EnISSA

Enhanced In Situ Soil Analysis

Pieter Buffel
Pieter.buffel@enissa.com

Fedexsol 27/05/2015

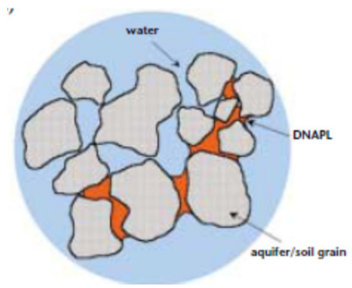
1. Introduction: DNAPL's
2. EnISSA MIP
3. Soil characteristics
4. Case studies

1. Introduction

Chlorinated Solvents and DNAPL

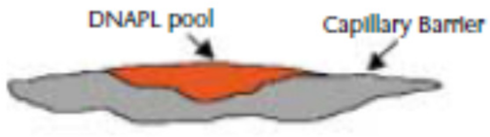
1.1 CVOC transport

Chlorinated volatile organic compounds:



•Density > water

- Migrate to substantial depths ➔ DNAPL (Dense non-aqueous phase liquids)
  - residual DNAPL ("blobs and ganglia")
  - pooled DNAPL (continuous product)



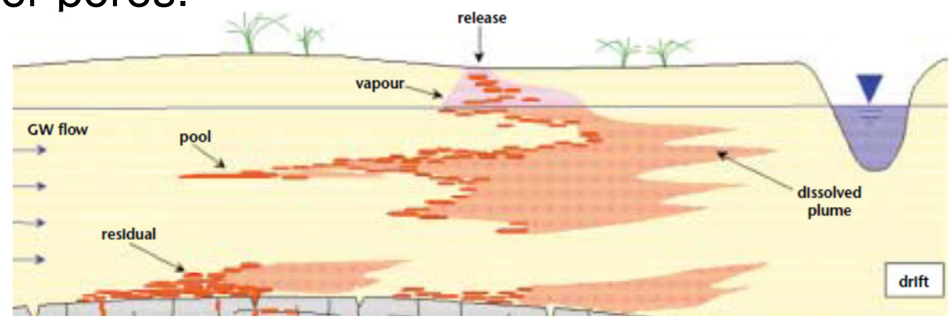
➔ slow dissolution ➔ long term groundwater contamination

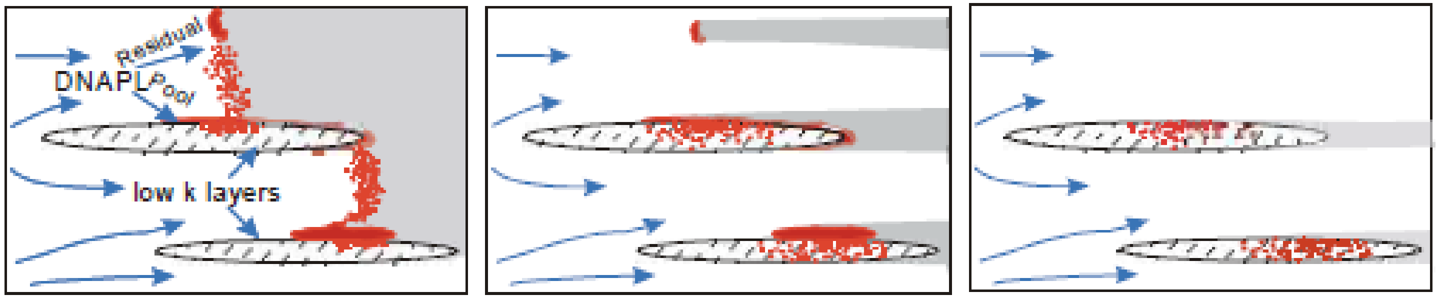
•Low K_{oc} values: no strong retardation ➔ high mobility

➔ extended plumes

CVOC transport

- DNAPL migration is strongly dependent on differences in soil characteristics
  - Finer grained material (capilary resistance):
    - acts as barrier ➔ DNAPL pooling & lateral spreading
    - Matrix diffusion and advection: DNAPL is ‘stored’ in smaller pores.

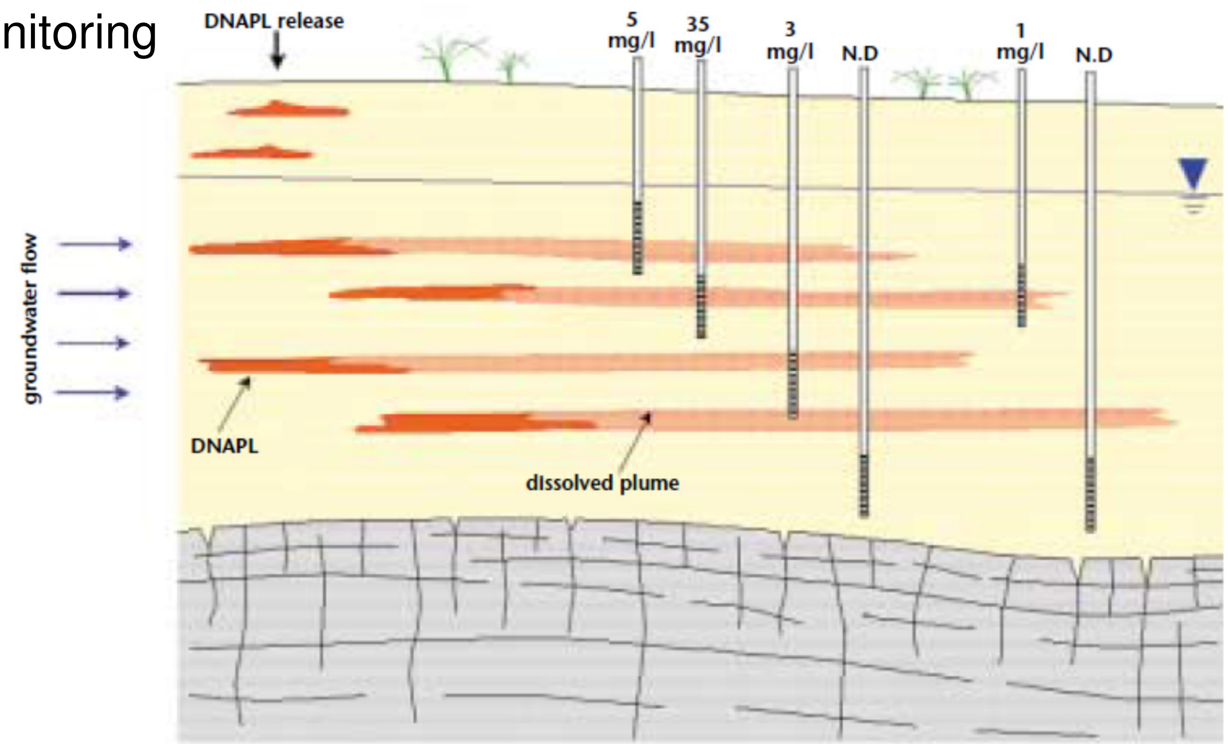




Early Time Mid-Time Late Time

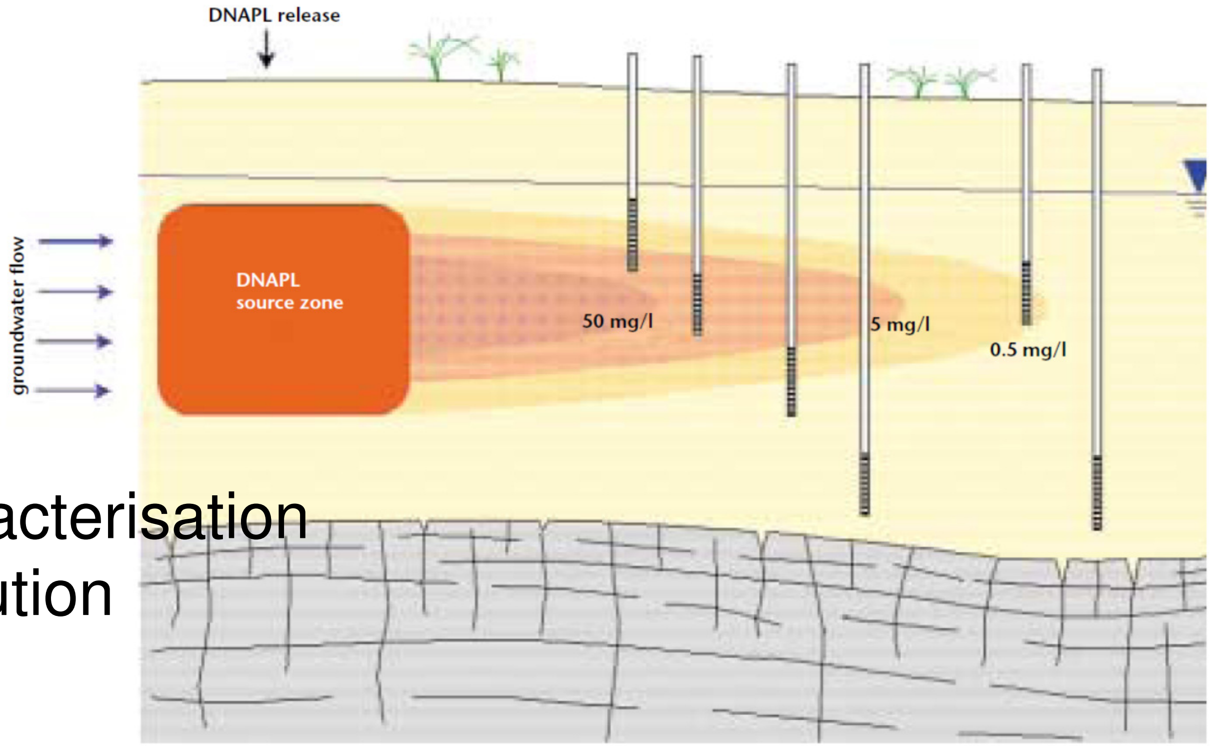
1.2 CVOC Characteristation

- Vertical cross-section of DNAPL and plumes
- results from monitoring wells



1.2 CVOC Characteristation

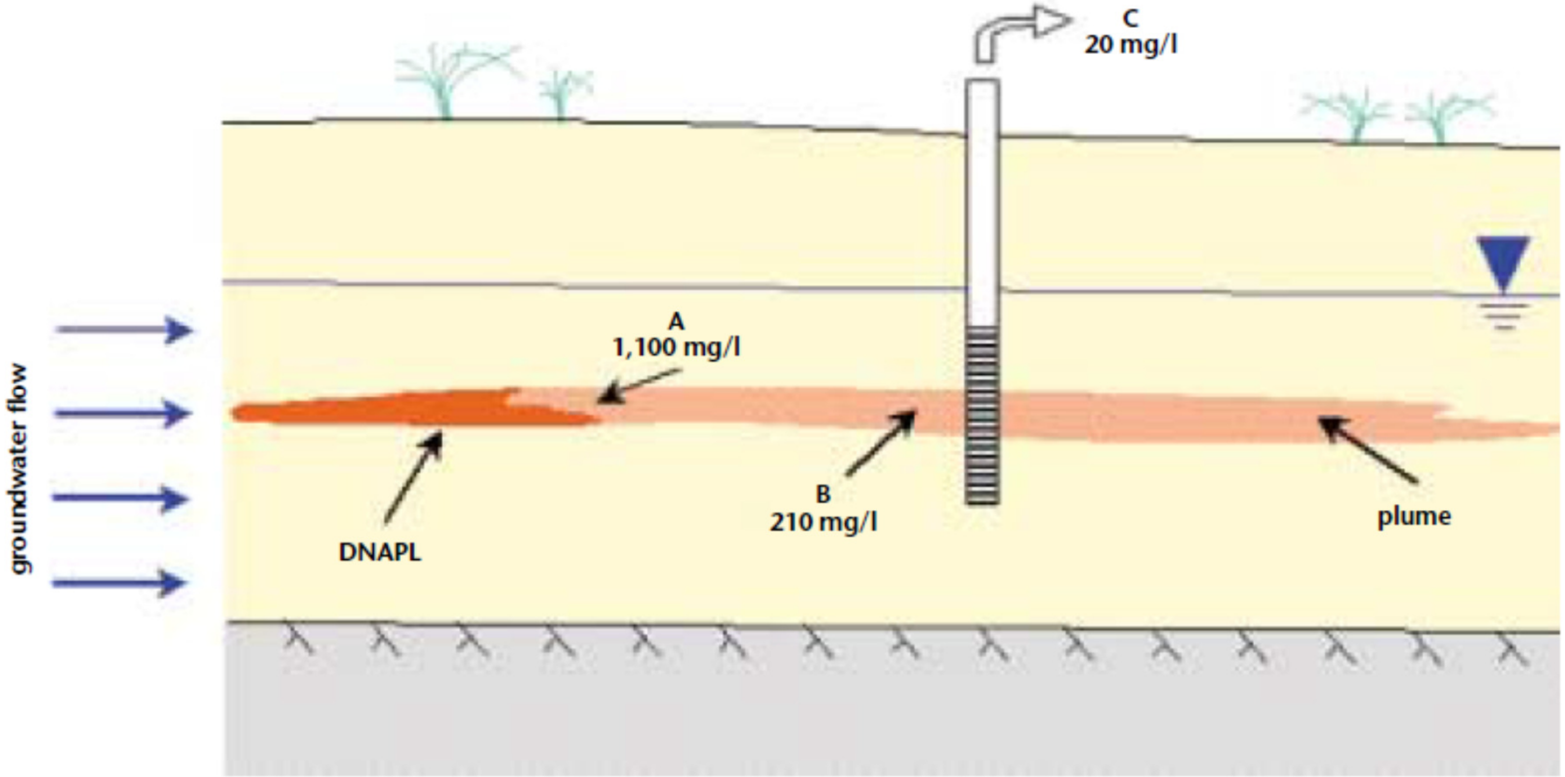
- Interpretation of CSM based on those results:



- Incomplete characterisation due to low resolution

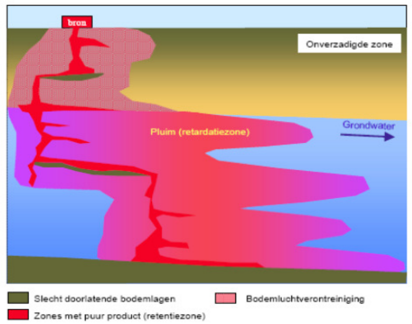
1.2 CVOC Characteristation

- Dilution in filter
- Preferenced flow from higher permeable material



1.2 CVOC Characteristation

classic sampling strategies (monitoring wells)

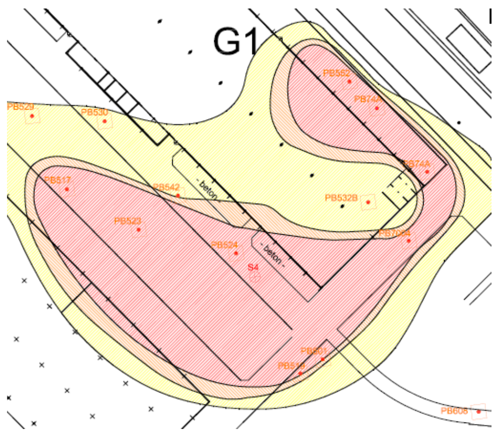


+ low detection level

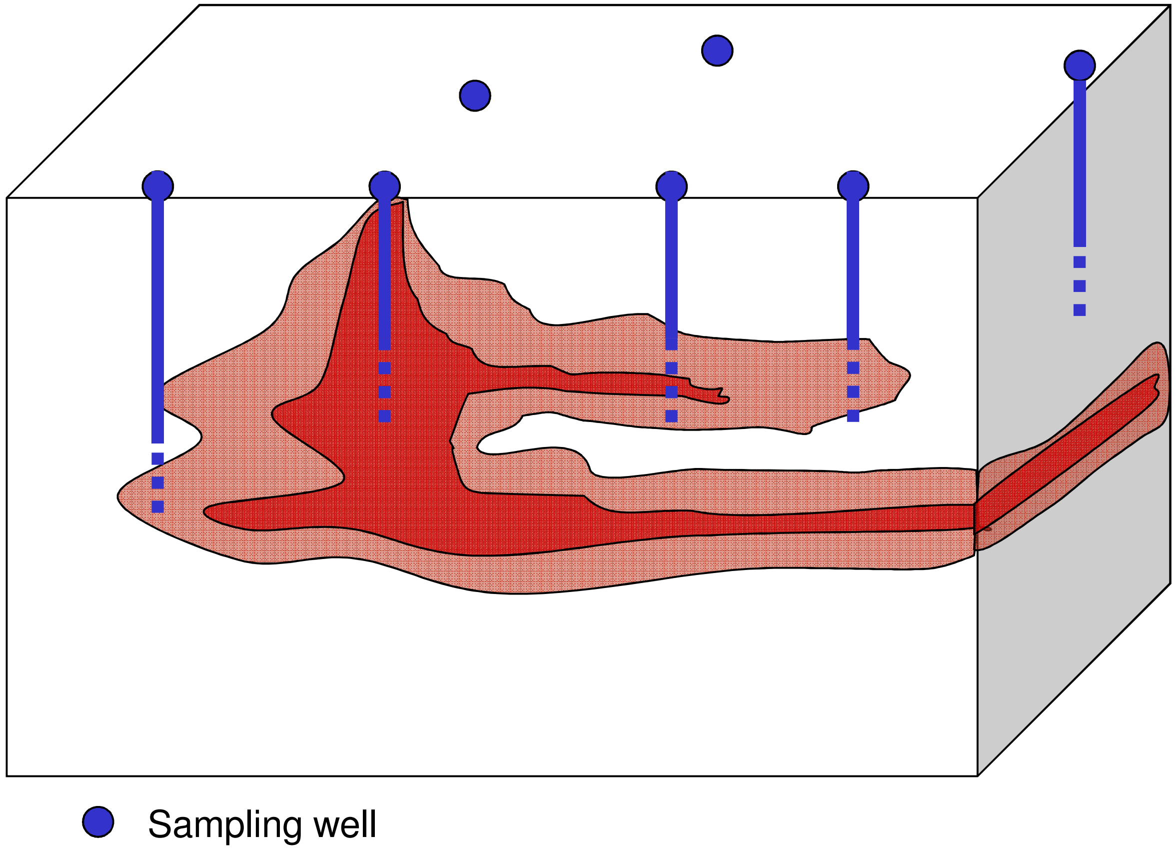
+ broad analysis spectrum

- Decision making: Time inefficient

- Large contaminated area: large information gaps



1.2 CVOC Characteristation



Data gaps

1.2 CVOC Characteristation

- The scale of measurement must be appropriate for the scale of heterogeneity:
  - hydraulic conductivity and contaminant concentration can vary on small scale

➔ Conventional monitoring wells are not optimal investigation tools :

- Wells yield depth-integrated data
- Cannot discern heterogeneities that control contaminant transport
- Limited sampling points

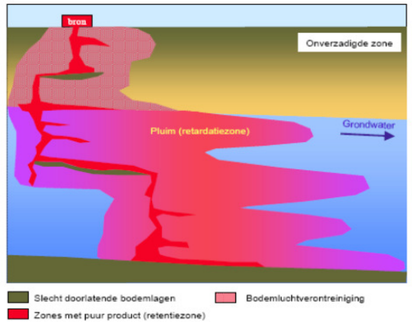
- EPA ➔ High Resolution Site Characterisation (HRSC)
  - scale-appropriate measurement and data density
  - to define contaminant distributions in environmental media with greater certainty,
  - supporting faster and more effective site cleanup

HRSC Addresses Two Critical Issues

- Sampling Scale and Data Averaging
  - Measurements must be made at a scale that is meaningful with respect to the variability of the quantity being measured
- Coverage
  - Enough measurements at the right locations
    - Horizontal spacing
    - Vertical spacing

1.2 CVOC Characteristation

classic ↔ Current “On Site” soil investigation
(MIP, ROST, …)



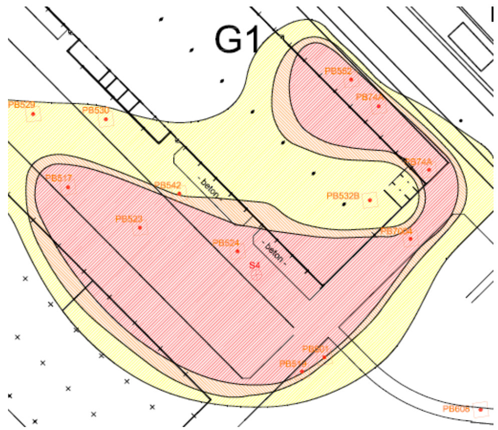
+ information in the field

+ detailed soil profiles = high vertical resolution

- information quality not equal to classic sampling

    - Detection limit > clean up values

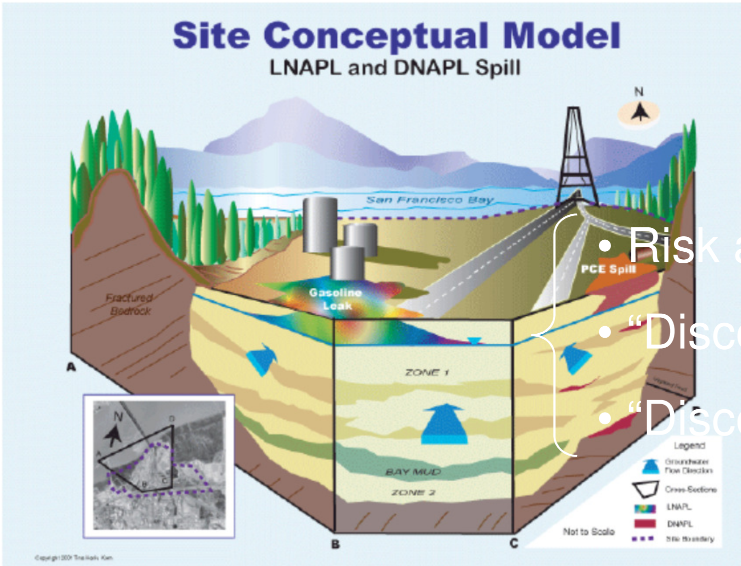
    - Sum detectors (indistinct)



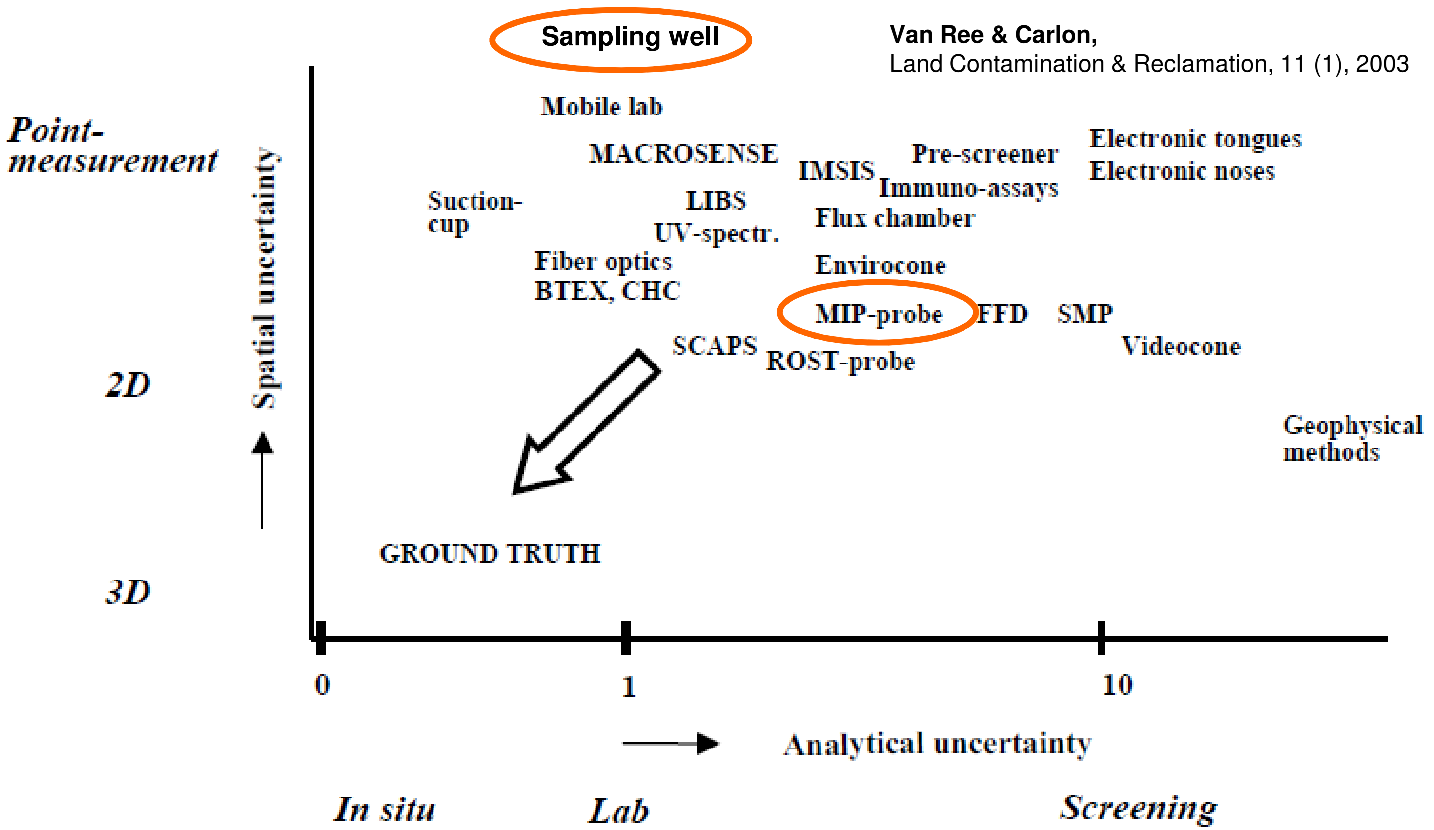
1.2 CVOC Characteristation

Analytical uncertainty

Spatial uncertainty



1.2 CVOC Characteristation



decrease uncertainty in conceptual site model by combining

"Best of both worlds" **in one method.**

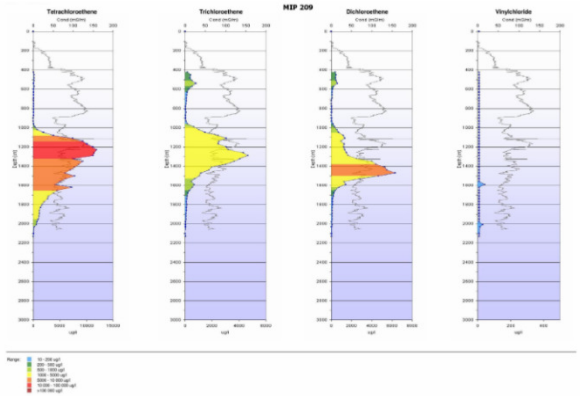
1.2 CVOC Characteristation

EnISSA project:

Combining best of both worlds

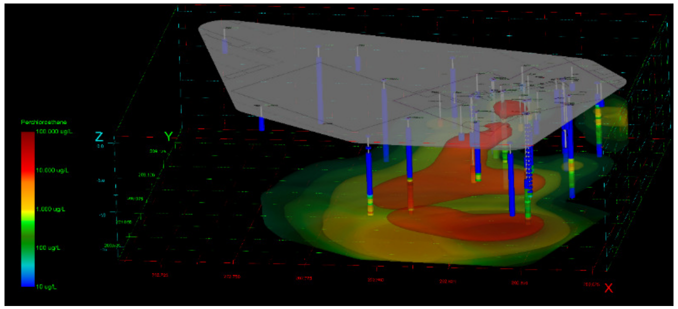
+ low detection level
+ broad analysis spectrum
+ information in the field
+ detailed soil profiles

Development of a **fast** in situ technology with detection limits and selectivity comparable to classis sampling methods.

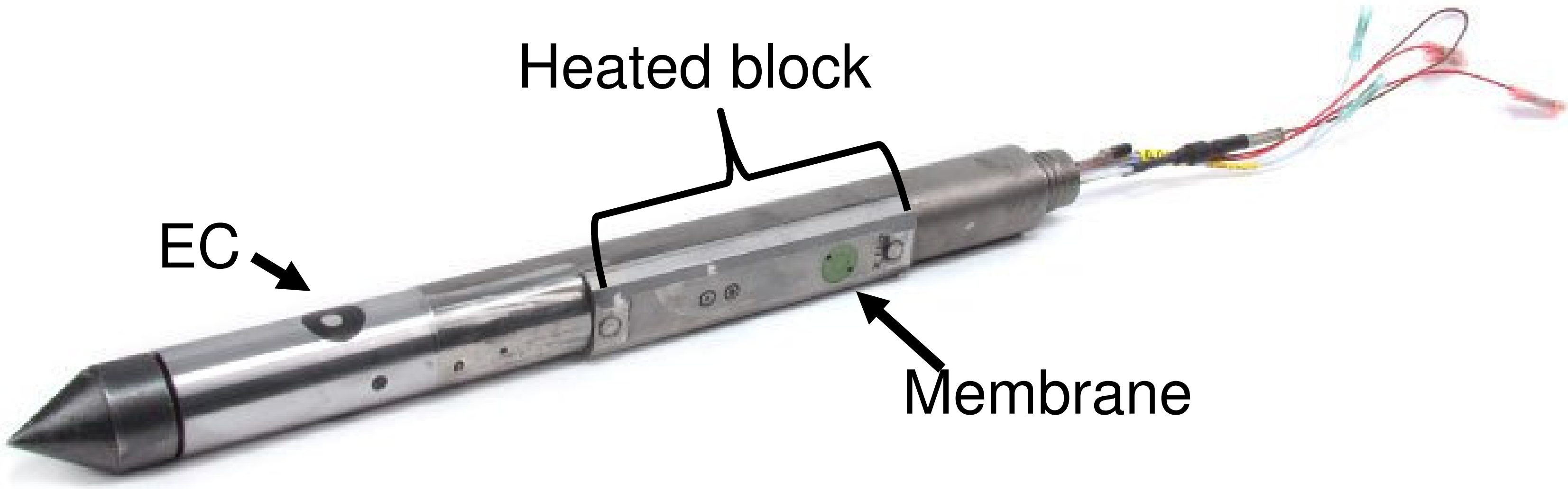


2. EnISSA-MIP

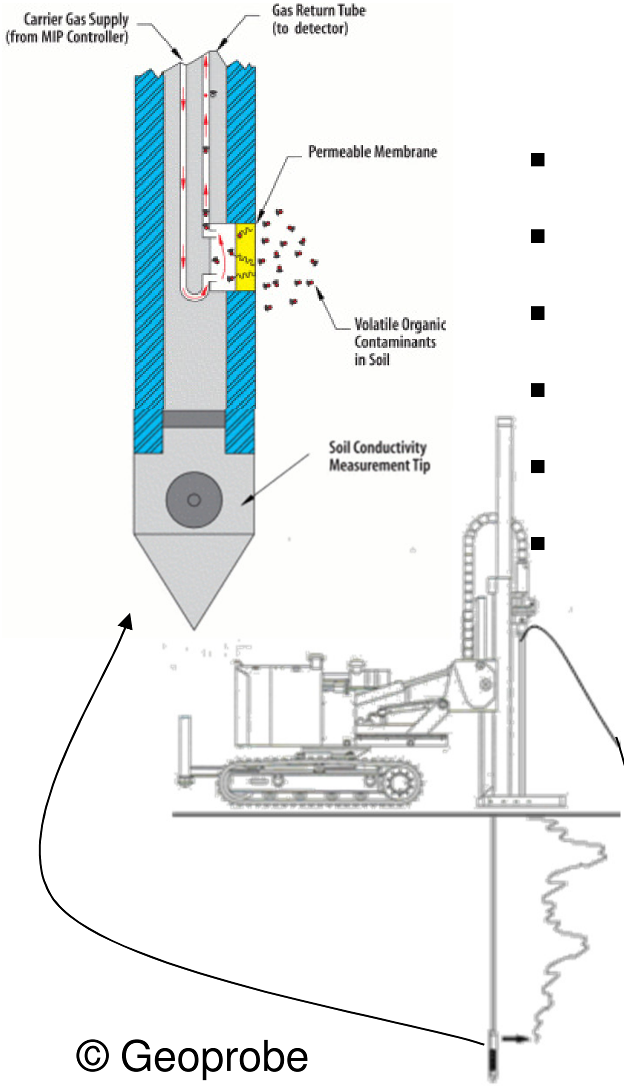
A powerfull tool for high resolution site characterisation



Membrane Interface Probe



2.1 MIP



Membrane Interface Probe

- Screening tool for VOC
- Cone: heated block and hydrophobic semi permeable membrane
- Direct push
- Local heating of soil
- Volatilization and diffusion through membrane
- Inert carrier gas & transport to detector

Typical setup: Combination of three detectors:

* Dry electrolytic detector (DELCD) or
  Halogen specific detector (XSD)
* Photo ionisation detector (PID)
* Flame ionisation detector (FID)

2.1 MIP

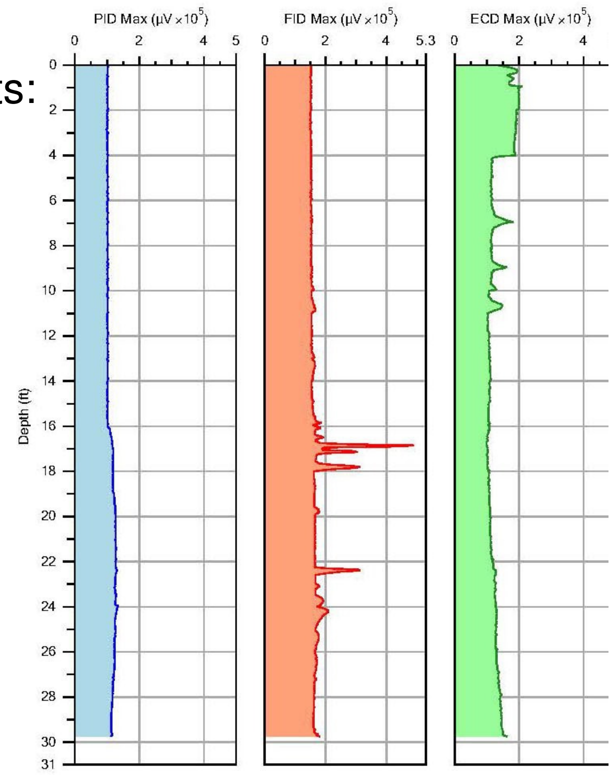
PID, FID, DELCD & XSD

→ Summation-detectors: no information on individual contaminants: polluent cocktails!

→ respons (µV signal) is component specific ➔ quantification difficult

→ detection limit > groundwater clean-up values in Flanders : µg/l

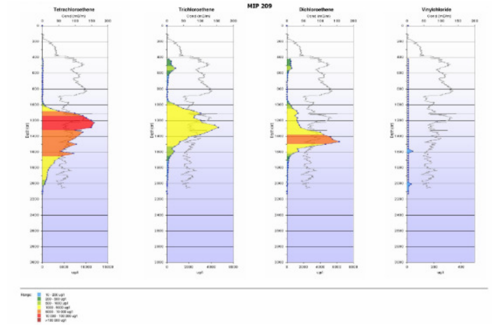
➔ Plume delineation is impossible



COLUMBIA TECHNOLOGIES

EnISSA MIP

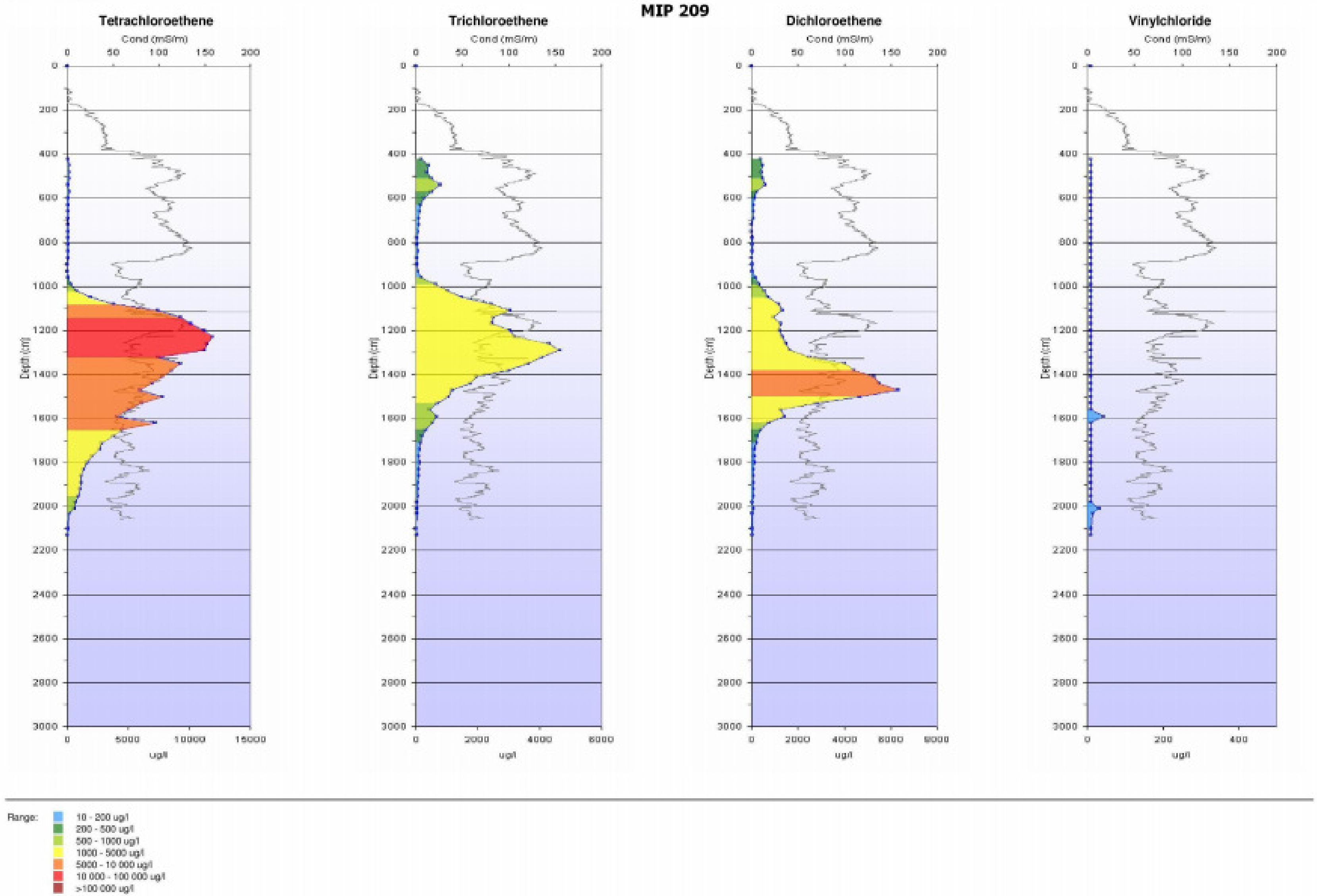
- MIP with dedicated **GC-MS detection** combined with proprietary contaminant sampling technology



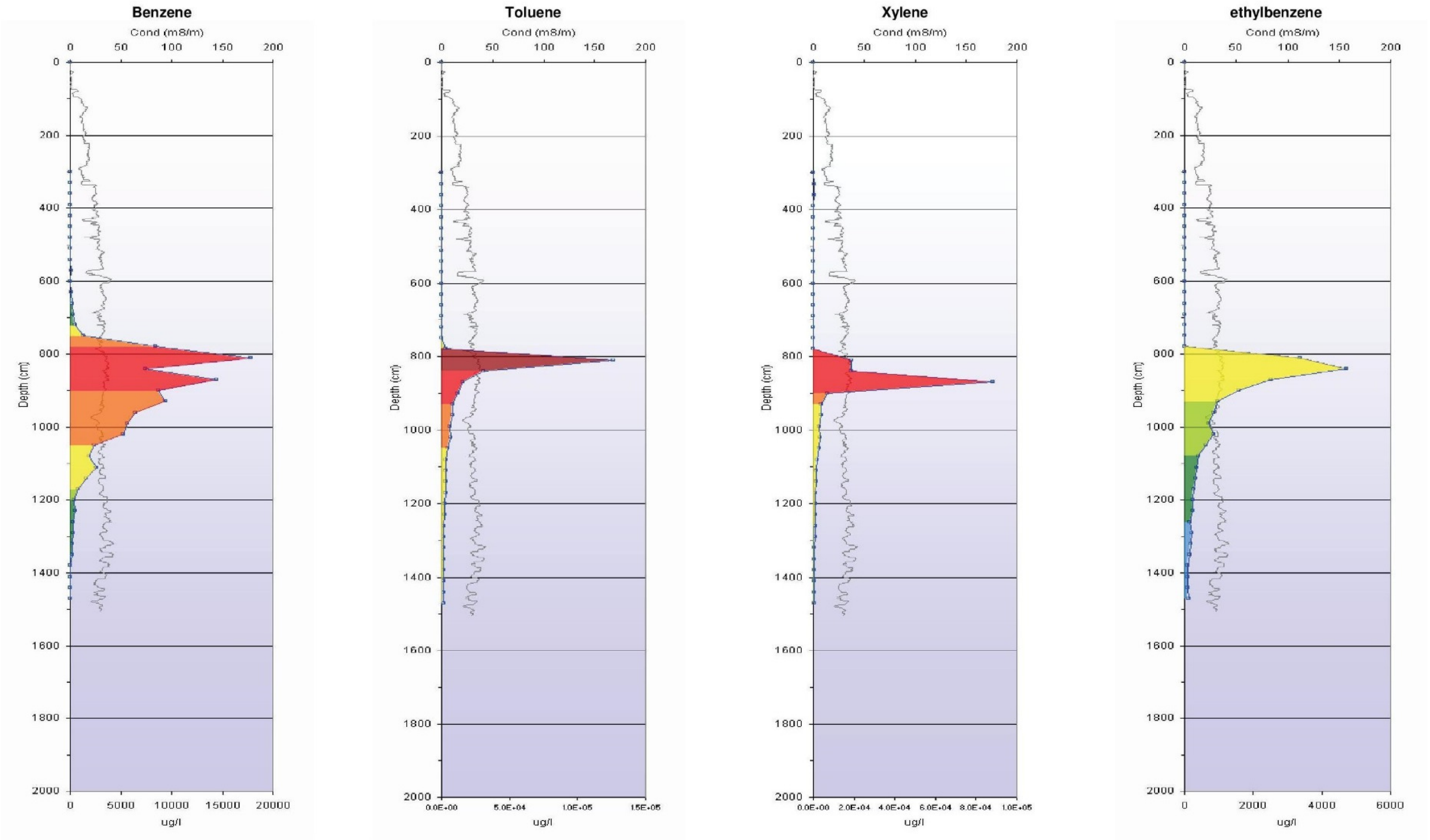
- GC-MS: Optimized for field measurements:
  * ruggedized
  *** cycle/analysis time: 1 min**
  → 1 measurement per 30 cm at probing speed of 30 cm/min
  *** up to 12 compounds simultaneously**

Highly detailed profiles for individual compounds on ppb level

2.2 EnISSA MIP



2.2 EnISSA MIP

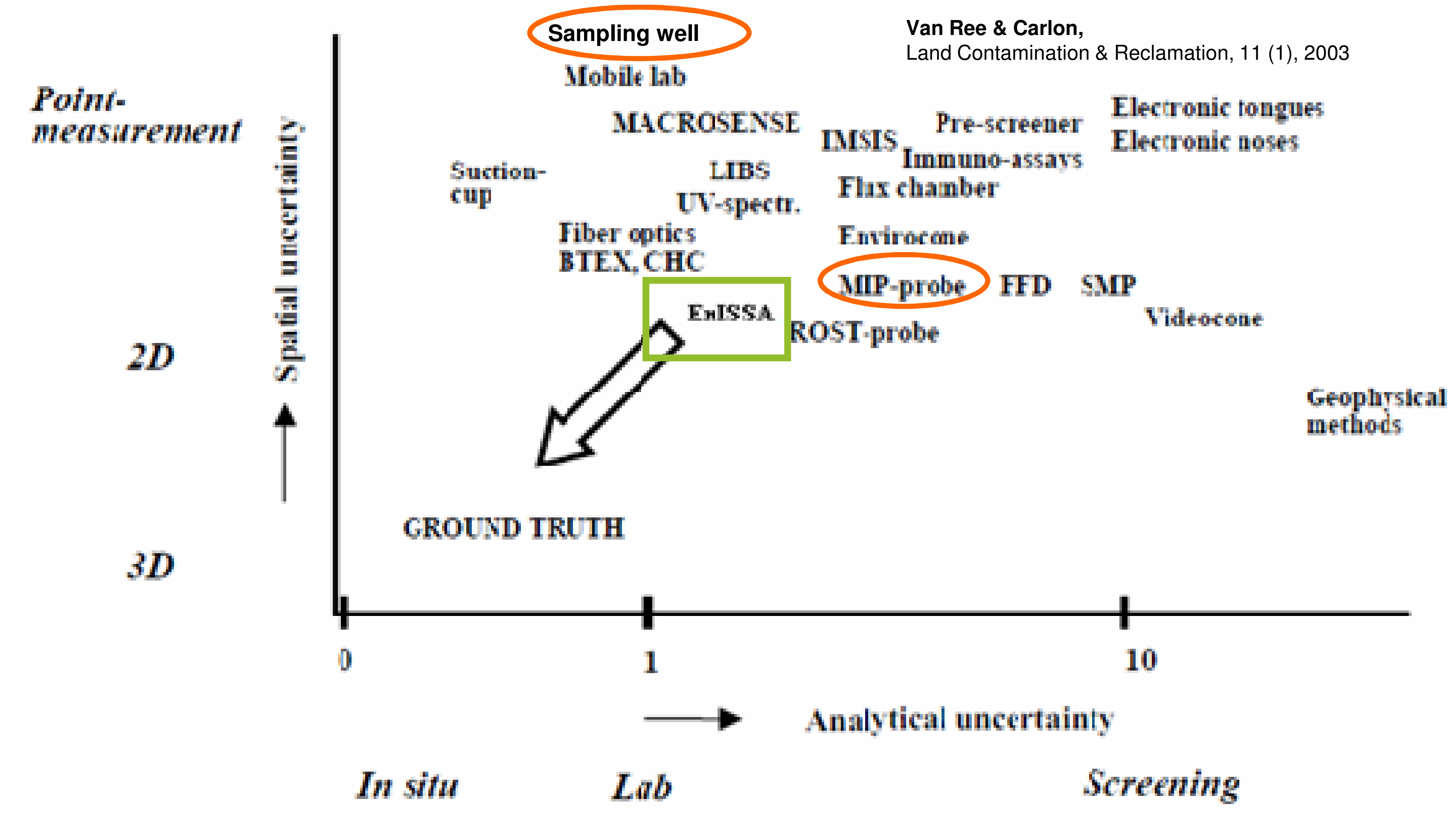


Range:
- 10 - 200 ug/l
- 200 - 500 ug/l
- 500 - 1000 ug/l
- 1000 - 5000 ug/l
- 5000 - 10 000 ug/l
- 10 000 - 100 000 ug/l
- >100 000 ug/l

2.2 EnISSA MIP

ARE WE THERE YET?

Van Ree & Carlon,
Land Contamination & Reclamation, 11 (1), 2003



2.2 EnISSA MIP

entire delineation of contamination: source + plume

EnISSA MIP measures on **ppb** level

→ source and plume

(Conventional MIP measures on sub-ppm level)

- Order of magnitude = groundwater sample → high quality screening tool -

"On site" information on pollution cocktails:

EnISSA MIP measures **individual compounds** in contrast to the sum-detectors used in conventional MIP

- Each 30 cm up to 12 compounds can be distinguished -

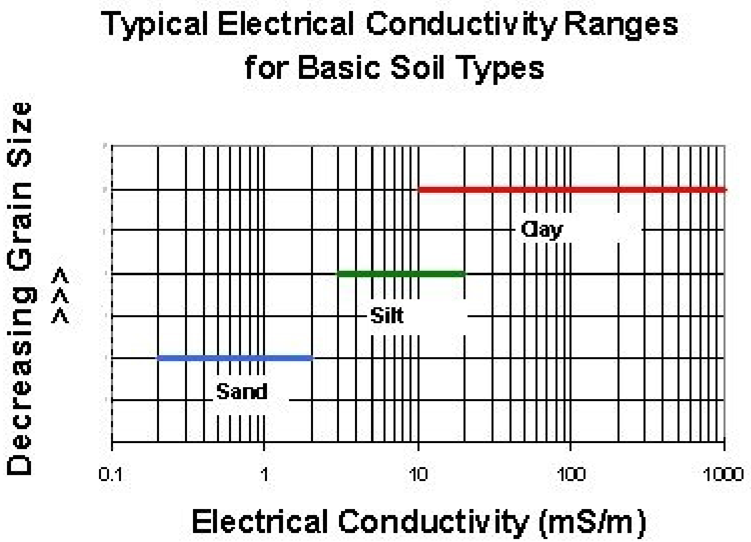
strategic sampling well locations:

The entire delineation of source and plume obtained by EnISSA MIP makes it possible to place sampling wells at strategic locations **reducing sampling costs and time**.

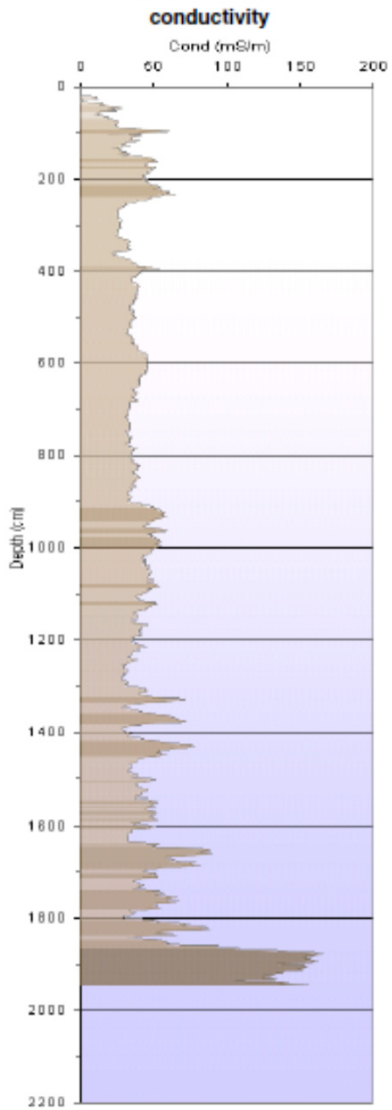
High resolution data is essential to characterize chlorinated solvents

2.3 Soil characteristics: EC

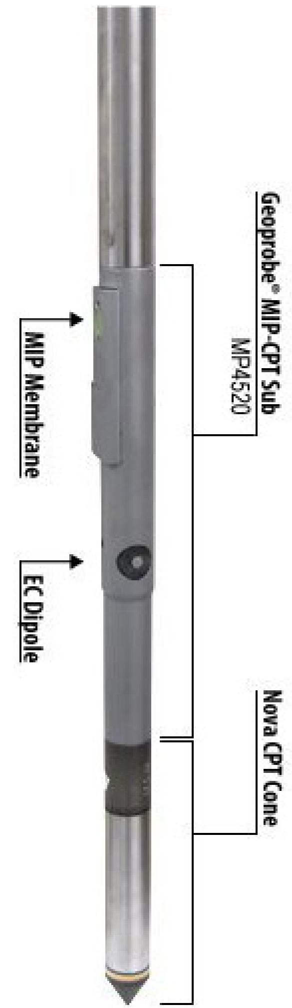
Electrical Conductivity (EC)



EC-dipool

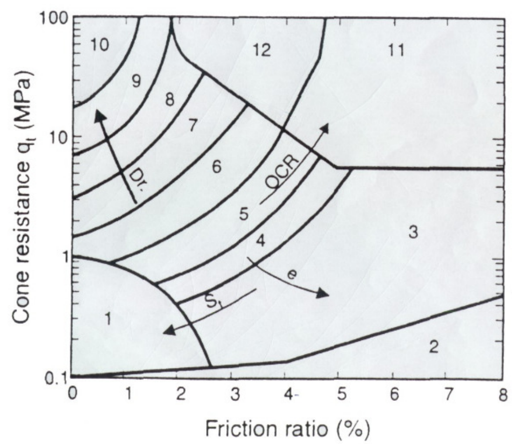


Cone Penetrometer Test (CPT)

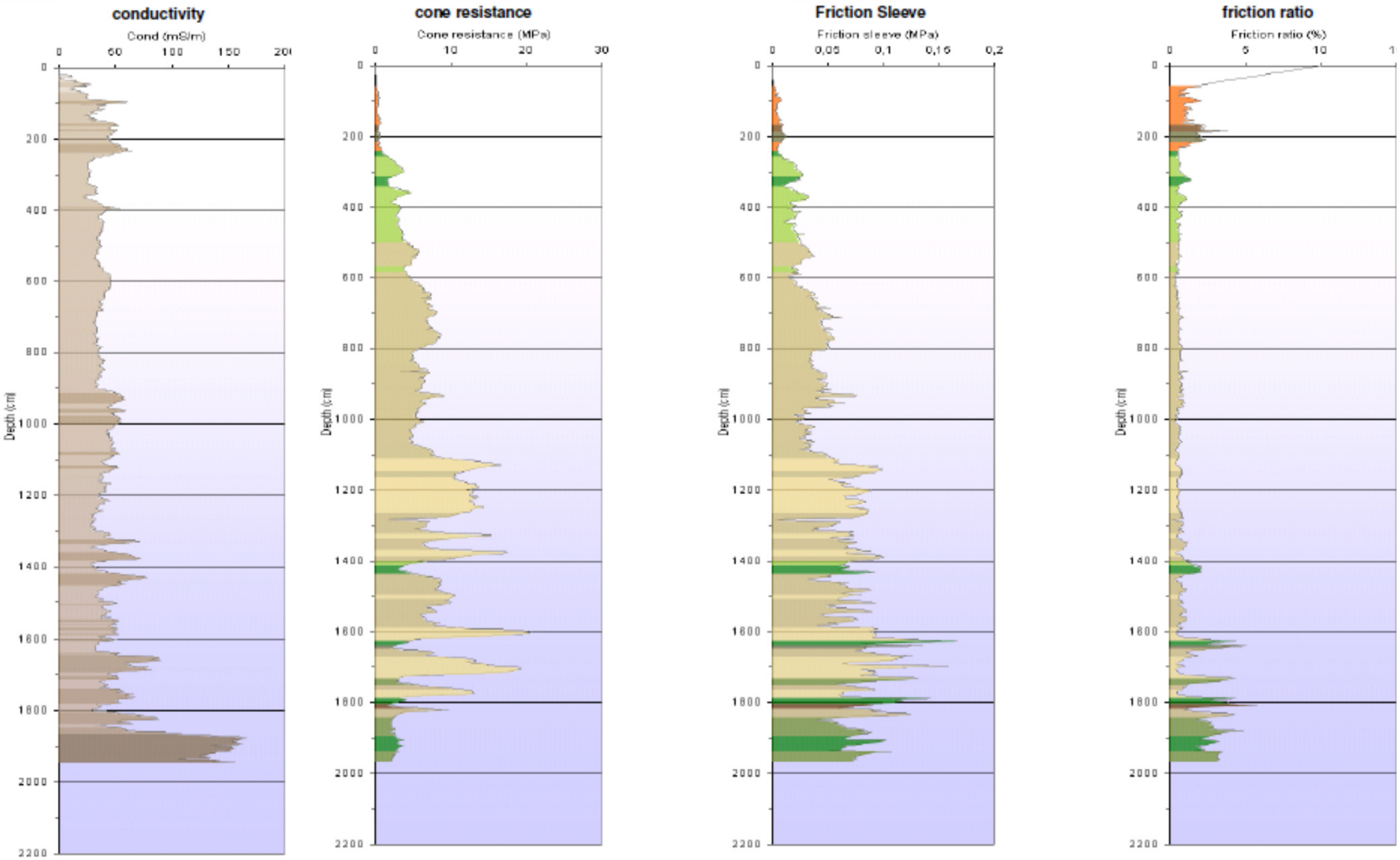


- Pushed without hammering
  - Anchoring of Geoprobe
  - 20 ton hydraulic push truck

- Local friction
- Point Resistance
- Classification in 12 soil categories

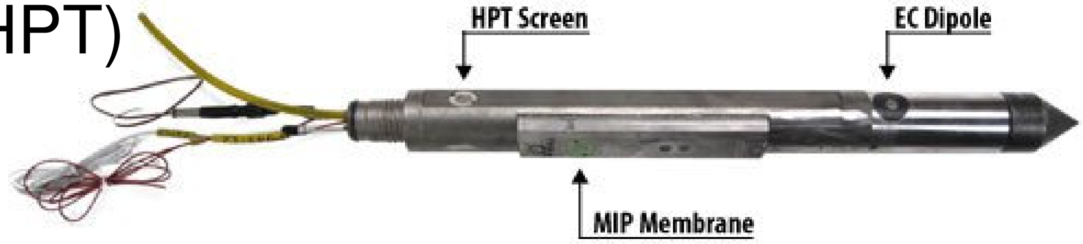


2.3 Soil characteristics: CPT



2.3 Soil characteristics: HPT

Hydraulic Profiling Tool (HPT)

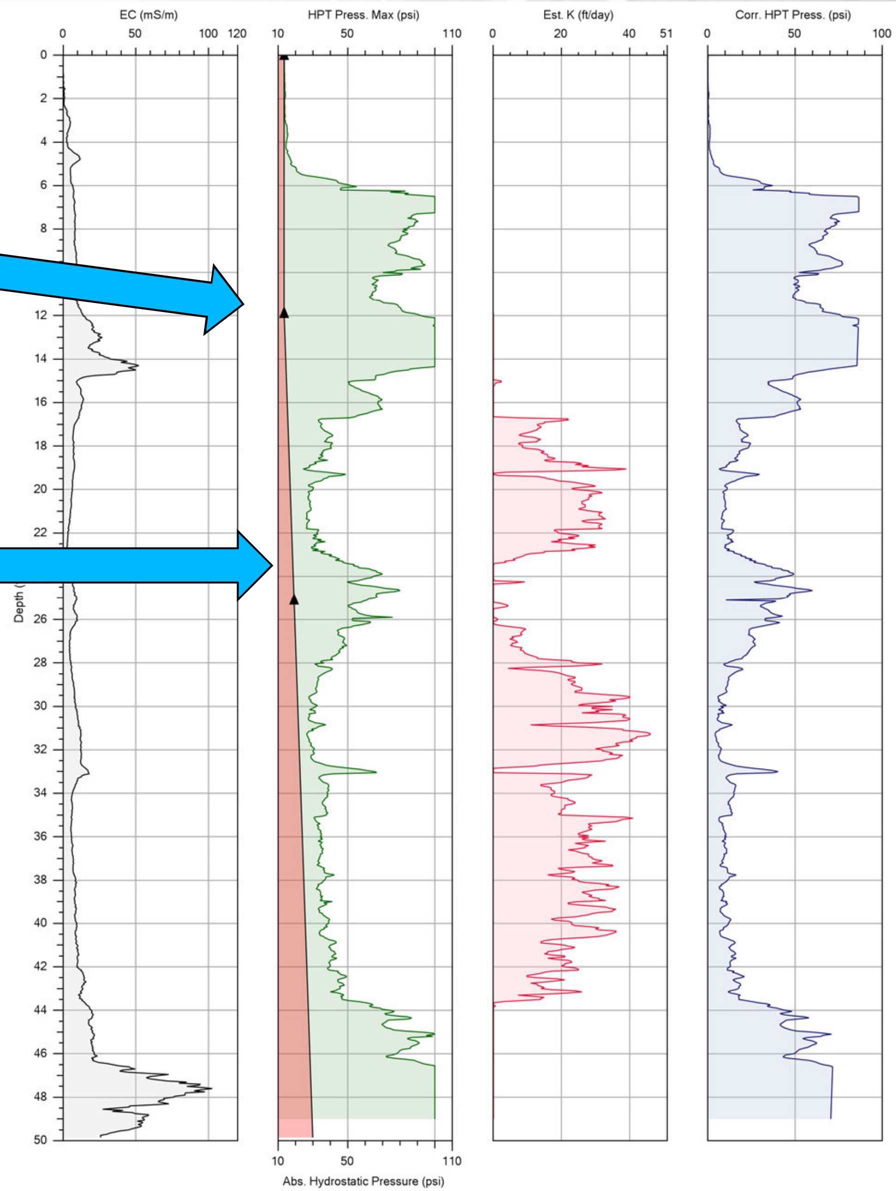


- MiHPT = MIP + HPT
- Injection of continuous water flow
  - injection pressure is an indication of the local permeability of the soil.
  - A real-time detailed pressure and flow log is generated for each probing location giving more insight in hydrogeology.
  - Combined with dissipation tests or groundwater level data, an Estimated conductivity (K [m/day]) can be calculated based on an empirical model.

2.3 Soil characteristics: HPT

Estimated water level

Hydrostatic pressure



Case studies

1. Weaving mill Kortrijk OVAM (Citychlor demo)

2. Wool production Mol

3. Gas station, MTBE plume

3. Case studies

Kortrijk – Weaving Mill
Antwerp region - Wool Factory
Antwerp region- Service station
Waregem – Metalurgy site

Case Study 1

Kortrijk: Former weaving mill: Demonstration project OVAM

Contamination: PCE, TCE, DCE, VC, 111TCA, BTEX, …

6 EnISSA-MIP locations compared to soil samples and wells

Full report at www.citychlor.eu

Original Monitoring Well

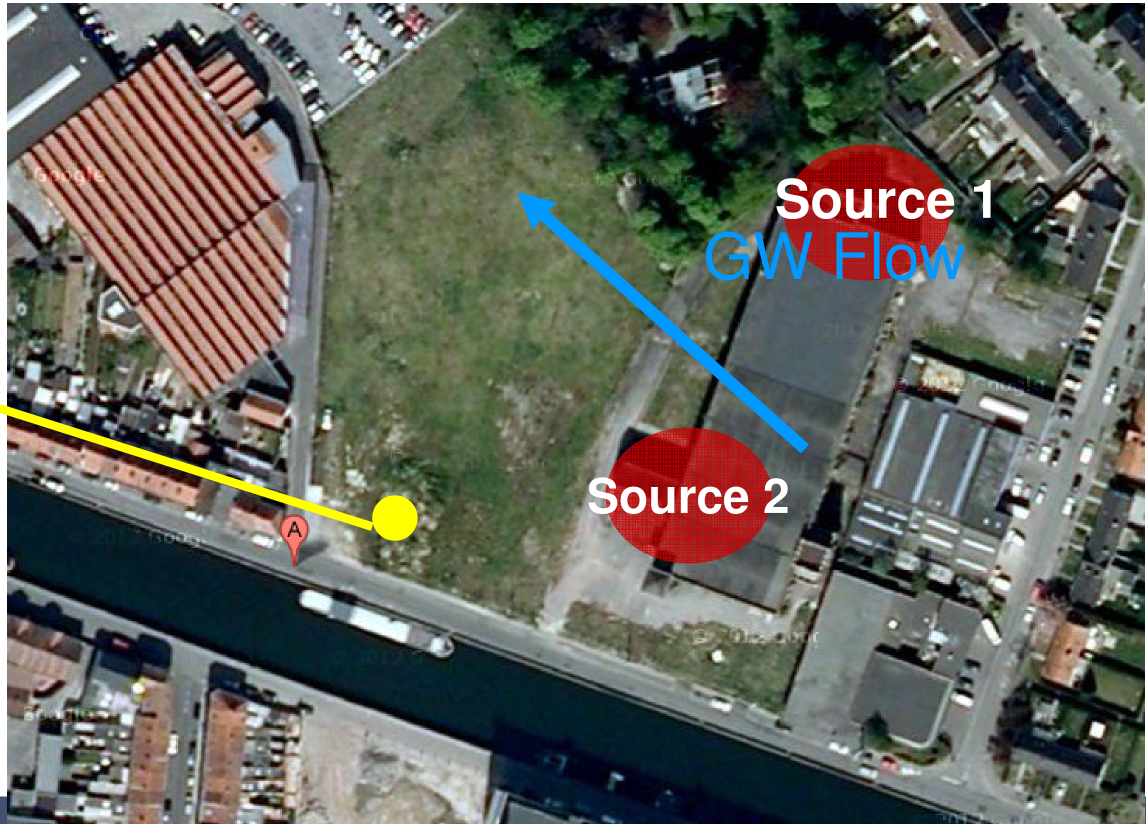
Screen 9-10 m-mv:

PCE: < 0,5 ug/l

TCE: < 0,5 ug/l

DCE: < 0,5 ug/l

VC: 94 ug/l



Case Study 1

EnISSA-MIP next to well:

Original Monitoring Well

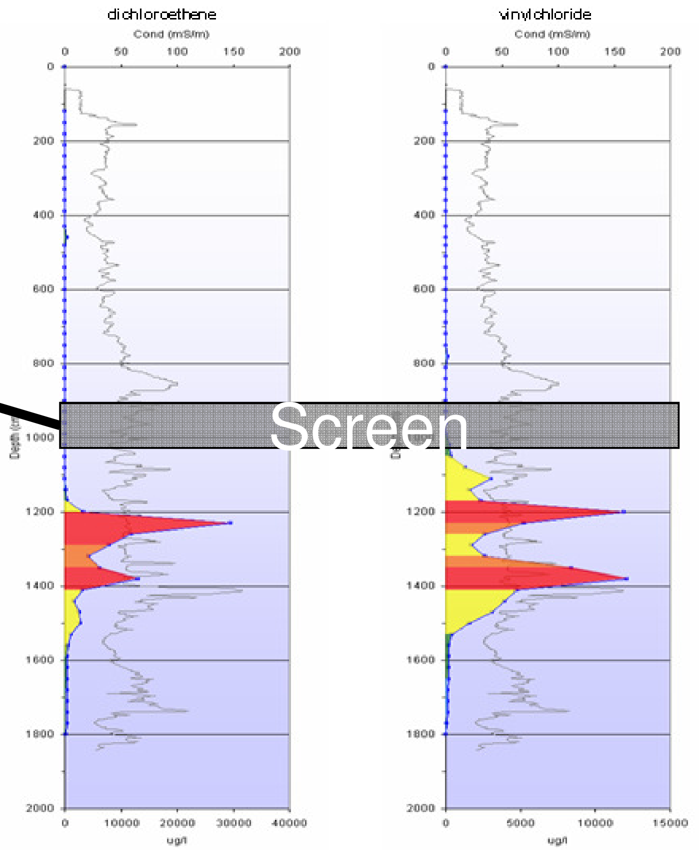
Screen 9-10 m-m-bgl:

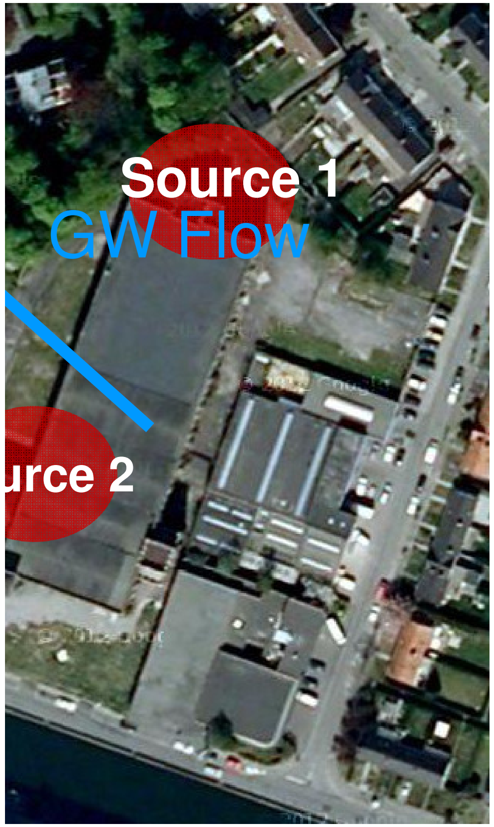
PCE: < 0,5 ug/l

TCE: < 0,5 ug/l

DCE: < 0,5 ug/l

VC: 94 ug/l





Case Study 1

EnISSA-MIP next to well and new targeted well:

Original Monitoring Well

Screen 9-10 bgl:

PCE: < 0,5 ug/l

TCE: < 0,5 ug/l

DCE: < 0,5 ug/l

VC: 94 ug/l

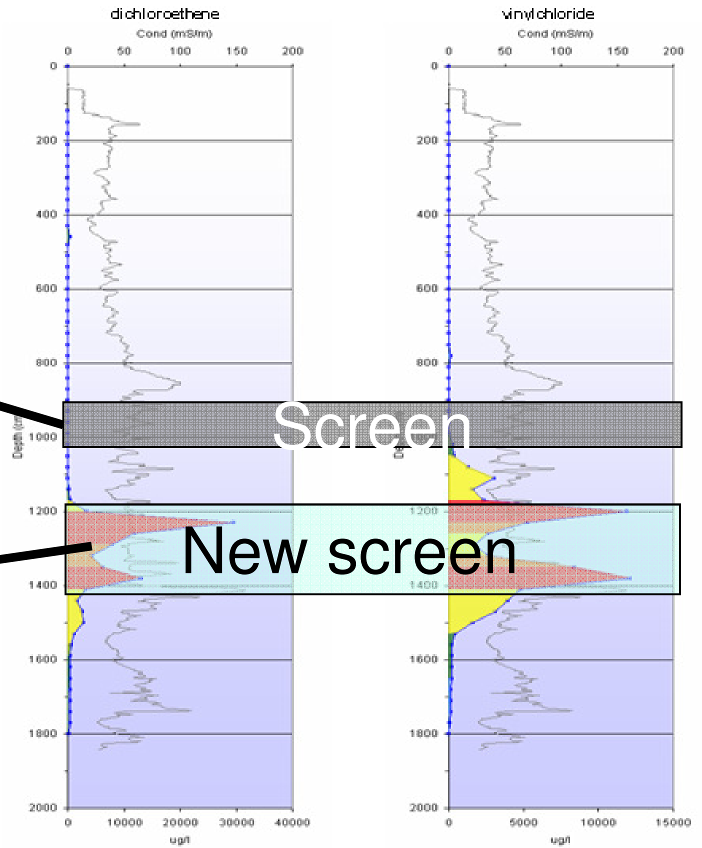
Screen 12-14 bgl:

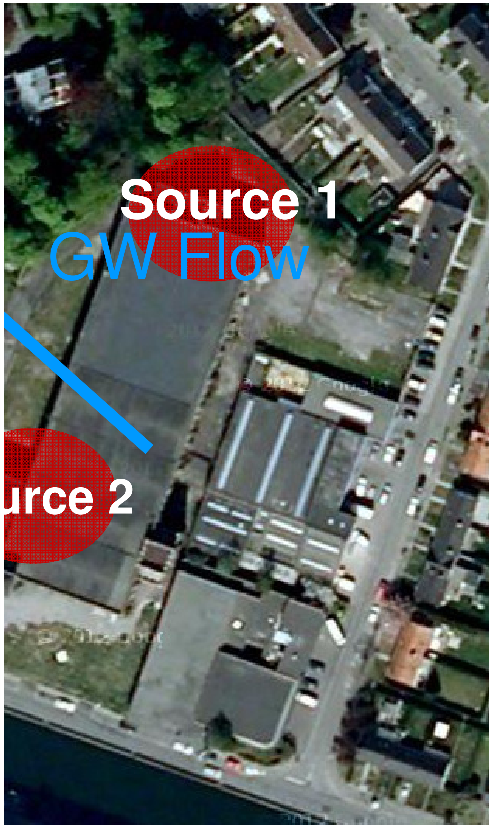
PCE: < 0,5 ug/l

TCE: < 0,5 ug/l

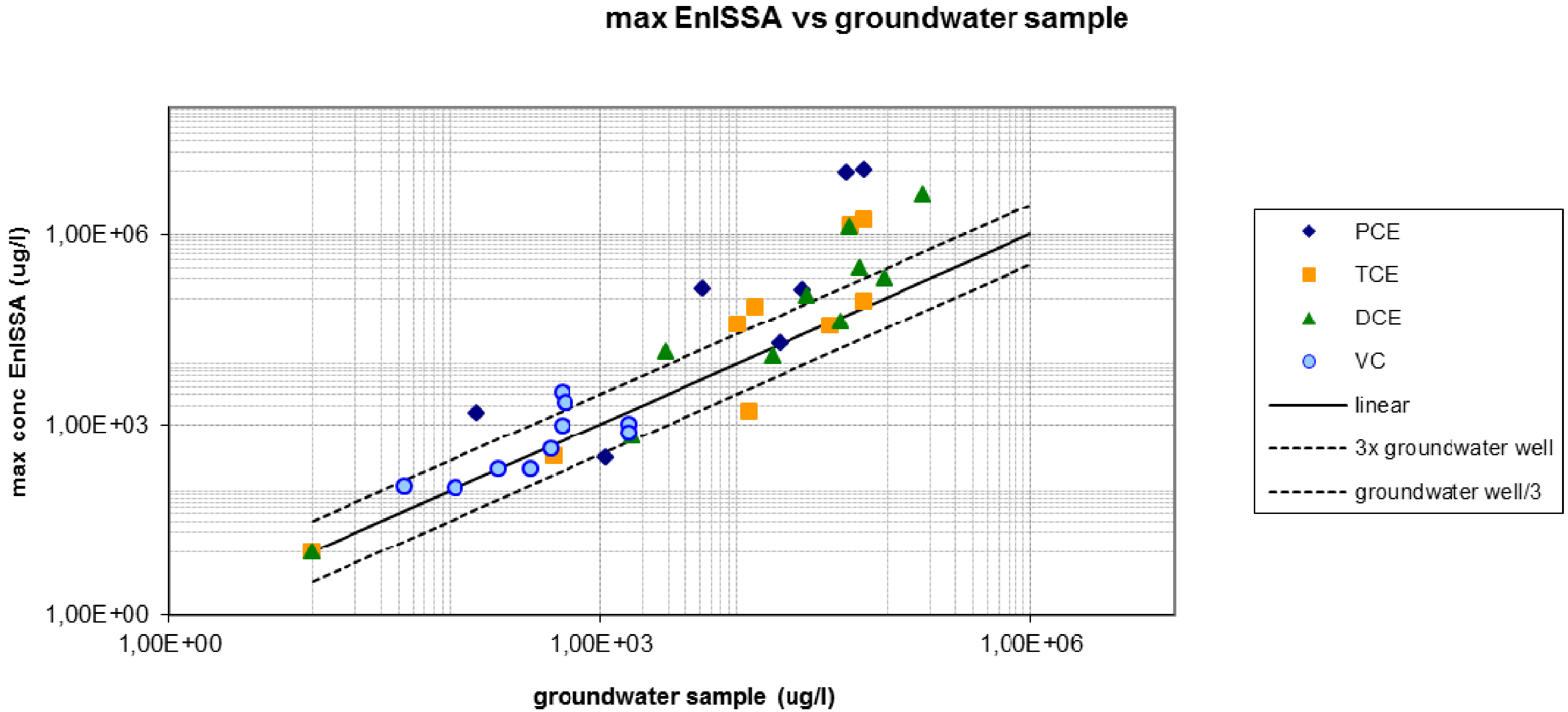
DCE: 30 000ug/l

VC: 12 000 ug/l





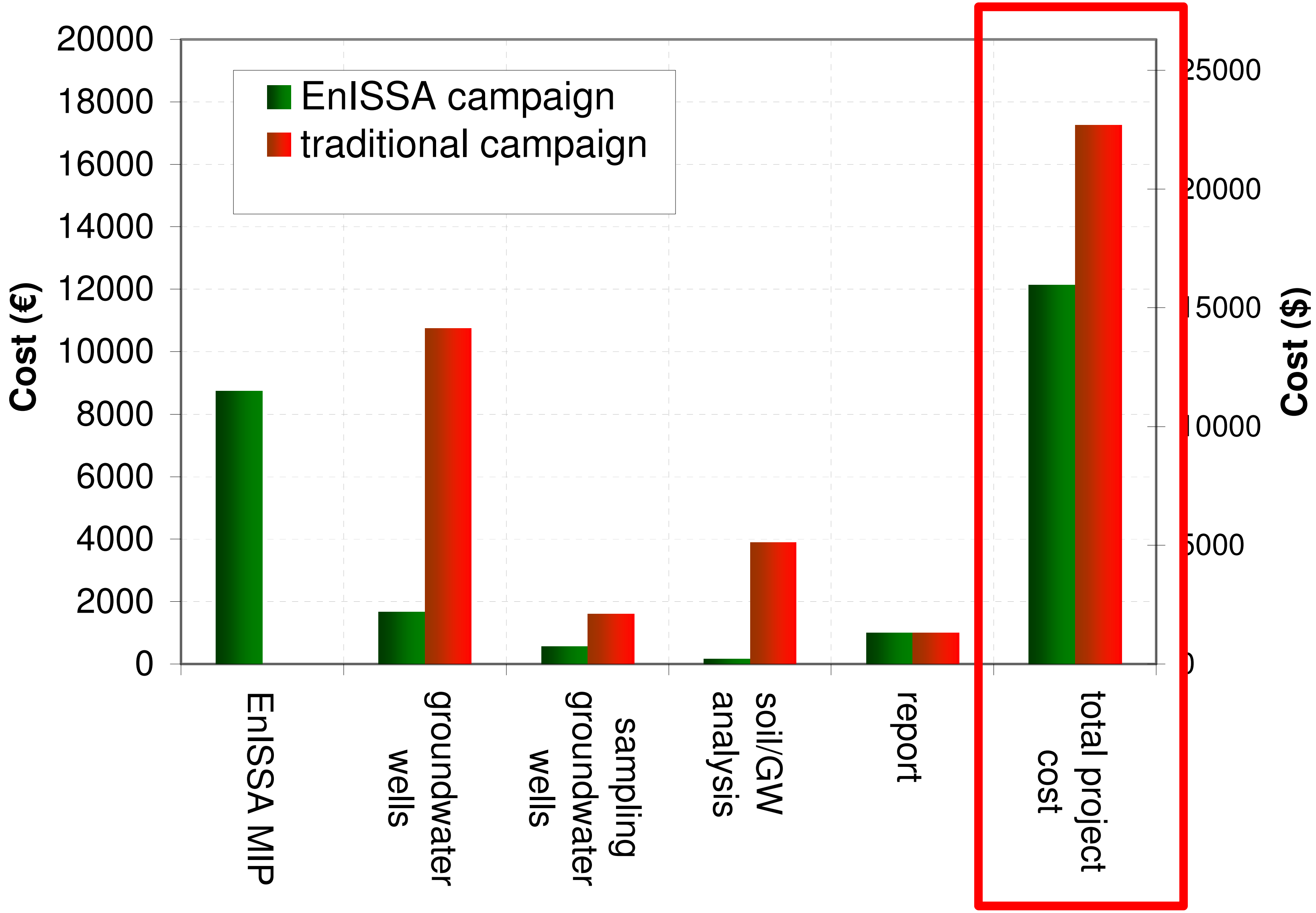
Case Study 1: GW Results



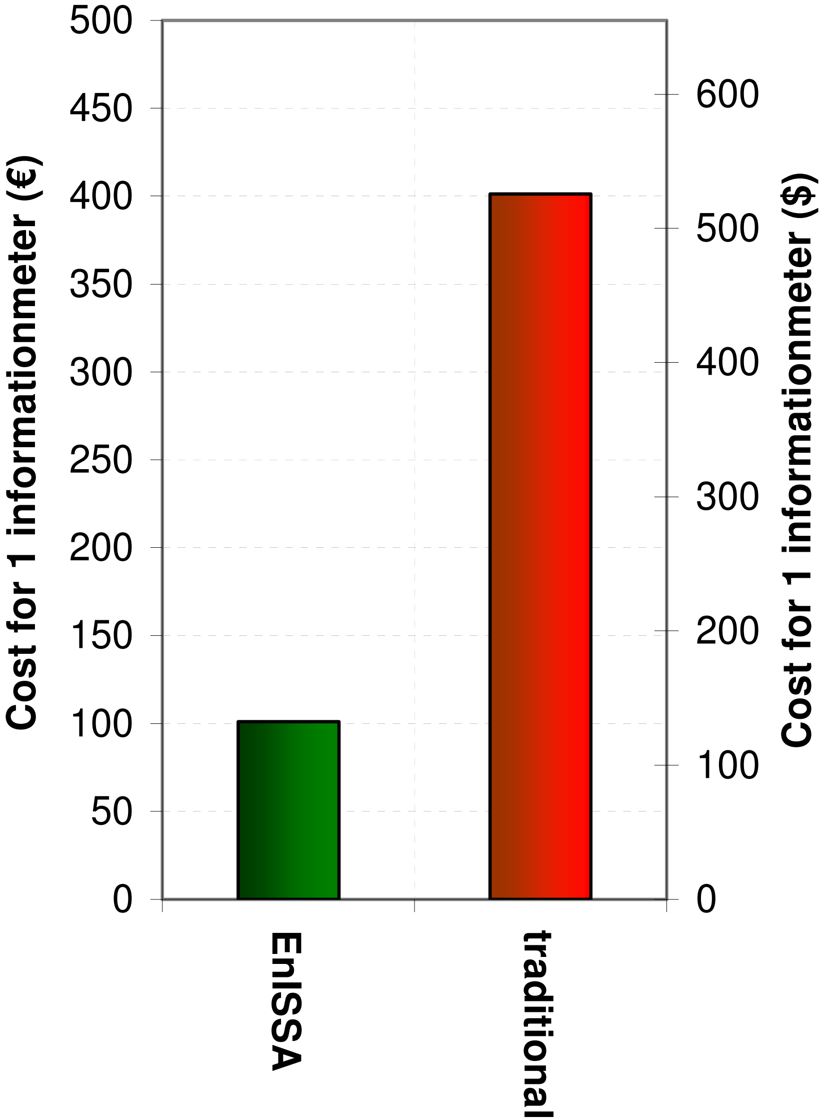
* contribution of the adsorbed contaminants which will be measured by EnISSA but not by the groundwater samples

* EnISSA results vs. groundwater results: order of magnitude is comparable → semi-quantitative or better?

Case Study 1: Cost comparison



Case Study 1: Cost comparison

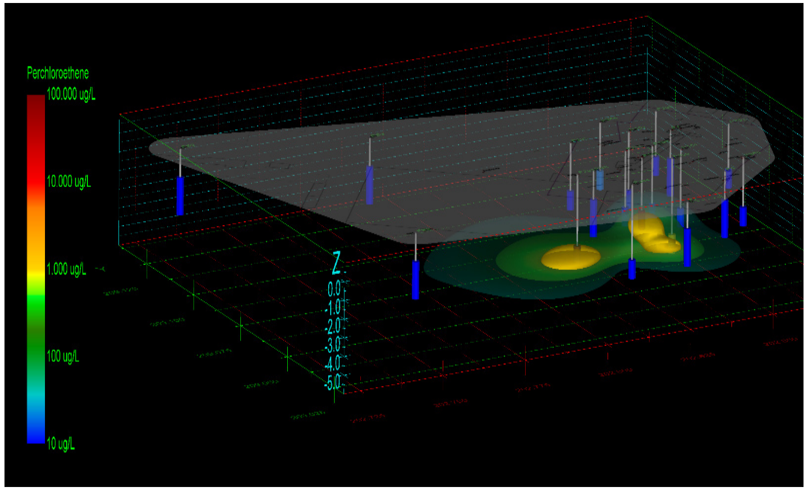


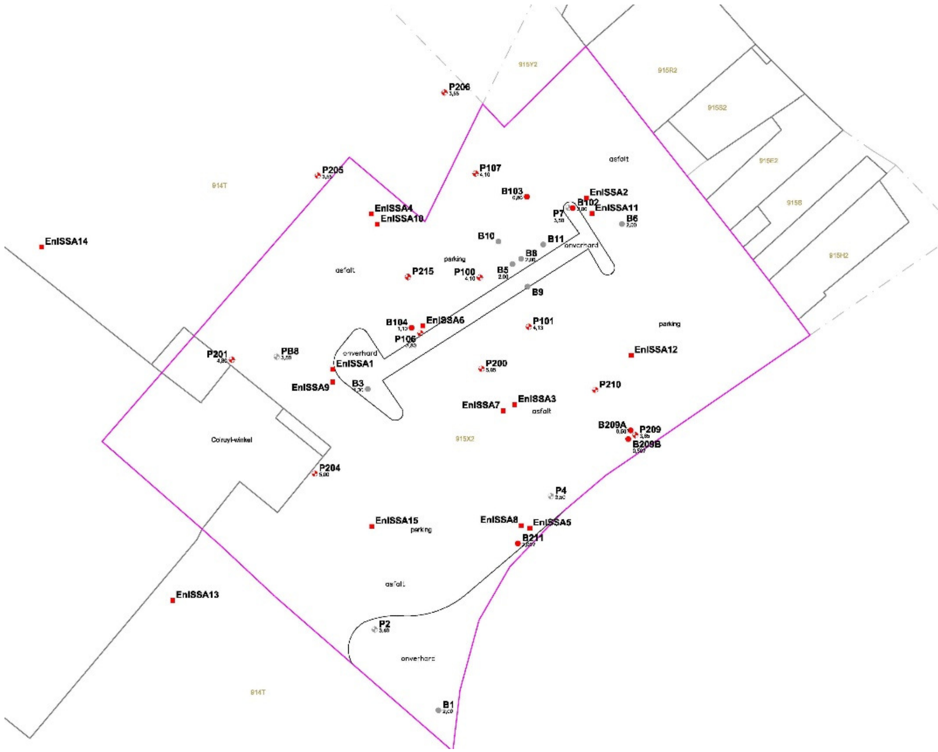
Case Study 2

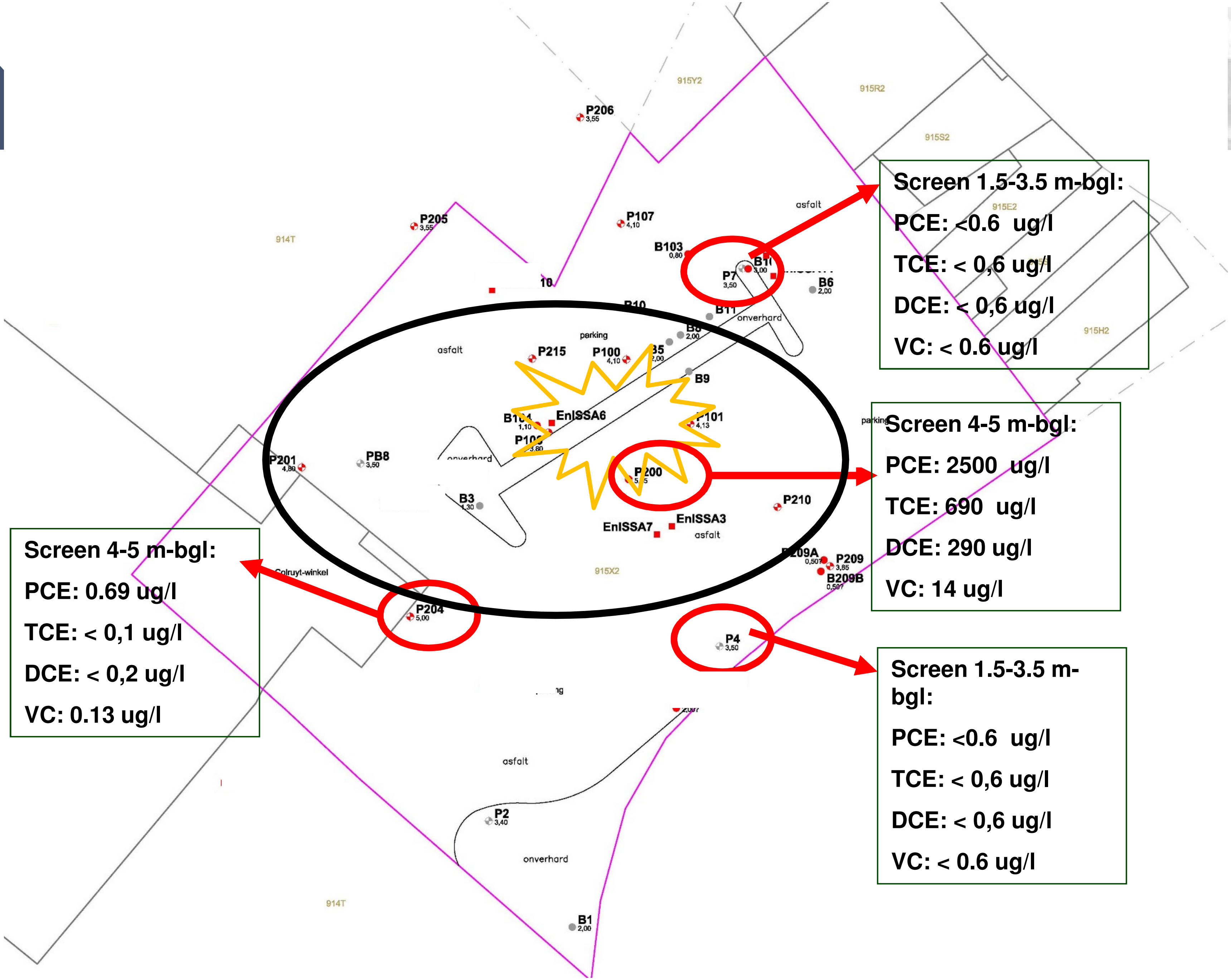
Antwerp region: Former Wool factory

Contamination: PCE, TCE, DCE, VC

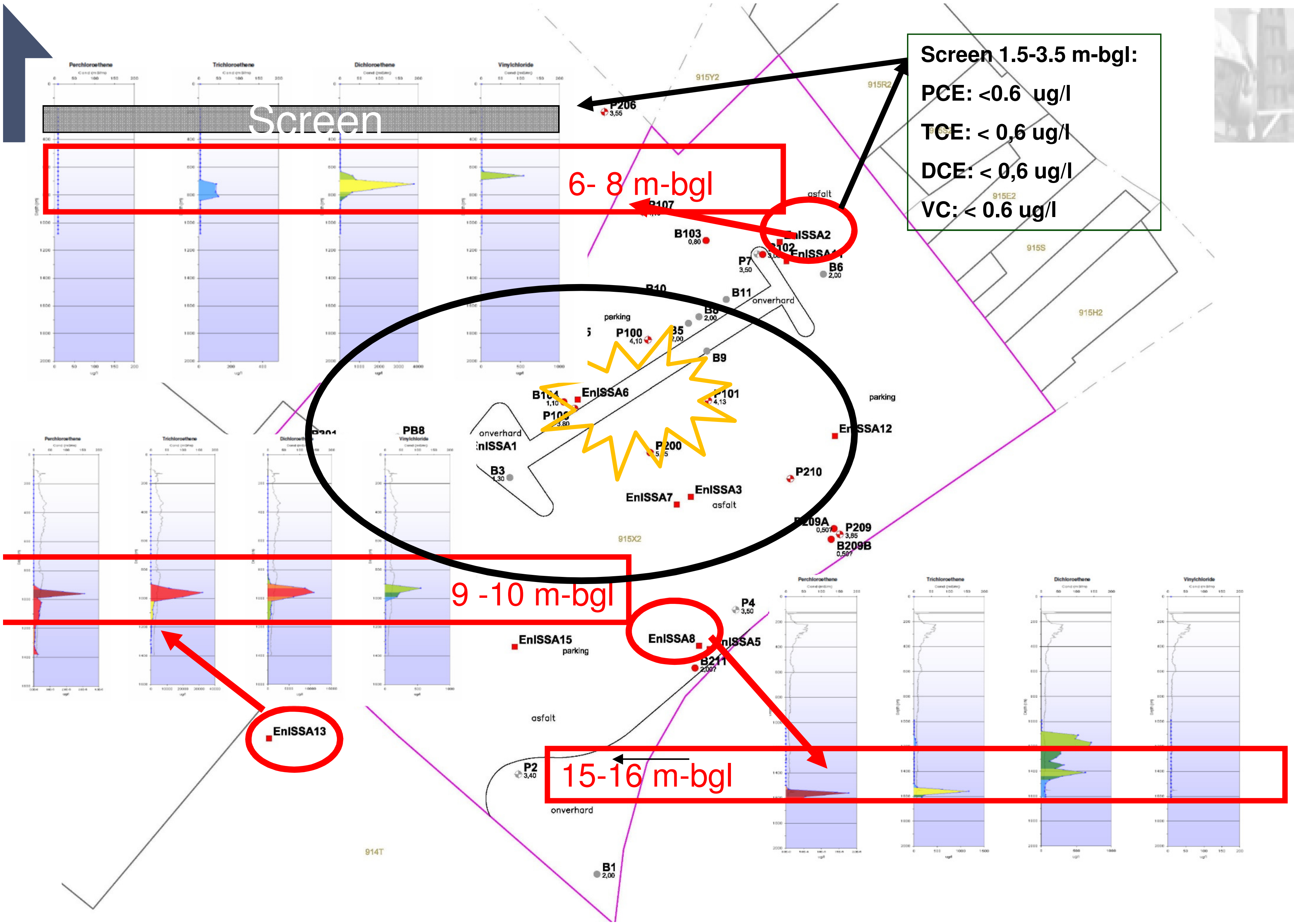
Incomplete CSM based on 20 monitoring wells ➔ EnISSA campaign





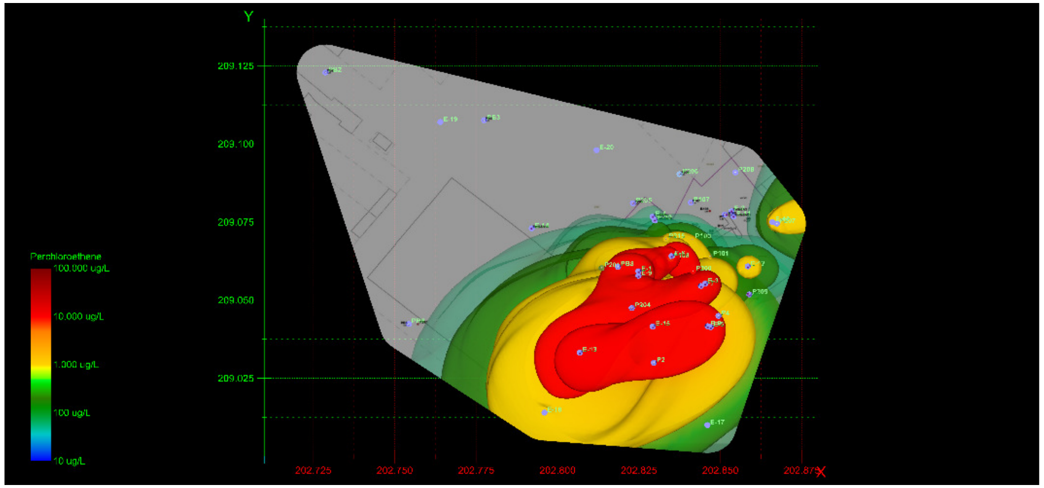

Screen 1.5-3.5 m-bgl:
PCE: <0.6 ug/l
TCE: < 0,6 ug/l
DCE: < 0,6 ug/l
VC: < 0.6 ug/l
Screen 4-5 m-bgl:
PCE: 2500 ug/l
TCE: 690 ug/l
DCE: 290 ug/l
VC: 14 ug/l
Screen 4-5 m-bgl:
PCE: 0.69 ug/l
TCE: < 0,1 ug/l
DCE: < 0,2 ug/l
VC: 0.13 ug/l
Screen 1.5-3.5 m-bgl:
PCE: <0.6 ug/l
TCE: < 0,6 ug/l
DCE: < 0,6 ug/l
VC: < 0.6 ug/l
P206
915Y2
915R2
915S2
P205
914T
P107
B103
asfalt
P7
B6
onverhard
parking
P215
P100
B9
EnISSA6
P101
PB8
P201
B3
P200
P210
EnISSA7
EnISSA3
915X2
Colruyt-winkel
P204
P209
B209B
P4
P2
B1


Perchloroethene
Trichloroethene
Dichloroethene
Vinylchloride
2 – 4 m-bgl
915R2
asfalt
915E2
915S
915H2
EnISSA2
EnISSA11
B6
2,00
EnISSA14
EnISSA6
P101
4,13
parking
EnISSA12
P201
4,80
PB8
3,50
onverhard
EnISSA1
EnISSA9
B3
1,30
P200
EnISSA7
EnISSA3
asfalt
P210
B209A
P209
3,85
B209B
915X2
Colruyt-winkel
P204
5,00
EnISSA15
parking
EnISSA13
10 – 12 m-bgl
P2
3,40
onverhard
914T
B1
2,00

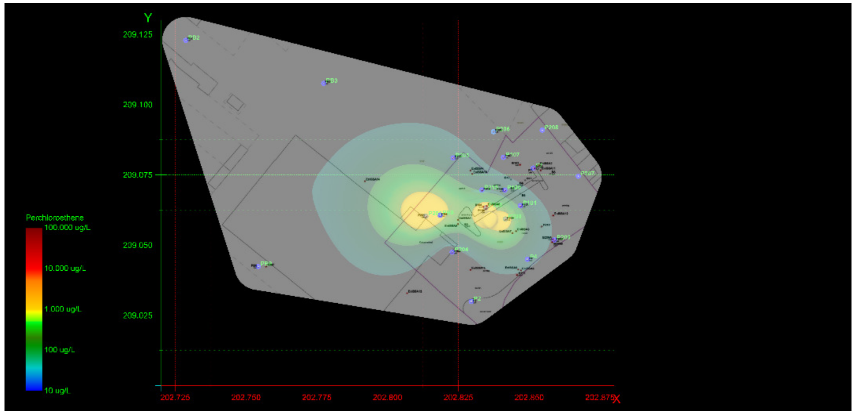

Screen 1.5-3.5 m-bgl:
PCE: <0.6 ug/l
TCE: < 0,6 ug/l
DCE: < 0,6 ug/l
VC: < 0.6 ug/l
Screen
6- 8 m-bgl
9 -10 m-bgl
15-16 m-bgl
Perchloroethene
Trichloroethene
Dichloroethene
Vinylchloride
P206
EnISSA2
EnISSA1
EnISSA3
EnISSA6
EnISSA7
EnISSA8
EnISSA12
EnISSA13
EnISSA15
B103
B6
B9
B11
P7
P100
P101
P200
P210
P209
B209B
PB8
P4
P2
B1
B3
asfalt
parking
onverhard
915Y2
915R2
915E2
915S
915H2
915X2
914T

Case Study 2

- Profound migration of PCE and breakdown products
- Variable depths
  - ➔ Easily missed
  - ➔ Full profiles are necesarry to completely and correctly characterise PCE contamination



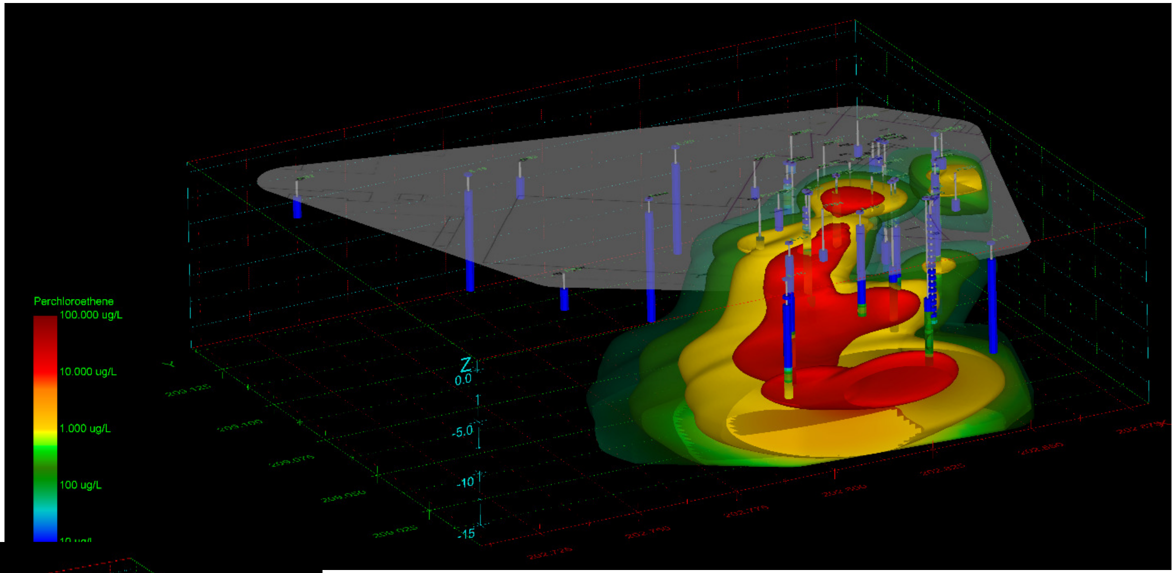
EnISSA-MIP PCE



Monitoring well PCE

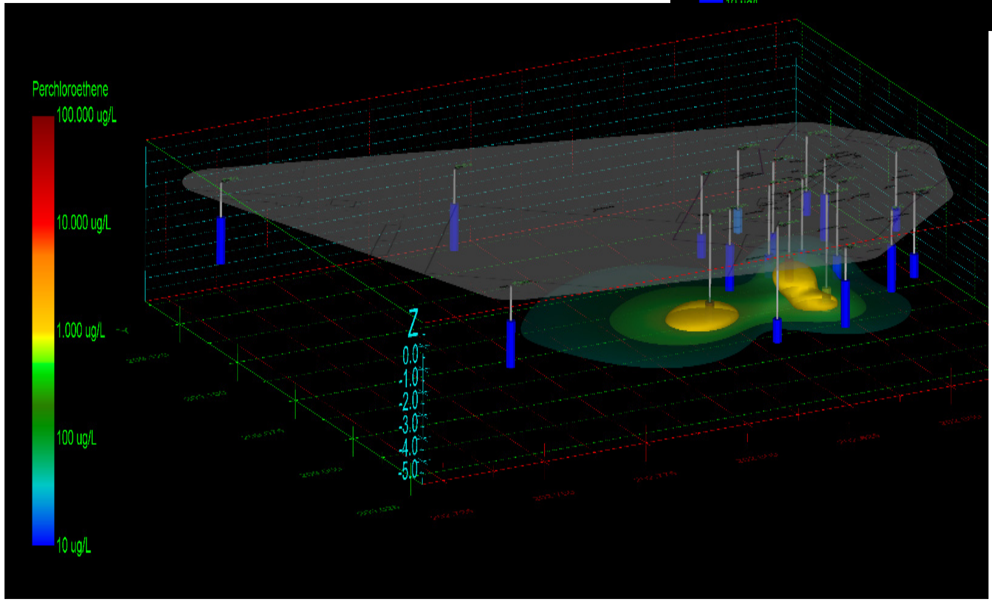
"It's far better to be approximately correct with a huge dataset than precisely wrong with a limited dataset"

Case Study 2



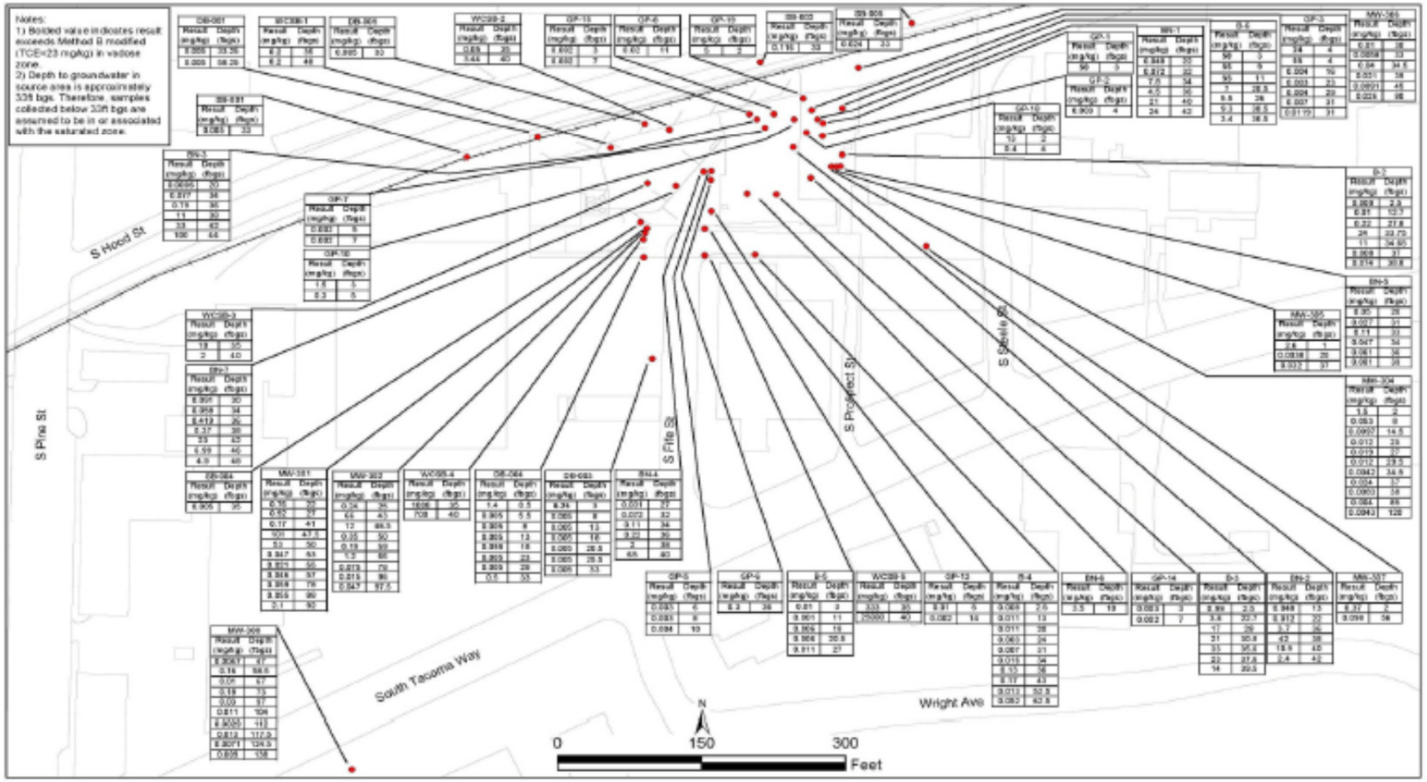
EnISSA-MIP PCE

Monitoring well PCE



Conceptual Site Model

Are We Effectively Using Data or Confusing Data?



Well 12A Superfund Site
Tacoma, Washington

Figure 2-6
Trichloroethylene in Soil

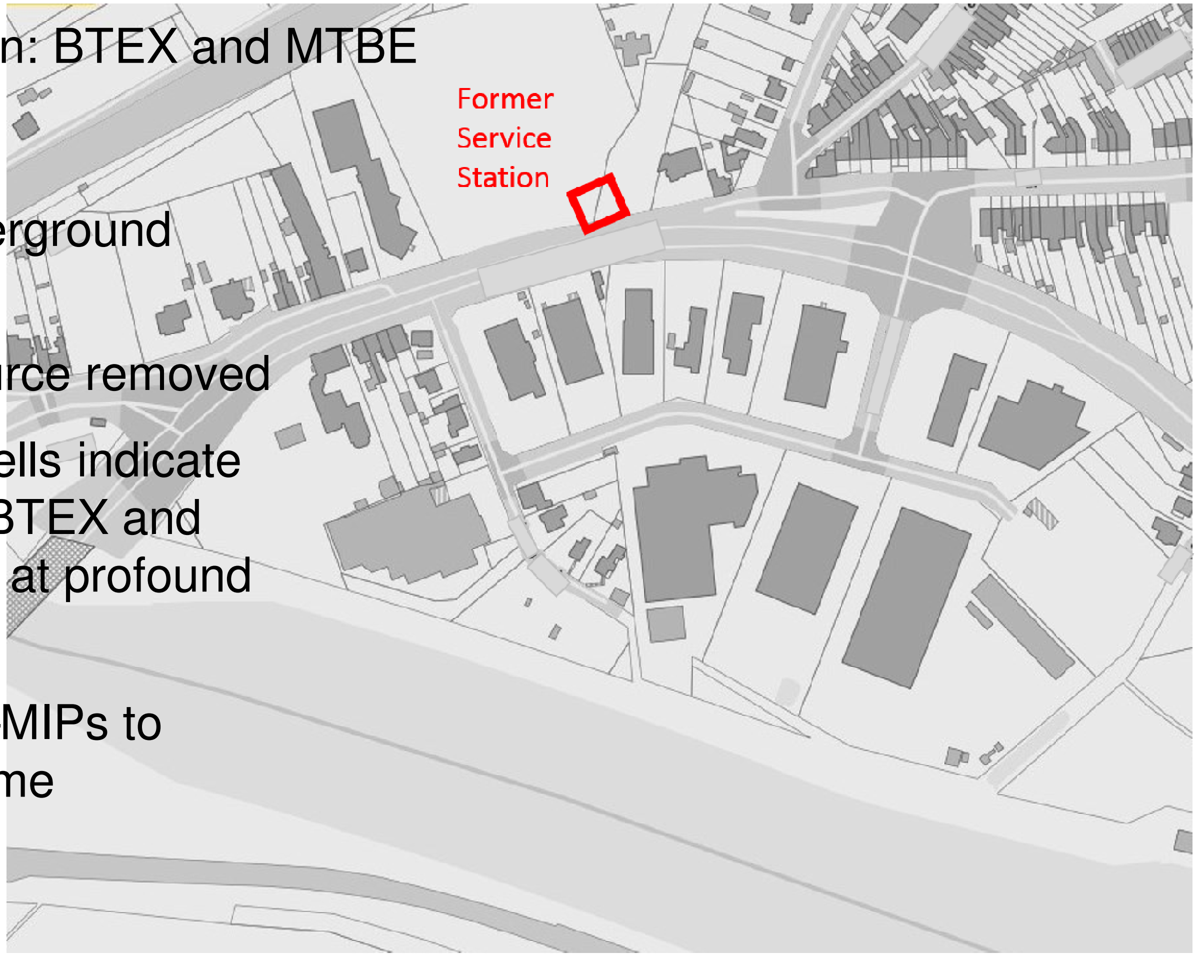
Case Study 3

Former service station, Antwerp region

Contamination: BTEX and MTBE

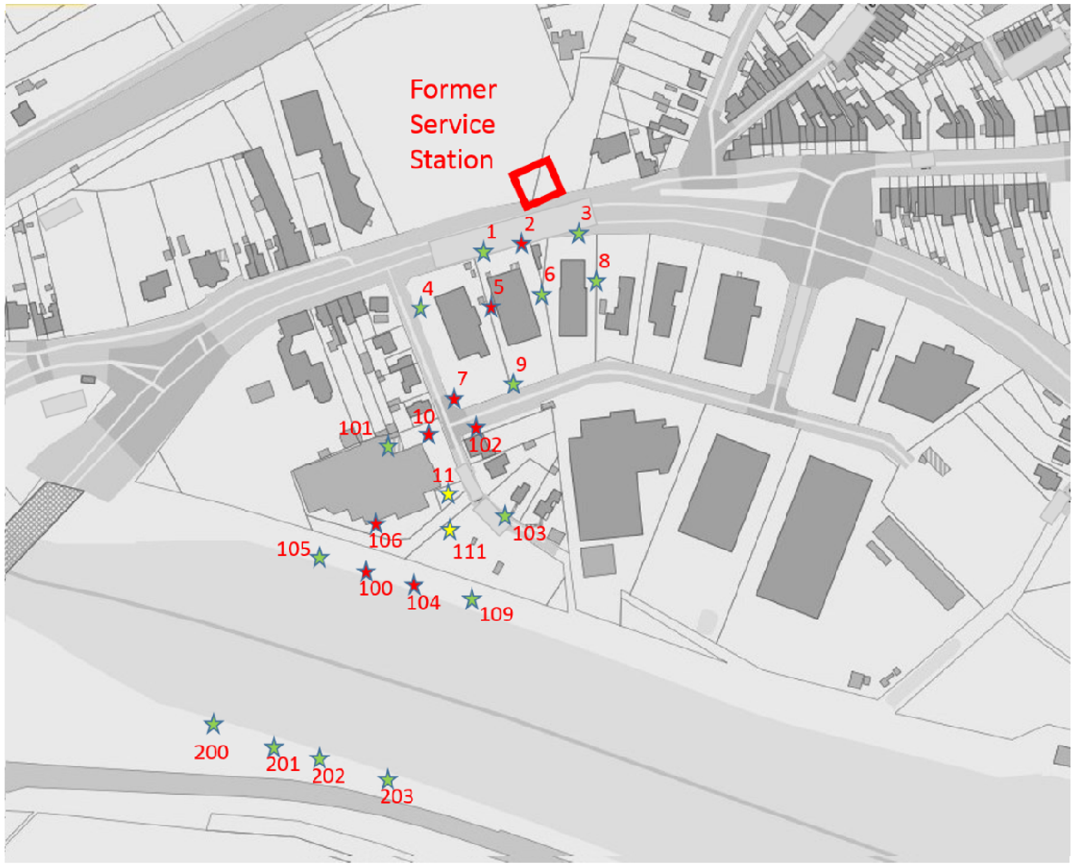
- Leaking underground storage tank
- Tank and source removed
- Monitoring wells indicate presence of BTEX and MTBE plume at profound level

➔ EnISSA –MIPs to delineate plume



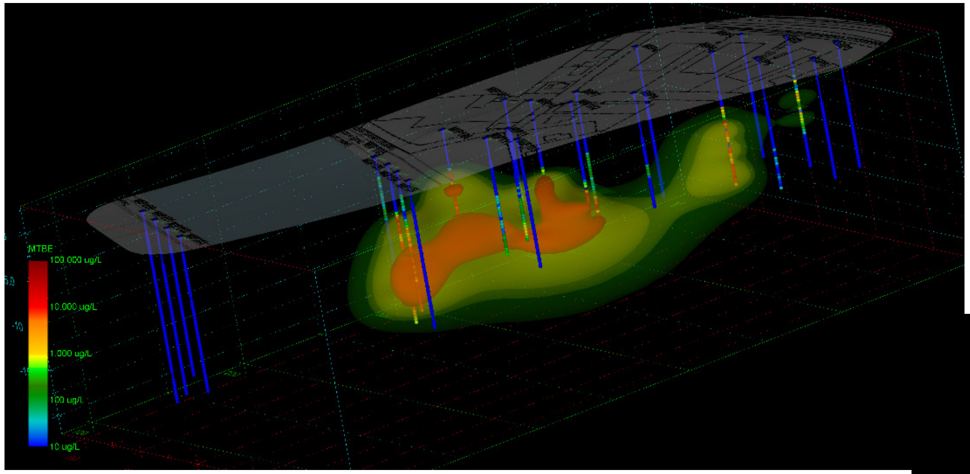
Case Study 3

- MTBE difficult parameter
  - ➔ feasability test
- 3 rounds of EnISSA MIP probings
- MTBE detected up to border of canal
- monitoring wells installed to confirm results
- Results imported in 3D software

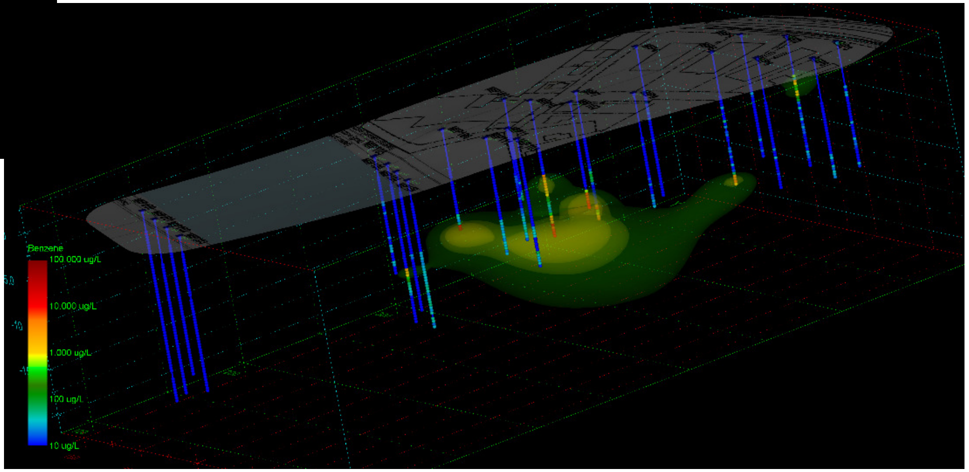


Case Study 3

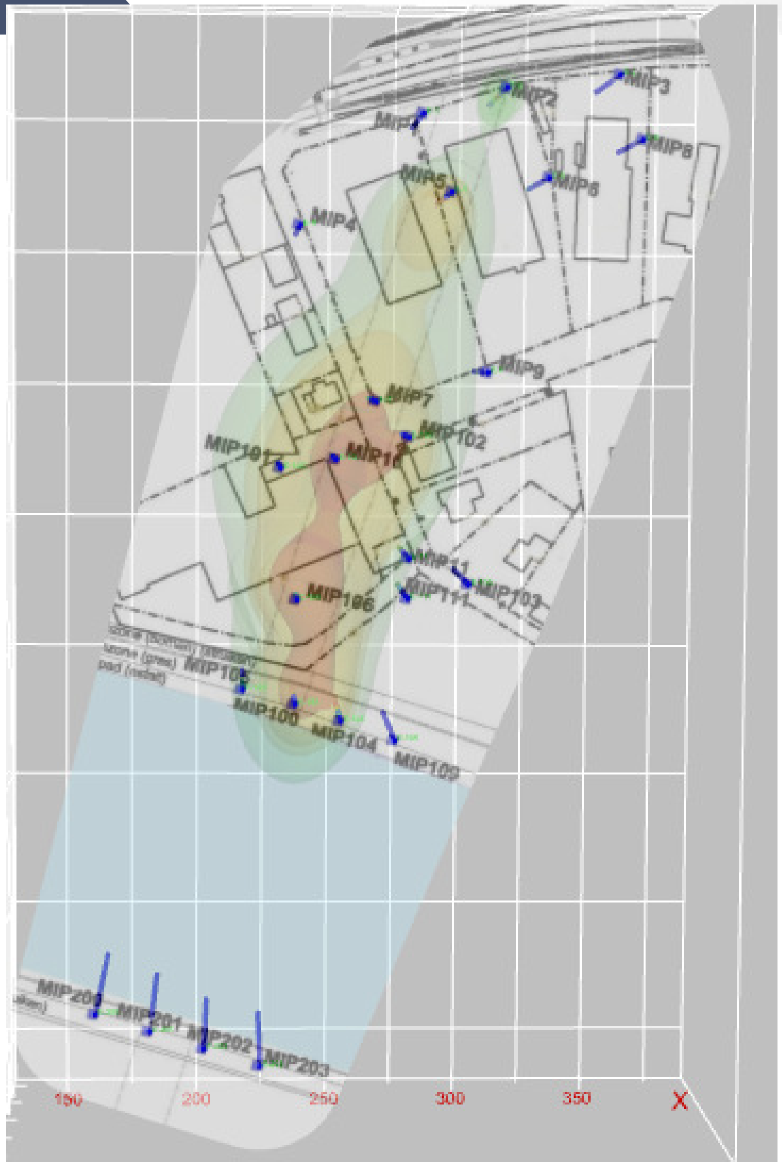
MTBE

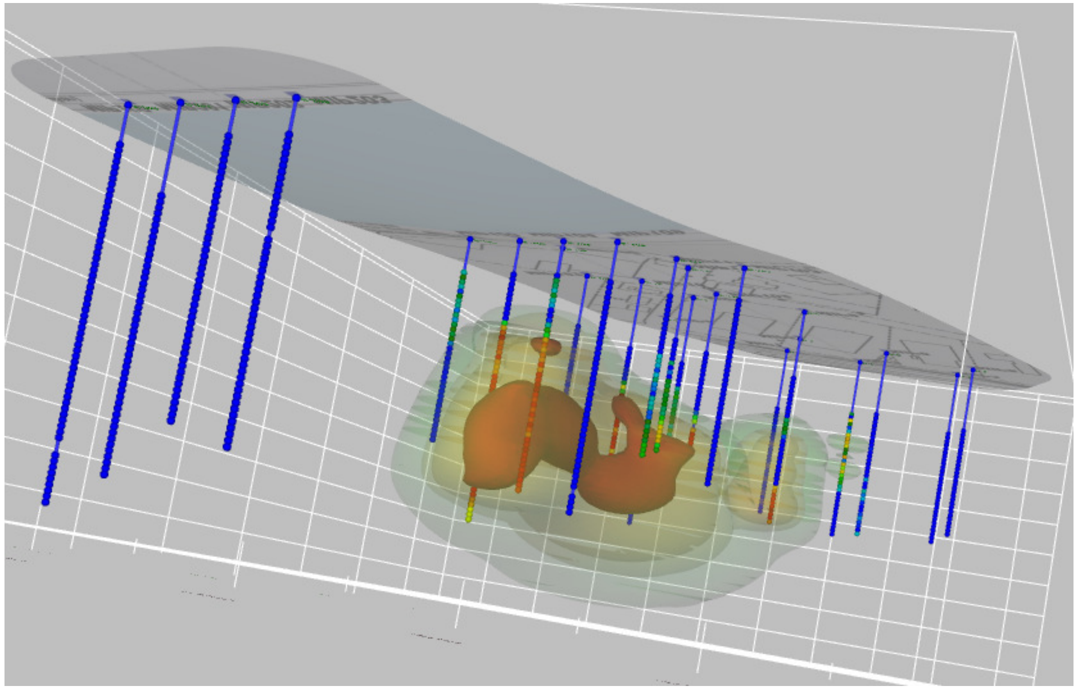


Benzeen



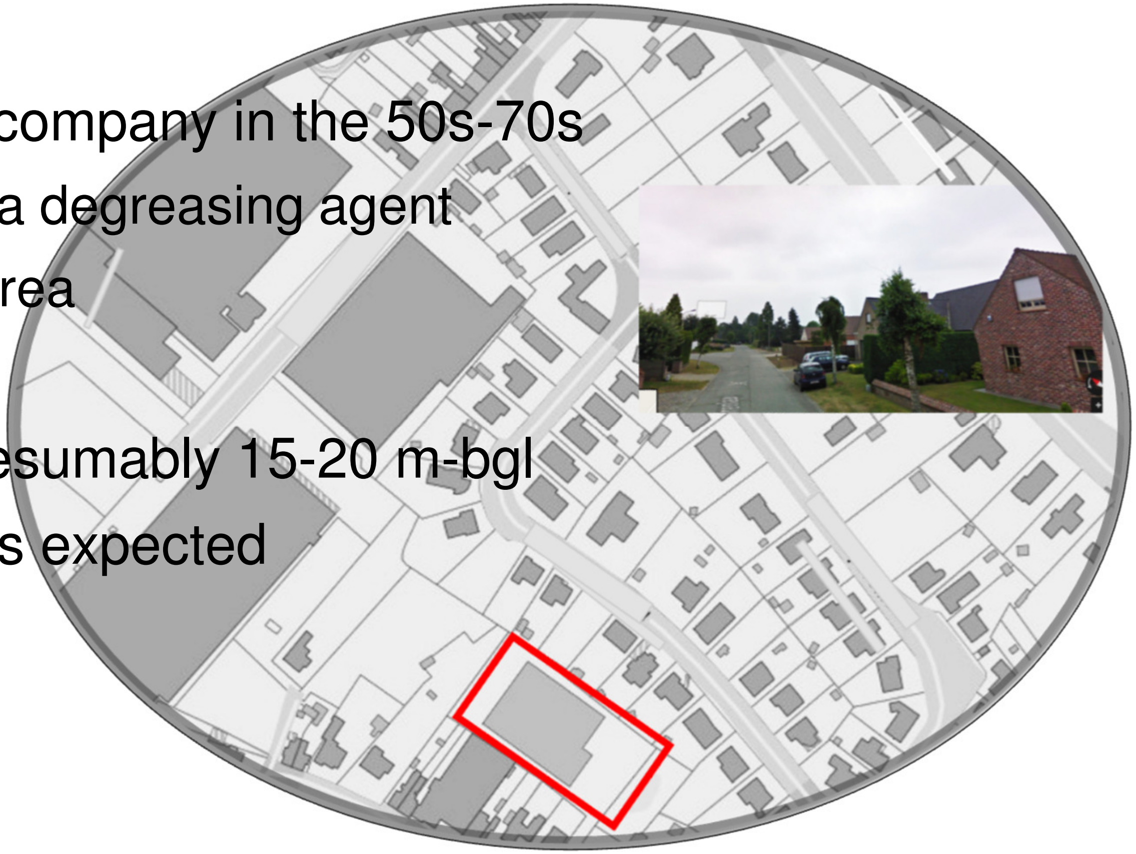
Case Study 3


MIP3
MIP2
MIP1
MIP8
MIP6
MIP5
MIP4
MIP9
MIP7
MIP102
MIP101
MIP10
MIP11
MIP103
MIP111
MIP106
MIP105
MIP100
MIP104
MIP109
MIP200
MIP201
MIP202
MIP203
150
200
250
300
350
X



Case Study 4

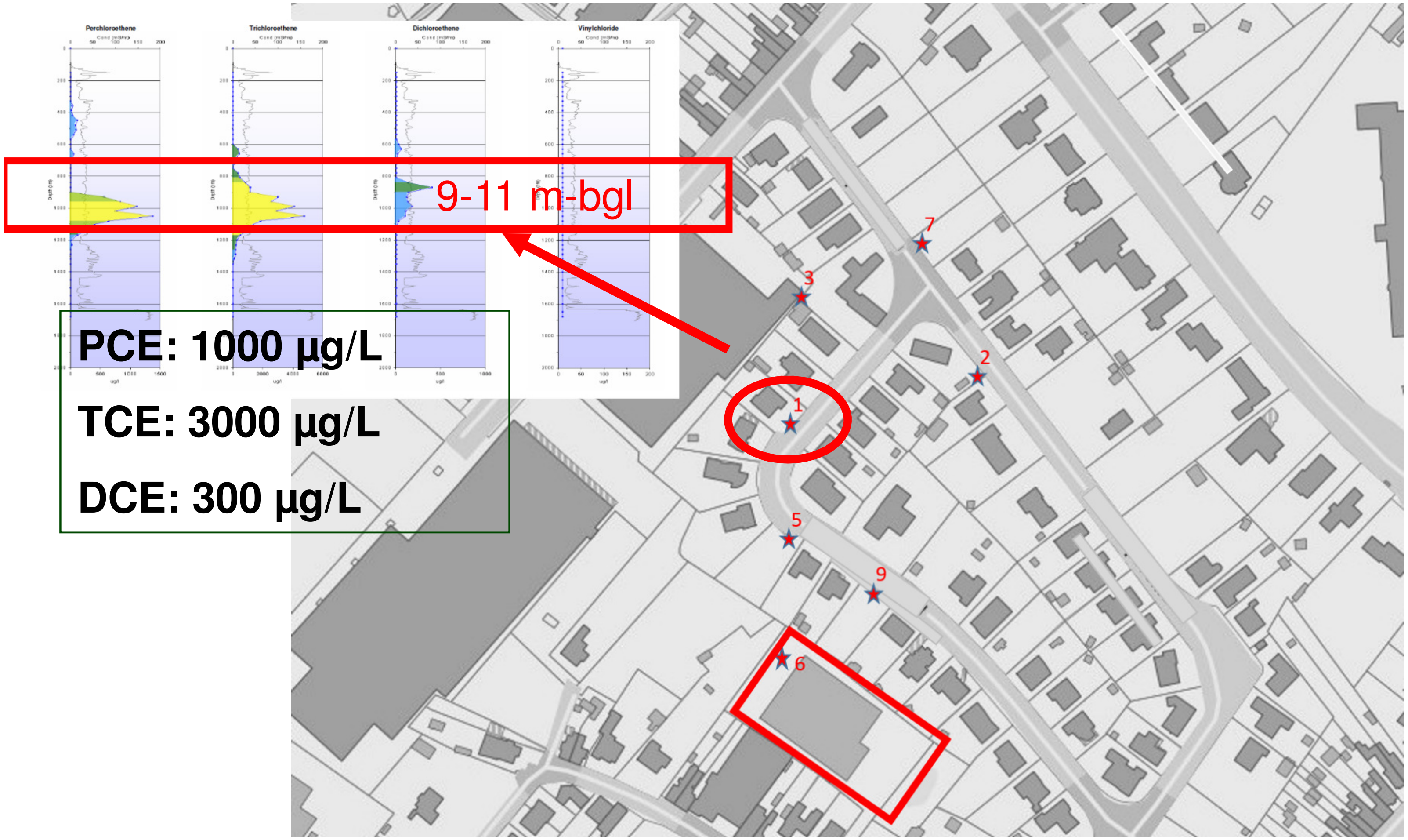
- Waregem
  - Site description:
    - A small metallurgy company in the 50s-70s
    - Perchloroethene as a degreasing agent
    - Current residential area
  - Geology
    - sand/loam up to presumably 15-20 m-bgl
    - Below a clay layer is expected



Case Study 4

2.5-3 m-bgl
Source area
20 000 µg/L PCE
Clay at 17.5 m-bgl
Perchloroethene
Trichloroethene
Dichloroethene
Vinylchloride
conductivity
Cond (mS/m)
Depth (cm)
ug/l
6

Case Study 4


Perchloroethene
Trichloroethene
Dichloroethene
Vinylchloride
9-11 m-bgl
PCE: 1000 µg/L
TCE: 3000 µg/L
DCE: 300 µg/L
7
3
2
1
5
9
6

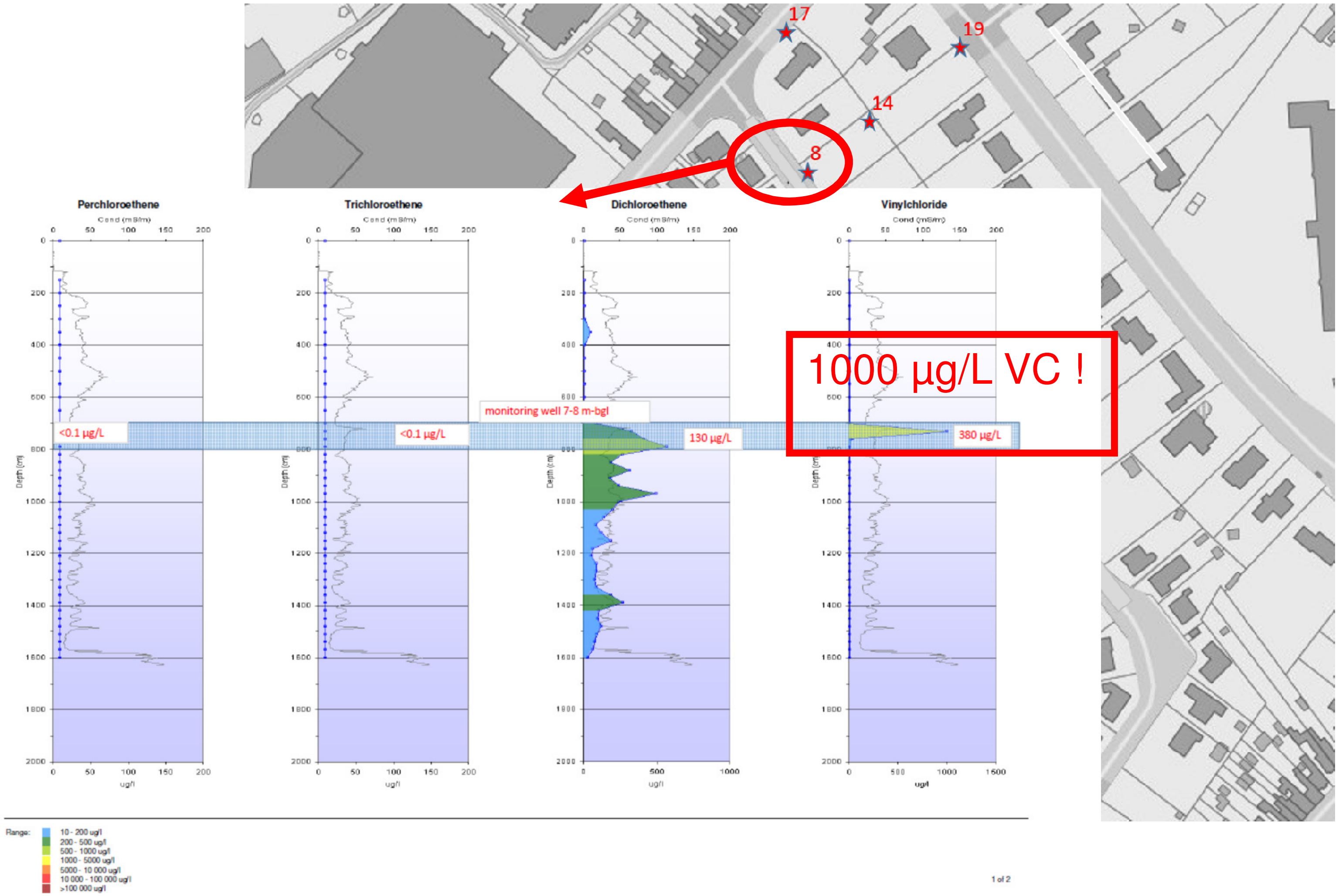
Case Study 4


Perchloroethene
Trichloroethene
Dichloroethene
Vinylchloride
12.5 – 13.5 m-bgl
DCE: 500 µg/L
7
3
2
1
5
9
6

Case Study 4

Perchloroethene
Trichloroethene
Dichloroethene
Vinylchloride
10 – 13 m-bgl
DCE: 1500 µg/L
7
3
2
1
5
9
6

Case Study 4

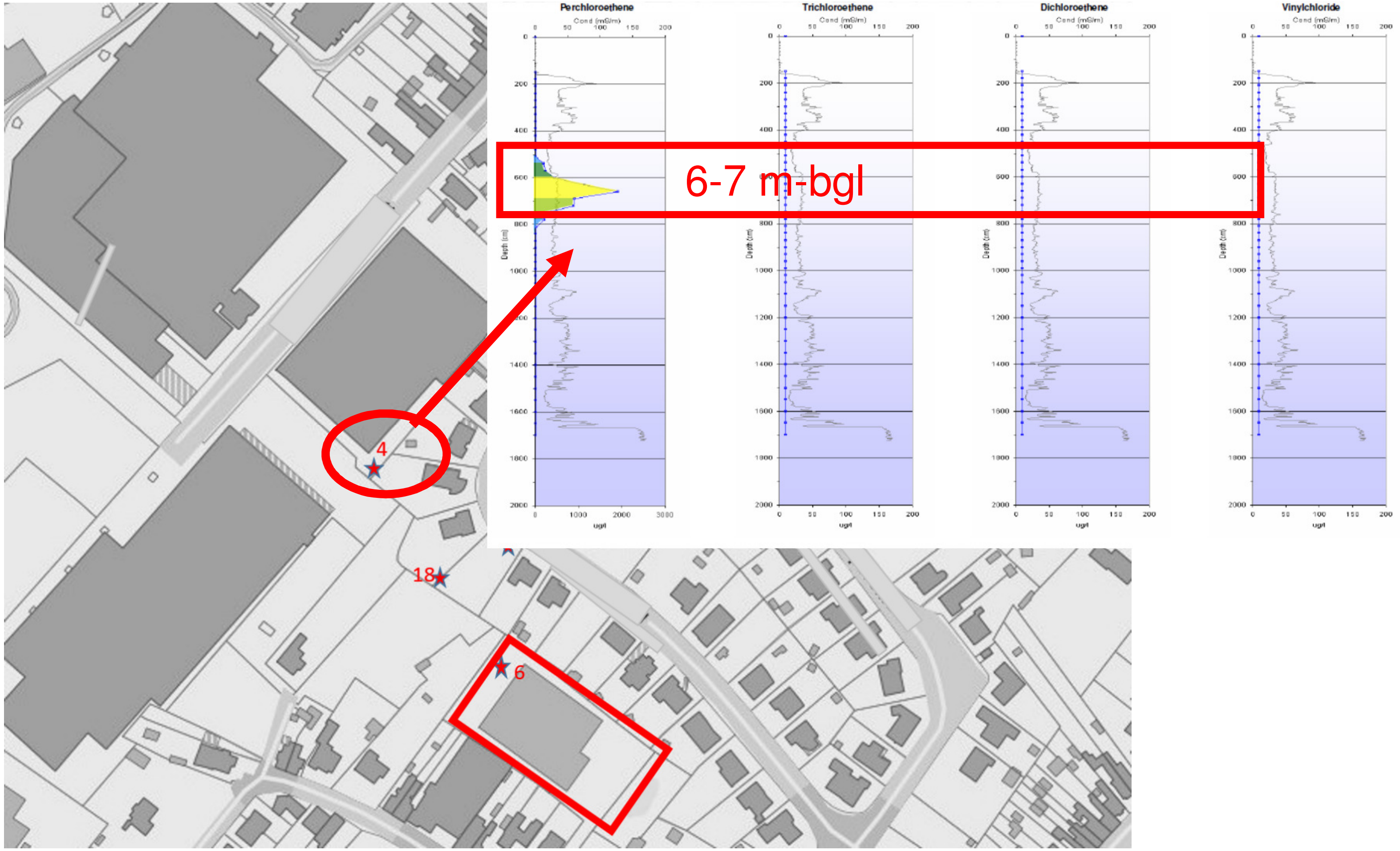


17
19
14
8
Perchloroethene
Trichloroethene
Dichloroethene
Vinylchloride
monitoring well 7-8 m-bgl
<0.1 µg/L
<0.1 µg/L
130 µg/L
380 µg/L
1000 µg/L VC !

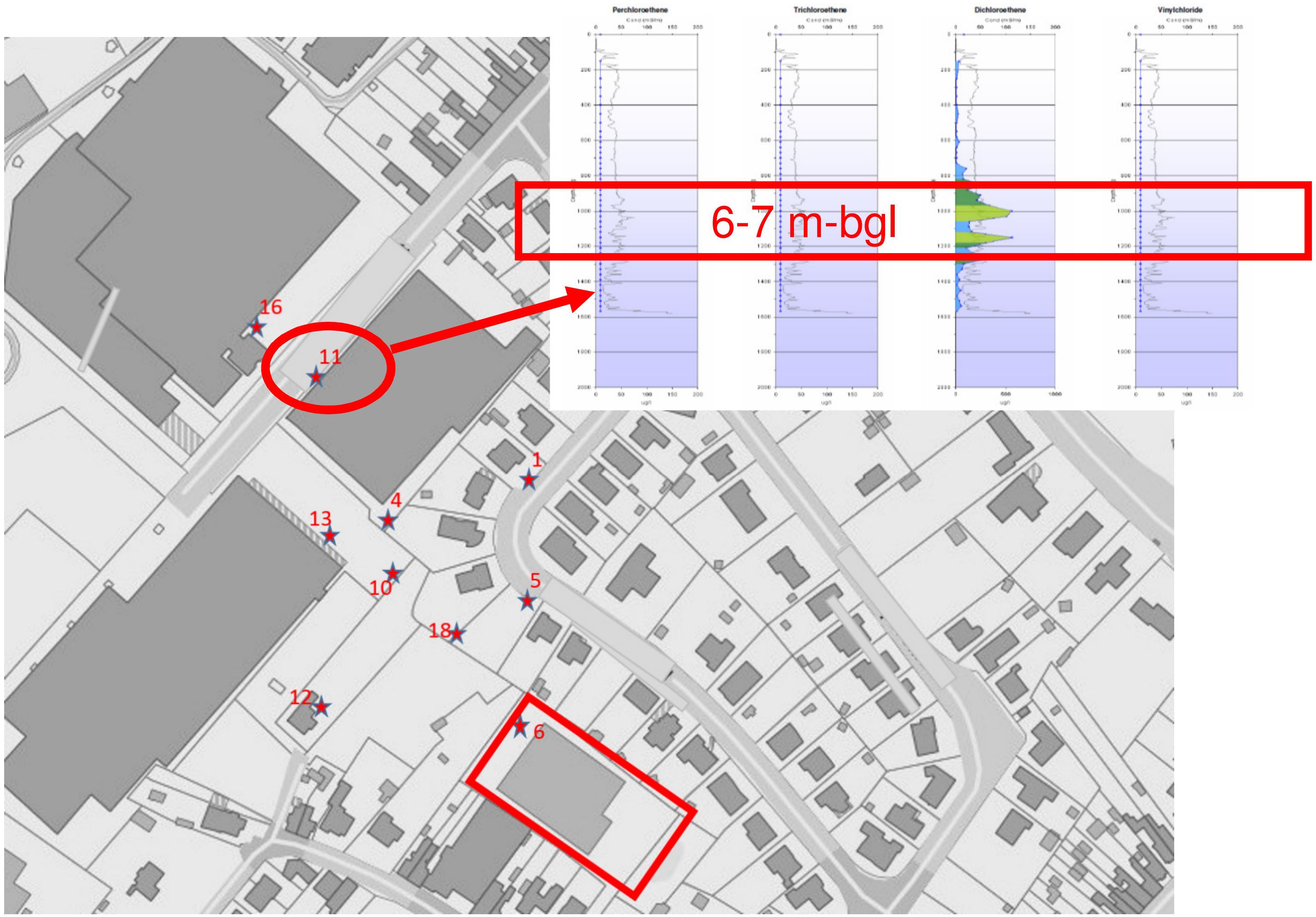
Case Study 4


17
19
14
8
7
3
2
15
1
5
9
6
Perchloroethene
Trichloroethene
Dichloroethene
Vinylchloride

Case Study 4


Perchloroethene
Trichloroethene
Dichloroethene
Vinylchloride
6-7 m-bgl
4
18
6

Case Study 4

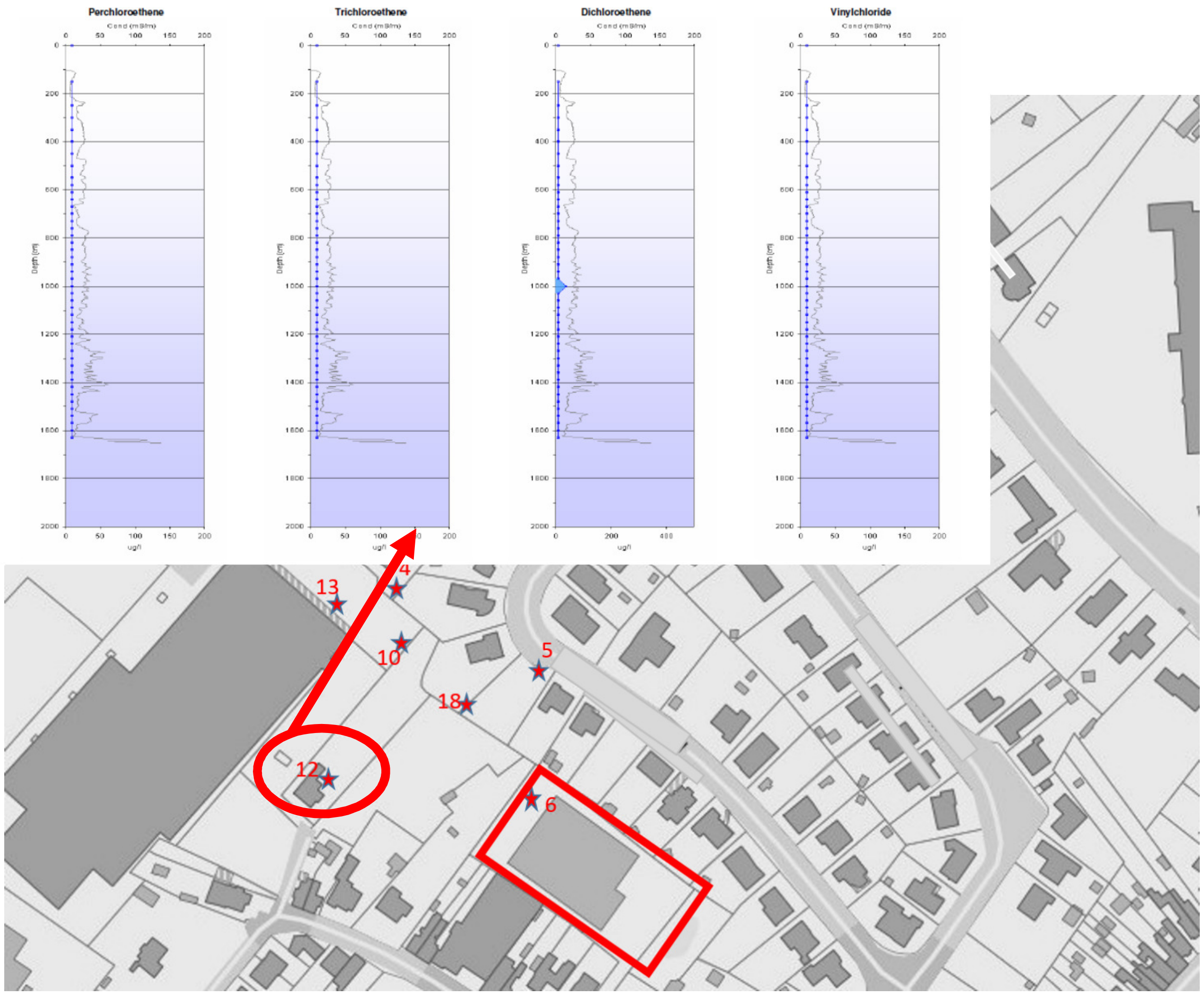


Perchloroethene
Trichloroethene
Dichloroethene
Vinylchloride
6-7 m-bgl
16
11
1
4
13
10
5
18
12
6

Case Study 4

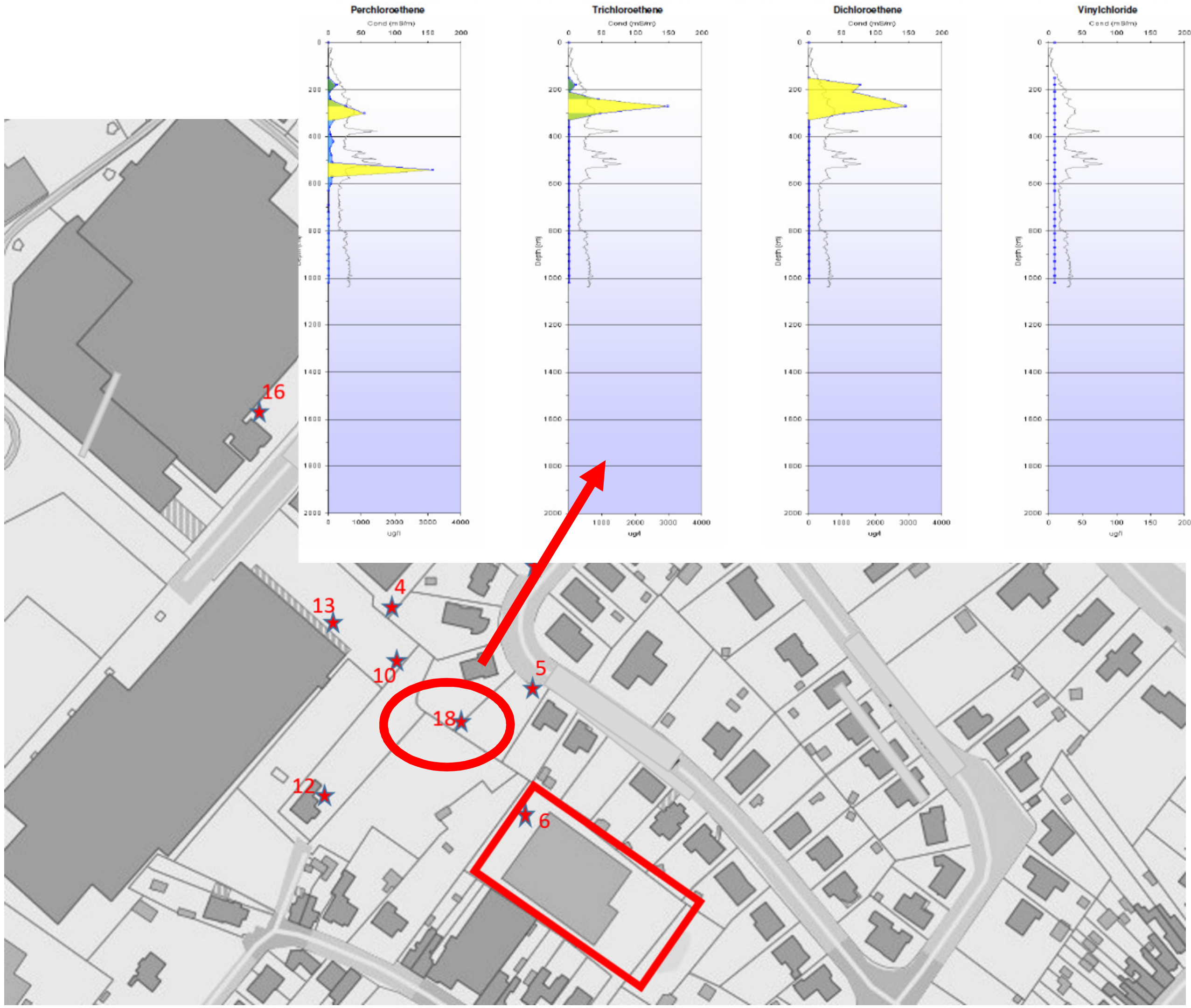

Perchloroethene
Trichloroethene
Dichloroethene
Vinylchloride
16
11
4
13
10
5
18
12
6

Case Study 4



Perchloroethene
Trichloroethene
Dichloroethene
Vinylchloride
13
4
10
5
18
12
6

Case Study 4



Perchloroethene
Trichloroethene
Dichloroethene
Vinylchloride
Cond (mS/m)
ug/l
16
13
4
10
5
18
12
6

EnISSA MIP

entire delineation of contamination: source + plume

EnISSA MIP measures on **ppb** level

→ source and plume

(Conventional MIP measures on sub-ppm level)

- Order of magnitude = groundwater sample → high quality screening tool -

"On site" information on pollution cocktails:

EnISSA MIP measures **individual compounds** in contrast to the sum-detectors used in conventional MIP

- Each 30 cm up to 12 compounds can be distinguished -

strategic sampling well locations:

The entire delineation of source and plume obtained by EnISSA MIP makes it possible to place sampling wells at strategic locations **reducing sampling costs and time**.

High resolution data is essential to characterize chlorinated solvents

- An illustrated handbook of DNAPL transport and fate in the subsurface

  http://www.cluin.org/conf/itrc/dnaplpa/dnapl_handbook_final.pdf

- High resolution site characterisation

  http://clu-in.org/characterization/technologies/hrsc/hrscintro.cfm

  https://clu-in.org/characterization/technologies/hrsc/pdfs/HRSC-Participant-Manual-NARPM-2014.pdf

More information:

www.EnISSA.com

info@EnISSA.com