



# ***Thermal Remediation***

## ***Electrical Resistance Heating (ERH)***

# Contents



- Introduction
- What is Electrical Resistance Heating (ERH)?
- Why ERH?
- Application Area's
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# *Introduction (1)*



The Electrical Resistance Heating (ERH) technology was developed by U.S. Department of Energy's Pacific Northwest Laboratory in the 1980s.

TRS Group was founded in 2000 to commercialize the ERH Technology and is the premiere provider of ERH.

TRS have performed over 80 ERH projects to date in North America

In 2012 HMVT started a Joint Venture with TRS to introduce the technology in Europe

# ***Introduction (2)***

## ***Why ERH for Europe***



### **‘Contact Sports’**

Extractive Techniques  
Chemical Techniques  
Biological Techniques

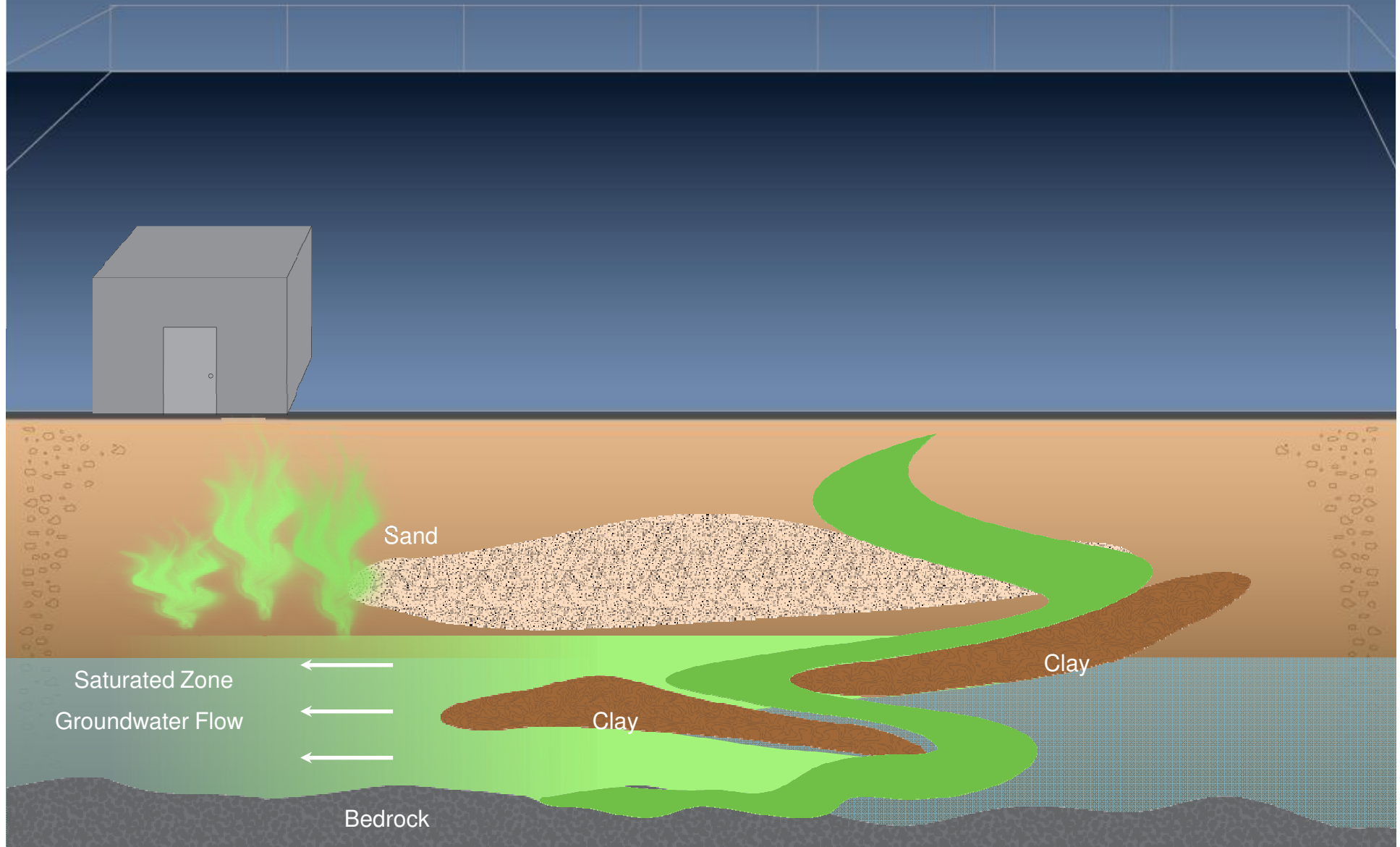
Electrical Resistance Heating **is not** a contact sport

The beauty is: the heat gets everywhere

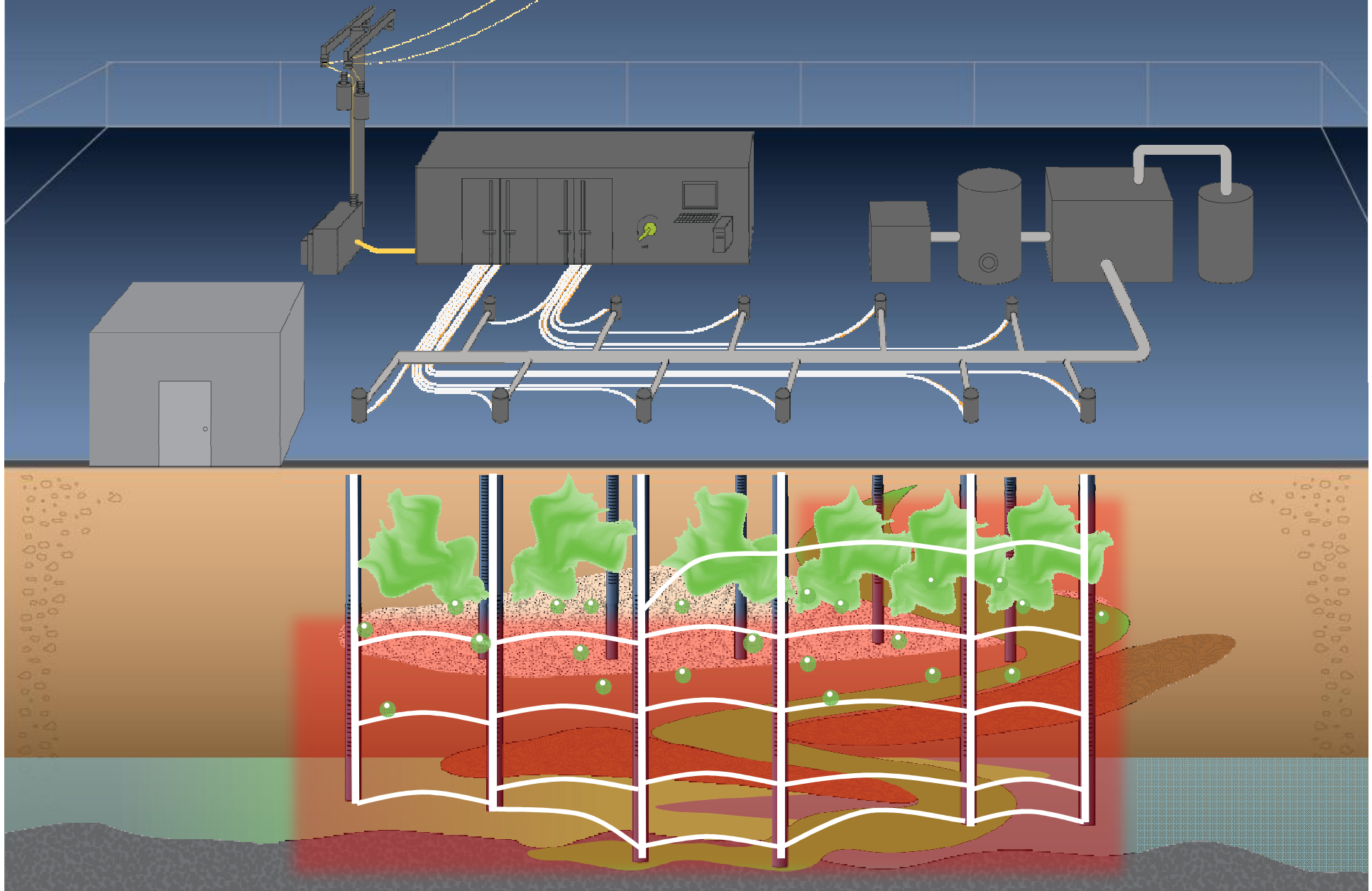
Regardless of sand, loam or clay layers

**The Result:** fast & robust removal of hot spot area's  
(e.g. Dnapi)

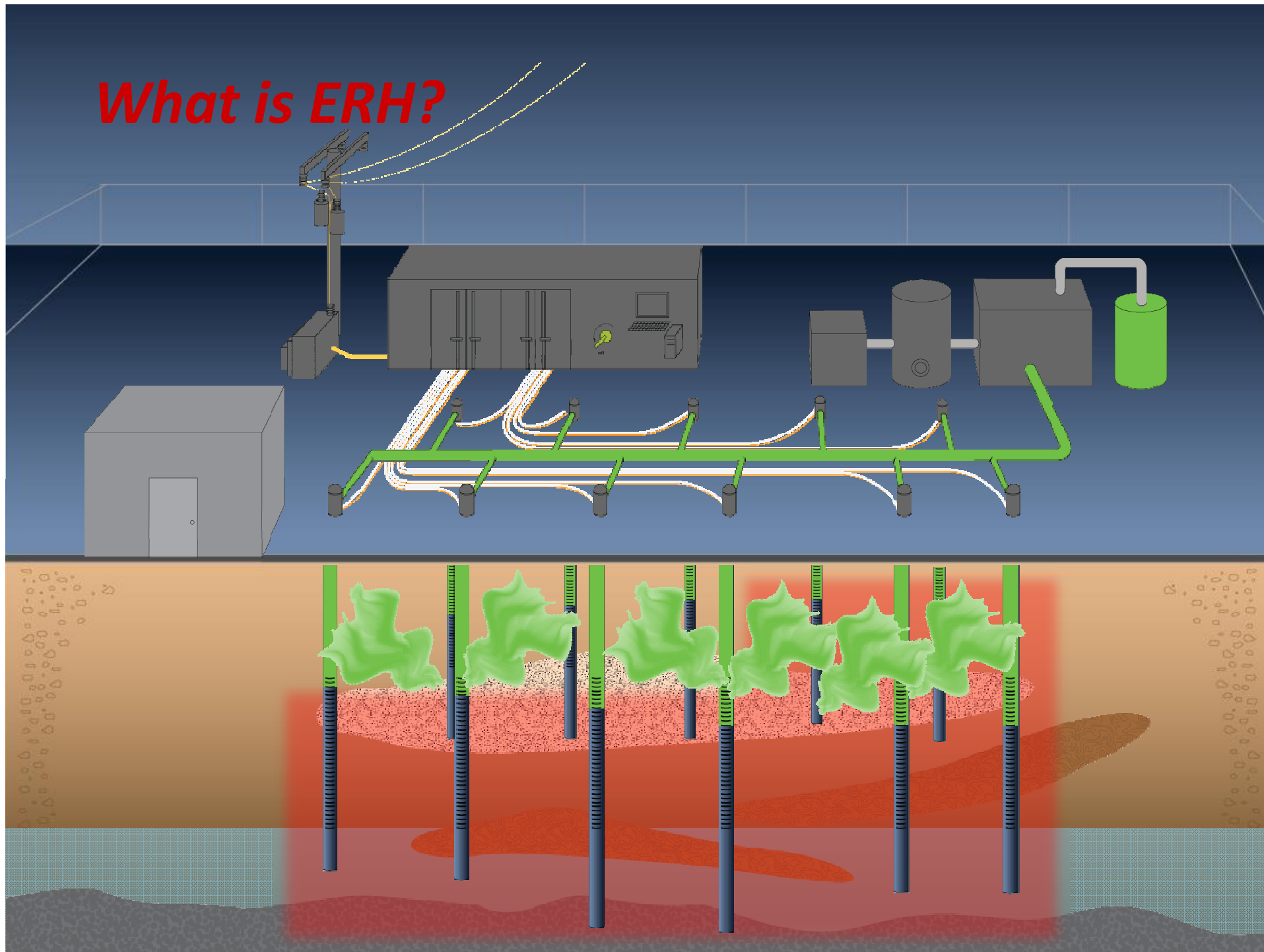
# *What is ERH?*



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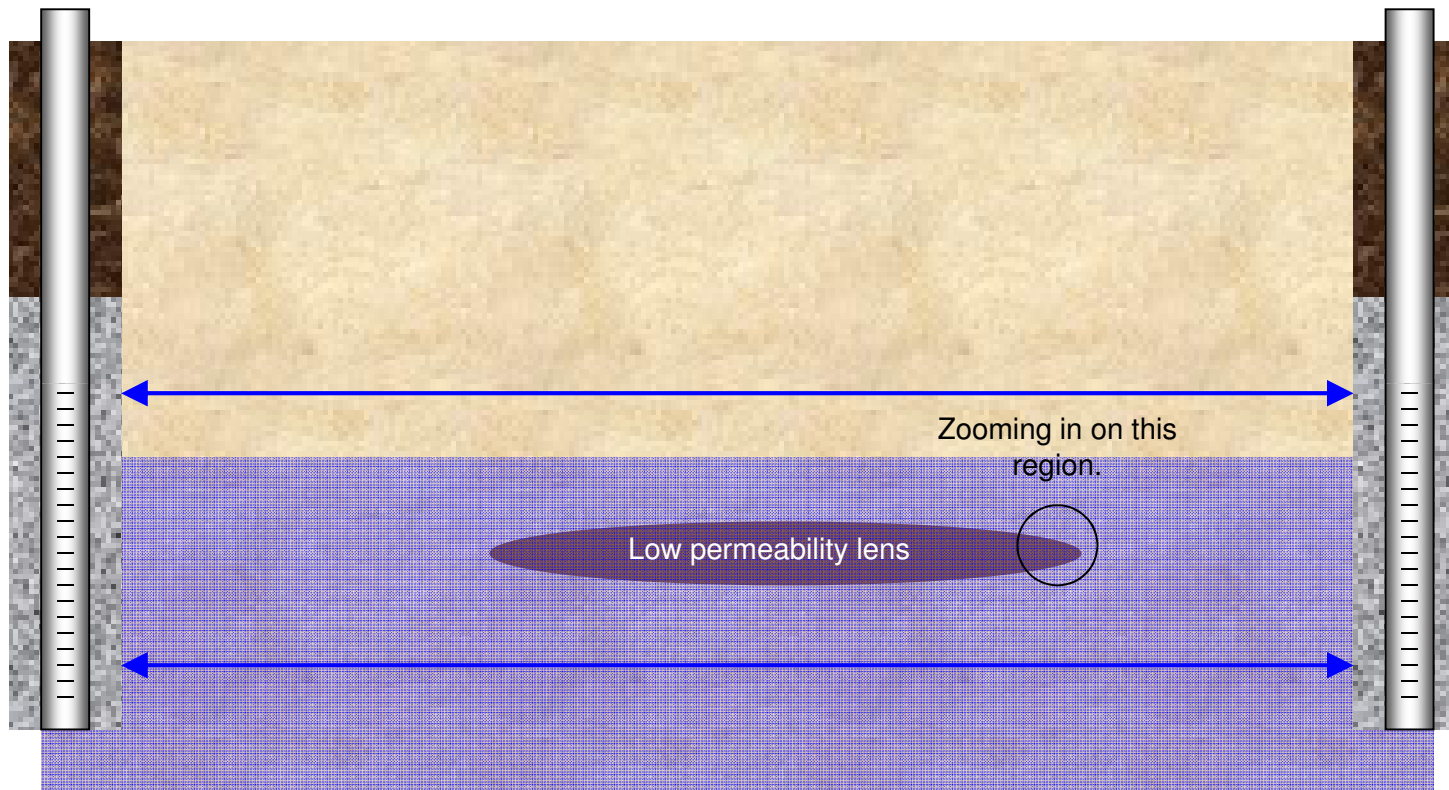
# *What is ERH?*





# ***What is ERH?***

## ***In-Situ Steam Generation***

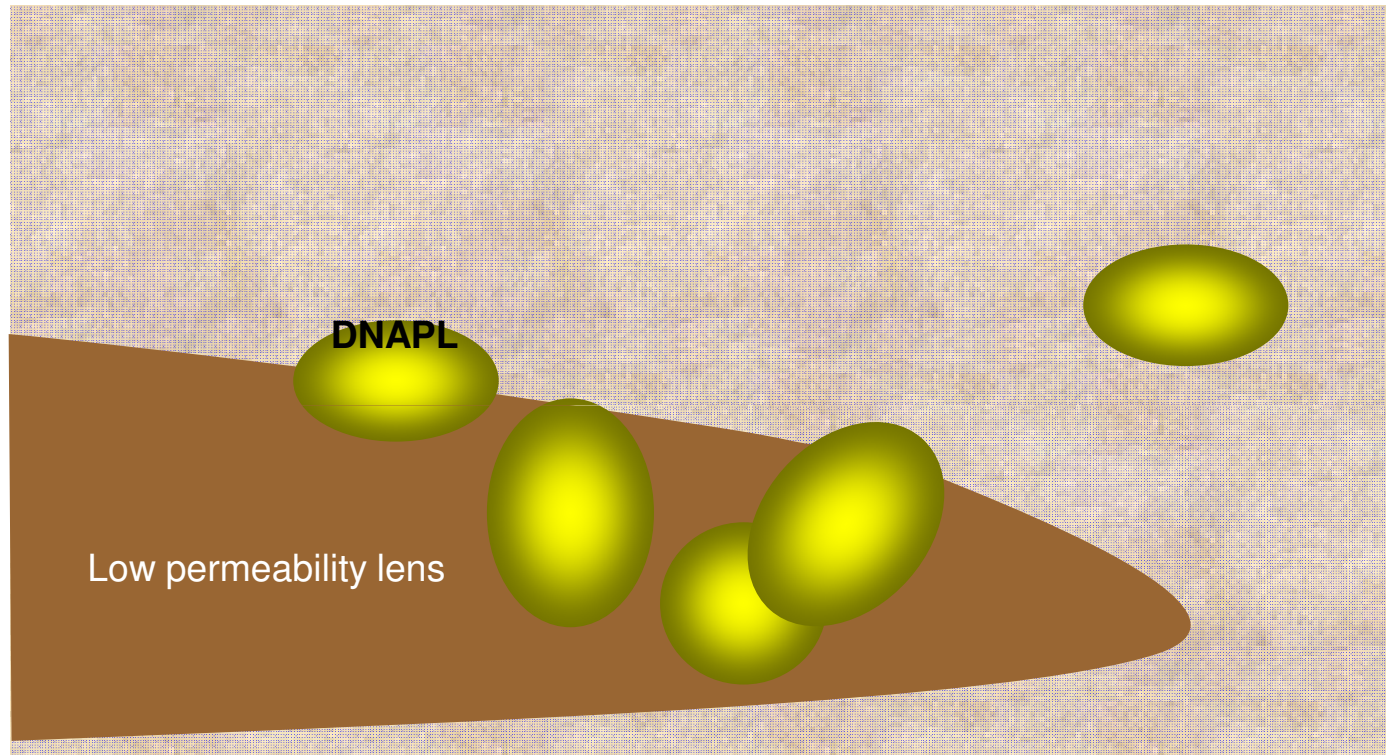


**Current flowing between electrodes heats soil directly**



# ***What is ERH?***

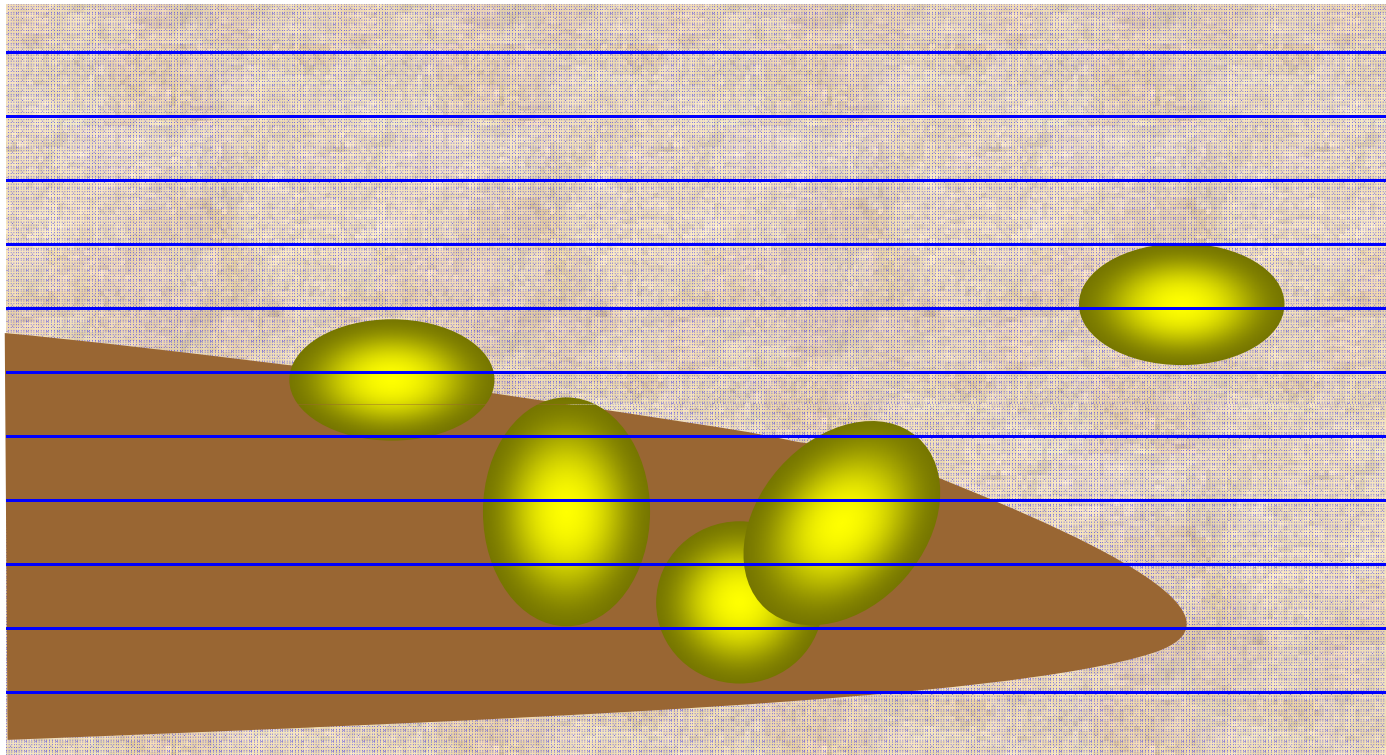
## ***In-Situ Steam Generation***



**Reductive dehalogenation creates a “halo” of  
chloride ions in CVOC hot spots**

# ***What is ERH?***

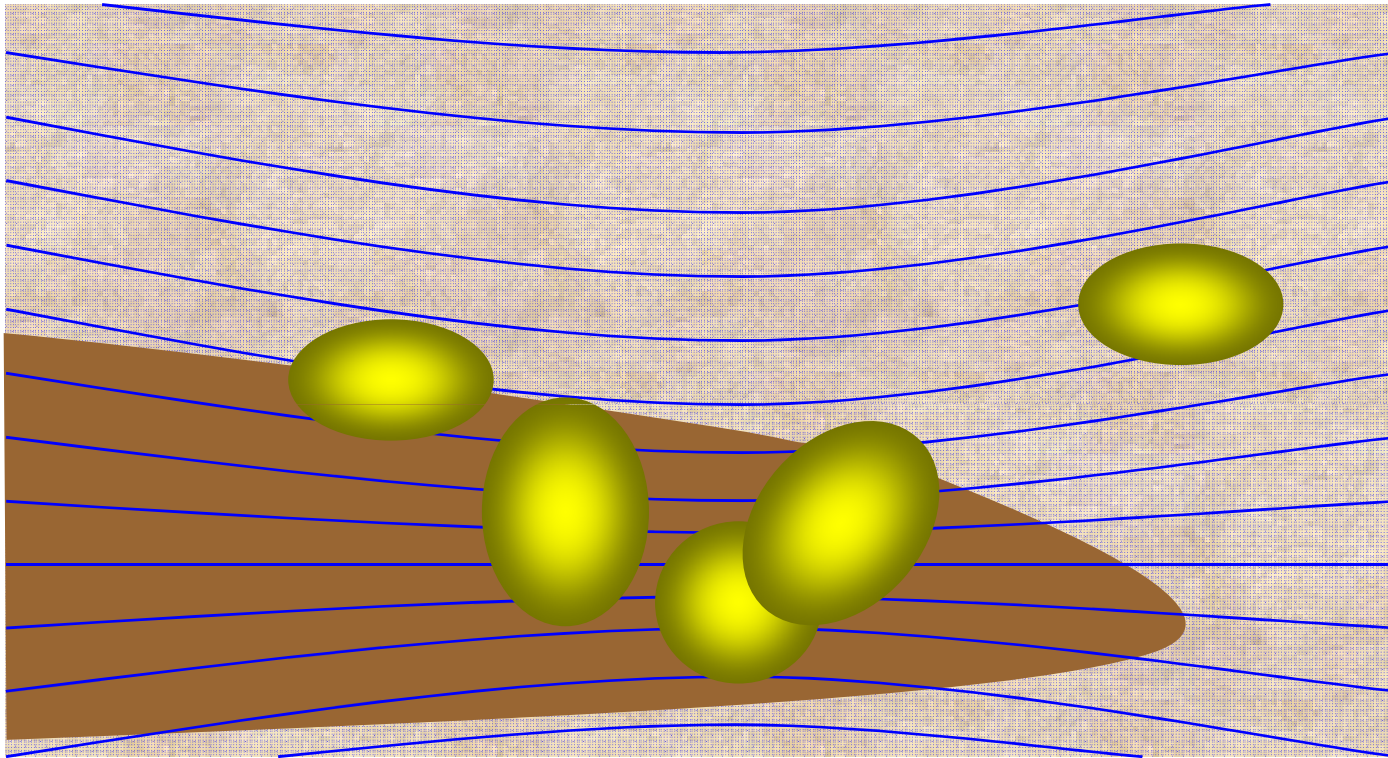
## ***In-Situ Steam Generation***



Uniform soils would lead to parallel ERH current lines –  
but soils aren't uniform

# ***What is ERH?***

## ***In-Situ Steam Generation***



**Low permeability lenses and CVOC hot spots attract current**

# ***What is ERH?***

## ***In-Situ Steam Generation***

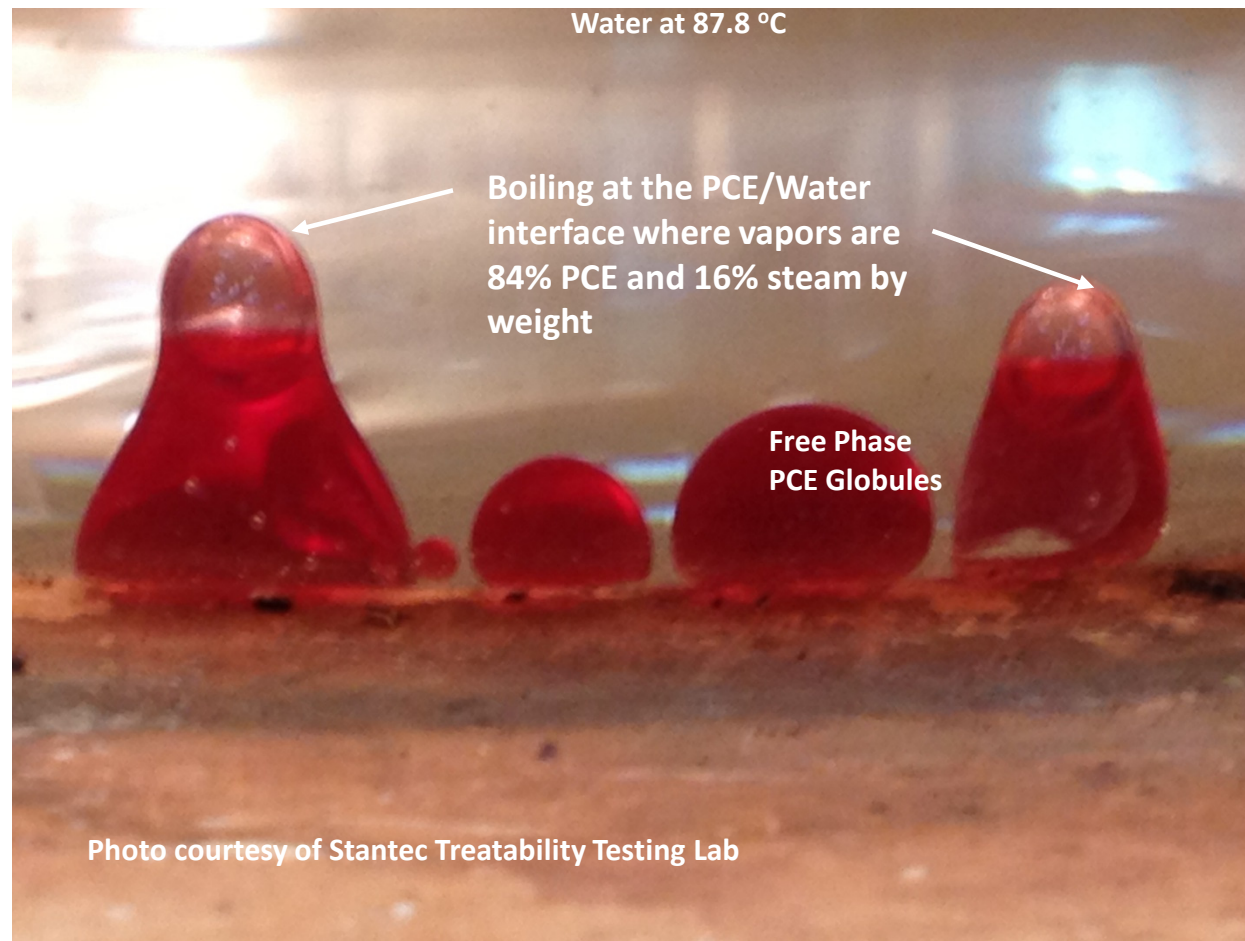


Regions with higher current density heat slightly more quickly.

Steam bubbles form more quickly at NAPL due to interfacial tension and reduced boiling temperatures.

# What is ERH?

DNAPL Addressed First in ERH by Azeotropic Boiling



# Why ERH?



Proven to be **very effective:**  
removal rates of over **99%** on  
dnapi hotspots!

**No rebound**

Heating is rapid and thorough

no soil desiccation

Proven to be **safe**



# *Application Area's*



In-situ soil and groundwater

Heterogeneous sites

VOC and semi-VOC's

DNAPL / LNAPL

Combination with other techniques

Solid grease or oil tar as NAPL



# *Typical ERH site*



## Remediation Parameters

Size	20 m <sup>2</sup> – 1,3 hectare
Depth interval	0 – 41 m bgs
Volume	30 – 150.000 m <sup>3</sup>
Unsaturated and saturated	Both
Days of operations	60 - 365
Electricity	Average 96%
Reduction achieved	88% - 99.999%
Price	75 – 350 Euro/m <sup>3</sup>
Guarantee fixed price	Possible

# ***Experience with ERH***

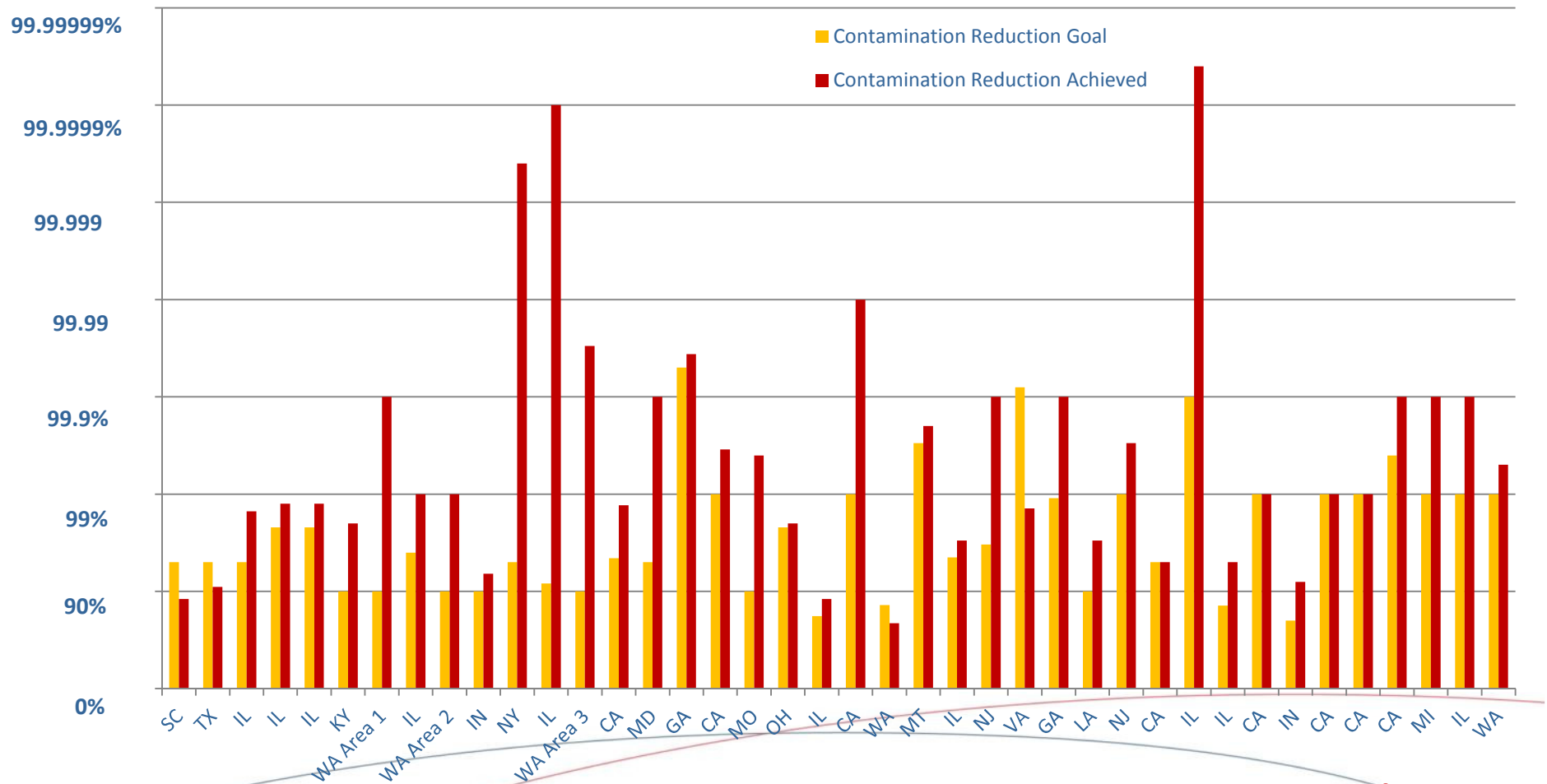
## ***Number of Projects***



trichloroethene (TCE)	34 sites
tetrachloroethene (PCE)	14 sites
diesel, gasoline, kerosene, grease	5 sites
methylene chloride (MeCl)	4 sites
benzene, xylene, toluene, ethylbenzene	4 sites
1,1,1-trichloroethane (TCA)	3 sites
dichloroethene (DCE)	multiple
vinyl chloride (VC)	multiple
1,1,2,2-tetrachloroethane (TeCA)	2 sites
1,2-dichloroethane (DCA)	1 site
ethylene dibromide (EDB)	1 site
1,2, dichlorobenzene and 1,4 dioxane	1 site
Naphthalene, oil tar	1 site

# Effectiveness of ERH

## Remedial Goals vs Reductions achieved



# ***Rebound***

## ***Positive post ERH Observations***



No Rebound – continued decline

Groundwater data after several years of 4 ERH projects:

- California – 2 sites
- Washington – 1 site
- Georgia – 1 site

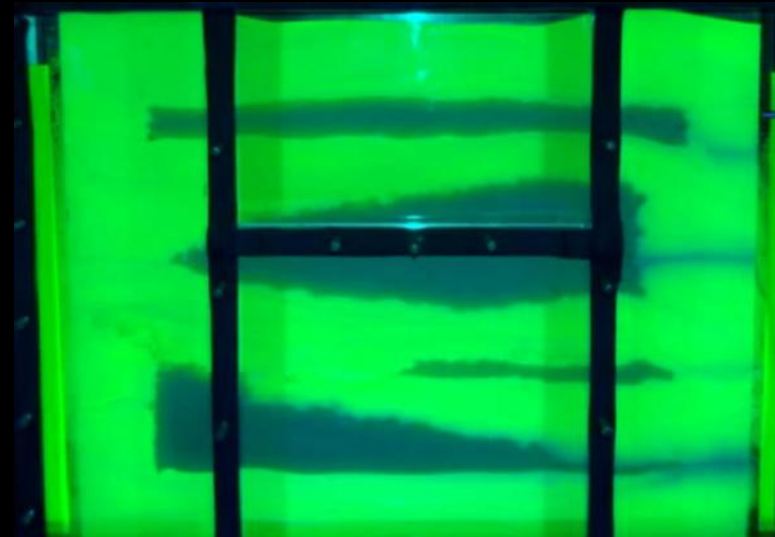
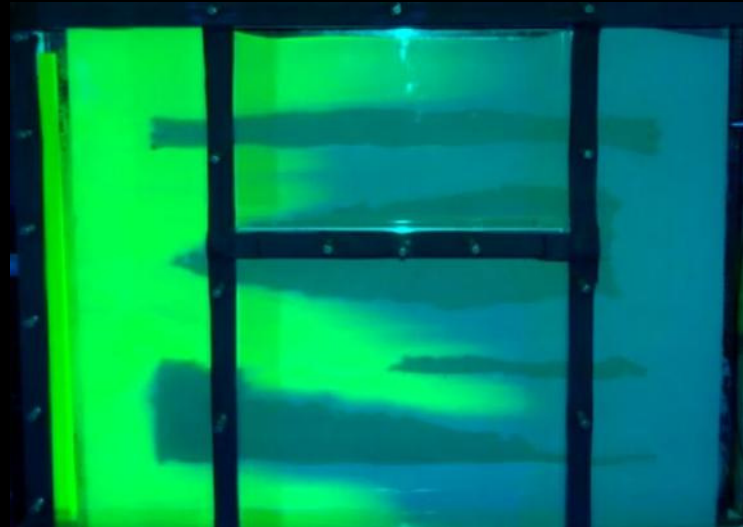
Attributable to thermally-enhanced mechanisms:

- Enhanced biodegradation
- Hydrolysis
- Abiotic reactions with soil mineralogy and/or
- Diffusion/dispersion

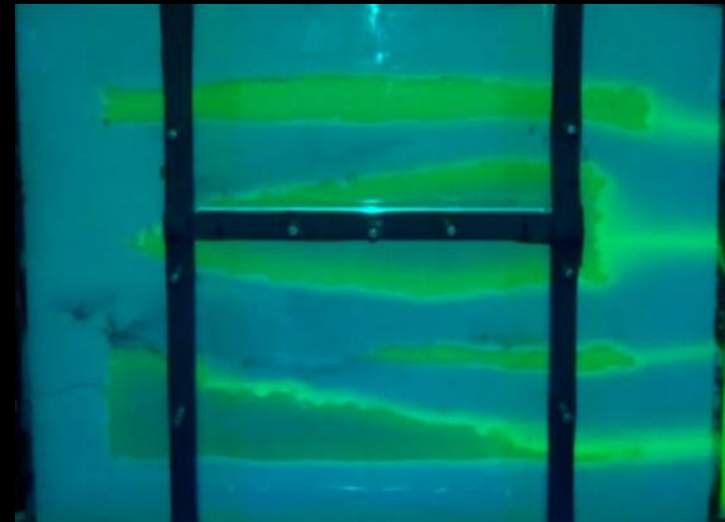
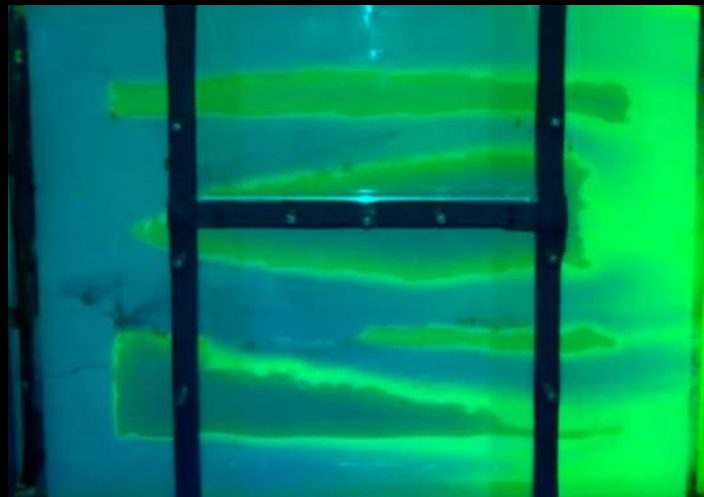
## ***Rebound***

*How likely is Matrix Diffusion after ERH?*

***Rebound:*** *How likely is Matrix Diffusion after ERH?*



**Fluorescein E into mixed heterogeneity system with low permeability layers**



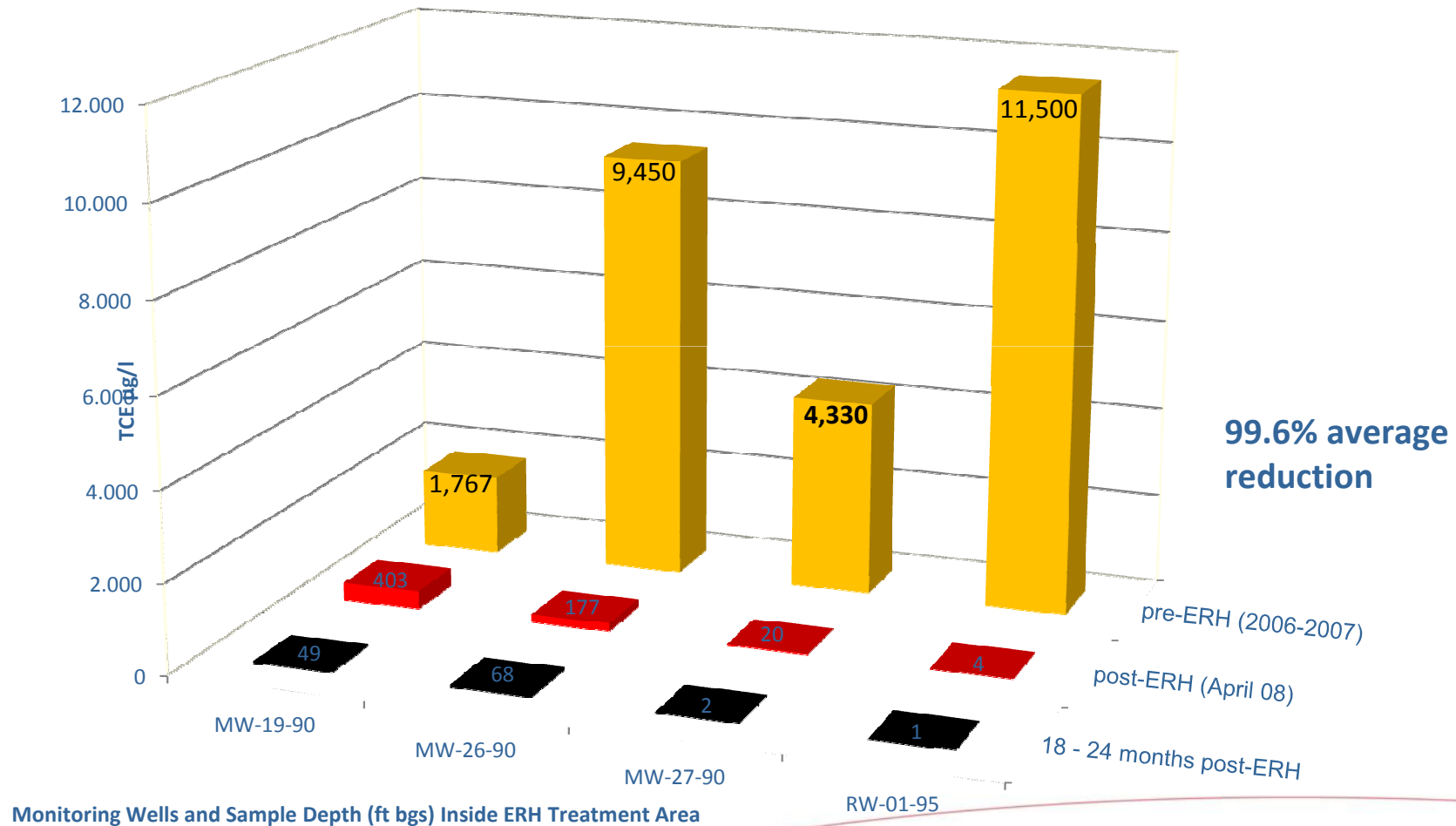
**Prolonged diffusion of Fluorescein E from low permeability layers occurs**

# Rebound

## Positive post ERH Observations



## California Site



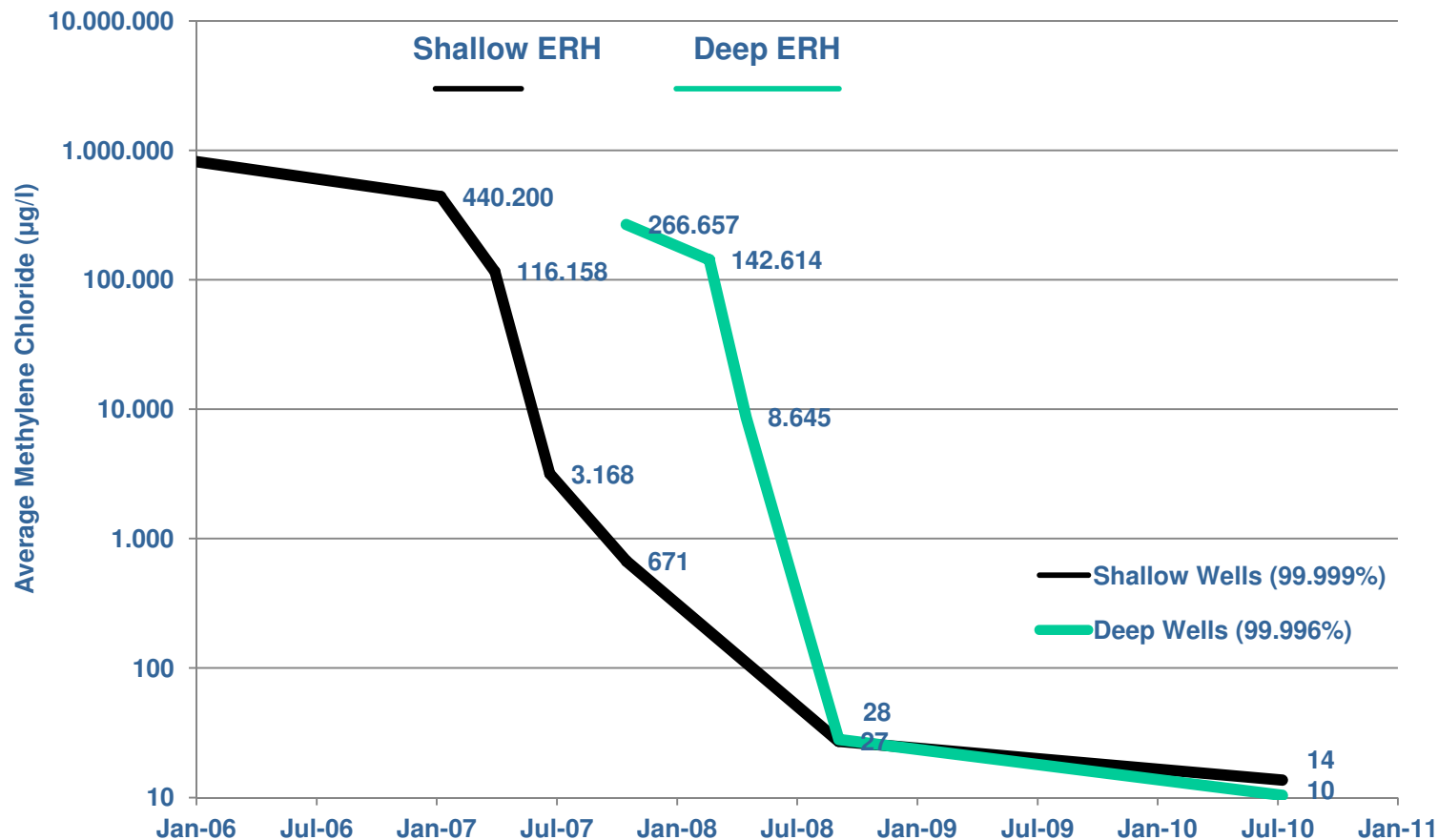


# Rebound

## Positive post ERH Observations



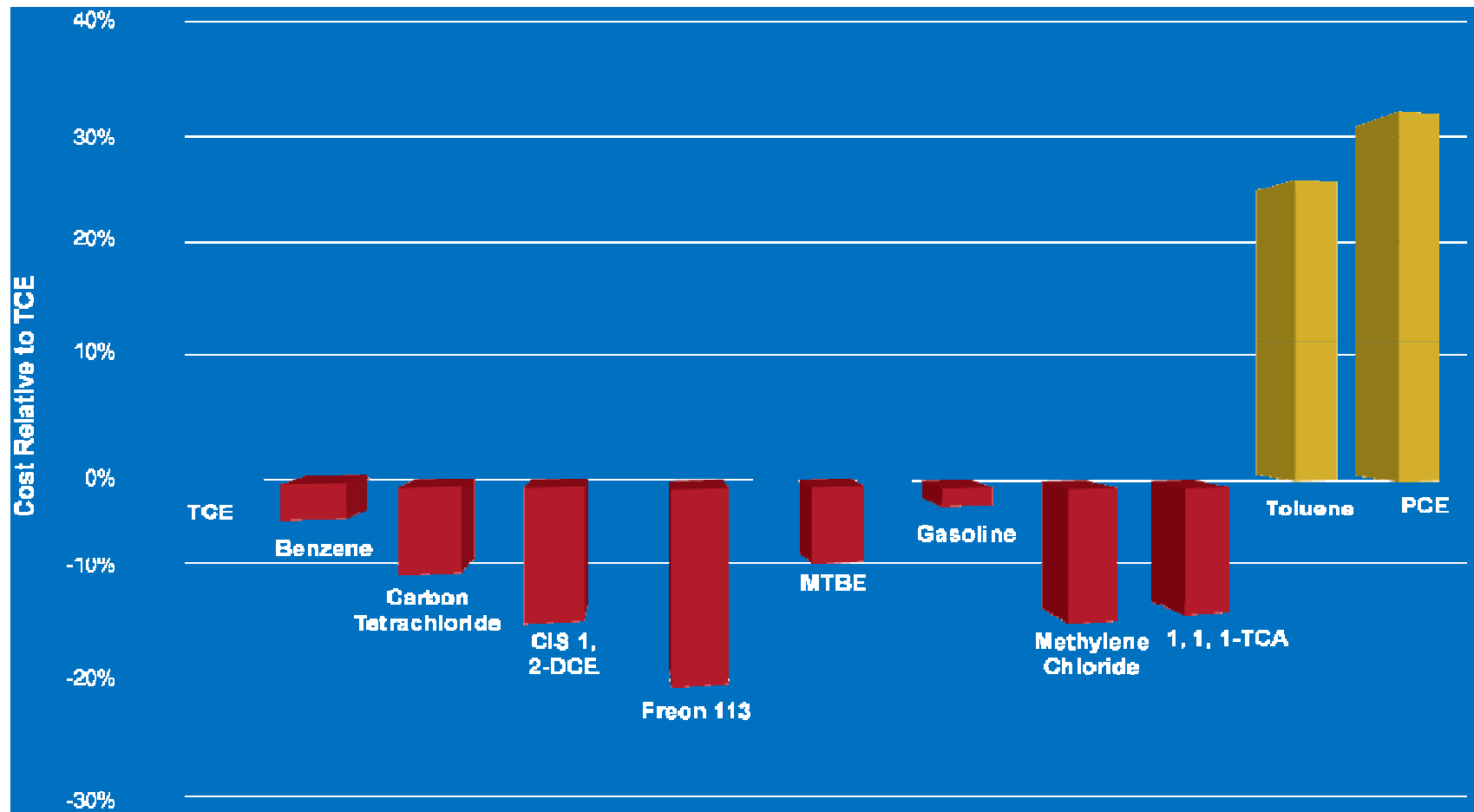
## Georgia Site



Methylene Chloride – 2 years post ERH

# Cost effects

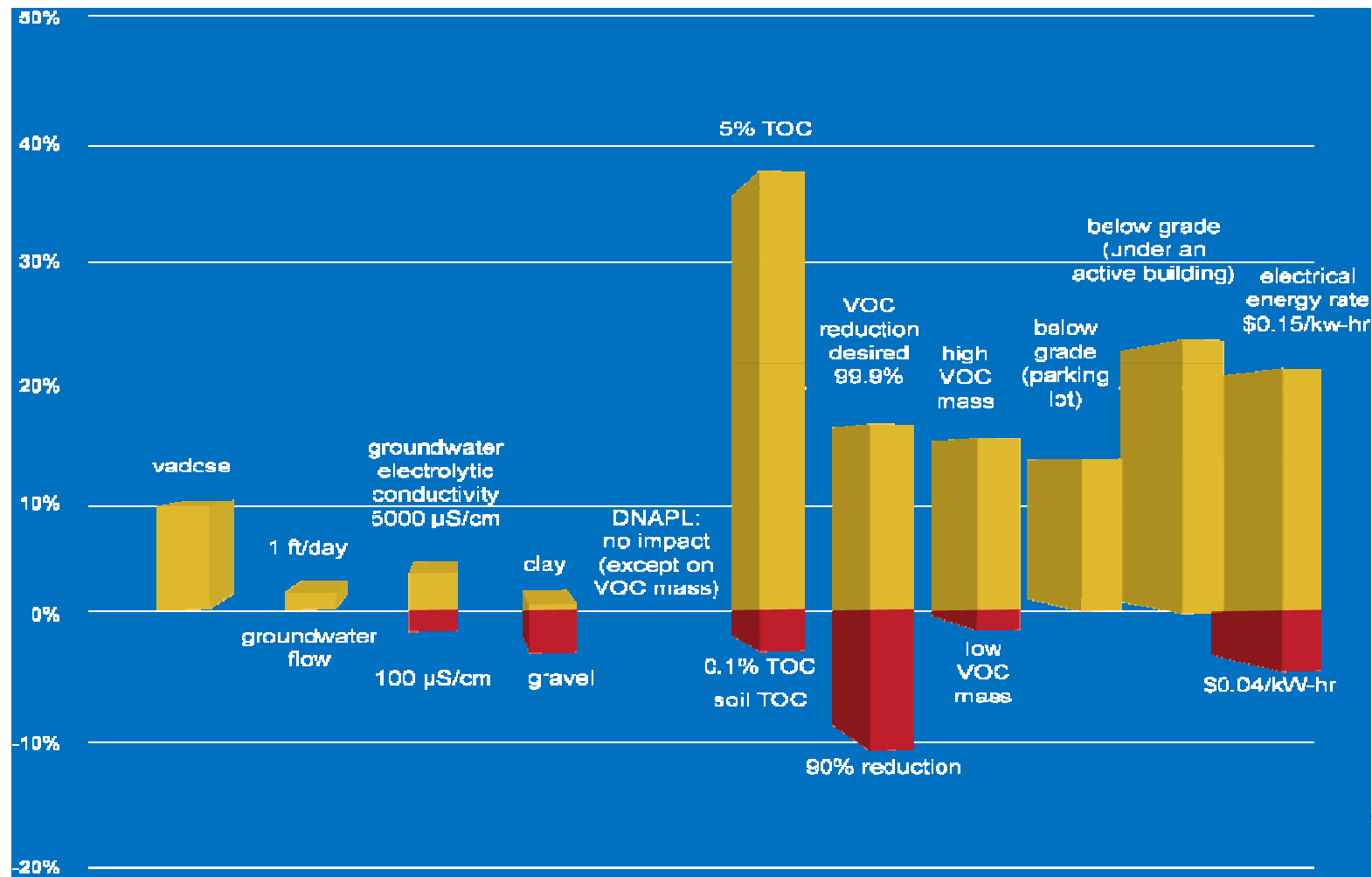
## Relative costs to treat common VOC's



Typical Site: 99% reduction of TCE, commercial application

# Cost effects

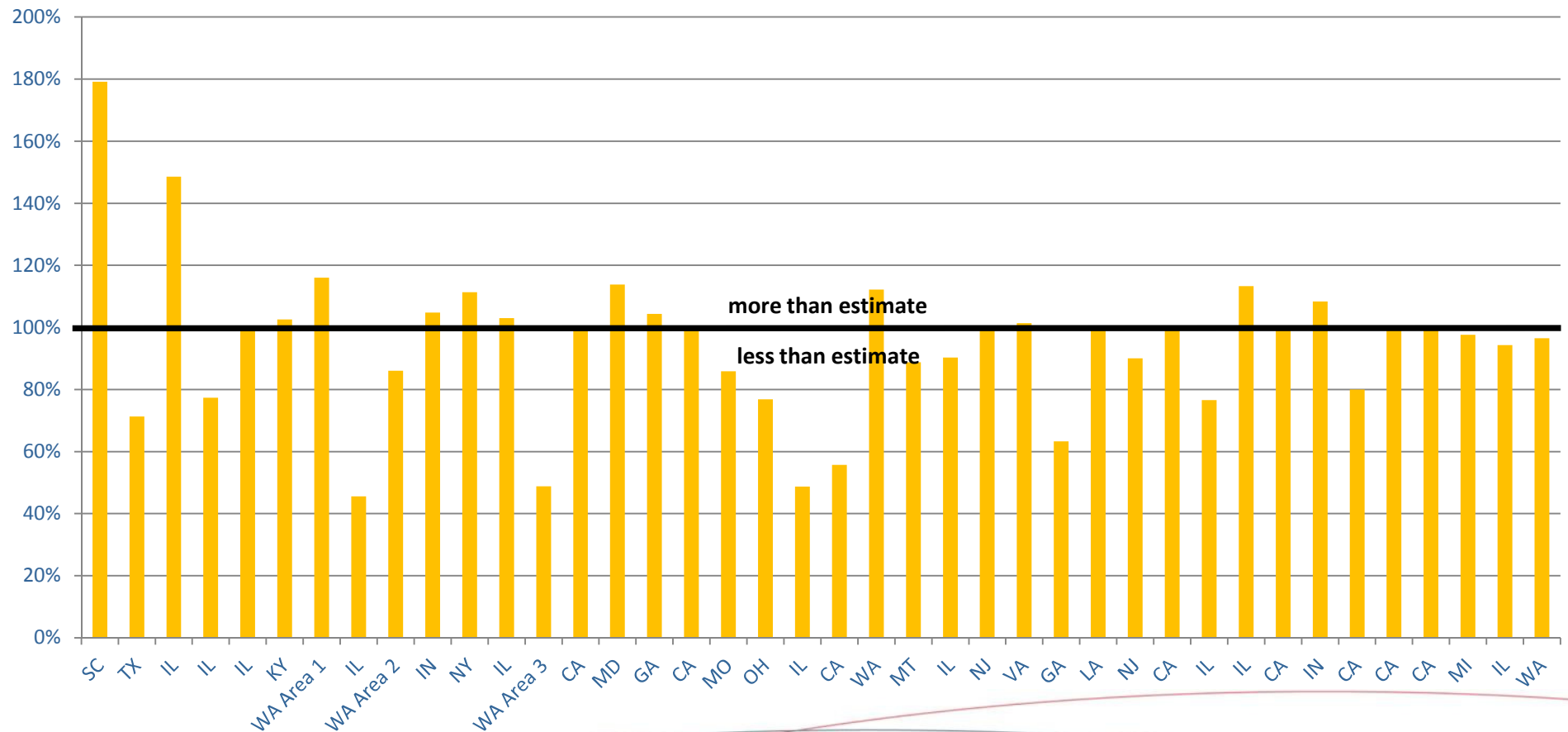
## Relative costs to treat common VOC's



Typical Site: 99% reduction of TCE, commercial application

# Cost effects

## Estimated vs Actual amount of Energy



# ***Photo Impressions***

## ***Electrodes***



Vertically Bored

Angled

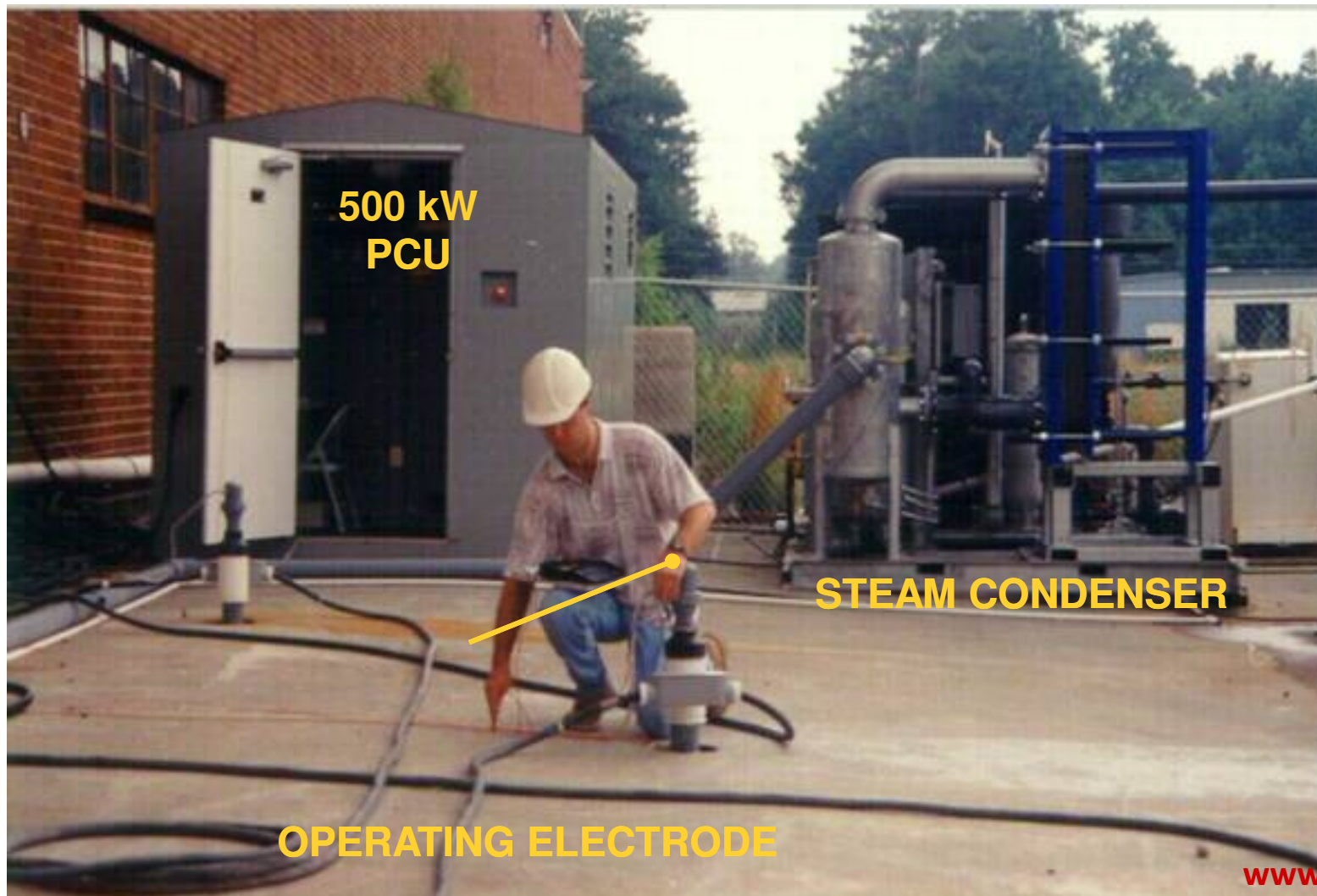
Sheet Pile

Horizontal



# ***Photo Impressions***

## ***ERH Surface Equipment***





# ***Photo Impressions***

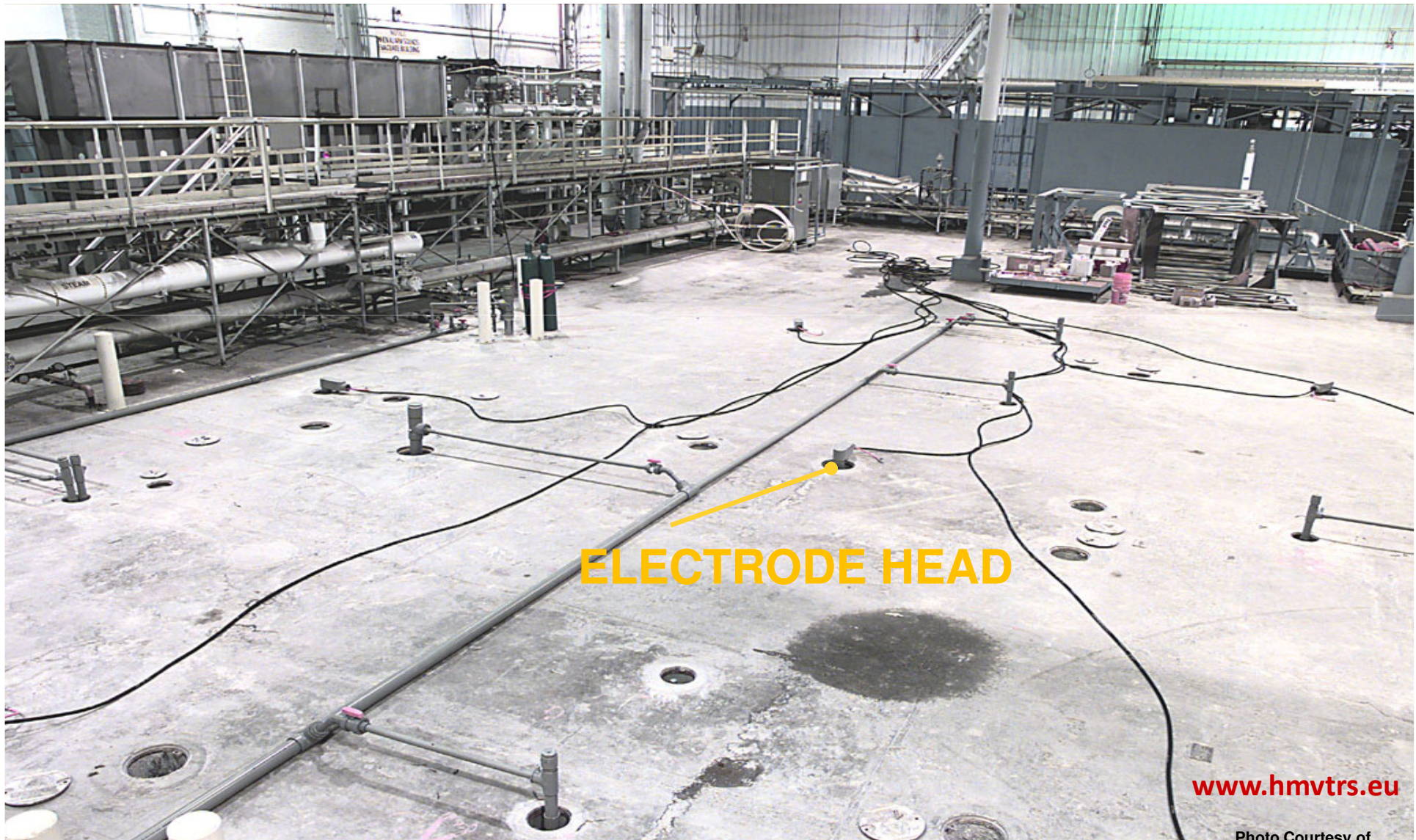
## ***Solid Grease in Knoc-out Tank***





# ***Photo Impressions***

## ***ERH operating under Industrial Plant***





# *Photo Impressions*

## *ERH inside Building*



**GFPR**  
**ERH Inside Building**

[www.hmvtrs.eu](http://www.hmvtrs.eu)



# *Photo Impressions*

## *ERH in public Area*



**Guaranteed fixed price remediation  
Greater than 99% reduction of PCE  
in soil samples.**

**EQUIPMENT  
COMPOUND**

**TREATMENT REGION**

**TREATMENT REGION**

# ***Photo Impressions***

## ***Underneath Vegetation***





# *Photo Impressions*

## *XXX Site*



# ***Photo Impressions***

## ***Great Lakes Site (IL)***





**HMVTRS**

## **ERH Summary**



Rapid in-situ remediation of soil and groundwater

Very high effectiveness – over 99%

Targets **dnapls** effectively

**No rebound**

Volatiles as well as semi-volatiles



# QUESTIONS?