

# Soil characterisation and performance of demining sensors

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# Introduction

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- **ITEP test of landmine detection sensors has taken place**
  - Stand-alone MD
  - Dual sensor (MD+GPR)
- **LIAG carried out pedological and geophysical investigations for characterising test soils**
  - Soil texture
  - Humus content
  - Magnetic susceptibility
  - Electric conductivity
  - Permittivity (dielectric constant), water content
- **A comprehensive soil characterisation has been made**

# Magnetic susceptibility

- Creates additional MD response – *false alarms, sensitivity loss*
- No influence on GPR
- *Frequency dependence* has more influence than *absolute level*
- Ground compensation function reduces the influence
- Absolute level – measured in field  
Frequency dependence – measured in lab.



For point measurement



For measurement of frequency dependence  
Left: dual frequencies, right: stepped frequencies

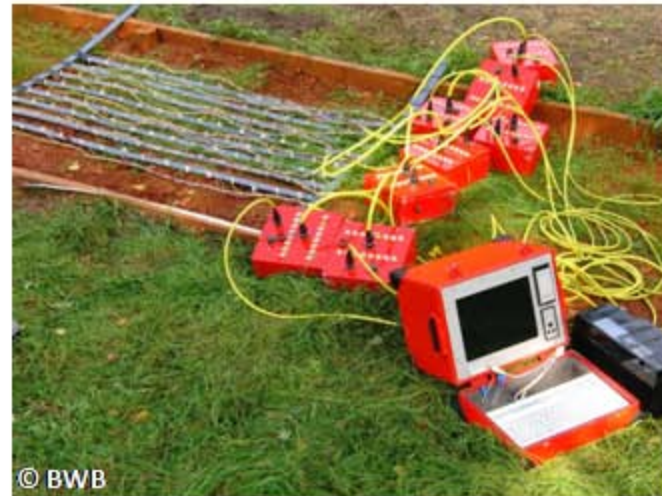


# Electric conductivity

- When considerably high, creates MD response – **false alarms, sensitivity loss**
- Attenuates GPR signal – **shortens penetration depth**
- Wet and saline soil particularly has high conductivity – **coastal area**
- Measured in field



For point measurement  
Quick measurement



For measurement of spatial distribution  
Sophisticated measurements and data analysis

# Permittivity (dielectric constant), water content

- No direct influence on MD
- Directly related with propagation velocity of GPR signal
  - *changes reflectivity, resolution, etc.*
  - *the influence can be positive and negative*
- Measured in field



For point measurement

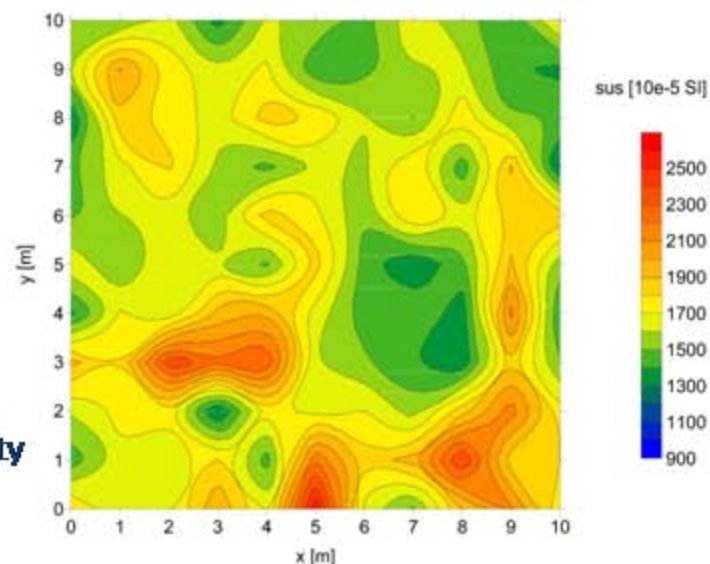


# Inhomogeneity of soil

- There are always spatial variation of soil properties – **inhomogeneity**
- Amount/size of variation have influences on sensors, for example:
  - MD: *ground compensation at a place is not valid at another place*
    - **false alarm, missing mines**
  - GPR: *spatial change of permittivity creates reflection which can cause false alarms or disturb mine signature*
    - **less false alarm reduction, misidentification of mines**
- **Must be measured in field**



Ex. Spatial distribution of magnetic susceptibility  
Measured area: 10 x 10 m  
Absolute level: 1400–2500 SI<sup>5</sup>



# Soils in ITEP DS test

Lane 1.1-1.4: **Laterite** – Red-coloured *laterite* classified as clay loam

Lane 2.1-2.4: **Magnetite** – Engineered *magnetite* mixed with *coarse sand*

Lane 3.1: **Humus** – Loam with *low stone content*

Lane 3.2-3.4: **Humus** – Loam with high humus and *high stone content*



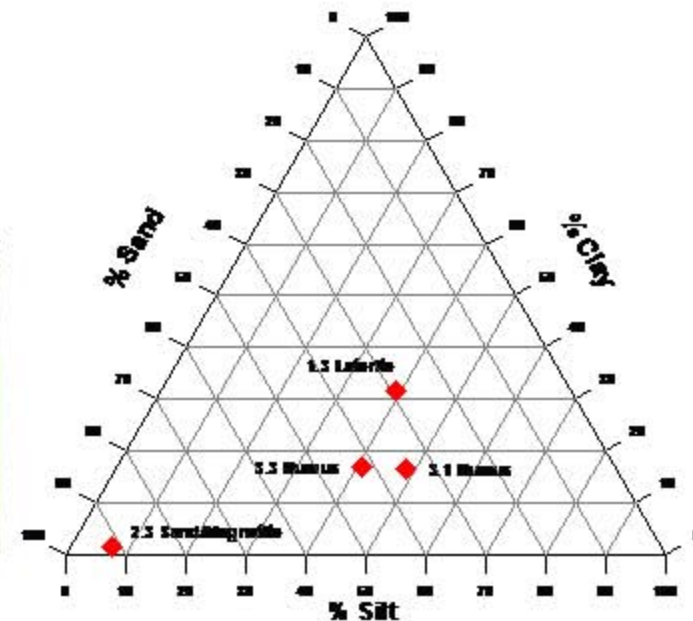
Lane 1



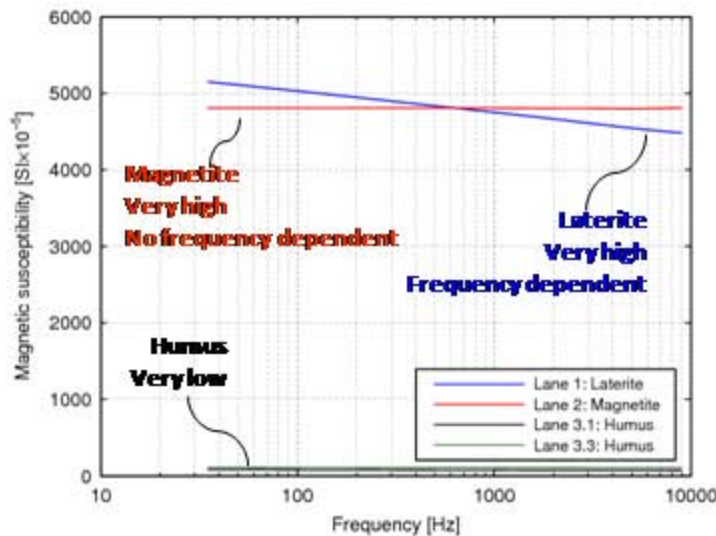
Lane 2



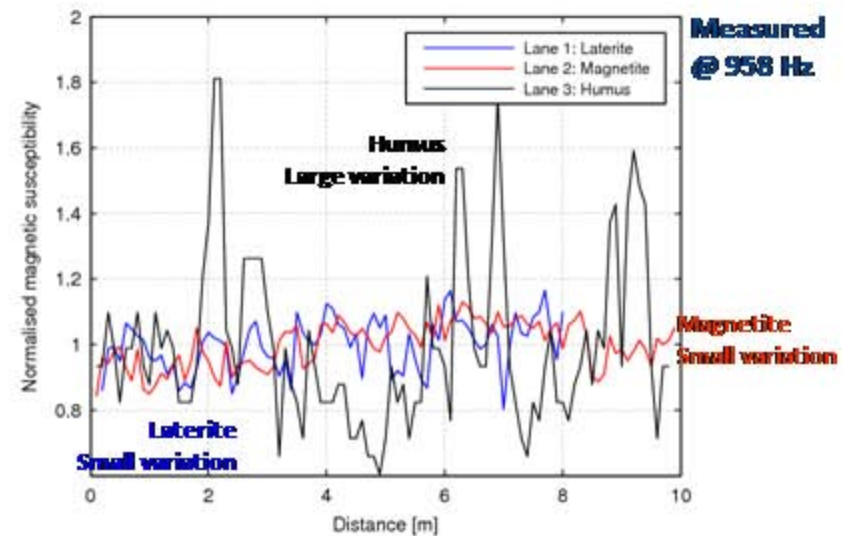
Lane 3



# Measured magnetic susceptibility



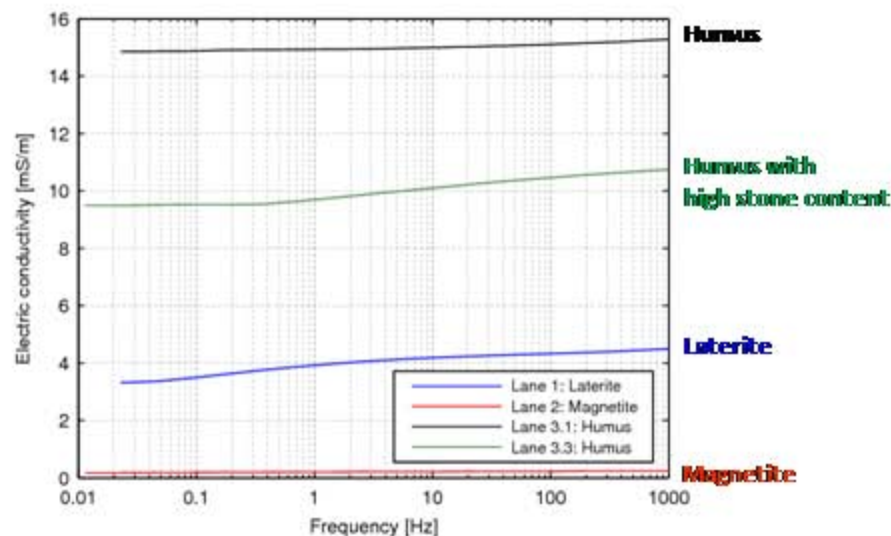
Frequency dependence of magnetic susceptibility



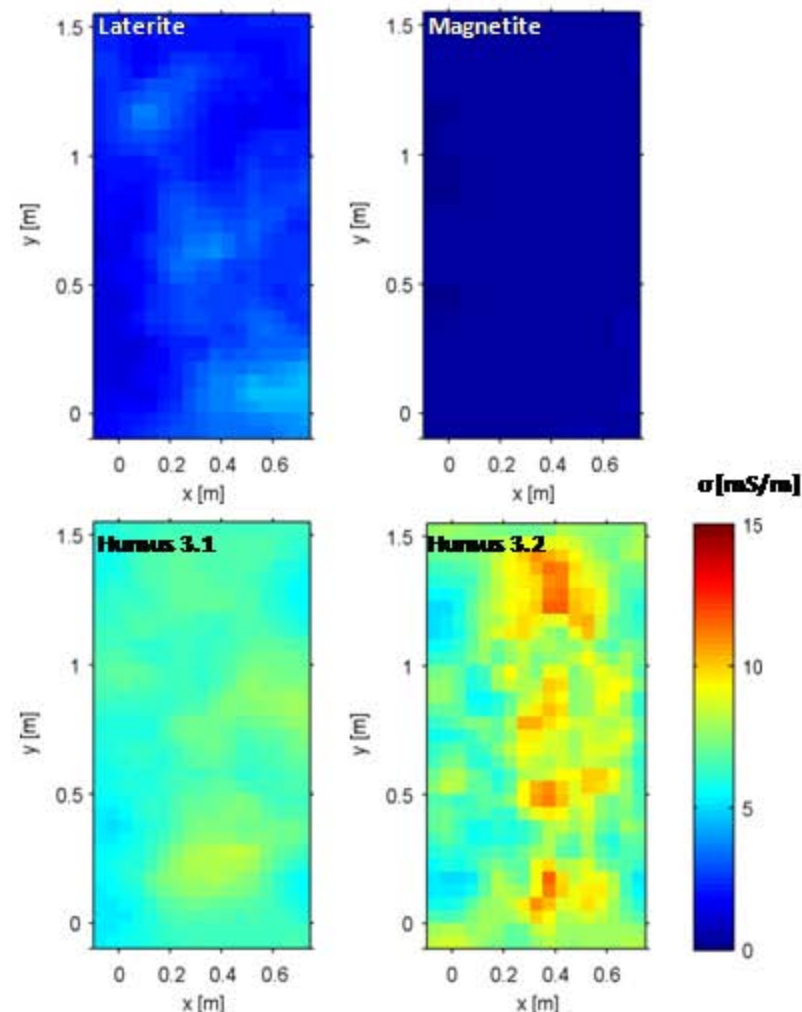
Relative spatial variability of magnetic susceptibility

	Laterite (Lane 1)	Magnetite (Lane 2)	Humus (Lane 3.1)	Humus (Lane 3.2)
<b>Absolute value</b>	Very high	Very high	-	Very low
<b>Frequency dependence</b>	High (6 %)	Very low (0.1 %)	High (7 %)	Very low (1 %)
<b>Spatial variation</b>	Small (8.4 %)	Small (7.4 %)	-	Large (38.9 %)

# Measured electric conductivity



Frequency dependence of electric conductivity

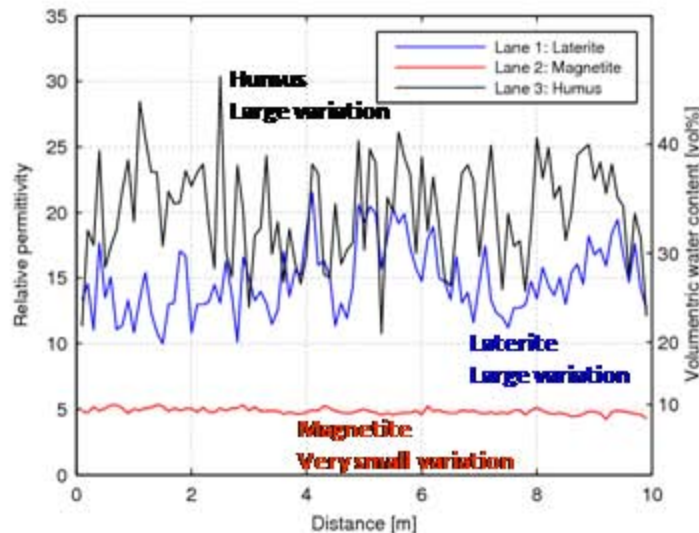


Spatial variability of electric conductivity

Conductivity is not high in all soils

... no influence on sensors is expected

# Measured permittivity



**Laterite, humus:**  
 high in average  
 large spatial variation

**Magnetite:**  
 low in average  
 very small spatial variation

**Spatial variability of permittivity, water content**

	Laterite (Lane 1)	Magnetite (Lane 2)	Humus (Lane 3)
<b>Mean</b>	High (14.9)	Low (4.8)	High (20.1)
<b>Correlation length</b>	1.35 m	-	0.63 m
<b>Variation</b>	Large (18 %)	Very small (4 %)	Large (19 %)

# Estimated impact of soil on sensors

	Laterite (Lane 1.1-1.4)	Magnetite (Lane 2.1-2.4)	Humus (Lane 3.1)	Humus with high stone content (Lane 3.2-3.4)
$\kappa$ $\kappa(\omega)$ $\epsilon, \theta$ $\epsilon(r)$	Very high Very high High Large	Very high Very low Low Very small	Very low High High Large	Very low Very small High Very large
MD	<i>Very severe</i>	<i>Moderate</i>	<i>Neutral</i> <i>Moderate</i>	<i>Neutral</i>
GPR	<i>Moderate</i> <i>severe</i>	<i>Neutral</i>	<i>Moderate</i>	<i>Very severe</i>

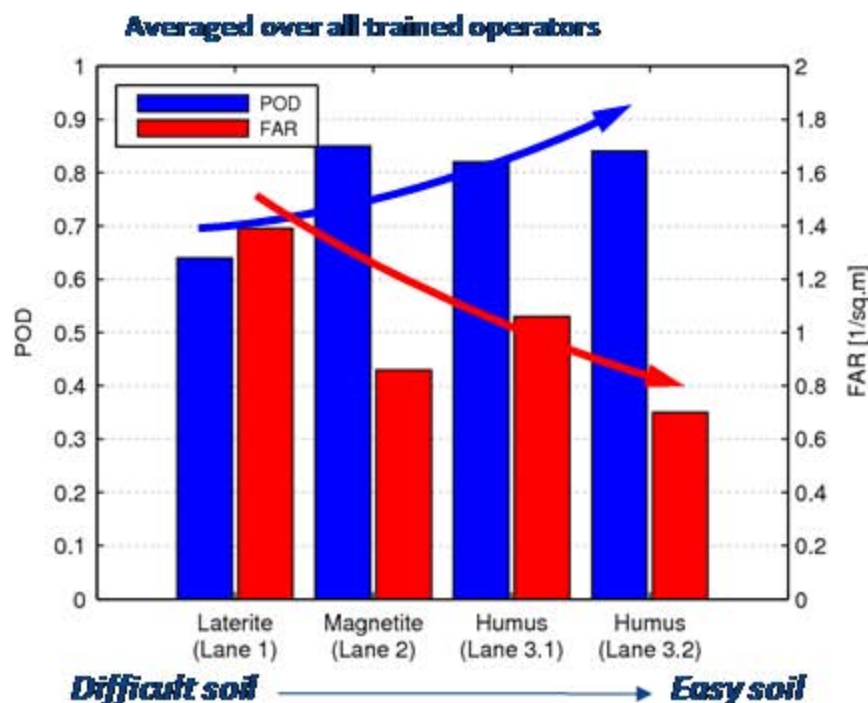
$\kappa$  : Magnetic susceptibility

$\kappa(\omega)$  : Frequency dependence of magnetic susceptibility

$\epsilon, \theta$  : Permittivity (dielectric constant), water content

$\epsilon(r)$  : Spatial variation of permittivity

# MD performance and soil



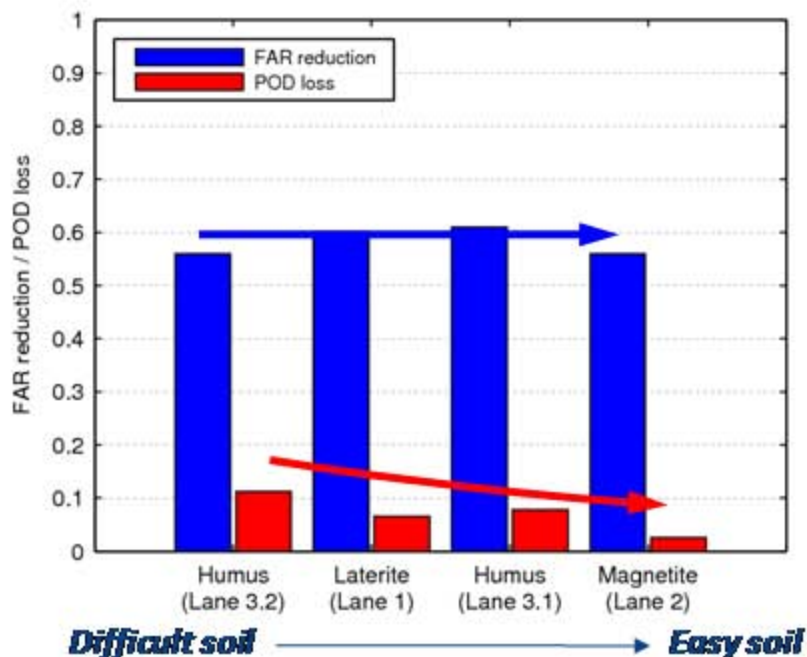
**POD** – how much mines/metals found  
**FAR** – how much false alarms obtained per a square metre

**Difficult soil:** Lower POD, higher FAR

**Easy soil:** Higher POD, lower FAR

	Laterite	Magnetite	Humus Lane 3.1	Humus Lane 3.3
<b>POD</b>	64 %	85 %	82 %	84 %
<b>FAR</b>	1.39 m <sup>-2</sup>	0.86 m <sup>-2</sup>	1.06 m <sup>-2</sup>	0.70 m <sup>-2</sup>

# DS (GPR) performance and soil



FAR reduction – how much metals/false alarms reduced by GPR

POD loss – how much mines falsely rejected

**Difficult soil: Higher POD loss**

**Easy soil: Lower POD loss**

	Laterite	Magnetite	Humus Lane 3.1	Humus Lane 3.3
<b>FAR reduction</b>	<b>60 %</b>	<b>56 %</b>	<b>61 %</b>	<b>56 %</b>
<b>POD loss</b>	<b>6.6 %</b>	<b>2.5 %</b>	<b>7.8 %</b>	<b>11.2 %</b>

# Summary

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- Pedological and geophysical investigations have been carried out in ITEP DS test
- Soil impact estimation on sensor performance has been made
- The estimation agrees with test results

**Confirms the influence of soil properties on sensors**

**Pedological/geophysical investigations are useful to predict performance/applicability of sensors**

Details of pedological/geophysical investigations:

H. Preetz, K. Takahashi and J. Igel

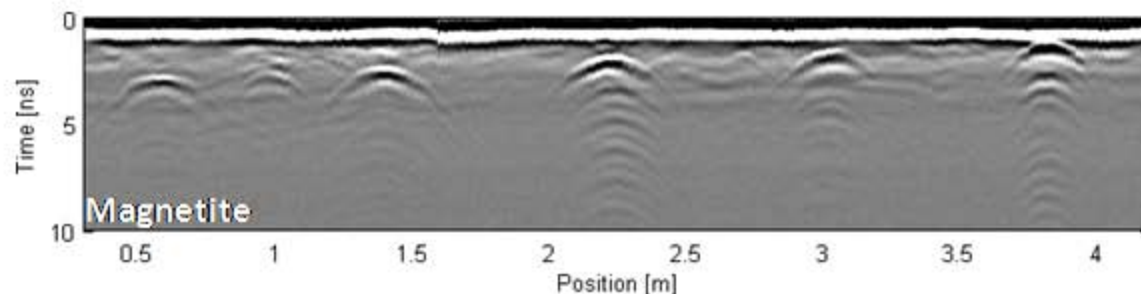
“Physical characterisation of the test lanes in the ITEP dual sensor test Oberjettenberg/Germany 2009”

*Will be available soon at <http://www.itep.ws/>*

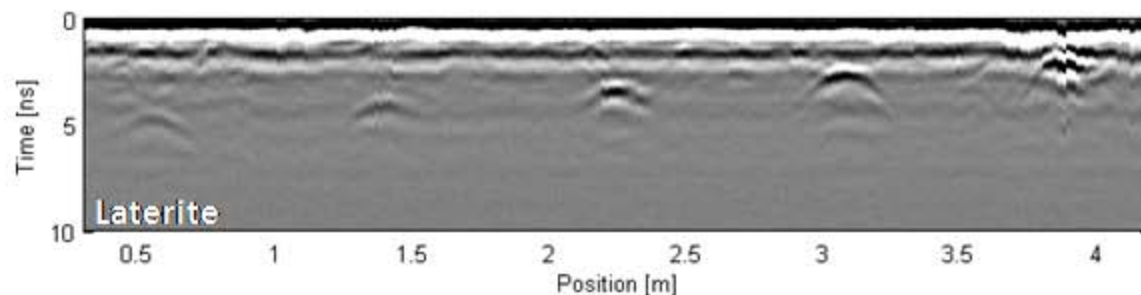
Details of test results:

*Test report will be available soon at <http://www.itep.ws/>*

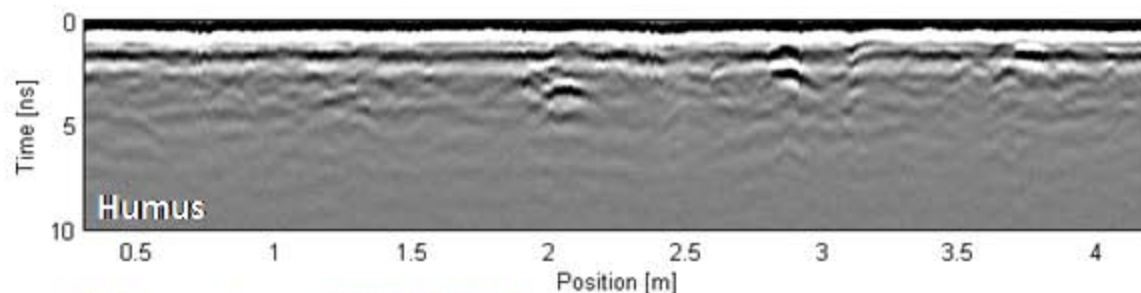
# GPR measurements in training lanes



Very clear hyperbolic curves at all depths



Curves are not so clear, but still recognisable



Curves are disturbed and not clear  
Some are unrecognisable at all

Radar system: GSSI 1.5 GHz

Target: PPM-2 at 5-25 cm