Interreg North-West Europe RAWFILL

European Regional Development Fund

EUROPEAN UNION

Co-funded by the Walloon region

High-performing **A**cquisition of landfill **D**ata by using a geophysical **E**xploration and **S**urveying **S**trategy **(HADESS)**

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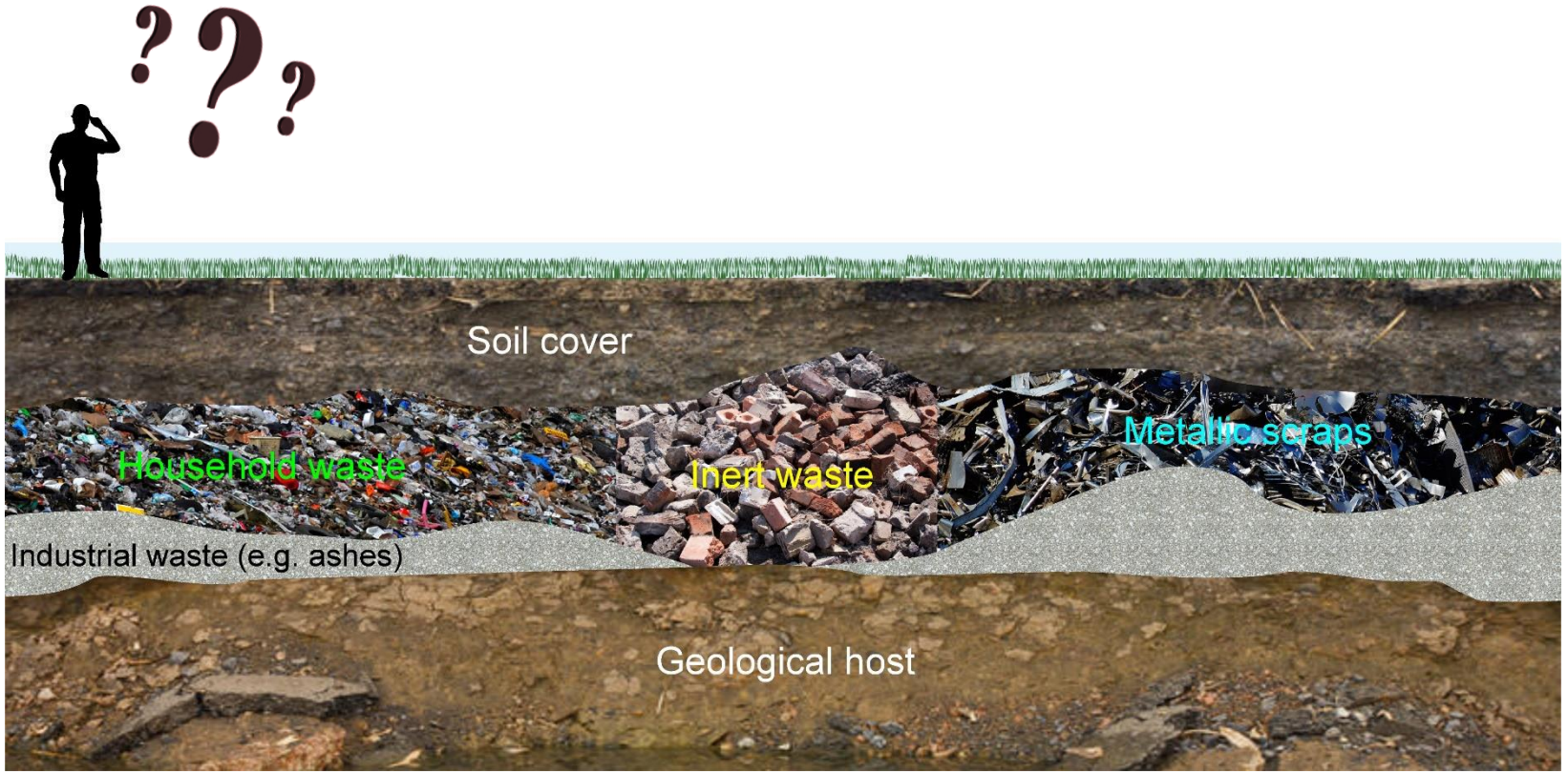
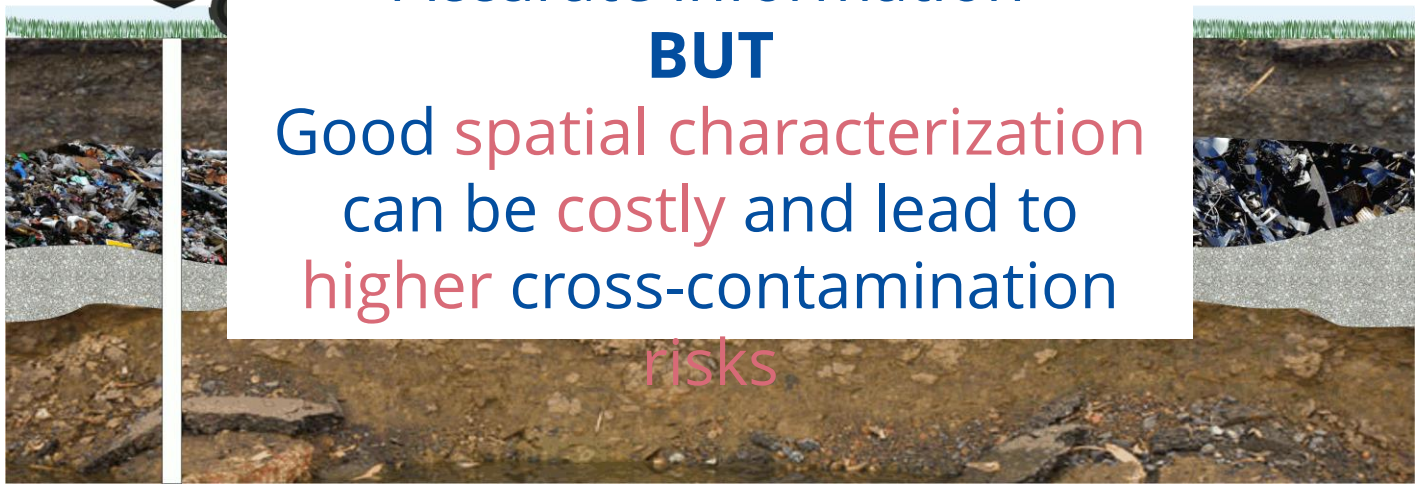
A short introduction to geophysics

"The subsurface site characterization of the geology, geological structure, groundwater, contamination, and human artifacts beneath the Earth's surface, based on the lateral and vertical mapping of physical property variations that are remotely sensed using non-invasive technologies" (EEGS 2018)

Why geophysics for landfill characterization?



Traditional approach: drilling – sampling - analysis



Accurate information
BUT
Good spatial characterization can be costly and lead to higher cross-contamination risks

RAWFILL - HADESS

Combine geophysics with traditional techniques

How?

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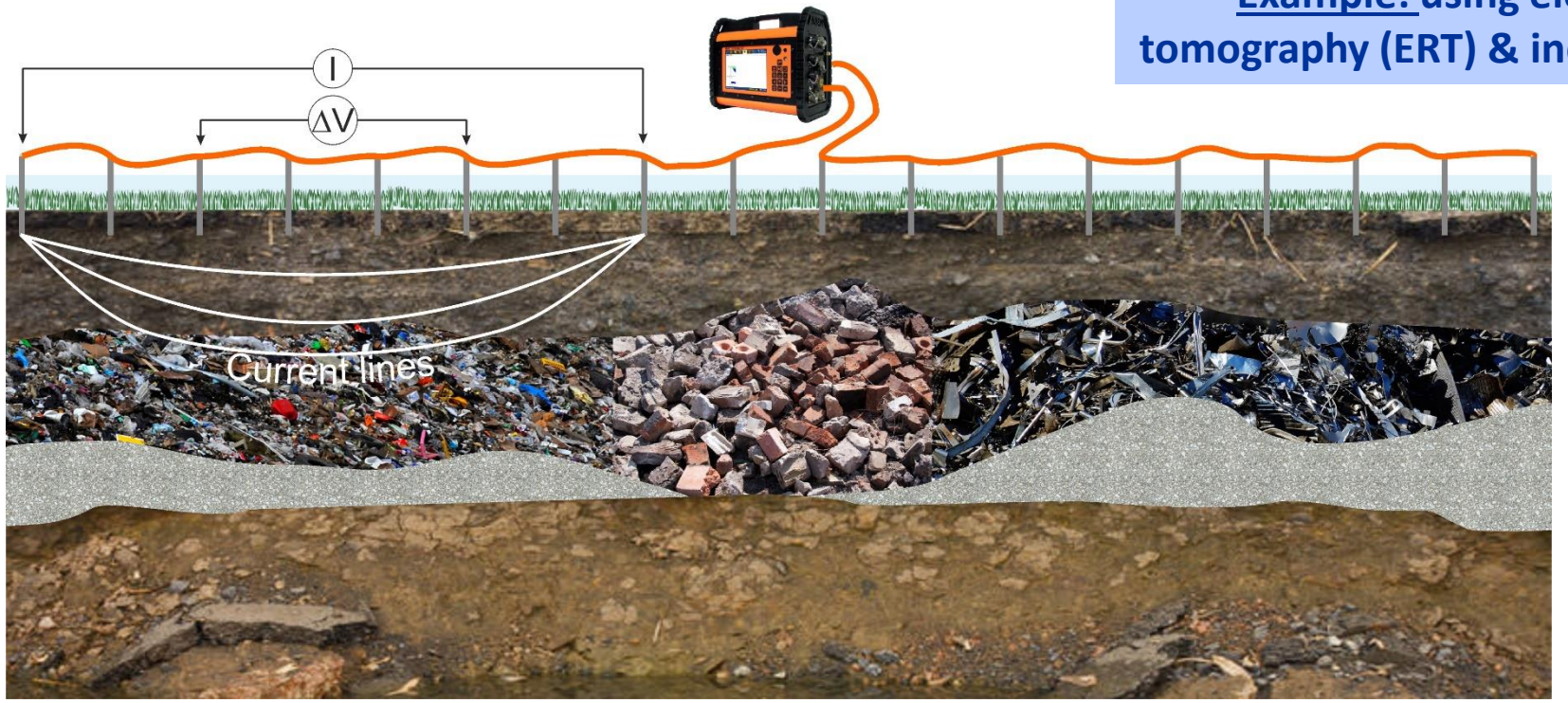
Principle 1:
combine complementary geophysical methods

Example: using electrical resistivity tomography (ERT) & induced polarization (IP)



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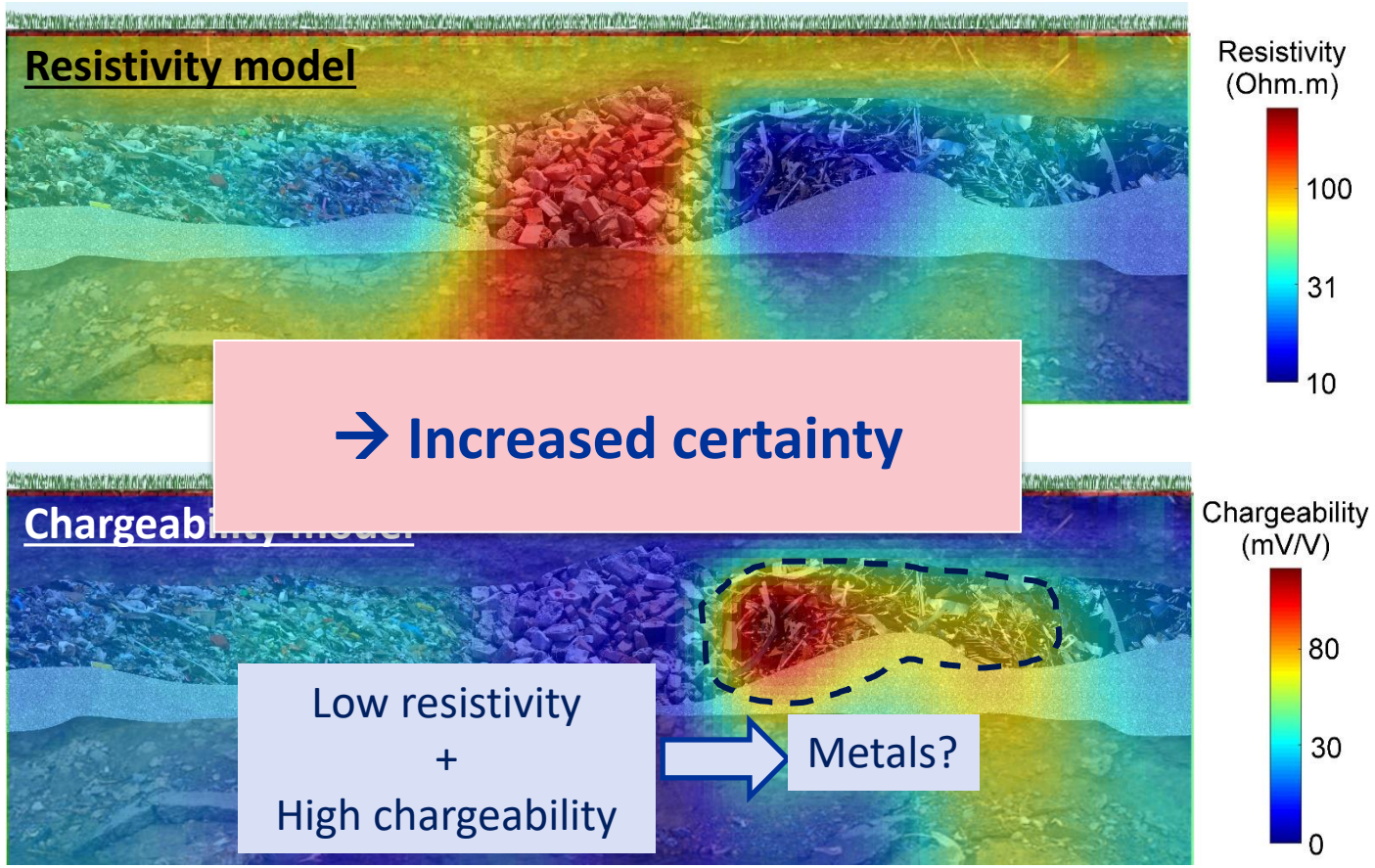
Principle 1: combine complementary geophysical methods



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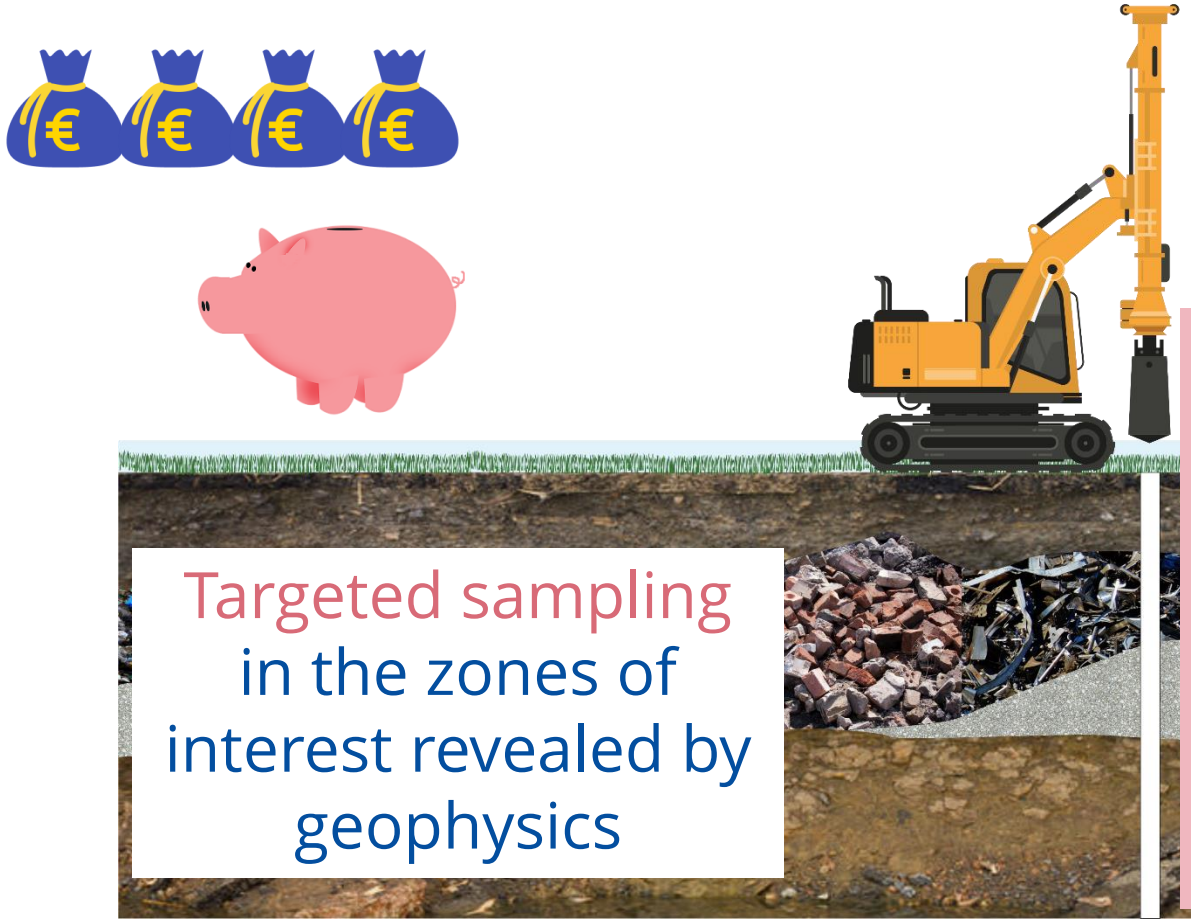
Principle 2: targeted sampling



Targeted sampling in the zones of interest revealed by geophysics

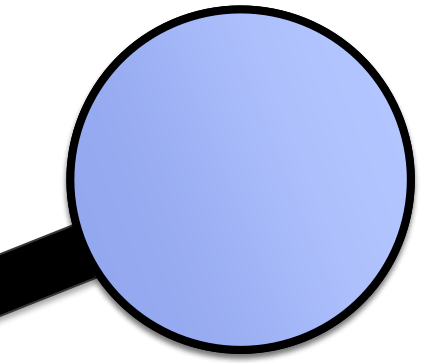
- Lower costs
- Reduced risk of damaging structures
- Reduced risks of contamination or exposure to hazardous materials

Pros and cons

- Non to minimally invasive
- Relatively low cost
- Large coverage
- See through technology

- Indirect information
- Resolution decreases with depth
- Prone to modeling errors (artefacts)
- Ambiguity

Proposed workflow of HADESS



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- Gather and summarize all available information
  → Build conceptual model
  → Assess knowledge gaps

Geophysical characterization

- Use complementary geophysical methods planned according to the conceptual model
  → Interpretation of geophysical results and detection changing properties

Calibration & validation

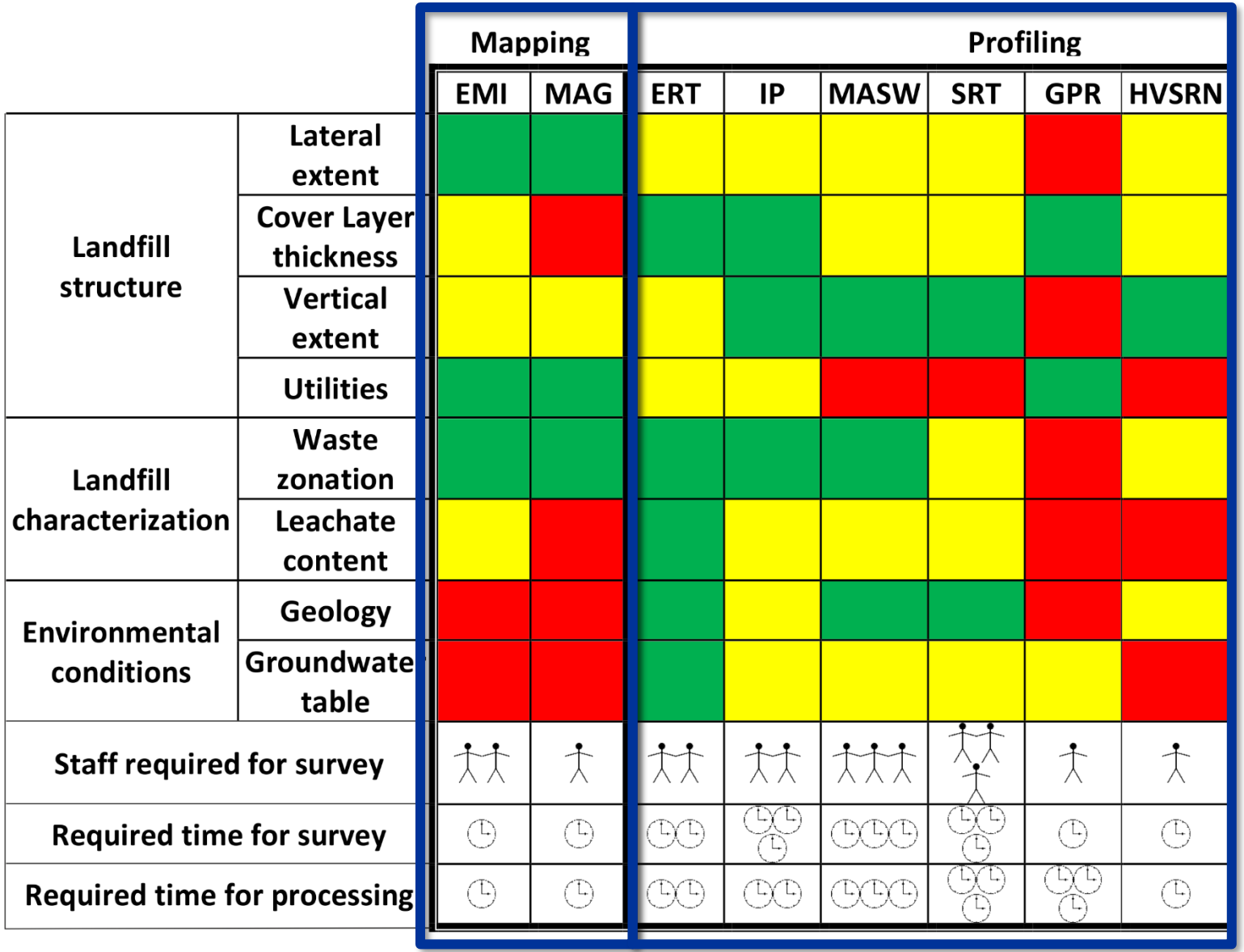
- Targeted sampling
  → Build sampling plan according to geophysical results
  → Verify and calibrate geophysical measurements to refine conceptual model

Additional measurements required?

Resource model construction

- Build a resource distribution model based on refined conceptual model

Geophysical methods



Geophysical methods

- Measure different/complementary geophysical properties
- Have different advantages and disadvantages

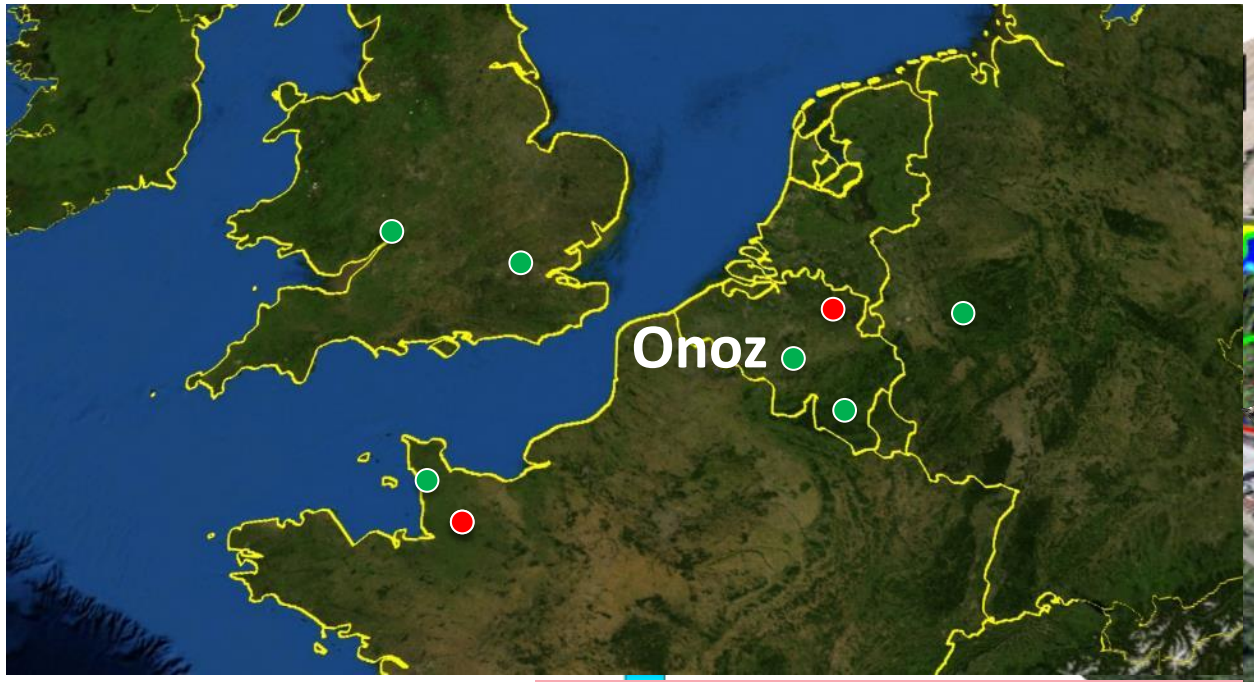
Mapping methods:

- Provide a wide spatial coverage
- Relatively easy to deploy and acquire data

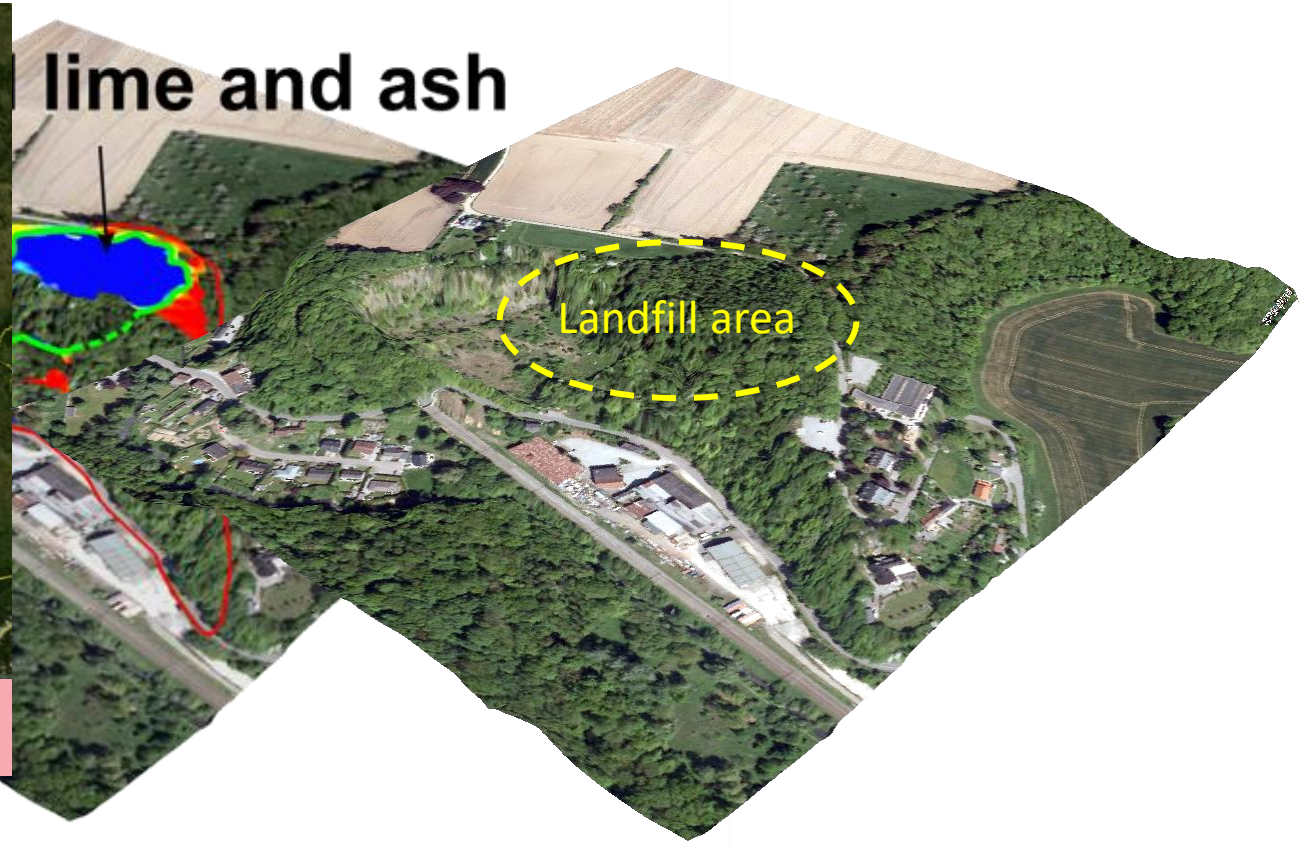
Profiling methods:

- Provide more detail and vertical resolution
- Require more staff time for fieldwork and processing

Mapping methods: Electromagnetic induction (EMI)

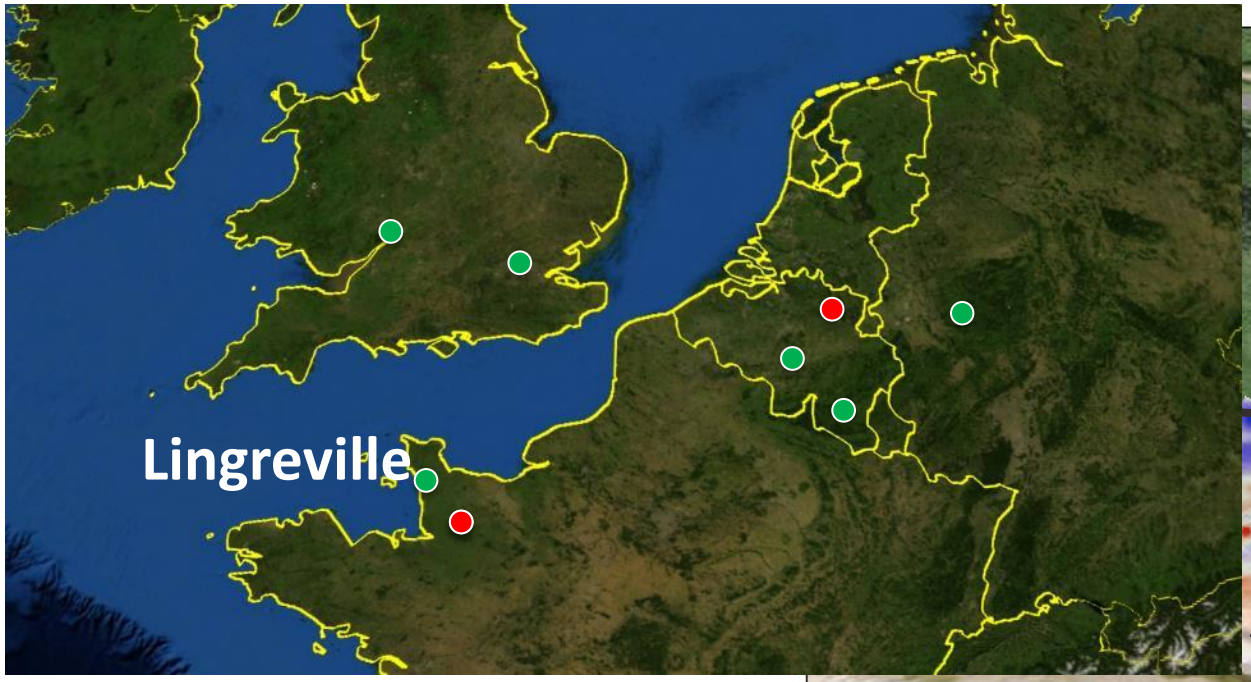


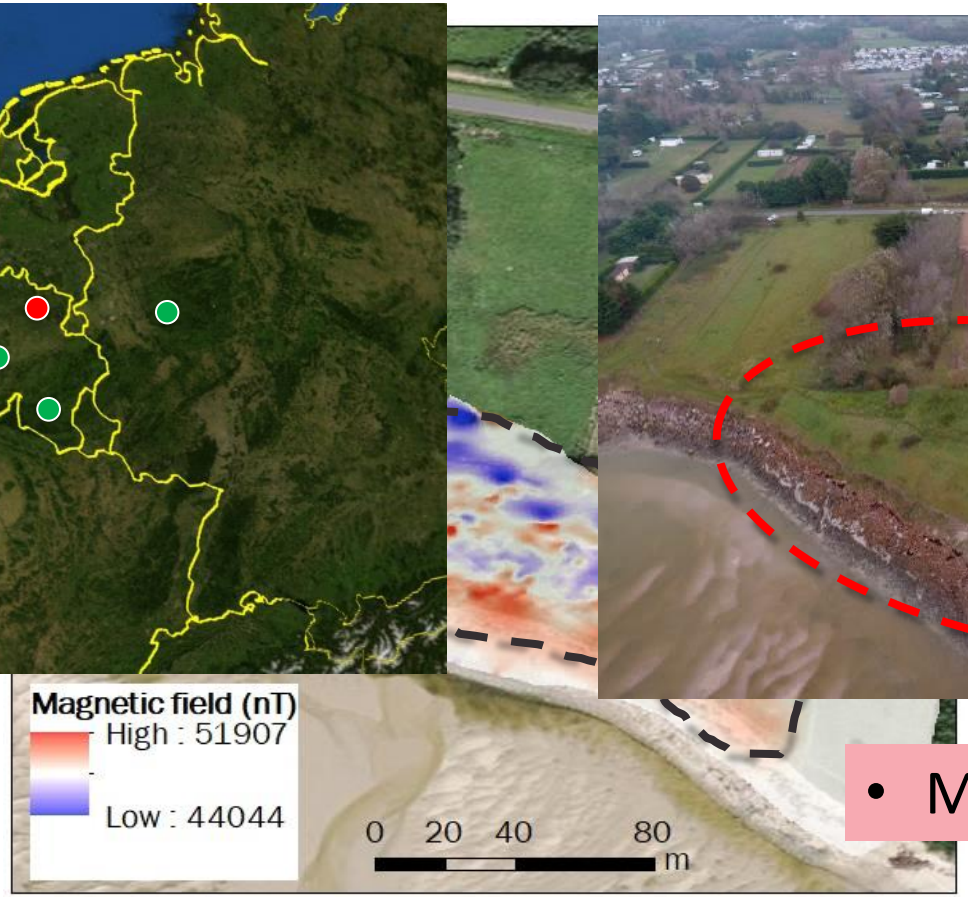
- Mainly industrial waste



Low

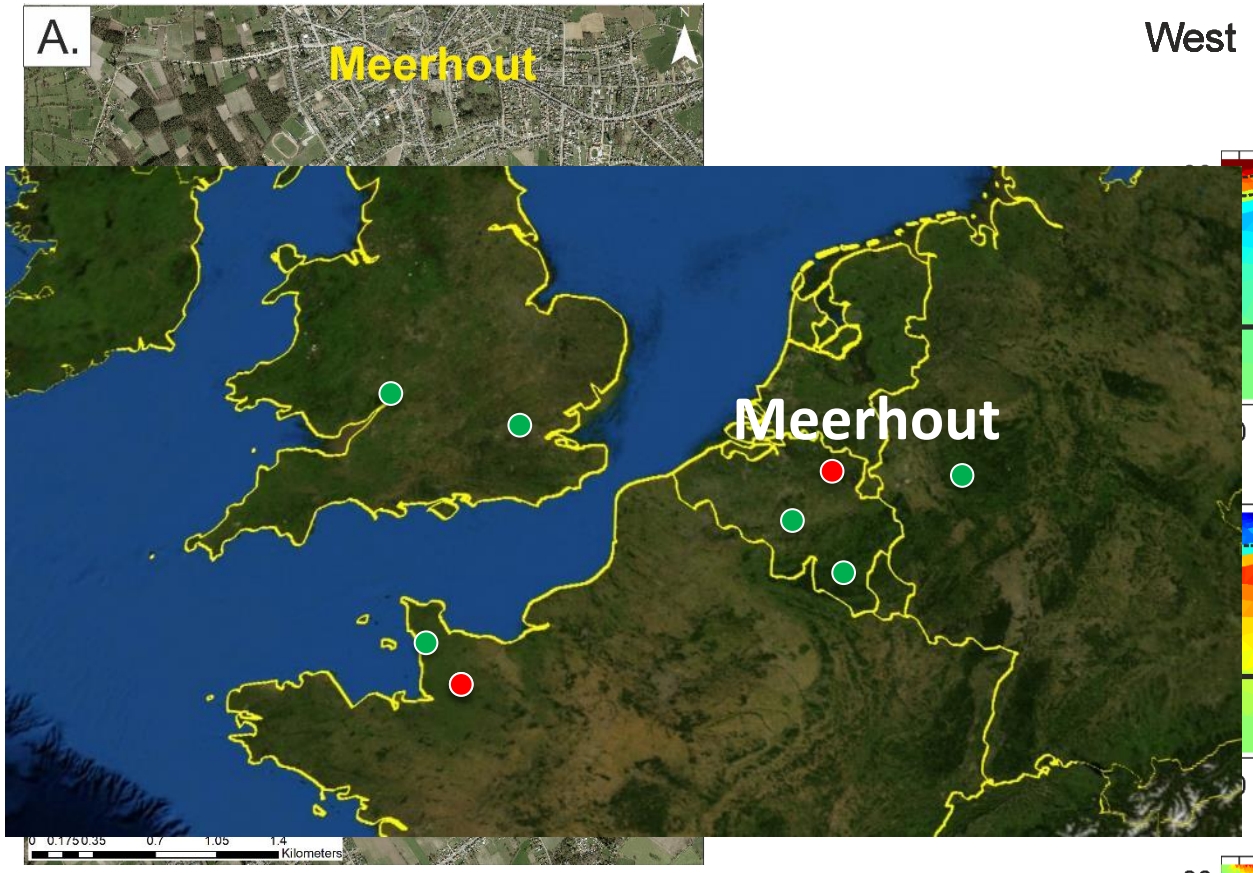
Mapping methods: Magnetics

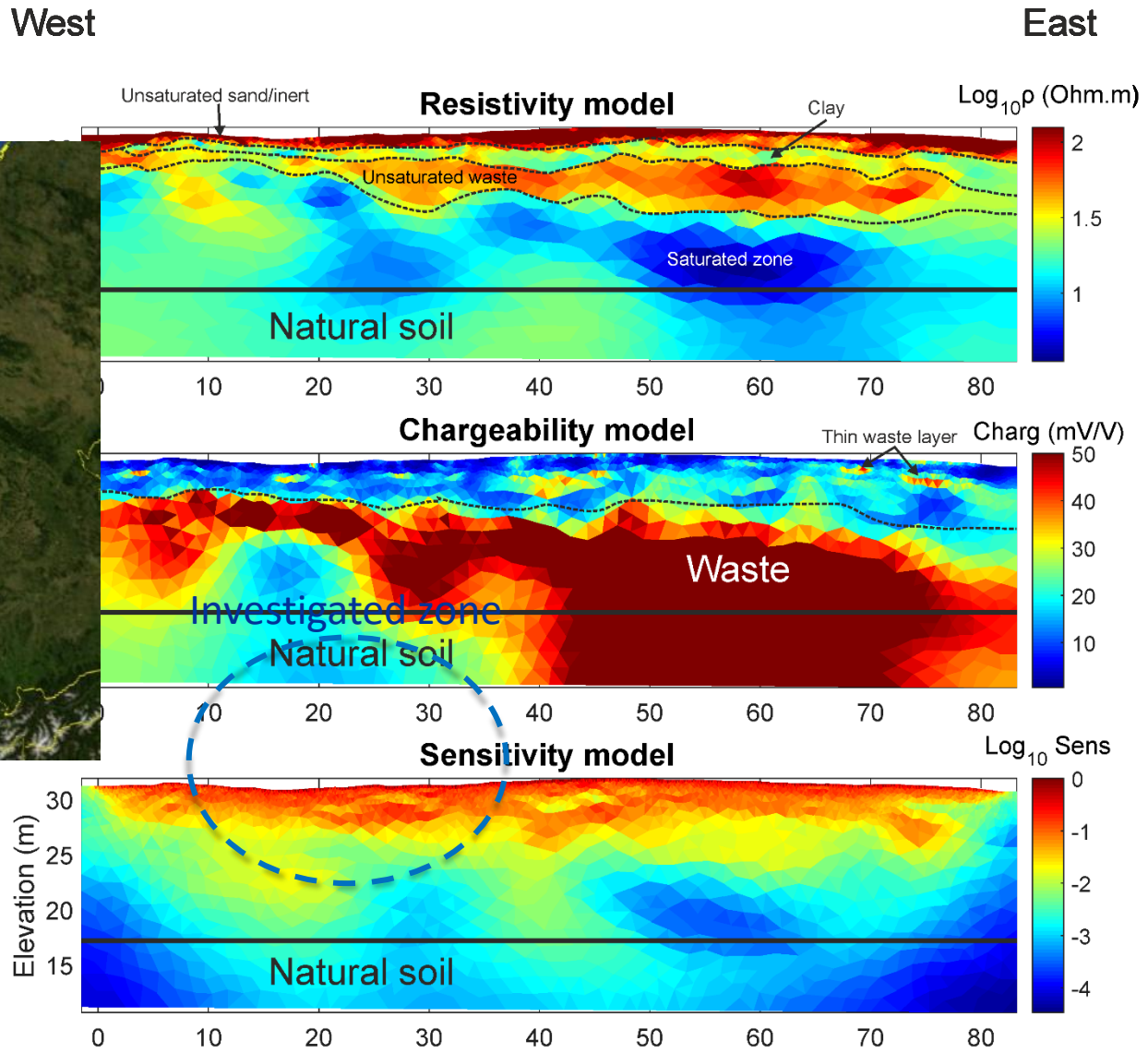




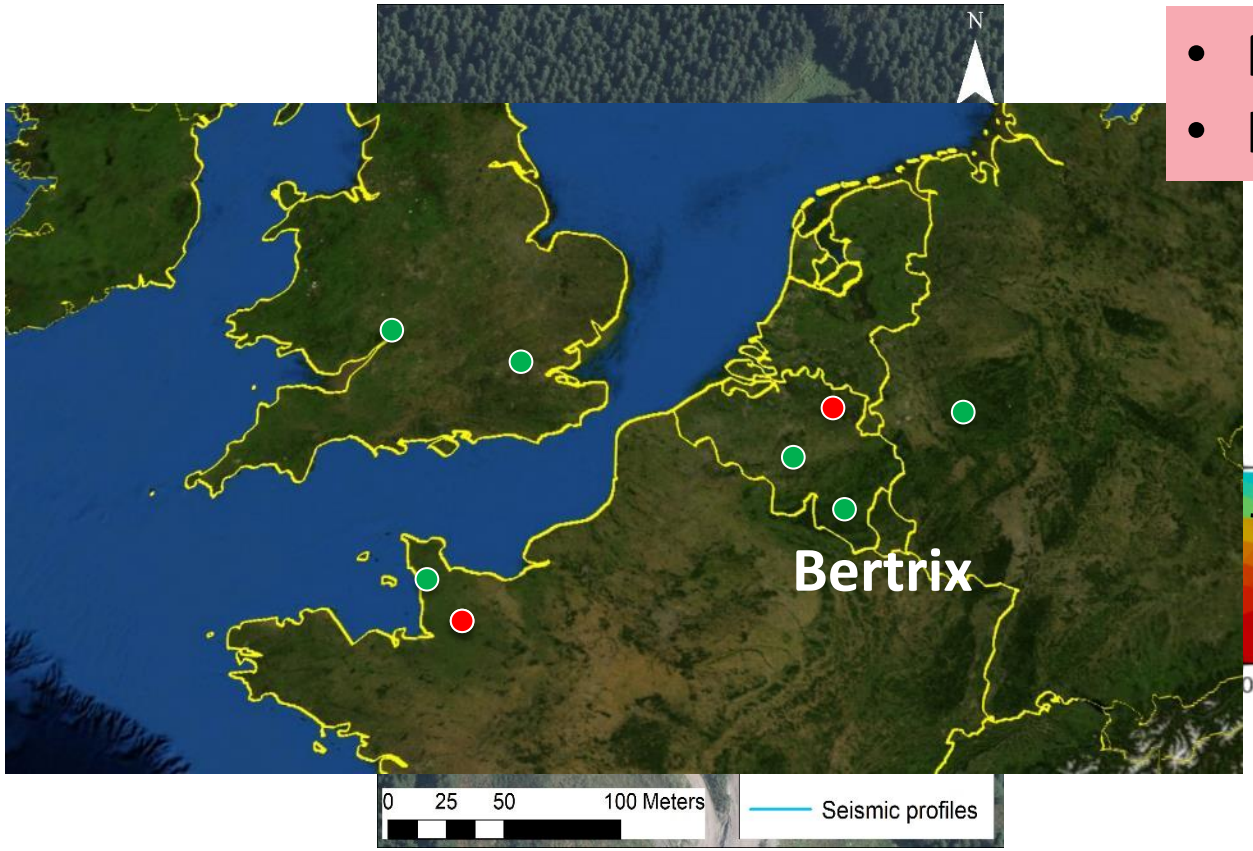
- Municipal solid waste

Profiling methods: ERT/IP



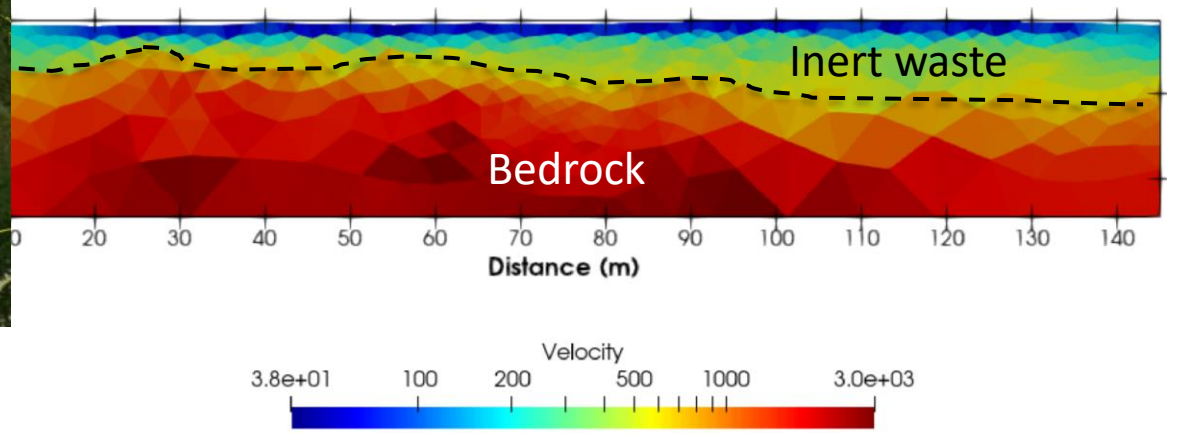


Profiling methods: Seismics

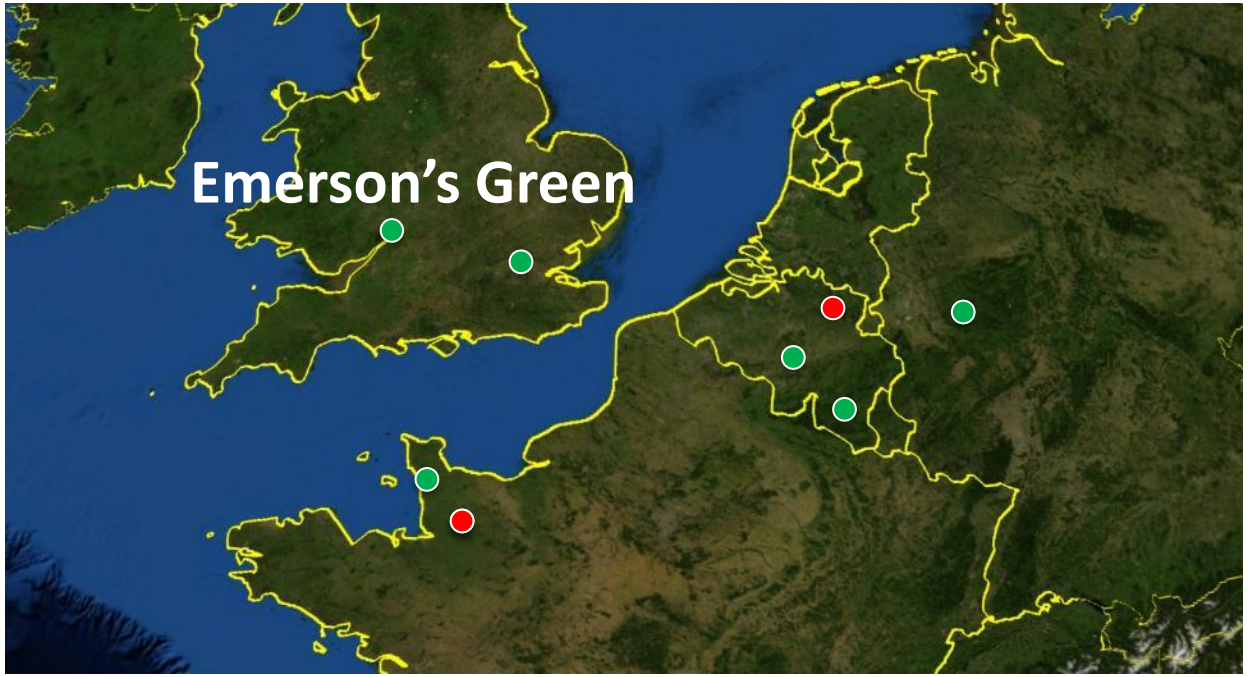


- Municipal solid waste
- Inert waste

P-wave velocity model



RAWFILL methodology applied to a real case study: Emerson's Green (UK)



Case study: Emerson's Green (UK)

- Location: UK, near Bristol
- Excavated for new housing in 2019

Case study: Emersons Green

- Location: UK, near Bristol
- Excavated for new housing in 2019

→ ground truth data to calibrate geophysics

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Geophysical characterization

Calibration & validation

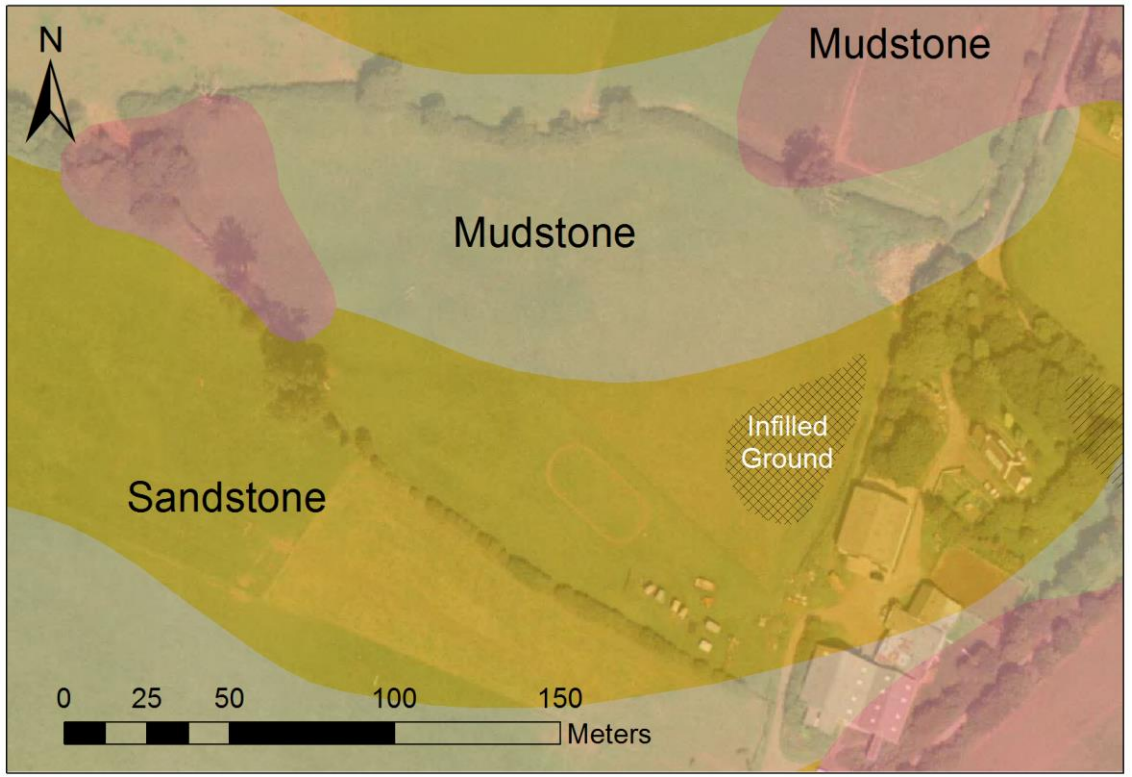
Resource model construction

Step 1) Information gathering: desk study

Landfill size: 23,000m^2
Smooth topography

Geology:
- North: Mudstone
- South: Sandstone
- East: historic quarry

Landfill operation (1984 – 1991)
- Inert & industrial/commercial waste
- Dilute & disperse basis



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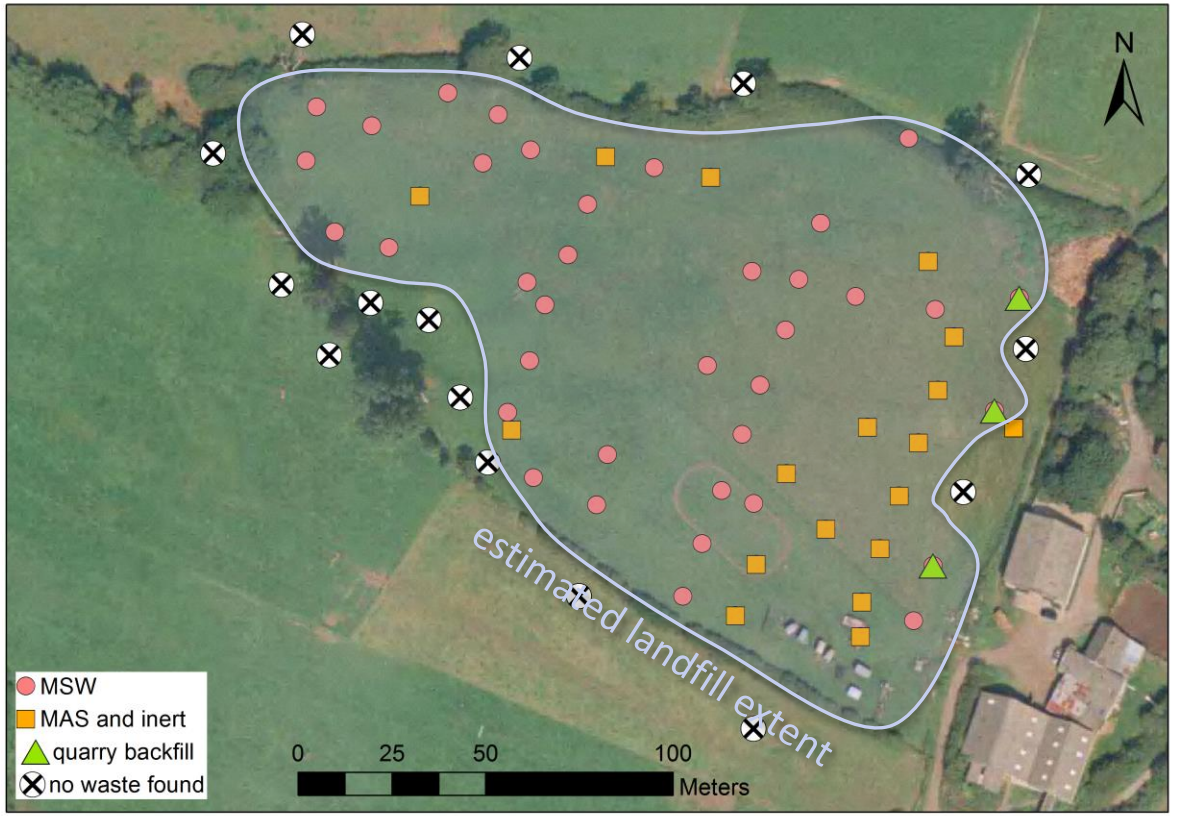
Step 1) Information gathering: available ground truth data

Ground truth data available across site:

- 59 Trial pits
- 12 E

	Name	Thickness
Cap	Clay cap	up to 2.6m average: 1.1m
Waste material	Municipal solid waste (MSW)	min: 0.3m max: > 4.1m
	Municipal solid waste (MSW) + inert content	min: 0.6m max: > 3.4m
	Quarry backfill	0.7m to 2m
Host	Clay	-
	Mudstone	-
	Sandstone	-



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Geophysical characterization

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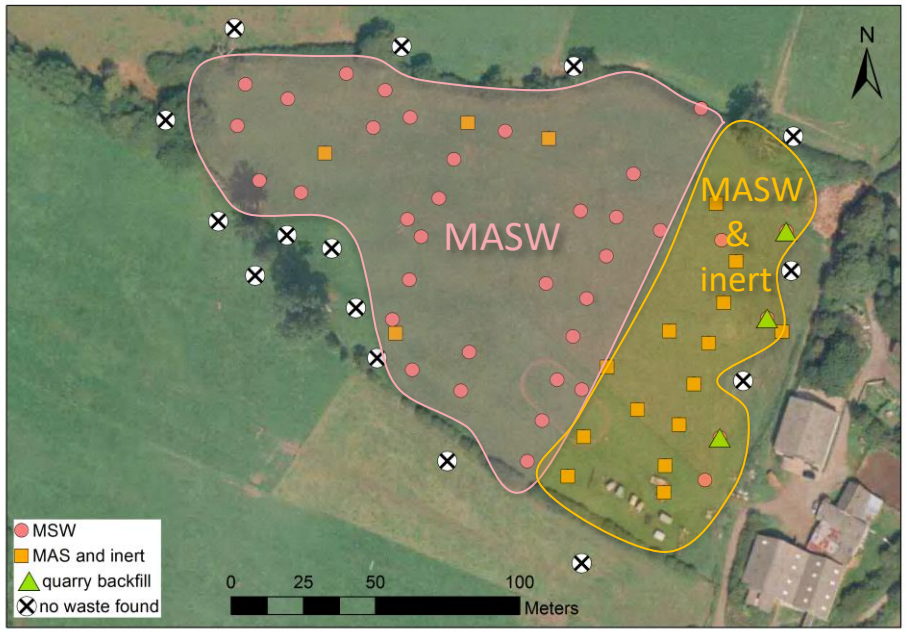
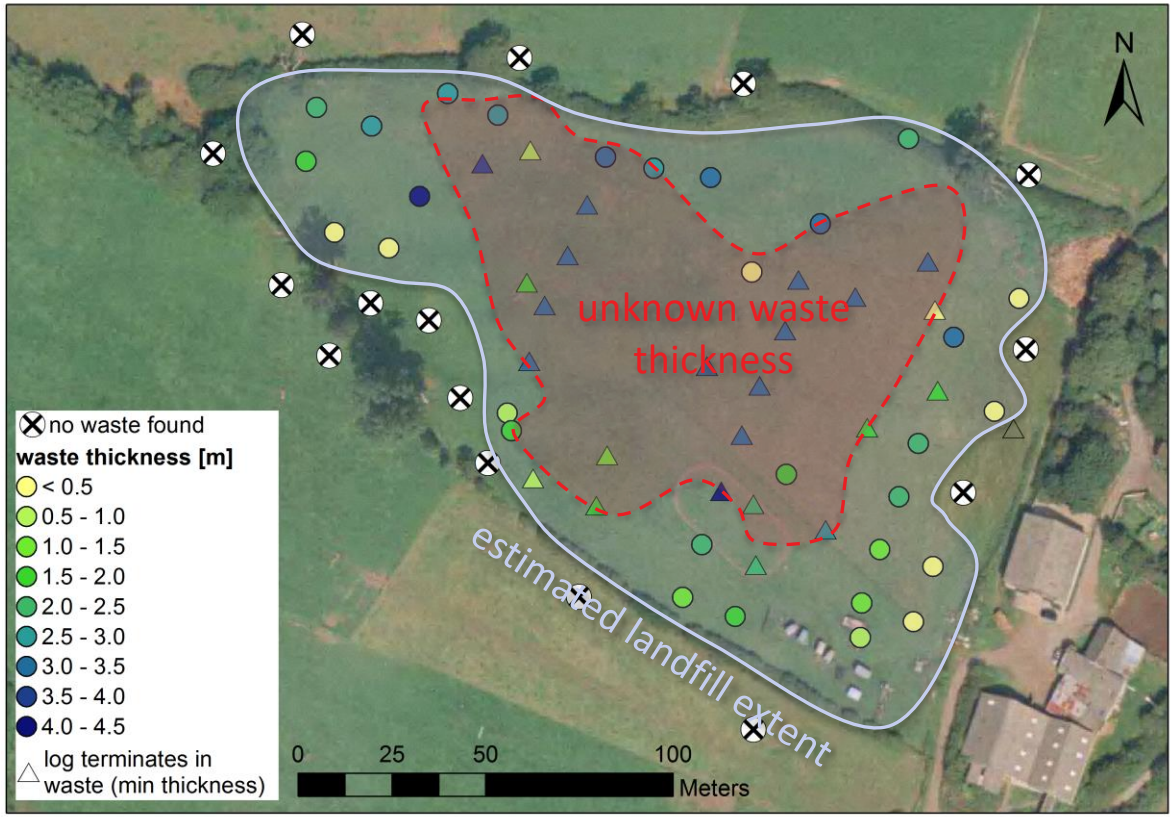
Resource model construction

Step 1: Identification of knowledge gaps

1. Waste thickness unknown towards centre of landfill
   → difficult to estimate waste volume

2. Structure of landfill unclear.
   Is there a change in waste composition towards East?





→ Use geophysics to fill these knowledge gaps

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Geophysical characterization

Calibration & validation

Resource model construction

Step 2) Geophysical characterisation: Planning

Site conditions

Top soil stripped off (about 30cm)

In some places waste visible

High groundwater table

→ Site well accessible for all geophysical measurements

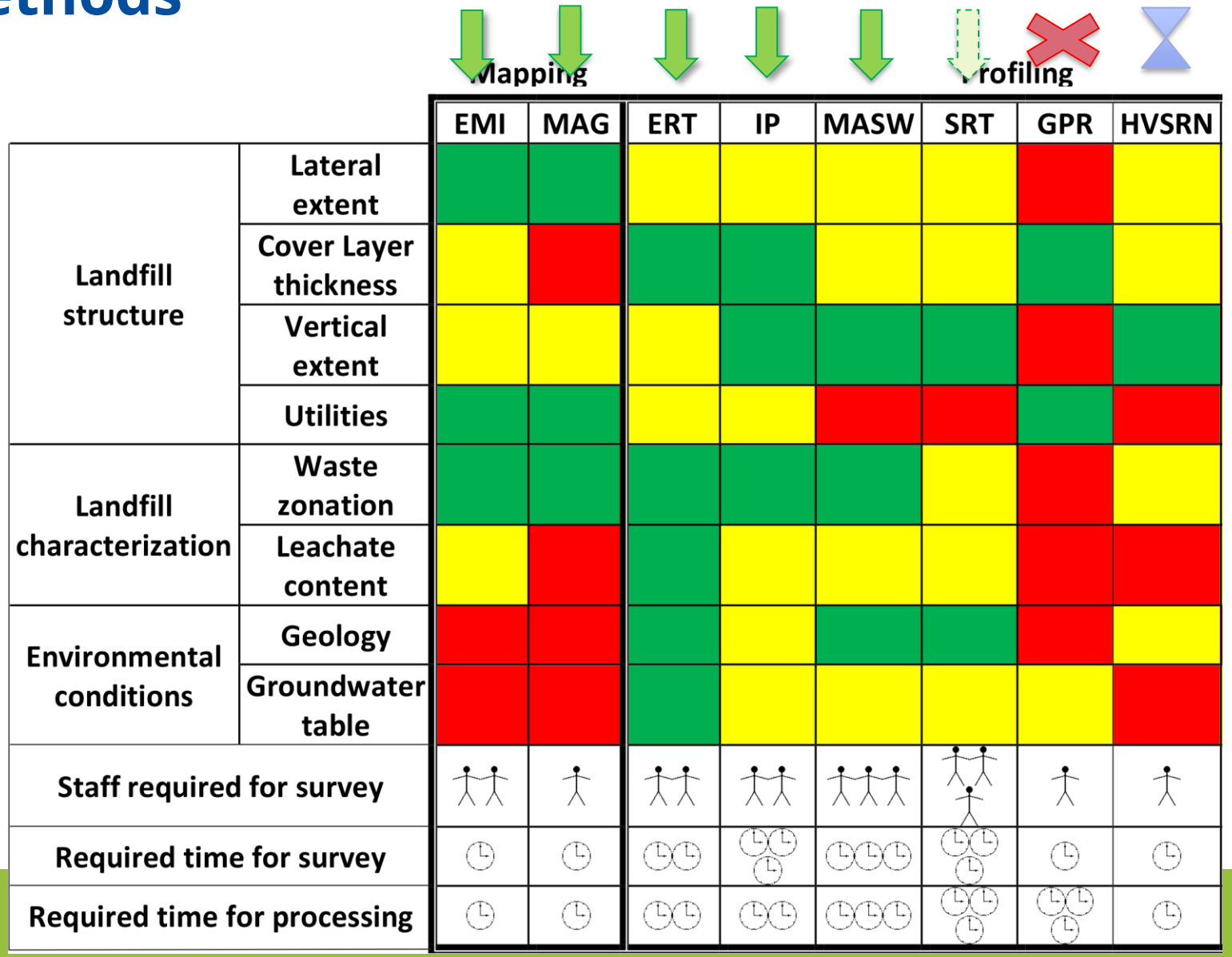
Archives & inventory report

Geophysical characterization

Calibration & validation

Resource model construction

Step 2) Geophysical characterisation: Selecting methods



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Geophysical characterization

Calibration & validation

Resource model construction

Step 2) Geophysical characterisation: Selecting methods

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MAPPING METHODS

Goal:

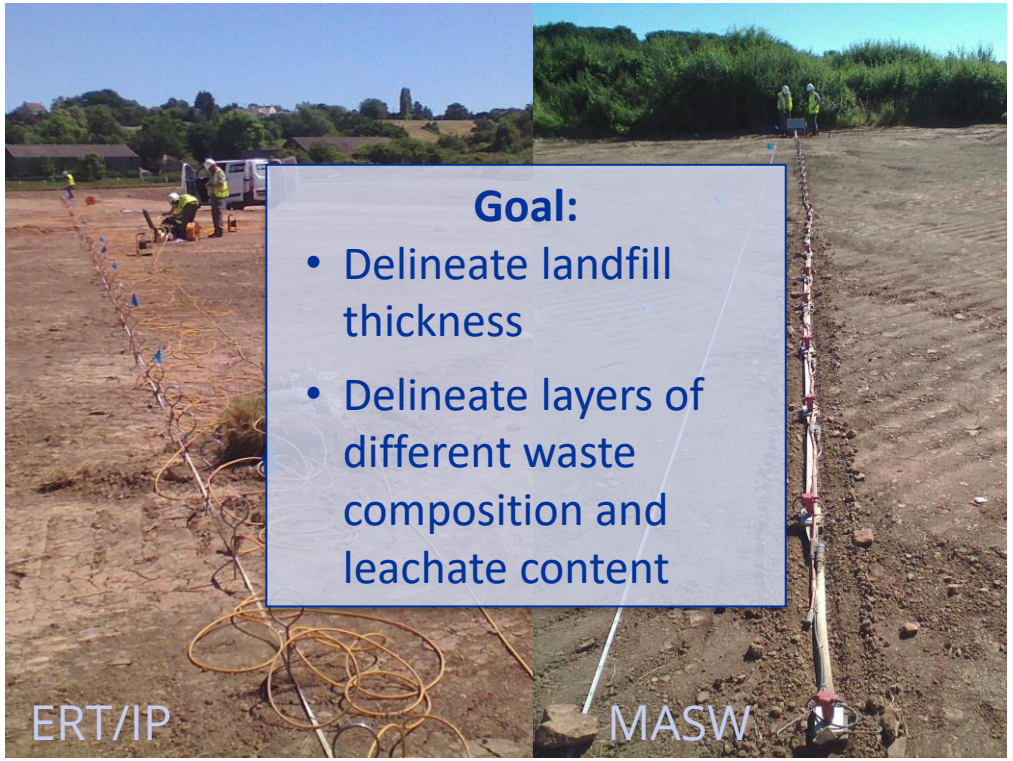
- Improve knowledge of lateral landfill geometry
- Delineate zones of different waste composition

Lateral extent
Leachate content
Metal content

Lateral extent
Metallic items
Metal content

Electromagnetics

PROFILING METHODS



Goal:

- Delineate landfill thickness
- Delineate layers of different waste composition and leachate content

ERT/IP

Waste types
Leachate content
Thickness of landfill

MASW

Layers of different stiffness
Thickness of landfill

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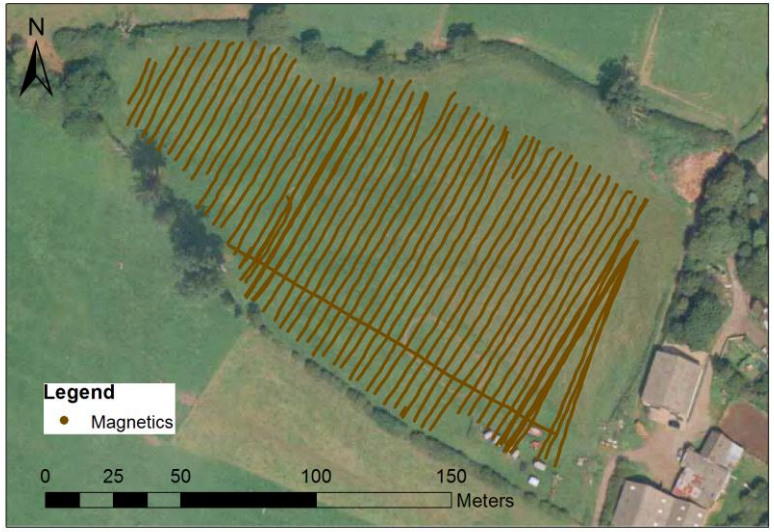
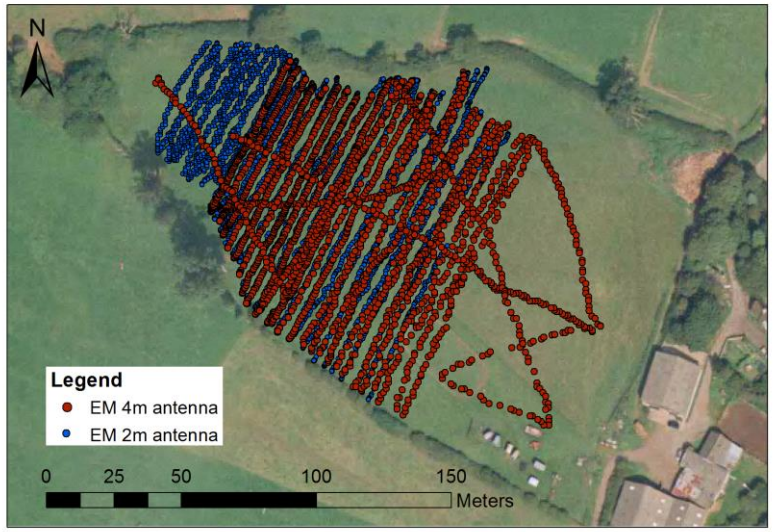
Geophysical characterization

Step 2) Geophysical characterisation: Measurement extent

Magnetics



EM: depths: 1.5m, 2.5m, 3m, 6m



ERT/IP and MASW

Step 2) Geophysical characterisation: Results Magnetics

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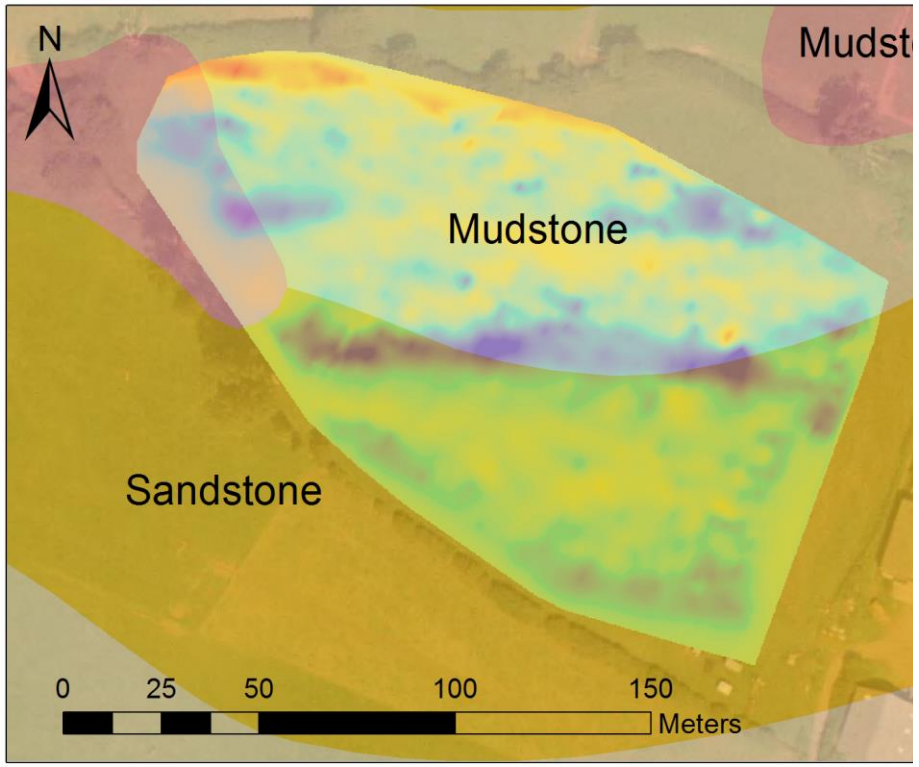
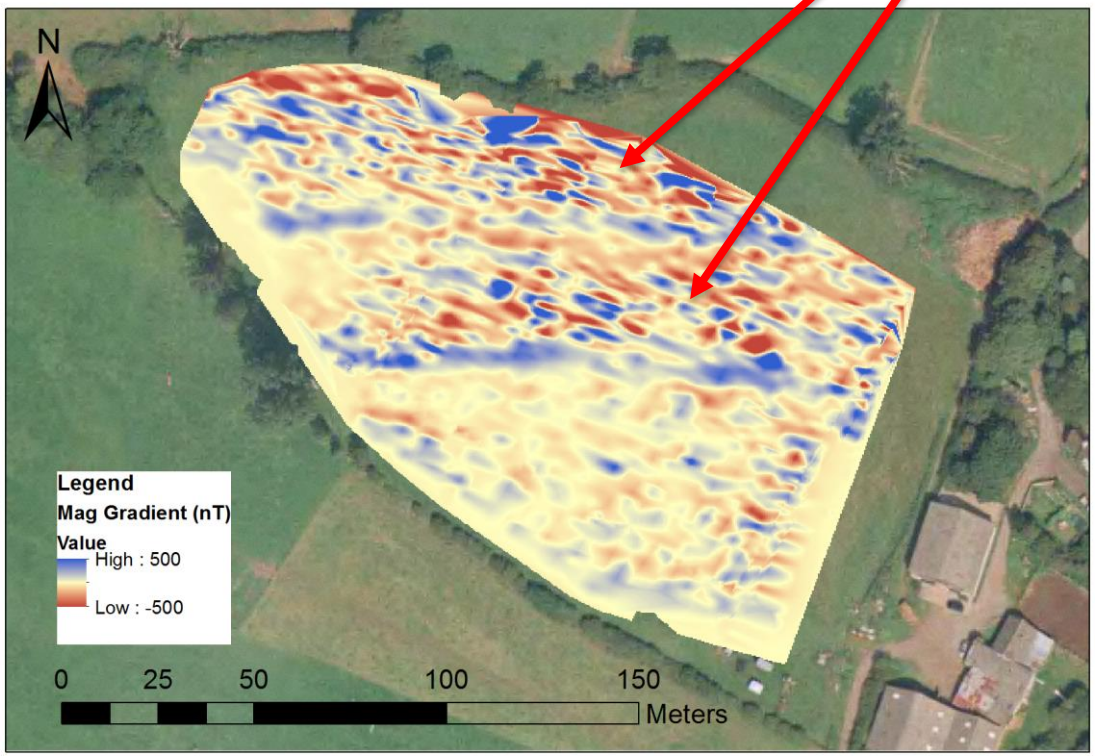
Total magnetic field (nT)



Vertical magnetic Gradient (nT)

Higher metal content?



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Geophysical characterization

Calibration & validation

Resource model construction

Step 2) Geophysical characterisation: Results EM

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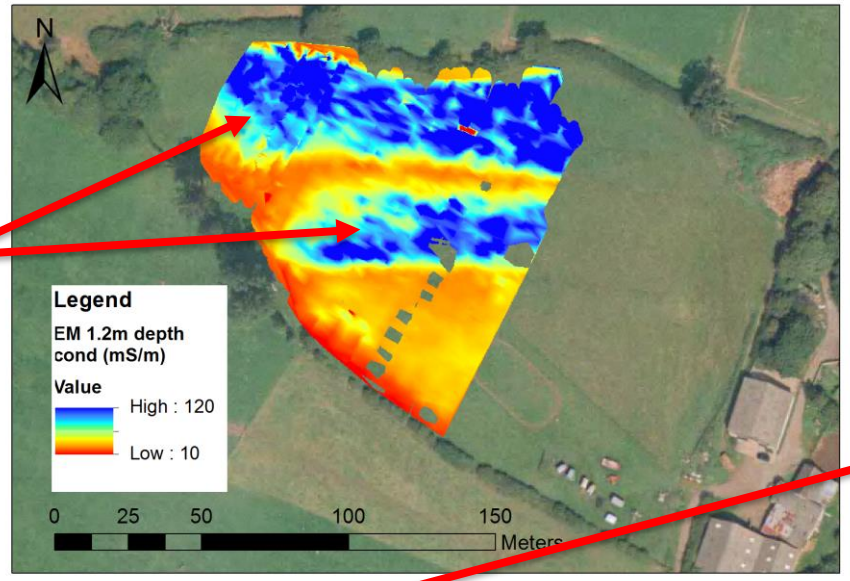
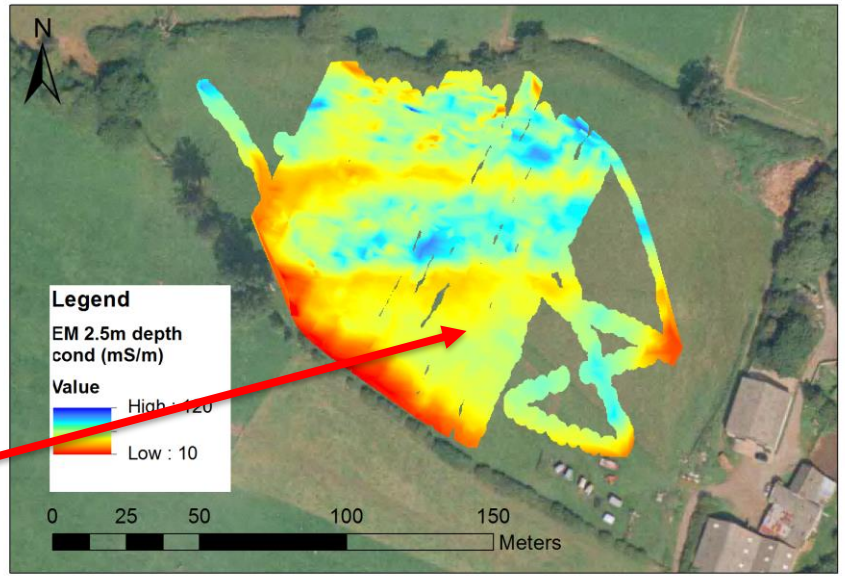
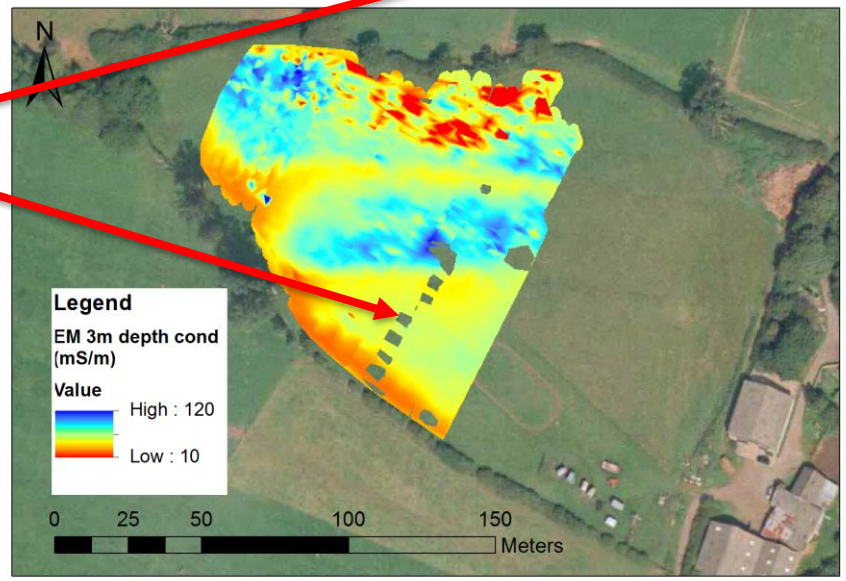
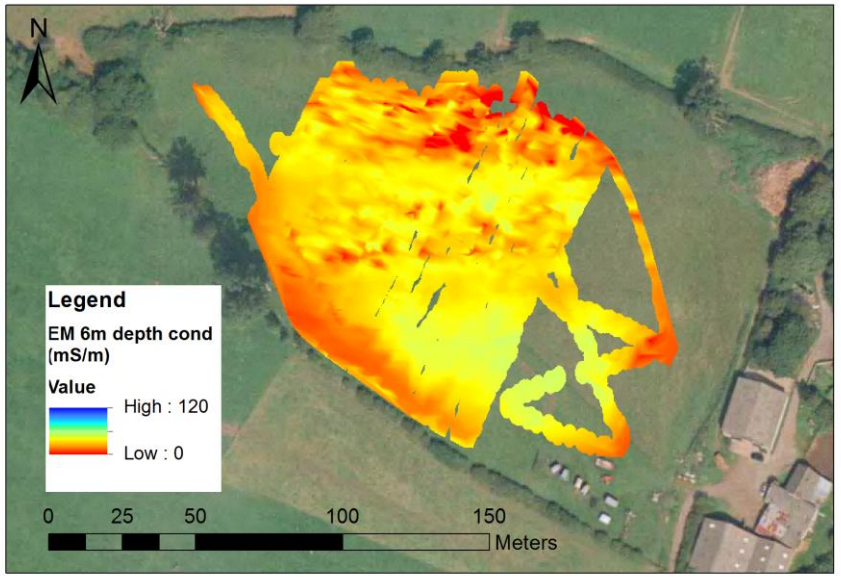
Cell type structure?

Additional cell with less metal content or thicker cover layer?









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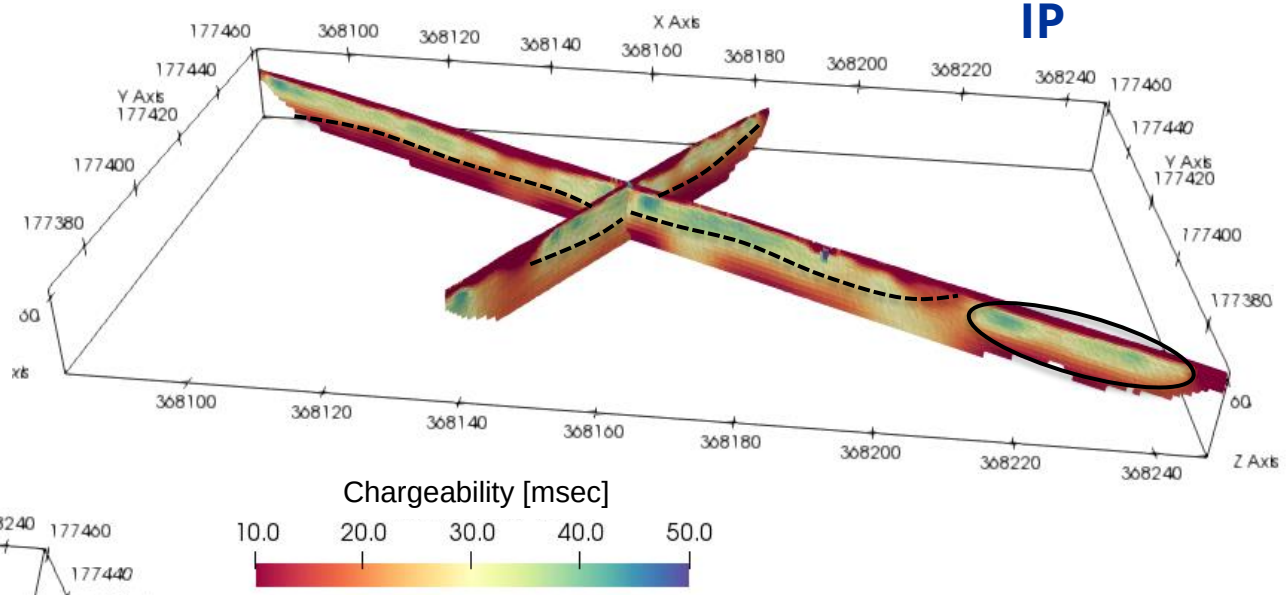
Geophysical characterization

Calibration & validation

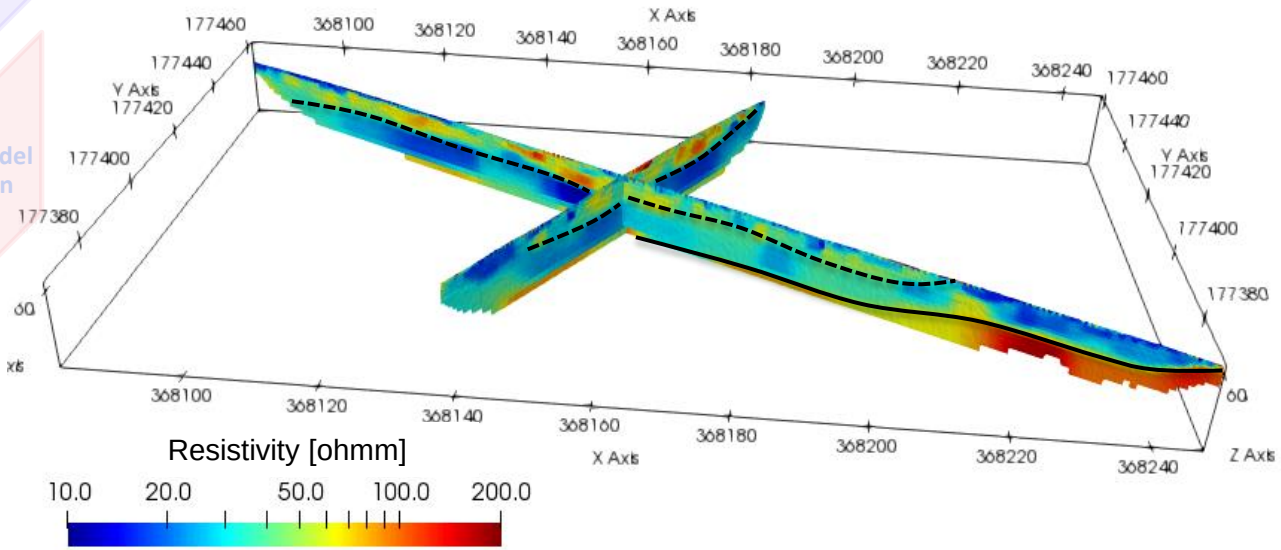
Resource model construction

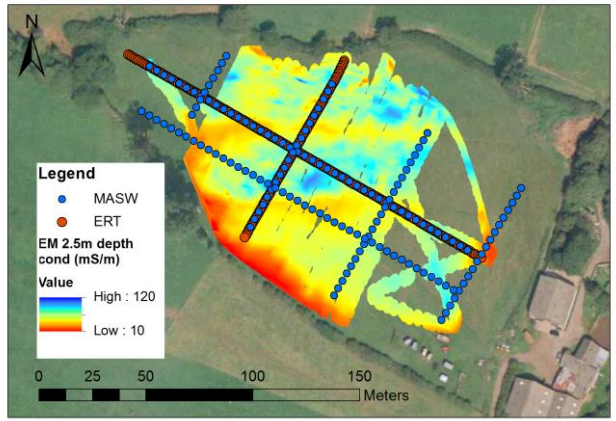
Step 2) Geophysical characterisation: Results ERT and IP

IP



ERT





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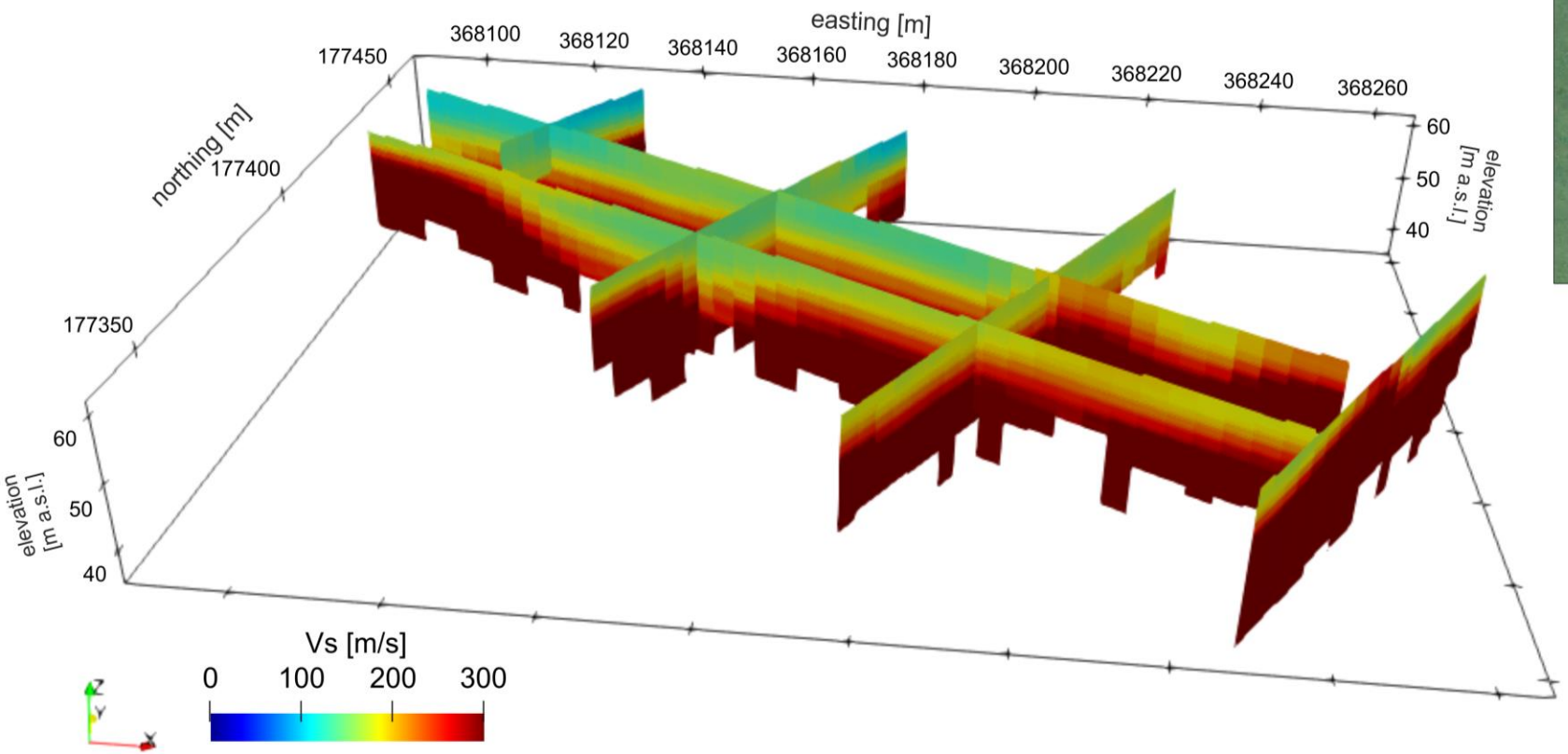
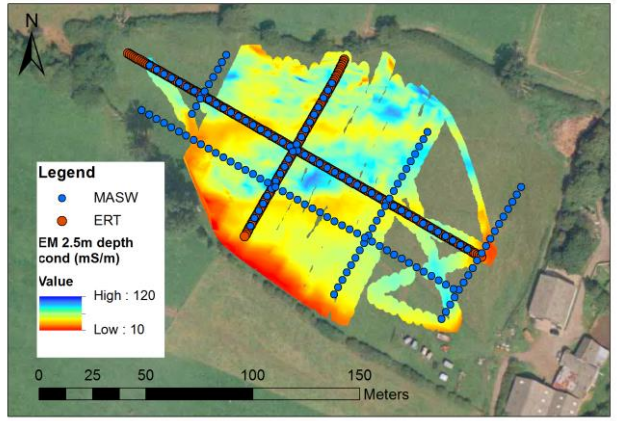
Geophysical characterization

Calibration & validation

Resource model construction

Step 2) Geophysical characterisation: Results MASW





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Geophysical characterization

Calibration & validation

Step 3) Calibration and Validation

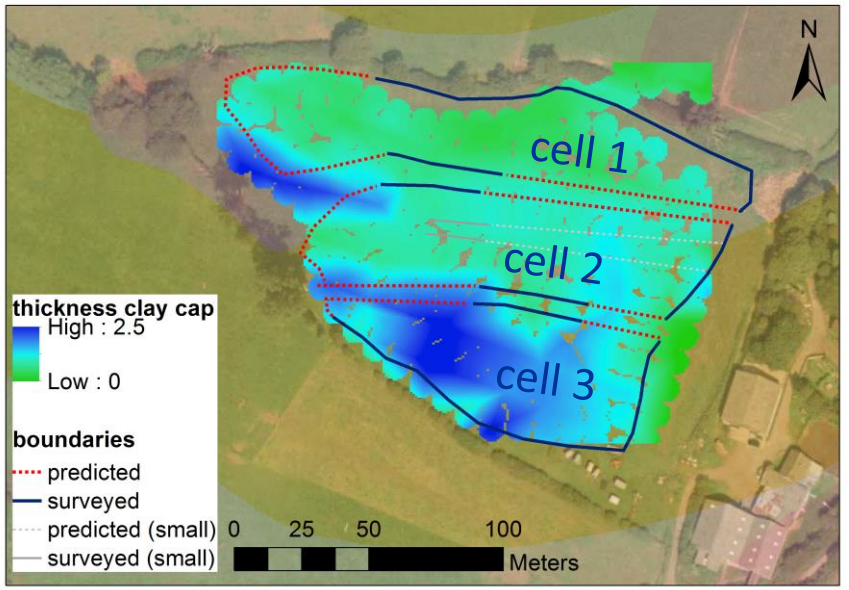
Additional ground truth data through excavations

- The landfill was separated into three cells. These cells were excavated into the natural clayey ground and filled with waste.
- A thicker clay cap and a thinner waste layer was found in cell 3.
- A step in the landfill base between cells 2 and 3 might be associated with the underlying sandstone.

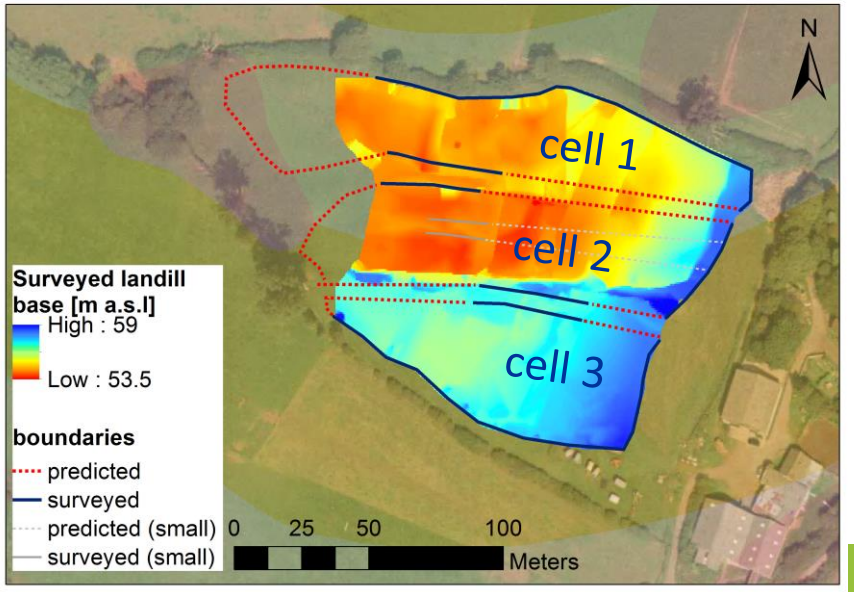
clay stank dividing the waste cells

- The waste composition was a mix of plastic, metal, wood, paper, fabric, inert with no strong compositional changes across the site.

clay cap thickness



base of waste layer



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Geophysical characterization

Calibration & validation

Resource model construction

Step 3) Calibration and Validation

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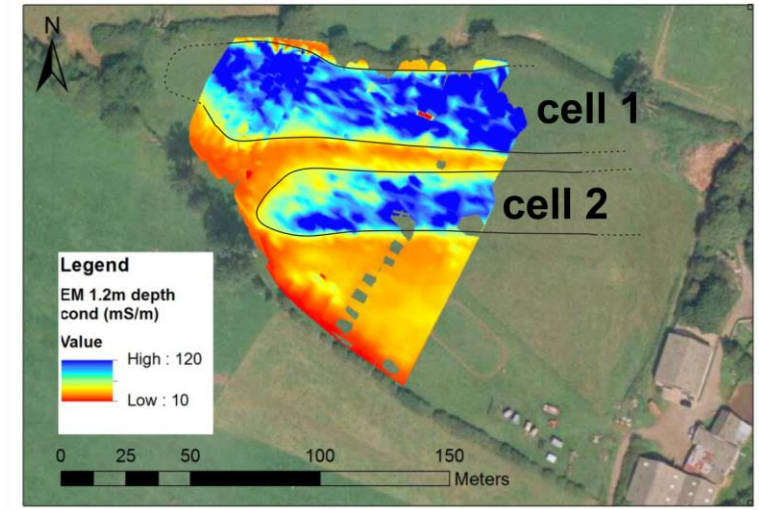
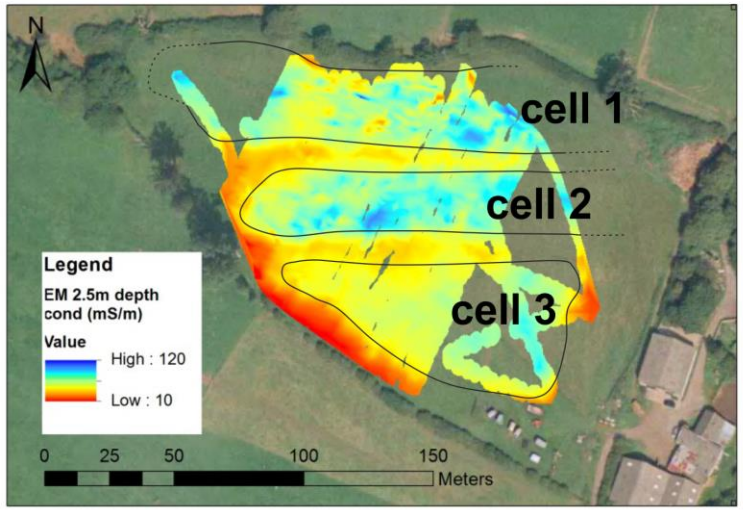
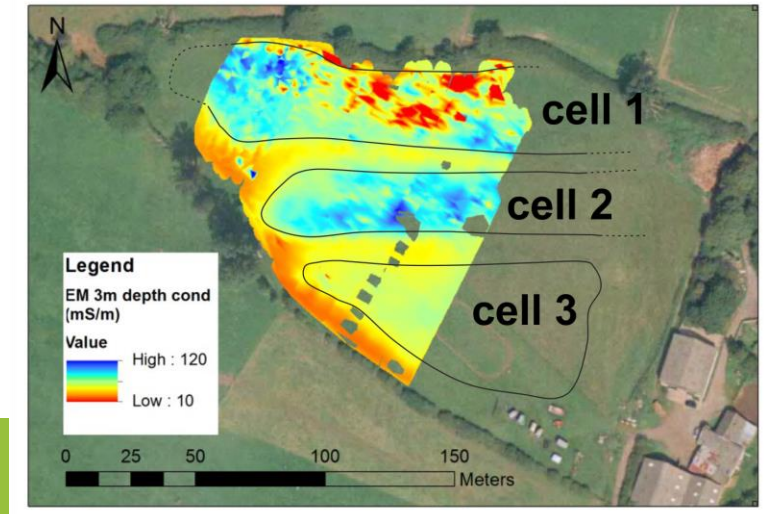
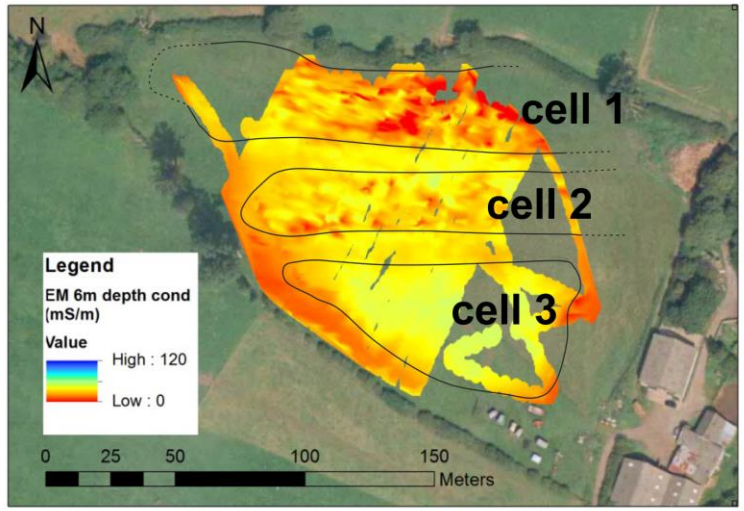
EM: good delineation of waste cell extent and cover layer









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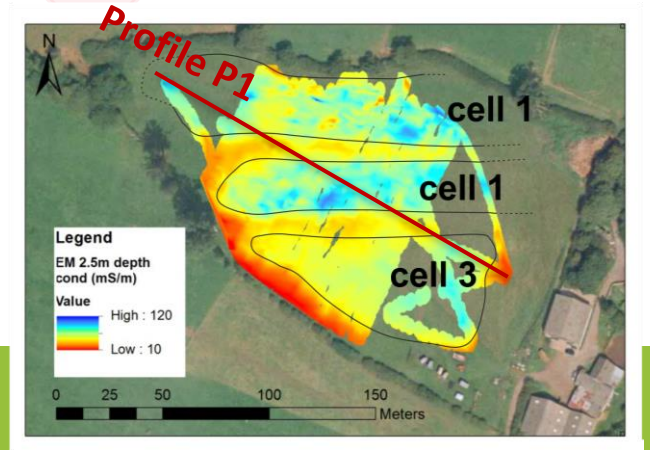
Geophysical characterization

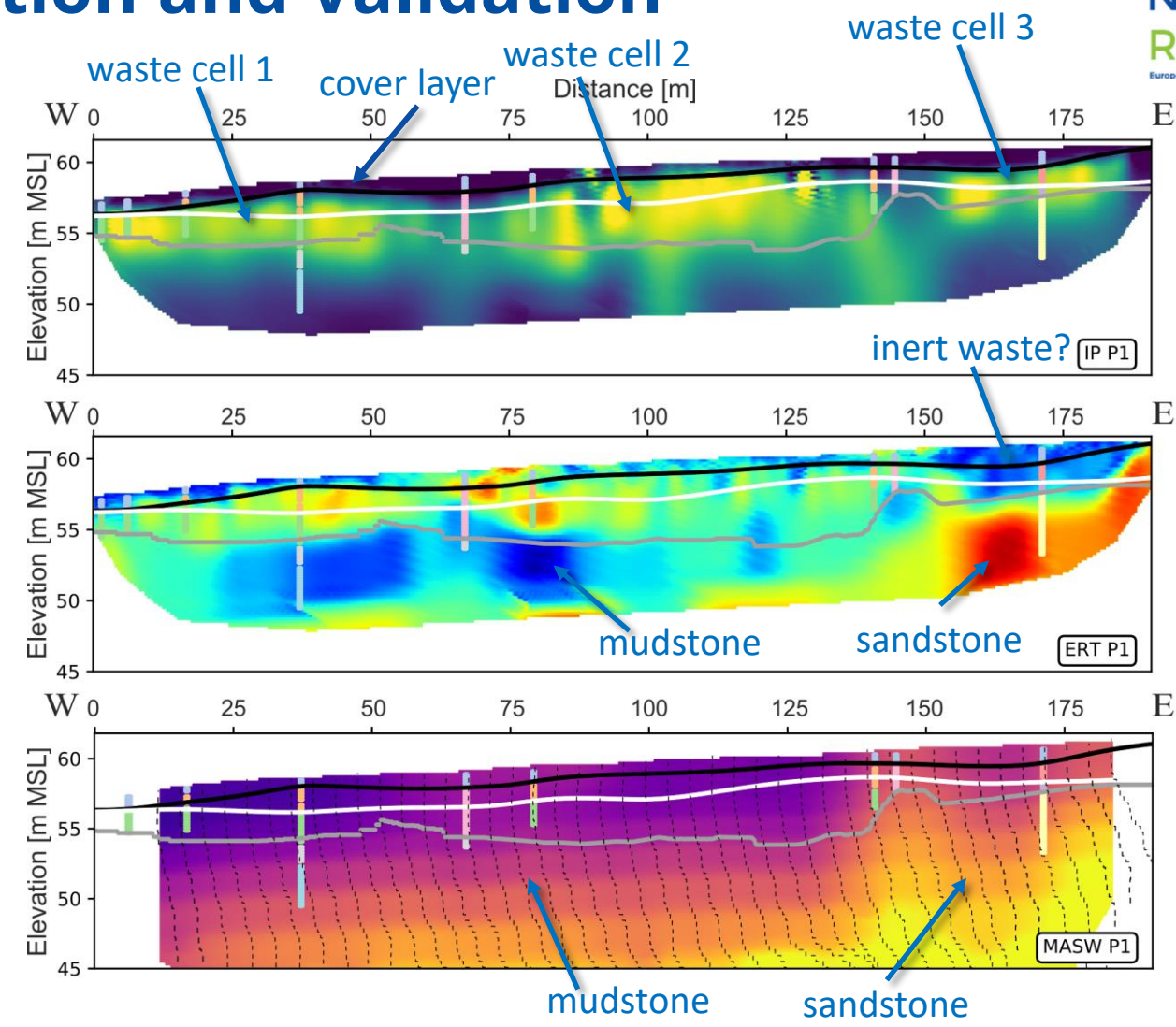
Calibration & validation

Resource model construction

Step 3) Calibration and Validation

Sampling data
- Clay cap
- MSW, dry
- MSW, saturated
- MSW + inert, dry
- MSW + inert, saturated
- Clay stank (derived from EM)
- Clay (insitu)
- Mudstone
- Sandstone
- Water level
- surveyed waste base
- surveyed clay cap base





IP
resolves clay cap and waste cells

ERT
resolves sandstone interface

MASW
resolves sandstone interface, mudstone interface less clear

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Geophysical characterization

Calibration & validation

Resource model construction

Step 4) Building Resource Distribution Model

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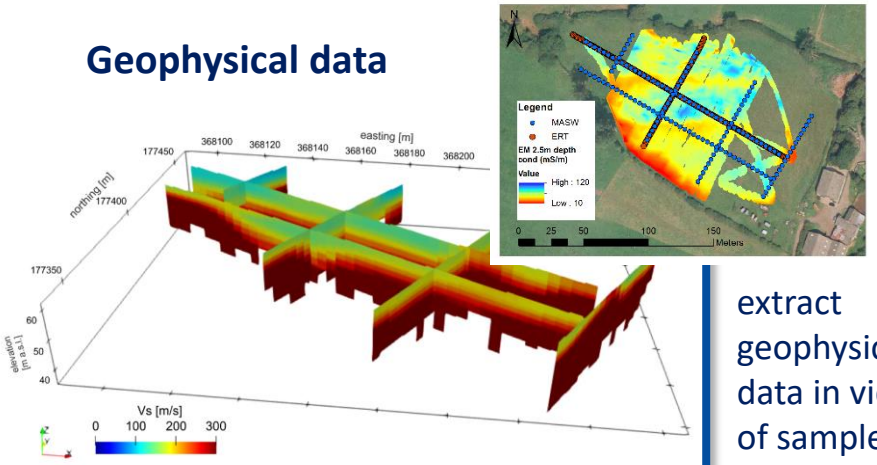
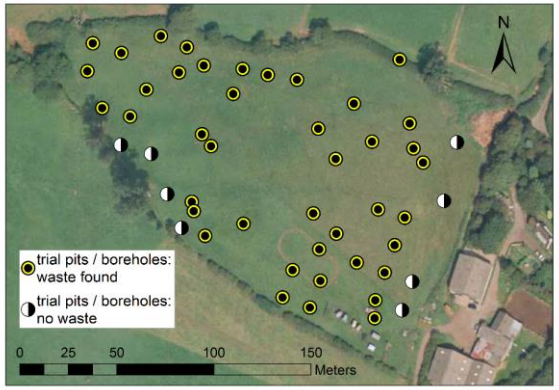
Geophysical data



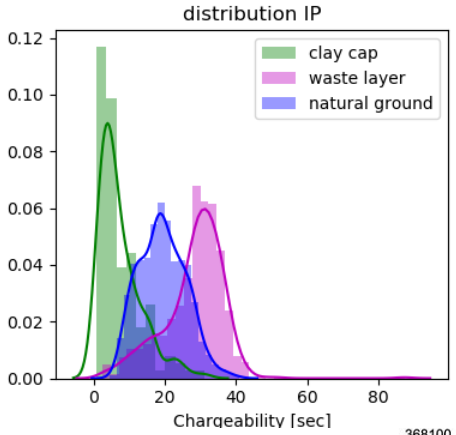
extract geophysical data in vicinity of samples

Trial pits & boreholes



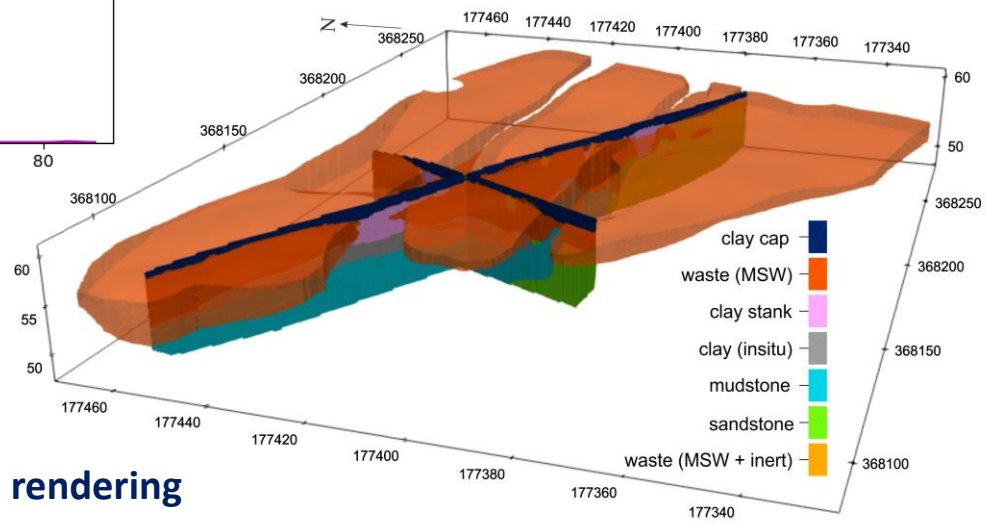
discretize sampling logs into relevant categories (e.g. clay cap, saturated waste…)

Correlation analysis



choice of relevant geophysical parameters

Model building through supervised machine learning (classification)



Volume rendering

	Cell 01 (North)	Cell 02 (centre)	Cell 03 (South)	Total
Volume of waste material (m3)	15’258	10’654	9’547	35’450

Step 4) Building RDM: Correlation analysis

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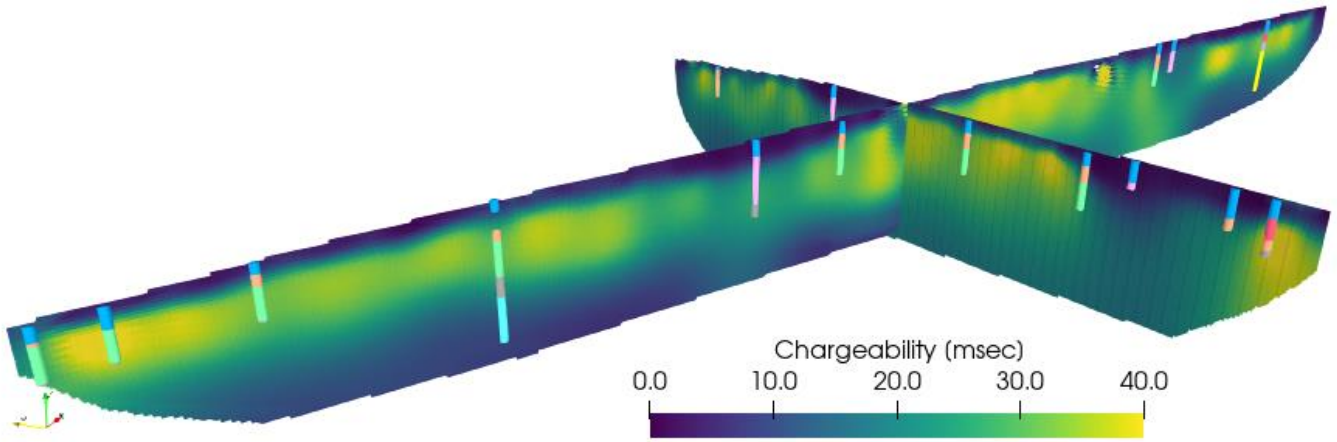
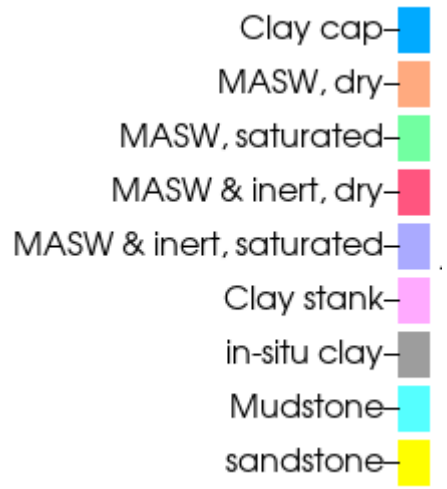
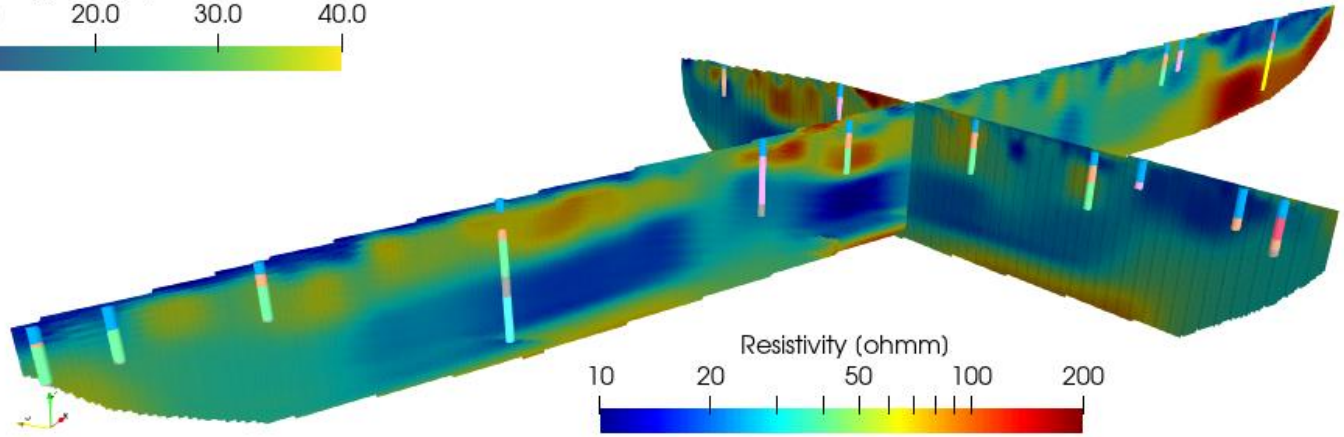
Extract geophysical data in vicinity of samples







- Position of clay stank was defined according to EM data
- Same was done for MASW data

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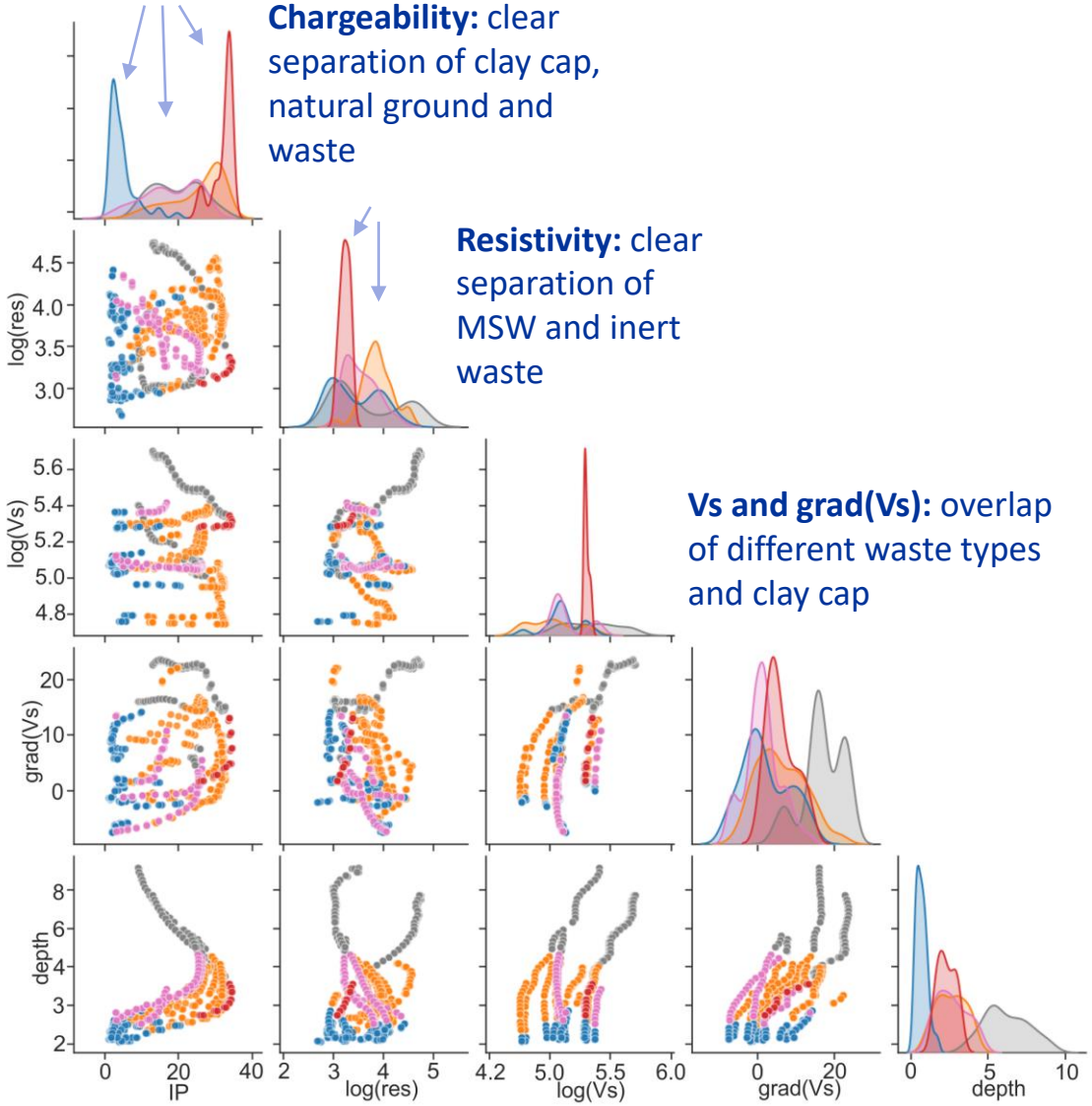
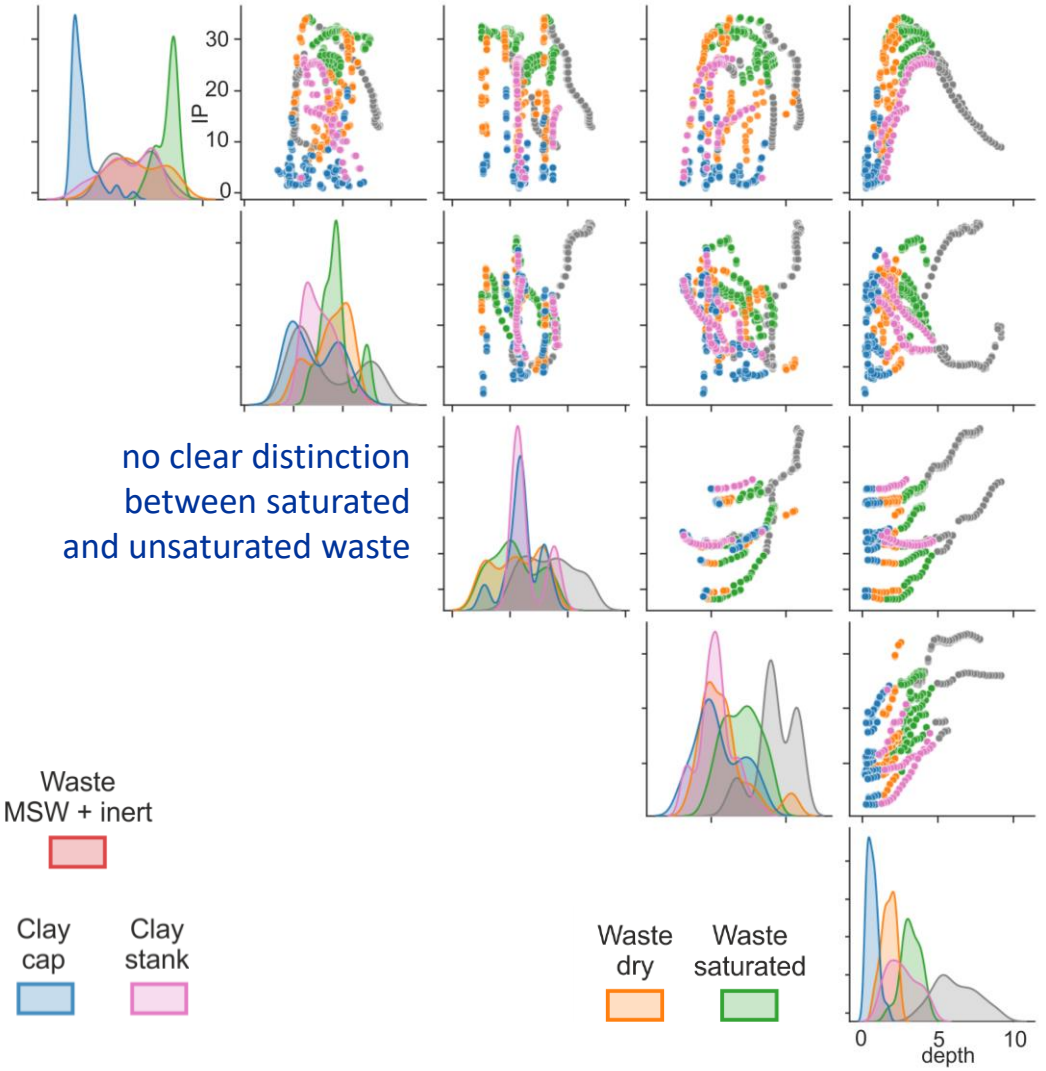
Chargeability: clear separation of clay cap, natural ground and waste

Resistivity: clear separation of MSW and inert waste

Vs and grad(Vs): overlap of different waste types and clay cap





no clear distinction between saturated and unsaturated waste

Waste MSW

Waste MSW + inert

Natural Ground

Clay cap

Clay stank

Waste dry

Waste saturated

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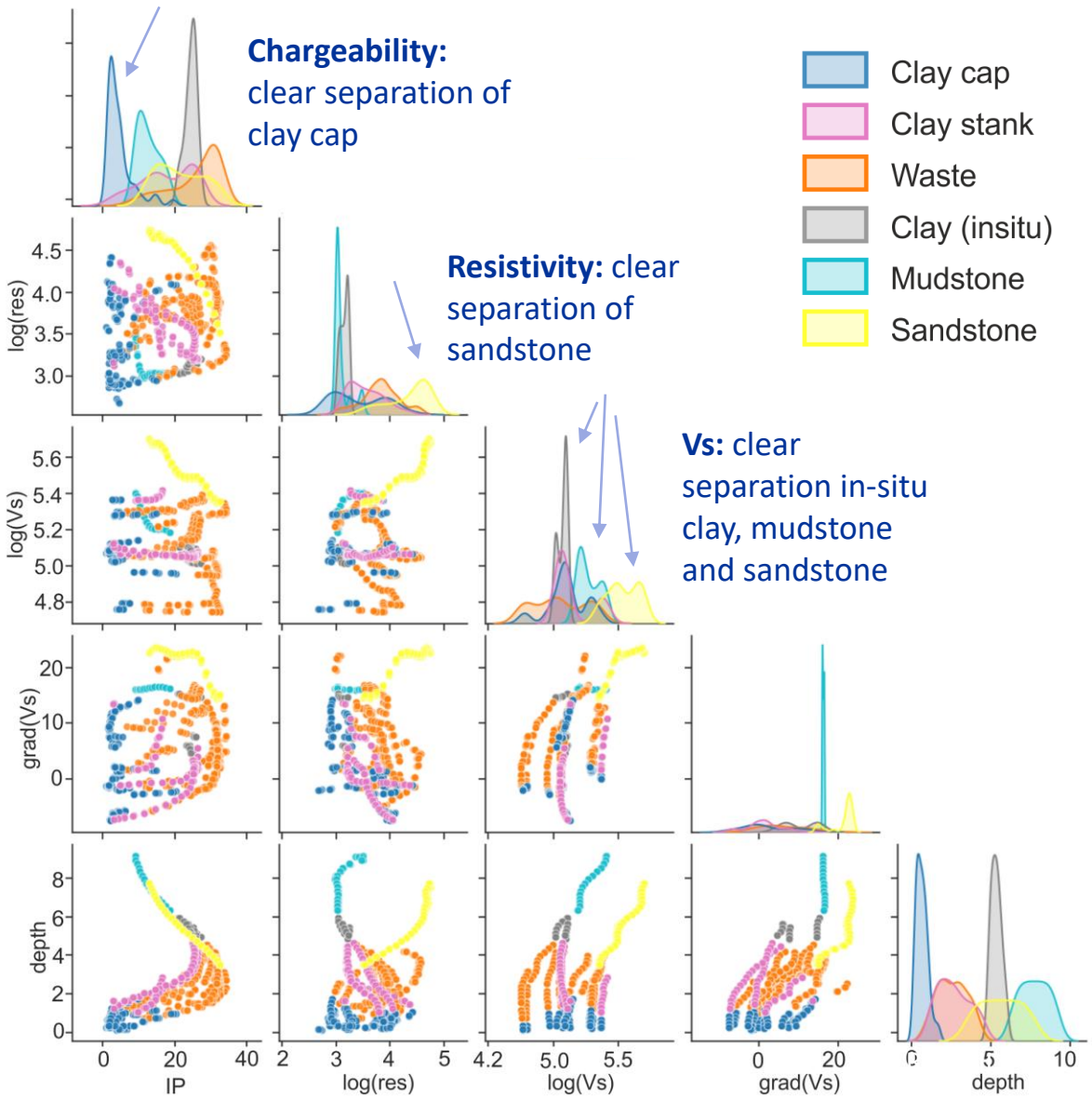
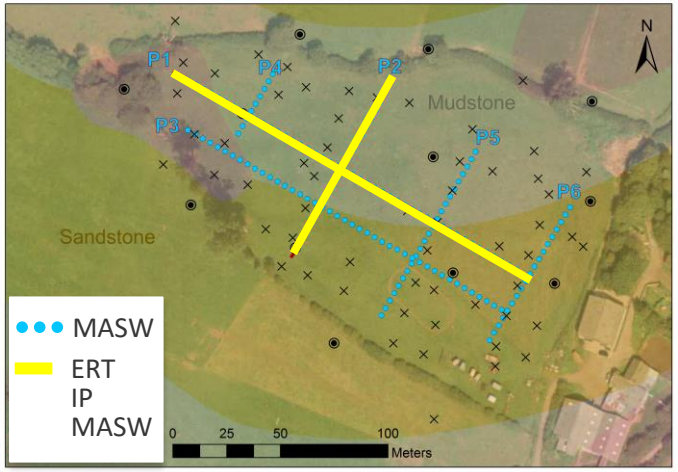
Step 4) Building RDM: Correlation analysis





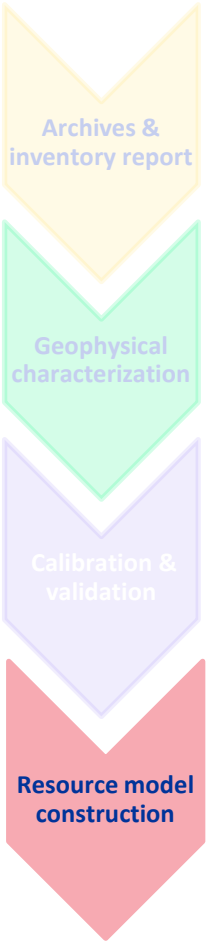
Conclusions for classification:

Geophysical properties to include for classification:

- along profiles with ERT, IP and MASW: chargeability, log(resistivity), log(Vs), $\partial Vs/\partial z$ and depth
- along profiles with MASW only: log(Vs), grad(Vs) and depth
- use standardised datasets

Classes used for classification:

- along profiles with ERT, IP and MASW : clay cap, clay stank, MSW, MSW & inert, in-situ clay, sandstone, mudstone
- along profiles with MASW only: clay cap, waste (incl. clay stank), in-situ clay, sandstone, mudstone



Step 4) Building RDM: Classification

Two step process:

1) <u>"training":</u>
   Use pre-classified dataset, i.e. geophysical data extracted at the sample location with known material type (class), to fit/train a model, which links the geophysical properties to the corresponding material type.

2) <u>"prediction":</u>
   Use the trained model to predict the material types at each position on the measurement profiles.

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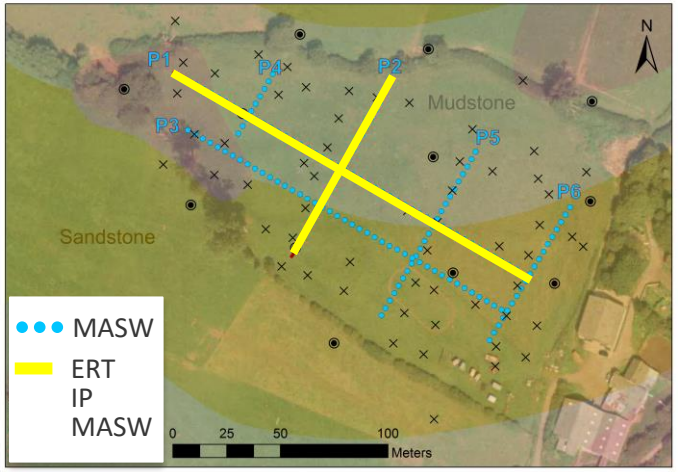
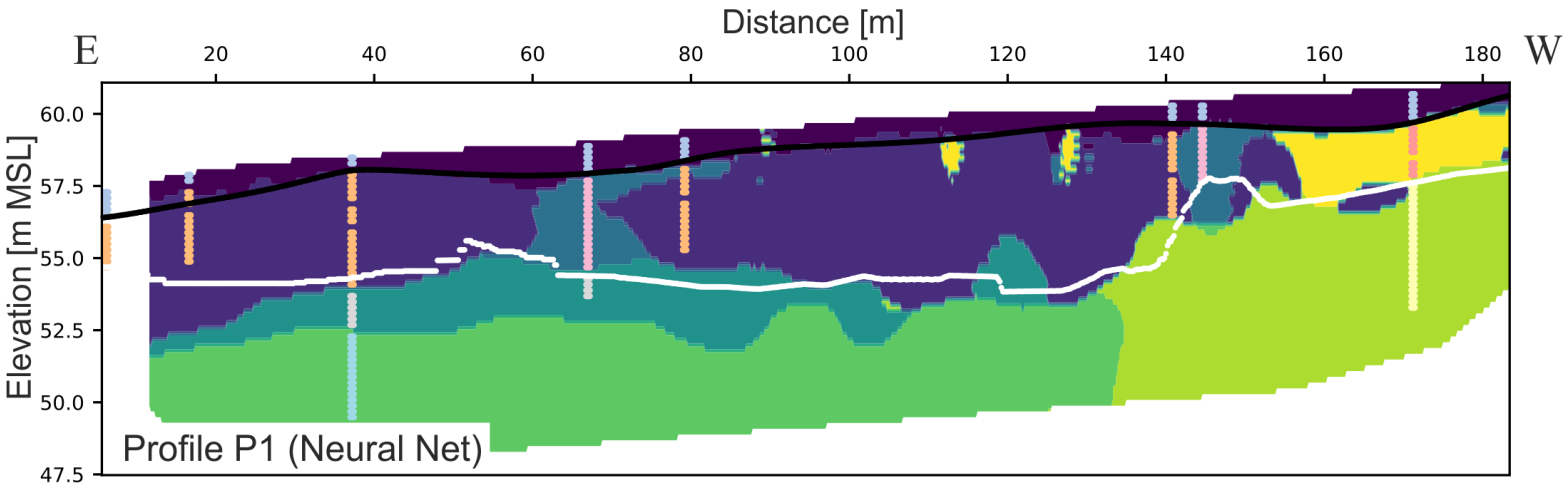
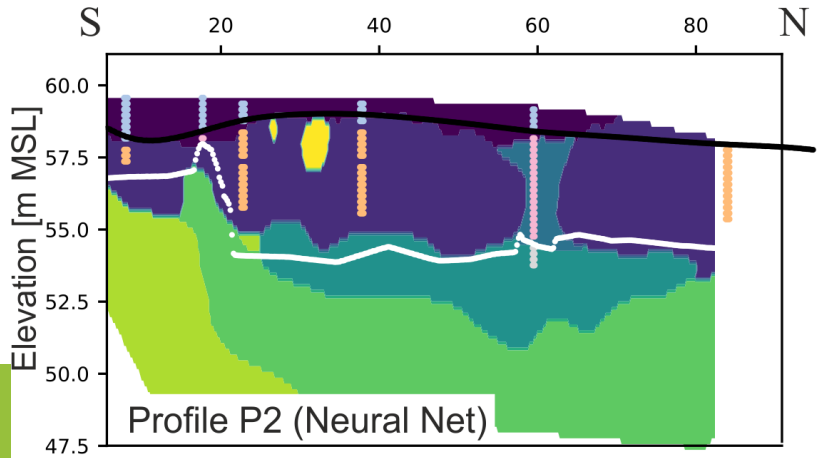
Step 4) Building RDM: Classification

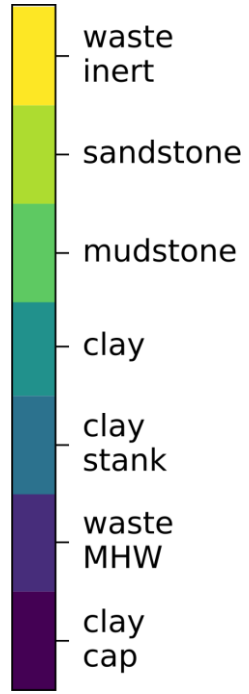
Tested and compared different classification algorithms.
Best results achieved with Neural Network.







Water level
surveyed waste base
surveyed clay cap base



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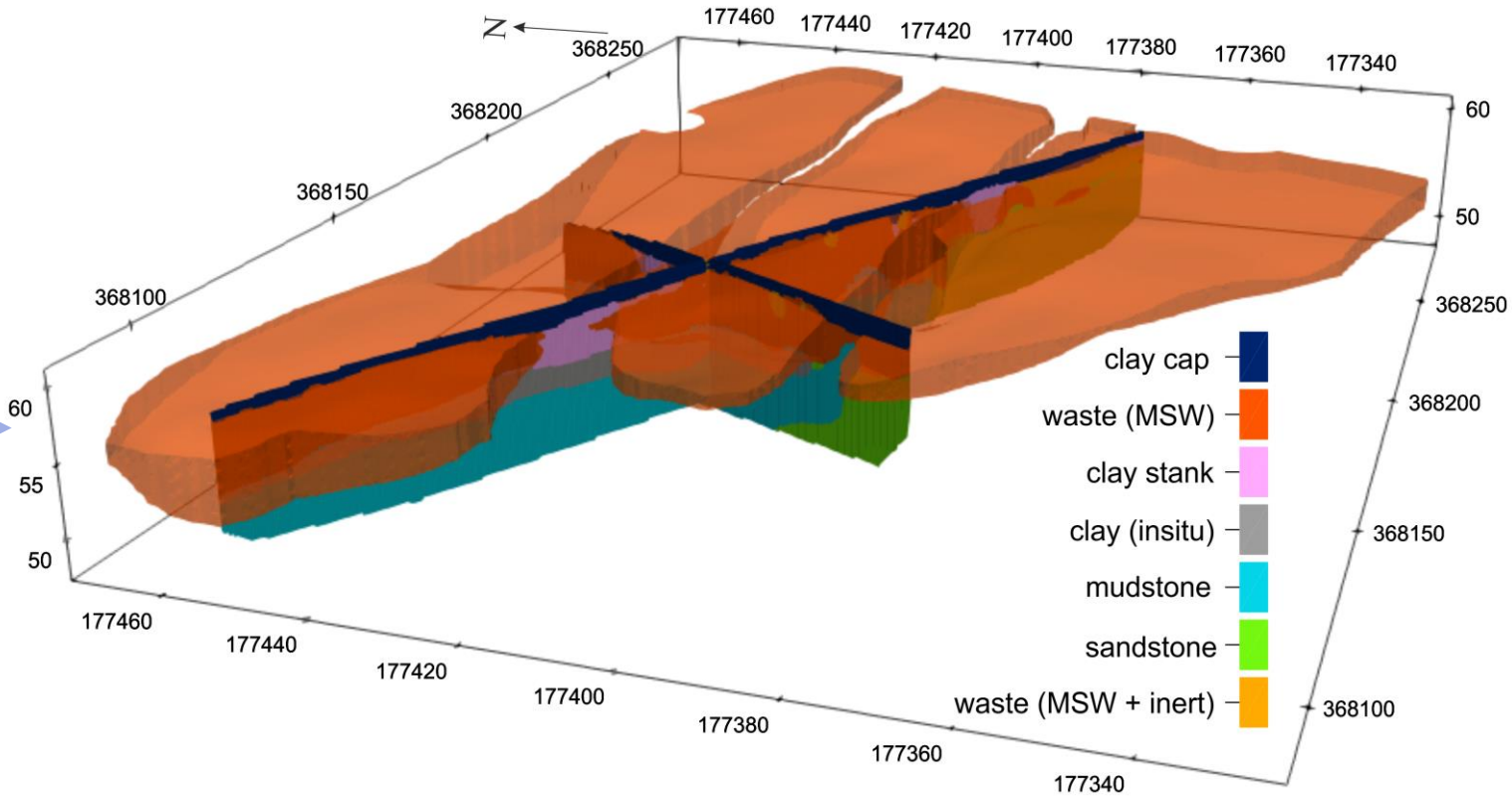
Step 4) Building RDM: Volume rendering

Inputs

- Boundaries from classification
- Depth information from samples
- Lateral extent from EM data



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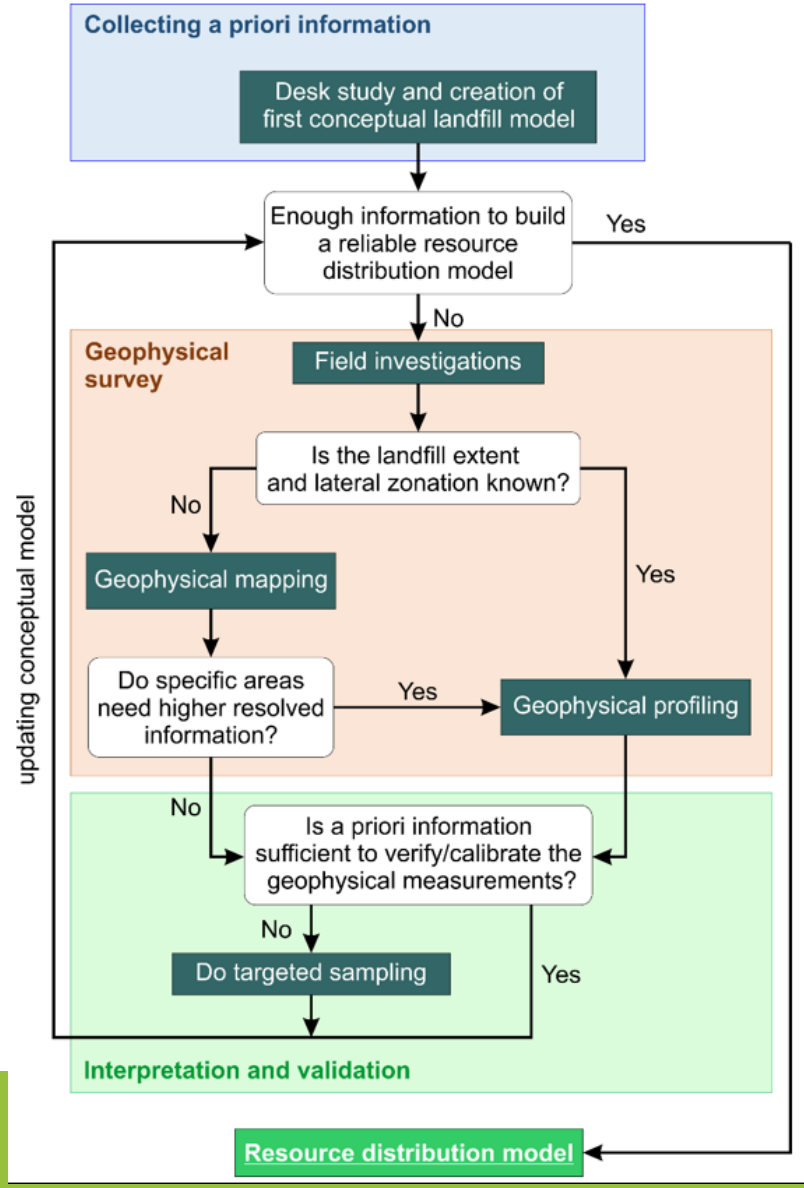
Take-home message



Using geophysics:

- is cost effective
- allows targeted sampling
- delivers relatively high resolution data (when mapping and profiling techniques are combined)

Our proposed workflow:

- integrates *a priori* information, geophysics and targeted sampling to build a resource distribution model specific to each landfill
- Provides "ready-to-use" information for decision makers (DST 2)

Interreg

EUROPEAN UNION

North-West Europe

RAWFILL

European Regional Development Fund

Co-funded by the Walloon region

Thank you!

Raw materials recovered from landfills

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