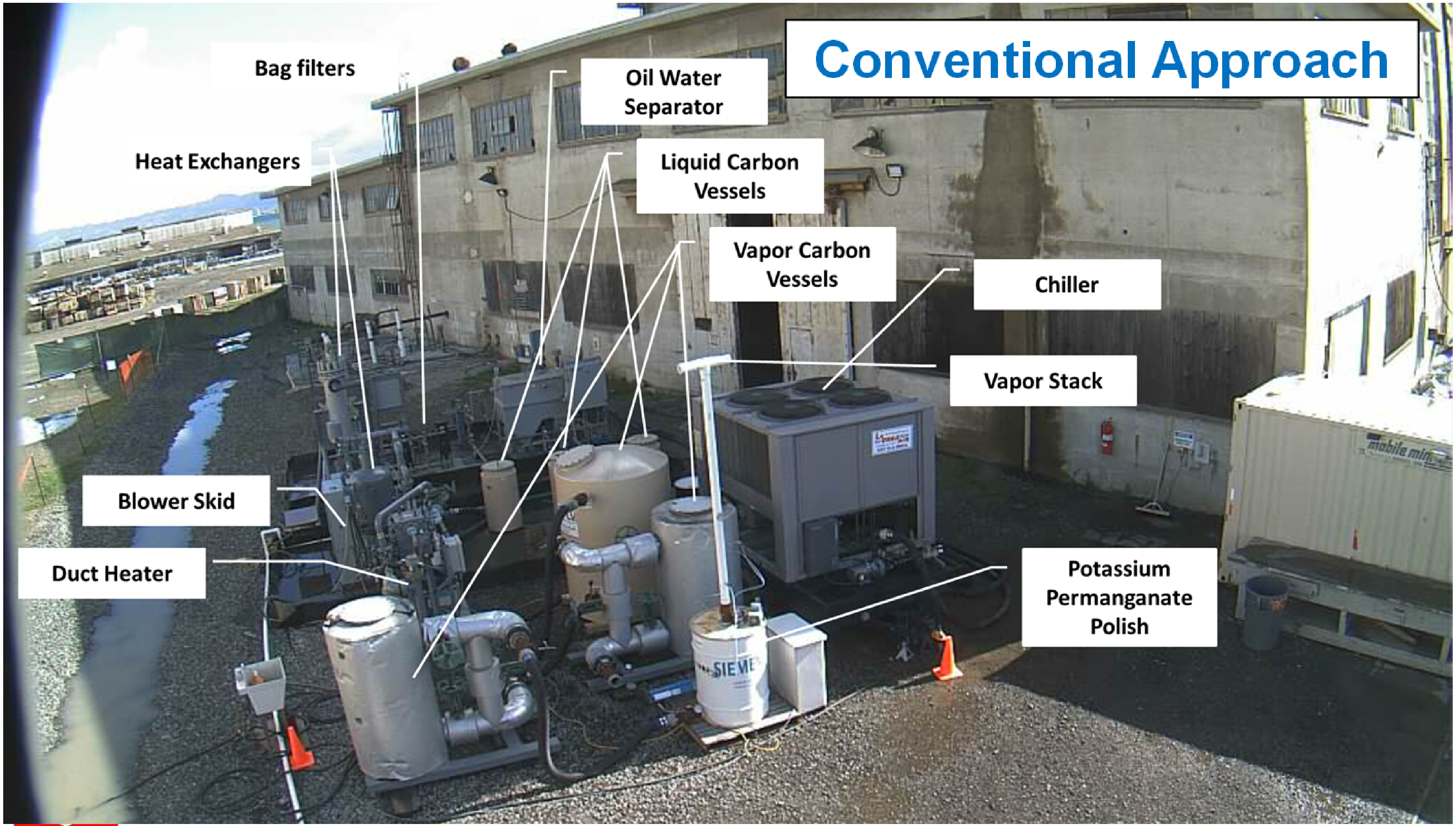
Kern River oil field

Modern ISTR site

Thermally enhanced oil field equipment

ISTR treatment equipment

From This…


Conventional Approach
Bag filters
Oil Water Separator
Heat Exchangers
Liquid Carbon Vessels
Vapor Carbon Vessels
Chiller
Vapor Stack
Blower Skid
Duct Heater
Potassium Permanganate Polish

To This…

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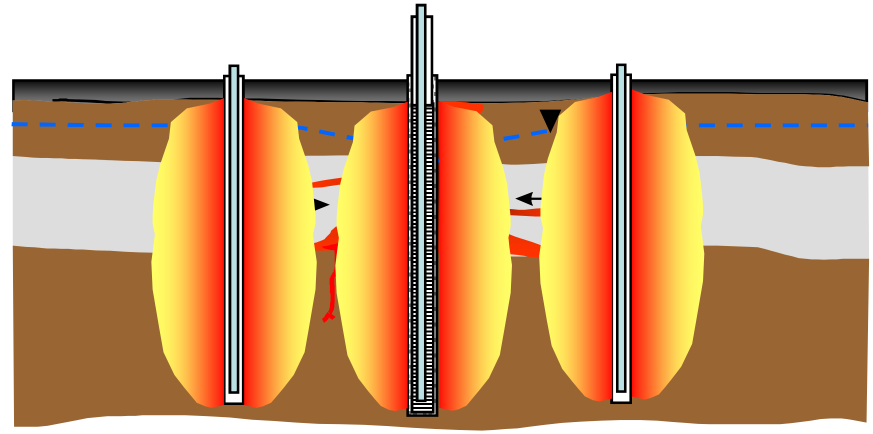
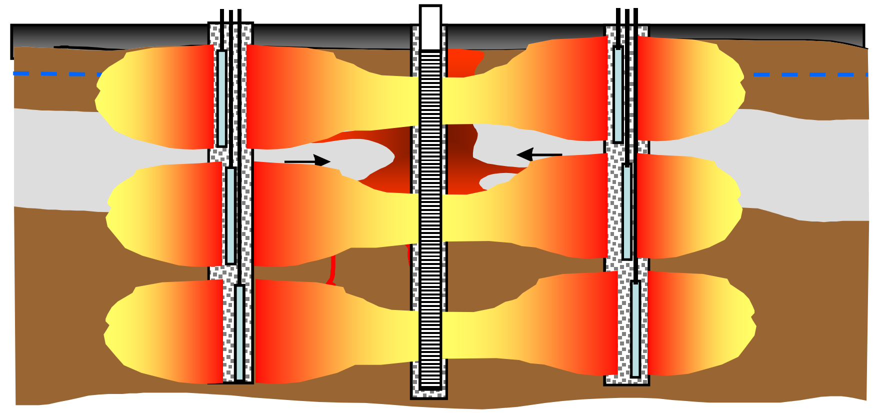
ISTR Technologies

TCH/ISTD - Heating governed by **thermal conductivity**



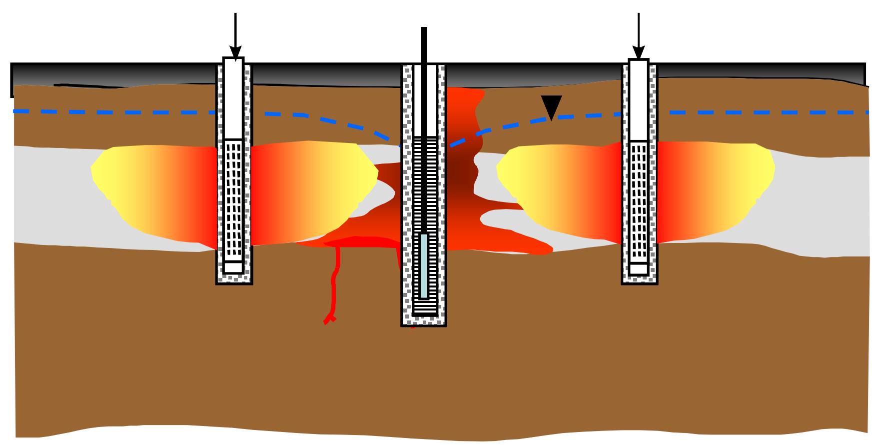
ET-DSP/ERH - Heating governed by **electrical conductivity**

(max temp = boiling point)



SEE - Heating governed by **hydraulic conductivity**

(max temp = boiling point)



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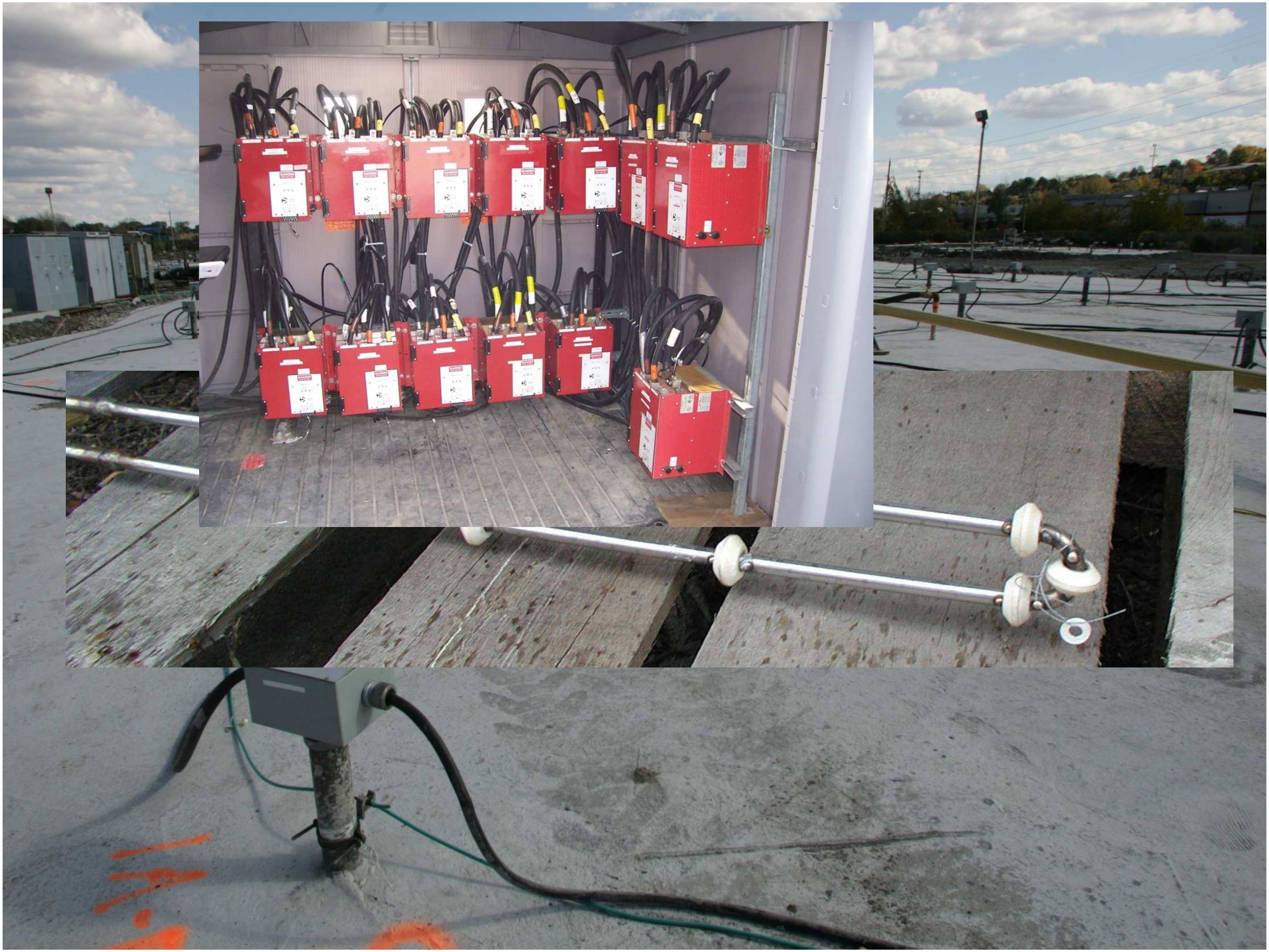


Lull
Hertz
888-777-2700
16 6:03 AM

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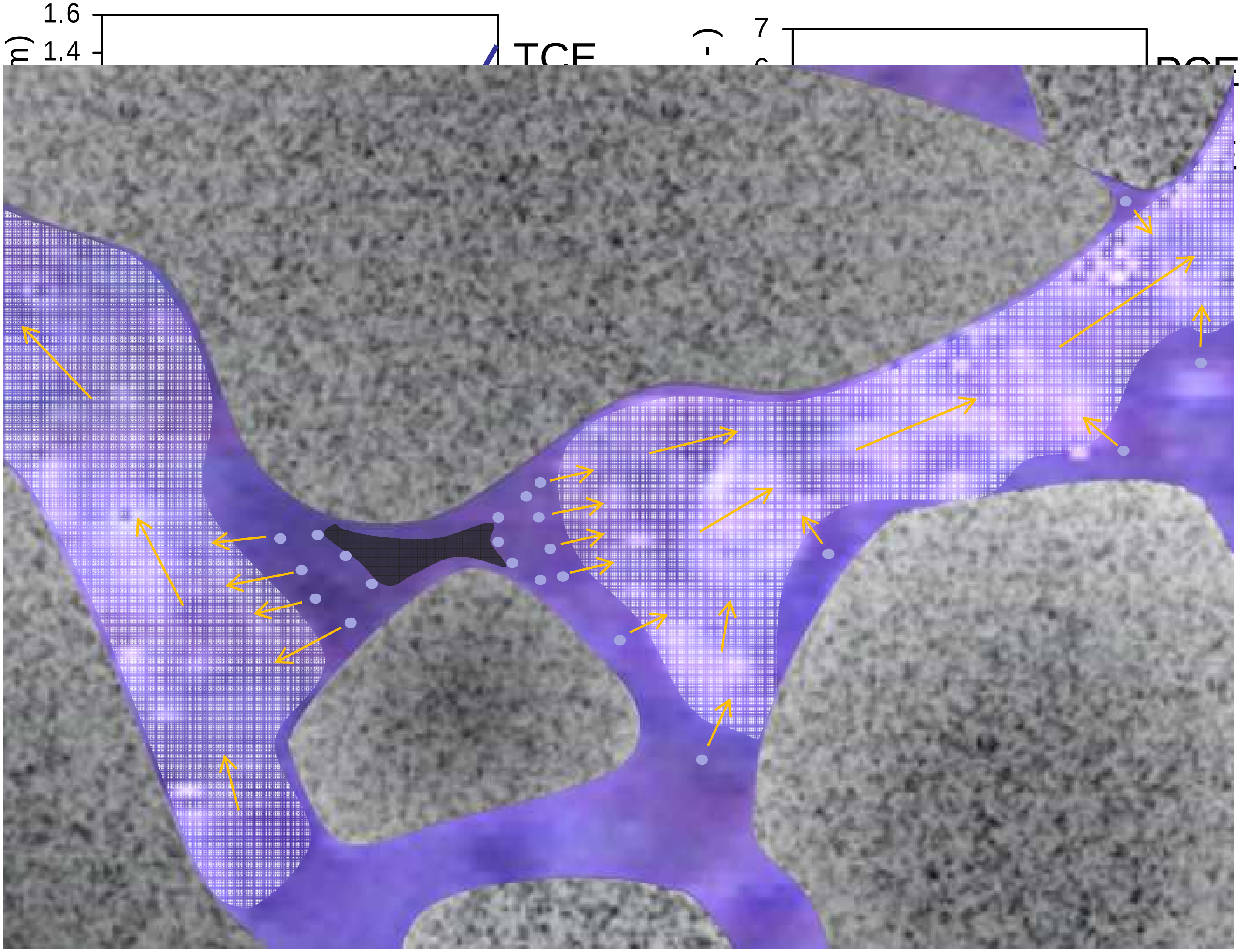
Mechanisms – for VOCs



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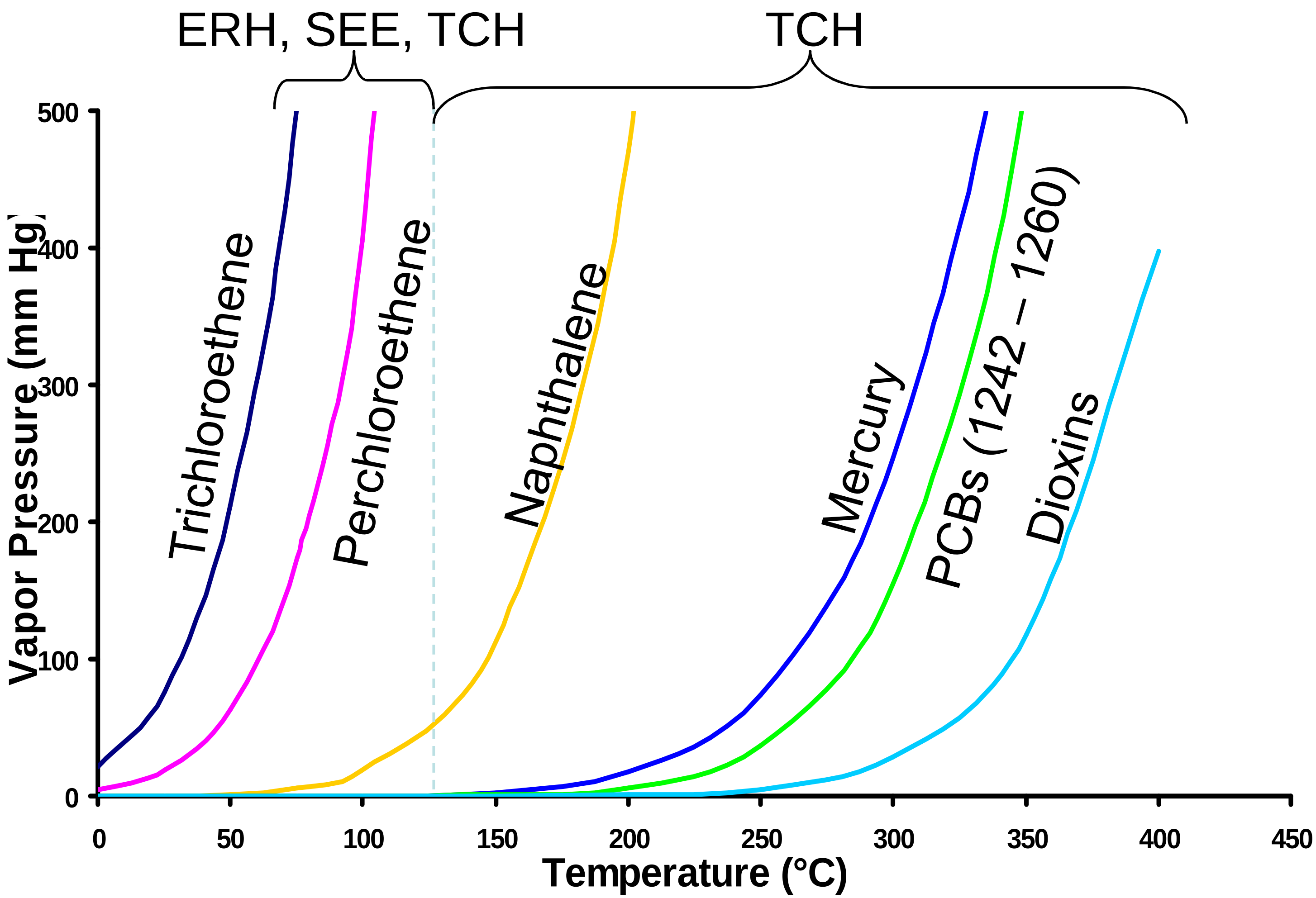
Vapor Pressure vs. Temperature



Vapor pressures increase exponentially with temperature

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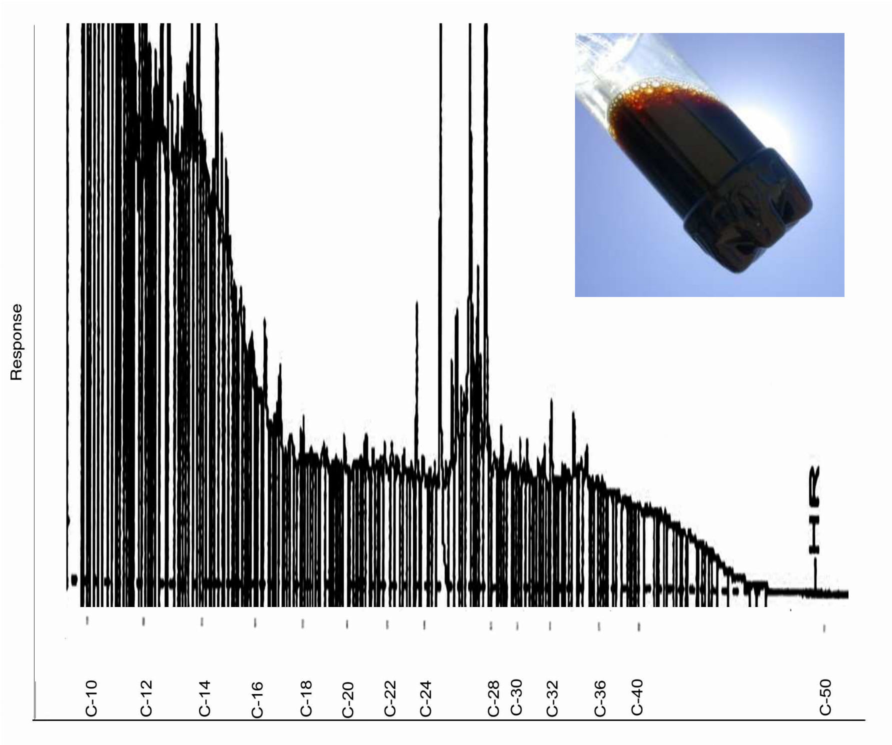
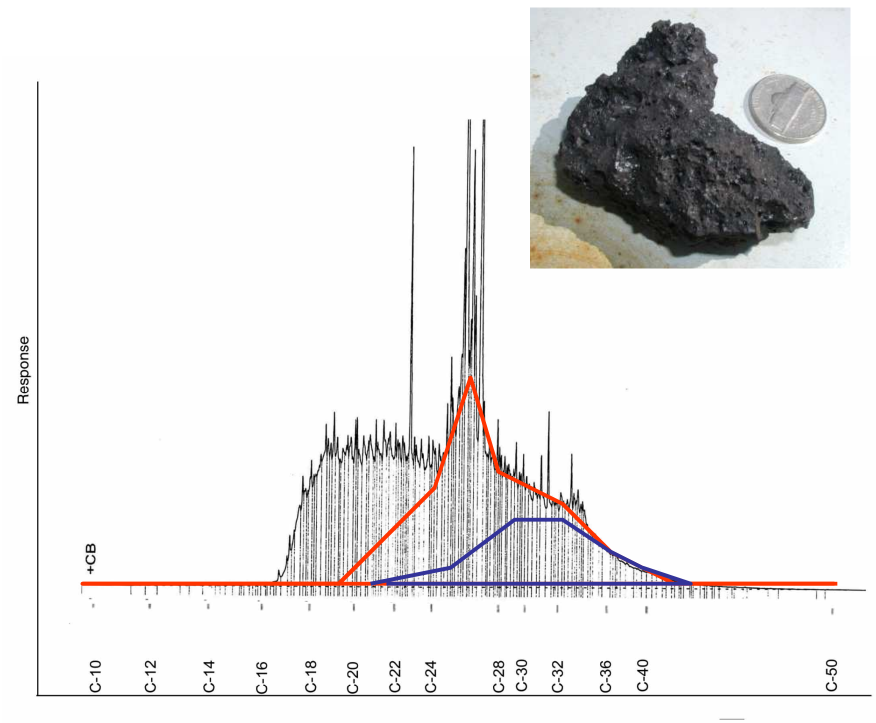
Light ends are removed at 100 ^{o}C or higher

Typical Soil Chromatogram
Before SEE

Soil Residual Chromatogram
After SEE





Chromatograms from TPH analysis of soils from Alameda Point, CA (Udell et al. 2000)

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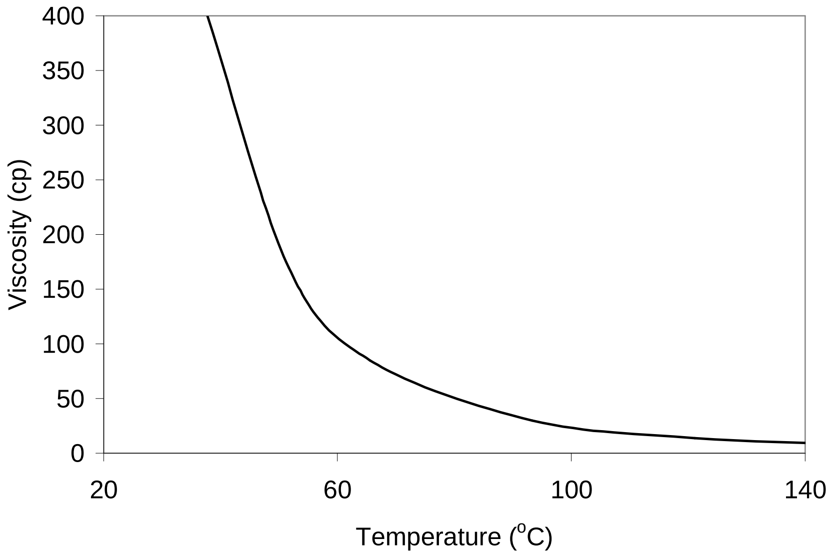
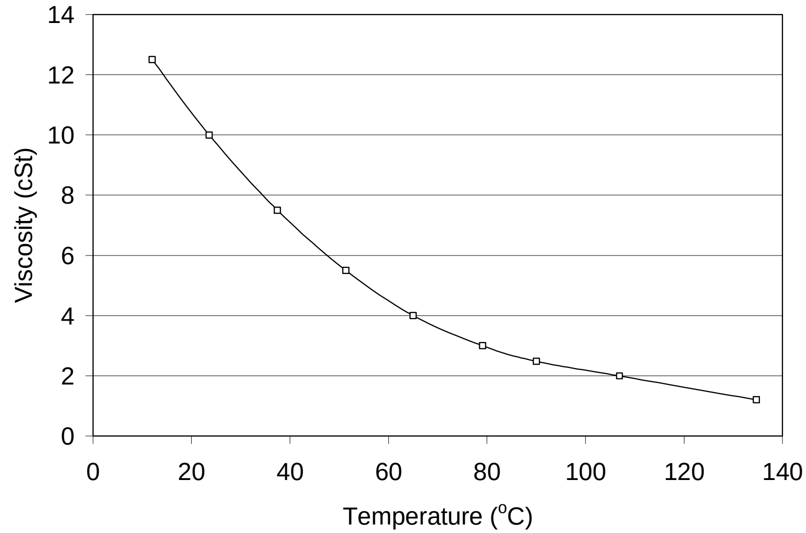
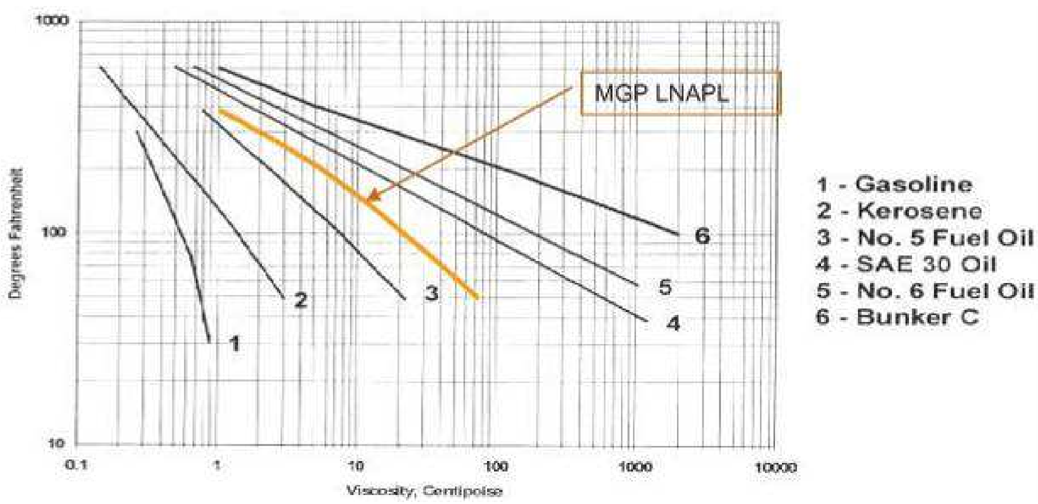
Oils - Viscosity reduction

Fuel oil, 14 gravity



No. 5 fuel oil





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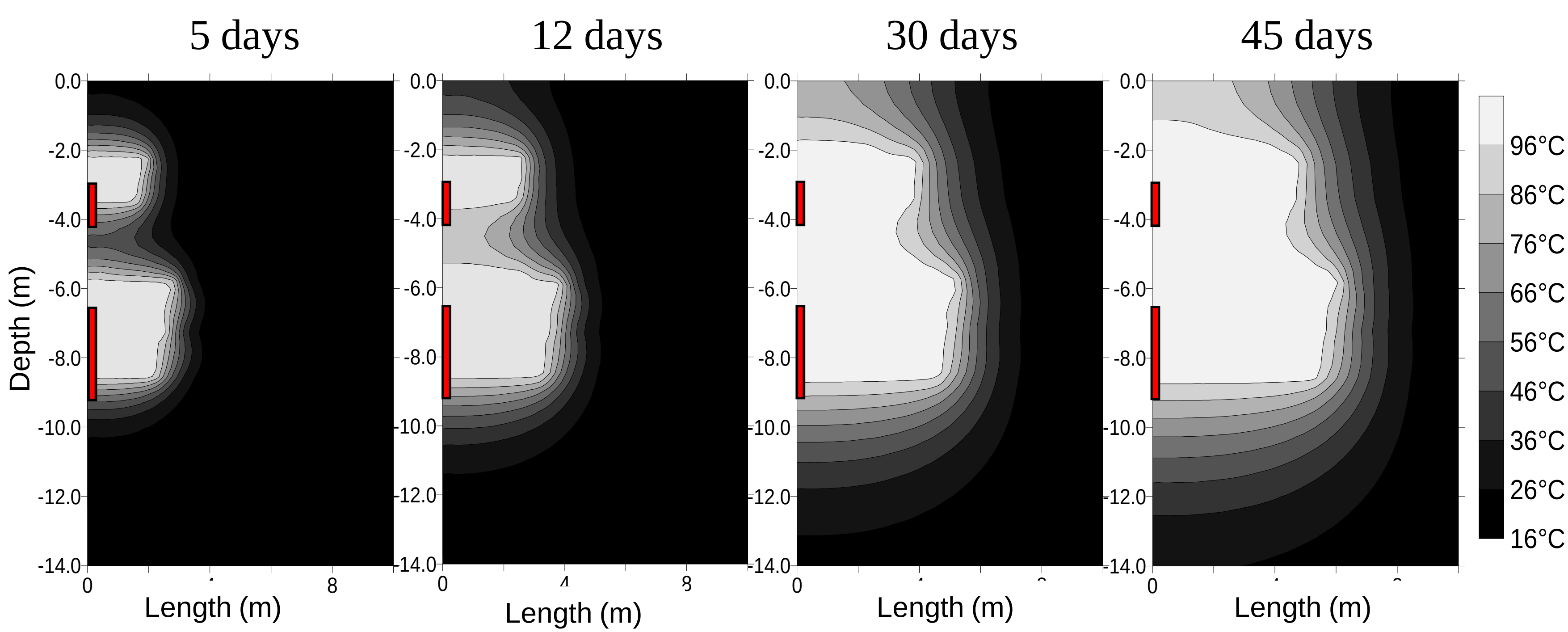
Example steam modeling



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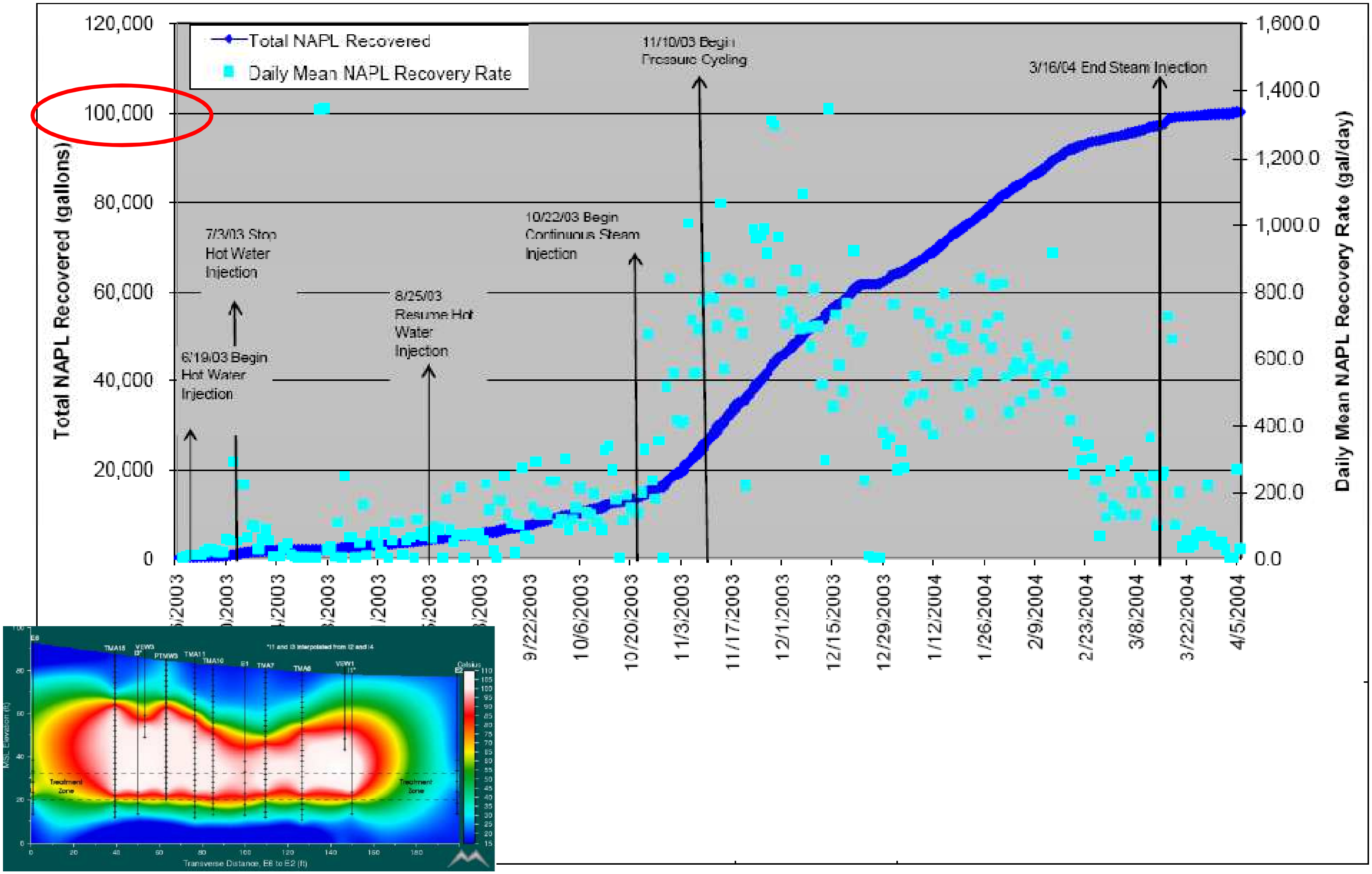
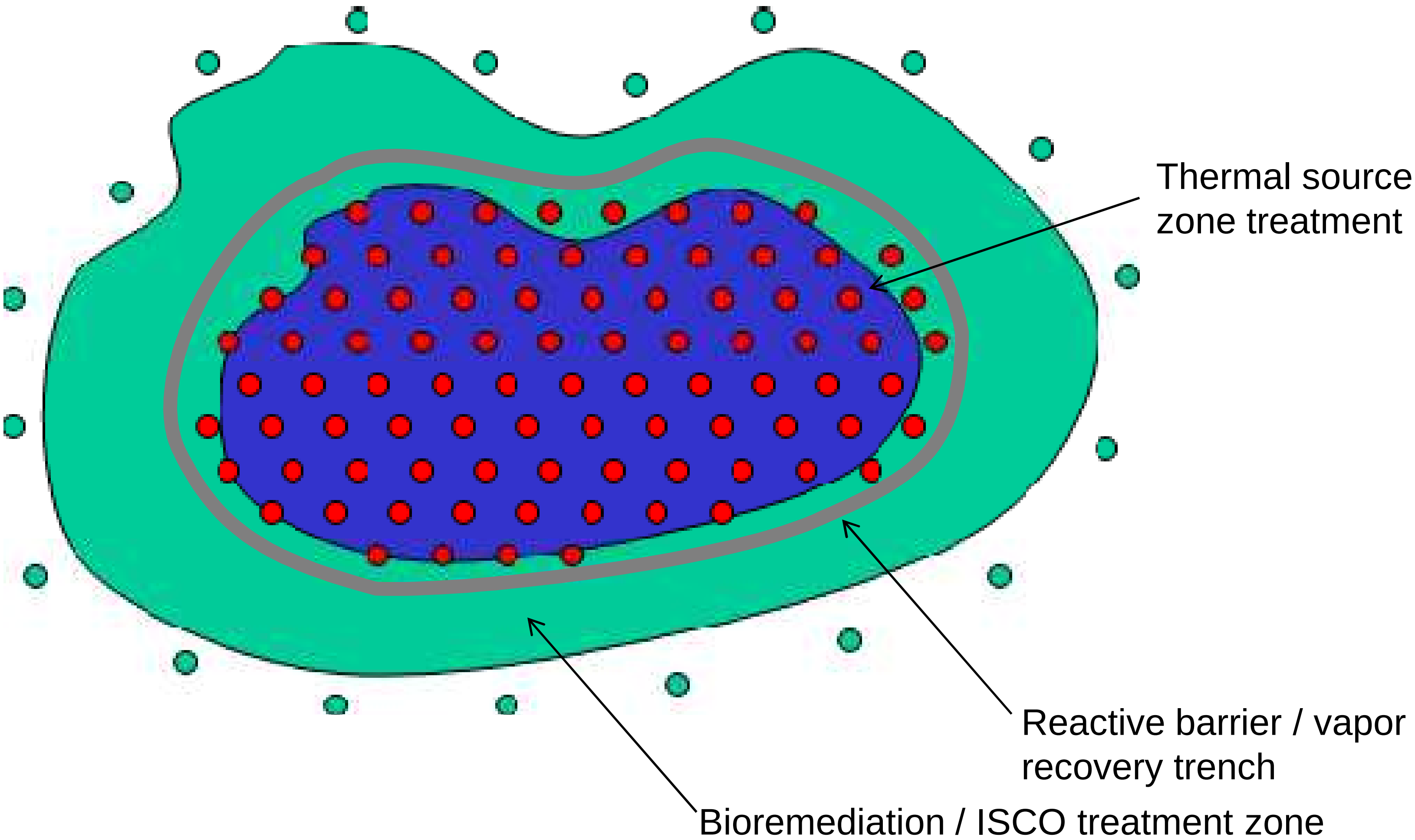
Guadalupe project – Diluent and crude oil

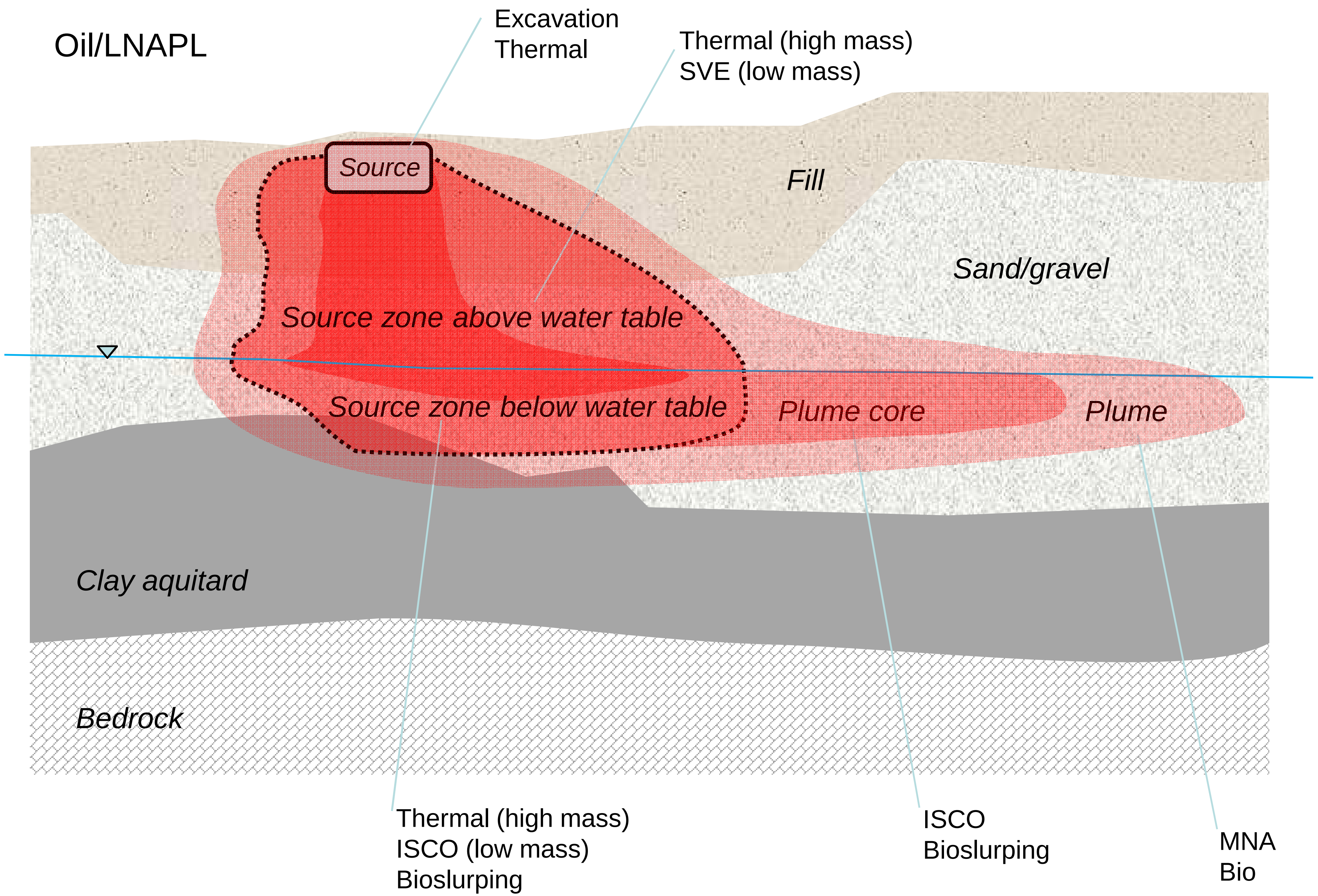


Basics

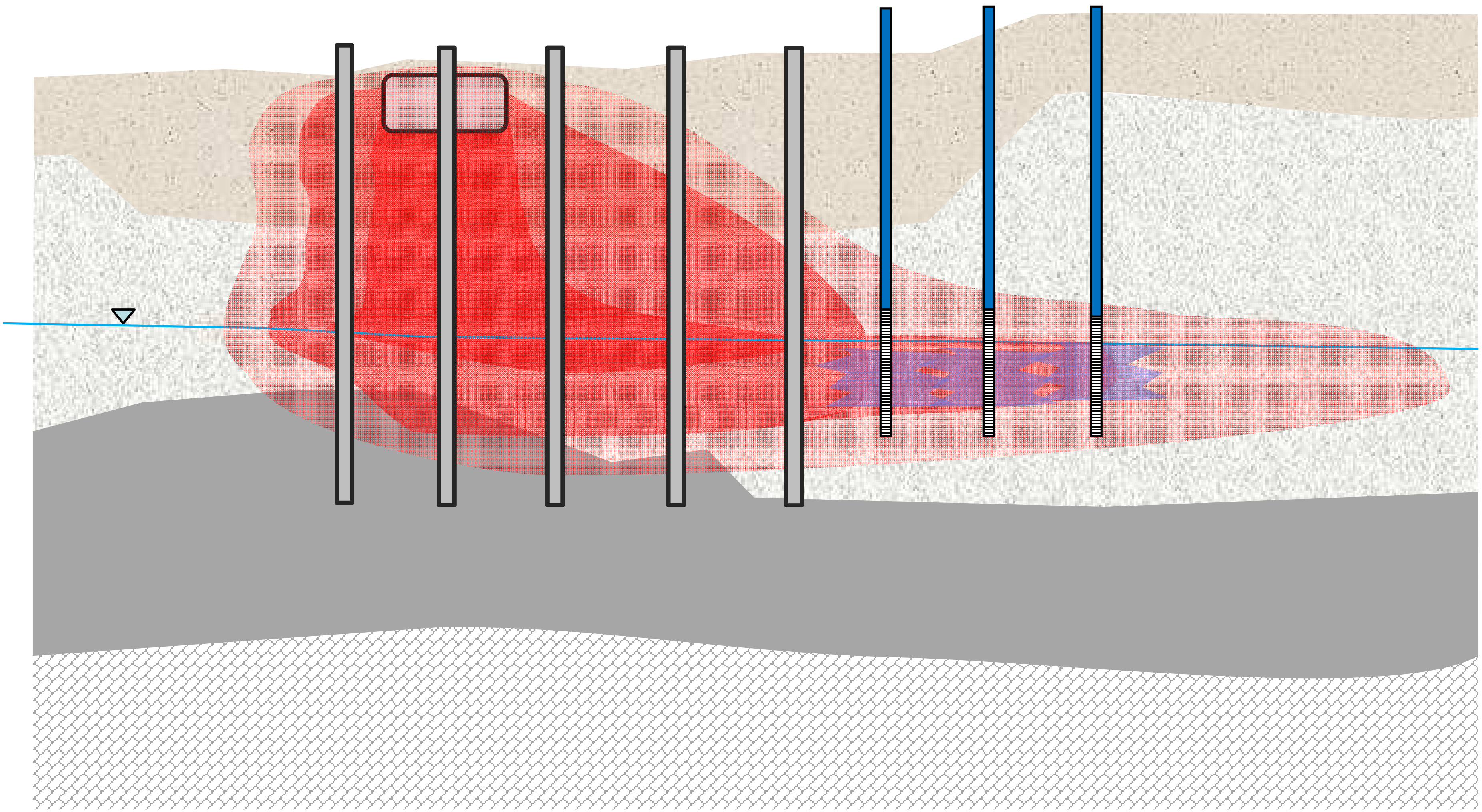
- NAPL zone has to be defined in 3D
  - Top
  - Bottom
  - Perimeter
- Mobilized NAPL must be captured
  - Hydraulic control
  - Pneumatic control

Combined Remedies




Oil/LNAPL
Excavation
Thermal
Thermal (high mass)
SVE (low mass)
Source
Fill
Sand/gravel
Source zone above water table
Source zone below water table
Plume core
Plume
Clay aquitard
Bedrock
Thermal (high mass)
ISCO (low mass)
Bioslurping
ISCO
Bioslurping
MNA
Bio

Combined remedy for LNAPL - example



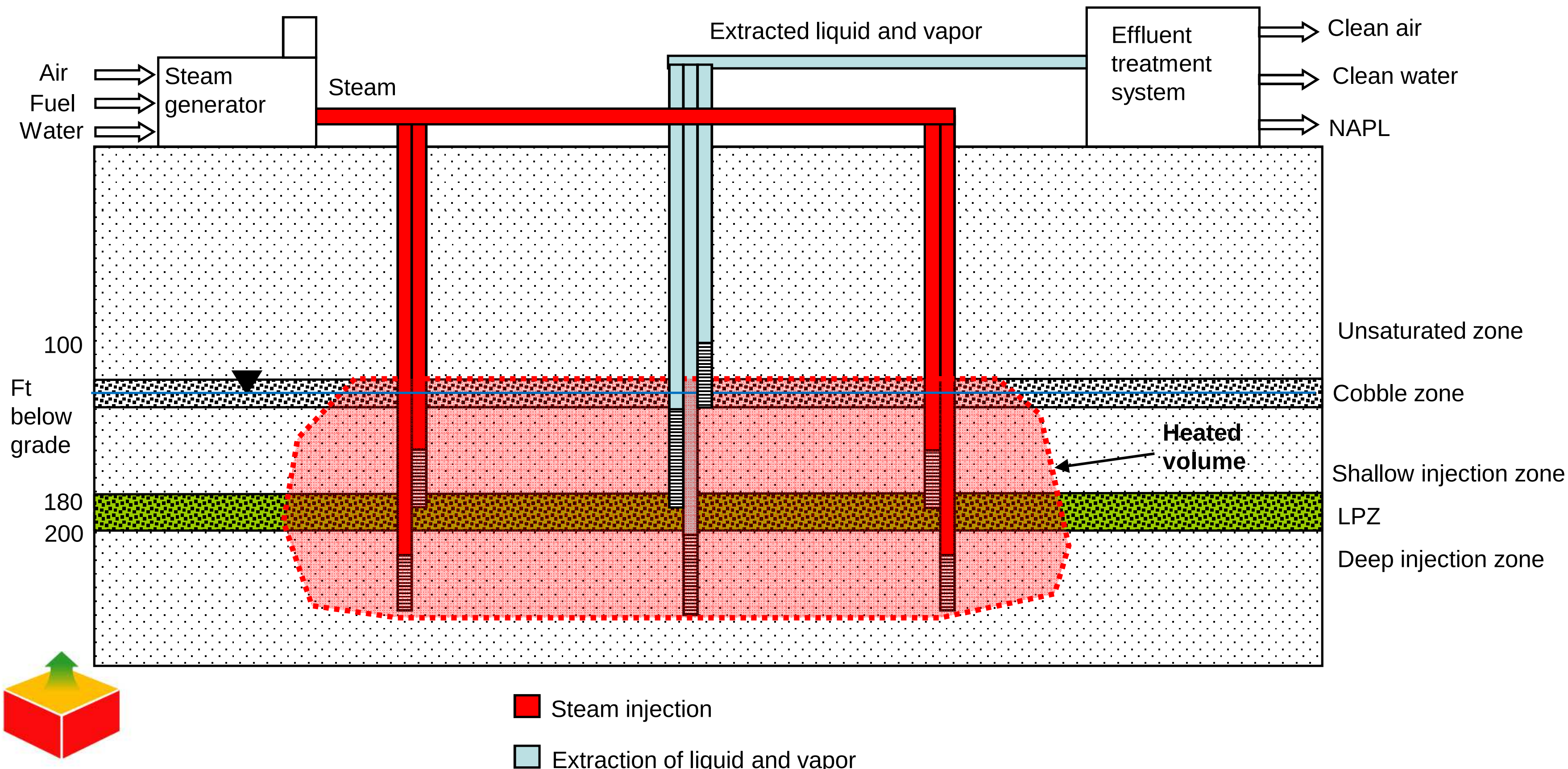
Thermal source treatment
ISCO treatment of plume core/residuals
MNA in plume

How much energy is in the ground?

	Completed projects				Imaginary	
	Visalia Pole Yard	Guadalupe RP	Young-Rainey A	Alameda Point	Refinery	
	Creosote	Oil spill	Solvents	TCE and oil	Oil on water table	
	Dip tanks and pipes	Tank overflow	Buried waste and surface spills	UST leak	Multiple sources	
Heated volume	400,000	20,000	14,000	3,000	100,000	cubic yards
Steam injection rate	20,000	6,000	4,000	1,000	10,000	lbs/hr
Power draw for process	1,000	200	125	50	250	kW
Duration	1,000	147	135	60	360	days
Mass removed	1,000,000	650,000	5,000	4,800	*9,750,000*	lbs
BTU value	12,500	8,125	63	60	122,000	million BTU
Energy injected	480,000	20,746	12,960	1,440	86,400	milion BTU
Vapor rate	3,000	1,000	500	150	1,000	scfm
Water rate	400	139	50	3	100	gpm
Energy added per unit volume	1.20	1.04	0.93	0.48	0.86	million BTU/cy
NAPL energy content per volume	0.031	0.406	0.004	0.020	1.22	million BTU/cy
Fraction of energy in NAPL/used	0.03	**0.39**	0.005	0.04	**1.41**	(-)

Sites with large oil mass and CVOCs are prime targets for optimization

Traditional design



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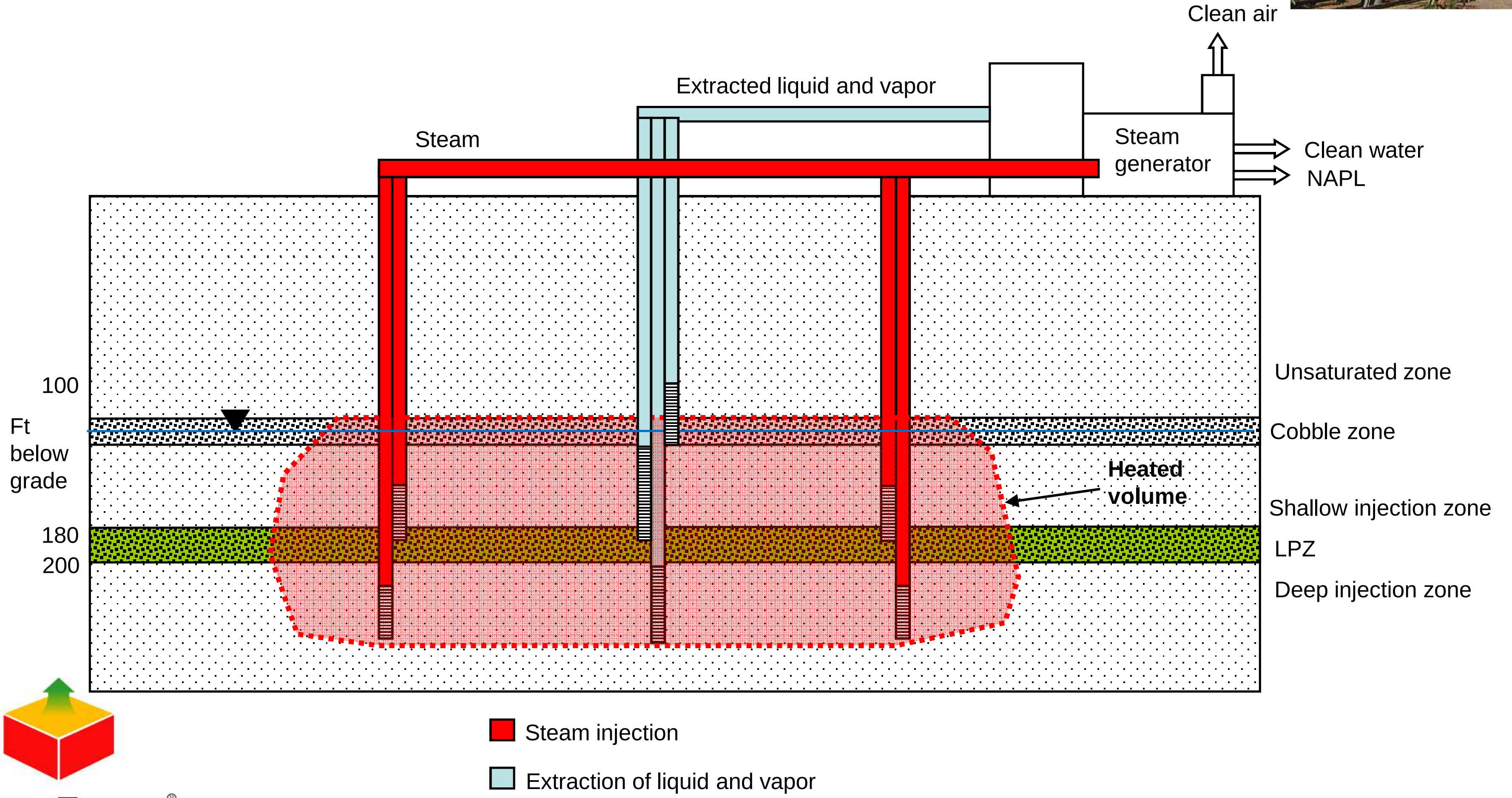
New design



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Summary – thermal remediation of LNAPL

Can remove risk associated with LNAPL and meet site-specific remedial goals

Thermal technologies maturing

Options for optimization/sustainability

Level 1

Level 2

Level 3

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