DTU Library

Risk assessment of contaminated sites to water resources: The role of the contaminant mass discharge approach

Bjerg, Poul Løgstrup

Publication date:
2018

Document Version
Publisher's PDF, also known as Version of record

Risk assessment of contaminated sites to water resources: The role of the contaminant mass discharge approach

Professor Poul L. Bjerg and many others

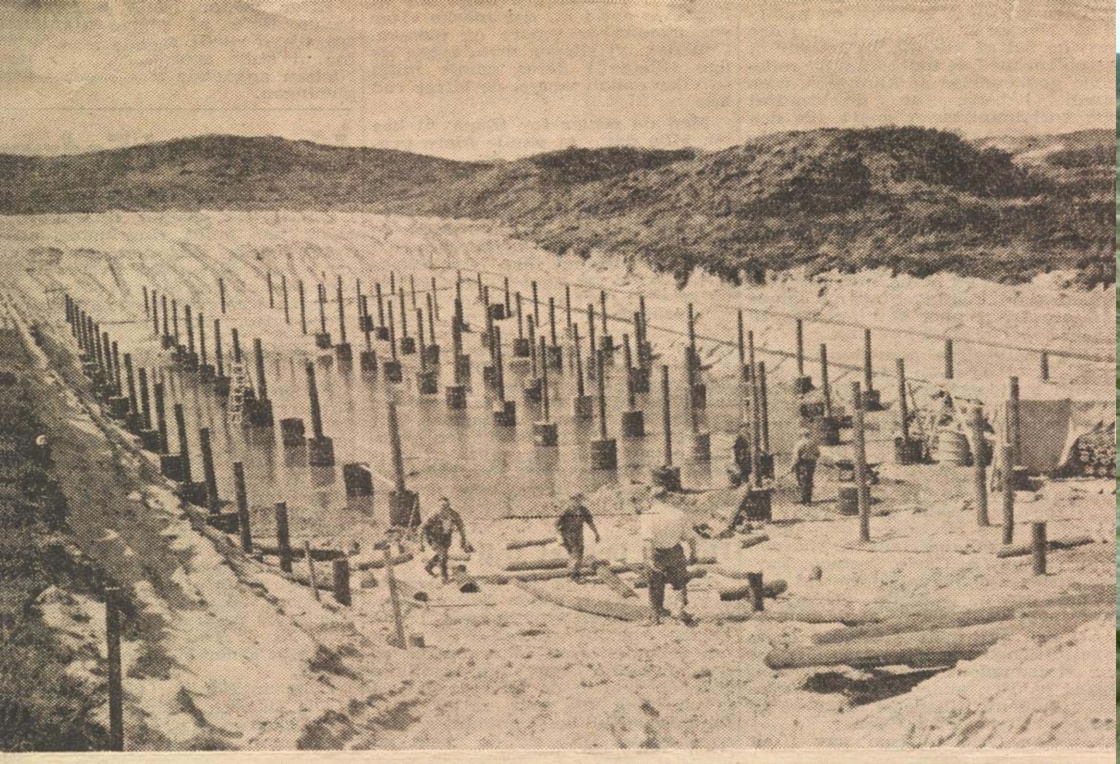
September 4th 2018

DTU Environment
Department of Environmental Engineering


Super Dry Cleaners
1211
Dry Cleaning Laundry 441-4743 Wash & Fold • Alterations
ALTERATIONS
TAILORING
Wash & Fold
(Alterations 20% Off)
Dry Cleaning
Laundry
441-4743

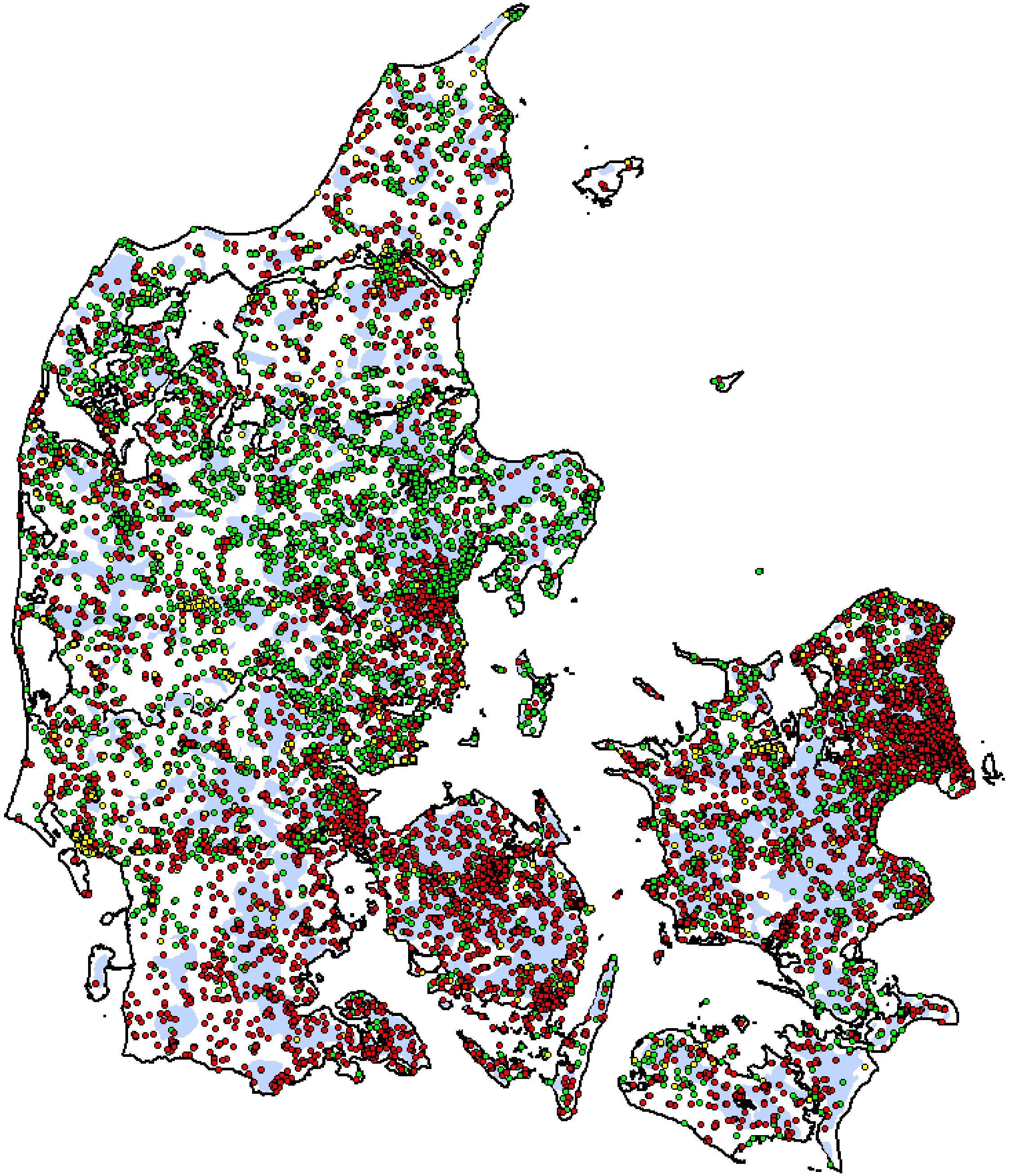

中国石化 SINOPEC
92
易捷


骆驼蓄电池
特约经销

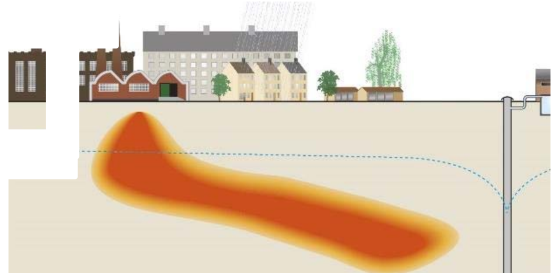


Dette hul i jorden bliver sikkert landets hidtil dyreste. Det skal bruges til udtømning af spildevand fra „Grindstedværket".

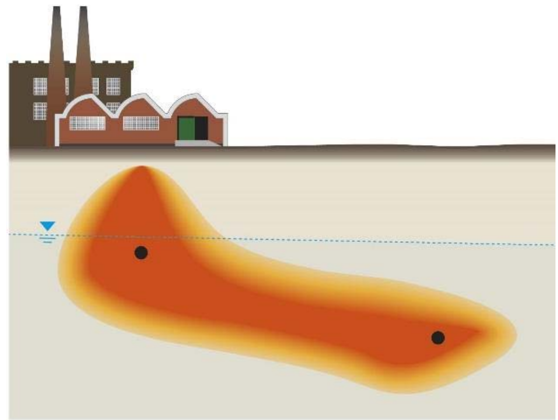
Contaminated sites in Denmark



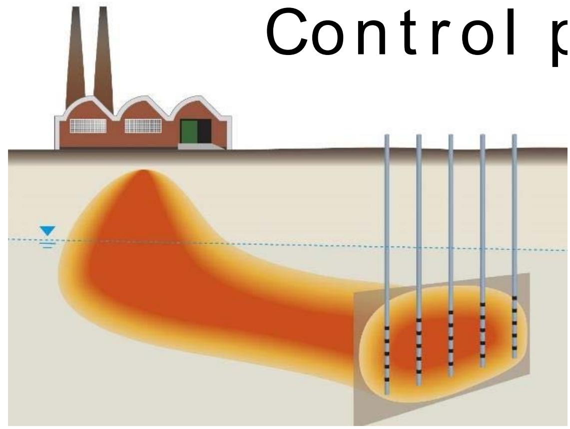
Risk assessmen
groundwater reso



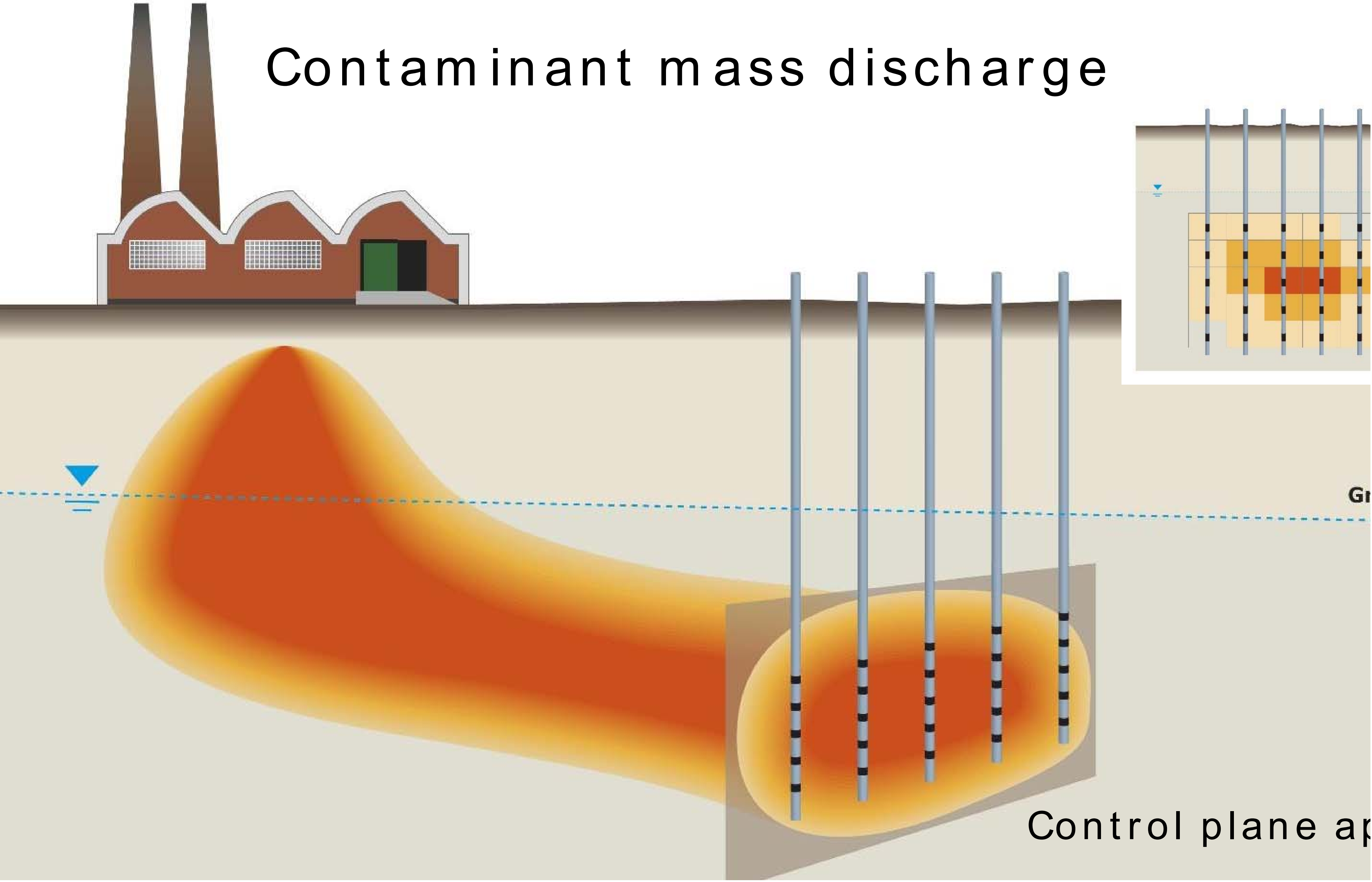
Point of compli

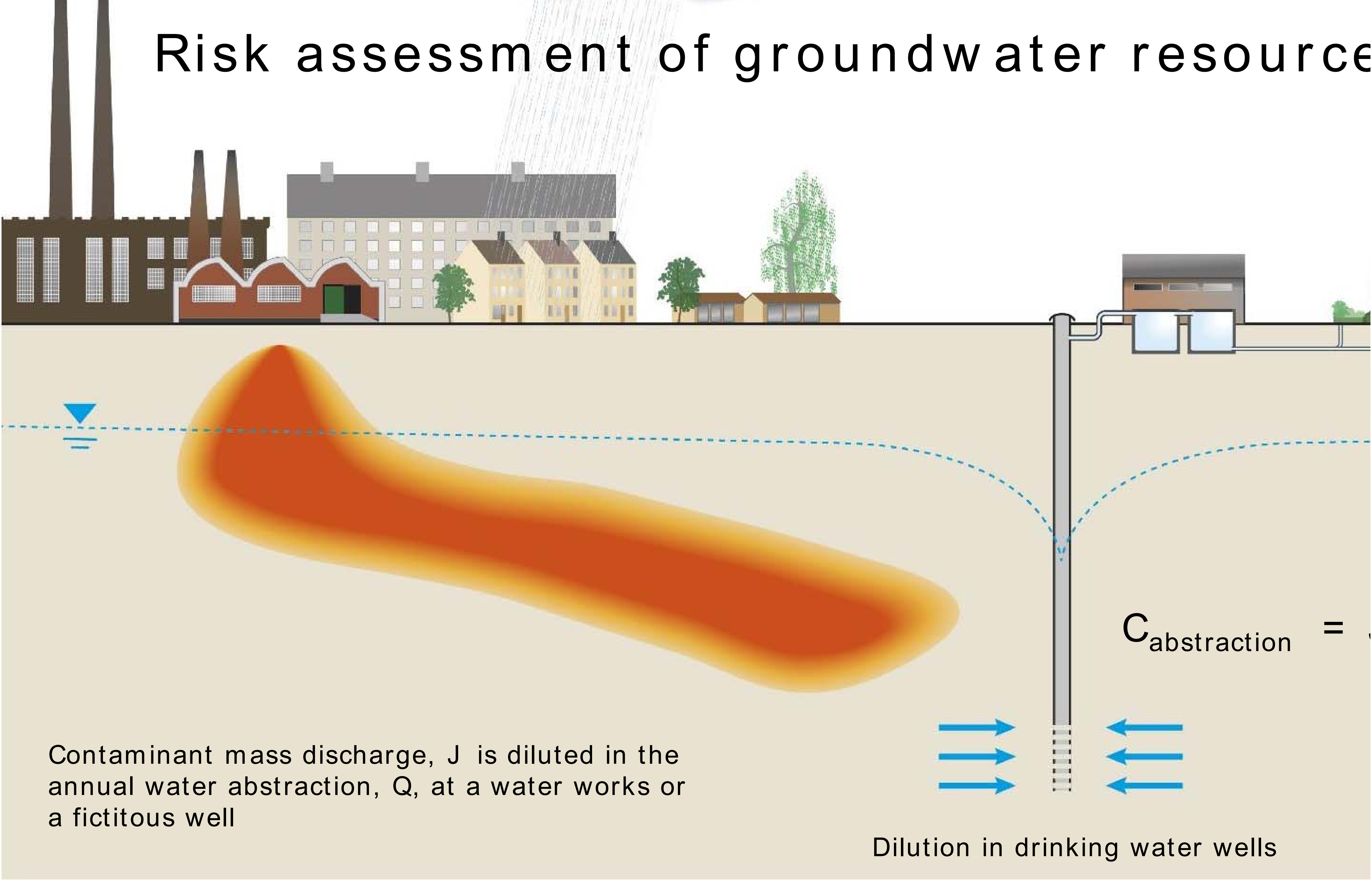


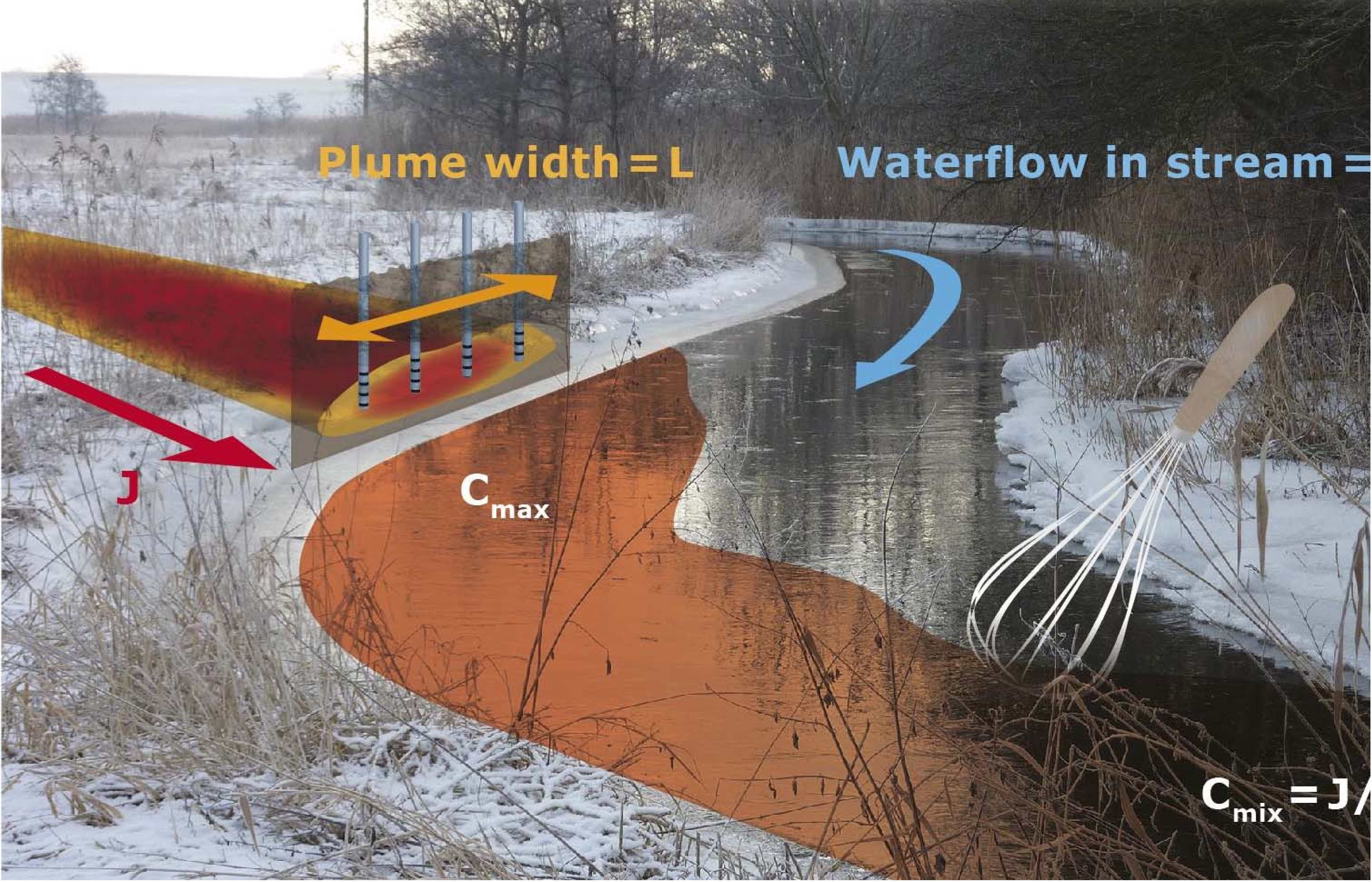
Control p

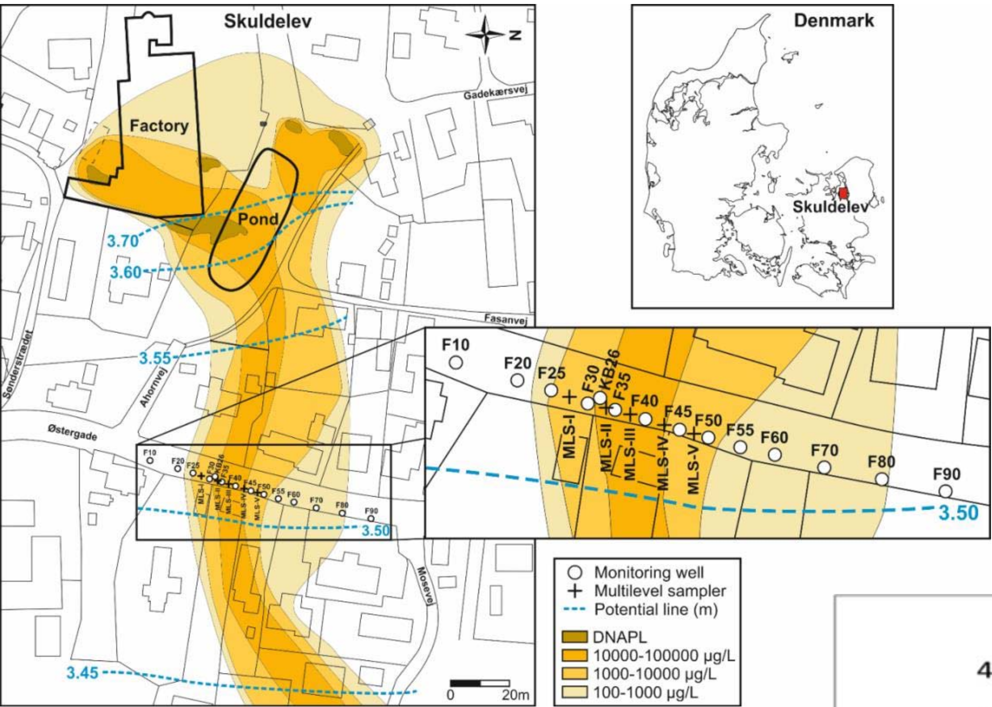


Contaminant mass discharge




Risk assessment of groundwater resource
Cabstraction =
Contaminant mass discharge, J is diluted in the annual water abstraction, Q, at a water works or a fictitous well
Dilution in drinking water wells


Plume width = L
Waterflow in stream =
J
C max
C mix = J /



Otte tons gift skal væk fra Sku

Region Hovedstaden er begyndt på oprydningen i Skuldelev. Formålet er at sikre, at hverken mennesker eller grundvand kommer i kontakt med de opløsningsmidler, som Stelton hældte i kloakken igennem tre årtier.

briksbygning lige ud til gadekærets skrænter.

Her brugte man klorerede opløsningsmidler til at affedte metallet som blev til de kendte og prisbelønnede produkter i rustfrit stål. Når metallet var affedtet blev opløsningsmidlerne skyllet ud i kloakket. Og det måtte virksomheden gerne, for dengang havde man ikke den viden man har i dag. At klorerede opløsningsmidler kan ødelægge menneskers helbred.

- De fulgte gældende reg-

dekæret i Skuldelev strømmer grundvandet mod øst, ud mod Roskilde Fjord. Undervejs løber det under en lang række boliger og tæt forbi Skuldelev Vandværk.

- Vores opgave er at undgå at det kommer i grundvandet. Og at undgå at folk kommer i kontakt med det, siger Mads Terkelsen.

Malerhjerne

Undersøgelserne viser, at forureningen ligger som

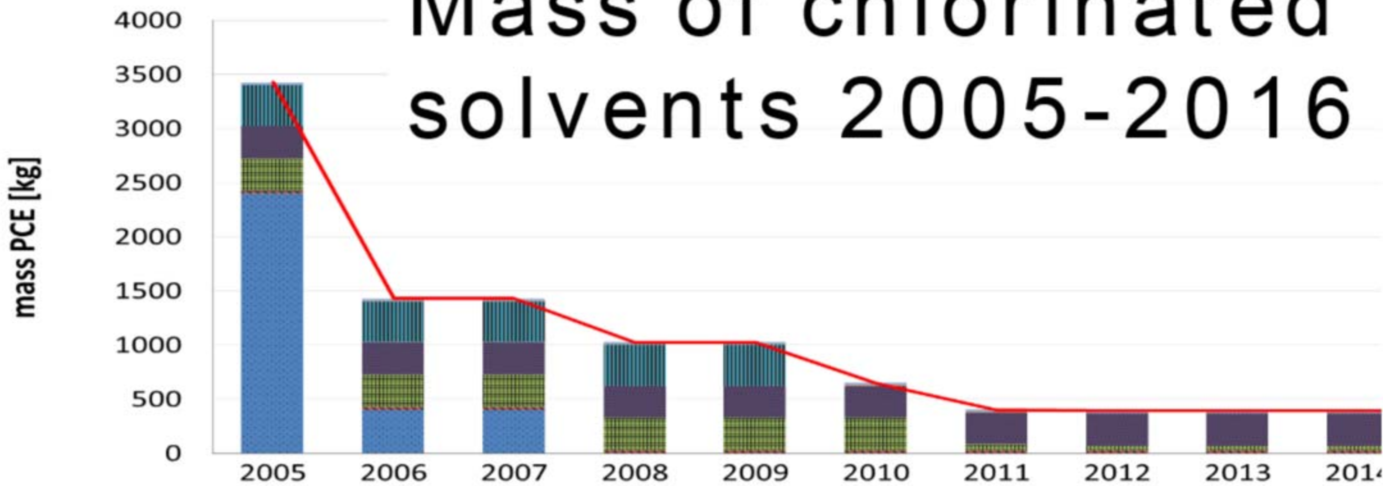
Courtesy NIRAS and the C

Klar til kogning i Skuldelev

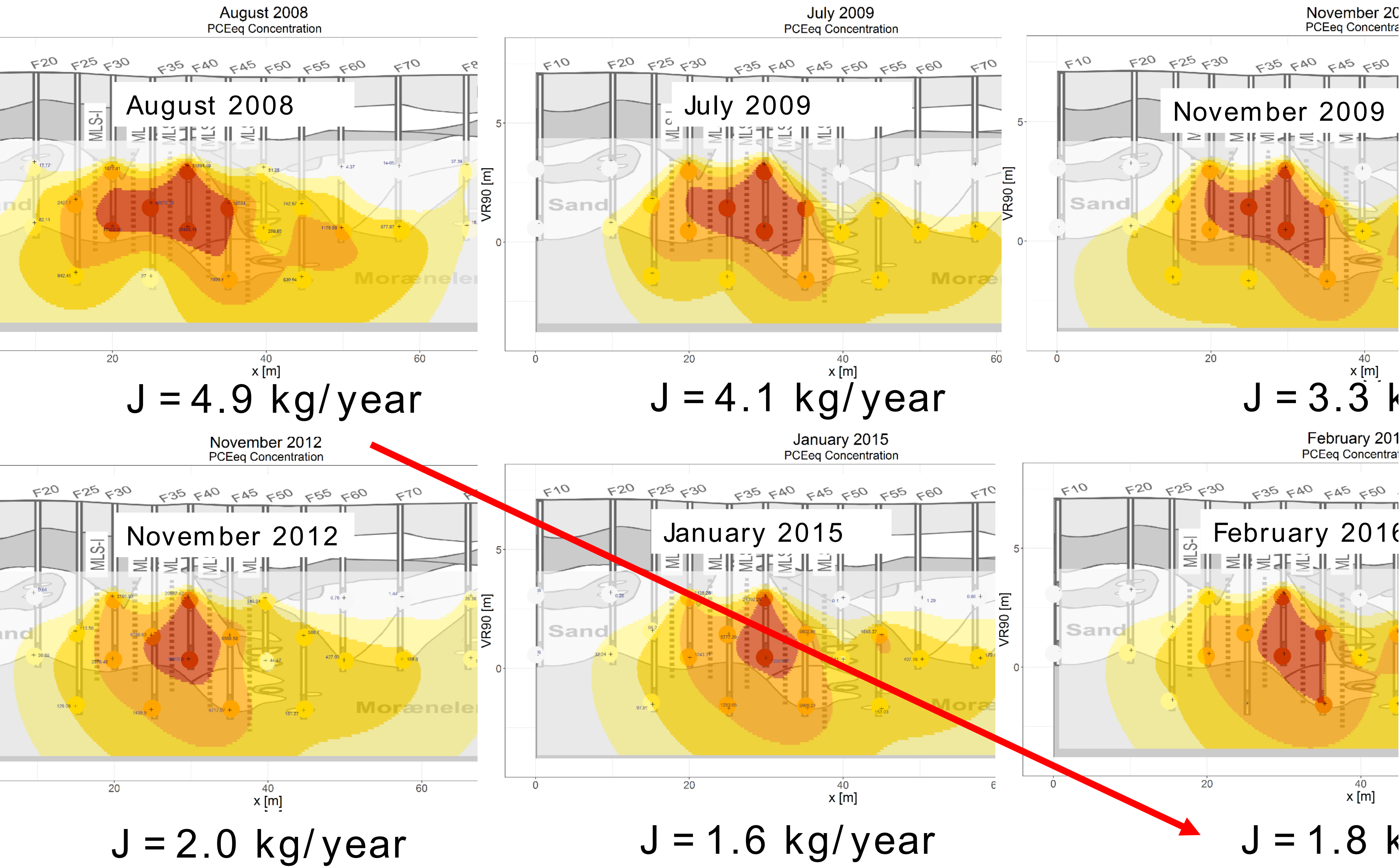
Anlægget i Skuldelev, der ved at varme jorden under det tidligere gadekær op til kogepunktet skal fjerne den alvorlige forurening med klorerede opløsningsmidler, er nu taget i brug. I løbet af kort tid vil vandet i jorden begynde at koge, og dampen vil stige op af jorden og medbringe de giftige stoffer. Dampen samles op i rørene, og på den måde kan 99 procent af forureningen fjernes, mener Region Hovedstaden.

Foto: Lars Skov

Mass of chlorinated solvents 2005-2016

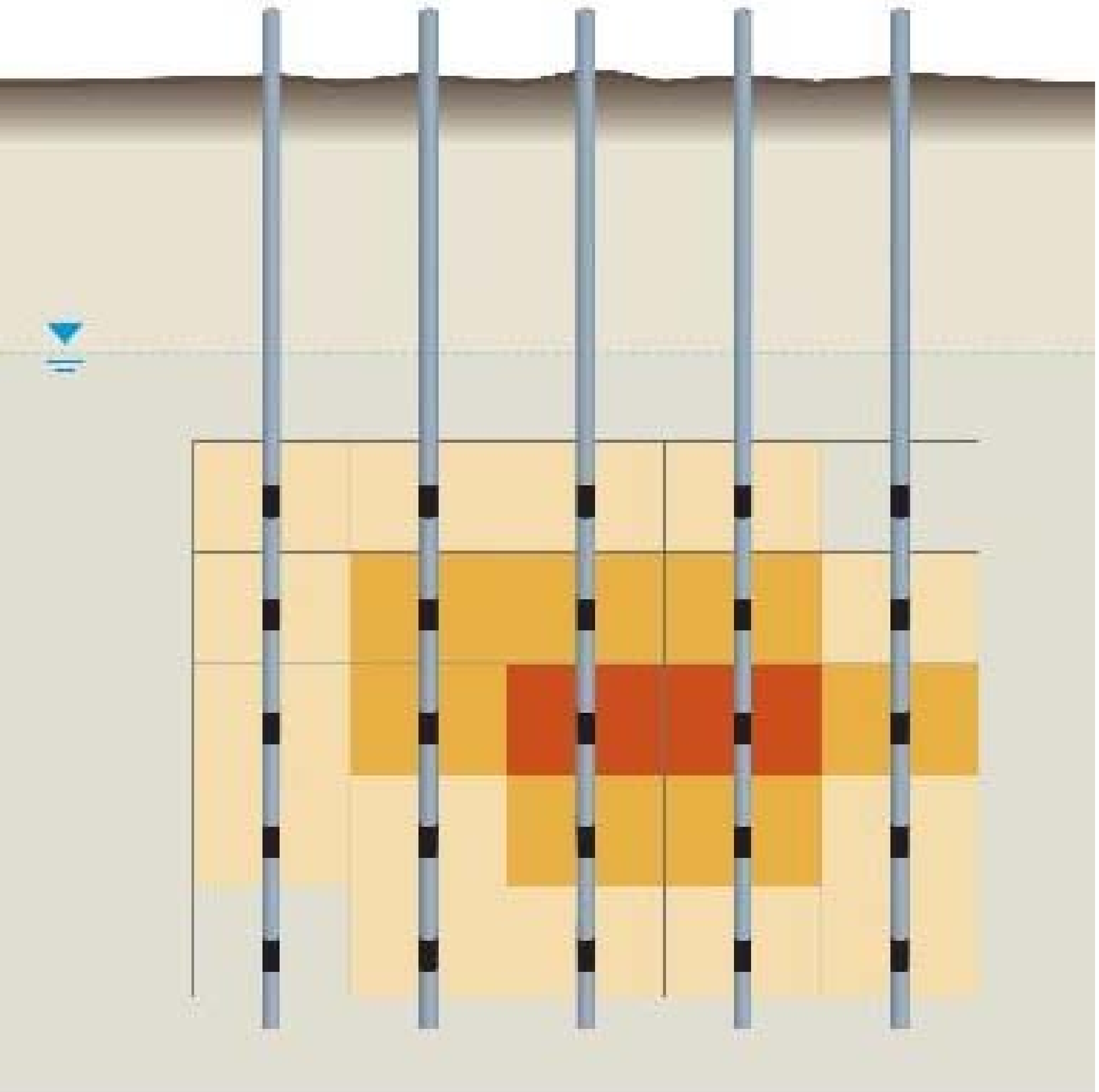


	2005	2006	2007	2008	2009	2010	2011	2012	2013	201
hotspot VII	20	20	20	20	20	20	20	20	20	20
hotspot VI	2	2	2	2	2	2	2	2	2	2
hotspot V	380	380	380	380	380	0	0	0	0	0
hotspot IV	300	300	300	300	300	300	300	300	300	300
hotspot III	300	300	300	300	300	300	55	46	46	46
hotspot II	25	25	25	25	25	25	25	25	25	25
hotspot I	2400	400	400	0	0	0	0	0	0	0
TOTAL	3427	1427	1427	1027	1027	647	402	393	393	393



August 2008
PCEeq Concentration
J = 4.9 kg/year
July 2009
PCEeq Concentration
J = 4.1 kg/year
November 2009
J = 3.3
November 2012
PCEeq Concentration
J = 2.0 kg/year
January 2015
PCEeq Concentration
J = 1.6 kg/year
February 201
J = 1.8
Sand
Moræneler
VR90 [m]
x [m]

How to determine contaminant mass dischar



Contaminant mass dichar

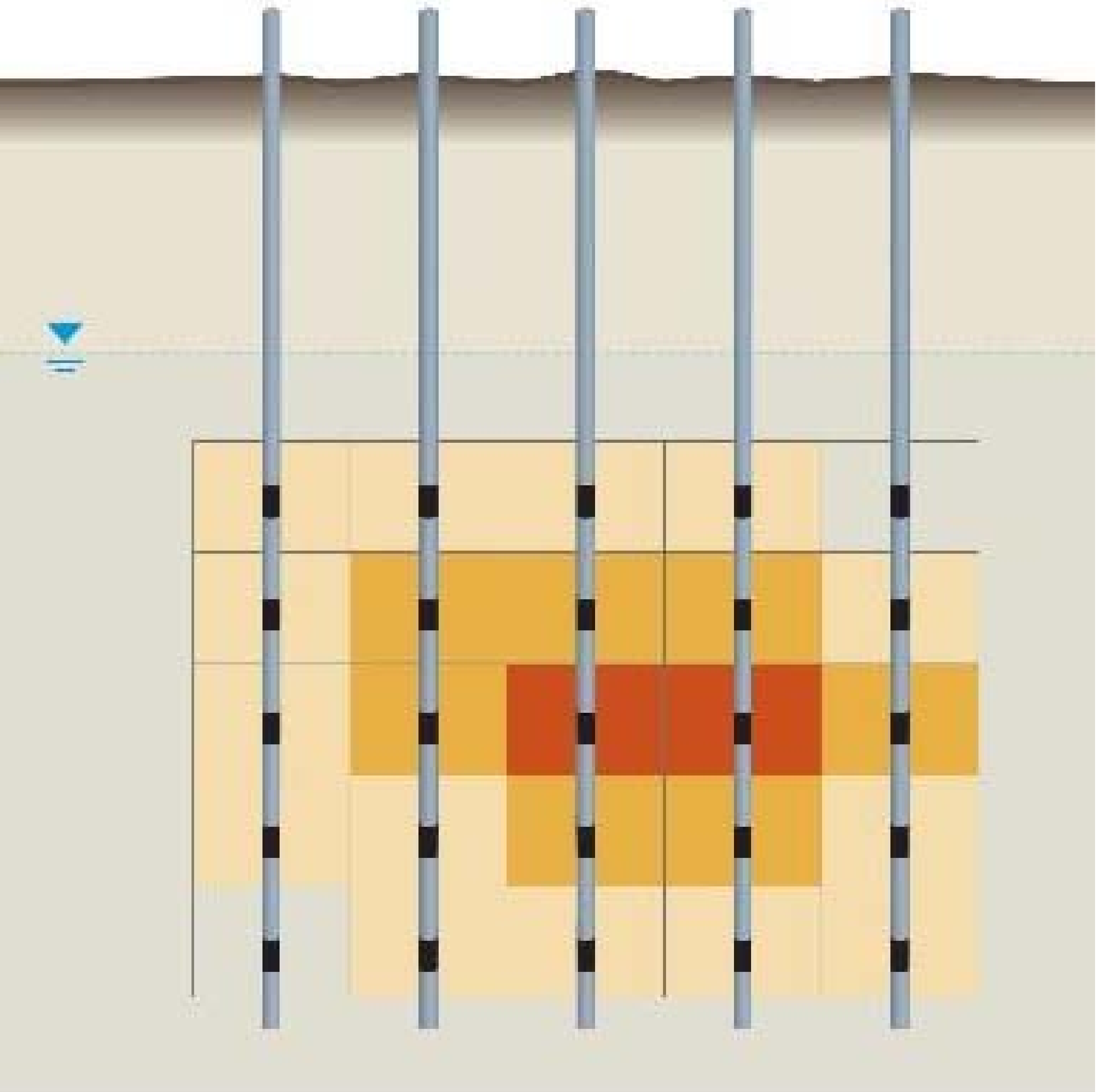
J = Flow * Concentration *

J = K* I* Concentration* Ar

K = Hydraulic conductivity

I = Hydraulic gradient

Contaminant mass discharge



Contaminant mass dichar

J = Flow * Concentration *

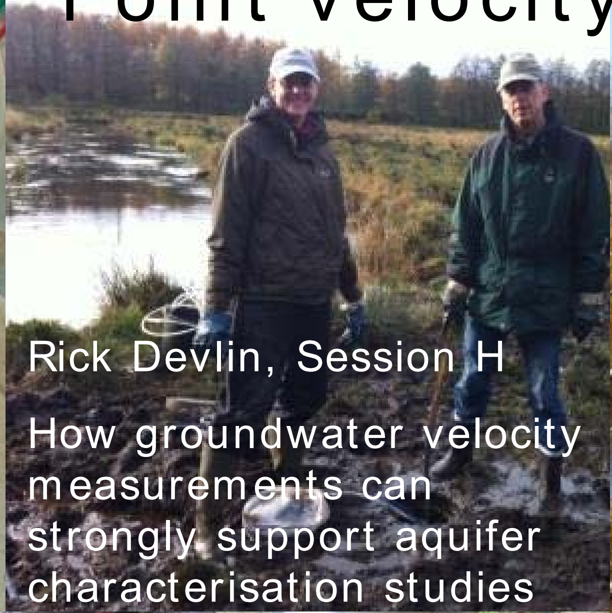
J = Mass flux * Area

J = K* I* Concentration* Area

K = Hydraulic conductivity

I = Hydraulic gradient

Point velocity probes



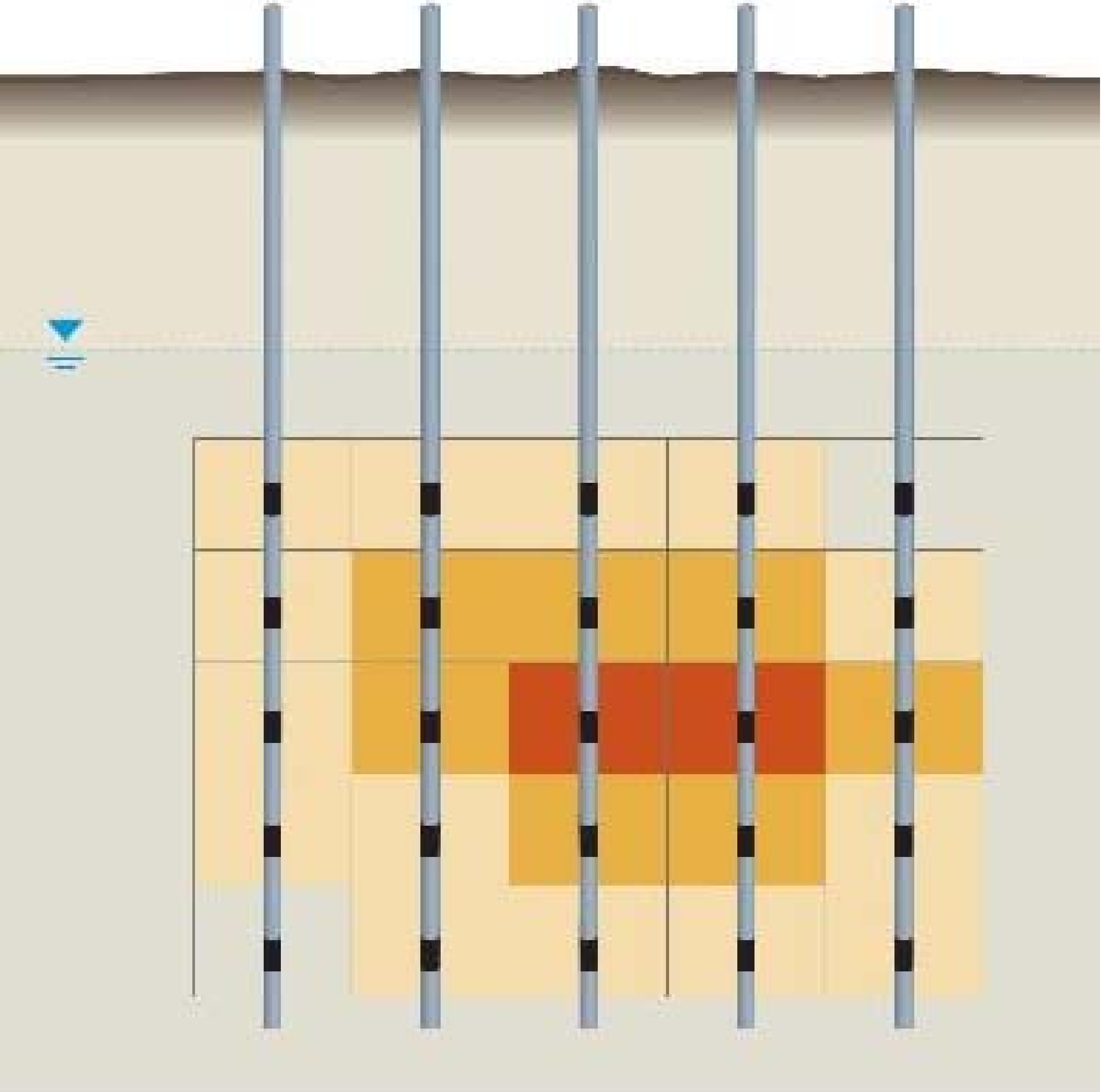
Rick Devlin, Session H

How groundwater velocity measurements can strongly support aquifer characterisation studies

Rønde et al. (2017). Contaminant mass discharge to streams: comparing direct groundwater velocity measurements and multi-level groundwater sampling with an in-stream approach. Journal of Contaminant Hydrology. 206, 43-54.

Passive meters

How to determine contaminant mass dischar



Contaminant mass dichar

J = Flow * Concentration *

J = K* I* Concentration* Ar

K = Hydraulic conductivity

I = Hydraulic gradient


Challenge I: Geological variation
A homogenous aquifer doesn’t exist

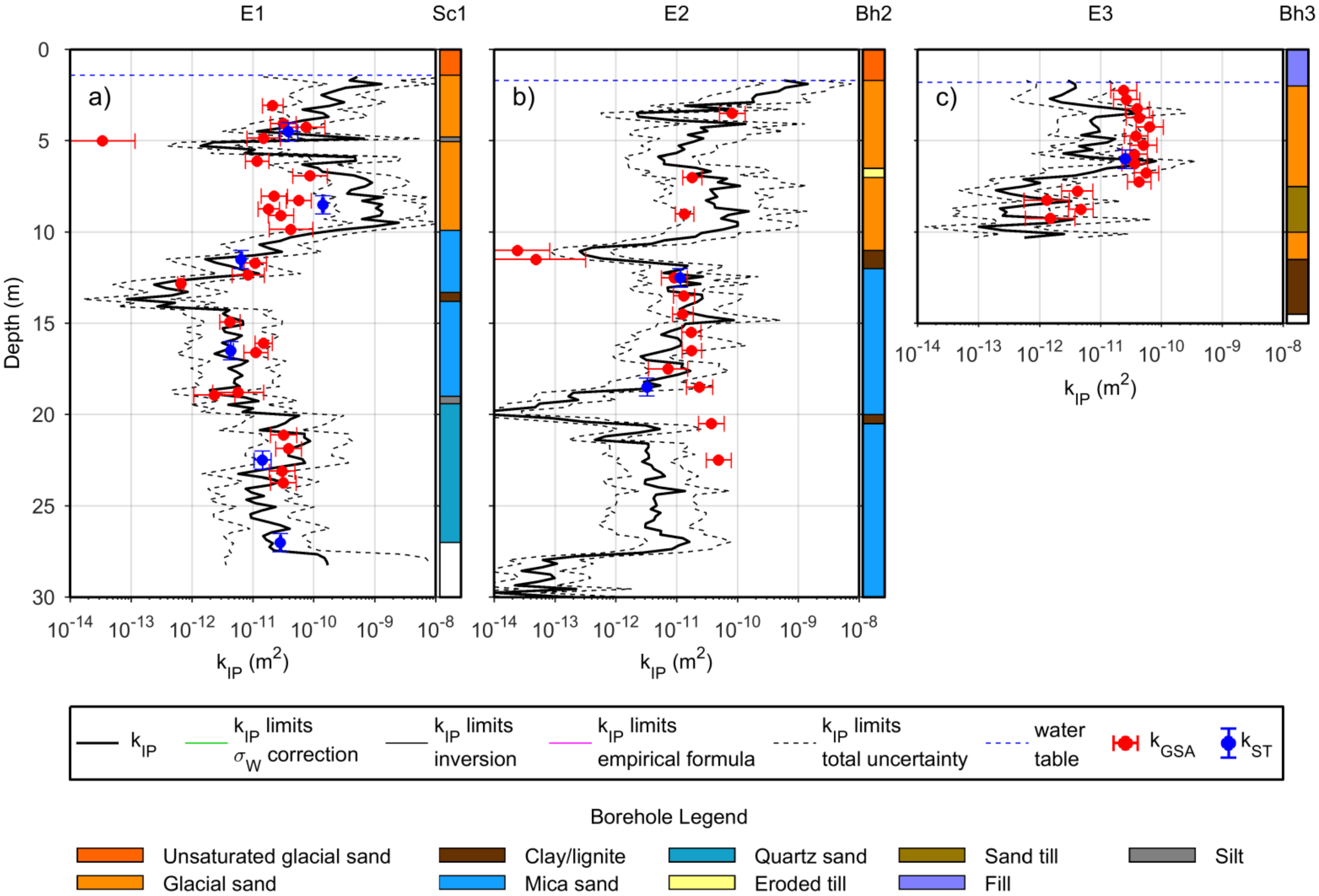
- Heterogeneity, uncertainty and are key questio

- Kitanidis (2015 Persistent ques of heterogeneit uncertainty and in subsurface fl and transport, Water Resource Research, 51, 5904.

- Heterogeneity, uncertainty and are key questio

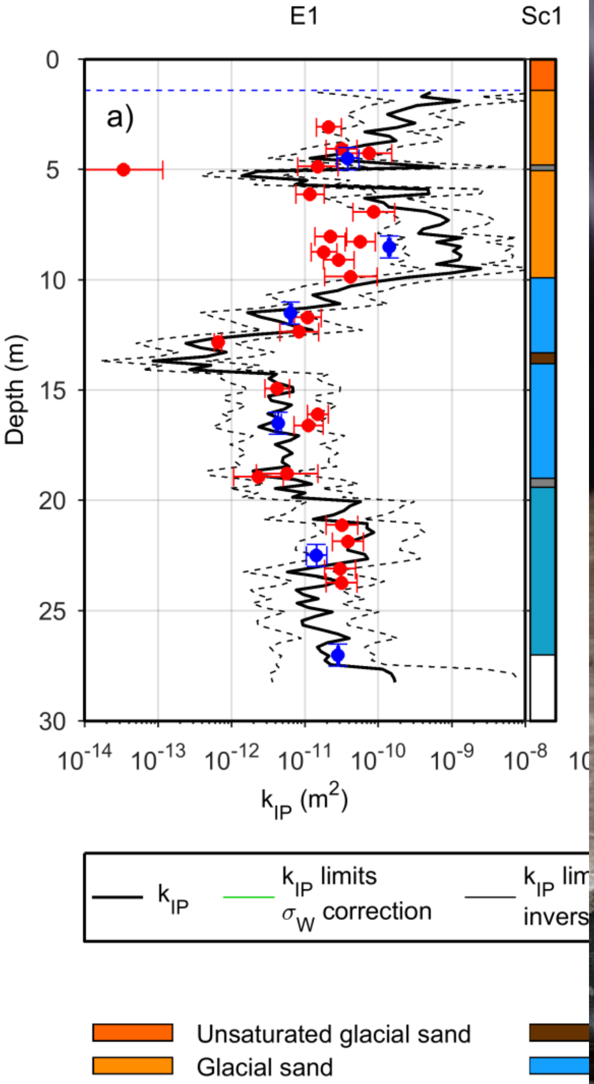
- Kitanidis (2015 Persistent ques of heterogeneit uncertainty and in subsurface fl and transport, Water Resource Research, 51, 5904.

Spatial variability in hydraulic conductivity is a fa



- Heterogeneity, uncertainty and are key questio
- Variations in hydraulic conductivity are orders of magn in mildly heterogeneous aquifers

Fiandaca et al. (2018). Water Resources Research. 54, 2851–2870.

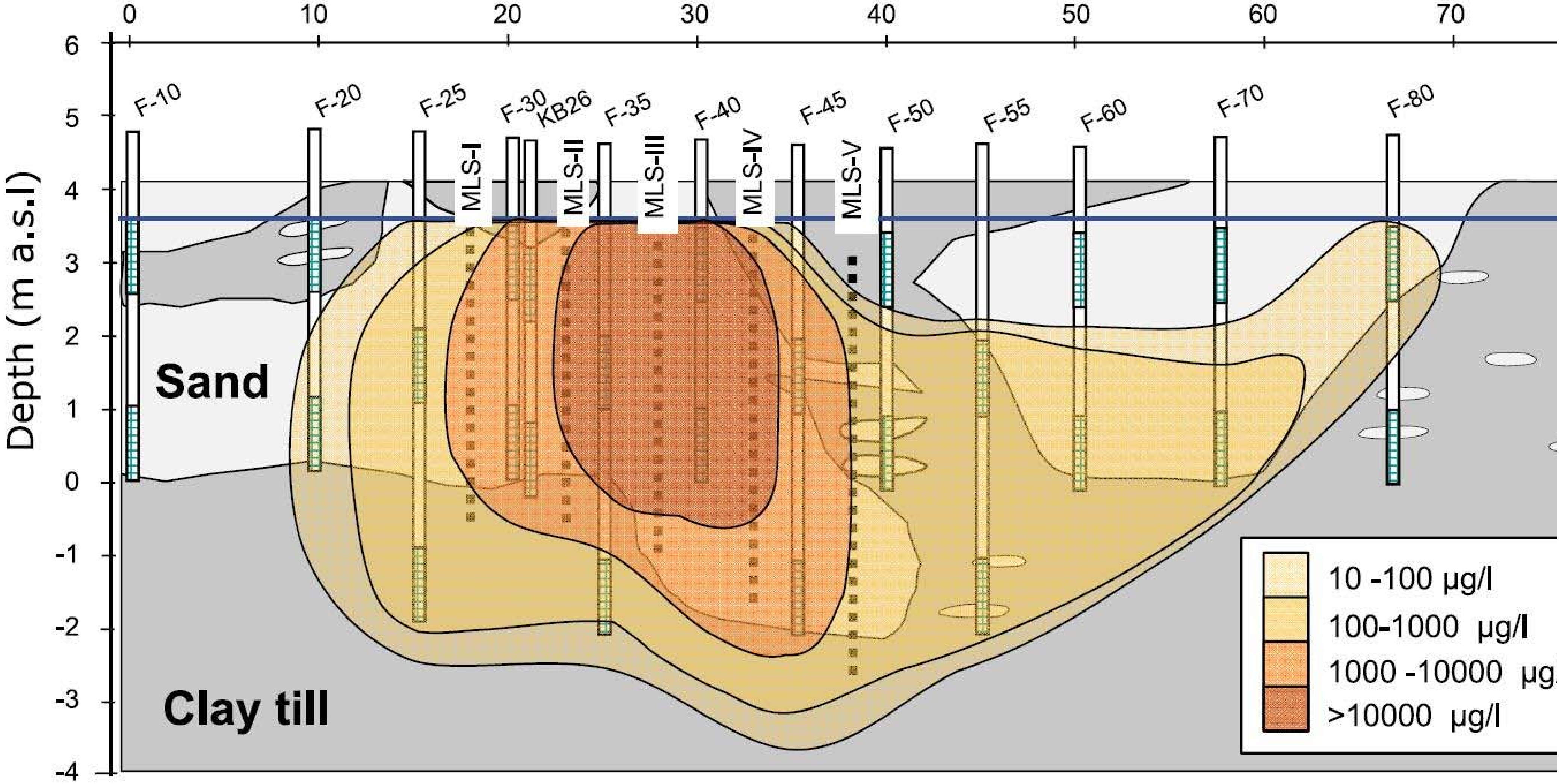


- Heterogeneity, uncertainty and are key questio
- Variations in hydraulic conductivity are orders of magn in mildly heterogeneous aquifers
- We still lack me to determine th ”true” hydraulic conductivity

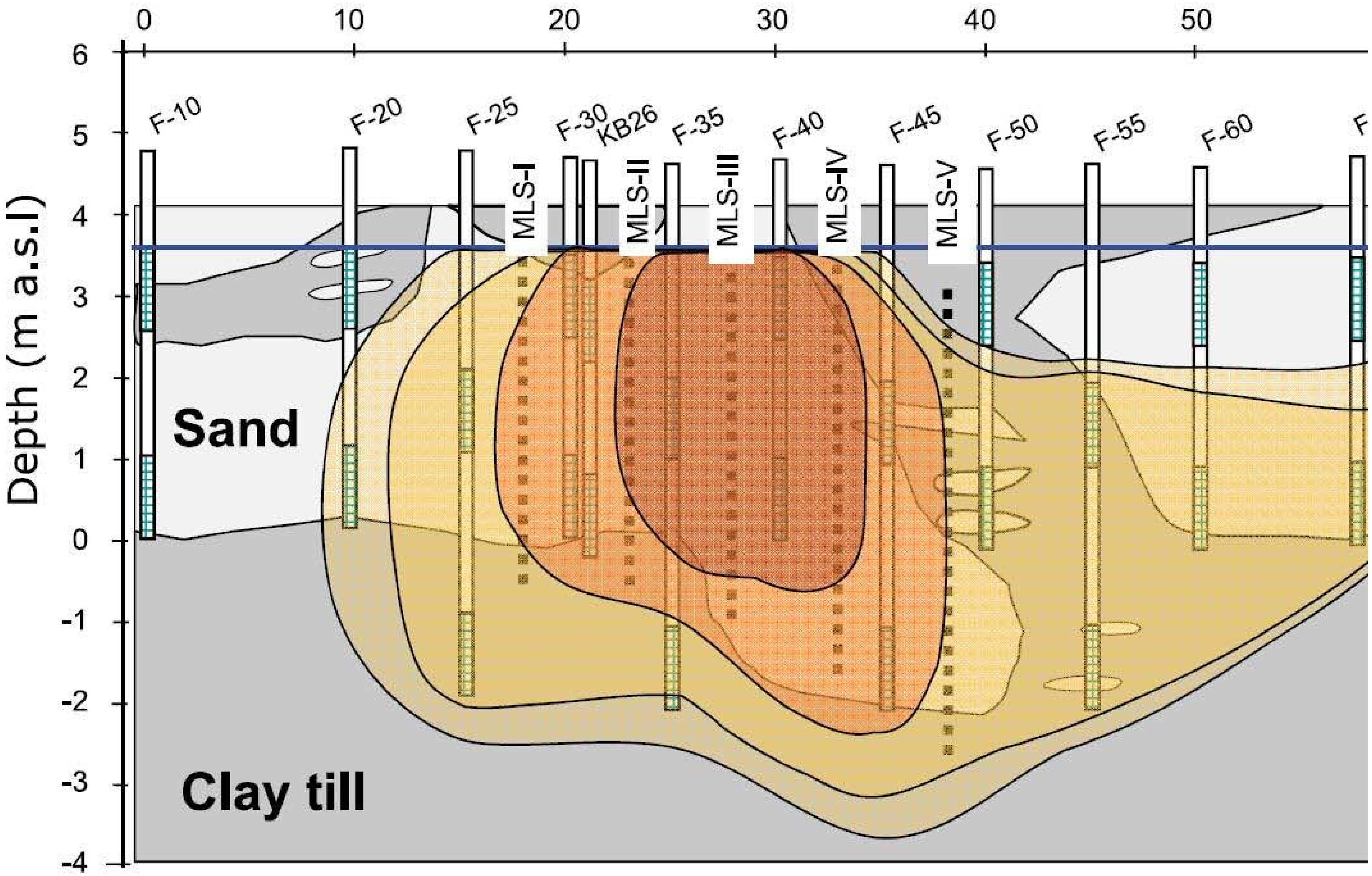
Forschen für die Umwelt
Geoprobe
7730DT
CAUTION

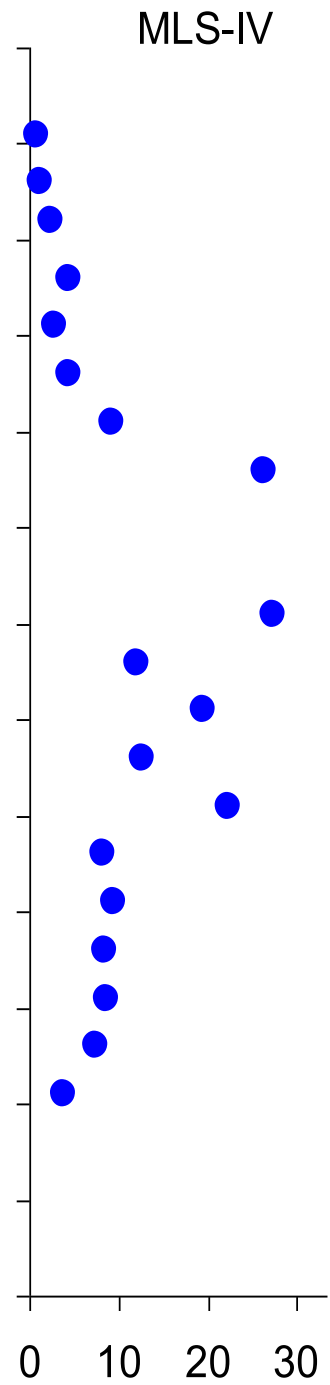
Challenge II: Steep chemical gradients in plume

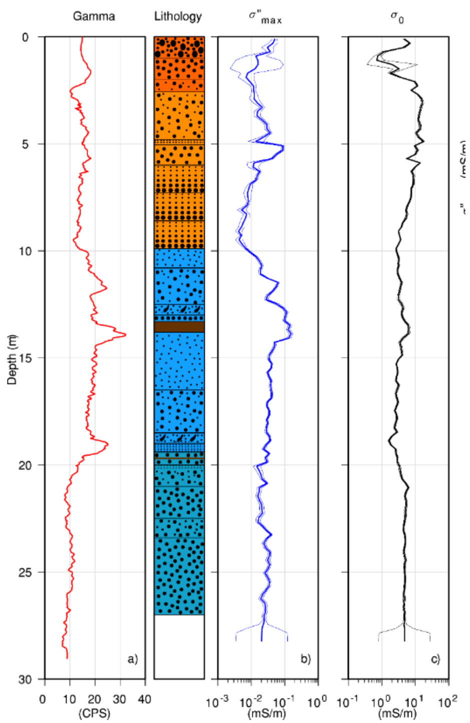
We need many sampling points to delineate the plume



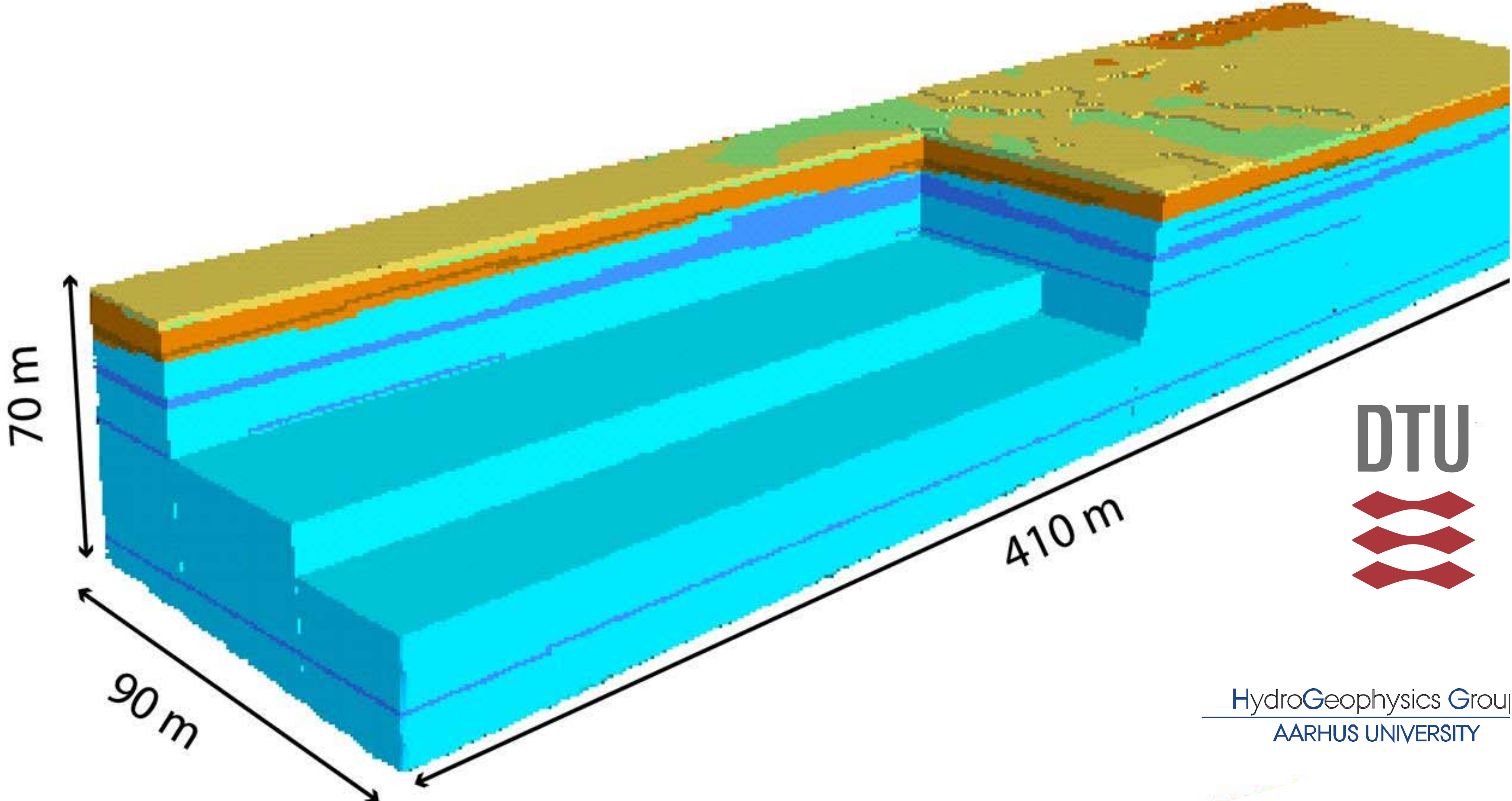
Large spatial variation in concentrations



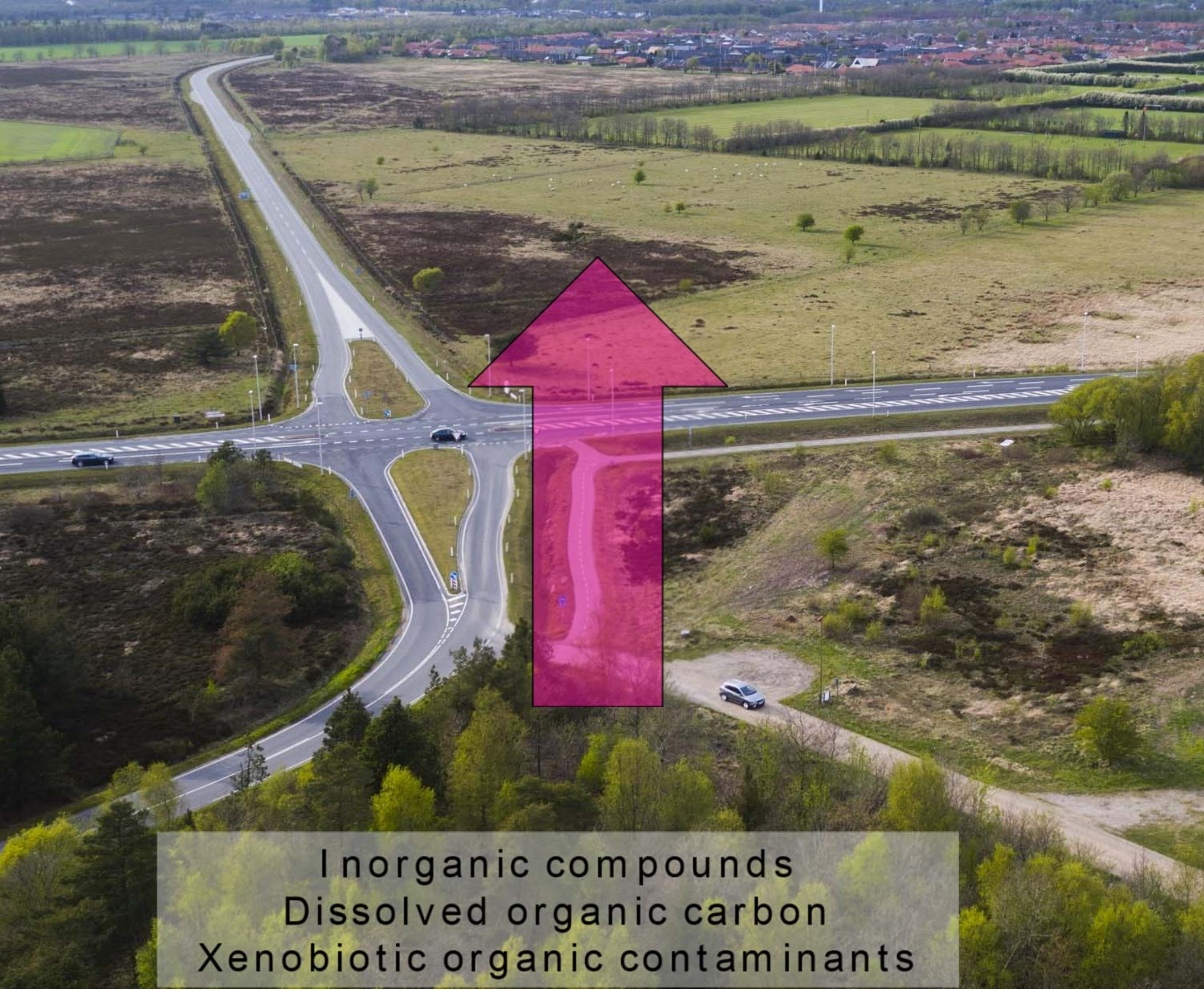


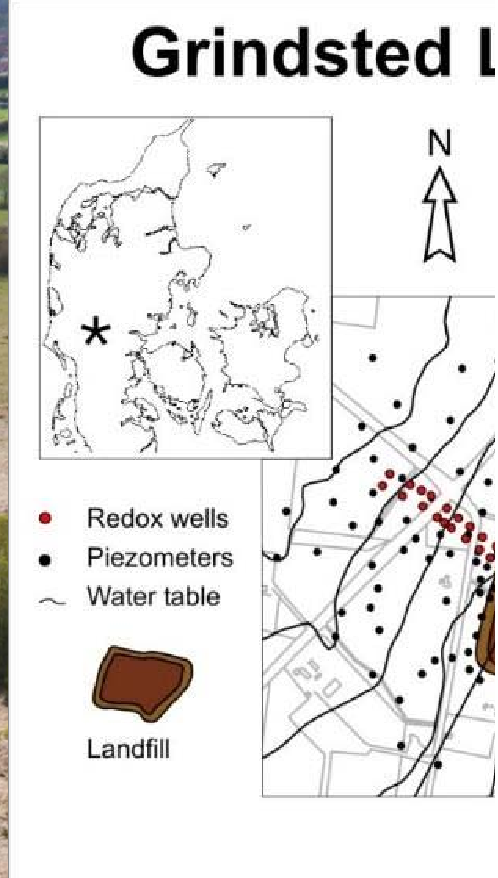


Geology, geophysics and contamina

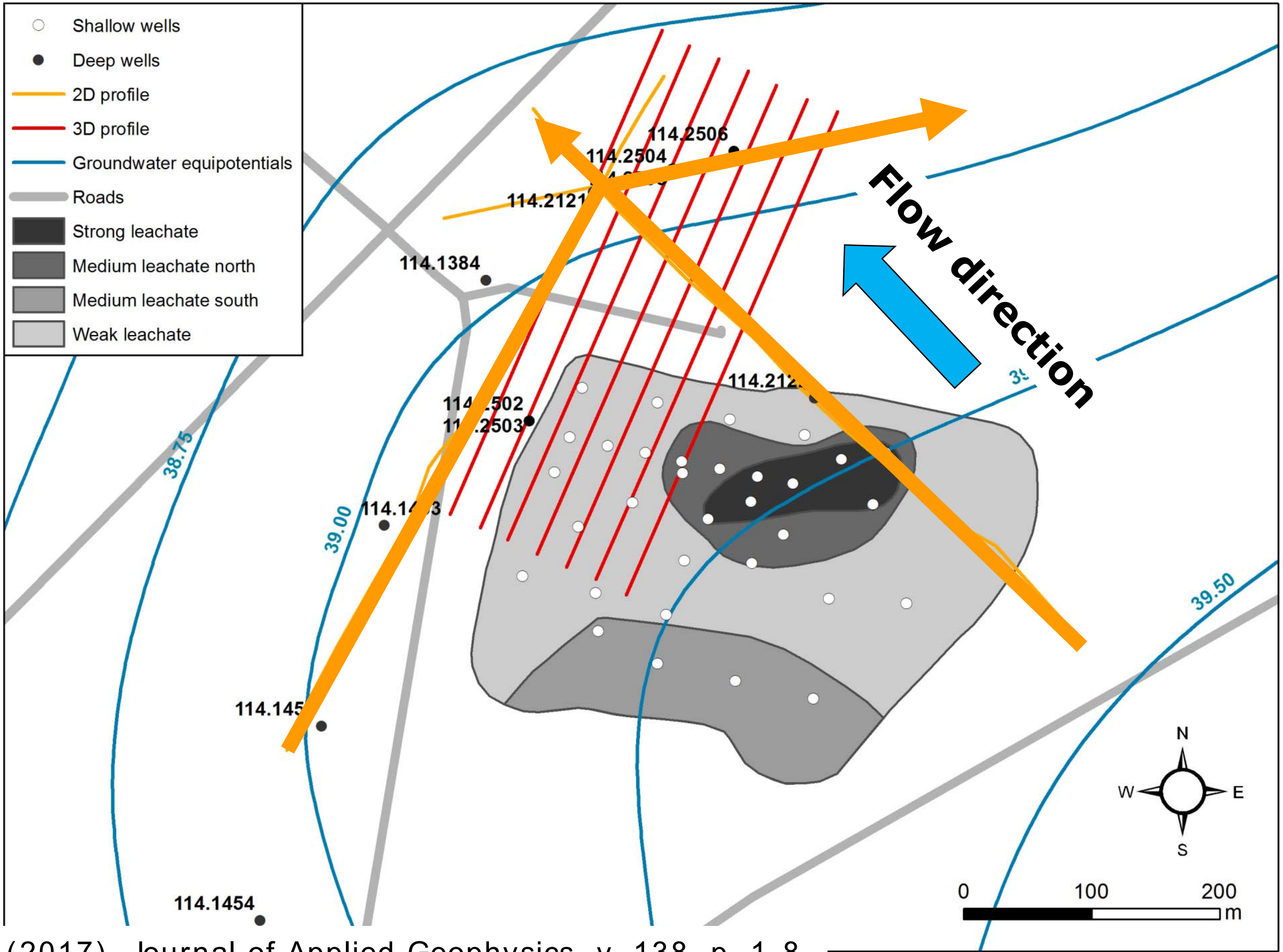


HydroGeophysics Group
AARHUS UNIVERSITY


Inorganic compounds
Dissolved organic carbon
Xenobiotic organic contaminants


Grindsted L
N
Redox wells
Piezometers
Water table
Landfill


Bjerg 1992

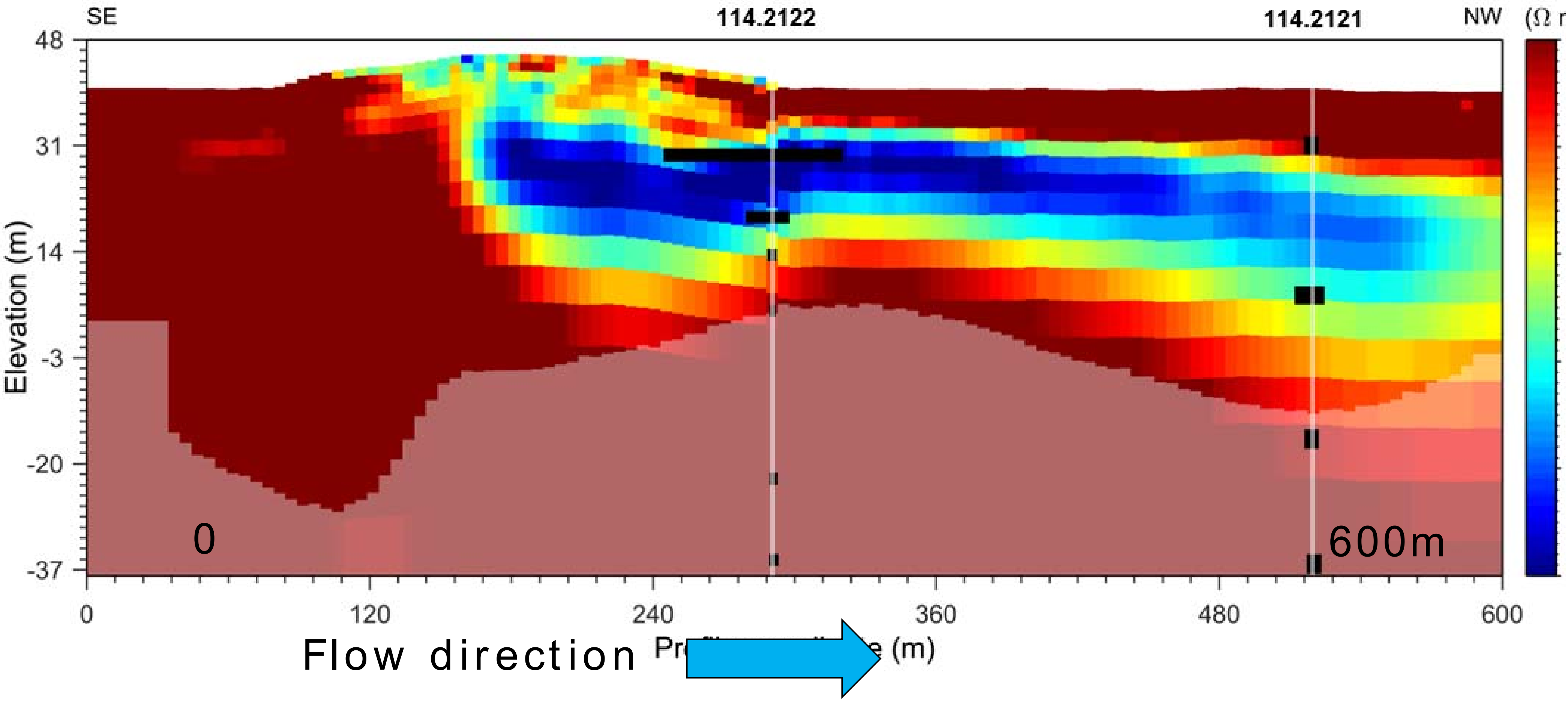


Maurya et al. (2017). Journal of Applied Geophysics, v. 138, p. 1-8.

Direct current Induced polarization, DCIP

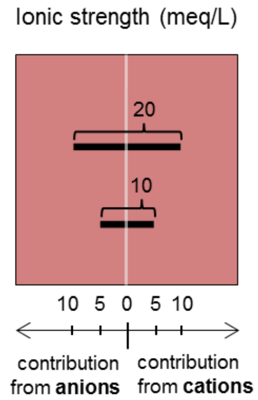
Landfill leachate plume Along flowline

Resistivity - ionic strength

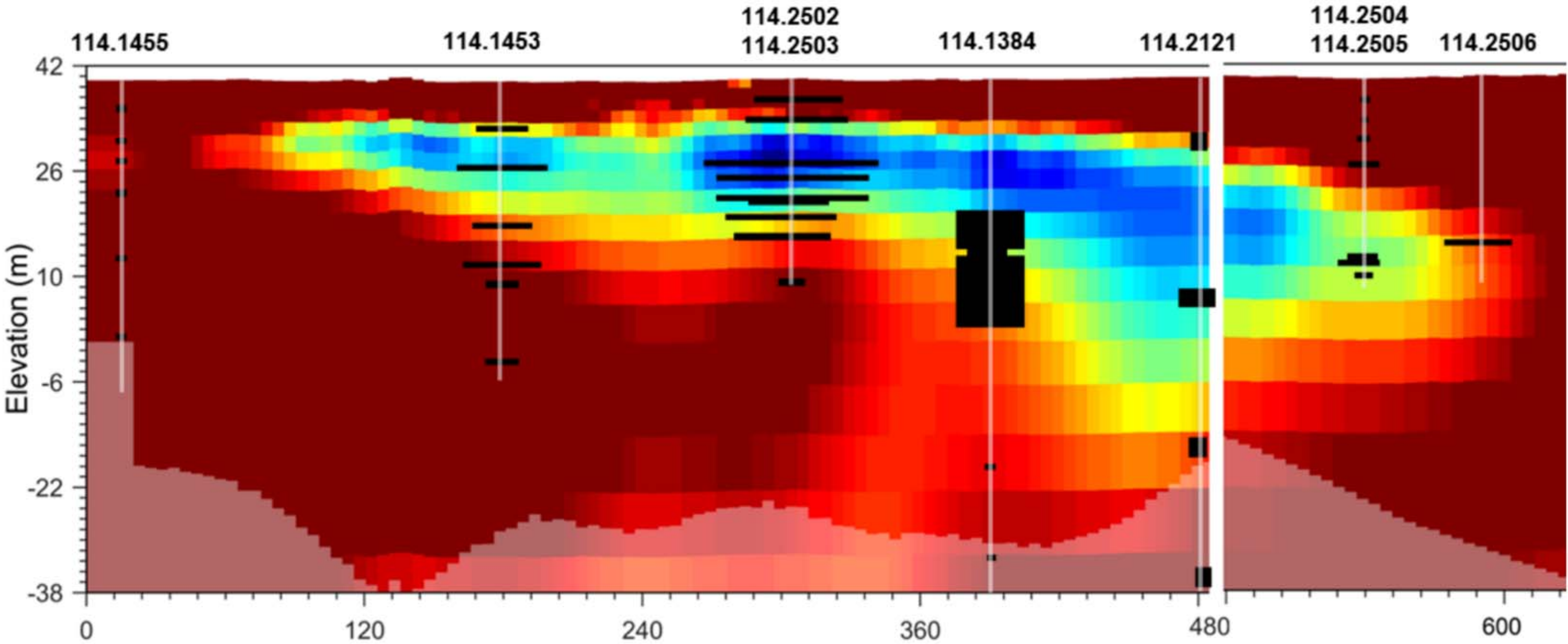


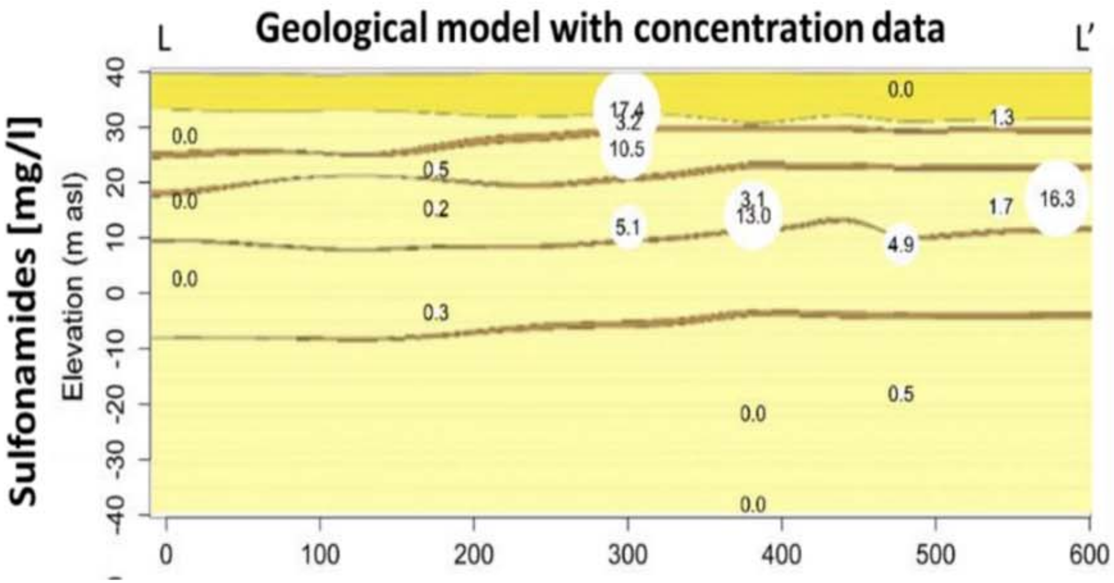
Direct current Induced polarization, DCIP

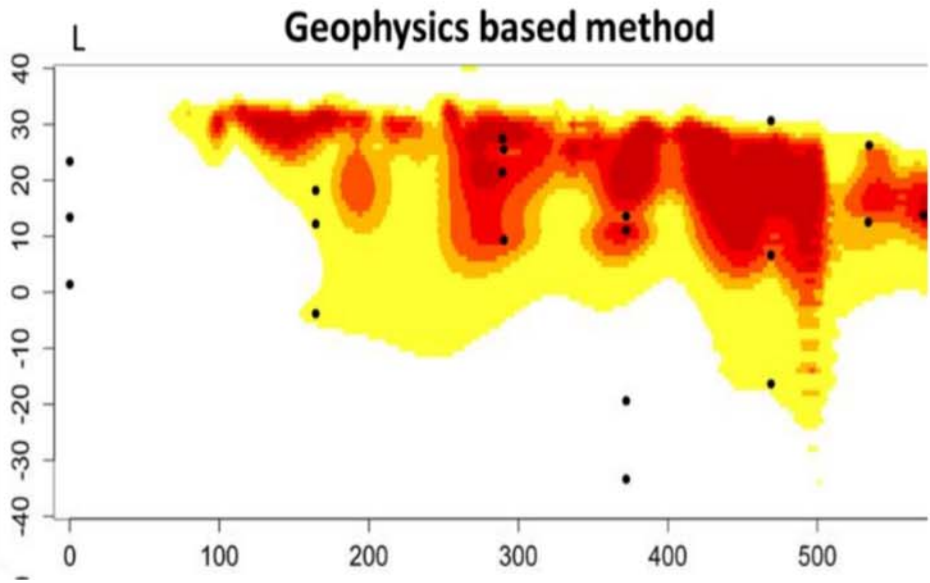
Landfill leachate plume Cross section

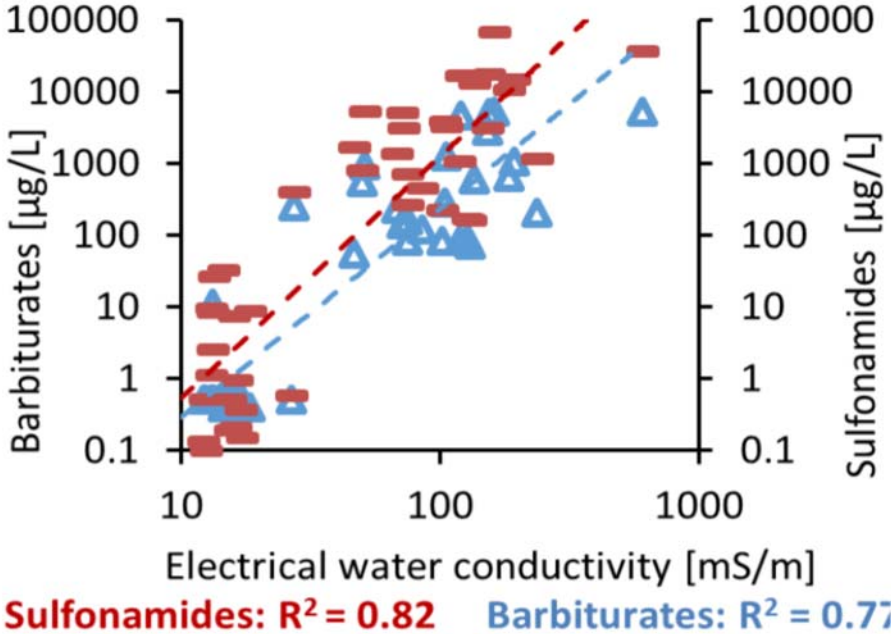


Resistivity - ionic strength





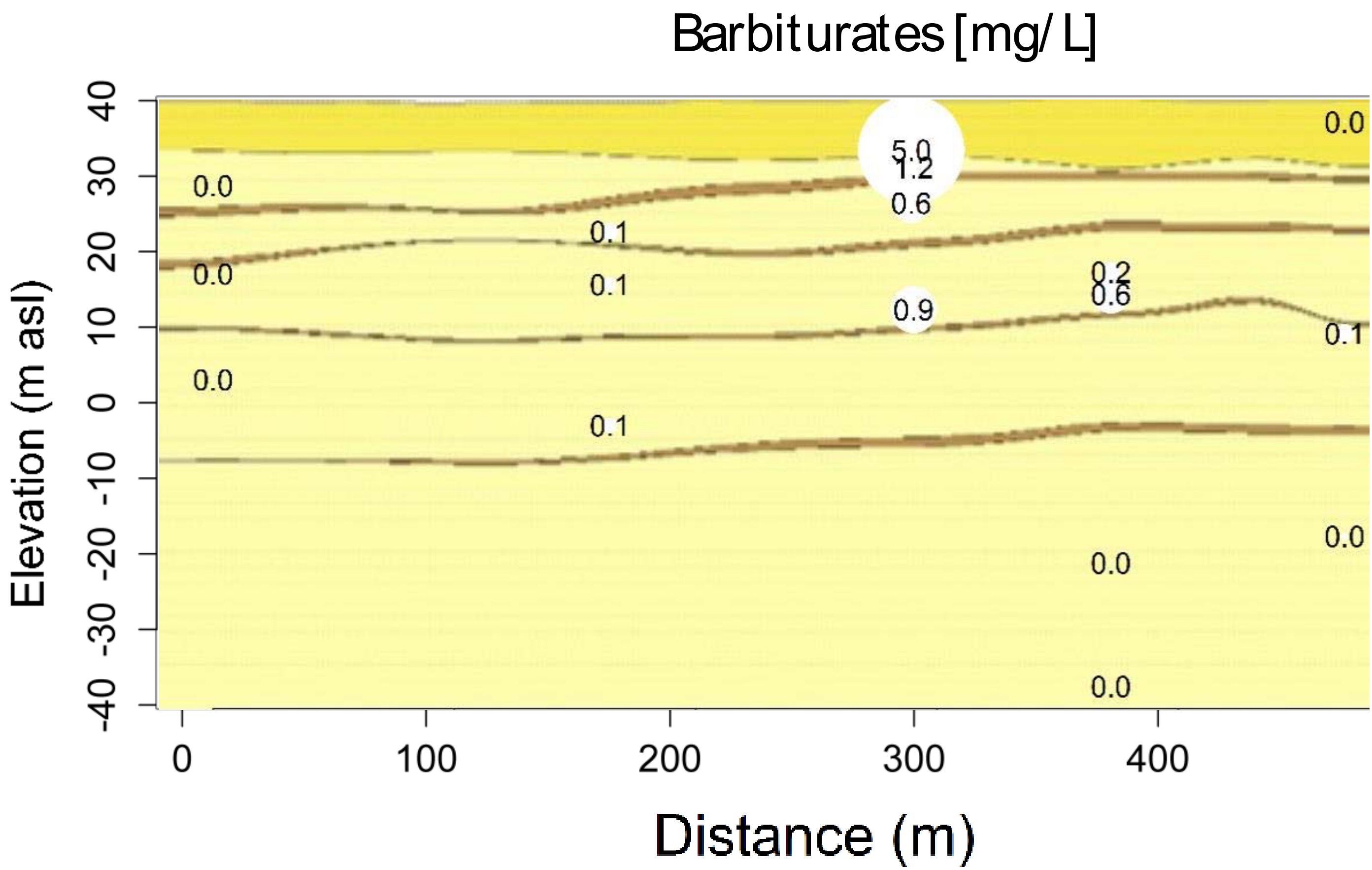


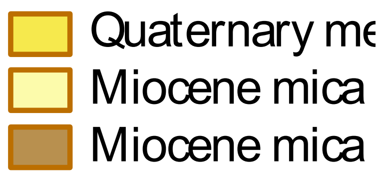


Contaminant mass discharge kg/ year	Contaminant concentration based method	Ge… m…
Sulfonamides	750	
Barbiturates	88	

Sampling density and uncertainty

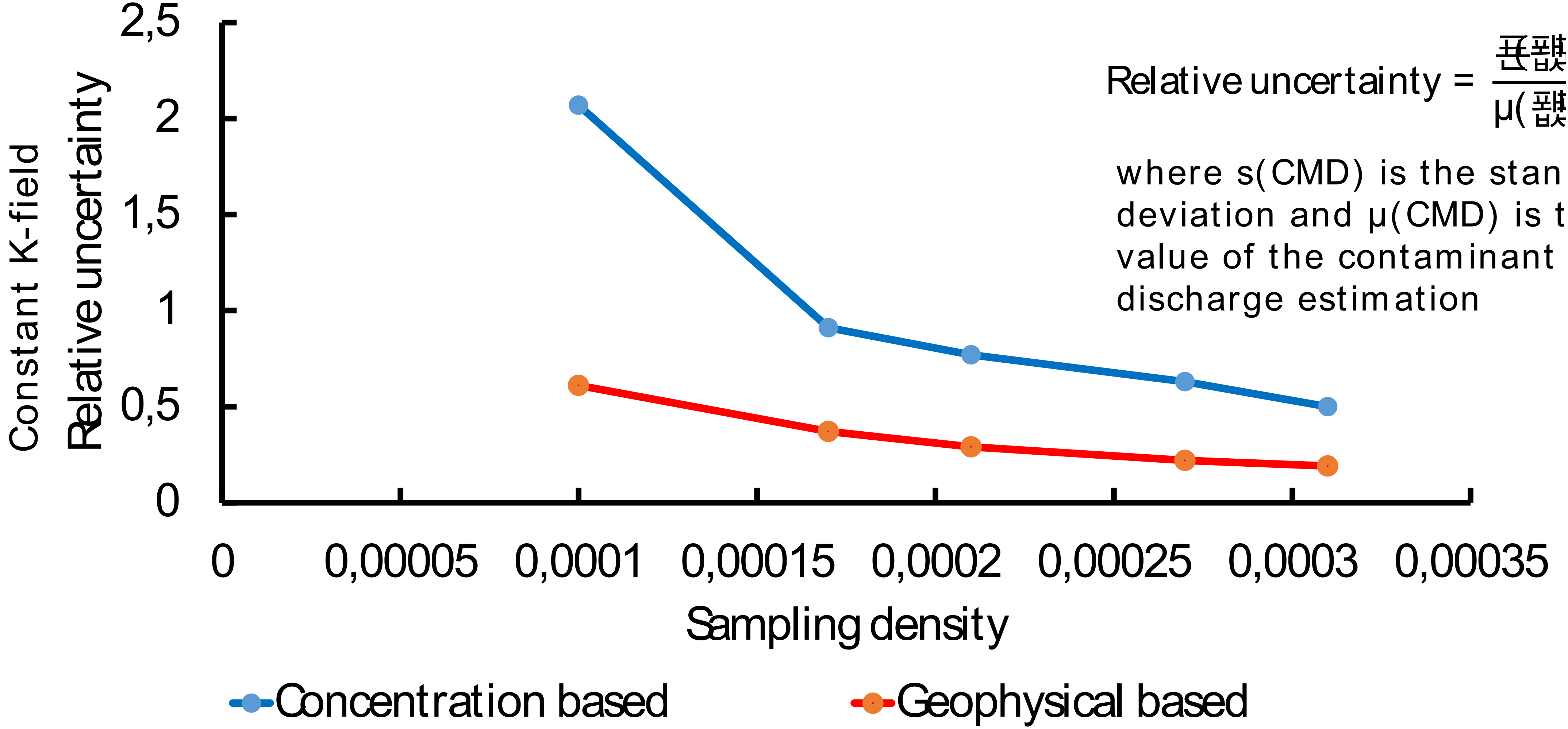
- Number of samples pr. m^2 control plane
- Grindsted landfill plume: 48000 m^2
- 20 sampling points
- Sampling density: 0.0004 samples/m^2
- We don't know the true number





Balbarini et al 2918. *Water Resources Research*. 54, doi.org/10.1029/2017WR021855.

Uncertainty analysis: Barbiturates



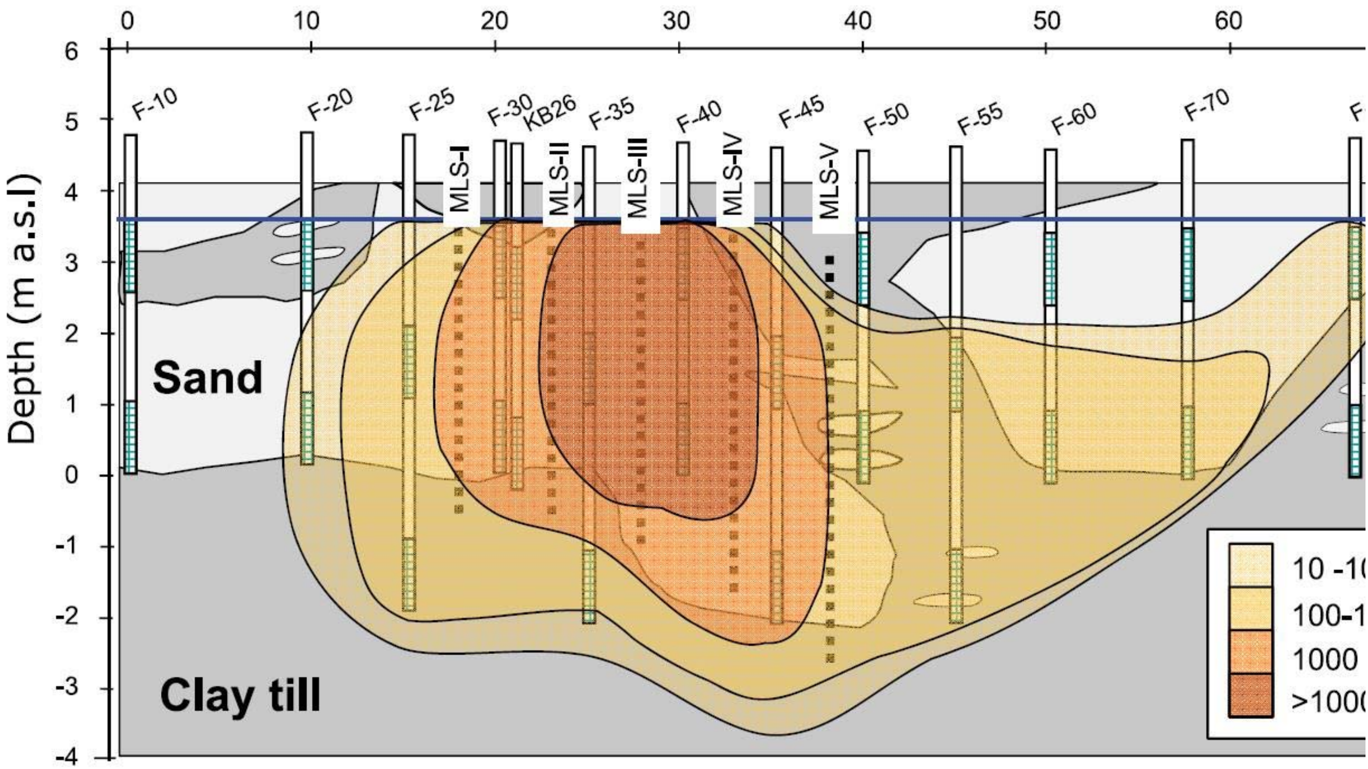
Balbarini et al 2918. *Water Resources Research*. 54, doi.org/10.1029/2017WR021855.

Sampling density and uncertainty

- Number of samples pr. m^2 control plane

- Skuldelev plume: 380 m^2
- 121 sampling points
- Sampling density: 0.3 samples/m^2

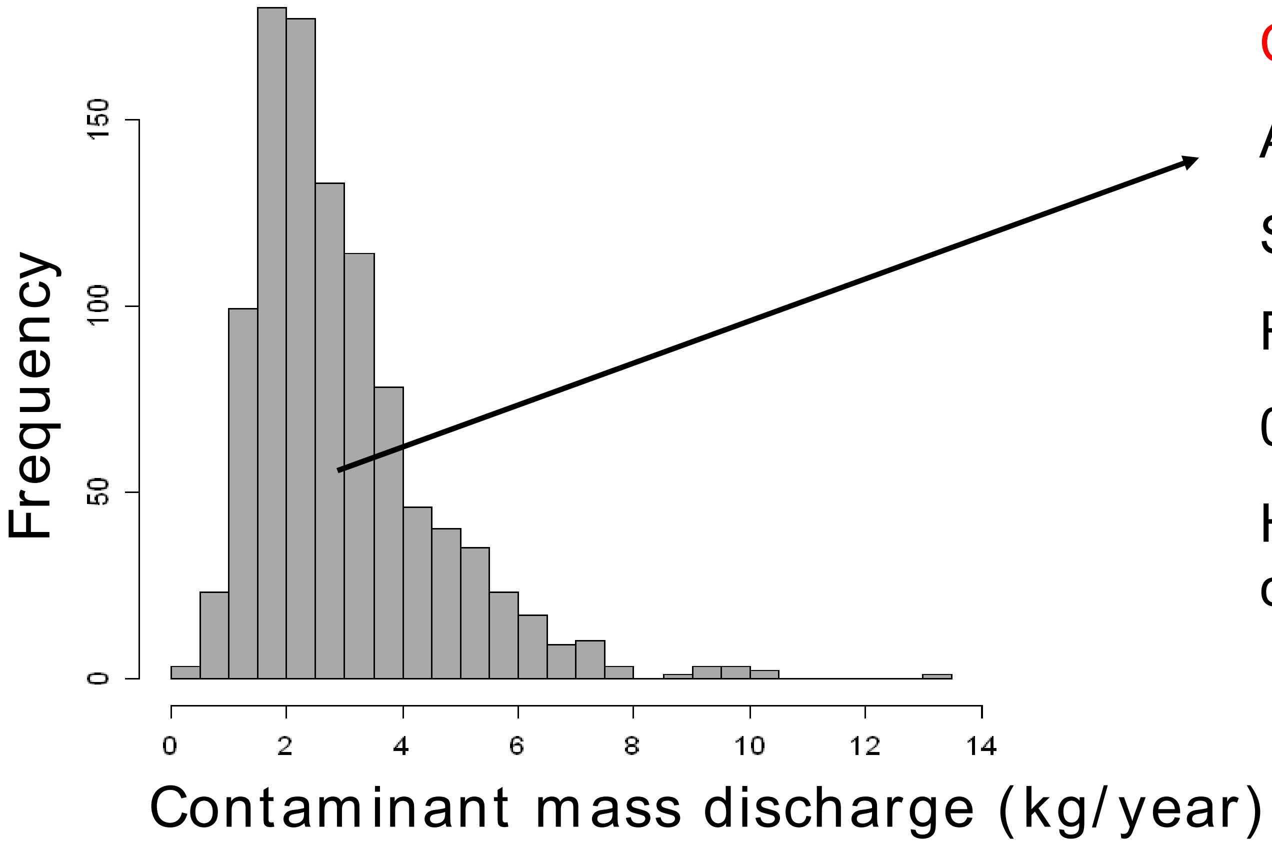
- We don't know the true number



Troldborg et al. (2012), Water Resources Research, VOL. 4

High sampling density: high certainty!

- Advanced statistics



Contaminant mass discharg

Average 3.0 kg/year

Standard deviation 1.5 kg/year

Relative uncertainty 50%

0.05-0.3 sampling points pr. m

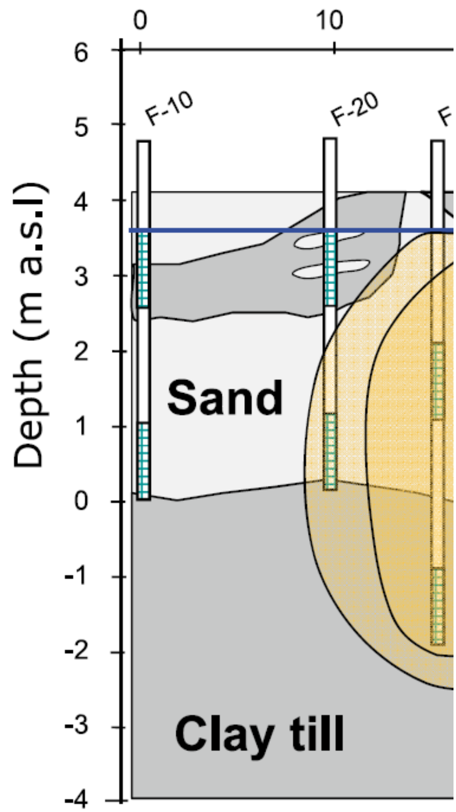
Hydraulic conductivity and concentration field included

Troldborg et al. (2012), Water Resources Research, VOL. 48, W0

Contaminant mass discharge and uncertainty?

Absolute values of contaminant mass discharge

- Conceptual errors
  - Delineation of plume incomplete
  - Full break through at control plane
  - Bias in hydraulic conductivity or hydraulic gradient



Relative uncertainty

- Sampling density – more wells decreases uncertainty
- Hydraulic conductivity field
  - Larger variability larger relative uncertainty
- Concentration field
  - Distance from source – smoothing effect at larger distances

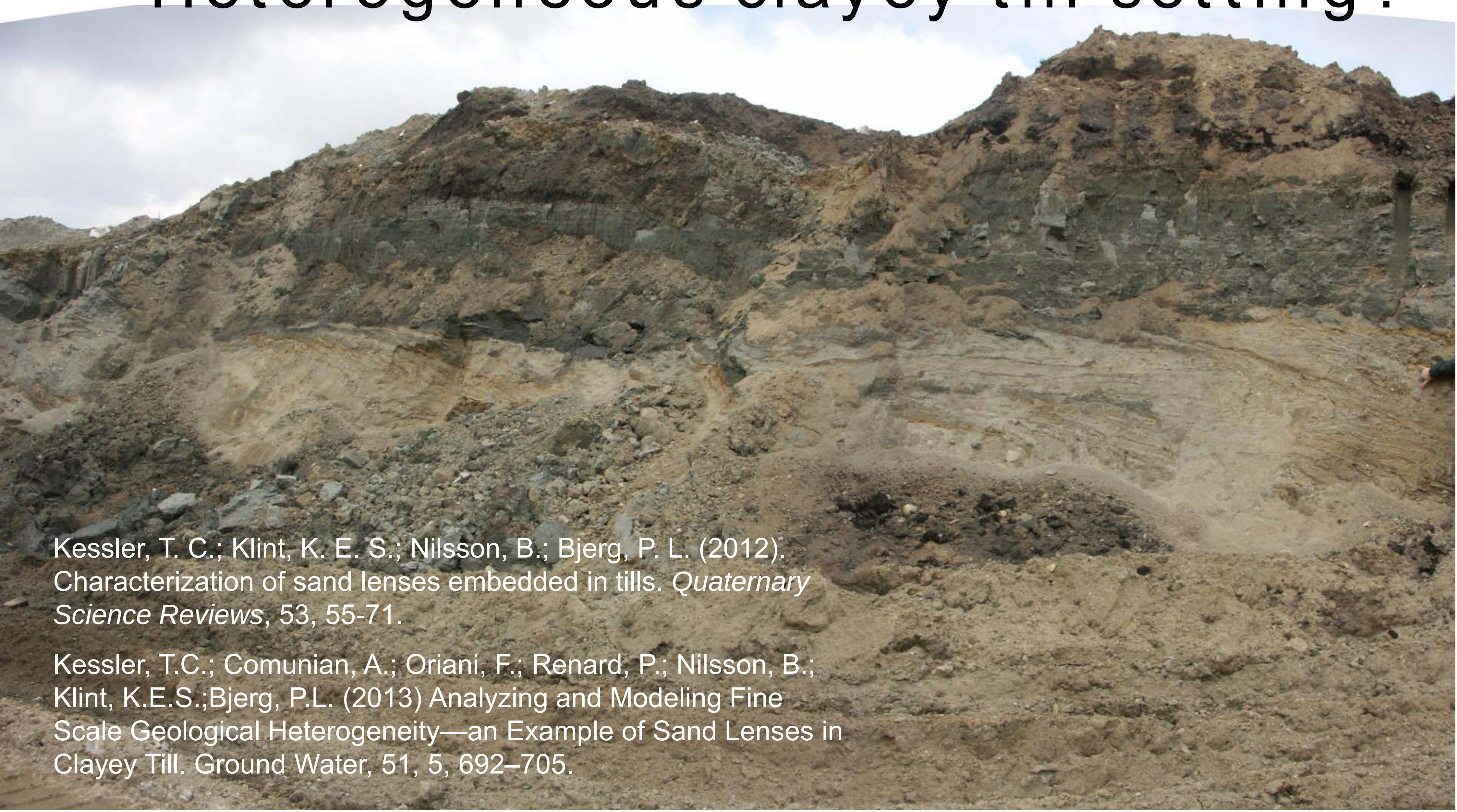
- 0.1 sampling points pr. m^2 to obtain 50% relative uncertainty in a mildly heterogenous aquifer

Contaminant mass discharge in fractured me

Chambon (2010). *Journal of Contaminant Hydrology*, 112, 77-90.

Mosthaf et al.. *Journal of Hydrolo*

Heterogeneous clayey till setting?

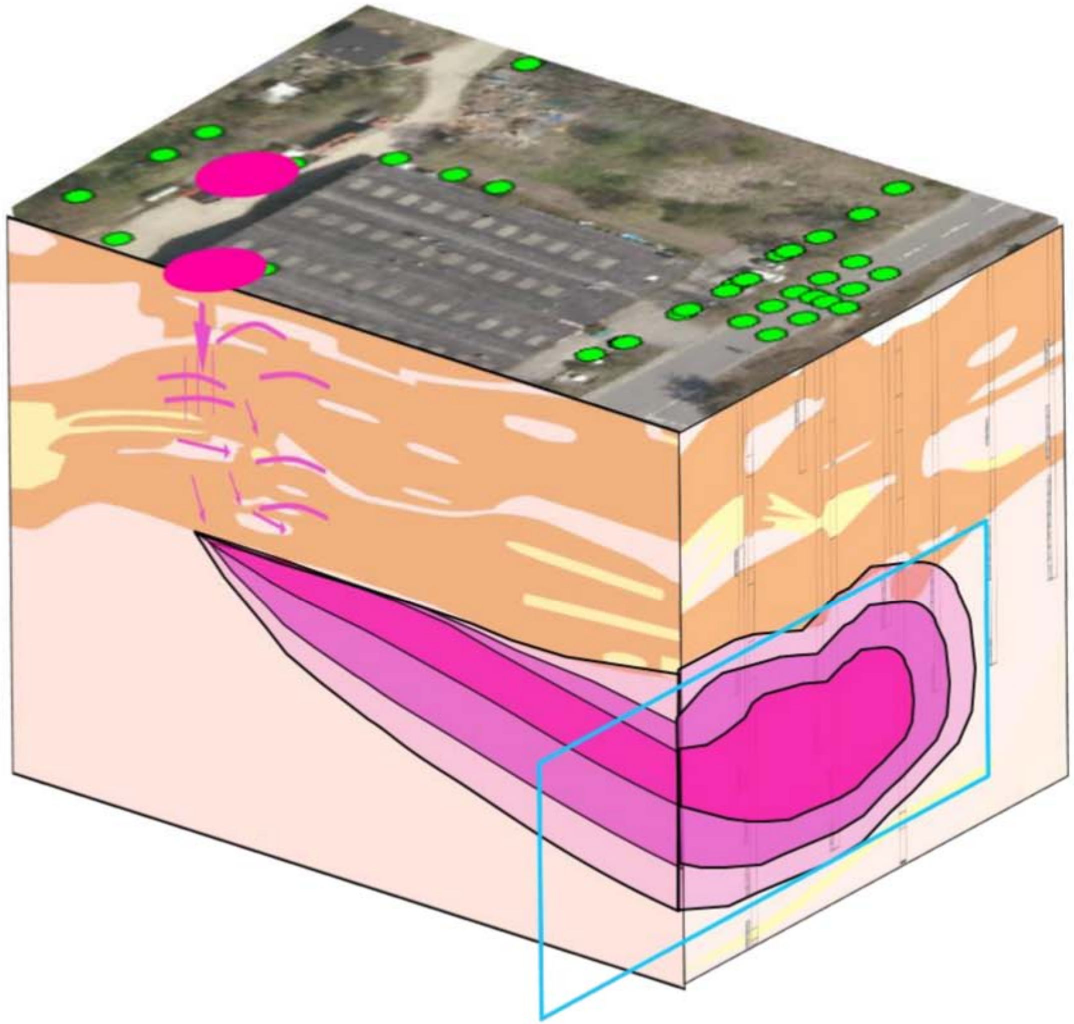


Kessler, T. C.; Klint, K. E. S.; Nilsson, B.; Bjerg, P. L. (2012). Characterization of sand lenses embedded in tills. *Quaternary Science Reviews*, 53, 55-71.

Kessler, T.C.; Comunian, A.; Oriani, F.; Renard, P.; Nilsson, B.; Klint, K.E.S.;Bjerg, P.L. (2013) Analyzing and Modeling Fine Scale Geological Heterogeneity—an Example of Sand Lenses in Clayey Till. Ground Water, 51, 5, 692–705.

How to determine contaminant mass discharge for a heterogenous clayey till setting?

- Contaminant mass in clay till system?
- Contaminant mass discharge and timeframe for leaching into underlying aquifer?
- Relationship with contaminant mass discharge measured in underlying aquifer?

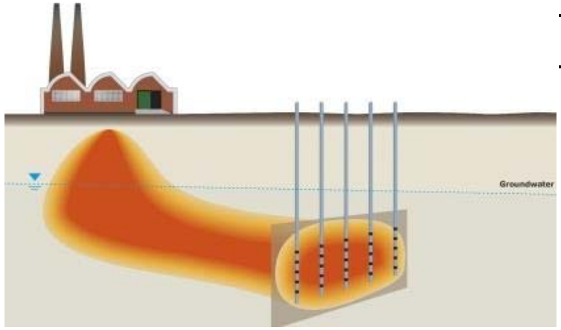


Communication of risk, uncertainty and contaminant mass discharge

- Communication of uncertainty and risk?
- How do we include uncertainty in risk assessment?
- Contaminant mass discharge or concentrations?
- Report contaminant mass discharge (and uncertainty) and concentration in point of compliance

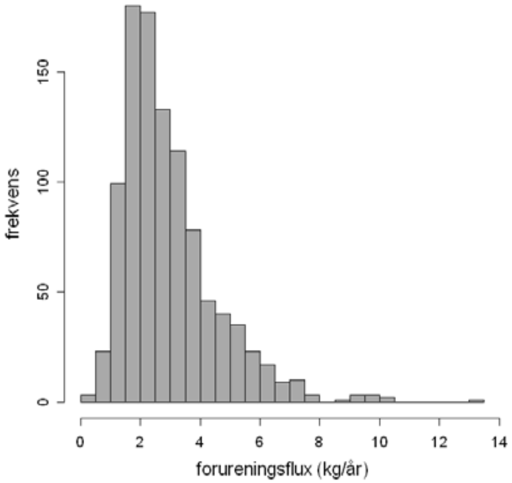
Summary

1. Contaminant mass discharge is a useful metri
   - Supplements concentrations in point of compliance
   - Hydraulic conductivity and gradient
   - Concentration field in control plane

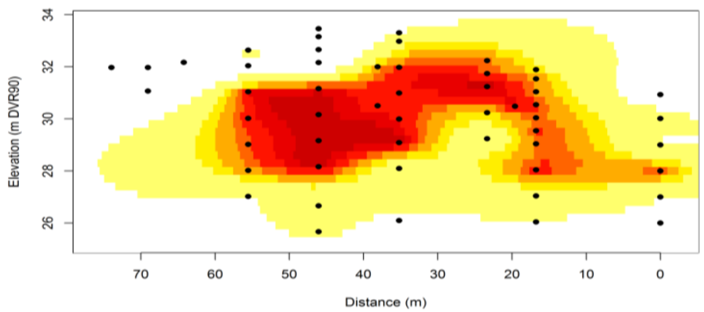


2. Challenges
   - Geological heterogeneity
   - Spatial variability in hydraulic conductivity
   - Steep concentration gradients

3. Innovative field methods
   - New methods for direct determination of contaminant mass discharge or velocity
   - Direct push techniques (conc. and hydraulic conductivity)
   - Hydraulic conductivities from geophysical data



4. Uncertainty
   - Reducing uncertainty by use of geophysical data
   - Sampling density and uncertainty



5. Future work
   - Uncertainty analysis
   - Fractured and heterogeneous media
   - Communication of uncertainty and ri

Acknowledgements

GEOCON

GEOlogical, geophysical and CONtaminant monitoring technologies for contaminated site investigation.

Research institutions

DTU

universitätbonn
Rheinische Friedrich-Wilhelms-Universität Bonn

AARHUS UNIVERSITET

LUND UNIVERSITY

GEUS

KU
THE UNIVERSITY OF KANSAS

Industry partners

ORBICON

Region Syddanmark

midt
regionmidtjylland

REGION H
The Capital Region of Denmark

InnovationsFonden
FORSKNING, TEKNOLOGI & VÆKST I DANMARK

Miljømini
Miljøstyre