Thermal treatment

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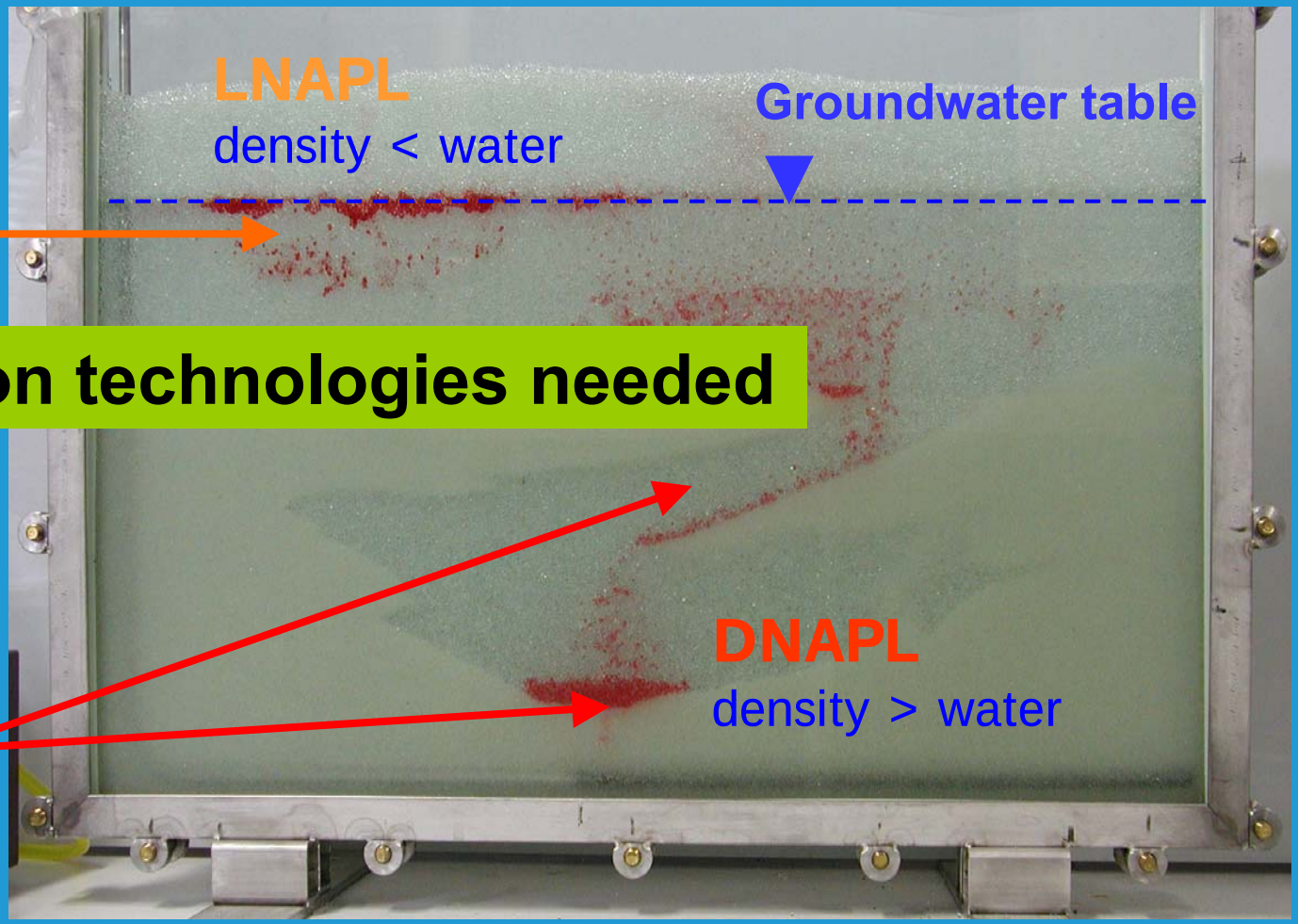
May 16th, 2013

This project has received European Regional Development Funding through INTERREG IV B.
INTERREG IVB

What you can expect

- Why in-situ thermal remediation, ISR ?
- Basics of thermal technologies
- Operating windows
- A successful example of steam-air-injection
- Therefore ISR - Conclusions

LNAP – DNAPL problem



LNAPL

Remediation technologies needed

DNAPL

NAPL = Non-aqueous phase liquid (not miscible with water)

Why thermal treatment ?

T_1 = 20°C

ca. 2 cm

T_2 = 70°C

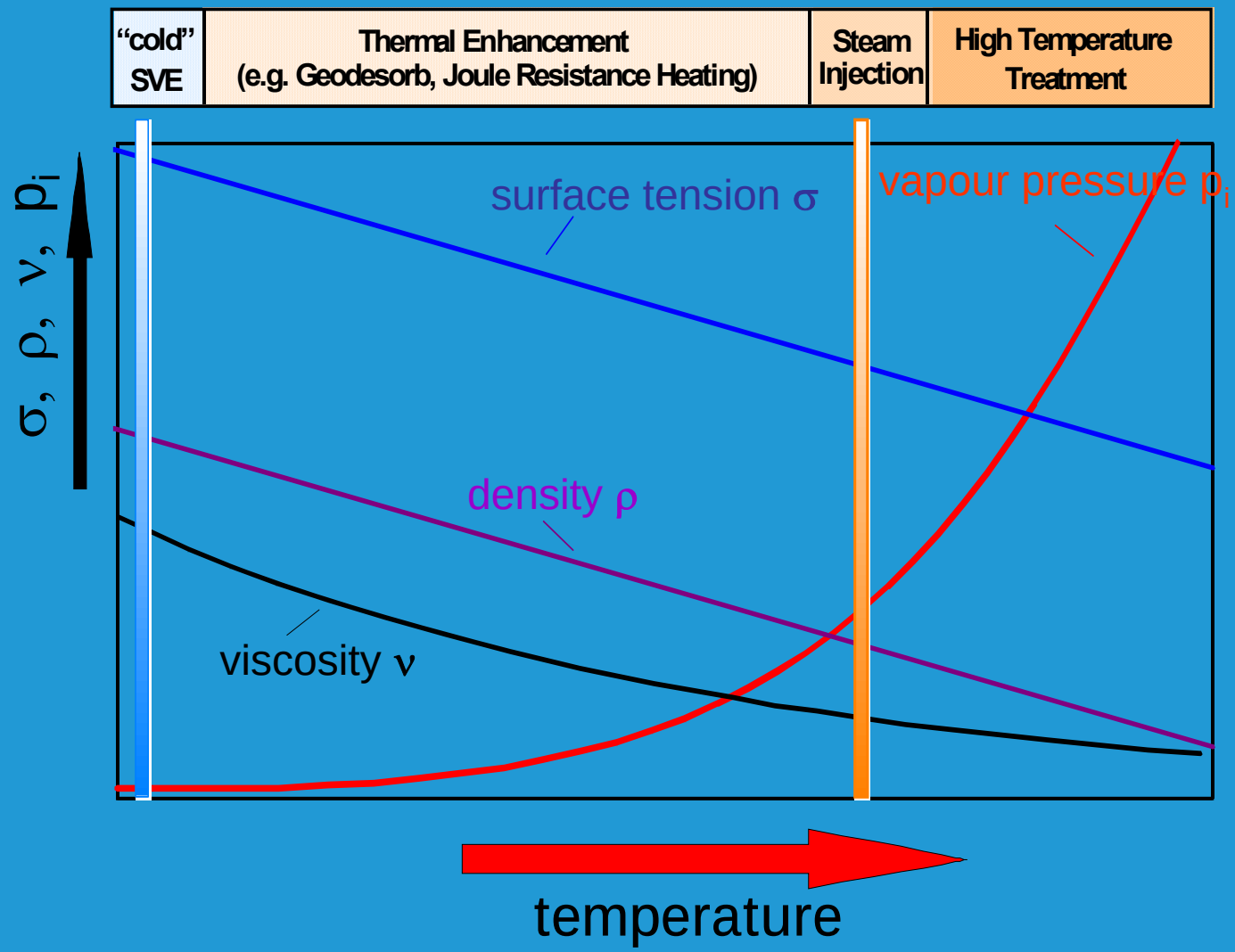
Photos: A. Winkler

Fluid properties - f(Temp)

T_1 = 20°C

T_2 = 70°C

Photos: A. Winkler



Steam distillation

Increasing temperature: 20°C → 80°C

and vapour pressure

- Water: factor 20
- PCE: factor 15
- Xylene: factor 19

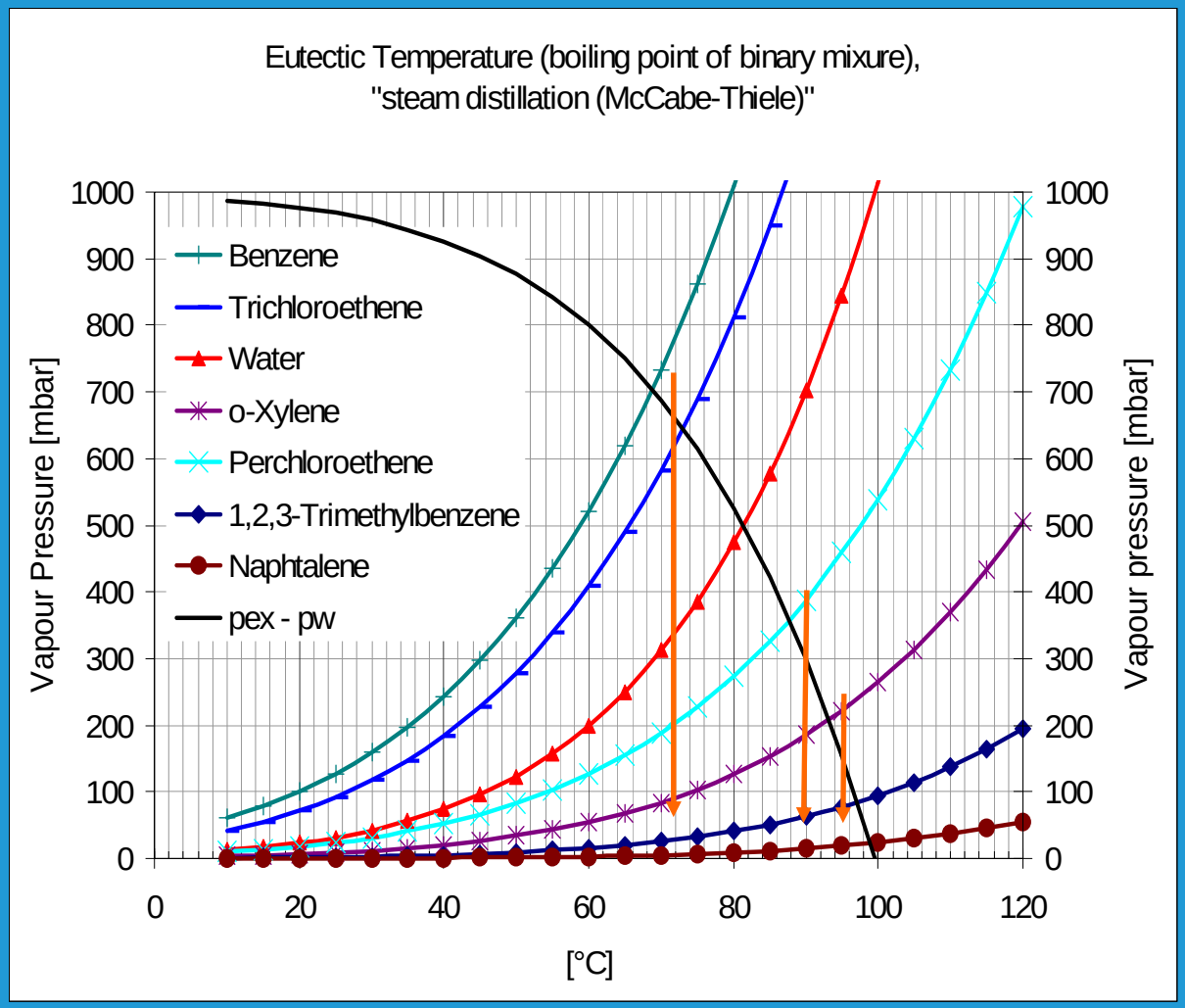
Reduction of boiling point by steam distillation (azeotropic point):

Benzene 80 → 69°C

TCE 87 → 74°C

PCE 121 → 87°C

m-Xylene 144 → 93°C

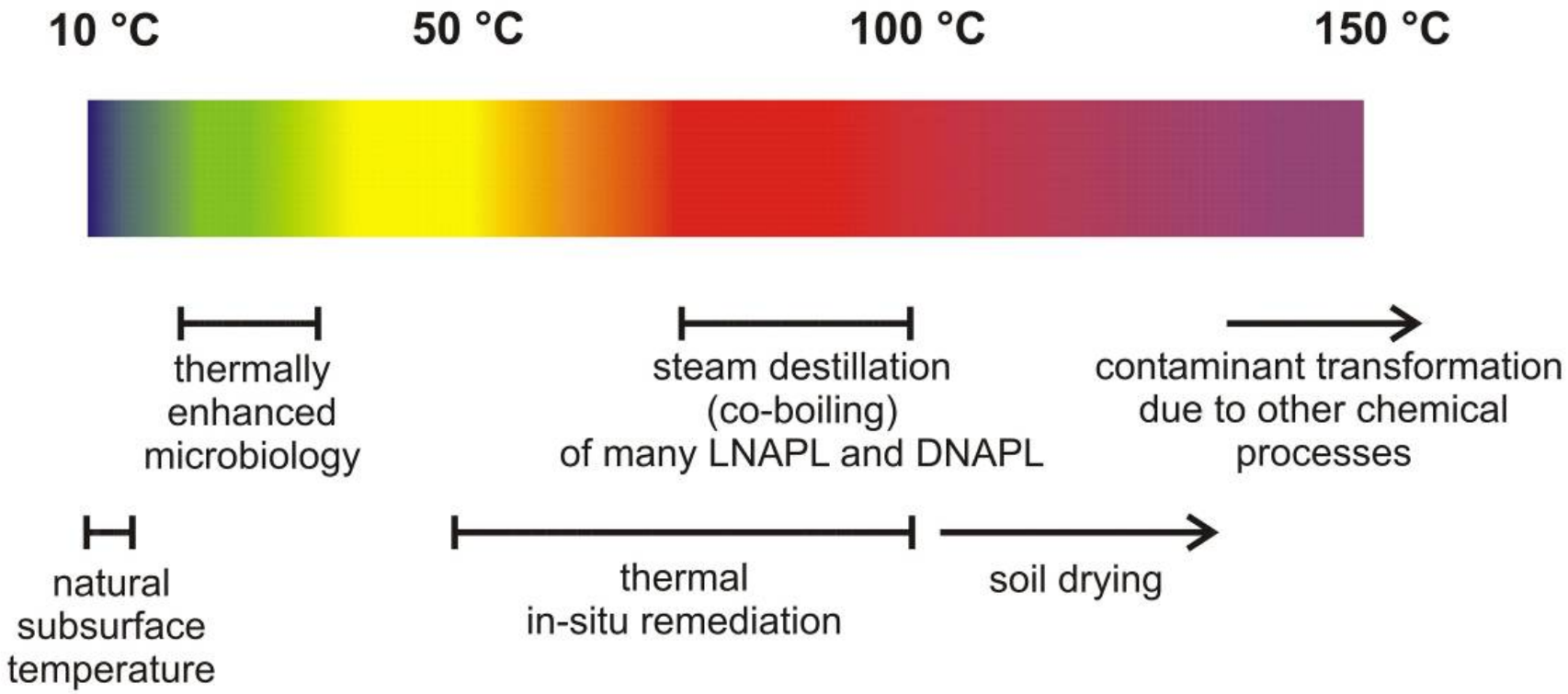


Thermal In-situ Technologies

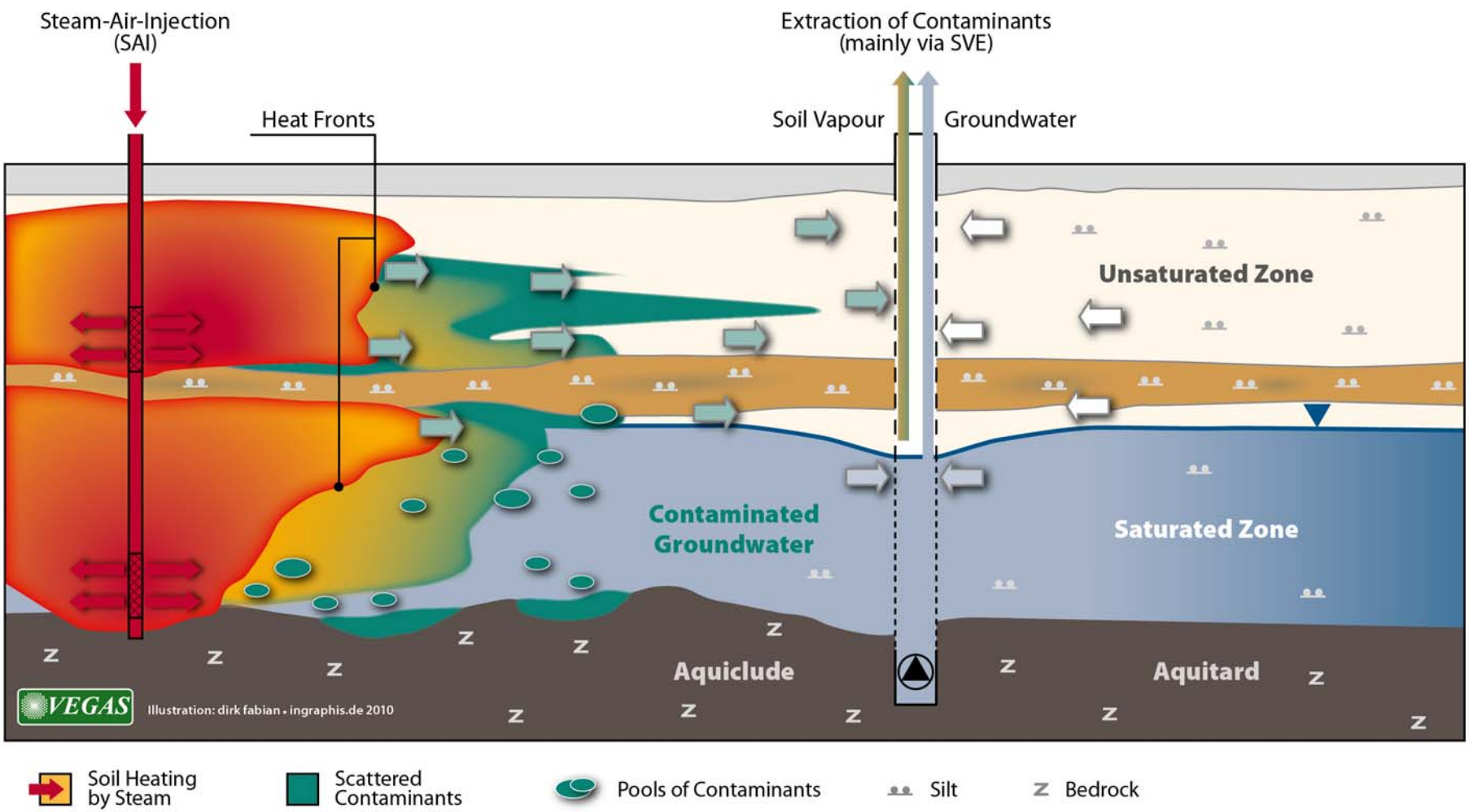
Convection →	Conduction	Ohm	di-electric
Steam- / Steam-Air - Injection	Conductive Heating, Thermal Wells (electric or hot gas)	Electric Resistance Heating	RF- / Radio-frequency Heating

- organic compounds (LNAPL & DNAPL)
- increase of vapor pressure of contaminant by heating of subsurface / steam distillation
  ➔ by factors enhanced extraction rates
- **Extraction of contaminants as gas** (SVE Soil Vapour Extraction)
- fast and reliable (and controllable) remediation process
  ➔ selection of technique dependent on site conditions and "composition" of contaminants (mixtures)
  ➔ expert knowledge required

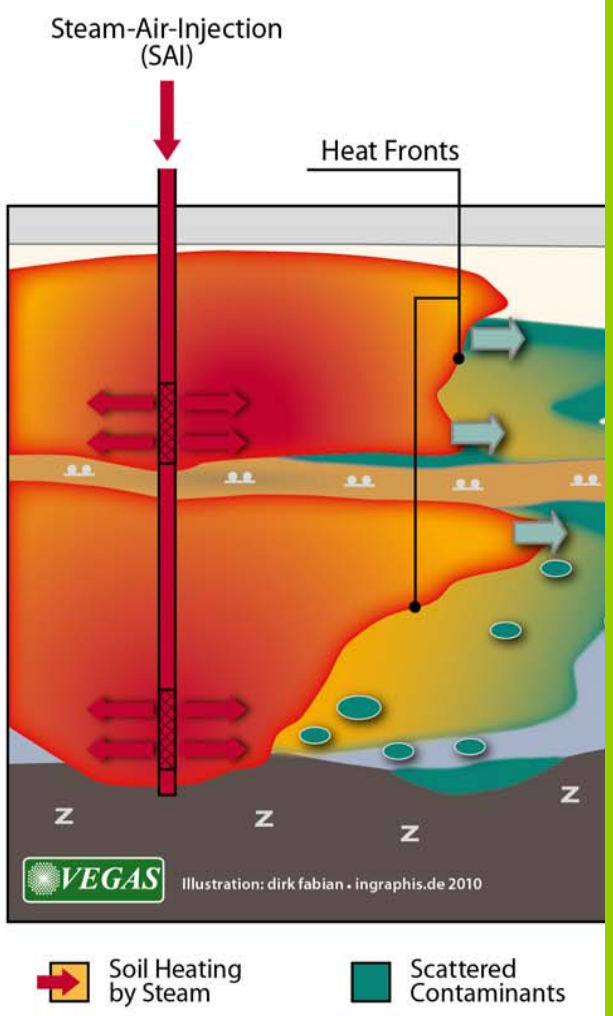
Operating Windows



Steam – Air – Injection (SAI)



Characteristics



Operation windows

DNAPL and LNAPL, light and medium volatile, boiling points < 180°C

UZ: Unconsolidated soil, mean to good permeability (silt → gravel)

GZ: Pore aquifer (sand to silt)
k_f: 5 x 10^{-5} to 1 x 10^{-3} m/s

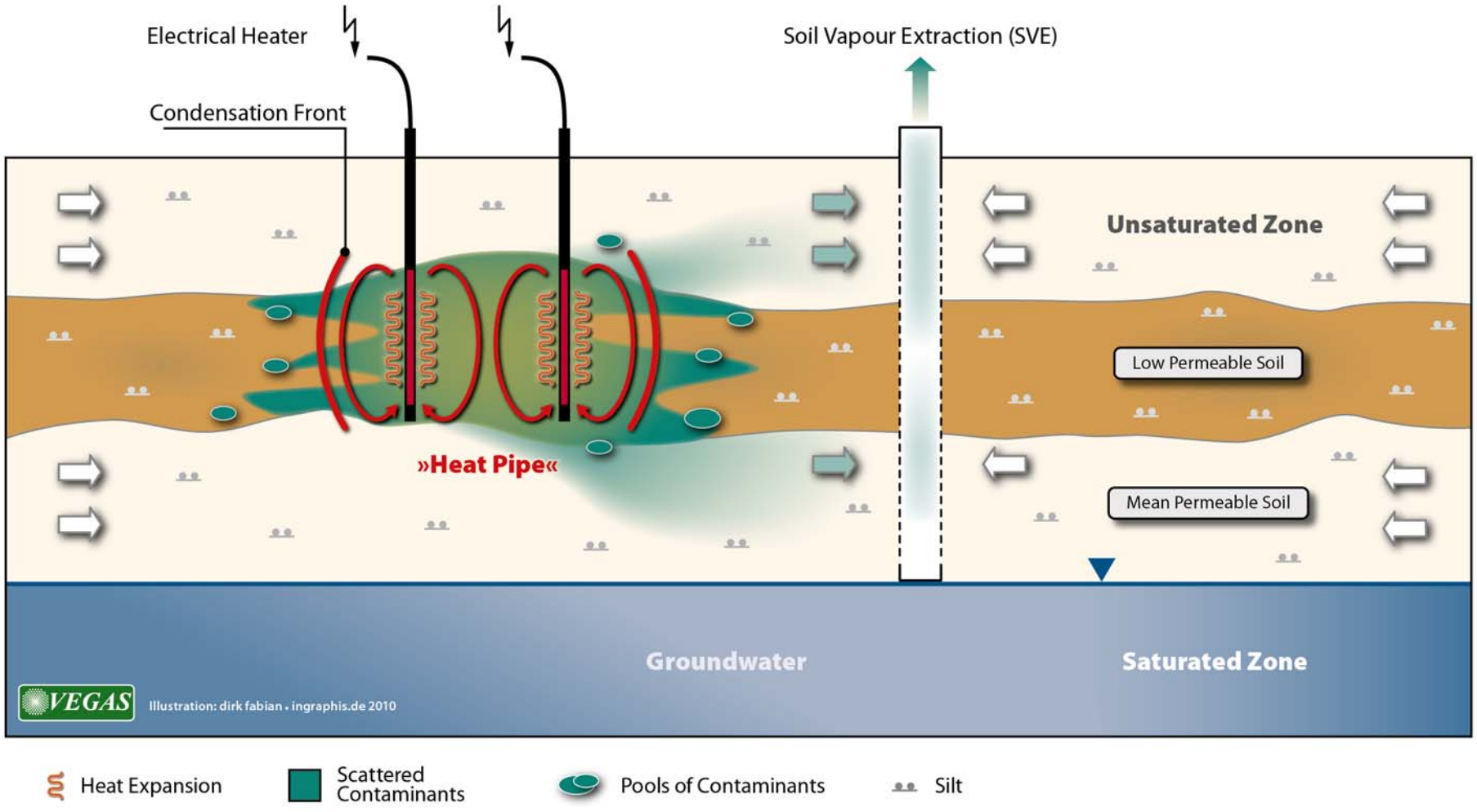
Thermal radius of influence (groundwater)

- Permeability: 0,5 – 5 x 10^{-4} m/s
- Steam propagation: 3 - 5 m radius for 150 kg/h steam
- Advantage: anisotropic soil structure

Features

- Simultaneous remediation of aquifer and unsaturated soil zone
- Possible structural changes in highly organic soil structures (peat layers) → settlements?

Conductive Heating
(Thermal Wells)



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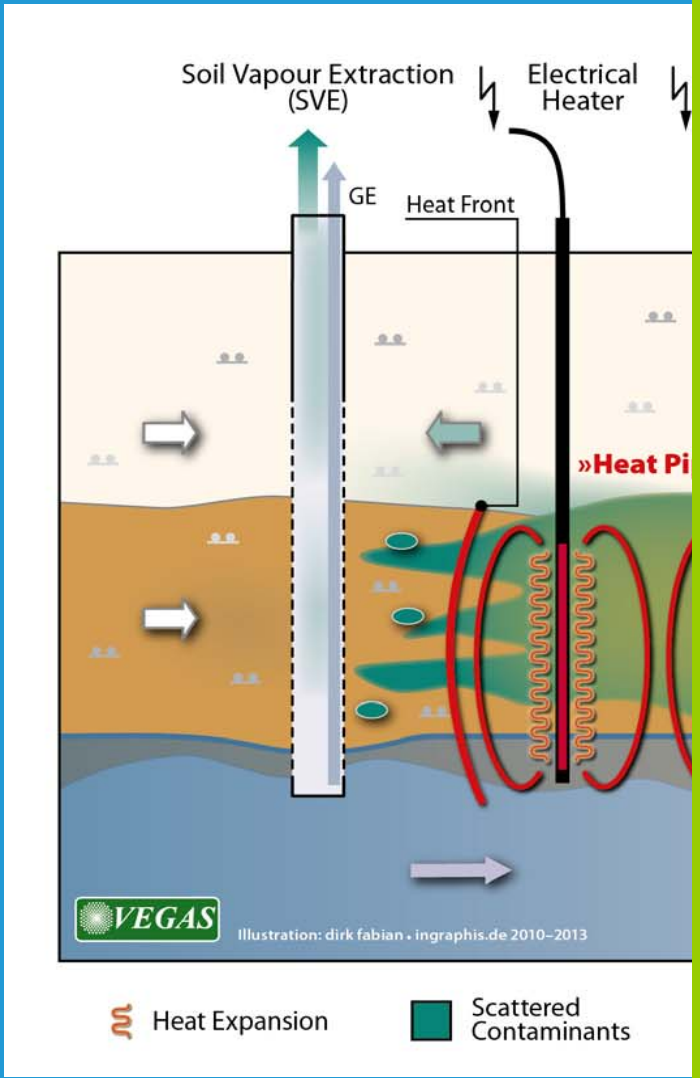


Operation windows

DNAPL and LNAPL, light and heavy volatile, boiling points < 250°C

UZ: Low permeable soil layers (fine sediments, silt, clay, …), permeability up to 10^{-9} m/s

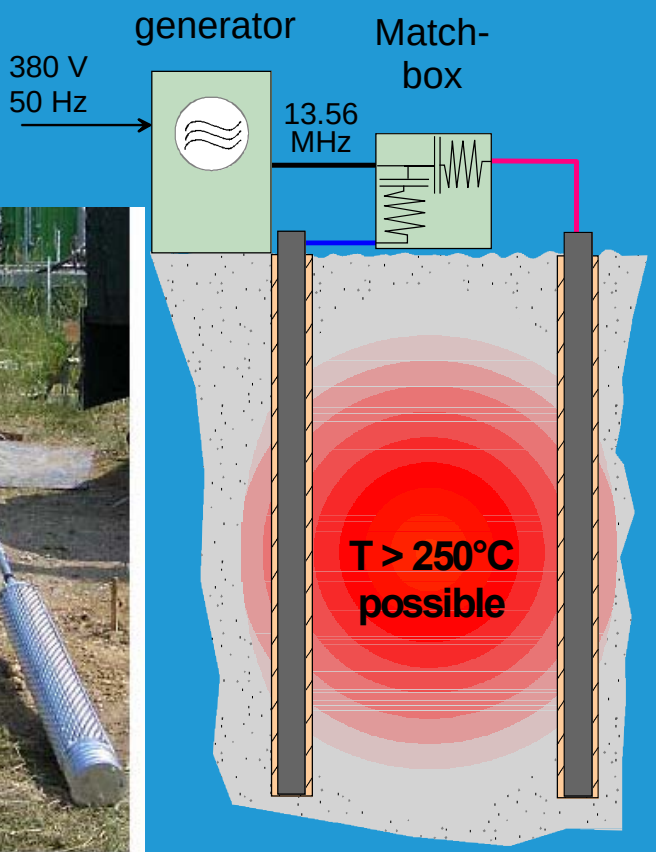
GZ: For special conditions feasible, to be proved by pilot investigations

Distance of heating elements in the range of meter (function of site)

Features

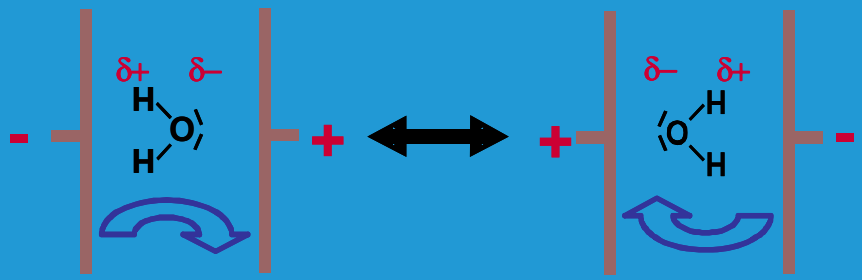
- During drying of the soil permeability for SVE can significantly increase
- Beware of possible settlements (clay layers,…)
- Low operating and maintenance costs

Radio Frequency / RF Heating



Principle
of heating

- Comparable to Microwave oven
- Heating by internal friction
- Dipole (e.g. water) or other polare structurs are activated by vibration



- Direct heat generation in the soil volume
- High flexibility (temperature programmes)
- Can be applied for dry and humid, sandy and tenaceous materials, e.g. soils

From Dr. Ulf Roland

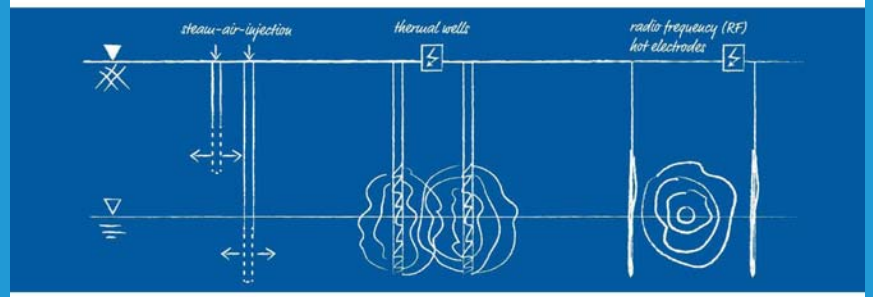
HELMHOLTZ ZENTRUM FÜR UMWELTFORSCHUNG UFZ

Guidelines and tools

Centre of Competence for Soil, Groundwater and Site Revitalisation - TASK

Guidelines

***In situ* thermal treatment (ISTT) for source zone remediation of soil and groundwater**



Funded by:

Federal Ministry of Education and Research

Helmholtz Centre for Environmental Research - UFZ

Grundlagen der Dampf-Luft-Injektion

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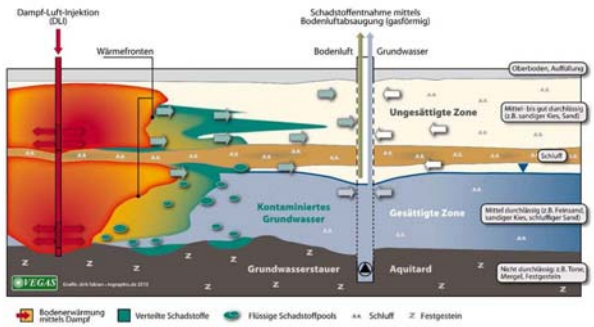
DLI-Tool zur Dimensionierung einer thermischen In-situ-Sanierung mittels Dampf-Luft-Injektion



Thermische Verfahren für die ungesättigte und gesättigte Bodenzone

Im Auftrag von

Erstellt von

Gefördert vom

Tool for Design Steam-air-injection

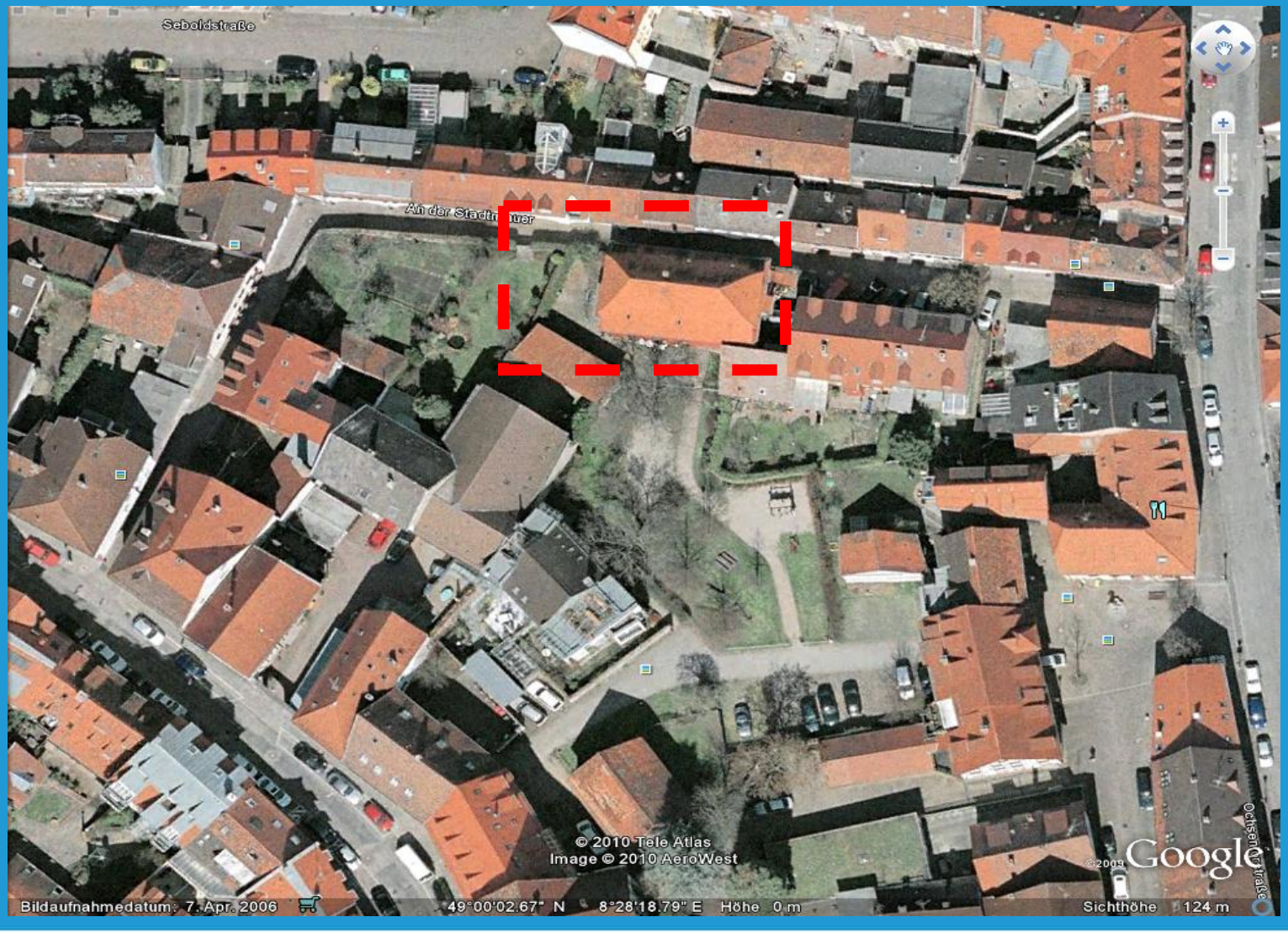
Field case: Steam-Air-Injection

Site *Karlsruhe Durlach*

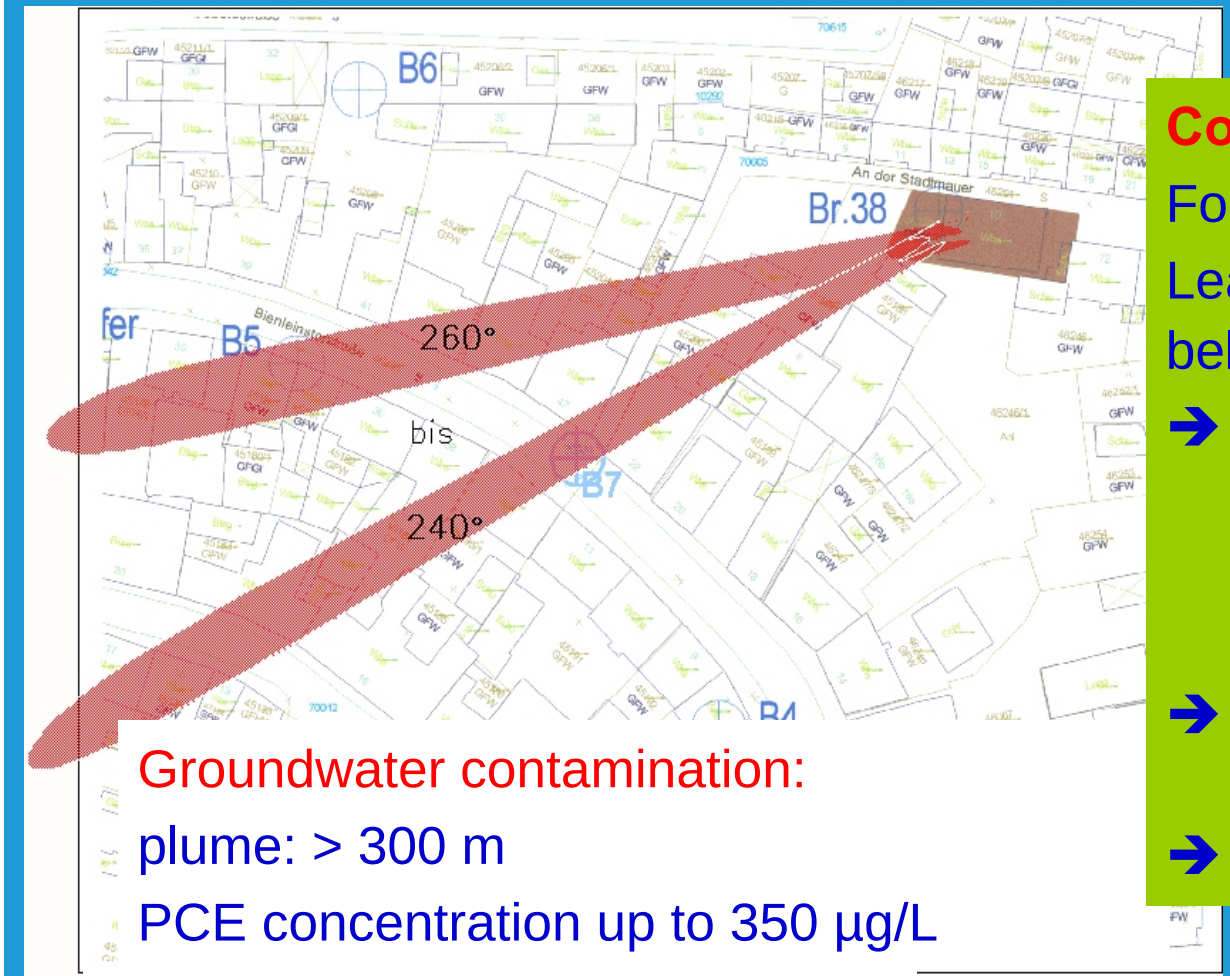
Slaughterhouse of 1574

➔ Dry cleaner

Historical City *Karlsruhe Durlach*



Contamination



Groundwater contamination:

plume: > 300 m

PCE concentration up to 350 µg/L

Contaminant source PCE

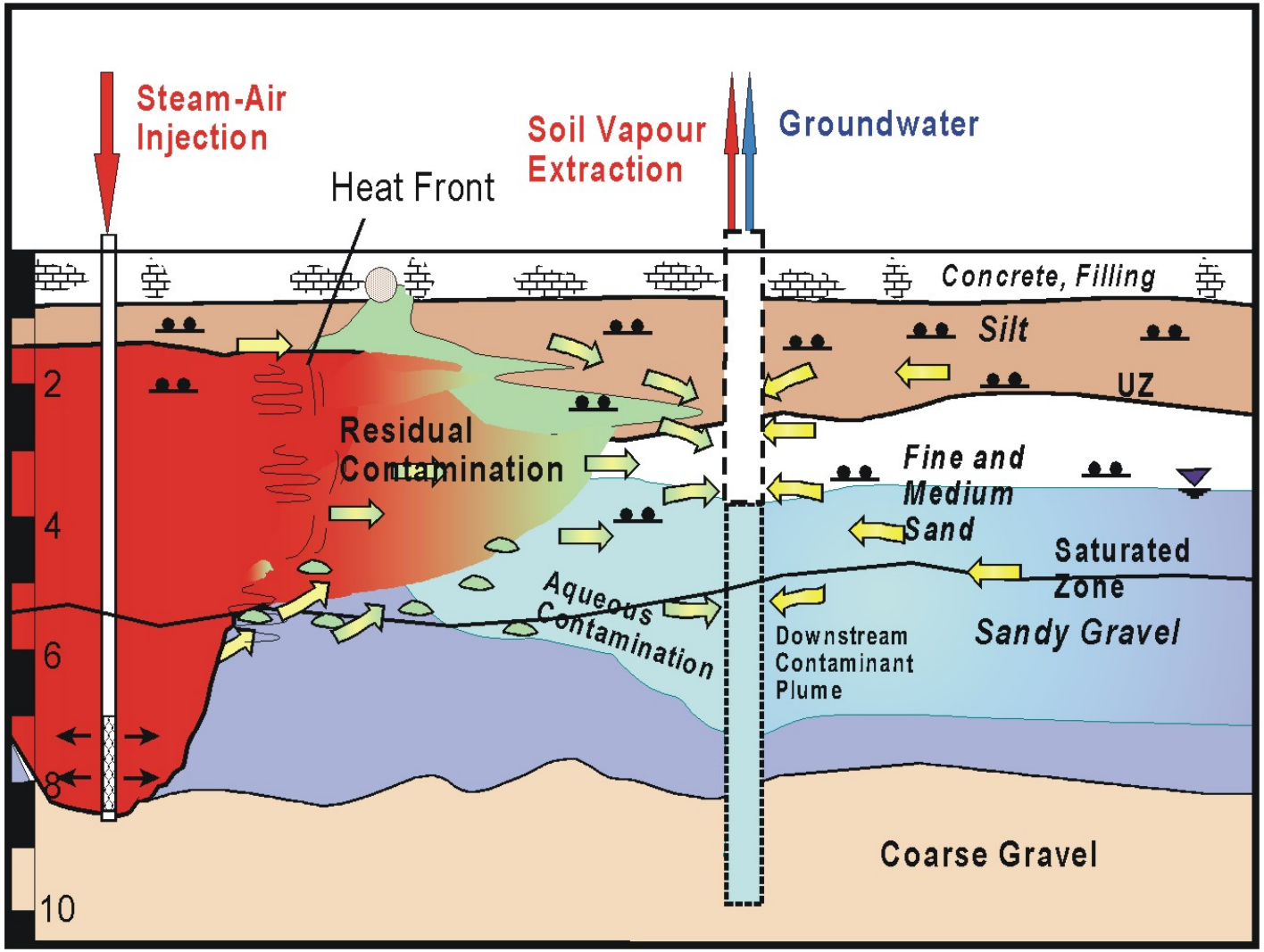
Former dry cleaner:

Leaking sewage system below the historical building

- ➔ PCE in the unsaturated zone, capillary fringe and saturated zone (silt, clay 5 m b.g.s.)
- ➔ PCE max. 3.800 mg/kg in vadose zone
- ➔ 60 mg/l in groundwater

O. Trötschler, H.-P. Koschitzky, Steffen Ochs, Stephan Denzel

Geology / remediation concept



S-A-injection:

7- 8 m b. g.s.
max. 200 kg/h

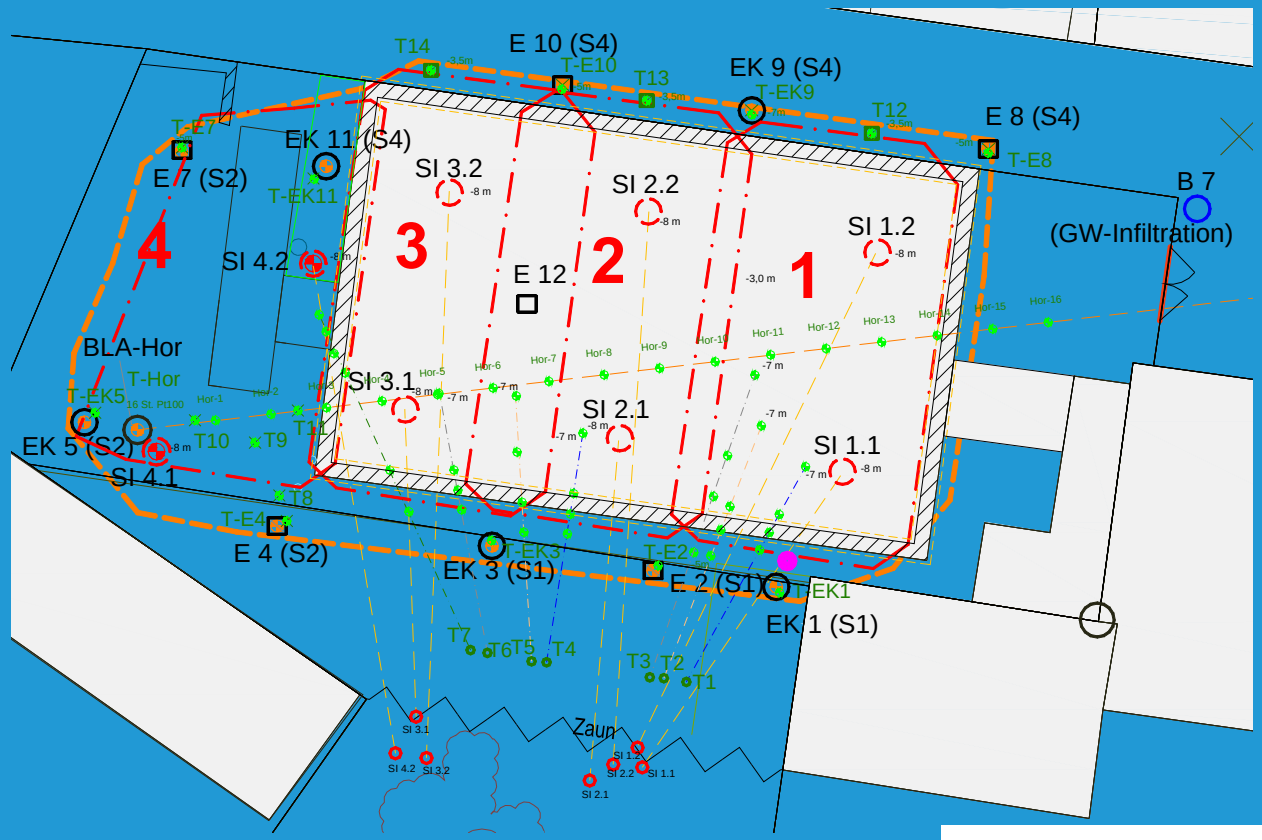
SVE:

100 - 150 m³/h

GW-pumping (cooling water)

1- 3 m³/h

Remediation: implementation

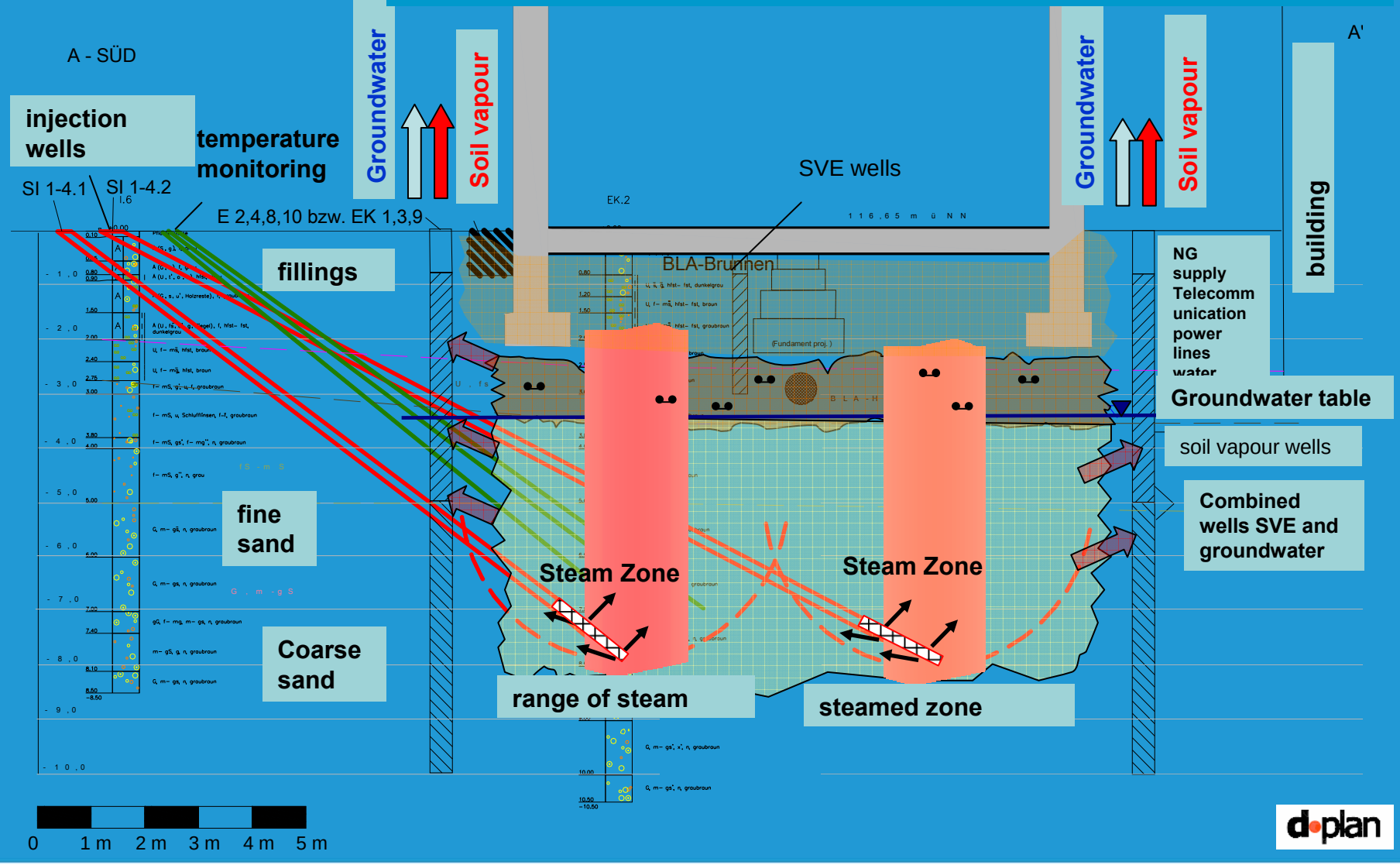


© *dplan, ZUT, VEGAS*

- Site owner:
  Stadt Karlsruhe
- Remediation planning and contracting:
  consultant dplan
  (& *VEGAS)*
- Operation:
  Züblin Umwelttechnik
- Scientific assistancy, monitoring and remediation control:
  VEGAS & dplan
- Advisory board
  RP-Ka, City of KA, EPA (LUBW) of Baden-Württemberg

Stadt Karlsruhe
Umwelt- u. Arbeitsschutz

SAI below the building



Drilling and installation of wells

Photo: Steffen Hetzer, ZUT


Photo: Steffen Hetzer, ZUT


Photo: Steffen Hetzer, ZUT

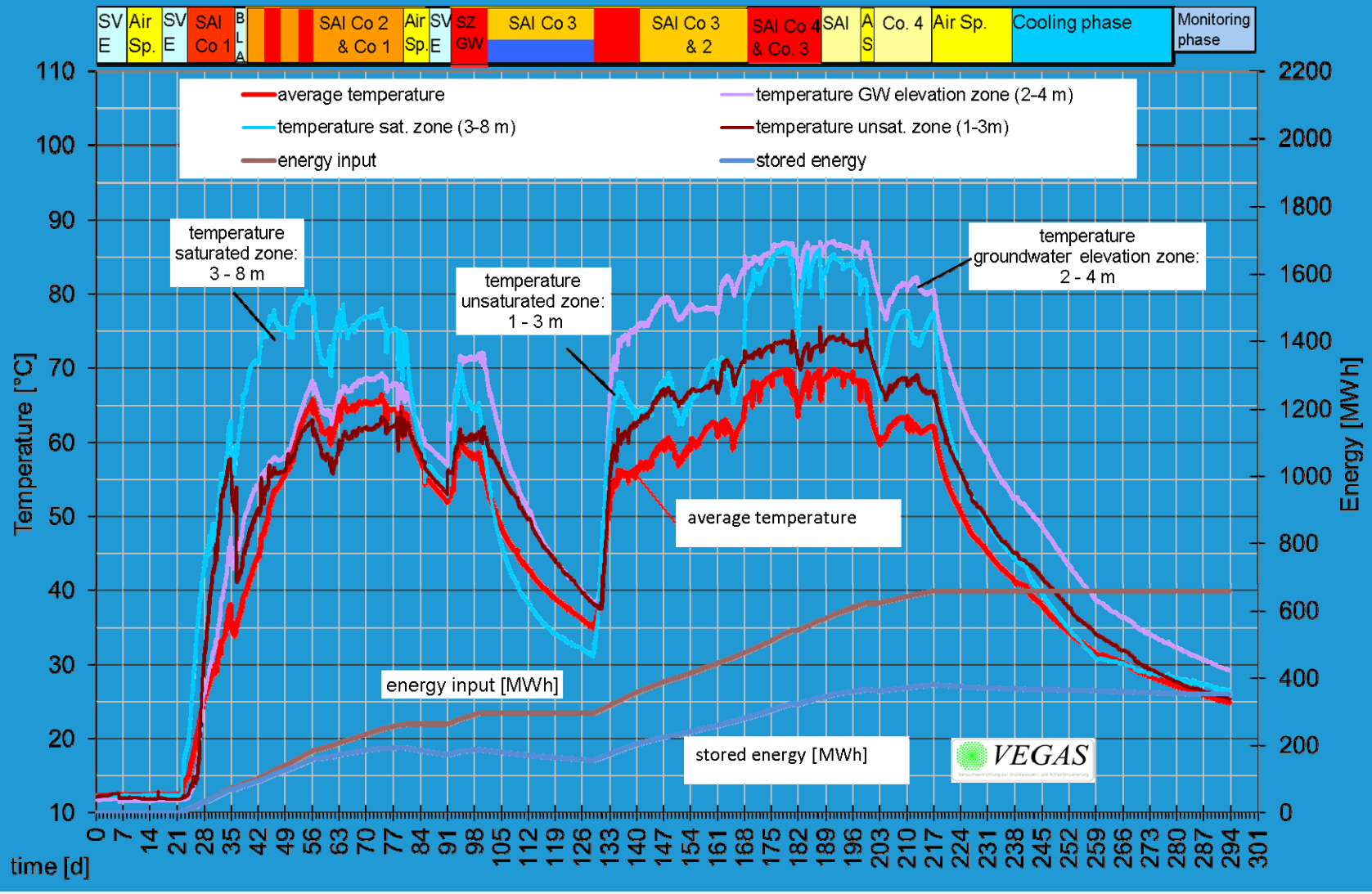
Field installation: remediation

Groundwater and soil vapour extraction, activated carbon filter

Exhaust chimny SVE

Extraction well and temperature measurement

Temperature development during remediation



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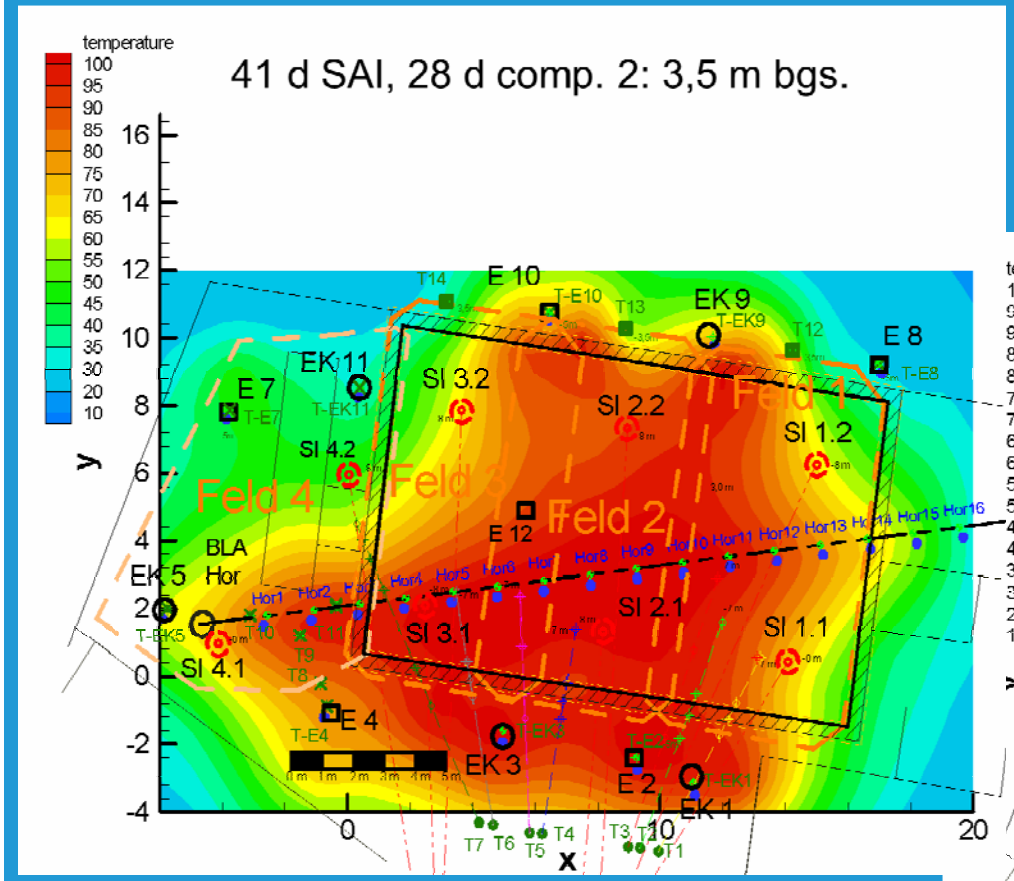
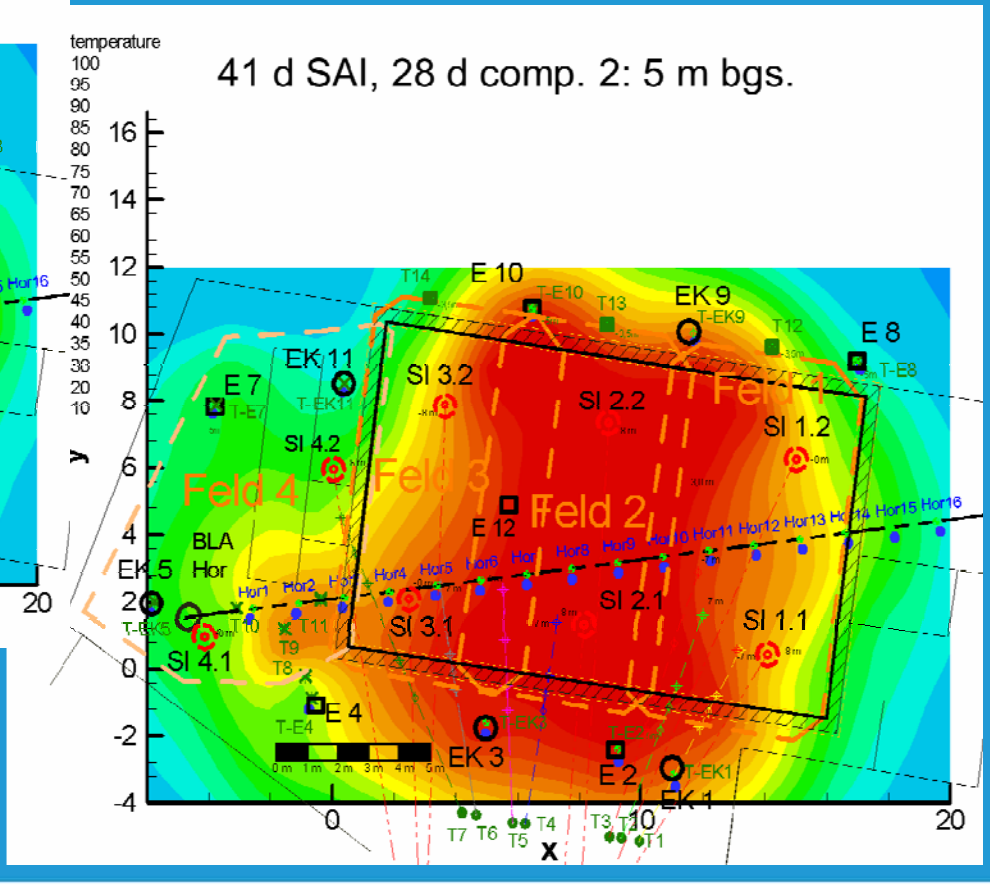
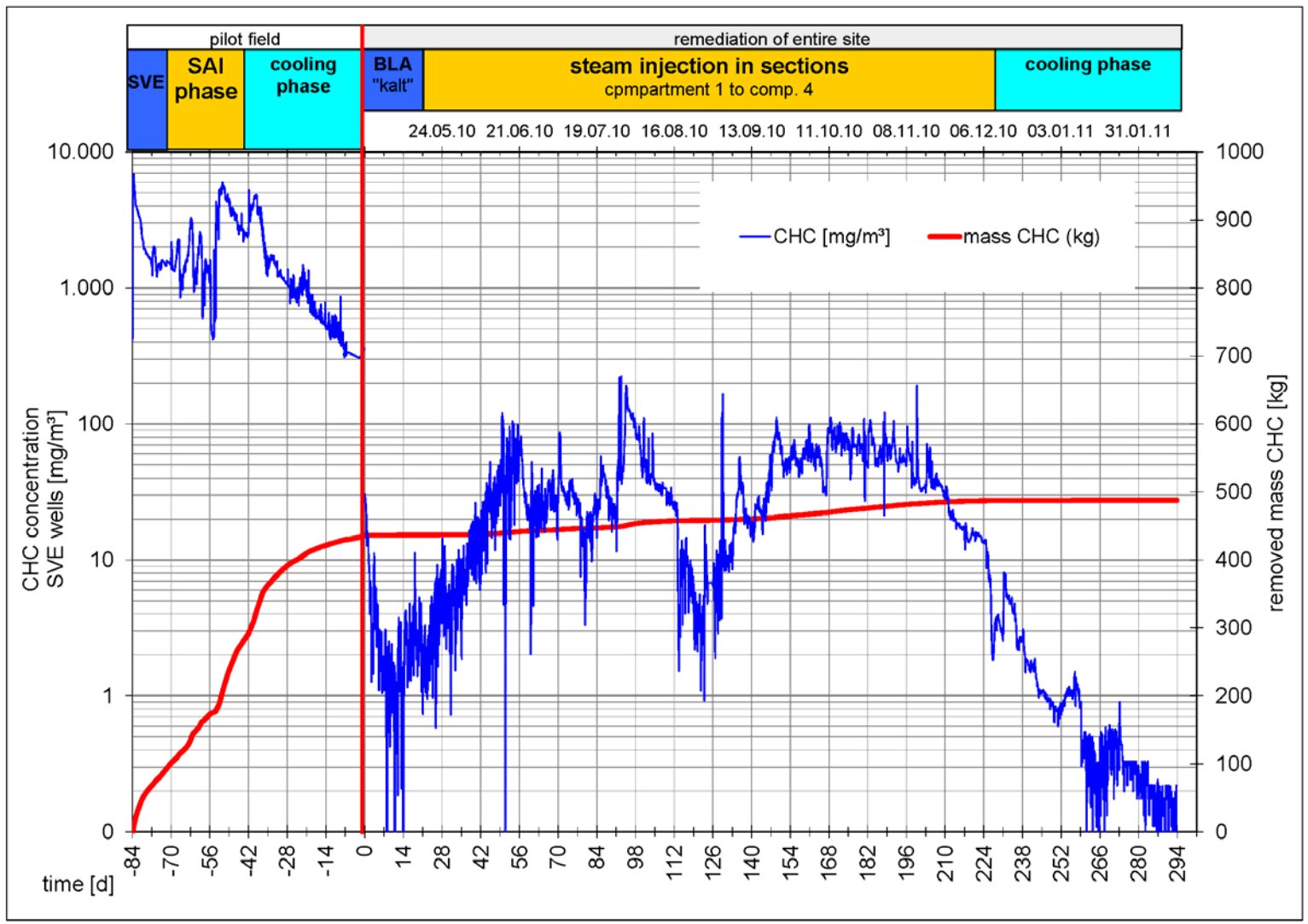
Heat propagation: compartment 2

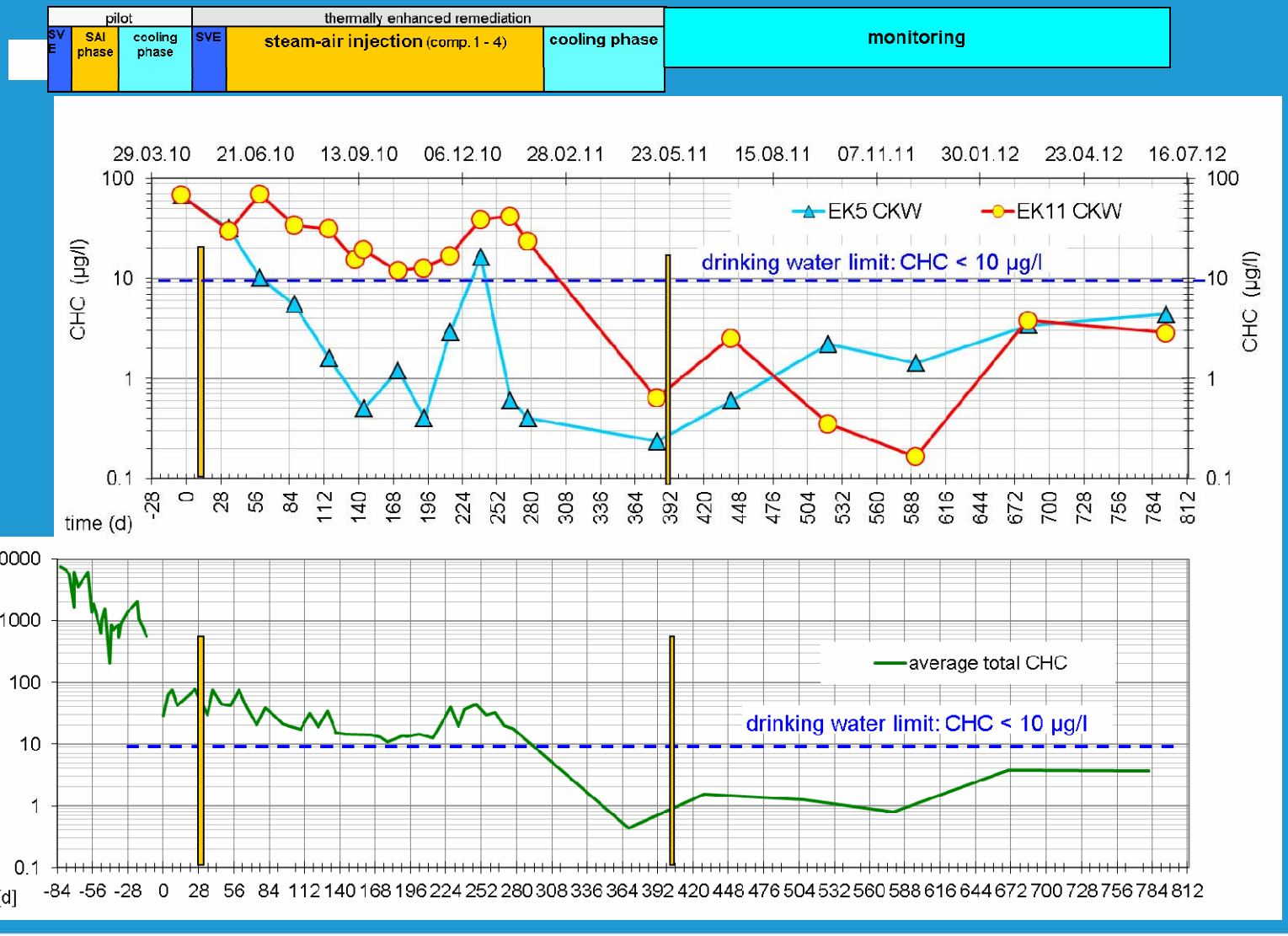




Contaminant removal by SVE



Development of CHC in groundwater



Summary and some numbers of remediation (1)

- **Total duration** incl. drilling works 70 weeks
- **Duration of remediation** 42 weeks
  (ca. 30 weeks steam-air injection)
- **Contaminant removal mass** 500 kg CHC (incl. pilot)

- **Remediation goals** achieved concerning CHC concentration
  (10 mg/m³ in soil vapour, << 10 µg/L in groundwater)
- **Impressive reduction of groundwater contamination**
  - before: 60.000 µg/L
  - two years after: < 5,0 µg/L down to not detectable

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Summary and some numbers of remediation (2)

- **costs** total budget ca. 600.000 €
  - 25% drilling and construction
  - 25% consumables, energy (mainly gas for steam production)
  - 50% for plants installation and operation

  ➔ specific costs: ~ 180 €/to soil

- **Energy balance:** 470 kWh/m³ soil (84% heat; 16% electric)

  total consumption: 780 MWh (thermal energy)

  153 MWh (electrical energy)

The site after the remediation
(15.11.2011)

Therefore ISR

- ISR can used under difficult and narrow conditions (even below buildings)
- ISR reduce remediation time at minimum by one order of magnitude
- ISR can reduce the total energy consumption by a factor 2
- Cost for subsurface heating and on site treatment (Soil vapour and groundwater) are approx. similar

Conclusion

- ISR can help to solve our contamination problems
- But - no “universal” remedy exists
- use ISR carefully → expert knowledge is needed

- Detailed site information is needed to chose an optimum solution
- Invest money in a serious site investigation
- Invest in (lab experiments, special problems) and pilots

→ **Both will save money and at least led to a cost and eco efficient and sustainable solution**

… at the very end

Thanks for your patience and your interest

Any questions ?

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