Interreg North-West Europe
RAWFILL
European Regional Development Fund

EUROPEAN UNION

Co-funded by the Walloon region

CONTRIBUTION OF GEOPHYSICAL METHODS TO THE STUDY OF OLD LANDFILLS: A CASE STUDY IN ONOZ (BELGIUM)

LIÈGE université

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PhD. student Itzel Isunza Manrique
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RAWFILL project

100,000 – 500,000 landfills

Landfill mining

Needs:

- Raw materials
- Energy sources
- Land

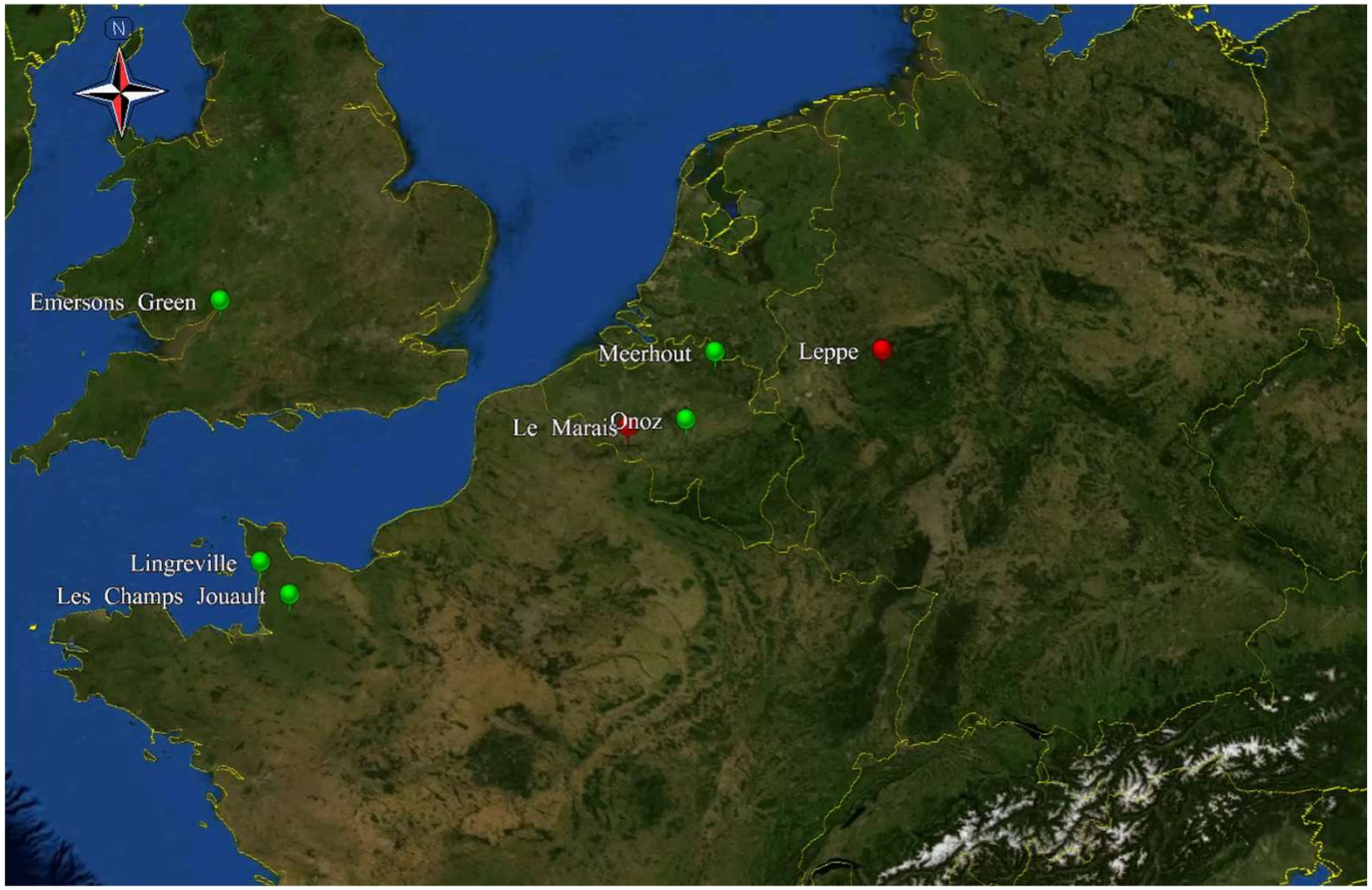
(Jones et al. 2013)

RAWFILL = Raw materials recovered from landfills

- focus on developing new methods to reduce the economic risk of LFM projects

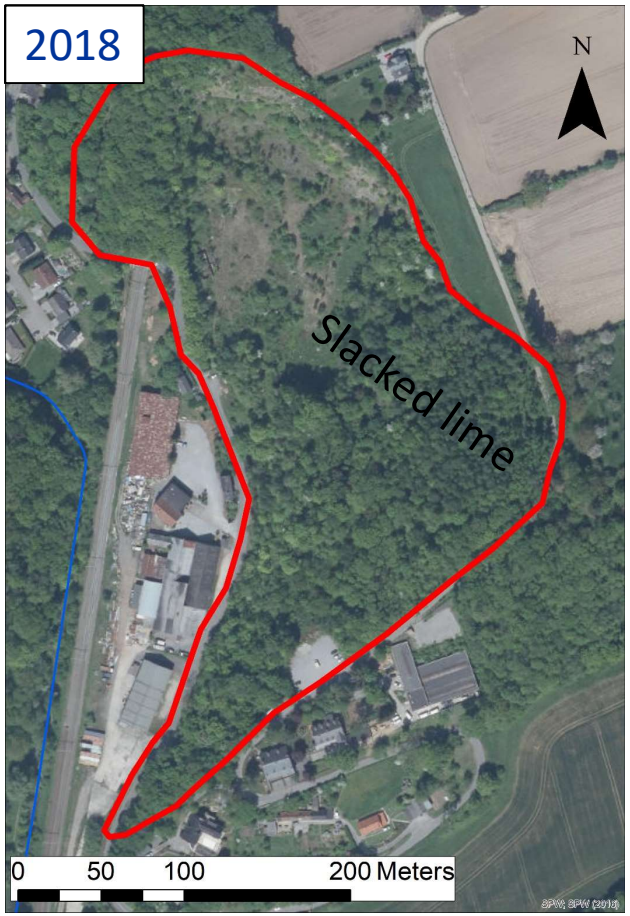
More information at the workshop "Landfill mining- Myth and Reality" at 15:30 in Naturista hall

Geophysics within RAWFILL

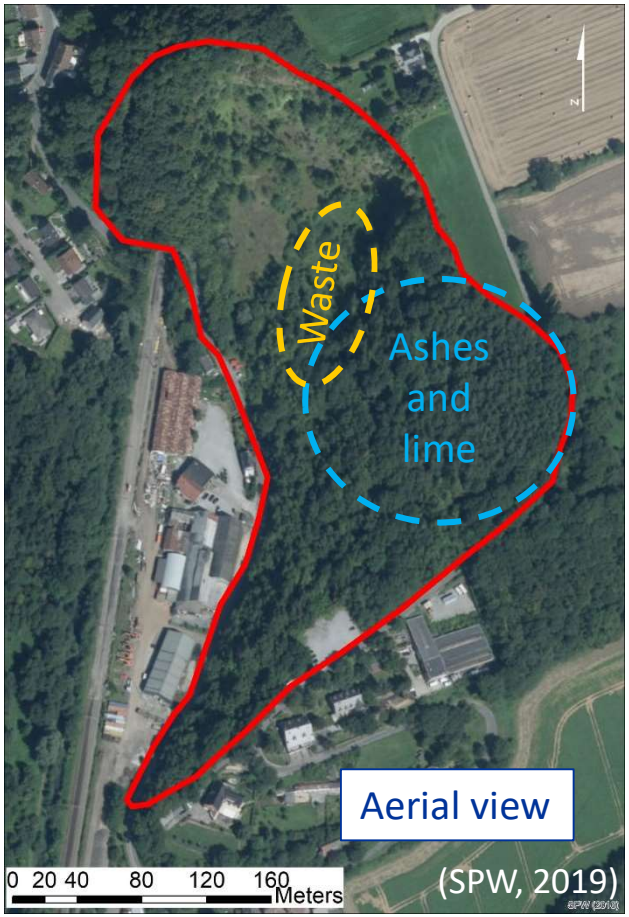


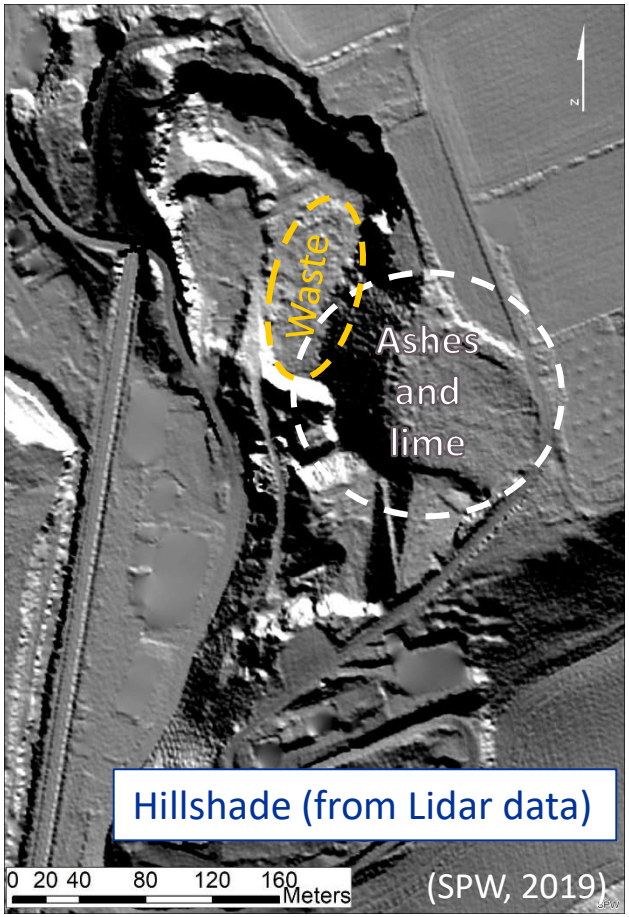
Context: history

- 1902-1967:
  - quarry (limestone extraction)
- 1967-1976:
  - slacked lime deposits followed by ashes deposits
- 1982-1987:
  - heterogeneous wastes (inert, tires, rubber, plastic, car parts, household…)



Context: current state





Context

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Selected methods

- Electromagnetic induction (EM)
- Magnetometry (MAG)
- Electrical Resistivity Tomography (ERT) and Induced Polarization (IP)
- Seismic method
  - Horizontal to Vertical Noise Spectral Ratio (HVNSR or H/V)

Mapping

Imaging

Sounding

Selected methods: EM

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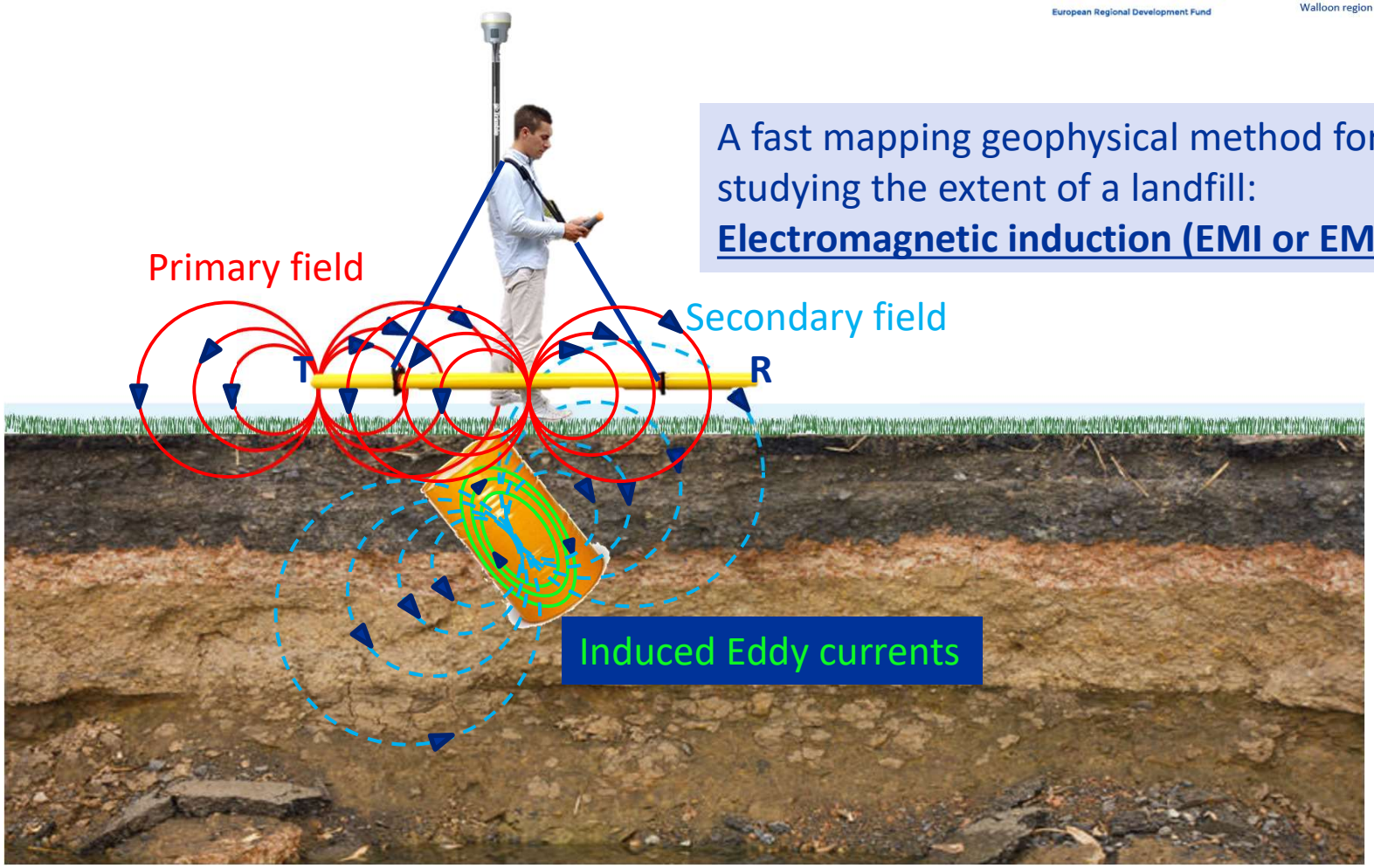
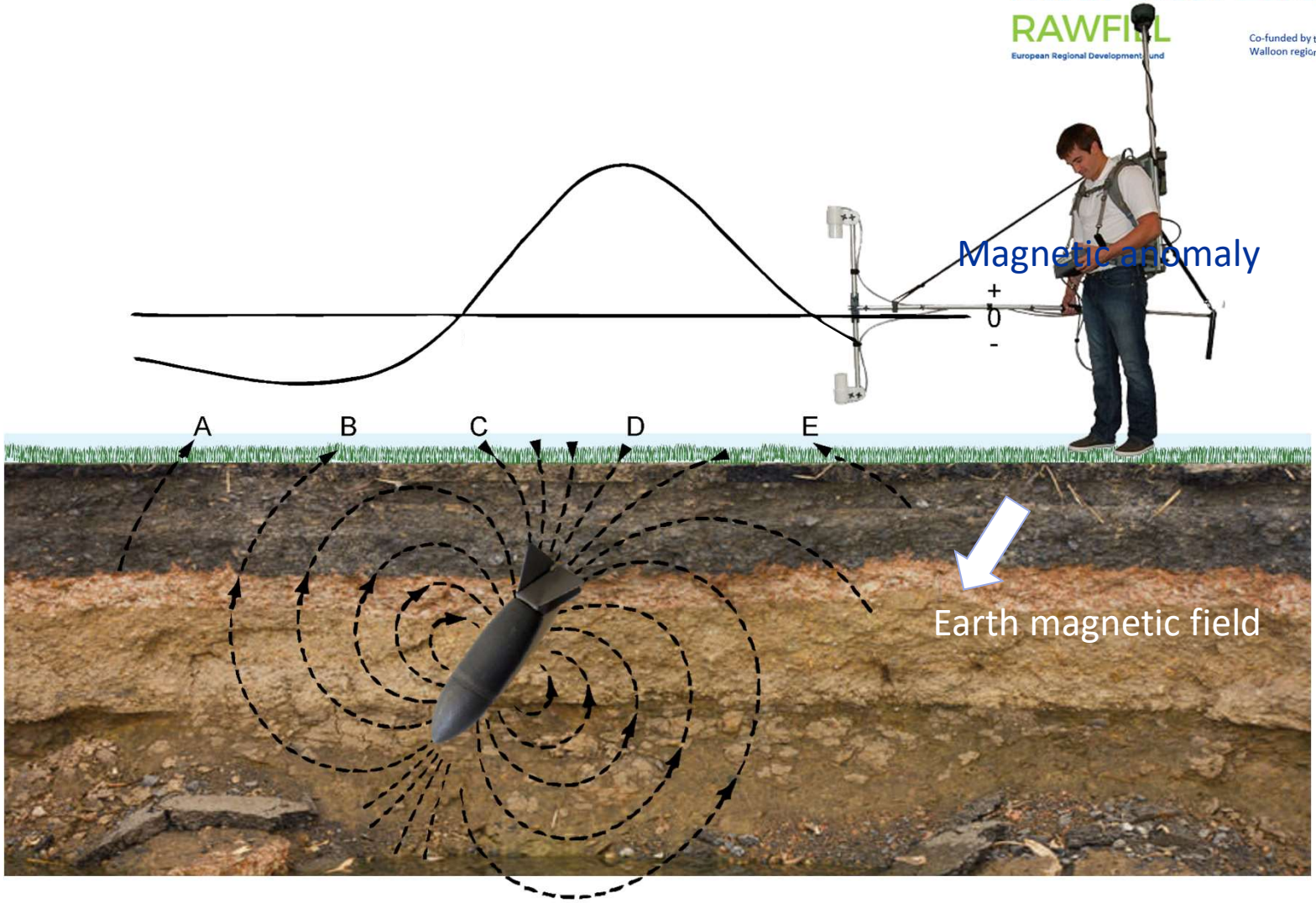
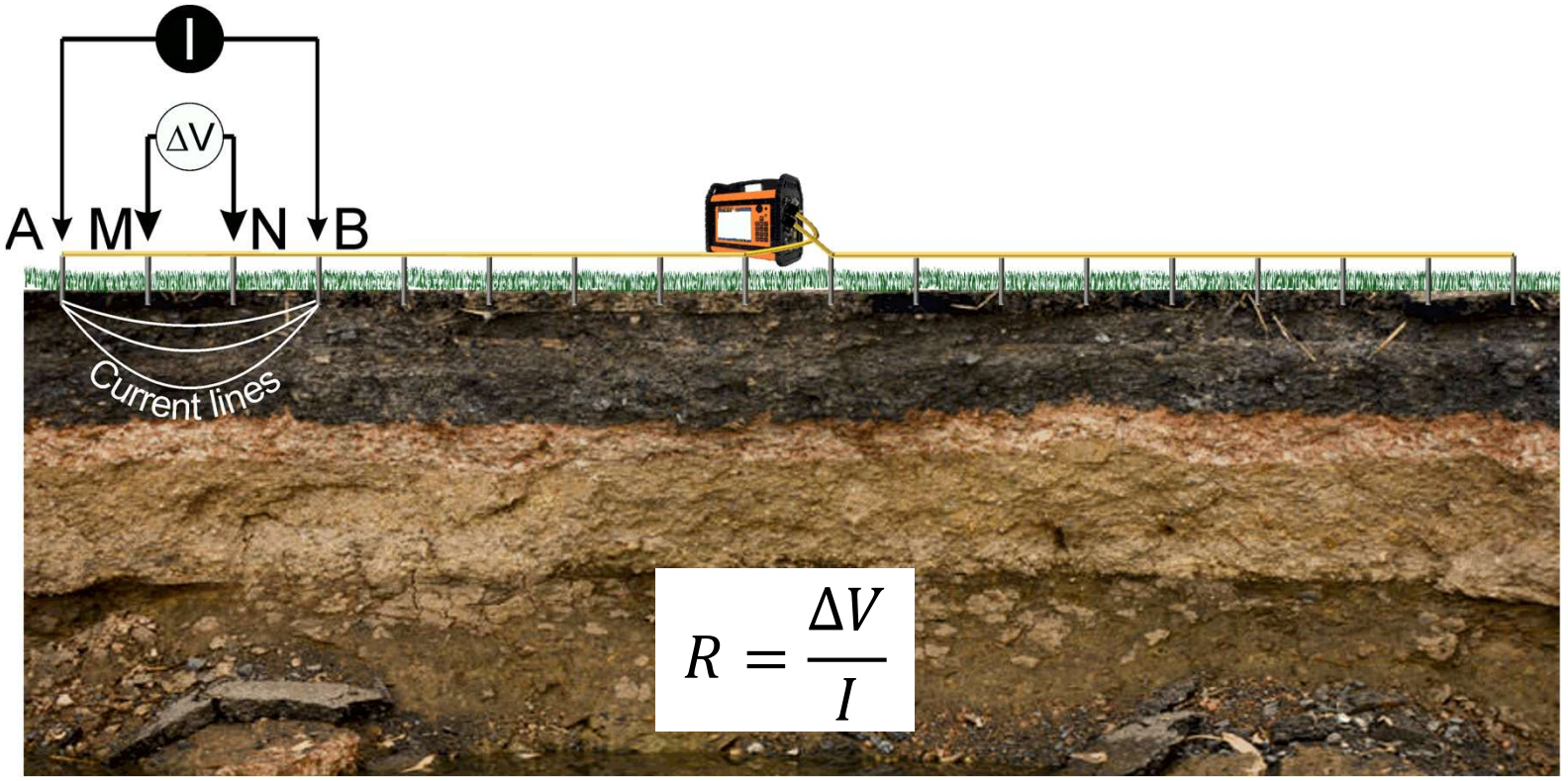
A fast mapping geophysical method for studying the extent of a landfill: **Electromagnetic induction (EMI or EM)**



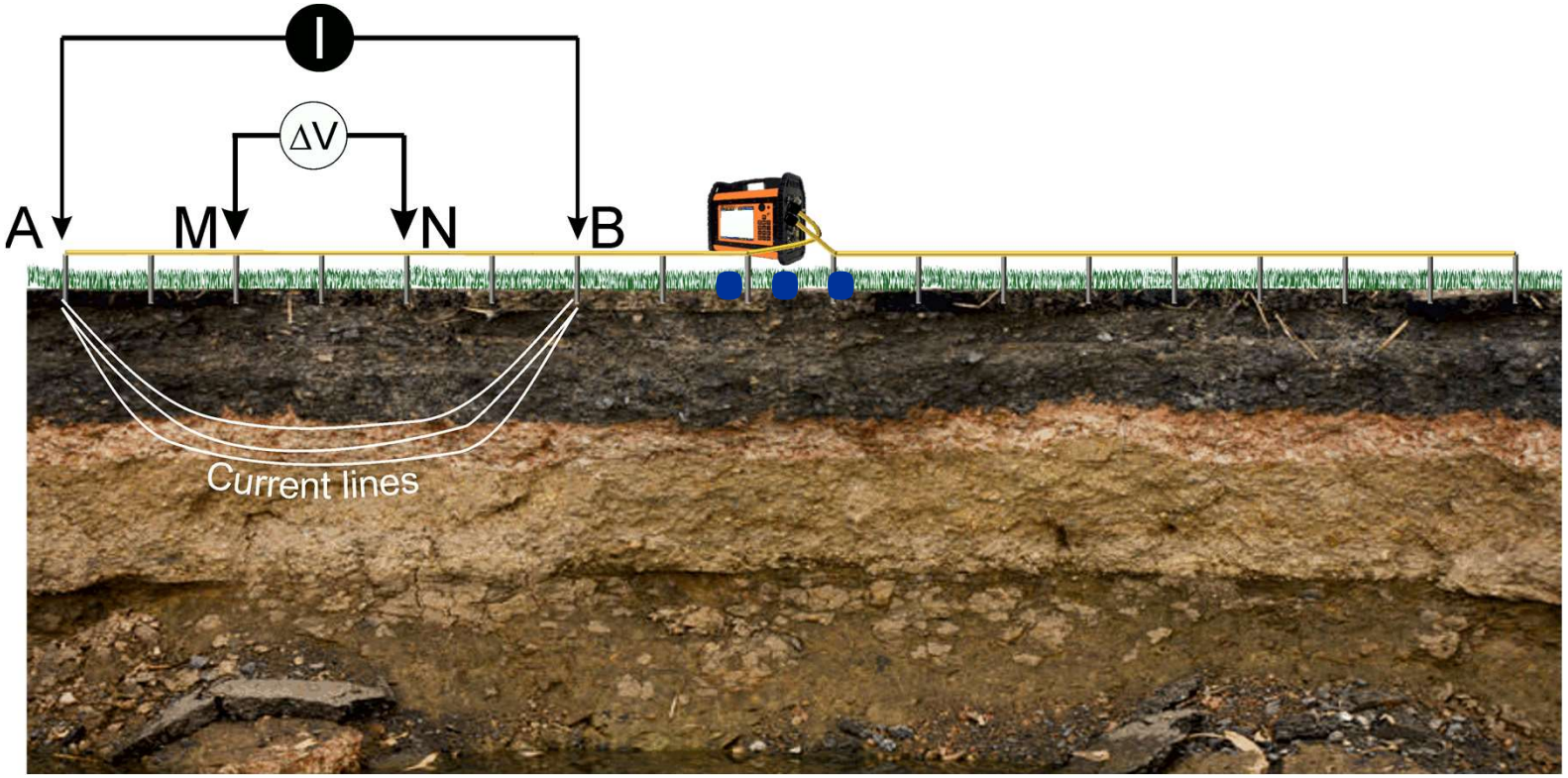
Selected methods: MAG



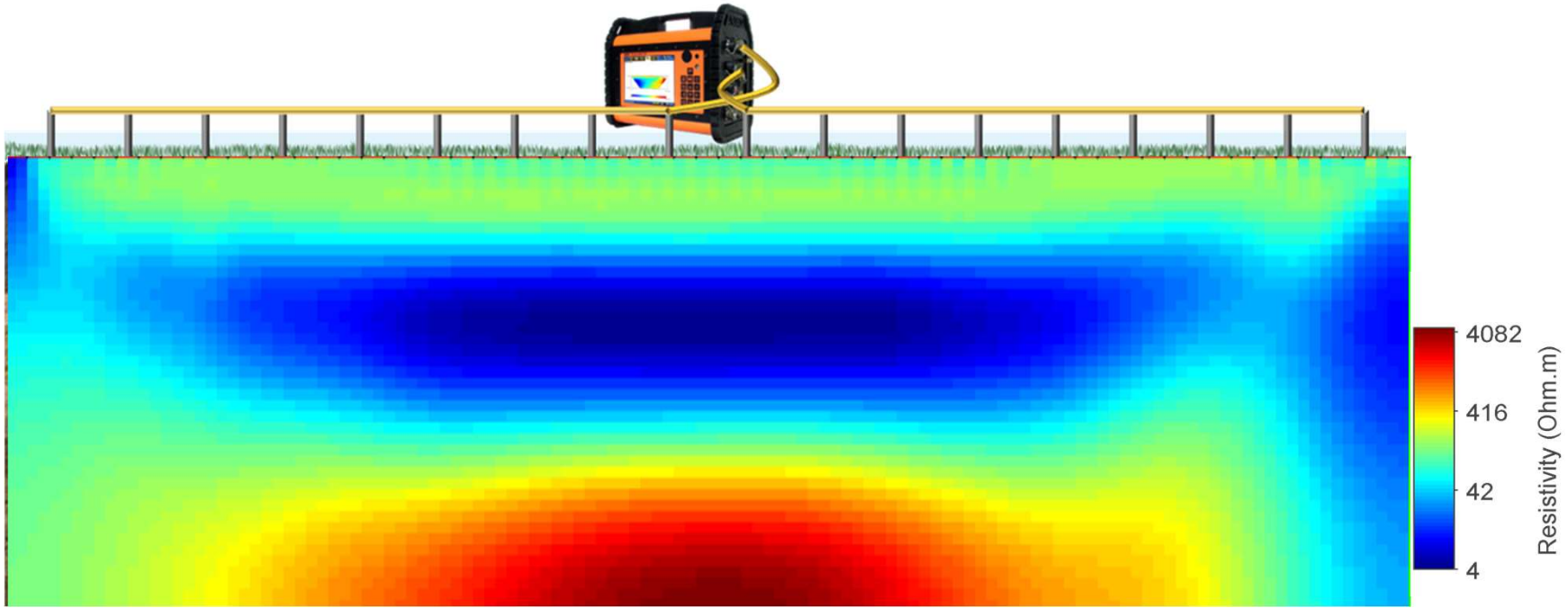
Selected methods: ERT/IP



Selected methods: ERT/IP

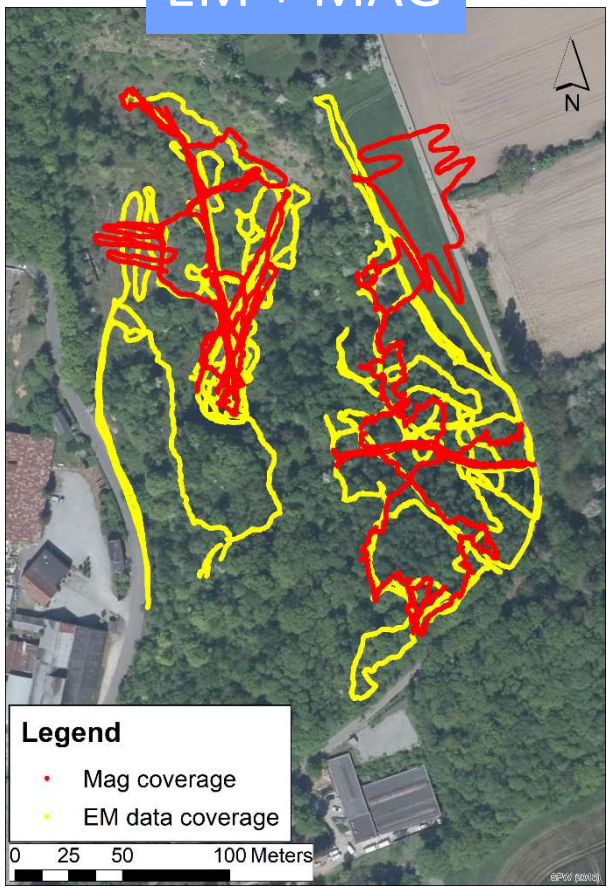


Selected methods: ERT/IP



Spatial coverage: EM & MAG

EM + MAG



EM

MAG

Results: EM at around 6 m depth

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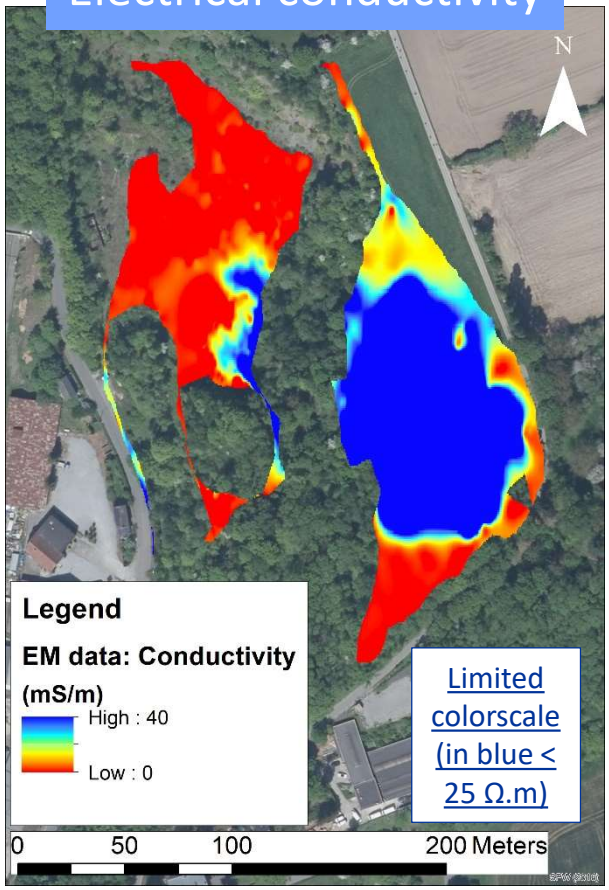
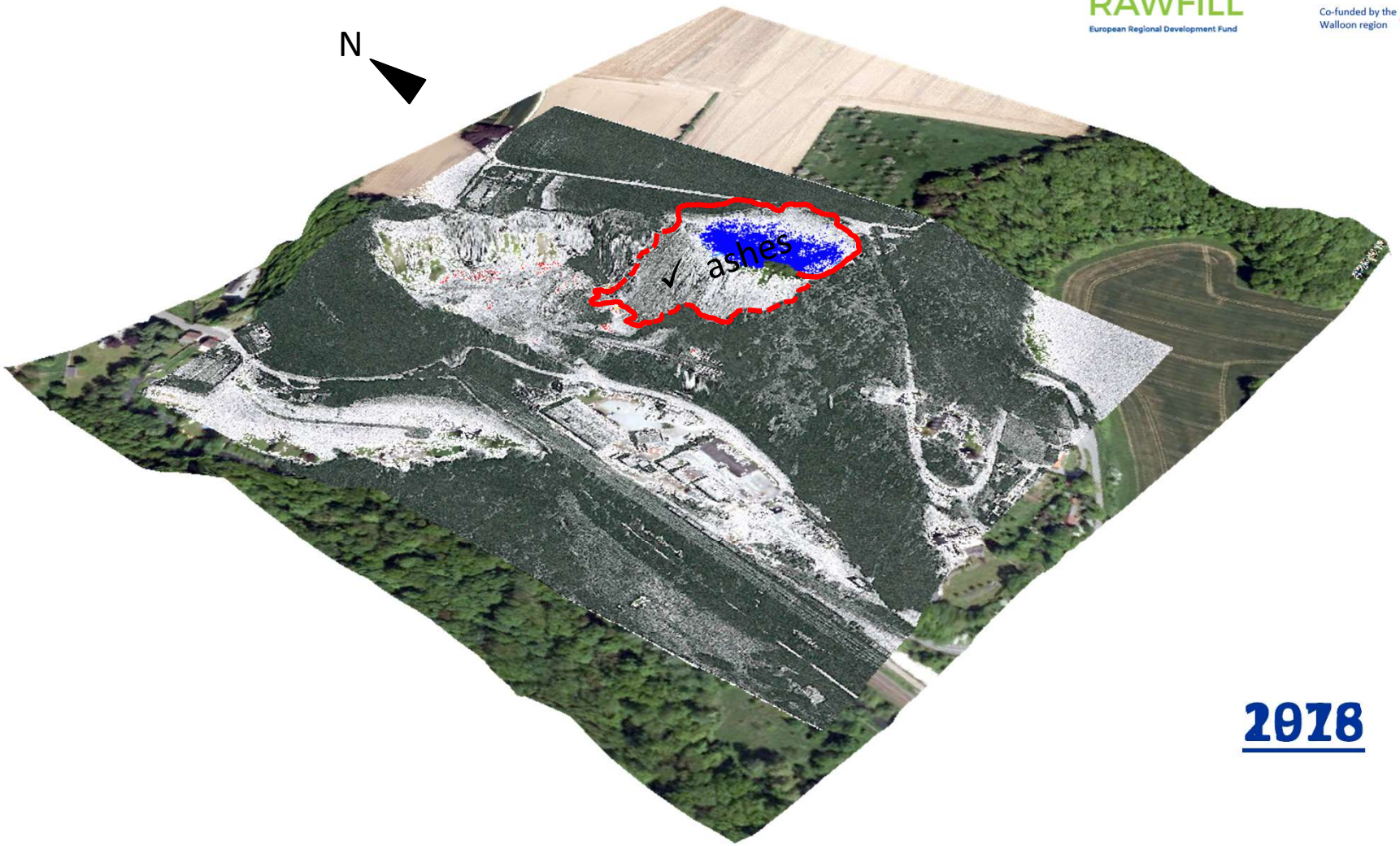
Electrical conductivity



Interpretation: EM



Results: Magnetometry

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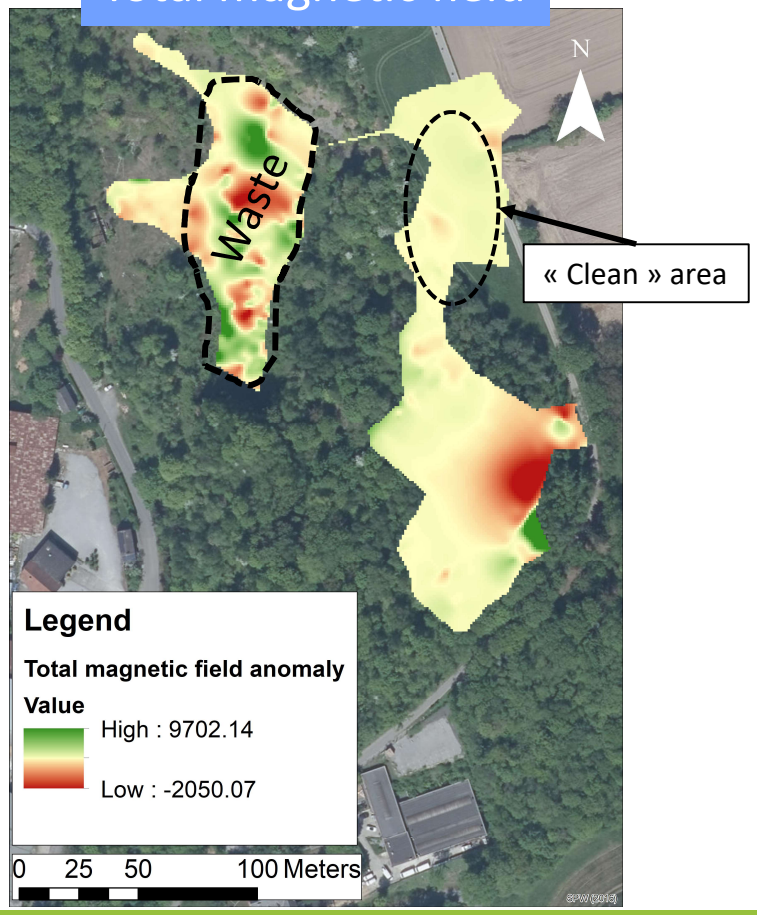
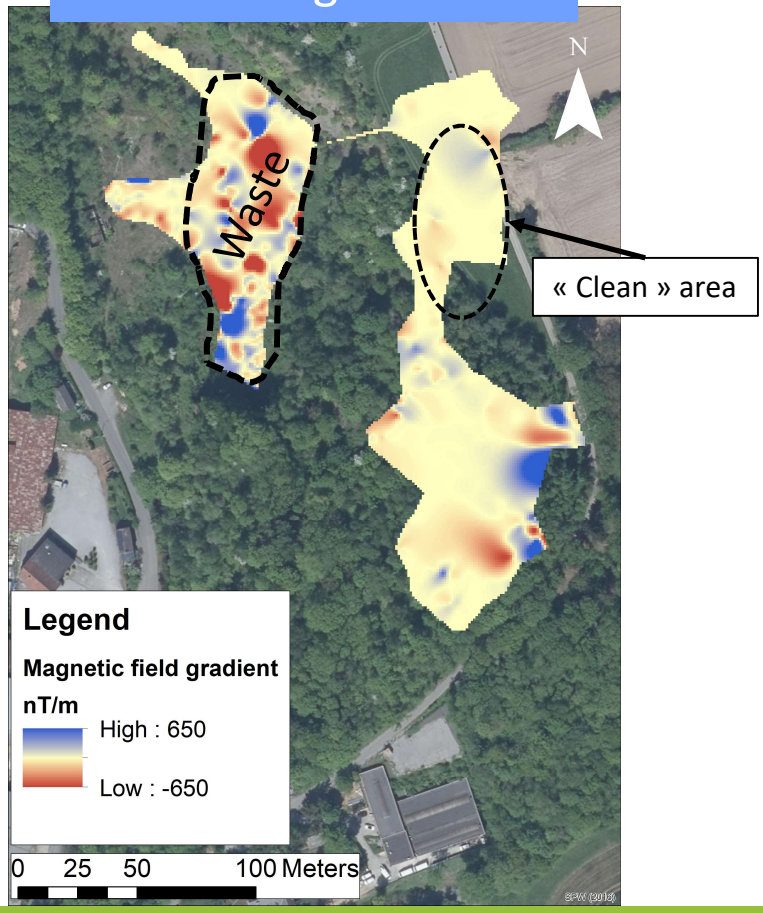
Total magnetic field

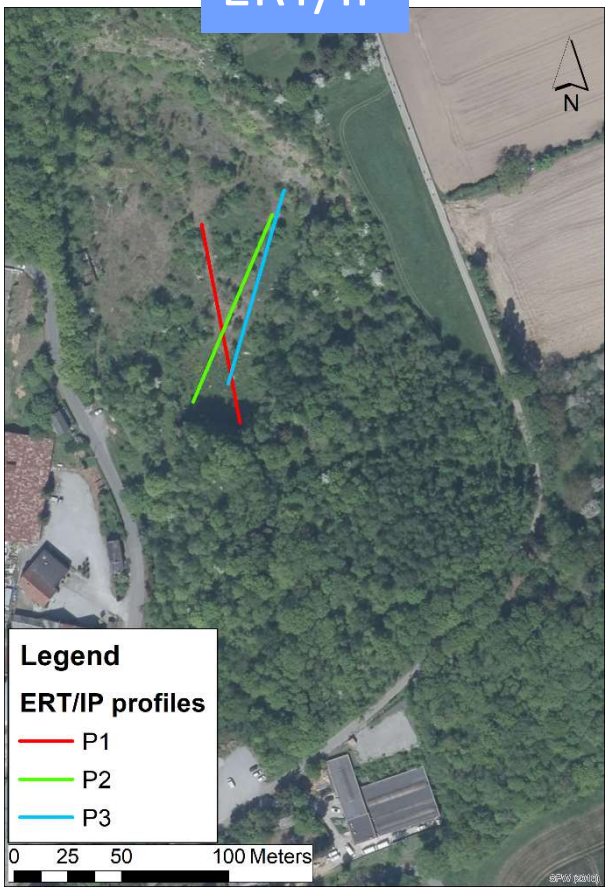


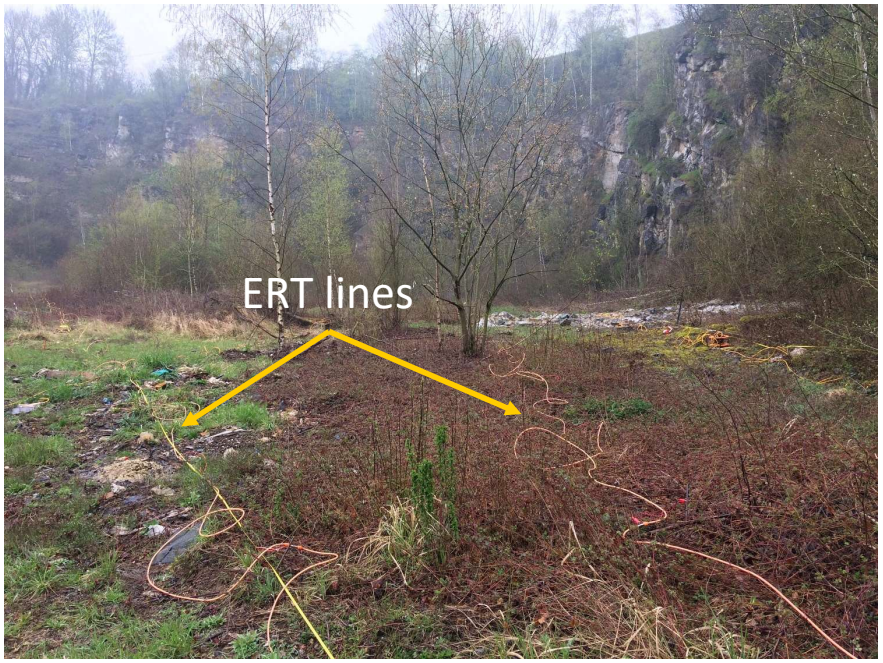
Vertical magnetic field



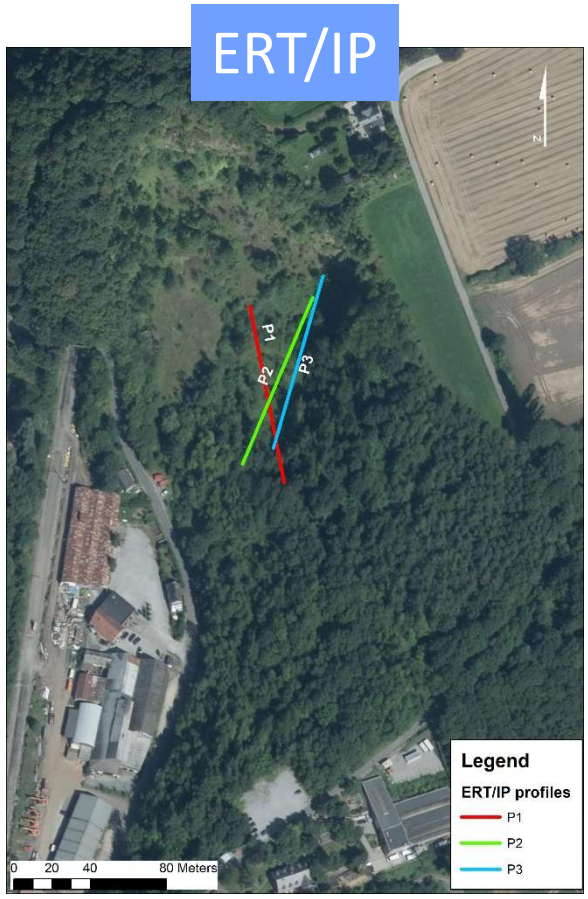
Spatial coverage: ERT/IP

ERT/IP

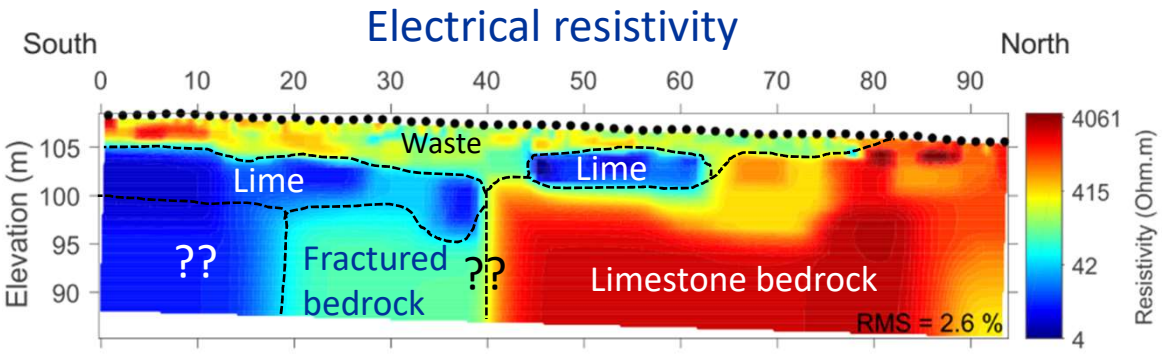




Results: ERT/IP



P1



Validation with ground truth data

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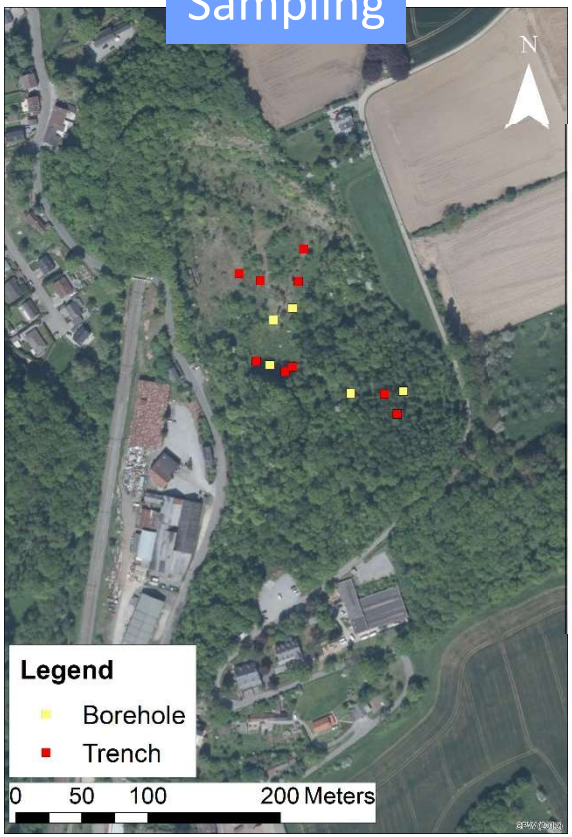
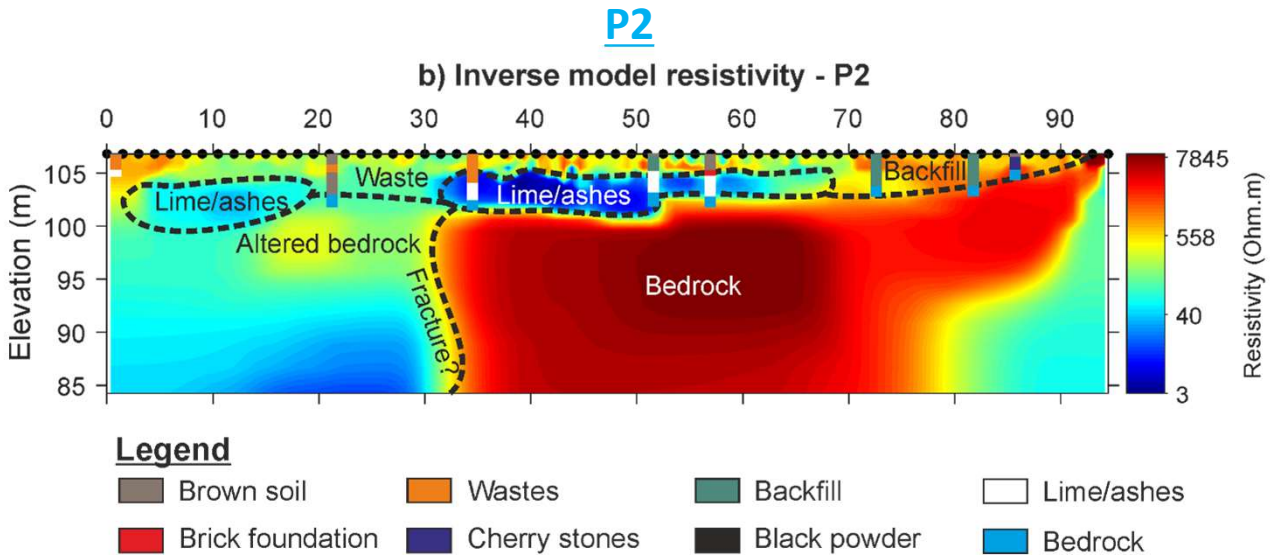
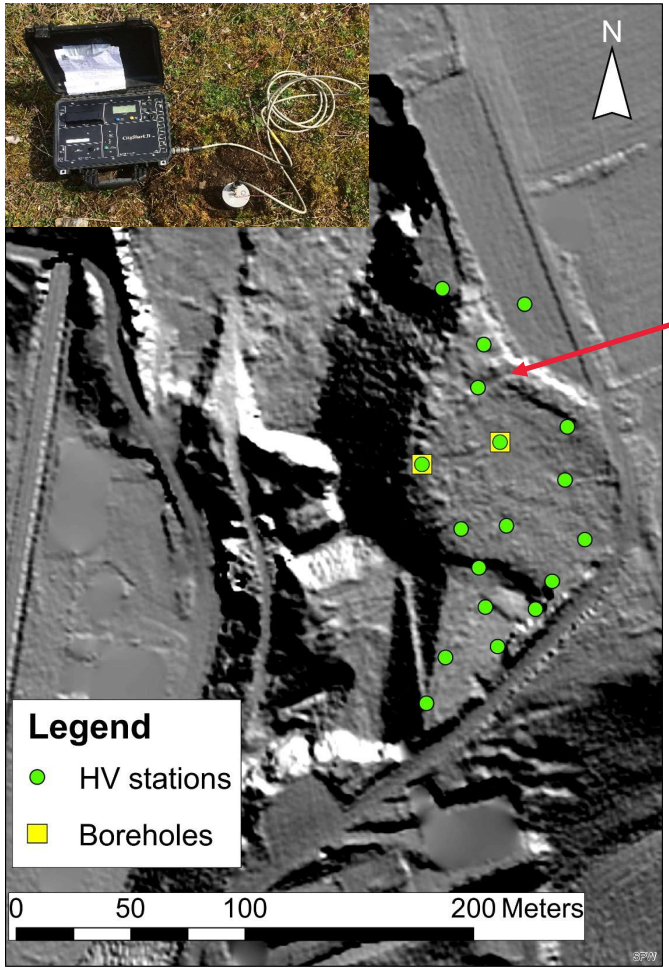
Sampling

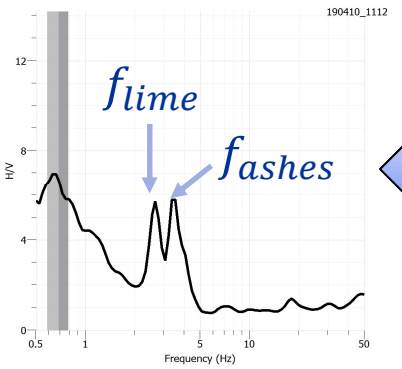




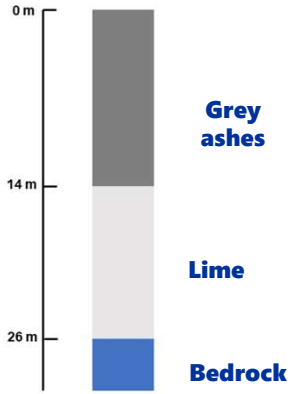
Refinement: H/V measurements



H/V measurement



Borehole log



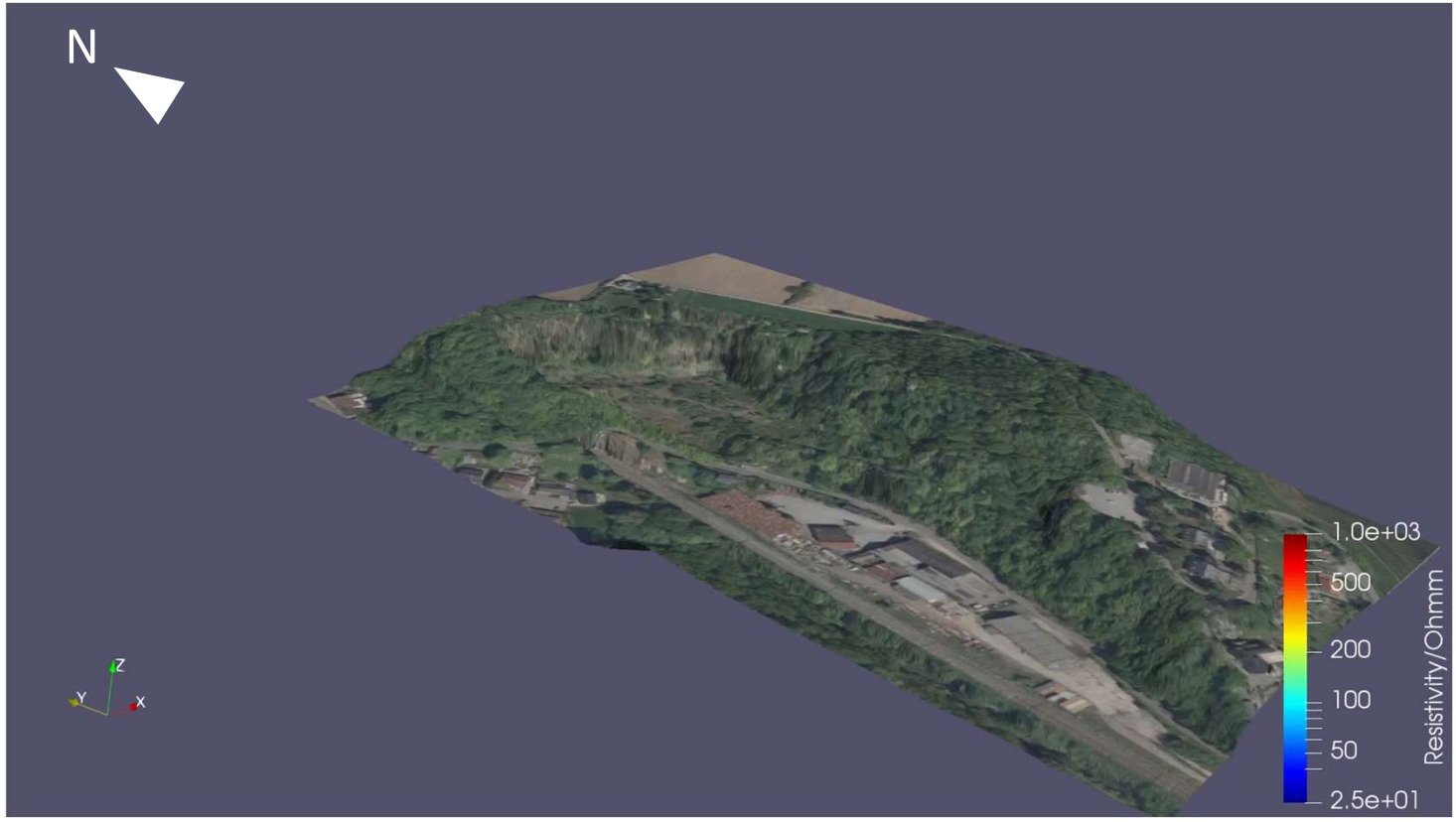
$V_{s\,lime} = 318 \frac{m}{s}$

$V_{s\,ashes} = 271 \frac{m}{s}$

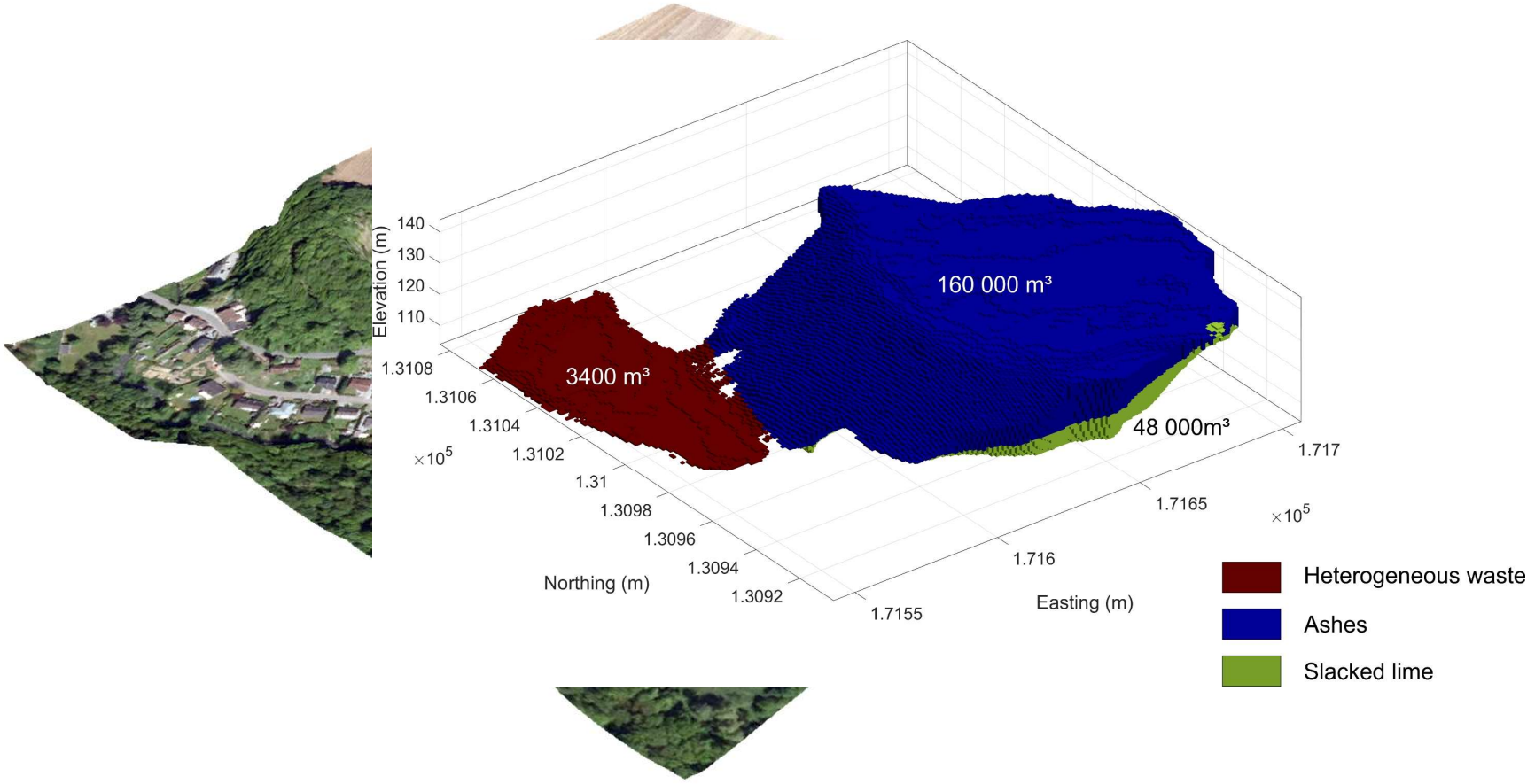
Possible to estimate the thickness of ash and lime at other HV stations

(Debouny, 2019)

Refinement: 3D ERT/IP



Resource distribution model



Summary: RAWFILL approach

1) Gather all available information

2) Use mapping methods (e.g. EM & Mag) to quickly delineate landfill extent, identify anomalies and decide upon location for more detailed 2D or 3D-surveys (ERT/IP, seismic)

3) Define a sampling plan based on geophysical results

4) Use ground truth data to calibrate and verify geophysical data

5) Build resource distribution model

In Onoz, this approach allowed to save up to 75 % of characterization costs

Raw materials recovered from landfills

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The Interreg North-West Europe Project is coordinated by SPAQuE and unites 8 partners from 4 EU regions.

SPAQuE.be
SAMEN MAKEN WE MORGEN MOOIER OVAM
LIÈGE université
BGS 1835 British Geological Survey Expert | Impartial | Innovative
atrasol SUSTAINABLE CONSULTANT
BAV Bergischer Abfallwirtschaftsverband
LES CHAMPS JOUAULT
Cleantech Flanders Powered by VITO

Interreg

EUROPEAN UNION

North-West Europe

RAWFILL

European Regional Development Fund

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Walloon region

Thank you!

Methods

- ERT/IP

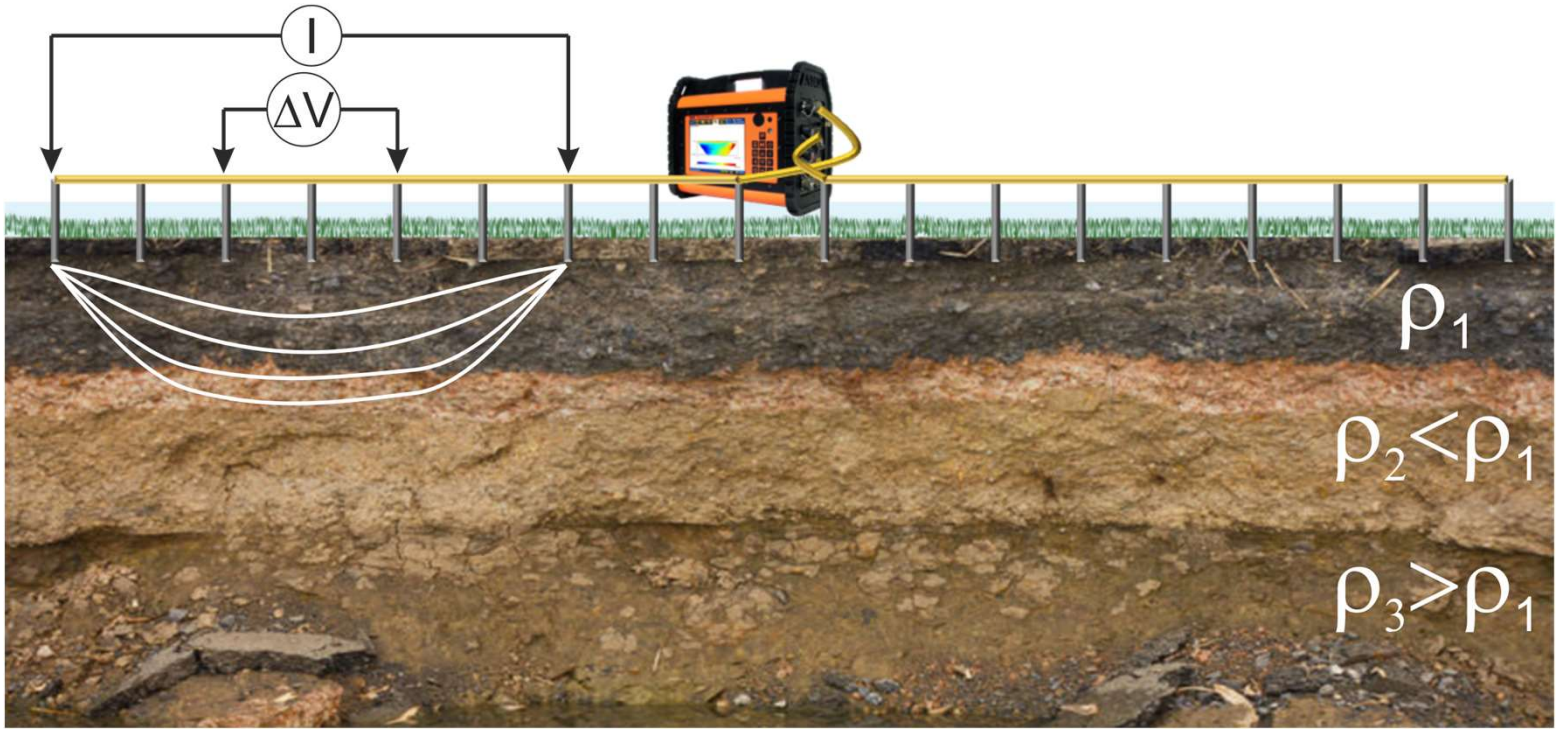
Stainless steel electrodes

Methods

- ERT/IP

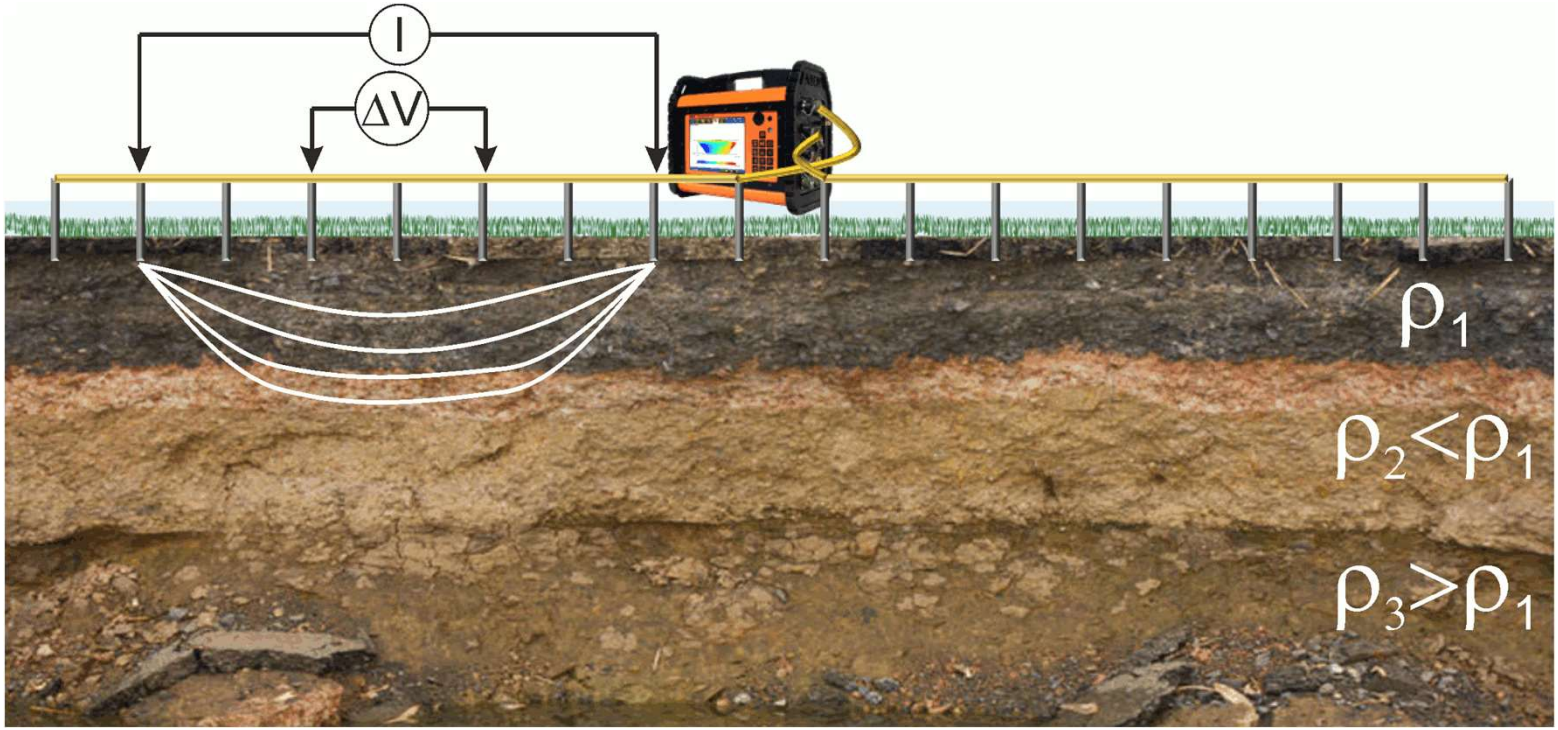
Methods

- ERT/IP

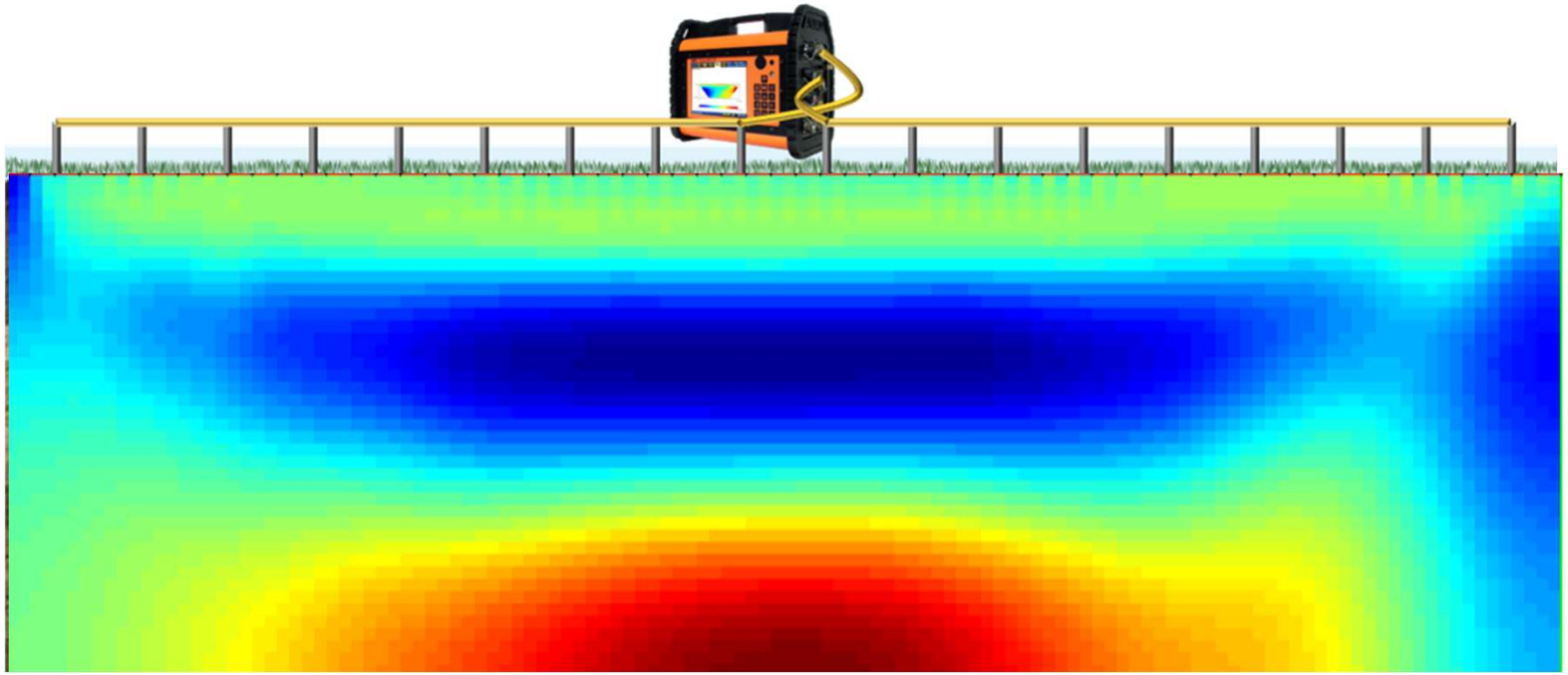


Methods

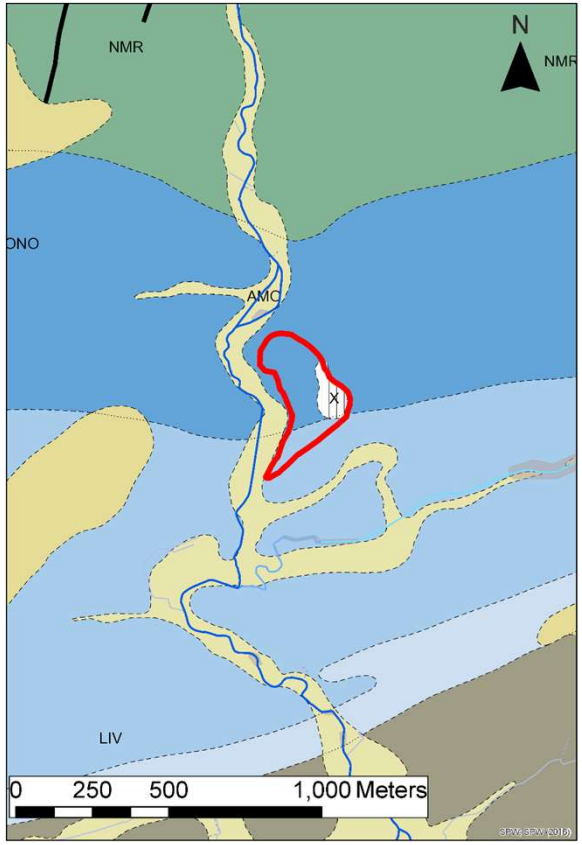
- ERT/IP



Methods



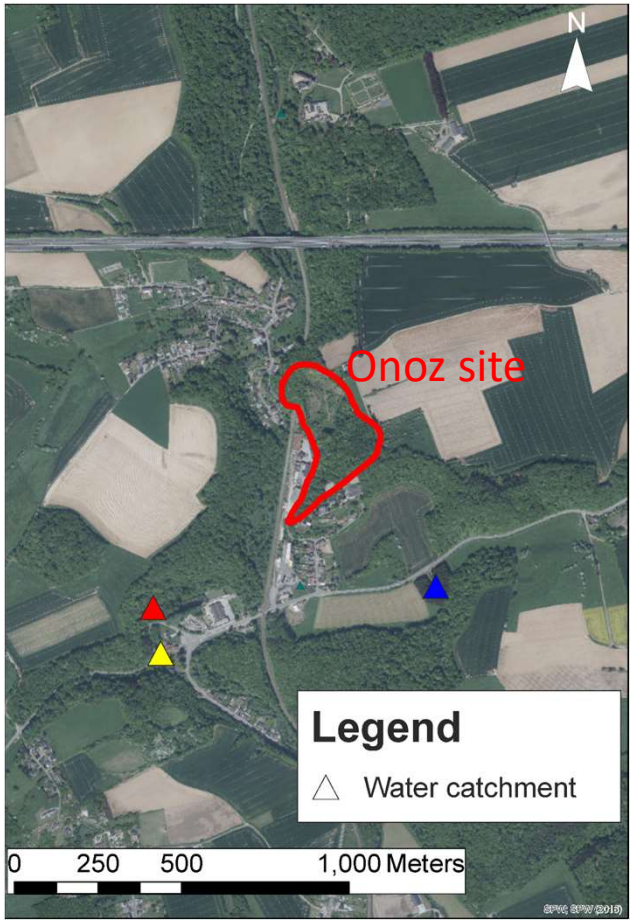
Site overview: geology

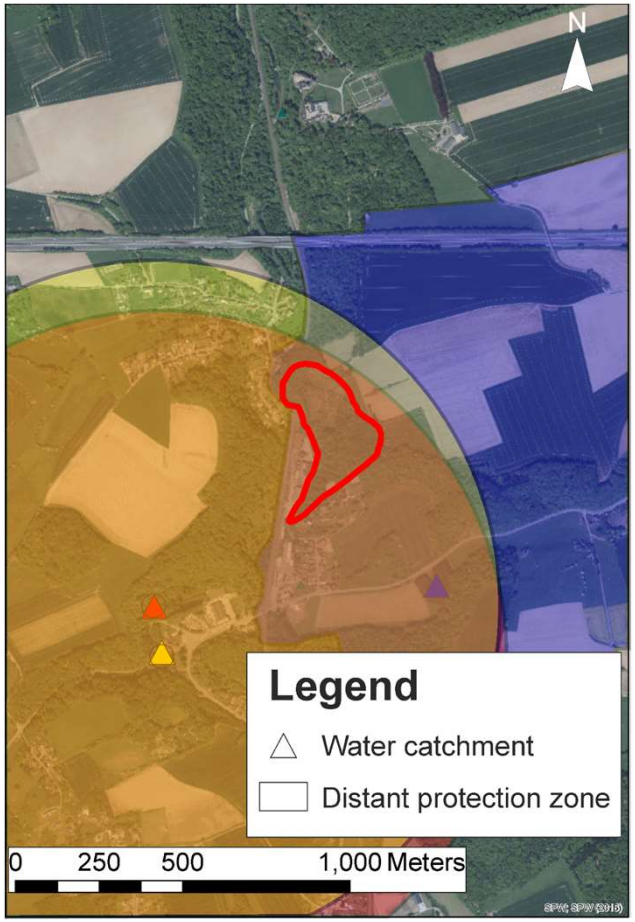


Legend

- Orneau river
- Modern alluvium - AMO
- Bruxelles formation - BXL
- Houiller group - HOU
- Hoyoux group - HOY
- **Lives Formation -LIV: Well-bedded limestones**
- **Onoz Formation - ONO: Thin- to thick-bedded limestones**
- Namur Formation - NMR

Context: water catchment





- Landfill is in the vicinity of three water catchments… and is located inside their distant protection zone

Results: EM at around 6 m depth

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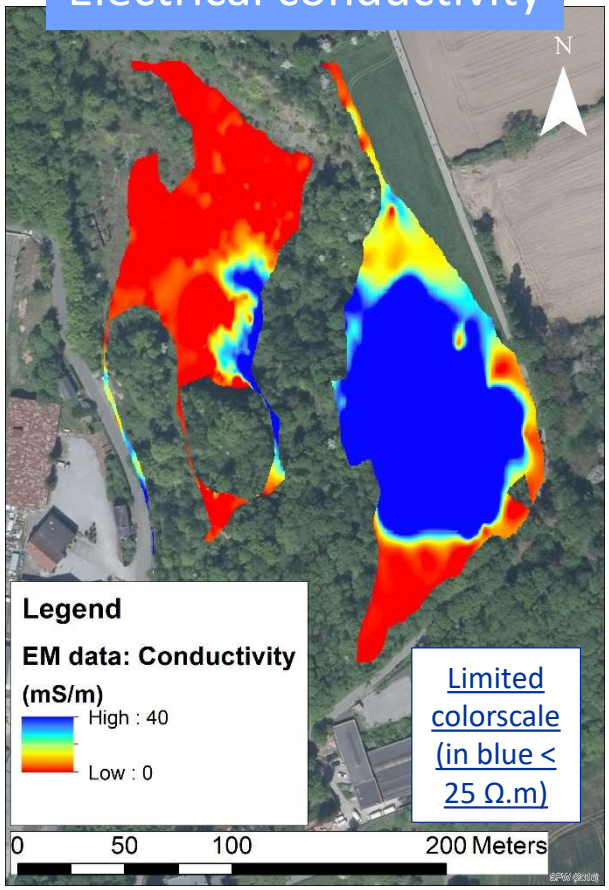
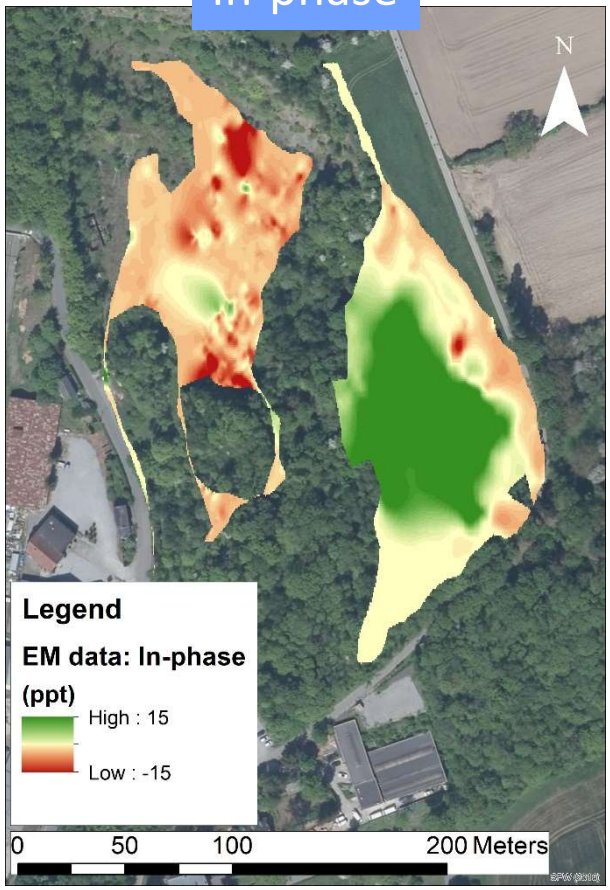
Electrical conductivity



Limited colorscale (in blue < 25 Ω.m)

In-phase



Results: ERT/IP

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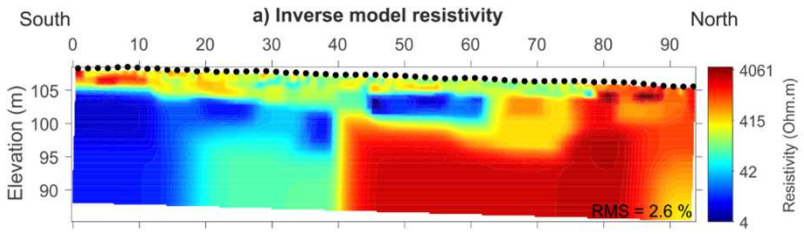
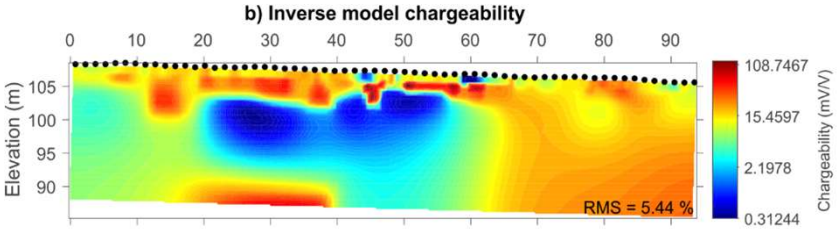
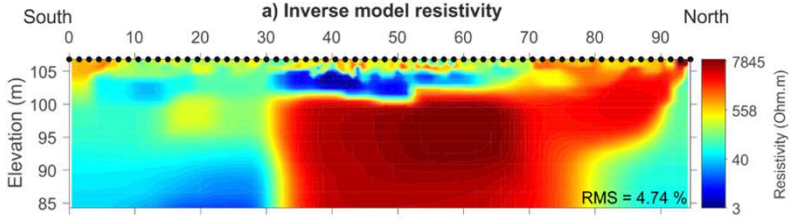
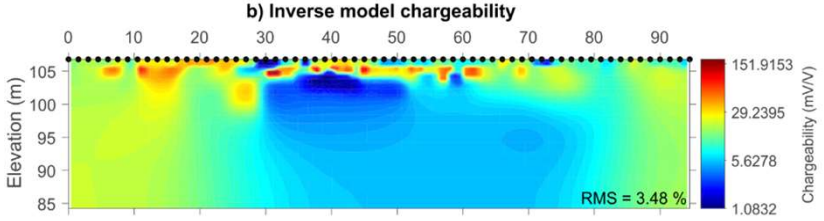
P1



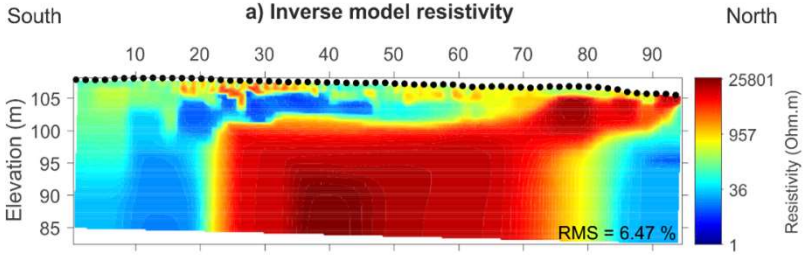


P2



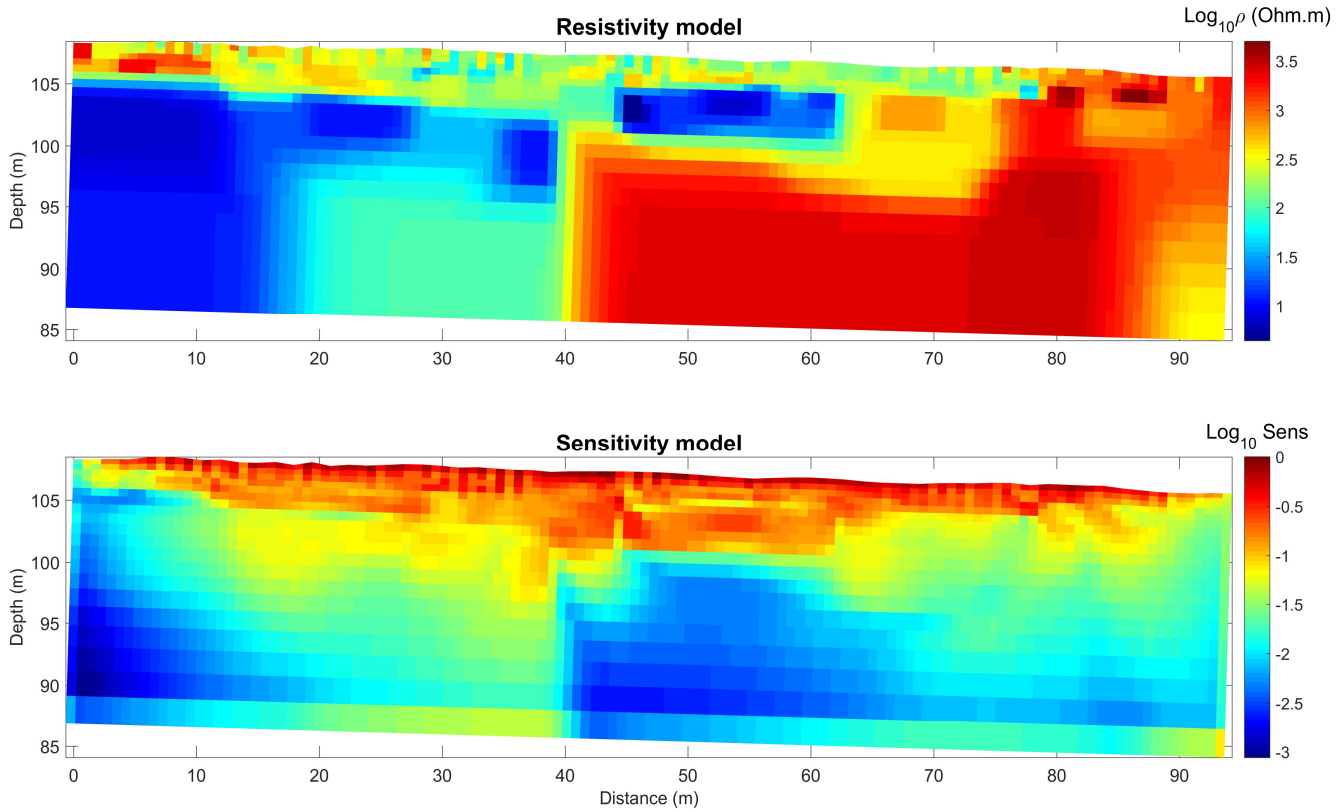


P3

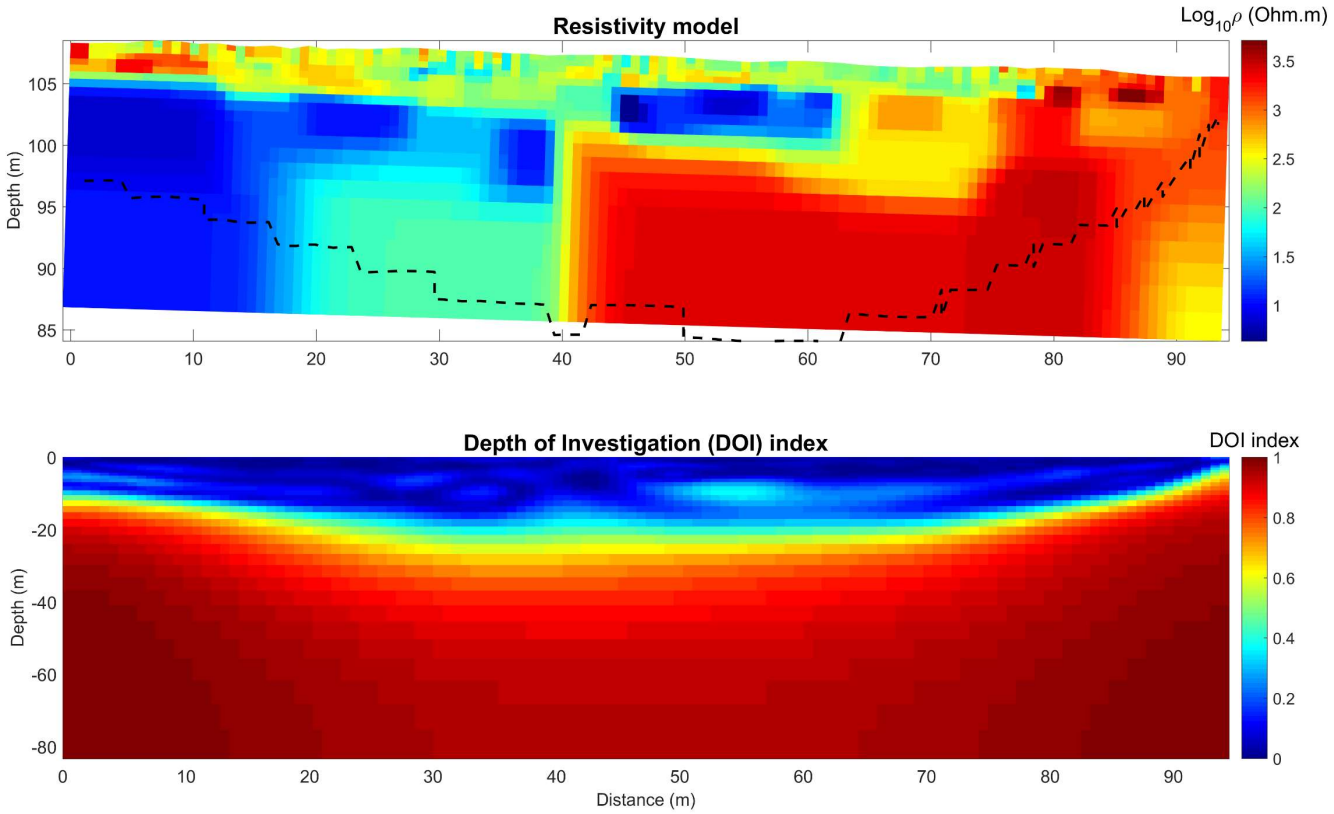


Similar structures observed in P2 and P3

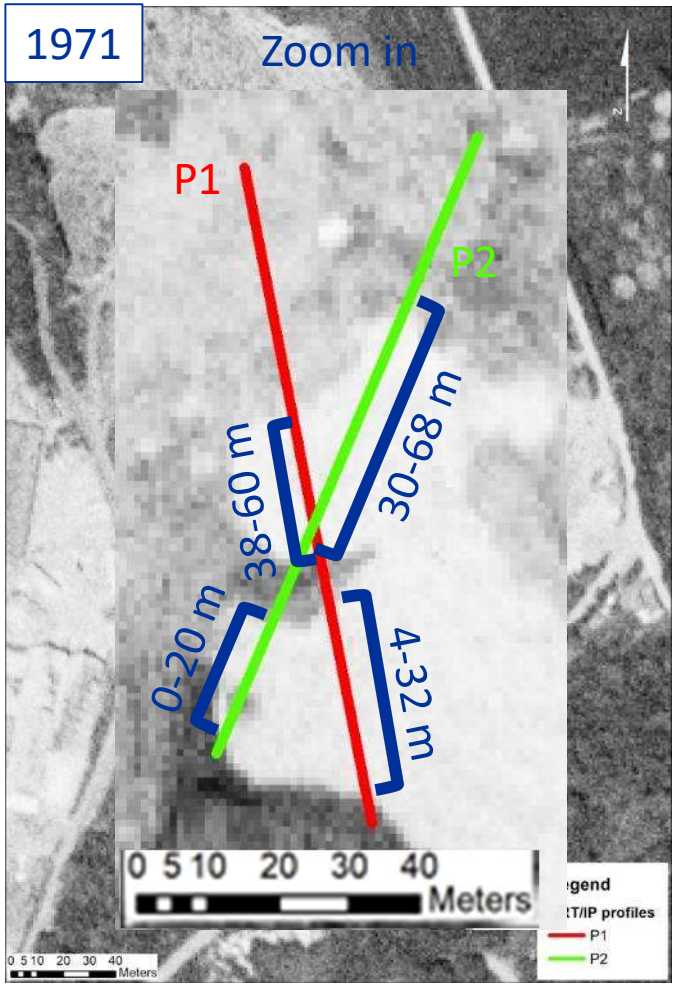
Sensitivity

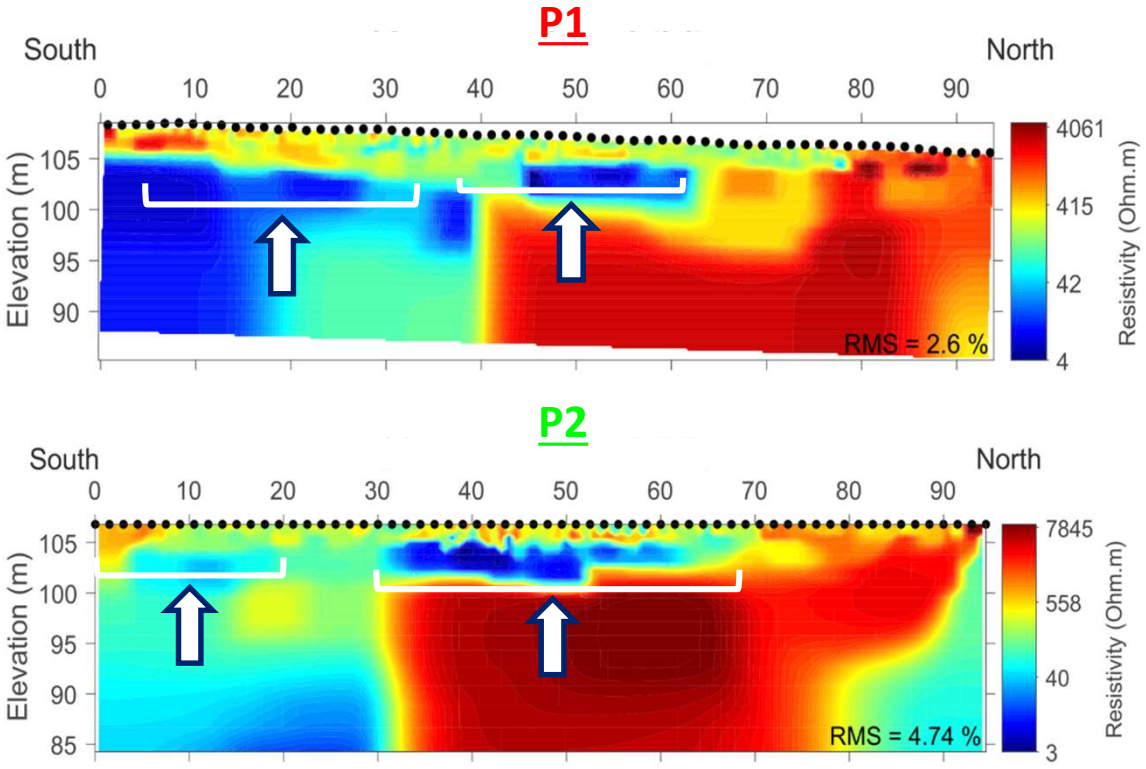


DOI


Resistivity model
$Log_{10}\rho$ (Ohm.m)
Depth (m)
105
100
95
90
85
0
10
20
30
40
50
60
70
80
90
3.5
3
2.5
2
1.5
1
Depth of Investigation (DOI) index
DOI index
Depth (m)
0
-20
-40
-60
-80
Distance (m)
1
0.8
0.6
0.4
0.2
0

Interpretation: ERT/IP





Validation with ground truth data

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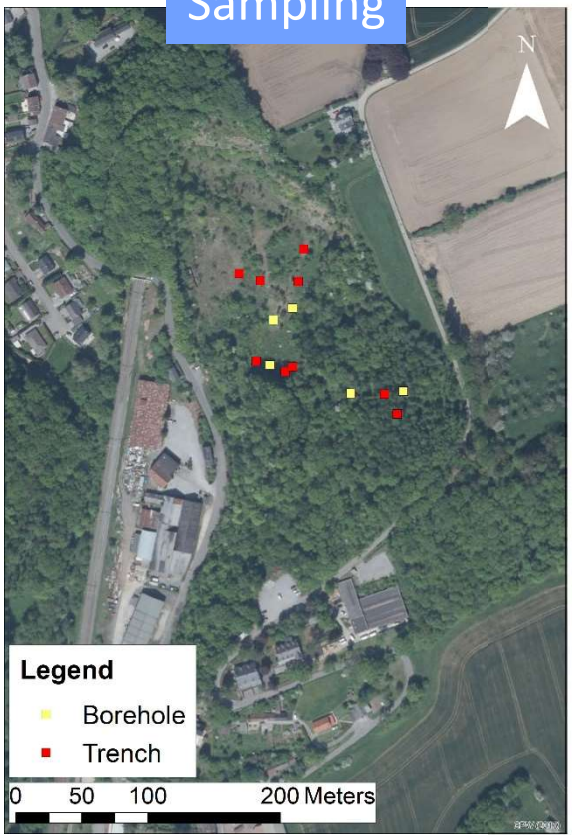
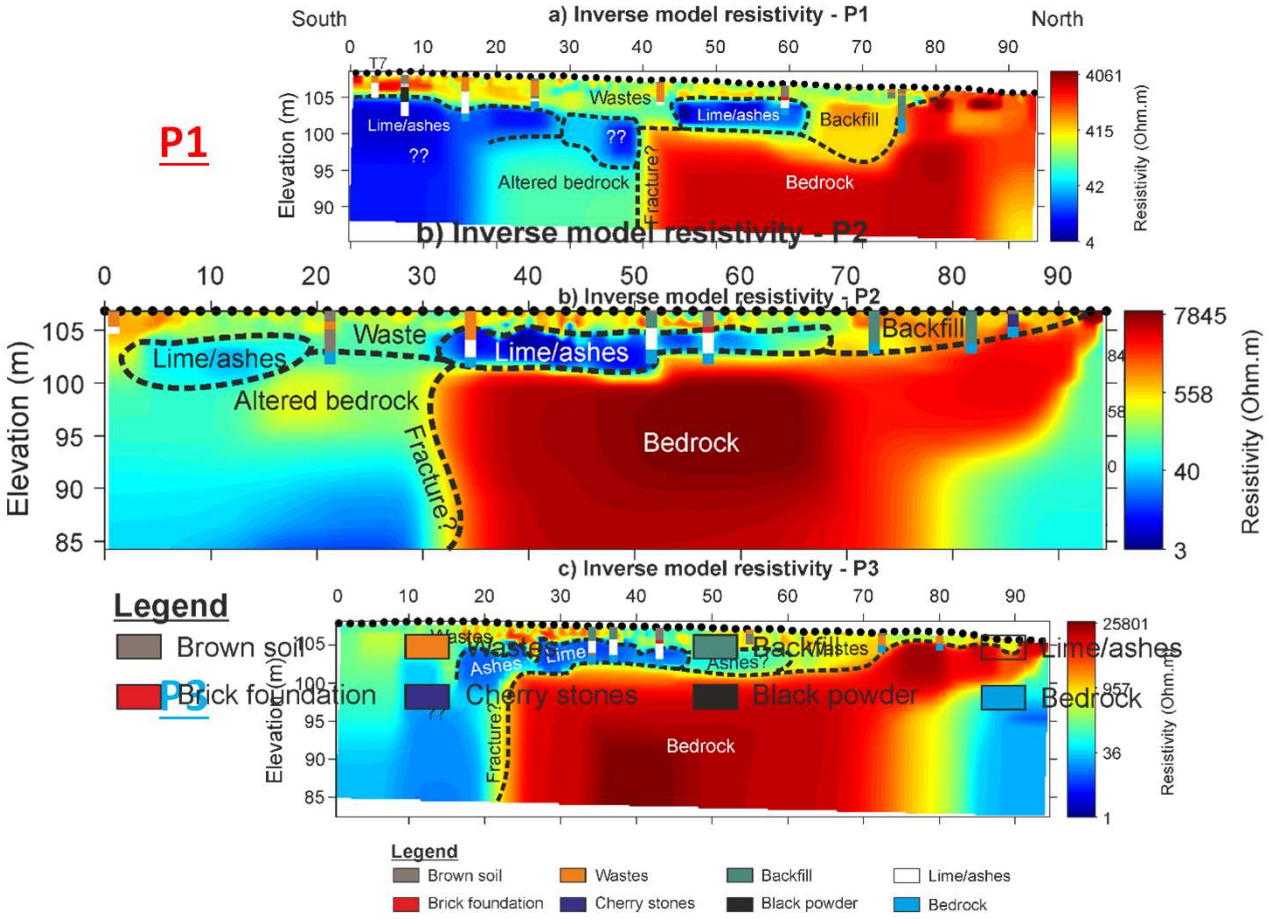
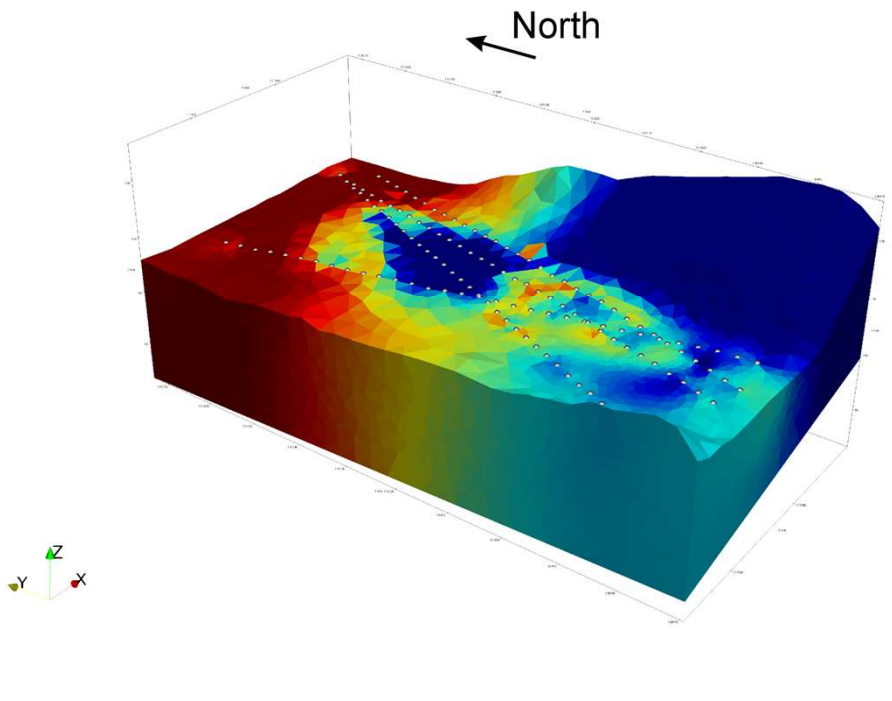
Sampling



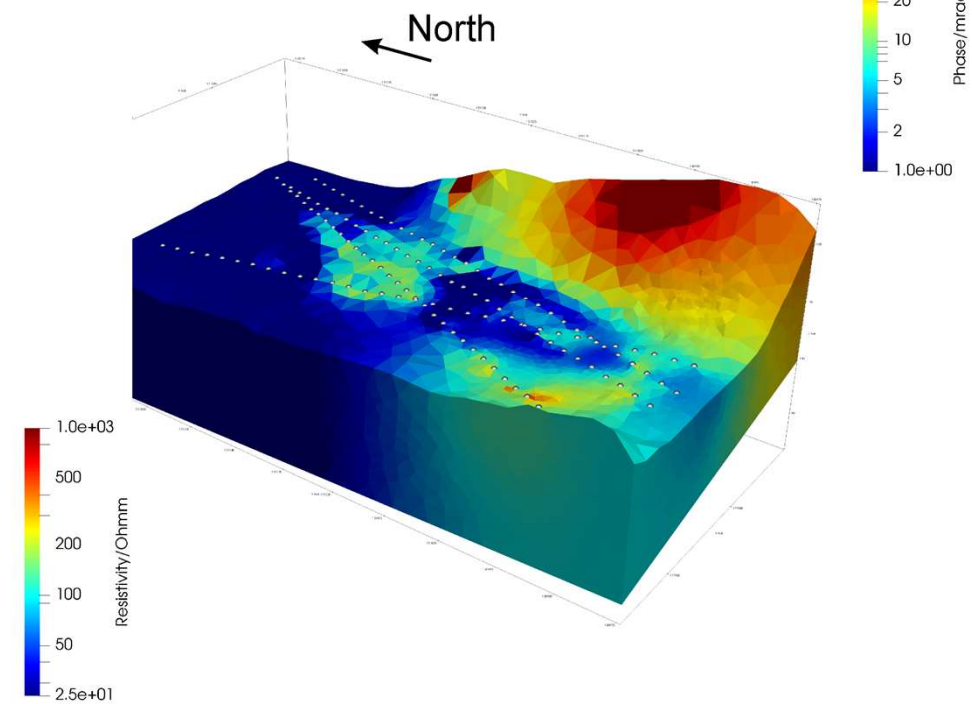


Refinement: 3D ERT/IP

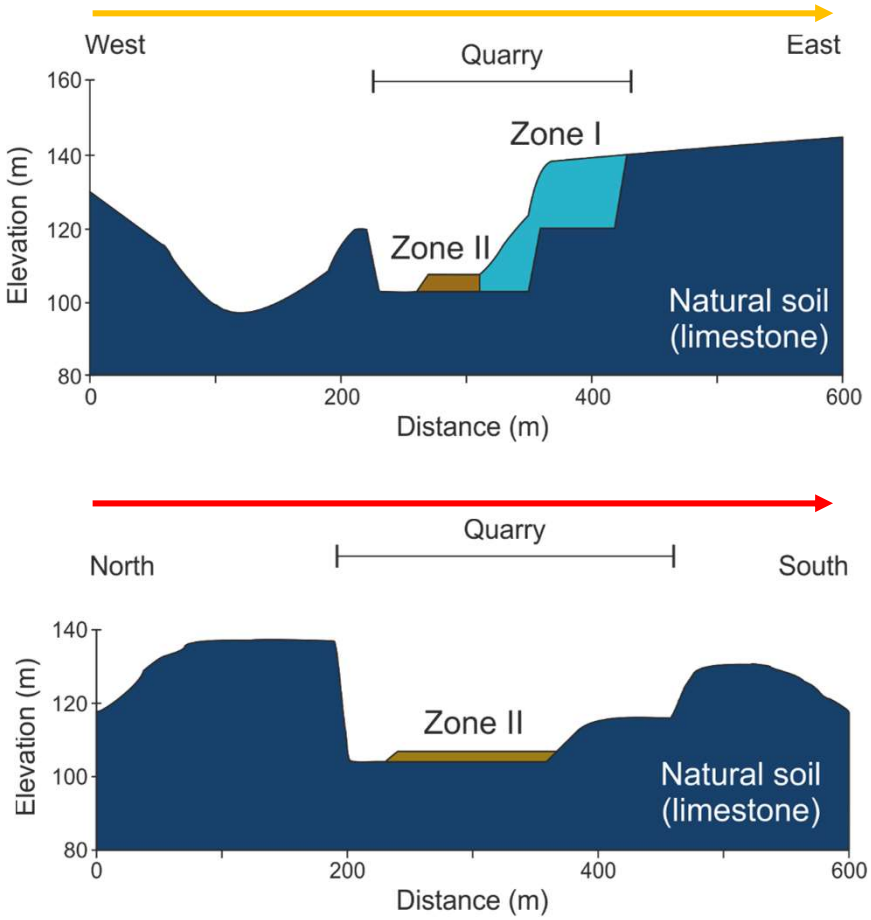
A) 3D Inverse resistivity model



B) 3D Inverse chargeability model



Site overview: current state



Soil contamination

ZONE	LAYER	TEST	POLLUTING ELEMENTS AND NORM EXCEEDANCE*
Lower	**Waste**	**Chemical**	▪ PAH > **TV** (T1,T2,T4,T6, F2), **VI** (T1, T4, F2) ▪ VOHC > **TV** (T1,T6, F2) ▪ Heavy metals > **TV**,**LV**, **VI** (T1 to T7 F2) ▪ Mineral oils > **TV** (T1,T2,T5,T6,T7, F2), **VI** (T1,T3,T4,T6, F2) ▪ Polychlorinated biphenyl (PCB) > **LV** (T1,T6)
		Leaching	▪ Heavy metals > **TV** (Pb), VI (Cu), **LV** (Al, Sb) ▪ Mineral Oils > **TV**, **VI** ▪ Total Organic Carbon (TOC) > Signal value ▪ …
	Lime	**Chemical**	▪ Heavy metals > **TV** (T1,T6), **VI** (T6, F2), **LV** (T6, F3) ▪ Mineral oils > **TV** (T1, T6, F2, F3) ▪ PCB > **LV** (T1) ▪ VOHC > **TV** (T1, F3), **VI** (T6, F2, F3) ▪ Hydrocarbons > **LV** (F2, F3) ▪ …
		Leaching	▪ VOHC > **TV** ▪ Heavy metals > **TV** (Pb), **LV** (Al, Ba) ▪ TOC > Signal value
Upper	**Lime**	**Chemical**	▪ Mercury > **TV** (F4, F5), **VI** (F4) ▪ Aluminium > **LV** (F4) ▪ Mineral oils > **TV** (F4, F5), **VI** (F5) ▪ VOHC > **TV** (F4), **VI** (F4, F5) ▪ Hydrocarbons > **LV** (F4, F5) ▪ …
		Leaching	▪ VOHC > **TV** ▪ Heavy metals > **TV** (Pb), **LV** (Al, Ba) ▪ TOC > Signal value
	Ashes	**Chemical**	▪ Aluminium > **LV** (T8, F4, F5) ▪ Mineral oils > **TV** (F4, F5) ▪ PAH > **TV**, **VI** (F5) ▪ VOHC > **VI** (F4, F5)
		Leaching	▪ Arsenic > **TV** ▪ Aluminium > **VL** ▪ Fluorides > **VL**

(Debouny, 2019)

HVNSR theory

Interreg North-West Europe RAWFILL
European Regional Development Fund
Co-funded by the Walloon region

BIMODAL MODEL

$$f_0 = \frac{V_S}{4\,H}$$

TRIMODAL MODEL

$$f_1 = \frac{1}{4\left(\frac{H_0}{V_{S0}} + \frac{H_1}{V_{S1}}\right)}$$

Cost-benefit analysis

Onoz case

	Traditional approach only		RAWFILL approach	
Characterization actions	• 1 borehole per 250 m² (20 m depth in Zone 1, 6 m depth in Zone 2) → 736 m in total • 1 trial pit per 250 m²		• 3 ERT and IP profiles • EM mapping (1/2 day) • MAG mapping (1/2 day) • 4 trial pits • 5 boreholes (65 m in total)	
Estimated cost	736 × 100 € 4 × 800 € 1000 € **77800 €**	Boreholes 4 days of trial pitting Machine transport **TOTAL**	65 × 100 € 2 × 800 € 3 × 2500 € 1100 € 2000 € 1000 € **19700 €**	Boreholes 2 days of trial pitting ERT/IP profiles EM mapping MAG mapping Machine transport **TOTAL**

75% savings with the RAWFILL approach for this site