

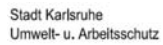
Steam-Air Enhanced In-Situ Remediation of a Chlorinated Hydrocarbon Source under a Historical Building - from Planning to Successful Rehabilitation -



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Umwelt- und Arbeitsschutz

AquaConSoil 2013, Barcelona 16-19 April 2013

AquaConSoil
Barcelona
2013

Introduction

Pilot Application (2005)

- remediation planning → site description
- thermally enhanced remediation → steam-air injection
- pilot; what for? → confirmation and design steam-air technology

→ Remediation concept

Remediation – Monitoring (2010/2012)

- remediation concept → sequential steam-air injection
- data monitoring → surveillance and process control
- Process operation → remediation progress and results

→ Realization of thermally enhanced remediation and aftercare

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Impressions from the
site in 2005

Site Karlsruhe Durlach



Slaughterhouse of 1574



→ Dry cleaner

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Site Karlsruhe Durlach



gallery and artist's workshop

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Pilot Site Karlsruhe Durlach



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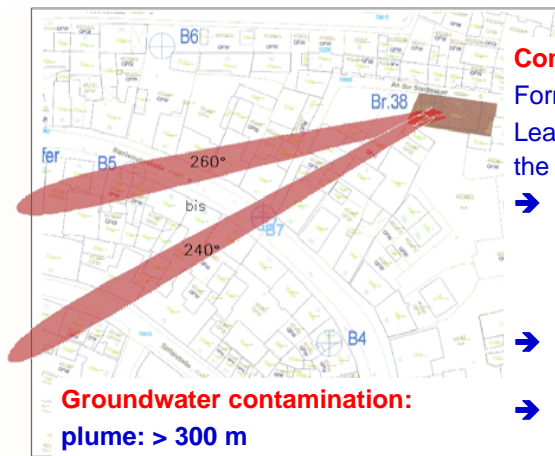
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Contamination



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

Groundwater contamination:

plume: > 300 m
PCE concentration up to 350 µg/L

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



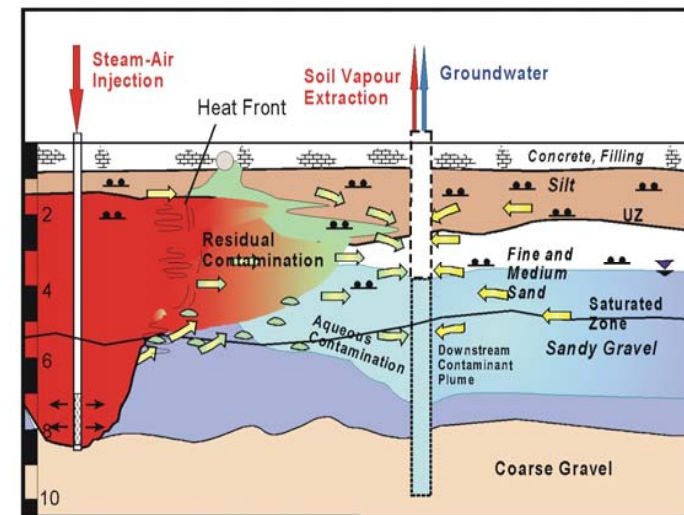
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Geology and remediation concept



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

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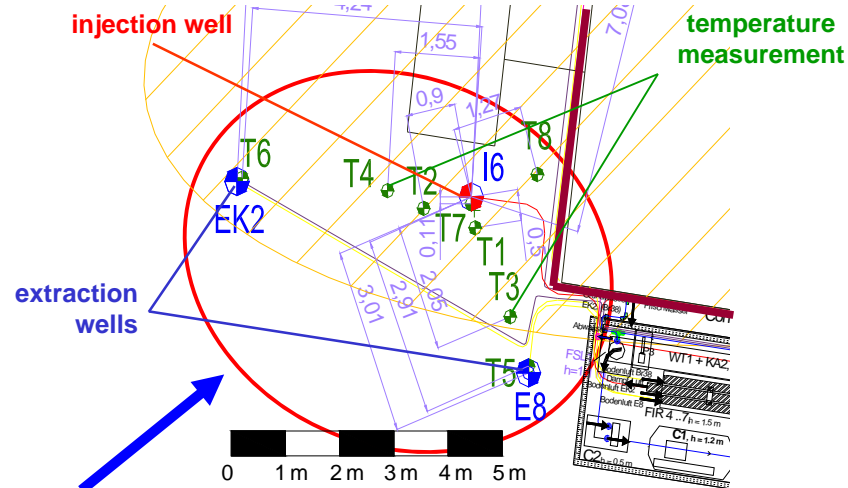
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Pilot field installation

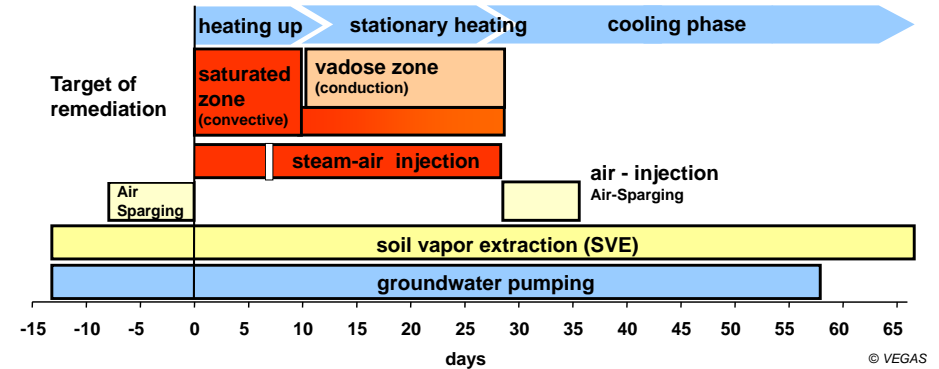


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Implementation of pilot remediation

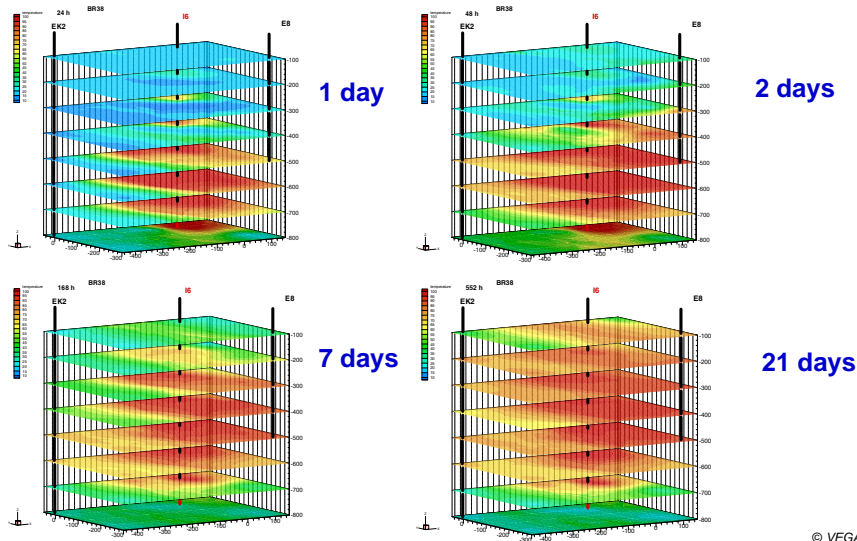
3 months duration → four different phases:

- (1) „cold SVE“ and groundwater pumping (5 days)
- (2) air-sparging (7 days)
- (3) steam-air injection (28 days)
- (4) Cooling phase: air-sparging, SVE und gw pumping (5 weeks)



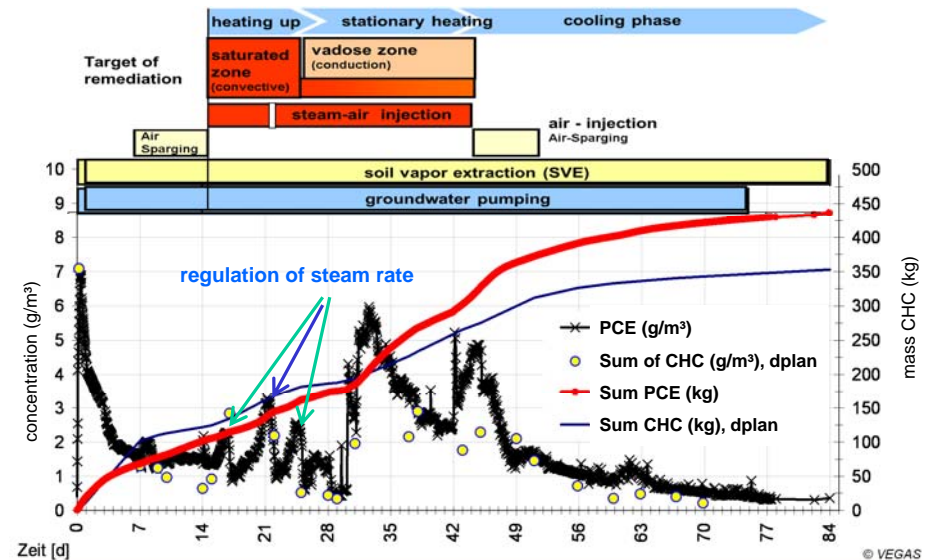
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Steam expansion – temperature monitoring



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Contaminant removal



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Summary of pilot application

- **Steam propagation > 4 m radius**
→ initial phase of maximum steam rate required
- **time required is dominated by conductive heating of the silt layers**
→ 4 – 6 weeks of reduced steam-air rate to heat up silt
- **440 kg PCE via SVE & 10 kg via GW removed:**
 - „cold“ SVE: 70 kg
 - air-sparging: 30 kg
 - steam-air: 340 kg
- **acceleration factor for steam-air of about 5**
- **safe design and cost estimation for full site remediation**

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Remediation goal and concept full scale

- ➔ 1.600 m³ of soil to be treated in-situ
- ➔ 10 months of steam-air injection
- ➔ 300 kW of steam injection power

Implementation of full scale remediation

➔ same as pilot

- (1) „cold“ soil vapour extraction and groundwater pumping all compartments (1 week)
- (2) air-sparging (each compartment)
- (3) steam-air injection (6 weeks, each compartment)
- (4) cooling phase: air-sparging and gw pumping 6 weeks)

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Remediation: implementation



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

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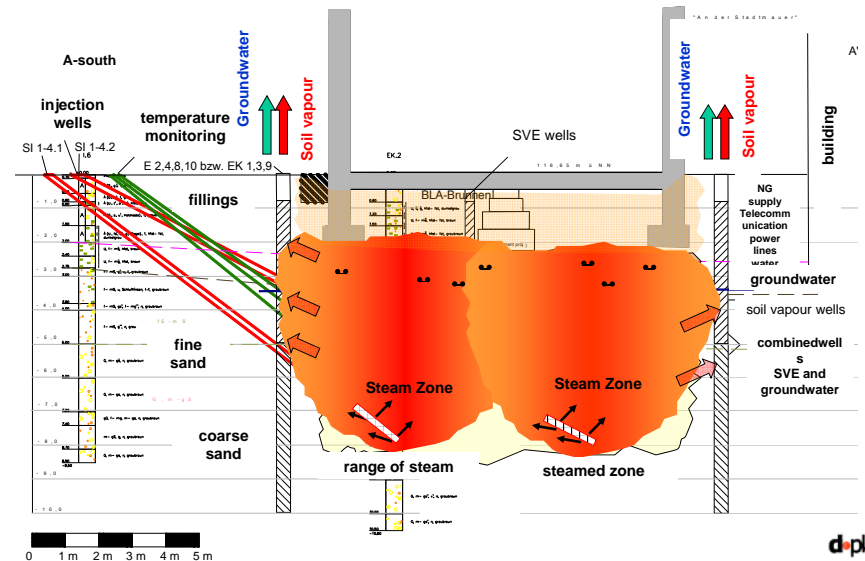
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Steam injection under the uilding



0 1m 2m 3m 4m 5m

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Remediation control and decision criteria

Control and balances

- Control of steam expansion and heat using 120 thermocouples in the subsurface
- Control and monitoring CHC and BTEX in soil vapour extraction (all lines, single wells and treatment)

Criteria of closure treatment of a compartment

1. target temperature of 87°C to be achieved in saturated zone (azeotropic temperature TCE-PCE-water)
2. Concentration of contaminant in SVE falling short of 20 mg/m³ and remaining constant or falling
 - compartment successfully treated
 - switch to next field

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Drilling works and wells construction



Photo: Steffen Hetzer, ZUT



Photo: Steffen Hetzer, ZUT



Photo: Steffen Hetzer, ZUT



ZUBLIN



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Betrieb Mai - Juli 2010



Groundwater and soil vapour extraction,
activated carbon filter

Exhaust chimney SVE

Extraction well and
temperature measurement

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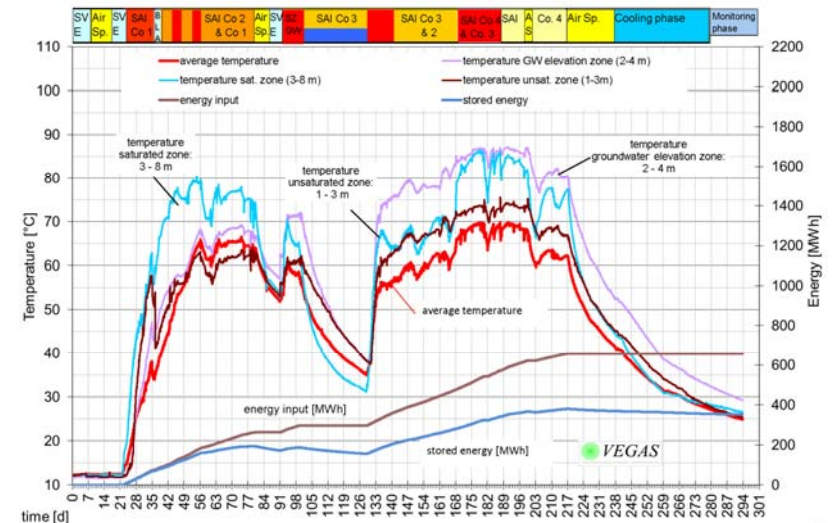
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Temperature development during remediation



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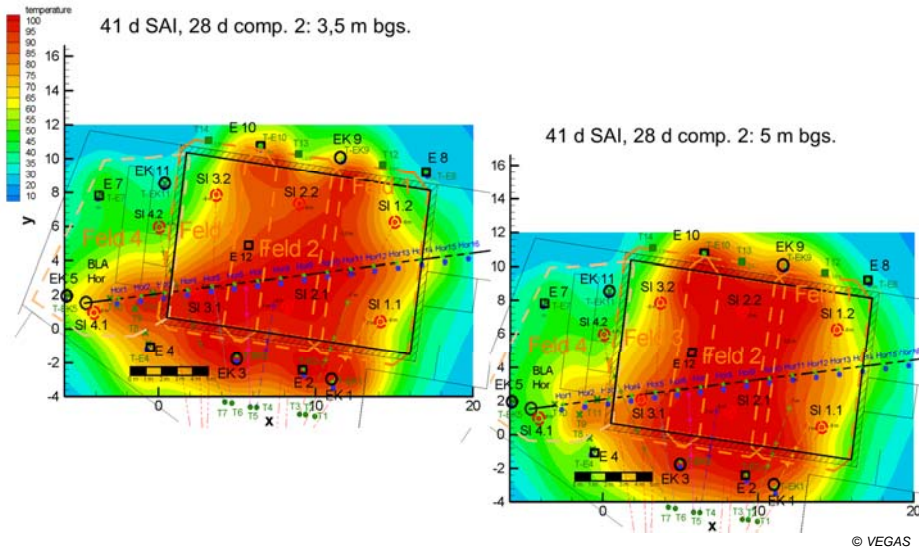
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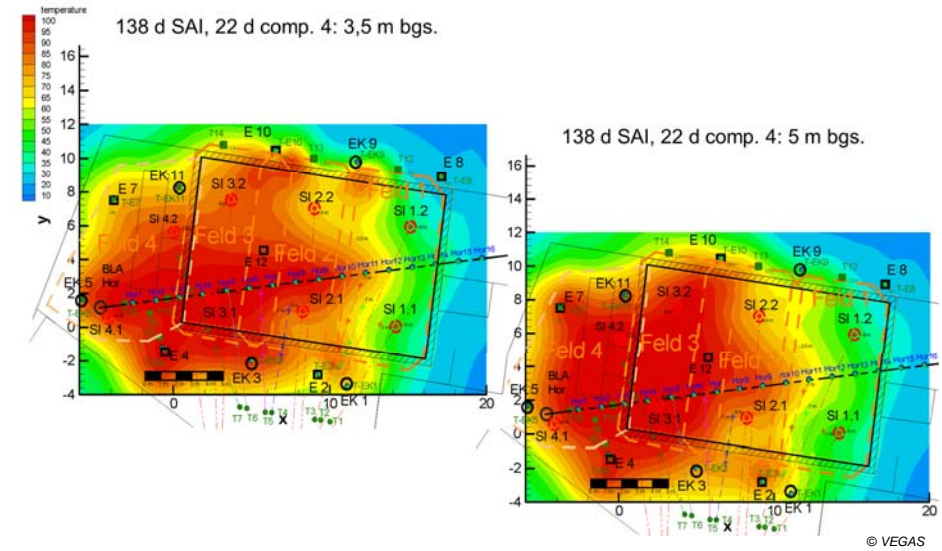


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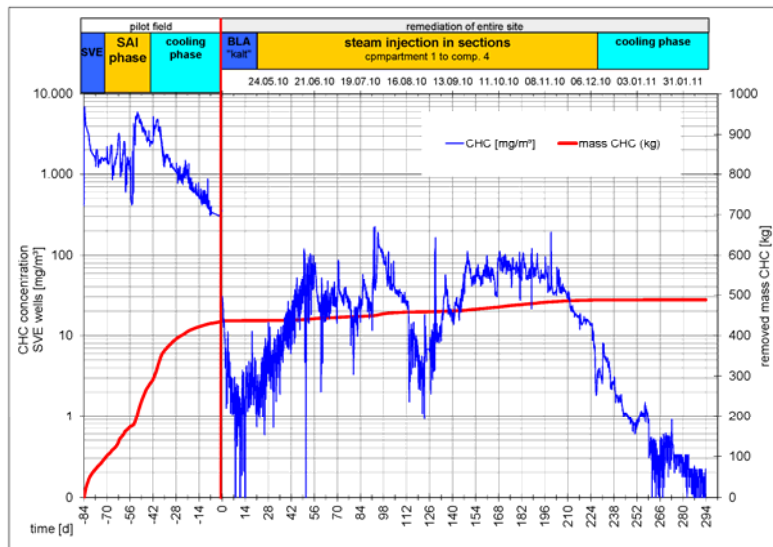
Heat propagation: compartment 2



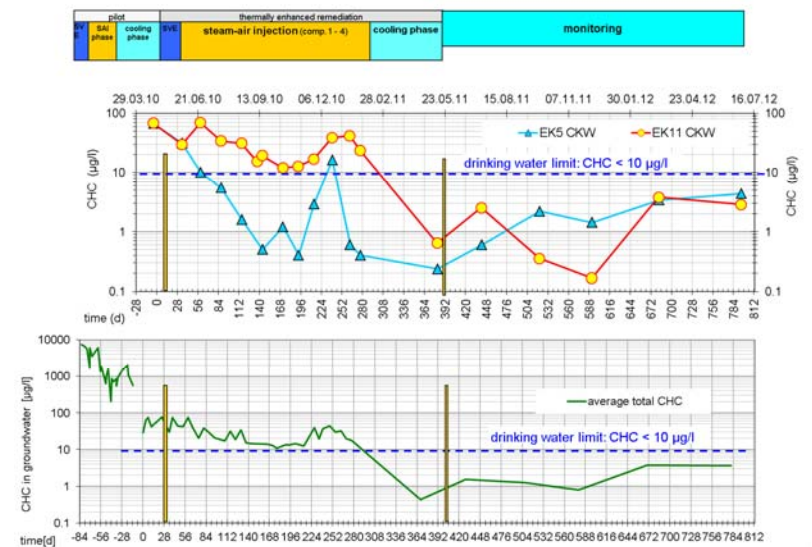
Heat propagation: compartment 4



Contaminant removal by SVE



Development of CHC in groundwater



Summary and some numbers of full scale remediation

- **Total duration** incl. drilling works 70 weeks
- **Duration of remediation** 42 weeks (ca. 30 weeks steam-air injection)
- **Contaminant removal mass** 50 kg CHC, (500 kg 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 bis n.n.

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Summary and some numbers of full scale remediation

- **Reduction of indoor contamination**
 - before: CHC up to 10 mg/m³
 - during and after: CHC = 0 mg/m³
- **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

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The site after the remediation
(15.11.2011)



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.. at the very end..

Thanks to all involved partners
for the good and team work and cooperation

Thanks for your patience and your interest

Any questions ?

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<http://www.vegas.uni-stuttgart.de>

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VEGAS, Versuchseinrichtung zur Grundwasser- und Altlastensanierung, Universität Stuttgart

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