



Basics of LIF Technology: ROST/ UVOST/ TarGOST - Technology and Applications

Dr. Markus Hirsch - Fugro Consult GmbH - Department In-Situ Technologies

- **In-Situ direct sensing technology/ available cones**
- **CPT equipment for use in combination with LIF**
- **Introduction to the basic concepts of the LIF technology**
- **Applications and benefits for the client**
- **Markets and rates**
- **Case study: Crude oil spill Gronau**
- **Summary**

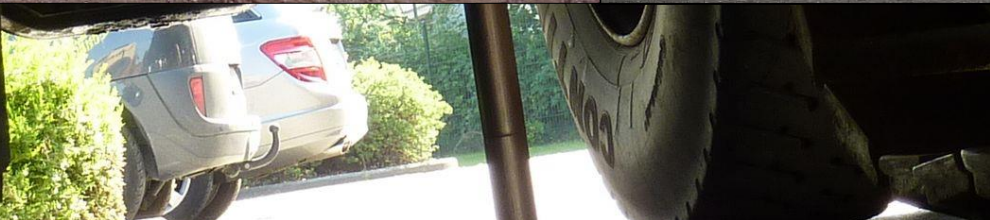
In-Situ Direct Sensing Technologies toolbox

- MIP (Membrane Interface Probe) - used for VOC detection (CHC, BTEX)
- CPT (Cone Penetration Test) and EC (Electrical Conductivity) - used for lithology and soil type investigation
- HPT (Hydraulic Profiling Tool) - used for continuous investigation of relative hydraulic conductivity
- In-Situ Slug-Testing - used for determination of absolute K-values
- Now available: XRF (X-Ray Fluorescence) - used for heavy metal detection
- LIF (Laser Induced Fluorescence e.g. ROST, UVOST, TarGOST) - used for Hydrocarbon-NAPL detection (fuels, oils, tars, etc.)

Combining CPT and LIF – Facts

- LIF-systems are developed by Dakota Technologies (DTI), in cooperation with Fugro with the target of in-situ and realtime screening of contaminants in soil and groundwater
- LIF-cones can be combined with all standard Fugro CPT-equipment worldwide (CPT-trucks, - crawlers, -mini-crawlers, -stand-alones, -seabed units)
- LIF-cone is mounted between CPT-cone (15 cm² digital cone) and standard CPT-rods (36 mm)
- LIF signals are transferred through fiber optical cables which are running inside CPT-rods
- Setting up at fieldsite takes about 1 to 2 hours (depending on target probing depth)
- No soil cuttings → no exposition to contaminated soil or groundwater
- Data acquisition and display in realtime with a resolution of ~2 cm

CPT rigs for LIF use





20t-Minicrawler



Stand-Alone-CPT-Rig (15 t)



GEOPROBE 6610DT

Mobile Static (☺) and Dynamic (☹) Direct Push Rigs

Minicrawler & Stand-Alone-CPT-Rigs



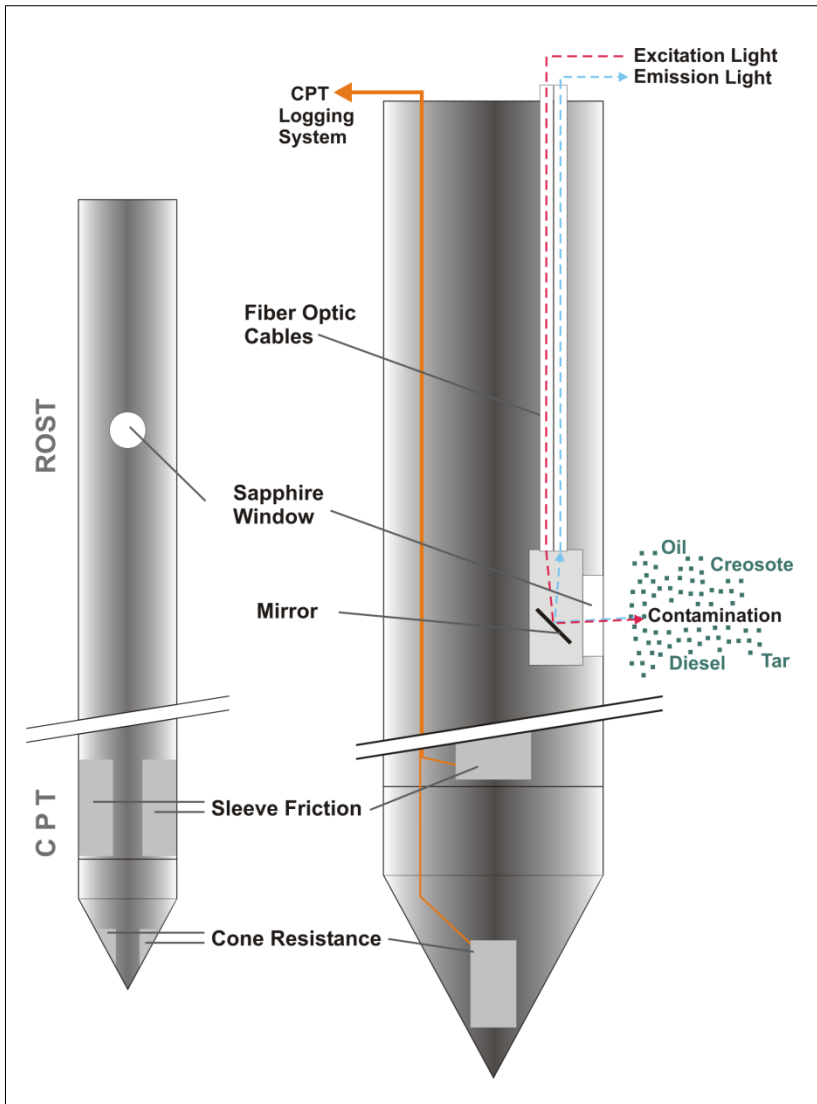
Combining CPT and LIF – What's the benefit?

- **Benefits:**
 - **Added value by combining LIF and CPT technology**
 - **CPT-data quality is not influenced by LIF data acquisition**
 - **In case further geotechnical investigation should be conducted, e.g. by drilling considerable reduction of Health & Safety measures (time & costs)**
 - **Reduction of mobilization costs**
 - **Faster completion of site investigations at lower costs compared to conventional methods**
 - **Adaptive site investigation allows for effective use of project budget**
 - **In case of contaminant mix: use of LIF in combination with other direct-sensing cones (MIP, HPT, XRF)**

Laser Induced Fluorescence CPT - Technology

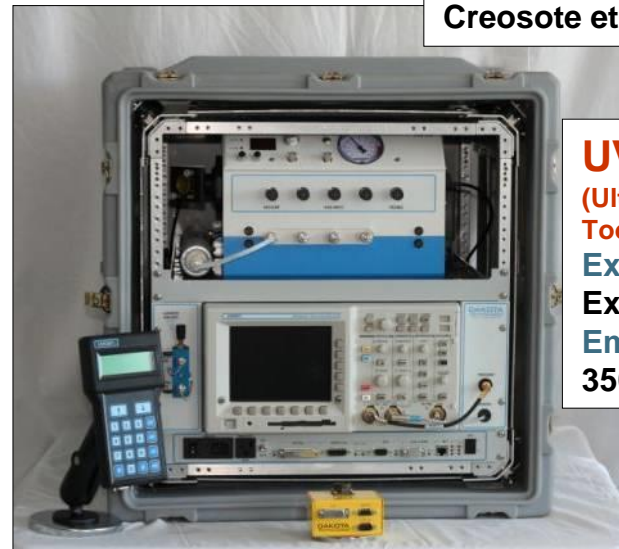
- Semi-quantitative detection of hydrocarbons like fuels, crude oil and tar products in both vadose (unsaturated & capillary fringe) and saturated zone
- Simultaneous logging of geological and chemical subsurface properties
- Digital data recording – realtime results
- Waveform product identification
- 2-D and 3-D representation of data: delineation of source and plume areas – supports on-site decision-making

Laser Induced Fluorescence CPT - Technology



ROST™
(Rapid Optical Screening Tool)
Nd-YAG-Laser/Dye-Laser
Excitation 290 nm
Emission Wavelengths
340 - 390 - 440 - 490 nm

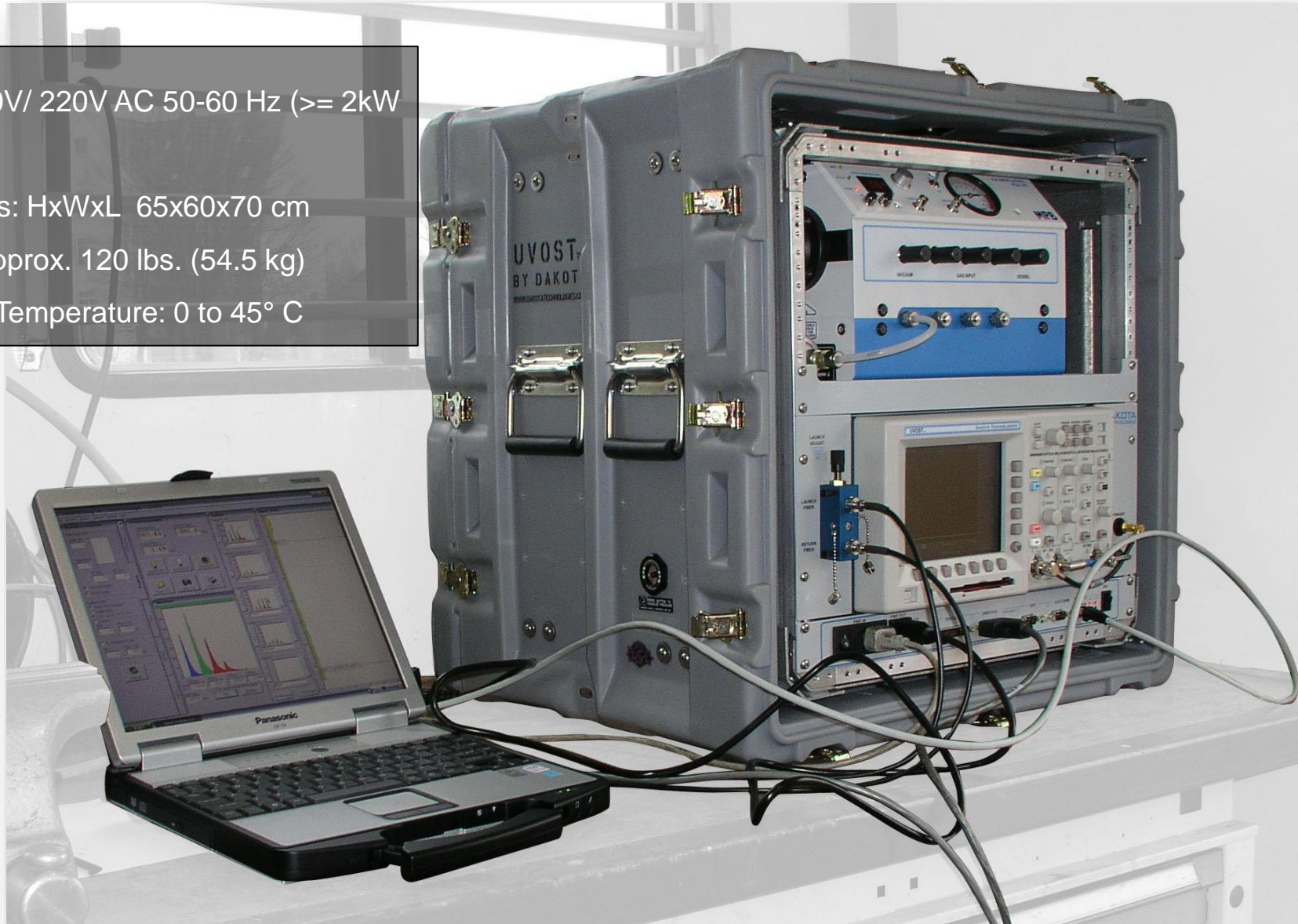
TarGOST™
(Tar-Specific Green Optical Screening Tool)
Green laser especially and solely
designed for Tar DNAPL (Coal Tar,
Creosote etc.)



UVOST™
(UltraViolet Optical Screening
Tool)
Excimer Laser
Excitation 308 nm
Emission Wavelengths
350 - 400 - 450 - 500 nm

UVOST/ TarGOST System Characteristics

- Power: 110V/ 220V AC 50-60 Hz (≥ 2 kW generator)
- Dimensions: HxWxL 65x60x70 cm
- Weight : Approx. 120 lbs. (54.5 kg)
- Operating Temperature: 0 to 45° C

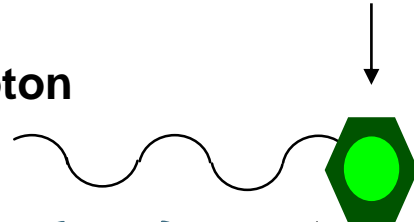




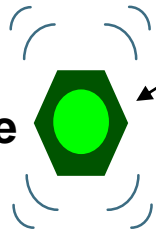
Fluorescence Process at PAHs (Polycyclic Aromatic Hydrocarbons)

ground state PAH molecule 

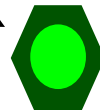
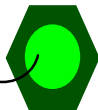
molecule absorbs photon



excited state

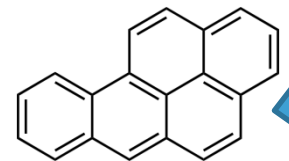


or

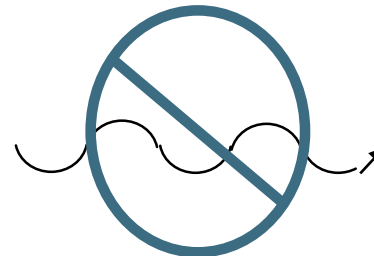


fluorescence

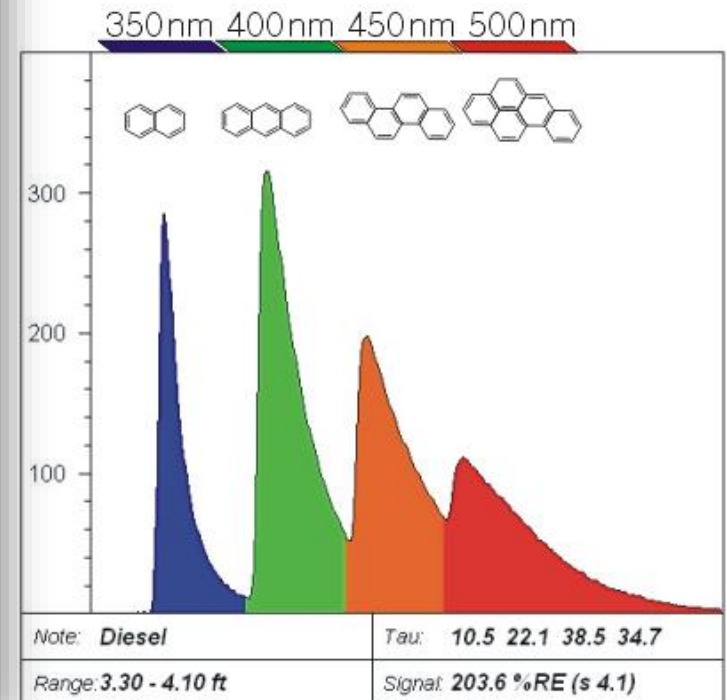
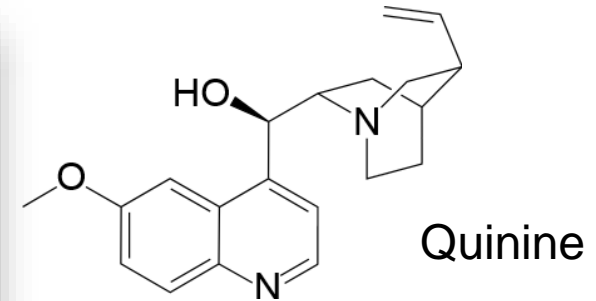
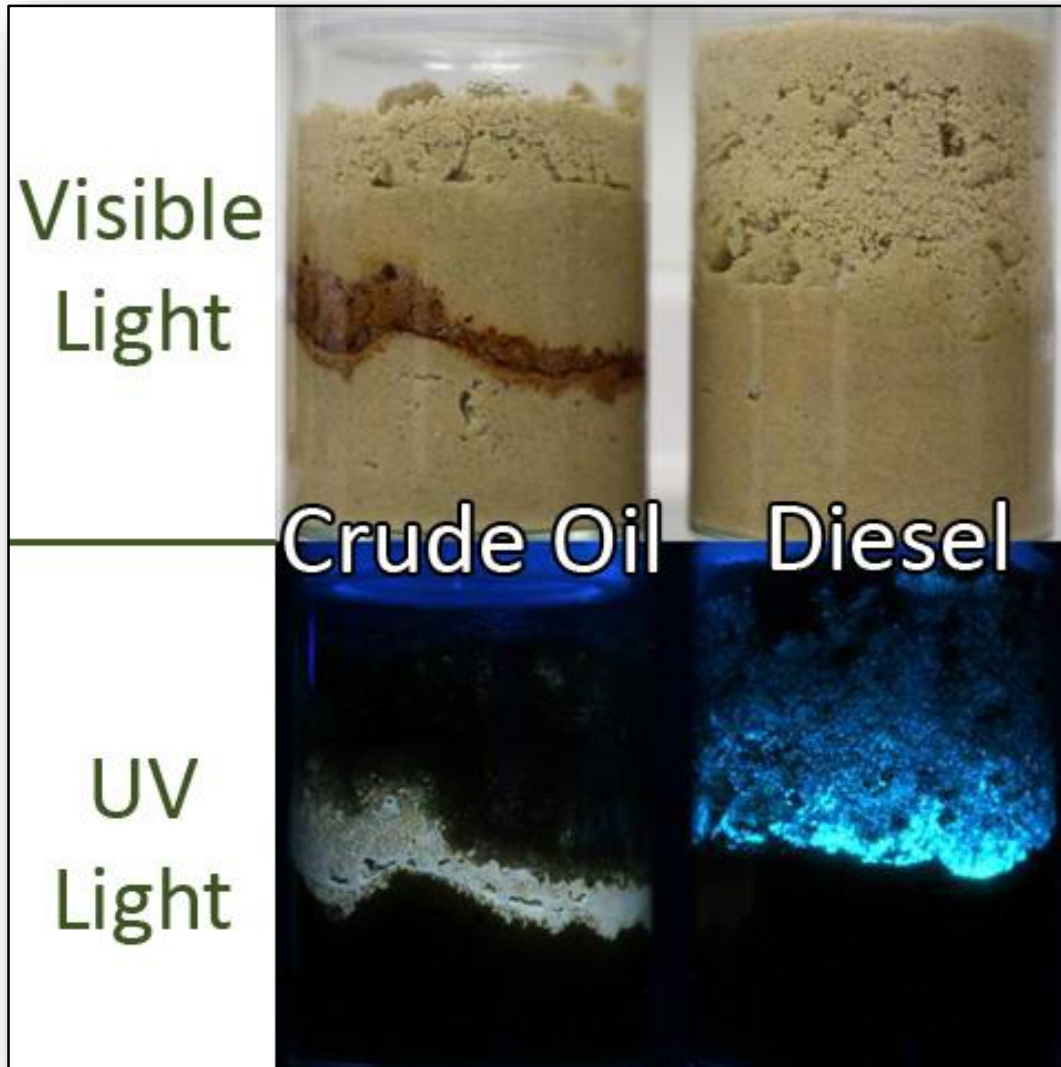
- Organic compounds containing only carbon and hydrogen composed in multiple aromatic rings
- PAHs are naturally occurring and found in fossil fuels (oil, coal and tar)
- They are produced when insufficient oxygen or other factors result in incomplete combustion of organic matter (e.g. in engines and incinerators, when biomass burns in forest fires, etc.).



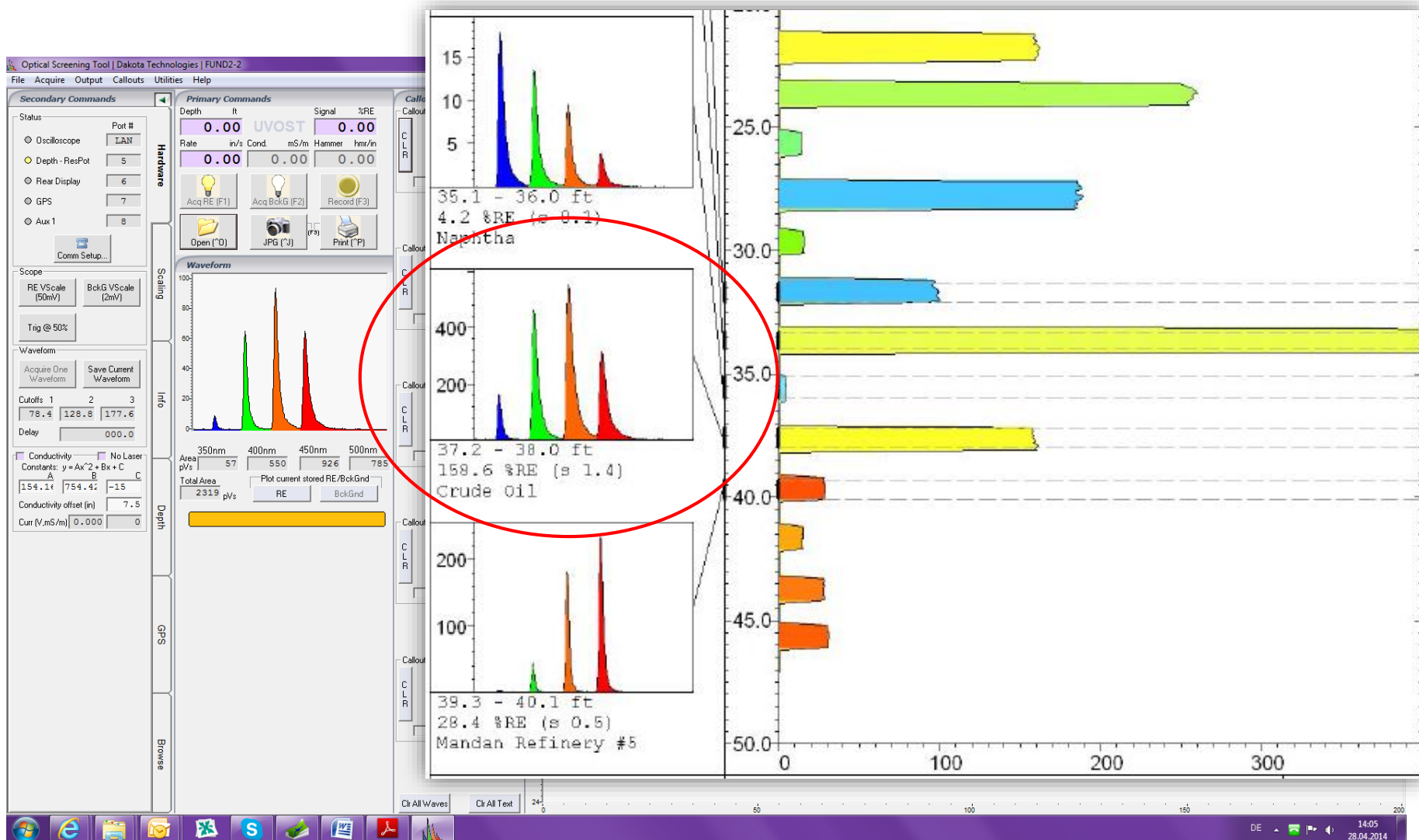
Benzopyrene
(contained in Coal Tar)



Example: Fluorescence in Tonic Water and Diesel



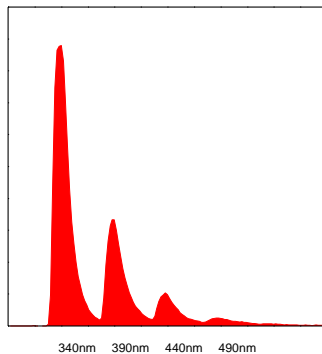
Laser Induced Fluorescence (LIF)



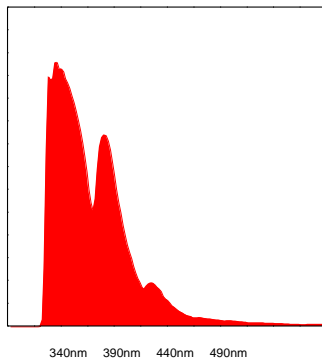
Laser Induced Fluorescence - typical waveforms “fingerprints”



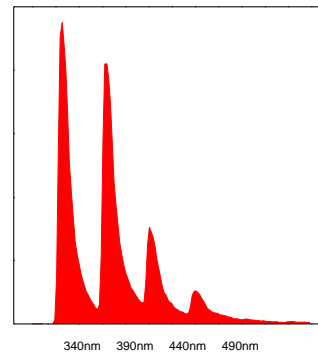
WAVELENGTH DISTRIBUTION
PETROL



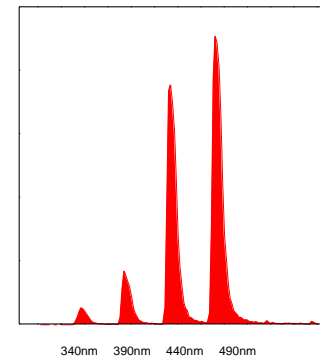
WAVELENGTH DISTRIBUTION
KEROSENE



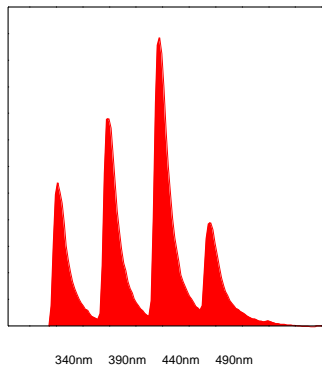
WAVELENGTH DISTRIBUTION
HYDRAULIC OIL



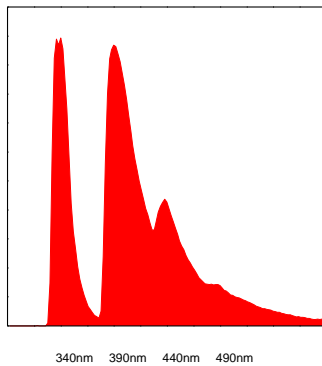
WAVELENGTH DISTRIBUTION
TAR



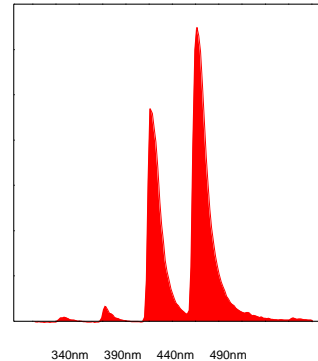
WAVELENGTH DISTRIBUTION
TURPENTINE



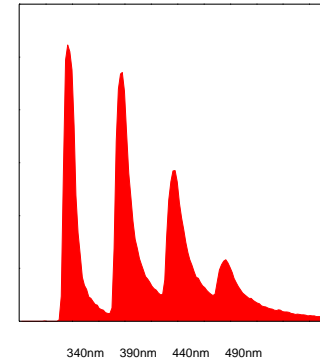
WAVELENGTH DISTRIBUTION
DIESEL



WAVELENGTH DISTRIBUTION
CREOSOTE



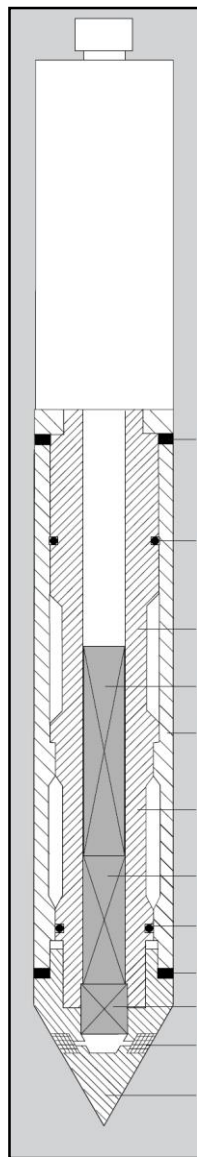
WAVELENGTH DISTRIBUTION
OIL



Laser Induced Fluorescence (LIF)

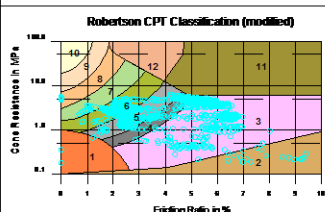
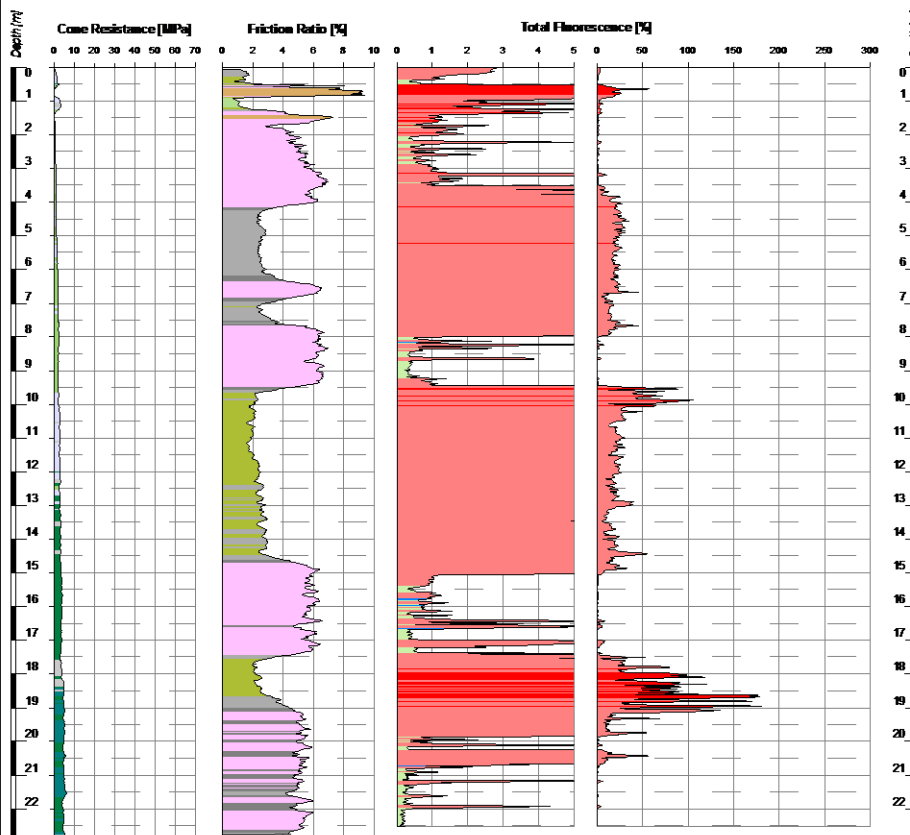


Results



Vertical Scale 1:150 (DIN A4)

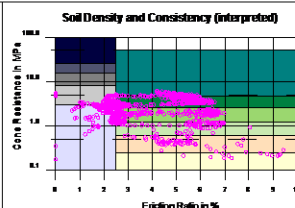
Fund2/2



Legend (Colors in Friction Ratio Profile)

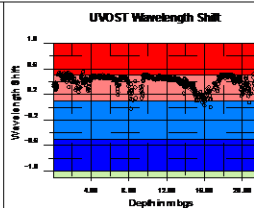
- 1 sensitive, fine grained
- 2 organic soils, PEAT
- 3 CLAY
- 4 CLAY to silty CLAY
- 5 clayey SILT to silty CLAY
- 6 sandy SILT to clayey SILT
- 7 silty SAND to sandy SILT
- 8 SAND to silty SAND
- 9 coarse to medium SAND
- 10 GRAVEL to gravelly SAND
- 11 very stiff, fine grained
- 12 very stiff SAND to clayey SAND

Soil types 11 and 12 are heavily overconsolidated or cemented.



Legend (Colors in Cone Resistance Profile)

- | | |
|--------------|------------|
| very loose | very soft |
| loose | soft |
| medium dense | firm |
| dense | stiff |
| very dense | very stiff |
| | hard |



Legend (Colors in Total Fluorescence Profile)

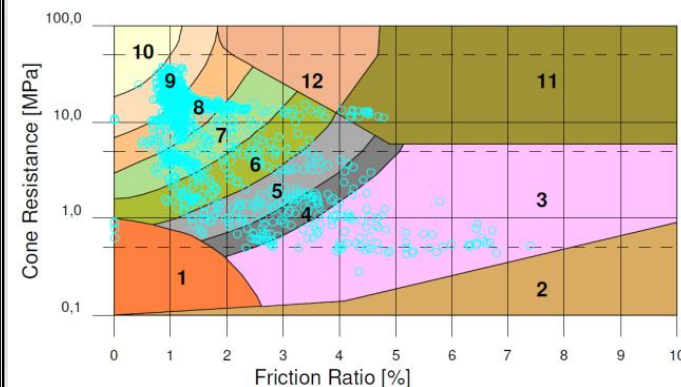
- | |
|-----------------------------|
| background or miscellaneous |
| heavy fraction |
| medium to heavy fraction |
| medium to light fraction |
| light fraction |

Project: 510-14-044 LIF-CPT Geomax Epe
 Test Location: Fund2/2
 Client: SCW X-Coord.: 2567928.1
 Contractor: Fugro Consult GmbH Y-Coord.: 5781472.8
 Processed by: JD Elevation: 44.90 m a.s.l.
 Test Date: 21.04.2014 Depth (CPT): 22.87 m bgs

FUGRO
 Fugro Consult GmbH
 In-Situ Technologies
 Burgwedel | Braunschw. | Mönchengladbach



Robertson CPT Soil Classification (modified)



Legend

(Colors in Friction Ratio Profile)

- 1 Sensitive, fine grained
- 2 Organic soils, peat
- 3 Clay
- 4 Clay to silty 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 Coarse to medium sand
- 10 Gravel to gravelly sand
- 11 Very stiff, fine grained
- 12 Very stiff sand to clayey sand

Soil types 11 and 12 are heavily overconsolidated or cemented.

Laser Induced Fluorescence (LIF)

LIF can detect:

- Gasoline
- Diesel
- Jet Fuel
- Motor Oil
- Hydraulic and Cutting Fluids
- Crude oil
- Coal Tar
- Creosote and phenols

But will not detect:

- Chlorinated solvents
- Dissolved phase PAHs

■ Markets – Typical sites where LIF-CPT is applied

- Refineries
- Chemical plants
- Oil terminals
- Wood treatment plants (creosote)
- Gas-stations/ storage stations/ tank farms
- Manufactured gas plants (MGPs)
- Airbases/ Airports
- Power plants
- Pipeline networks
- Filling stations
- Railroad

■ Rates

- Mobilization of LIF-CPT equipment and operators: ~ k€ 1.0 to 2.0 depending on location
- Daily rate: ~k€ 3.0 to 4.0 (depending on project scope and location): production:~ 150 m/day
- H&S measures strongly depending on site conditions. Usually fairly low, use of standard Fugro PPE sufficient

Case Study

Application of LIF Technology

Crude Oil Spill Gronau, Germany

Oil and gas reserves in Germany

- Crude oil is stored as energy reserve in large subsurface caverns since 1978
- German oil reserve amounts to 13,4 Mio t (value of 11 bn. €, at US \$ 70/barrel)
- Oil reserves last for 90 days at Germany's current energy consumption
- Storage caverns have been generated by solution mining (flushing) subsurface salt deposits
- Several cavern locations in Germany:
Gronau-Epe: 3 oil storage caverns, 73 Gas storage caverns



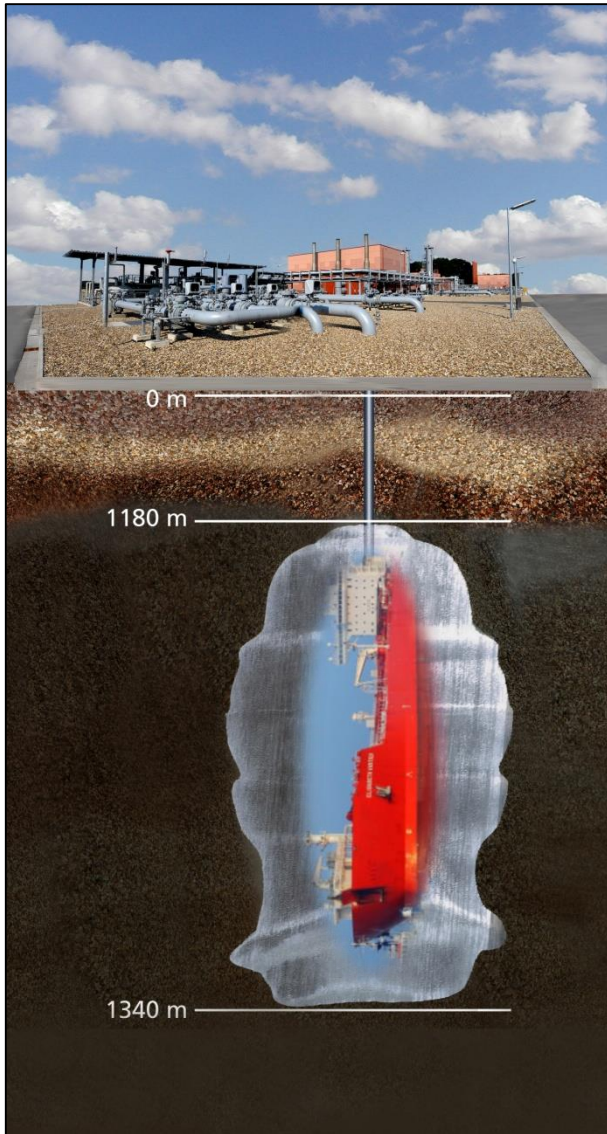
Cavern storage Gronau-Epe

Erdgas
Porenspeicher
● in Betrieb ● in Planung oder Bau
Kavernenspeicher
■ in Betrieb ■ in Planung oder Bau

Rohöl, Mineralprodukte,
Flüssiggas
Kavernenspeicher
■ in Betrieb

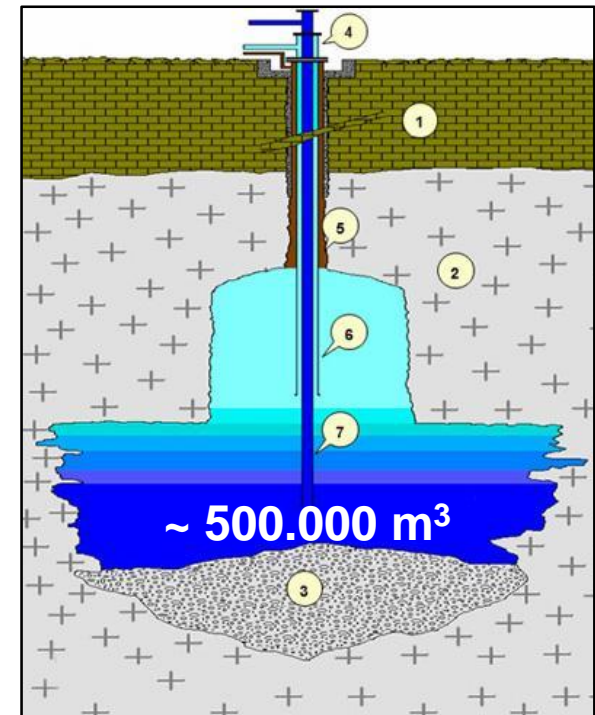
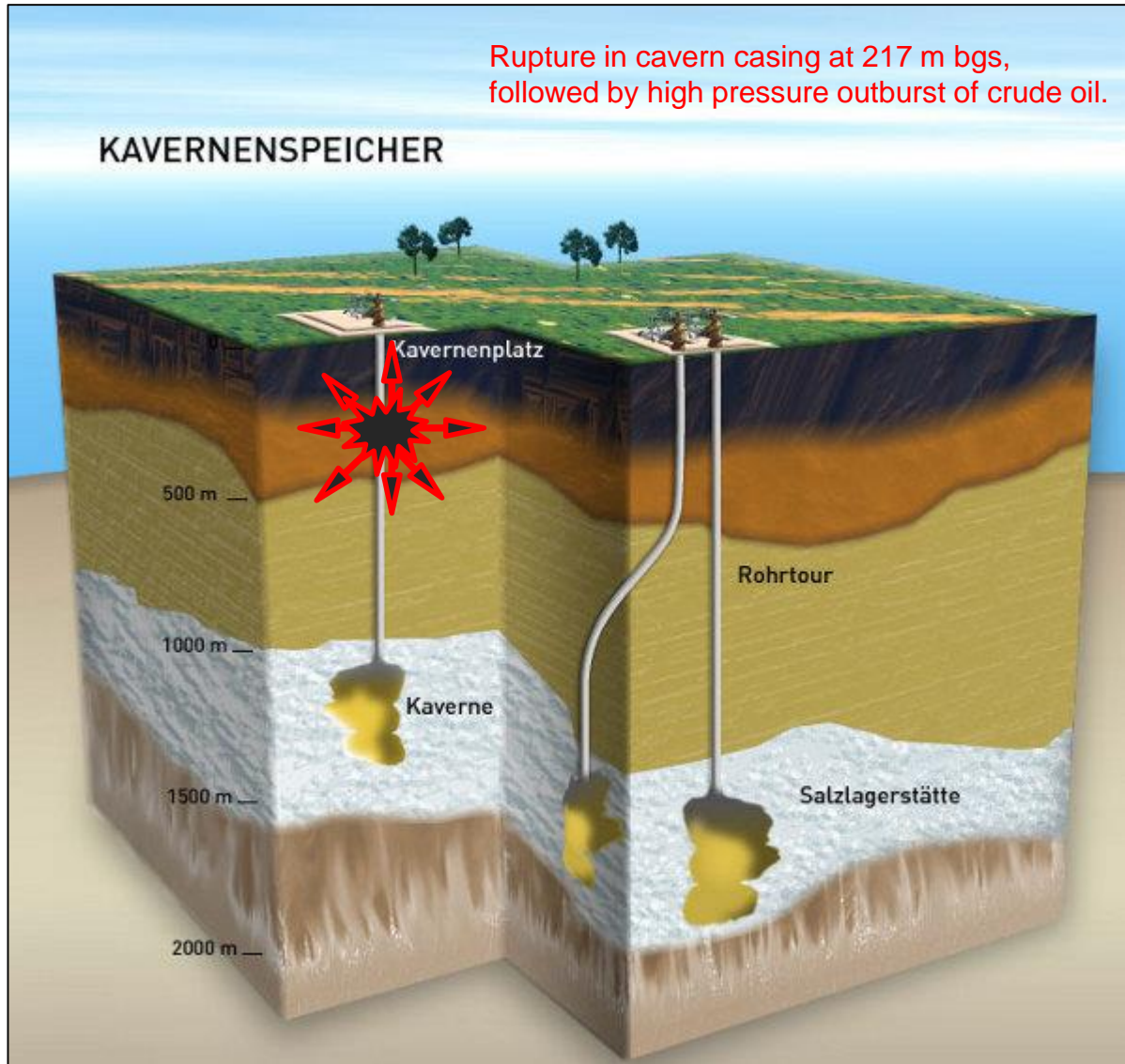
(Quelle: LBEG, 2010)

How much oil is in there?



Typical oil-tanker: 400.000 GRT (gross registered tons)
= 470.000 m³ = 470 mio liters

Cavern storage structure



1. Intercalated rocks
2. Salt-rock mass
3. Interbedded insolubles
4. Well head
5. Blanket oil (light ship oil)
6. Water injection string (pipe)
7. Brine delivery string (pipe)

Location of storage caverns and first oil spills



Oil spills on meadows and in the woods



Fugro parking lot Gronau



Di., 02.09.2014

Westfälische Nachrichten

► ANZEIGE AUFGEBEN

ichten

► ANZEIGE AUFGEBEN

DS FREIZEIT WELT WN-AKTION

STA

KRE

Start

Mo., 2

Sp

Emp

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Anzeige

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Mehr

Unter

Be



Zusammengefasst: Hinweise auf

Von Frank Polke und Martin Borck

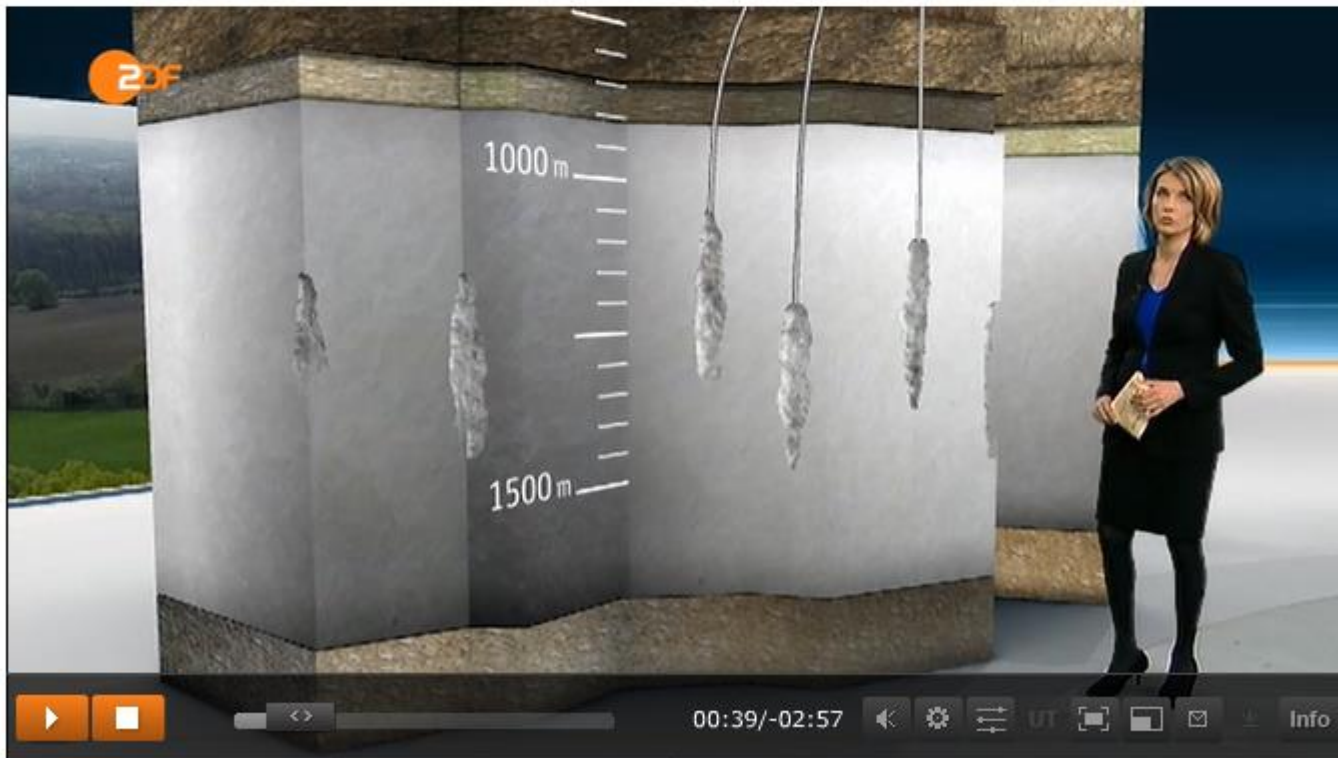
jetzt im Fokus

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Münsterland

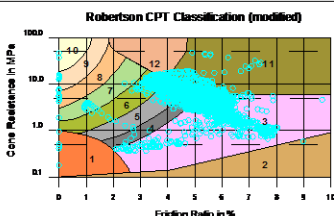
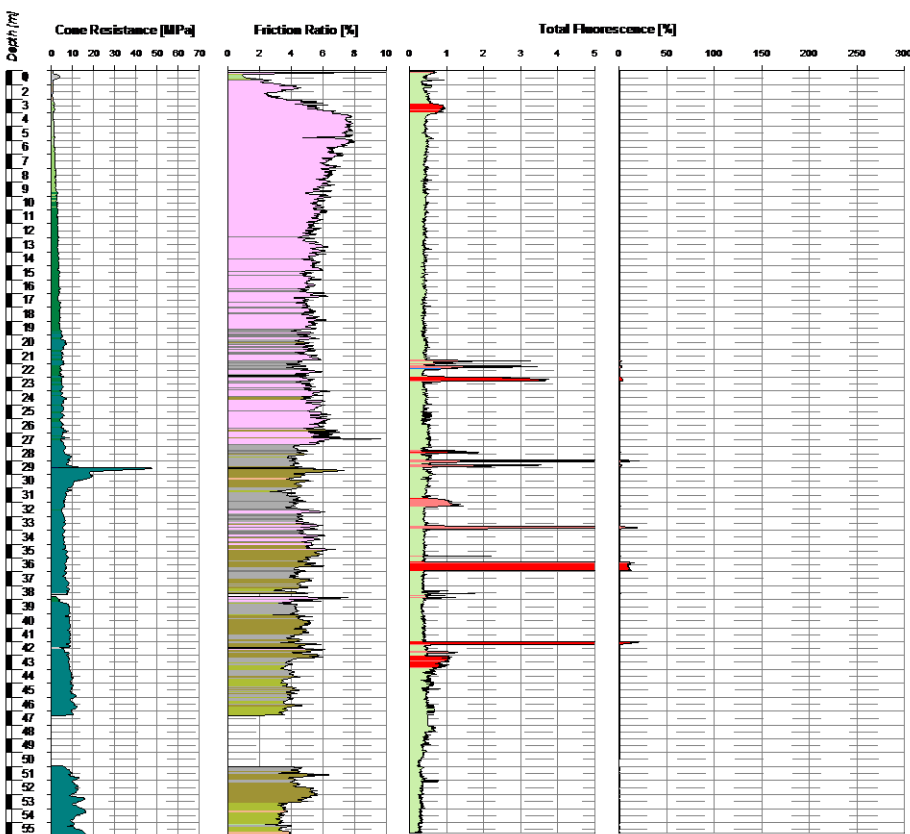


Umweltskandal: Ölpest im Natur-Idyll



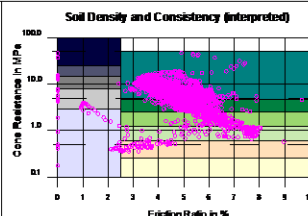
Video Ölpest im Natur-
Idyll

Video Münsterland:
Ölleck im Boden



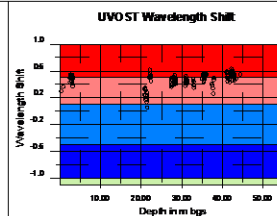
Legend (Colors in Friction Ratio Profile)

- 1 sensitive, fine grained
- 2 organic soils, PEAT
- 3 CLAY
- 4 CLAY to silty 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 coarse to medium SAND
- 10 GRAVEL to gravelly SAND
- 11 very stiff, fine grained
- 12 very stiff SAND to clayey SAND



Legend (Colors in Cone Resistance Profile)

- | | |
|--------------|------------|
| very loose | very soft |
| loose | soft |
| medium dense | firm |
| dense | stiff |
| very dense | very stiff |
| | hard |



Legend (Colors in Total Fluorescence Profile)

- | |
|-----------------------------|
| background or miscellaneous |
| heavy fraction |
| medium to heavy fraction |
| medium to light fraction |
| light fraction |

Project: 510-14-044 (5114095) LIF-CPT Groun Epe

Test Location: TB2

Client:

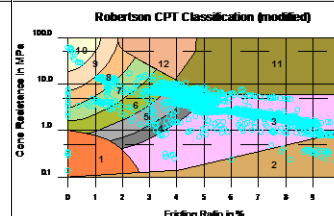
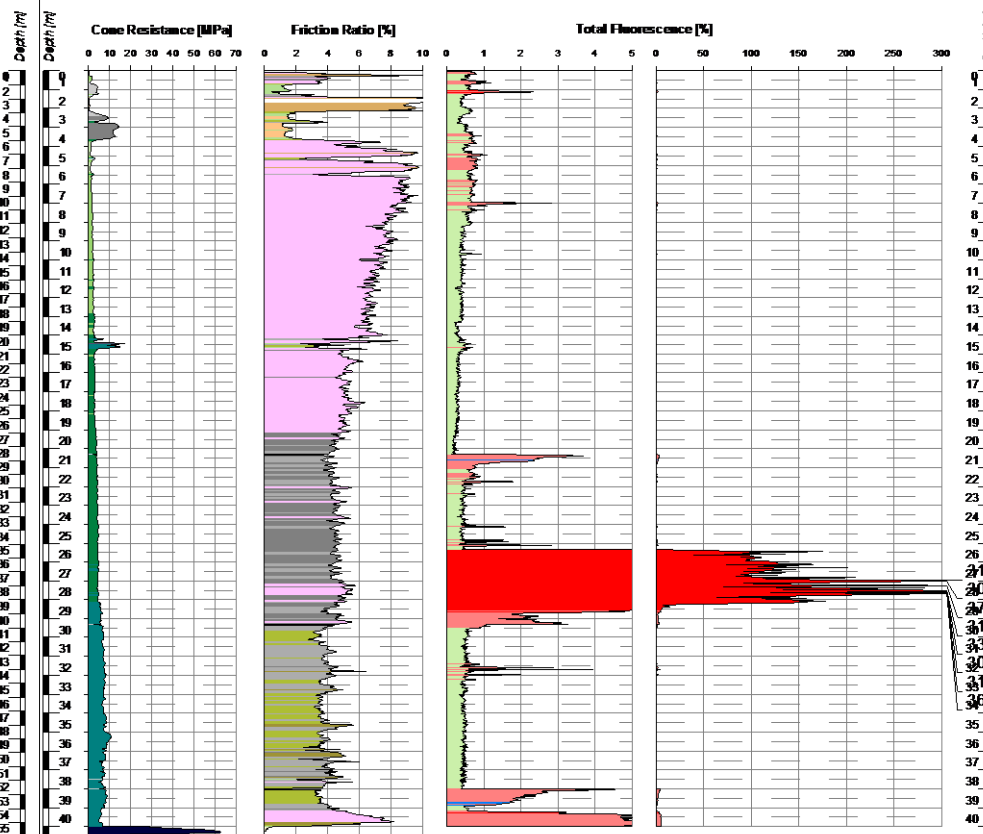
X-Coord: 0.0

Contractor: Fugro Consult GmbH

Y-Coord: 0.0

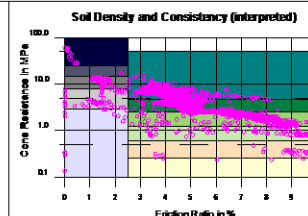
Processed by: JD

Elevation: 0.00 m asl



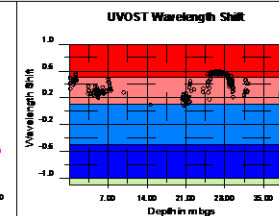
Legend (Colors in Friction Ratio Profile)

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Legend (Colors in Cone Resistance Profile)

- | | |
|--------------|------------|
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| loose | soft |
| medium dense | firm |
| dense | stiff |
| very dense | very stiff |
| | hard |



Legend (Colors in Total Fluorescence Profile)

- | |
|-----------------------------|
| background or miscellaneous |
| heavy fraction |
| medium to heavy fraction |
| medium to light fraction |
| light fraction |

Project: 510-14-044 (5114095) LIF-CPT Groun Epe

Test Location: TB5

Client:

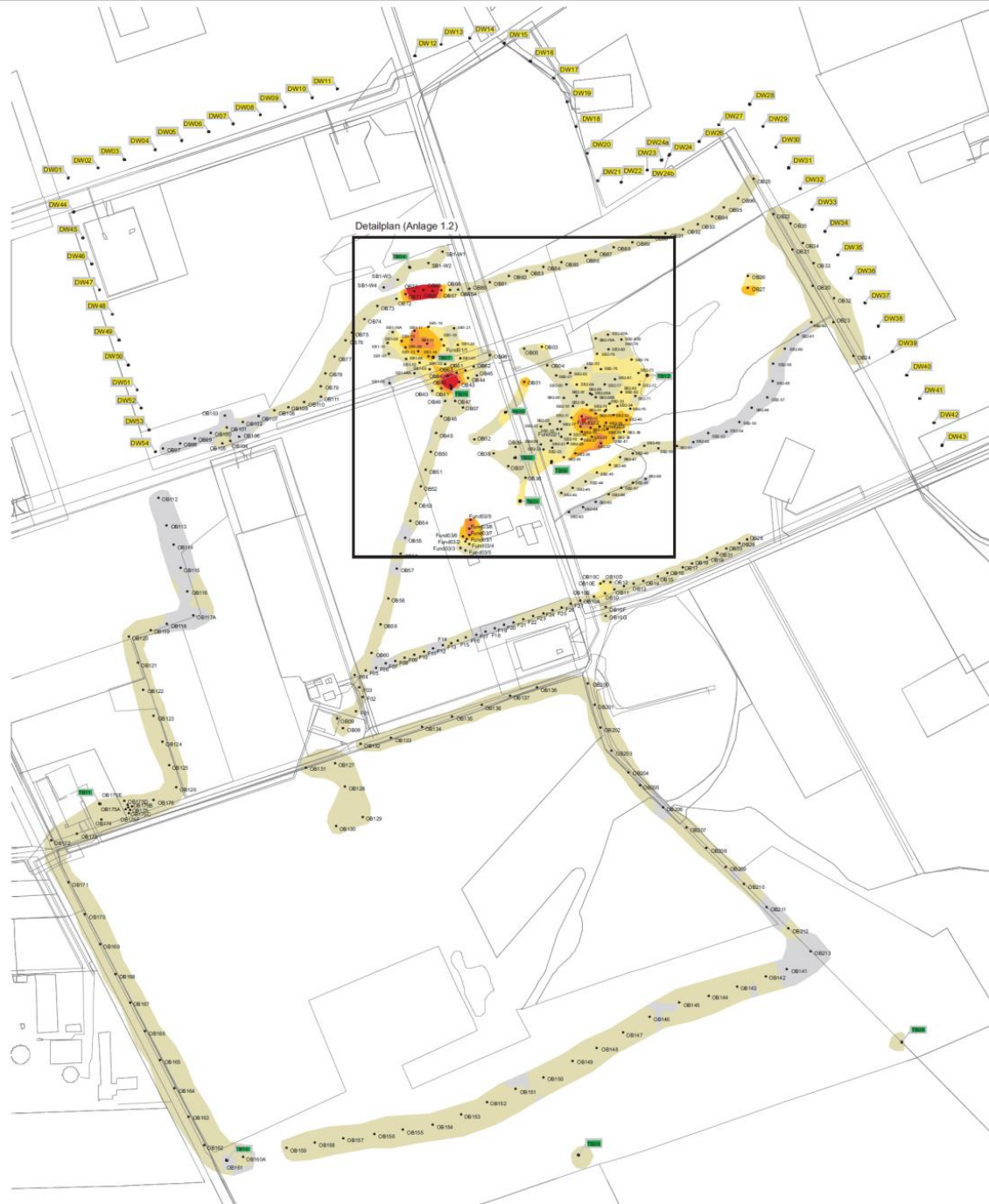
X-Coord: 0.0

Contractor: Fugro Consult GmbH

Y-Coord: 0.0

Processed by: JD

Elevation: 0.00 m asl



- TB LIF-Tiefbohrung
- DW LIF-Bohrung an Dichtwänden
- F LIF-Bohrung "Fugro"
- Fund LIF-Bohrung Fundstelle
- OB LIF-Bohrung ohne besondere Benennung
- SB1 LIF-Bohrung im Schwarzbereich 1
- SB2 LIF-Bohrung im Schwarzbereich 2

Legende:

0 - 1	
1 - 25	
25 - 50	
50 - 75	
75 - 100	
100 - 200	
> 200	

FUGRO CONSULT GmbH
 Volkmarer Straße 30 · D-38104 Braunschweig
 Tel. +49(0)531 - 213034-0 Fax +49(0)531 - 213033-29

Projekt: Gronau - Epe
 LIF-CPT Sondierungen

Auftraggeber:

Darstellung: Übersichtskarte der maximalen Summenfluoreszenzen (tiefenunabhängig)

gezeichnet am:	gezeichnet von:	gezeichnet mit:	Maßstab:	Anlage:
24.07.2014/ST	ST	ST	1 : 500	1.1



- TB LIF-Tiefbohrung
- DW LIF-Bohrung an Dichtwänden
- F LIF-Bohrung "Fugro"
- Fund LIF-Bohrung Fundstelle
- OB LIF-Bohrung ohne besondere Benennung
- SB1 LIF-Bohrung im Schwarzbereich 1
- SB2 LIF-Bohrung im Schwarzbereich 2



Legende:

Summenfluoreszenz (%)	Fluoreszenz
0 - 1	0 - 1
1 - 25	1 - 25
25 - 50	25 - 50
50 - 75	50 - 75
75 - 100	75 - 100
100 - 200	100 - 200
> 200	> 200

FUGRO Consult GmbH
 Volkswirtschafts-Straße 10 · D-59104 Reutheberg
 Tel.: +49 (0) 231 2 155 55-0 Fax: +49 (0) 231 2 155 55-29

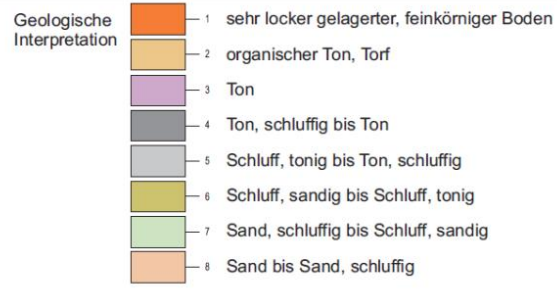
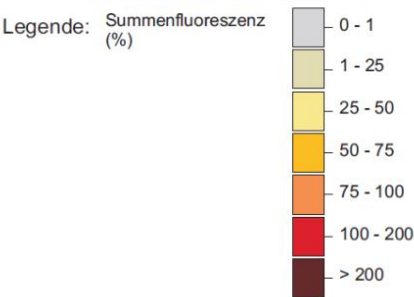
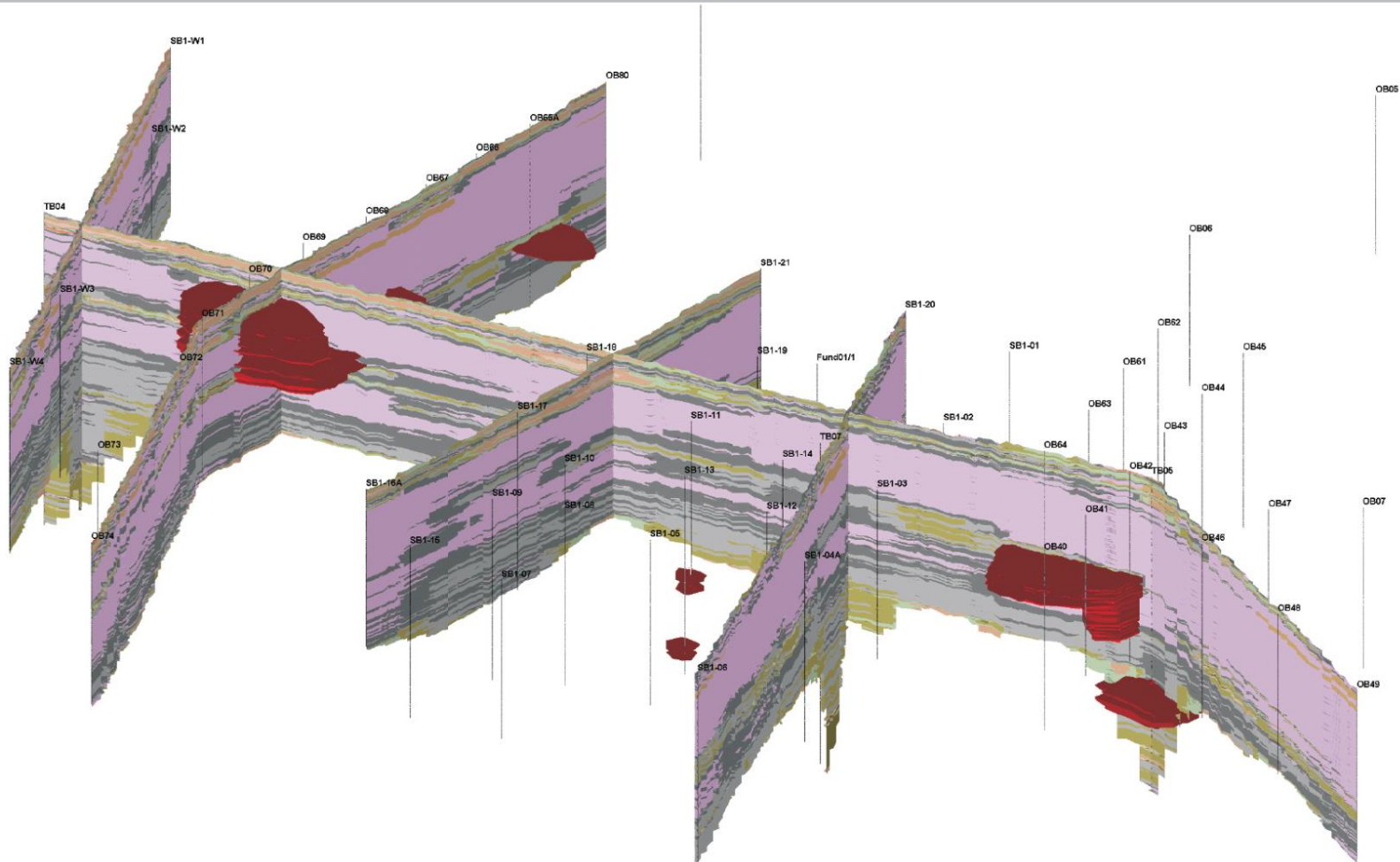
Projekt: Gronau - Epe
 LIF-OPIT Sondierungen


Auftraggeber:

Der Auftraggeber: **Detailkarte der maximalen Summenfluoreszenzen (tiefenunabhängig)**

geographische Breite: 50° 07' 30" N	geographische Länge: 08° 15' 00" E	Flächenmaß: 1:1000	Maßstab: 1:1000	Arbeits: 1:2
-------------------------------------	------------------------------------	--------------------	-----------------	--------------

3D-Fences West Geologische Interpretation + Summenfluoreszenz



 FUGRO Consult GmbH Volkmaroder Straße 8c • D-38104 Braunschweig Tel.: +49(0)531 - 213699-0 Fax: +49(0)531 - 213699-29			
Projekt: Gronau - Epe LIF-CPT Sondierungen			
Auftraggeber:			
Darstellung: 3D-Fences West Geol. Interpretation + Summenfluoreszenz			
gezeichnet am/von:	Papierformat:	Maßstab:	Anlage:
31.07.2014/ST	DIN A3	-	3.3.2

LIF-CPT - Take Home Messages

- Works in combination with almost any Fugro CPT-equipment worldwide.
- System readily available and easy to mobilize or ship.
- Real time data acquisition - results can be seen and interpreted directly.
→ Quick adaptation of the investigation strategy.
- Geotechnical and contamination data combined - Soil lithology and contamination can be correlated.
- No human exposure risks to contaminants during measurements.
→ minor H&S requirements.
- Rapid site screening (120 to 180m per day) - cost savings compared to traditional investigation methods.

Thank You!

Any Questions?

Email: m.hirsch@fugro.de

