**Nicole Workshop May 2011, Copenhagen**
***Operating windows for site characterisation***

# *Direct Push Technologies, Overview, Applications and Limits*


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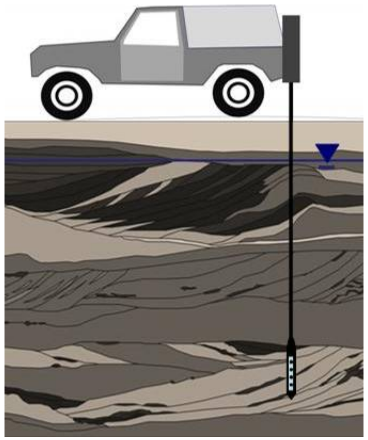
## Definition *Direct Push*



- Direct Push (DP) refers to a technology that consists of a (vehicle-mounted) **drive source** that is used for advancing **small-diameter stainless steel probes** into the subsurface
- The probes are advanced into the ground to take **depth-discrete** samples and measurements along a vertical axis
- Hereby, multiple samples or measurements can be taken in a single push to generate **vertical profiles** of subsurface information e.g. on hydraulic and geophysical parameters or contaminations



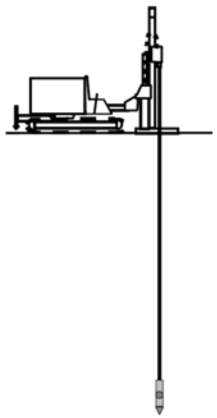
## Methods for advancing probe rods

**static pushing** | **pushing and percussion hammering**

(from: USGS fact sheet 028-03)

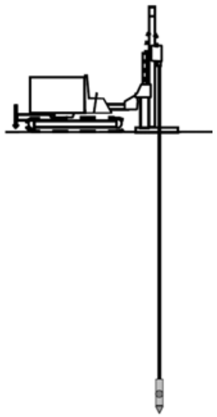



## Methods for advancing probe rods

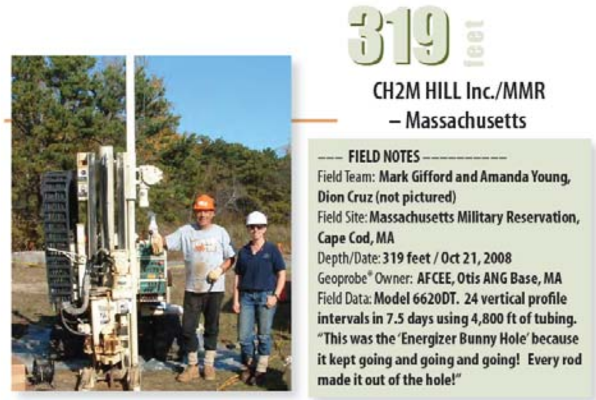

modified after Weiß (2007)

| | reactive mass | typ. probing depth | max. probing depth | mobility |
|---|---|---|---|---|
| **handheld hammer** | 14 – 40 kg | 2 – 5 m | 12 m | ++ |
| **hydraulic hammer on mobile platform** | 2.200 – 7.700 kg | 6 – 35 m | 75 m | + |
| **anchored hydraulic press** (static) | 90 – 18.000 kg | 6 – 35 m | 60 m | + |
| **truck with hydraulic press** (static) | 14.500 – 54.000 kg | 6 – 35 m | 100 m | o |

## Methods for advancing probe rods



modified after Weiß (2007)



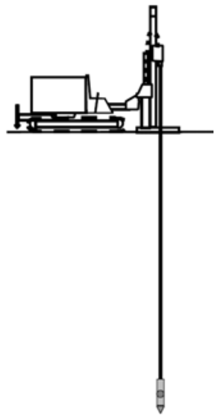

aus Probing Times (2009)

**319 ft = 97 m**

**1463 m in 7,5 days (*195 m per day!*)**



## Summary advancing probe rods



modified after Weiß (2007)

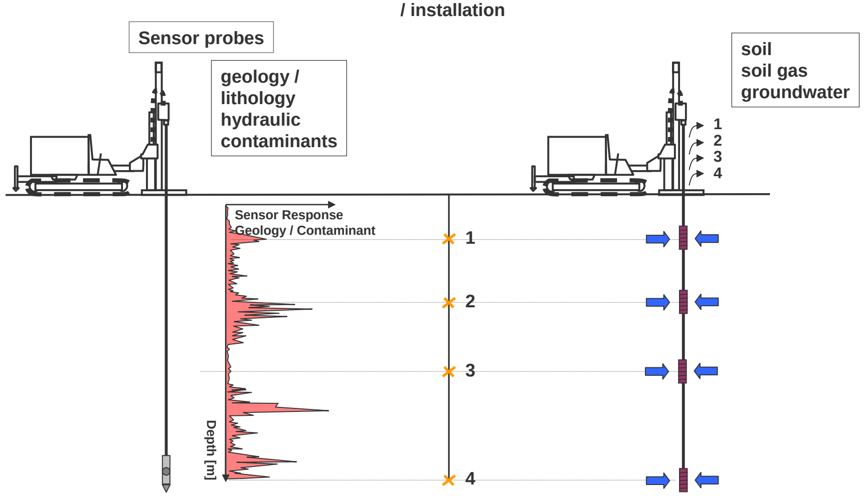
| | |
|---|---|
| **Probing depth** | 15 – 35 m<br>→ depending on subsurface conditions, probing diameter, abhängig von den Untergrundgegebenheiten, Sondier-durchmesser und Art der Sondiereinheit |
| **Probing diameter** | Outer diameter: max. 100 mm;<br>typically: 35-80 mm |
| **Time required for sounding to 15 m depth** | Simple soundings (e.g. EC-log):<br>***ca. 30 min***<br><br>Soundings for GW-sampling (5 depths):<br>***ca. 3 hours***<br><br>Installation 1"-piezometer:<br>***ca. 1 hour*** |
| **Size of probing unit** | From handheld to full size trucks<br>(> 30 tons) |

from Leven et al. (2010)



## Typical application of *Direct Push*

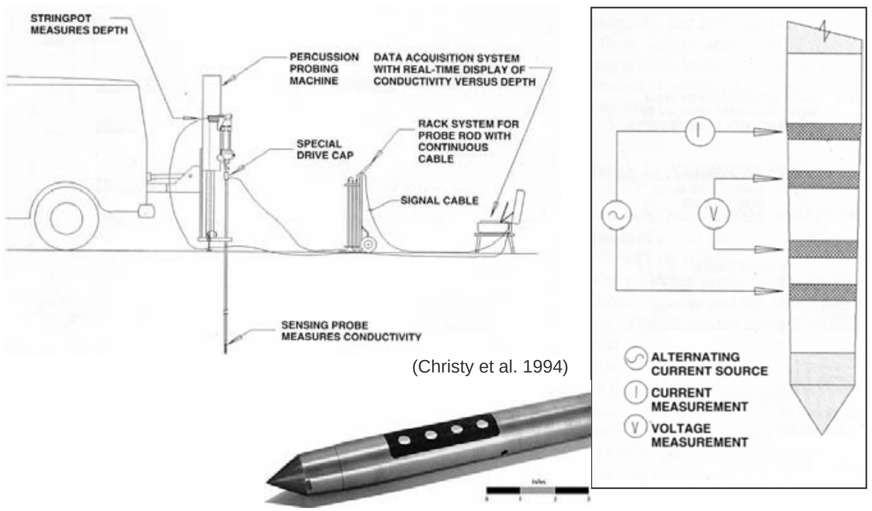
**Direct Push probing** ⇨ **Result of In situ measurement** ⇨ **On site desicion on location of sampling / installation** ⇨ **Sampling and / or installations**





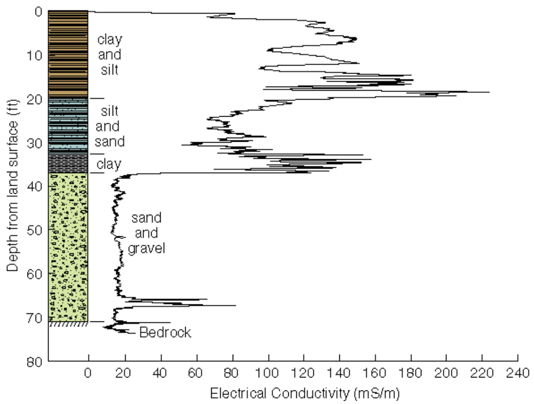

## In situ measurements (geology / lithology)

## ➔ EC-profiling (electronic conductivity)




(Christy et al. 1994)

## In situ measurements (geology / lithology)
### ➔ EC-profiling




(KGS Open-File Report 99-40)

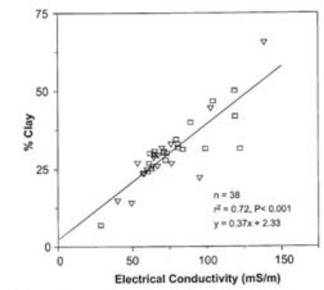
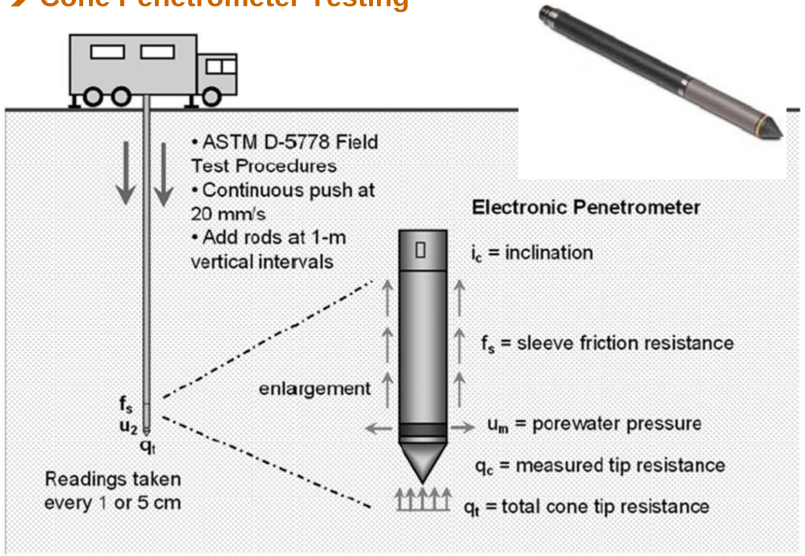



Figure 8. Percent clay and average EC values for samples from Core 1 (squares) and Core 2 (inverted triangles). Because EC data from the upper and lower 3 cm of sample interval reflect the transition between intervals, only those samples >6 cm in thickness were included in the regression. Similarly, EC data from the upper and lower 3 cm of a sample interval were not used to compute the average EC value for that interval.

(from: Schulmeister et al. 2002)



## In situ measurements (geology / lithology)
### ➔ Cone Penetrometer Testing




(from: NCHRP 2007)

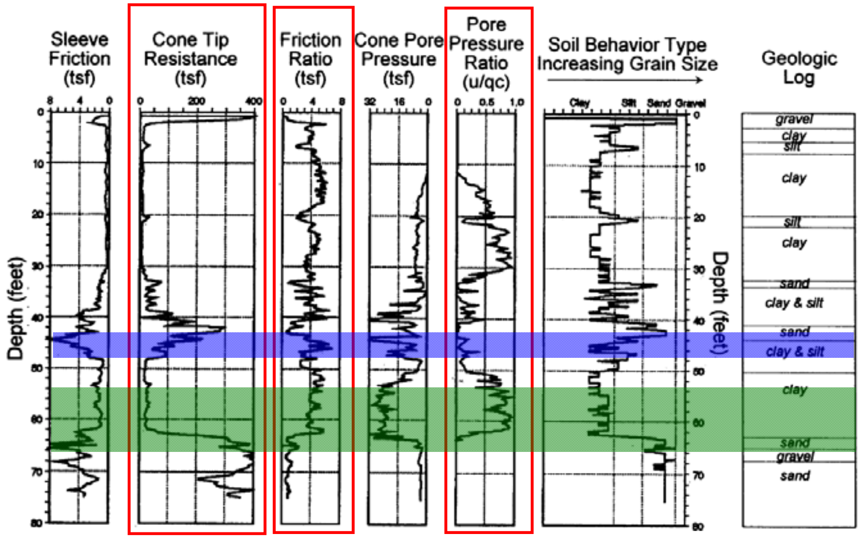


## In situ measurements (geology / lithology)
### ➔ Cone Penetrometer Testing

| Measured parameter | Derived parameter |
|---|---|
| Tip resistance $q_c$ | layering density |
| Sleeve friction $f_s$ | material / lithology |
| Pore pressure $u$ | consolidation, shear strenght |
| tilt $i$ ($x$ and $y$) | geotechnical risk |
| Rate of penetration | qualitity, vertical resolution |
| Probing depth | geotechnical risk |
| Total pressure | statics |
| Friction ratio $R_f = (f_s/q_c)$ | material, soil classification |



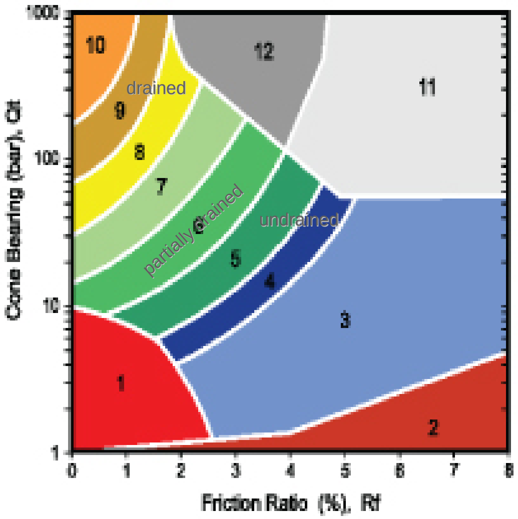
## In situ measurements (geology / lithology)
### ➔ Cone Penetrometer Testing




(Berzins, 1993)

## In situ measurements (geology / lithology)

### ➔ Cone Penetrometer Testing




| ZONE | SBT |
|---|---|
| 1 | Sensitive, fine grained |
| 2 | Organic materials |
| 3 | Clay |
| 4 | Silty clay to clay |
| 5 | Clayey silt to silty clay |
| 6 | Sandy silt to clayey silt |
| 7 | Silty sand to sandy silt |
| 8 | Sand to silty sand |
| 9 | Sand |
| 10 | Gravely sand to sand |
| 11 | Very stiff fine grained* |
| 12 | Sand to clayey sand* |

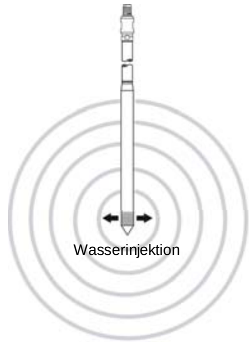
*over consolidated or cemented

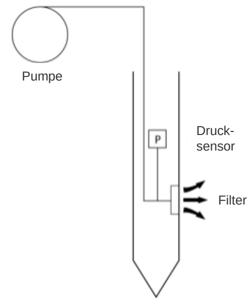
(after Robertson et al., 1986)

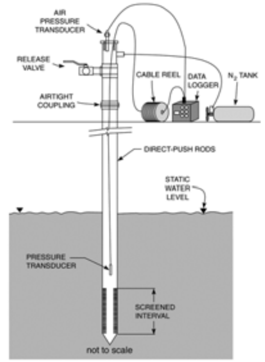


## In situ measurements (hydraulic conductivity)

### ➔ DP-IL, HPT, DPST



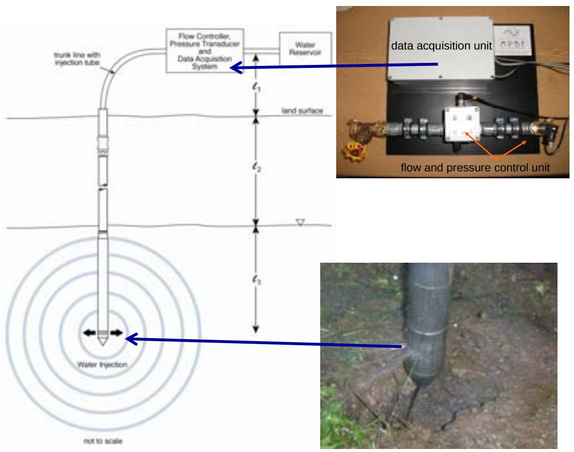

1. DP Injection logging (DPIL)
2. Hydraulic Profiling Tool (HPT)
3. DP slug test (DPST)

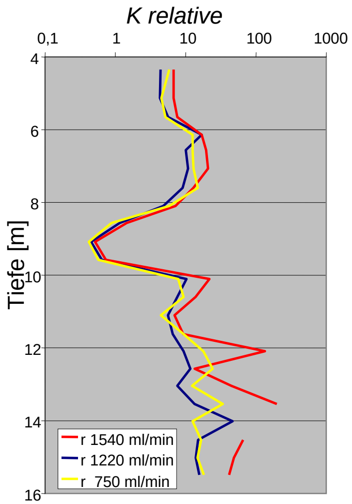


## In situ measurements (hydraulic conductivity)

### ➔ DP-Injection Logging (DP-IL)

➔ **relative K-values**




(Dietrich et al. 2008)



## In situ measurements (hydraulic conductivity)

### ➔ Hydraulic Profiling Tool (PD-HPT)

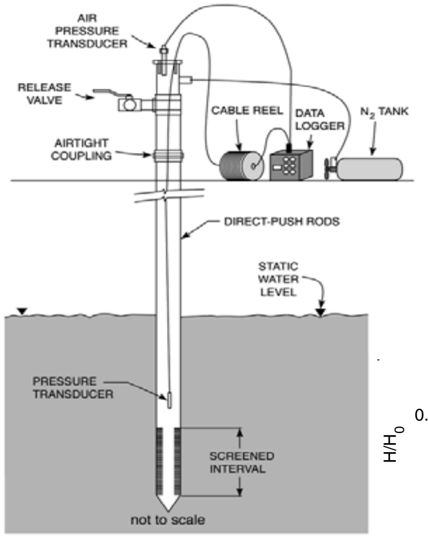
(comparable to DP-Injection Logging)

➔ **relative K-values**

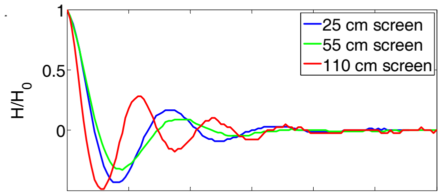
(Pictures by Geoprobe)

## In situ measurements (hydraulic conductivity)

## ➔ DP-Slug Test (DPST)



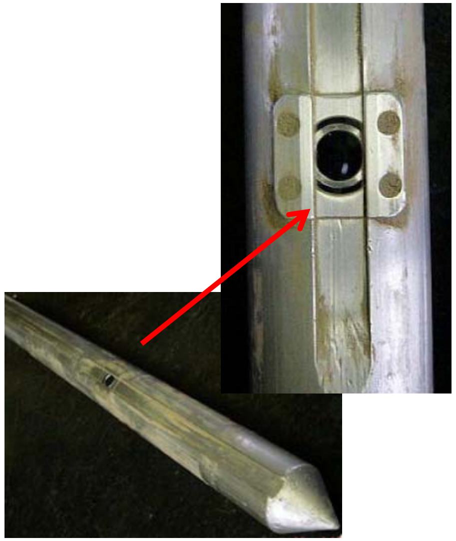

➔ real K-values

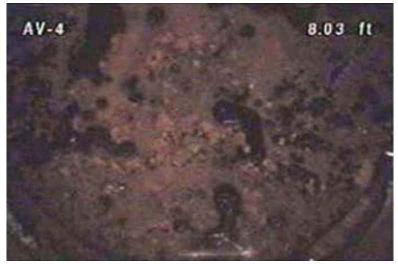





## In situ detection / images (contaminants)

## ➔ Video Cone




GeoDelft, GeoVisie

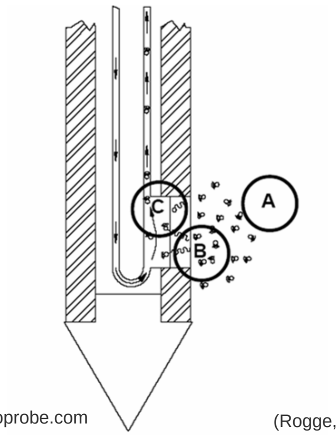
(Bratton, 2000)



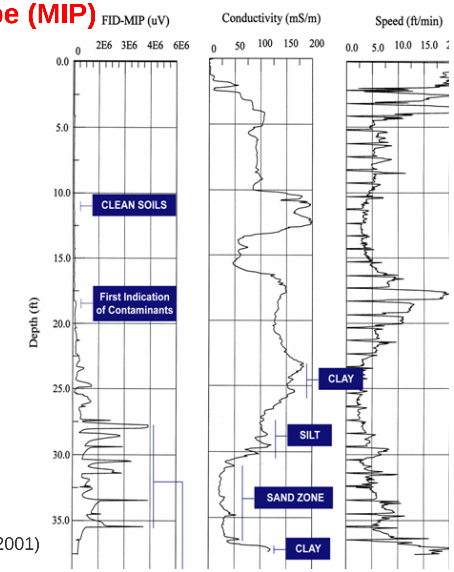
## In situ measurements (contaminants)

## ➔ Membrane Interface Probe (MIP)

➔ Qualitative screening for contaminants (CHC, BTEX)




www.geoprobe.com



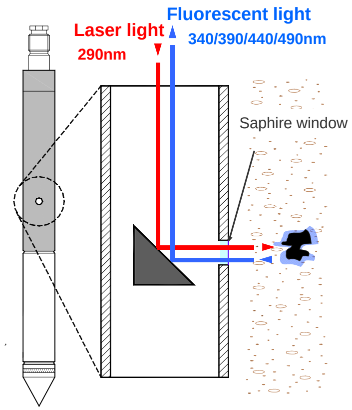

(Rogge, 2001)

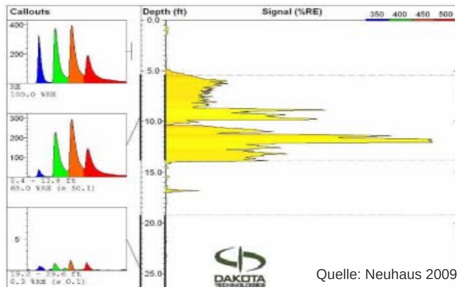


## In situ measurements (contaminants)

## ➔ Laser Induced Fluorescence (LIF)

➔ Qualitative screening for contaminants (BTEX, Hydrocarbons, PAH)



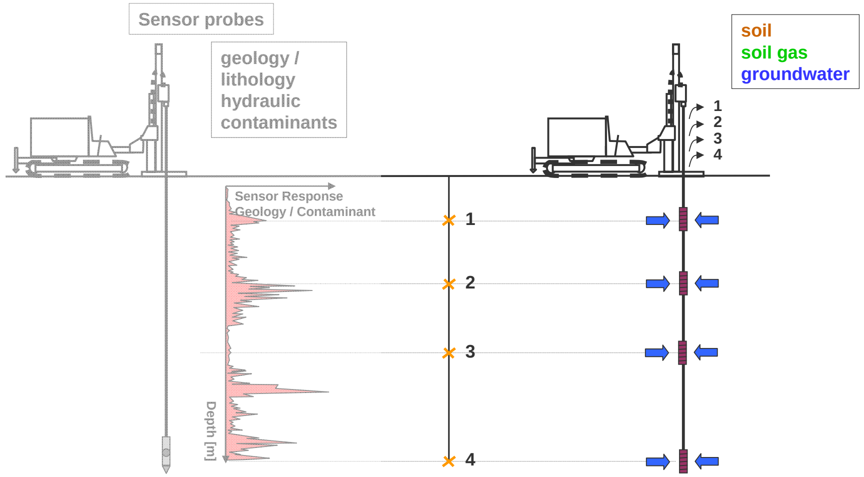




Quelle: Neuhaus 2009

- ROST™ Rapid Optical Scanning Tool
- TarGOST® Tar-specific Green Optical Screening Tool
- UVOST™ UltraViolet Optical Screening Tool

## More application of *Direct Push*

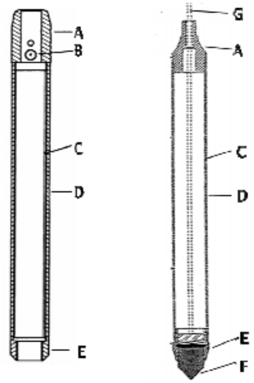
Direct Push probing ⇨ Result of In situ measurement ⇨ On site desicion on location of sampling / installation ⇨ **Sampling**






## Direct Push-based sampling methods
## ➔ Soil sampling

open sampler



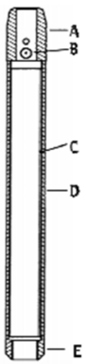

closed sampler

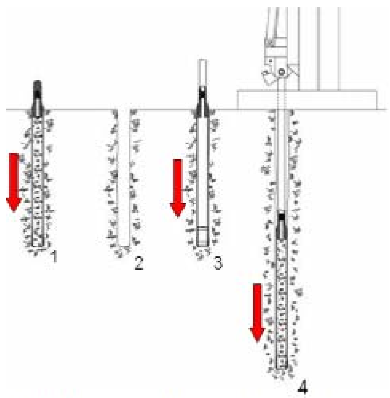
A: Gestängeanschluss
B: Rückschlagventil
C: Liner
D: Probenahmezylinder
E: Schneidschuh
F: Verschlusskolben
G: Hilfsgestänge

EPA 1997, ASTM 6282-98 (2005), modifiziert von S. Kögler, 2009



## Direct Push-based sampling methods
## ➔ Soil sampling with open samplers




A: Gestängeanschluss
B: Rückschlagventil
C: Liner
D: Probenahmezylinder
E: Schneidschuh

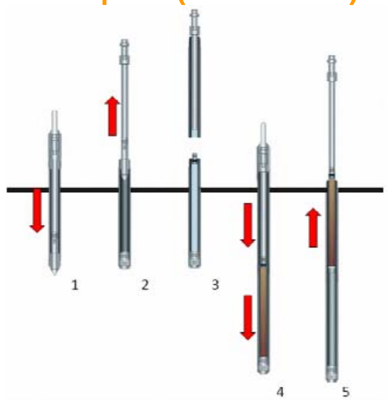
1: Probenahme des ersten Intervalls
2: Offenes Bohrloch des ersten Intervalls
3: Wieder Einbringen des offenen Bodenprobenehmers
4: Probenahme des nächsten Intervalls

www.amssamplers.com, modifiziert von S. Kögler, 2009



## Direct Push-based sampling methods
## ➔ Soil sampling with closed samplers (DUAL TUBE)

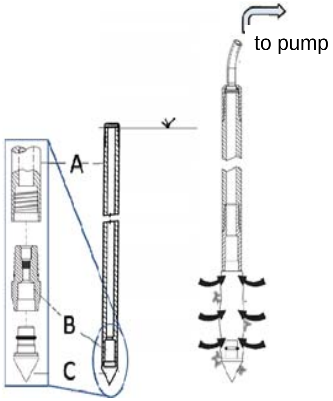
Geoprobe Dual Tube, ID: 32mm & 47mm

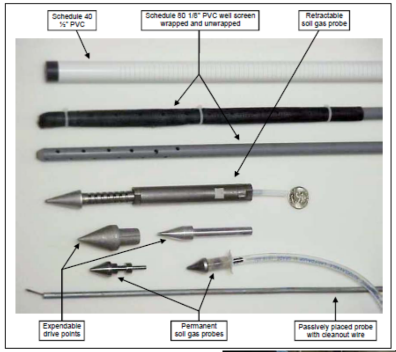



1: Vorsondieren bis in die gewünschte Zieltiefe
2: Entfernen von Verschlussspitze und Hilfsverrohrung
3: Einbringen des Liners, des Fängers und einer Hilfsverrohrung
4: Simultaner Vorschub von Außengestänge und Liner zur Probenahme
5: Entnahme der Bodenprobe durch Entfernen der Hilfsverrohrung und Herausnehmen des Liners mit der Bodenprobe

www.amssamplers.com, modifiziert von S. Kögler, 2009

## Direct Push-based sampling methods
### ➔ Soil gas sampling

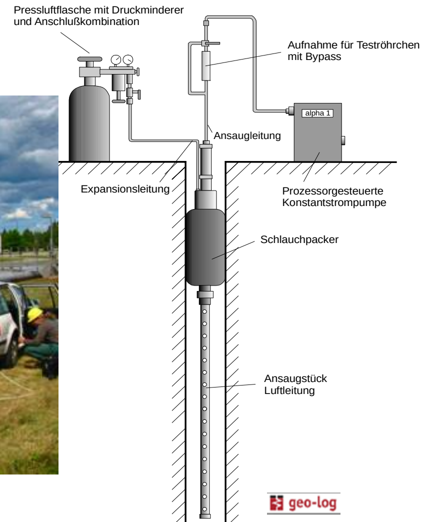



EPA (2006)



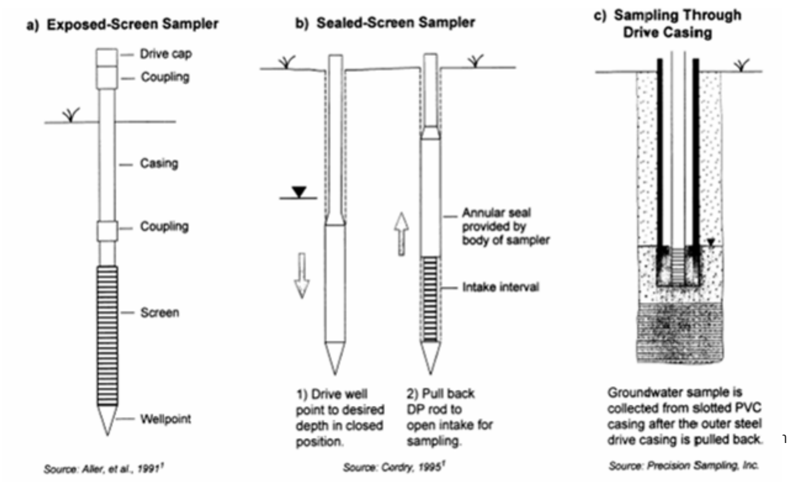
## Direct Push-based sampling methods
### ➔ Soil gas sampling using packer in open hole




## Direct Push-based sampling methods
### ➔ Groundwater sampling

EPA, 1997






## Direct Push-based sampling methods
### ➔ Groundwater sampling

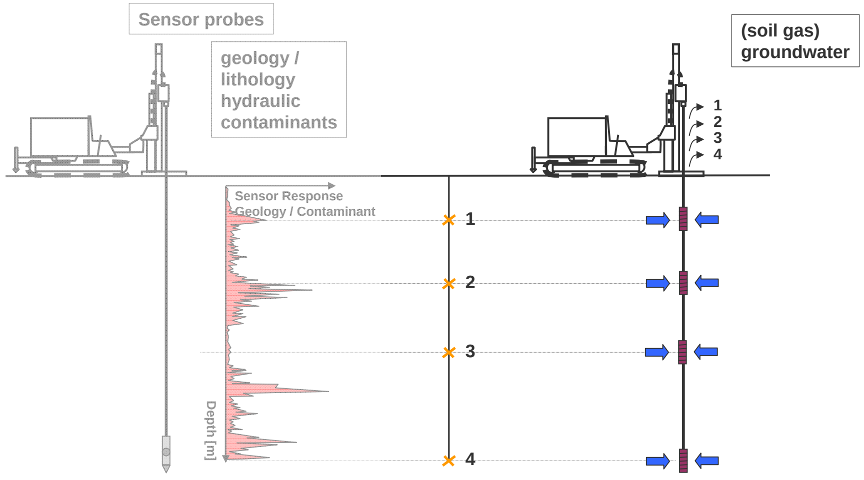


**Groundwater Profiler**

(from: US-EPA 542-R-04-017 (2004))

## More application of *Direct Push*

Direct Push probing ⇨ Result of In situ measurement ⇨ On site desicion on location of sampling / installation ⇨ **Installations**

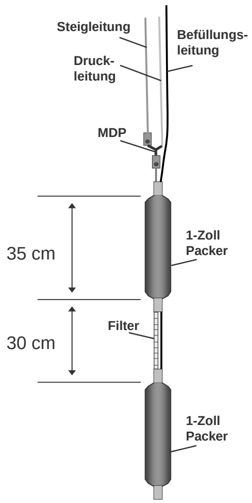


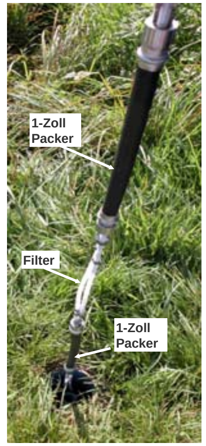



## Direct Push-based installations

## ➔ 1" / 2"-wells e.g. for sampling with double packer systems

ID: 2,5 cm






## Direct Push-based installations

## ➔ prepacked wells (screens and bentonite seals)


SonicSampDrill

Solinst



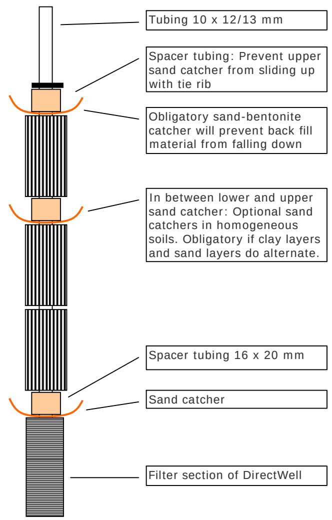
## Direct Push-based installations

## ➔ prepacked wells

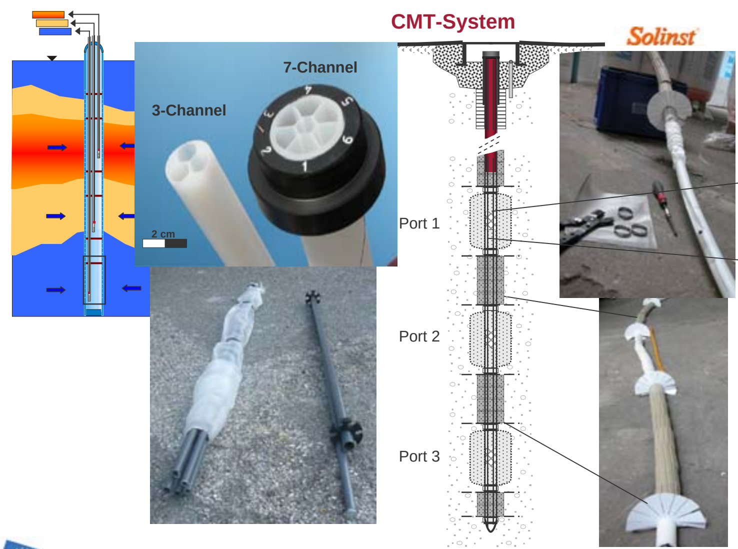

Direct Well

SonicSampDrill

Quality Well



## Direct Push-based installations
## ➔ Continous multi-channel tubing (CMT)



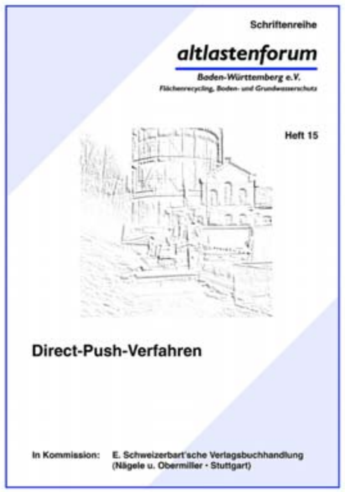

**3 canal CMT with prepacked screens and bentonite seals**



## Direct Push-based installations
## ➔ Continous multi-channel tubing (CMT)



## Direct Push references
## ➔ for more information




- Leven, C., H. Weiß, H.P. Koschitzky, P. Blum, T. Ptak, P. Dietrich (2010), **Direct-Push-Verfahren**, *36 pp., Schriftenreihe Altlastenforum Baden-Württemberg, Heft 15, Stuttgart*
- Dietrich, P., C. Leven (2006), **Direct push-technologies**, in *Groundwater geophysics. A tool for hydrogeology, edited by R. Kirsch, pp. 321-340, Springer, Berlin.*
- McCall, W., D. M. Nielsen, S. Farrington, T. M. Christy (2006), **Use of Direct-Push Technologies in Environmental Site Characterization and Ground-Water Monitoring**, in *Practical Handbook of Environmental Site Characterization and Ground-Water Monitoring, edited by D. M. Nielsen, CRS Press, Boca Raton.*
- and numerous publications by the US-EPA



## Application range

- suitable for acquisition of highly resolved information on
  - *geological / lithological setting*
  - *contamination situation*
  - *geotechnical, geophysical or hydraulic properties of the subsurface*
- unconsolidated sediments from clay to gravel, (reachable depth depends on „displacement potential“ of sediment)
- partly applicable in consolidated materials (e.g. clay stone, weathered sandstones)
- unknown conditions may require test probing

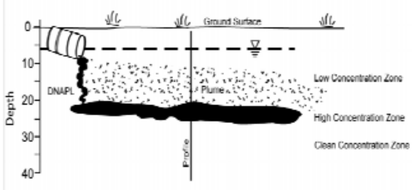
## Application range

- classic application:
  - *geotechnical investigations*
  - *contaminant site invesitgation*
- „new“ application window:
  - *groundwater monitoring in the frame of the EU Water Framework Directive*
  - *Investigation of surface-groundwater-interaction*
  - *mass flux estimation*
  - *dam and levee investigation*
  - *…*



## Limitations

- samples are only point measurements in space and time
  → *typically no repeated measurements are possible at the same location (except of installations)*
- many of the indirect measurements need calibration at conventional drillings or require soil sampling
- danger of cross-contamination
  *(which is the case for all invasive methods)*
  - *during probing*
  - *through open probing channel*
  - *by the use of contaminated equipment (high probing speed can lead to negligence in decontamination)*




aus US-EPA (1997)

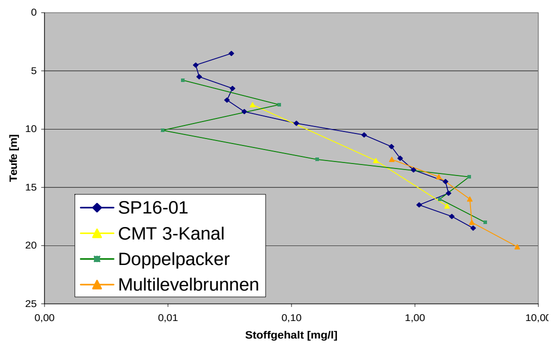


## Limitations

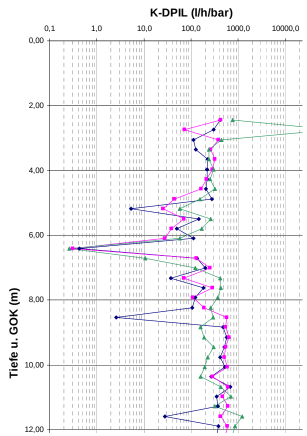
- **Acceptance of legal authorities has to be assured** (e.g. for what purpose will the data be collected → “court proof”)
- **Representativeness and reproducibility** of sampling / data acquisition must be assured (which is true for every investigation method)
  - ➢samples / data must reflect the lithological, physical and / or chemical conditions at the investigated point
  - ➢samples / data must be representative for
    - the in situ conditions,
    - the investigation volume,
    - the time of sampling / measurement
  - ➢sampling / data must be reproducible and repeatable



## Representativeness / Reproducibility




DP Injection logging



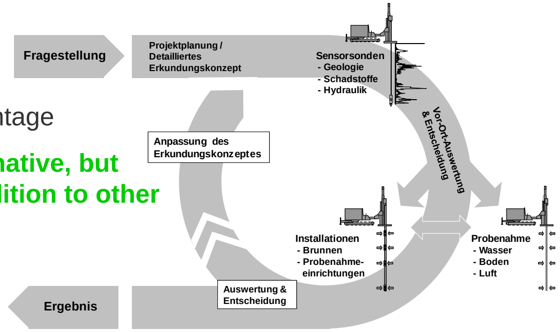
## Direct Push technologies: Advantages

- Direct Push systems are faster and more flexible than traditional drilling methods
  → fast sampling und data acquisition,
  → number of points is maximized with a given time and monetary budget
  → very flexible and mobile equipment
- with Direct Push no cuttings are generated
  → no contaminated soil material has to be disposed
  → cost reduction
  → effects along probing channel are minimized
- changes of in situ conditions (e.g. geochemistry) is minimized
- fast and efficient installations
- variety of different sensors and sampling equipment are available
- sampling equipment can be placed in situ



## Conclusions

- Adaption of applied technique to investigation objective
- Adaption of investigation plan to (unexpected) new measurement results is possible → **dynamic workplan**
- very often the combination with other (classical) methods is an advantage
- **DP can be an alternative, but „only“ a useful addition to other**




aus Leven et al. (2010)