Panel Session #87

Characterization & Survey for
Decommissioning and Waste Management

Geostatistics for Radiological Characterization and Sampling Optimization

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More information:
www.geovariances.com

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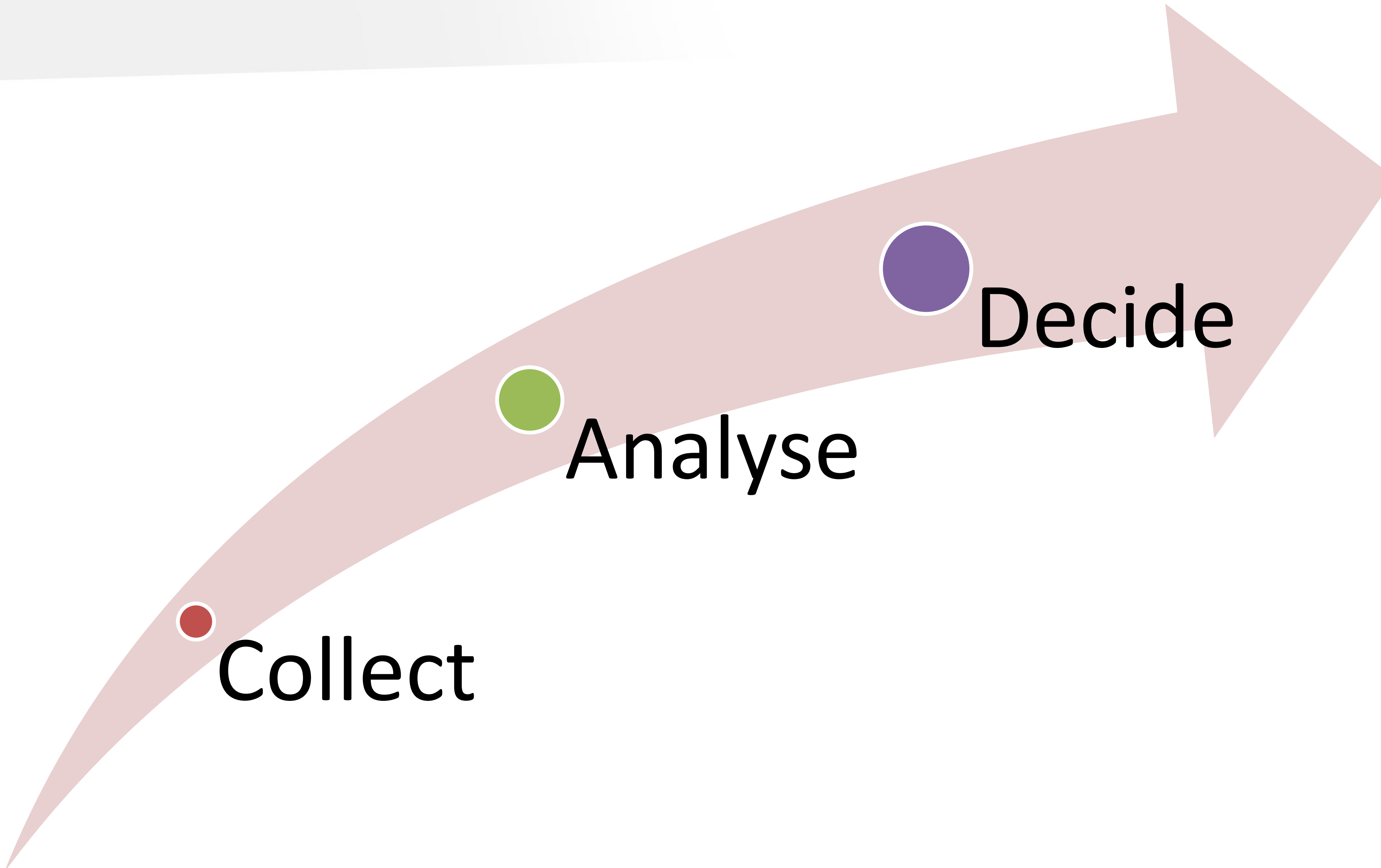
Collect
Analyse
Decide

Radiological Characterization Context

- Interrelated issues of D&D projects:
  - Regulatory deadlines, costs (maintenance, contractor, waste…)
  - Characterization: Radiation protection of workers, waste categorization and optimization, monitoring, clearance criteria…

Characterization
- Geostatistics
- Modeling…

Decontamination
- Monitoring
- Waste control

Decommissioning
- Statistical tests
- Sanitary impact

- Initial characterization: a key stage for D&D success
  - "Segregation and characterization of contaminated materials are the key elements of waste minimization"
    (*Methods for the Minimization of Radioactive Waste from Decontamination and Decommissioning of Nuclear Facilities*, IAEA)

The Characterization Triptych

- A three legged stool: stability and simplicity
- If one leg is missing, the stool falls
- A stable position but uncomfortable

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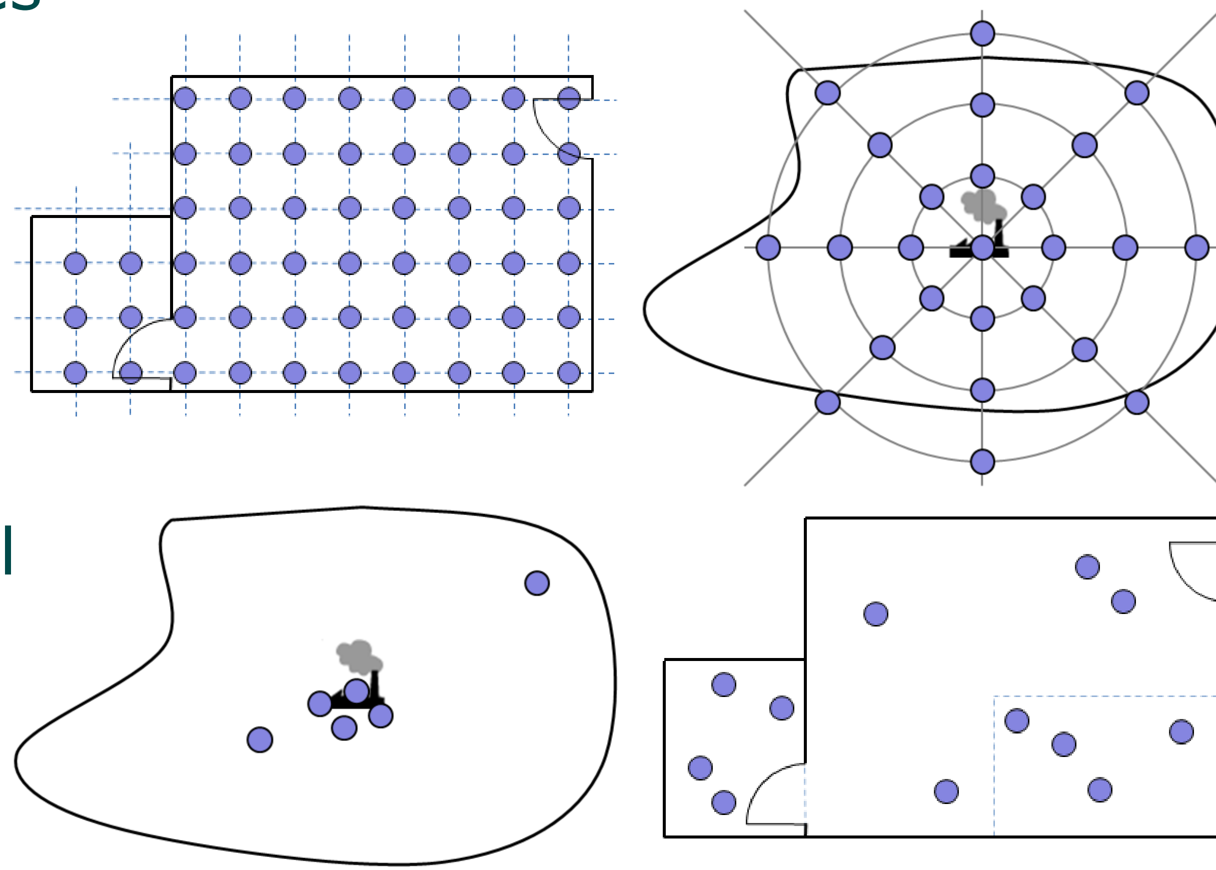
Reminder about Sampling Designs

- Two main categories
  - Probability-based
    - Systematic
    - Random
  - Judgmental



- Mix possible to fulfil the evaluation objectives
- Iterative approach recommended

Geostatistics for Initial Characterization

- Added values of geostatistics:
  - Successfully used for site characterization (chemical & nuclear)
  - Implemented in the methodology for the radiological waste characterization in former nuclear facilities
  - Sampling optimization according to spatial structure inventory

- Key issues:
  - How to optimize the investigation costs?
  - How to take auxiliary information such as historical inventory and radiation maps consistently into account?
  - How to quantify uncertainties in the remediation costs while computing contaminated surfaces or volumes?

Methodology: Geostatistics

- Geo + Statistics: integration of the phenomenon spatial continuity
- Main tool of geostatistics: the variogram
  (describes the variability between 2 points)
  - on average, the difference between two CLOSE measures is LOW
  - on average, the difference between two DISTANT measures is HIGH

$$\gamma(h)=\frac{1}{2}E\left[Z(x)-Z(x+h)\right]^2$$

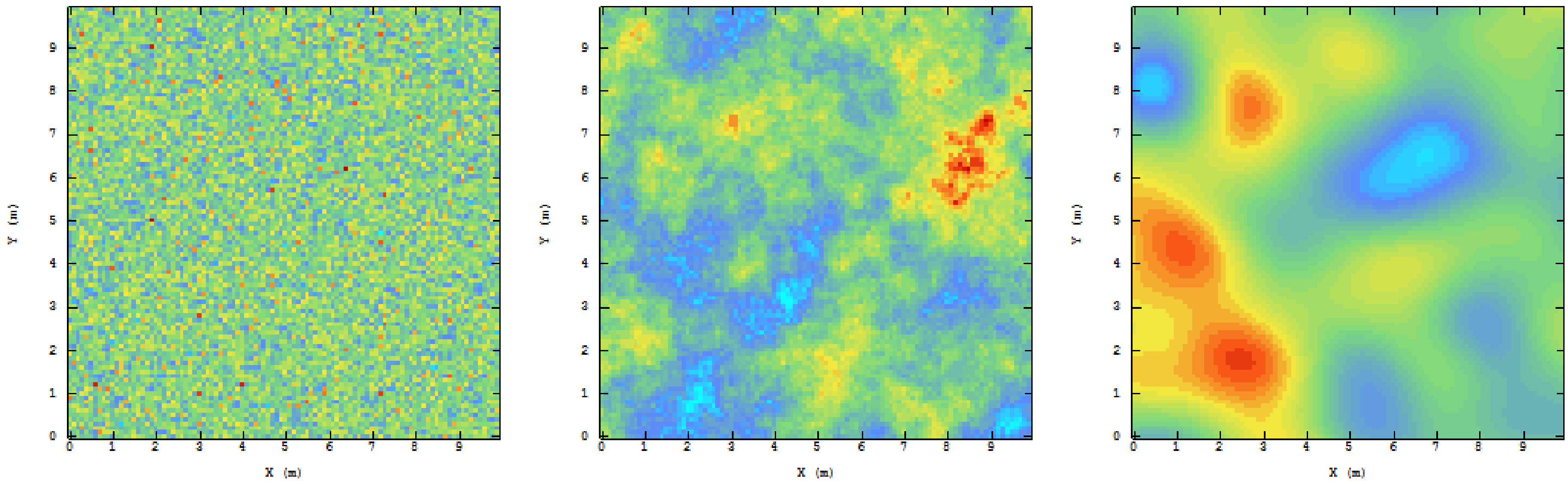
Model

Experimental

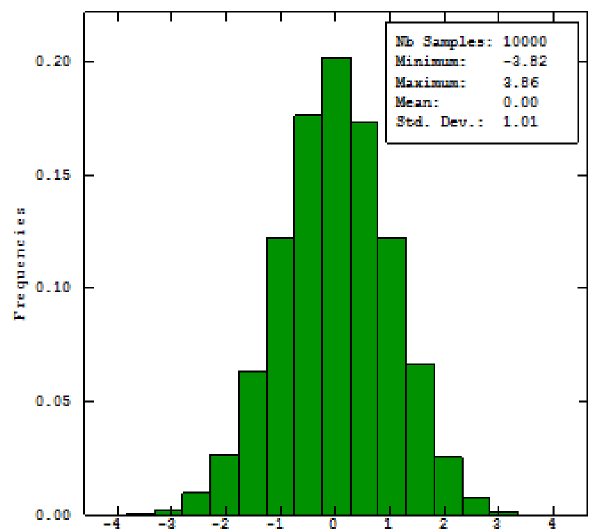
- The way the variogram increases with distance is linked to the phenomenon spatial variability

Spatial structure analysis: experimental variogram and its modelling

Three spatial structures



– Three spatial representations of the same statistical distribution



– Characterization of the spatial structures thanks to a regular sampling grid

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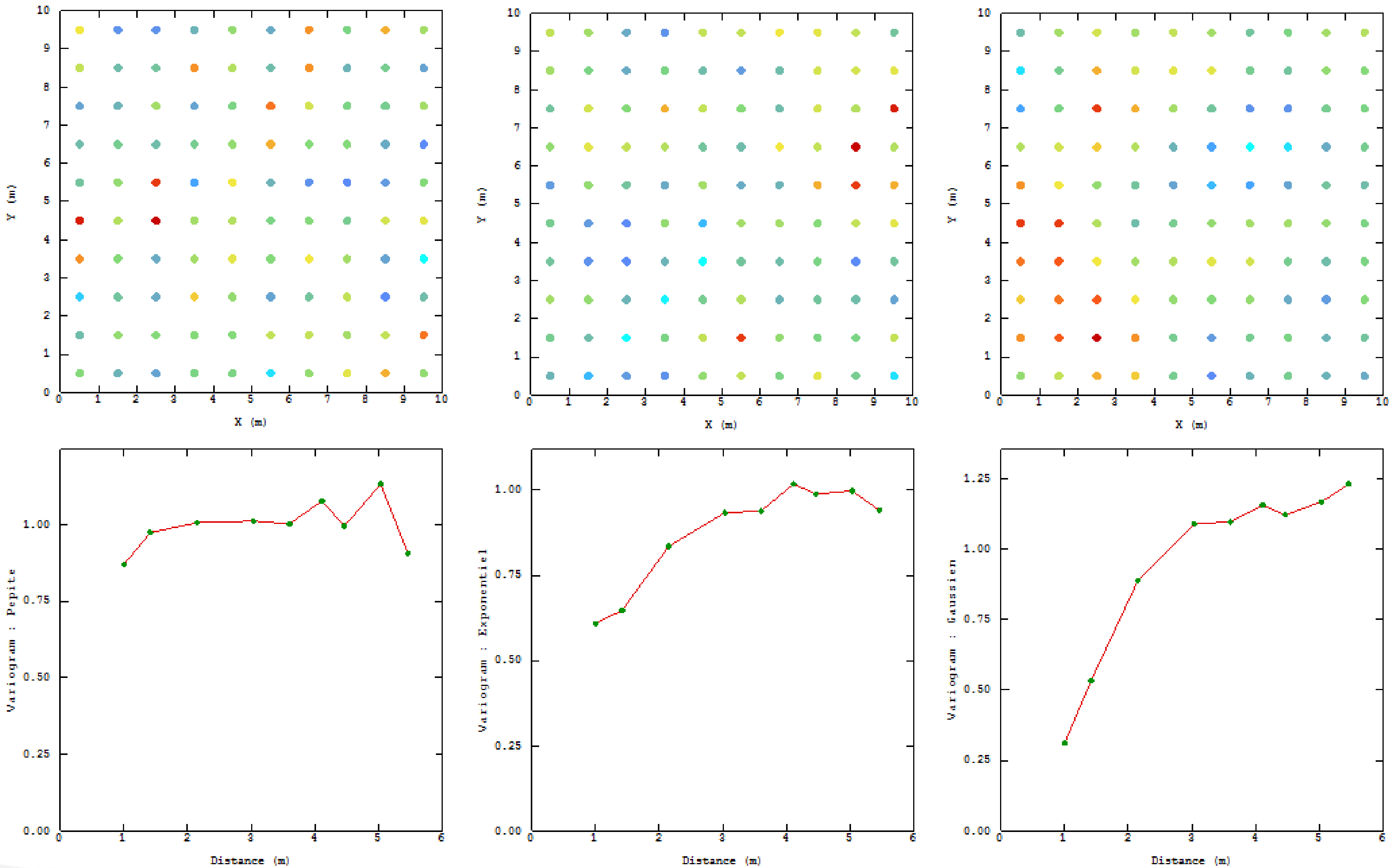
Three spatial structures



Characterization Methodology

Quantity

Historical and functional analysis

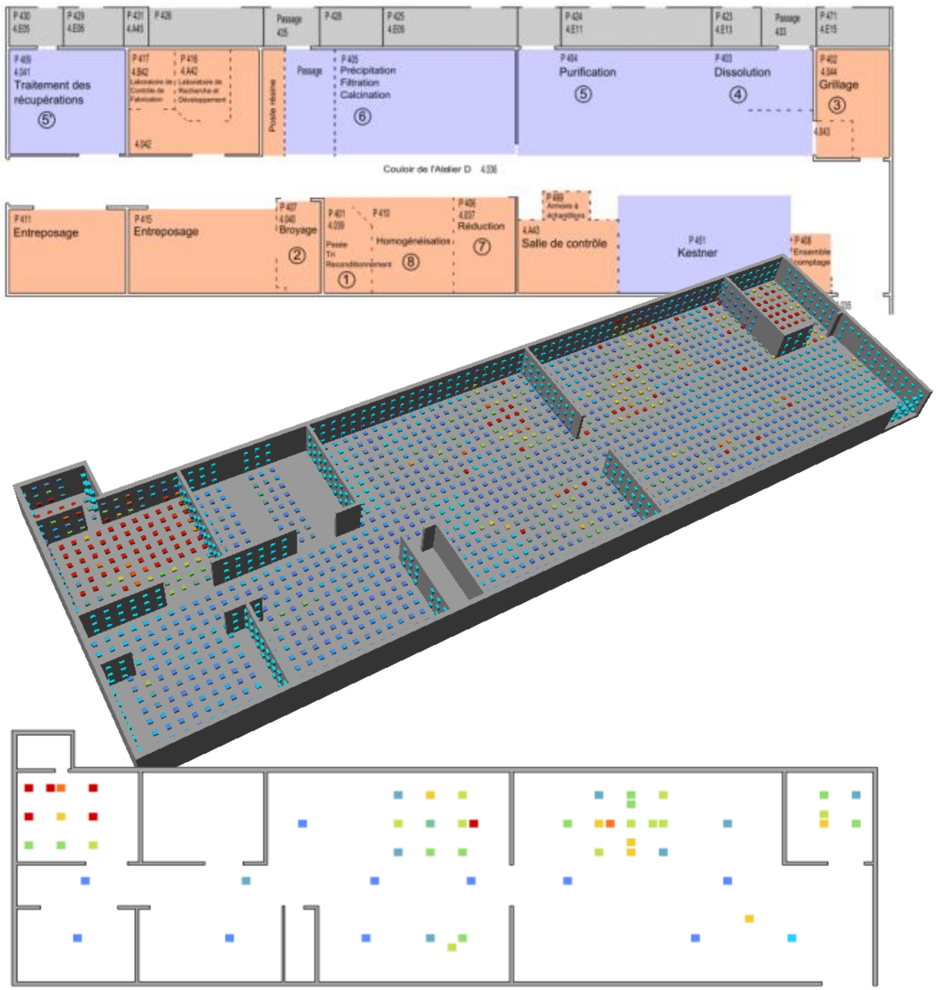
↓

Surface radiation survey

↓

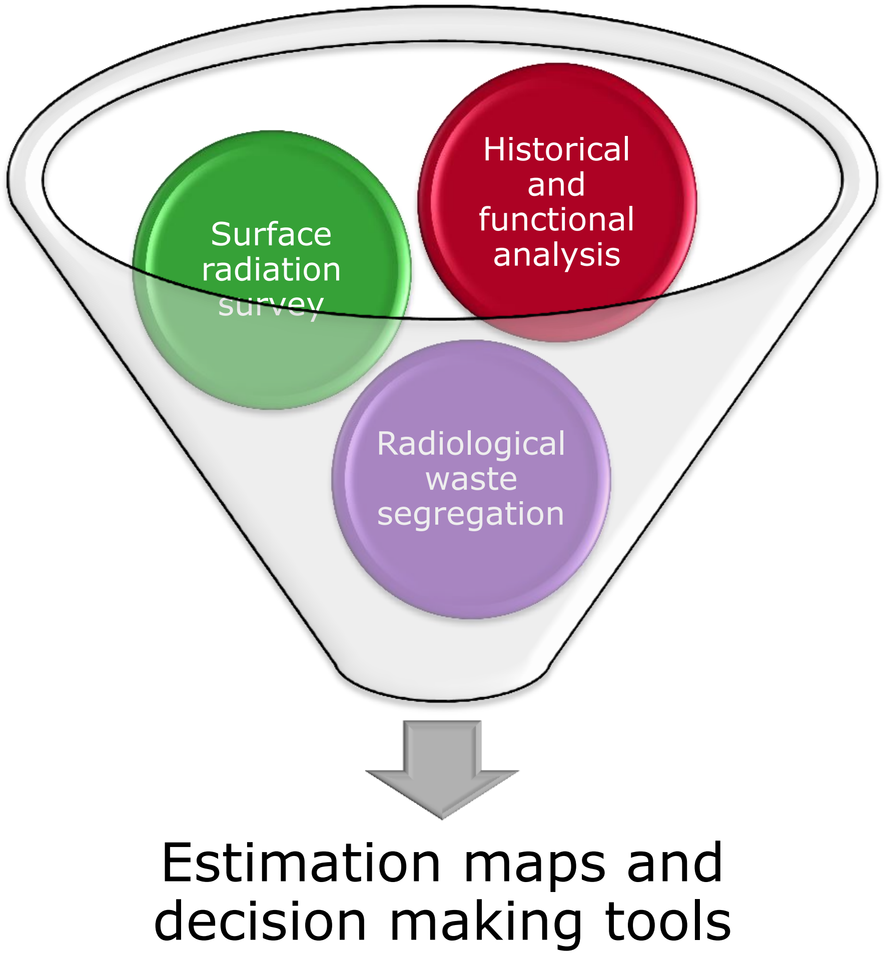
Radiological waste segregation

Cost and Time

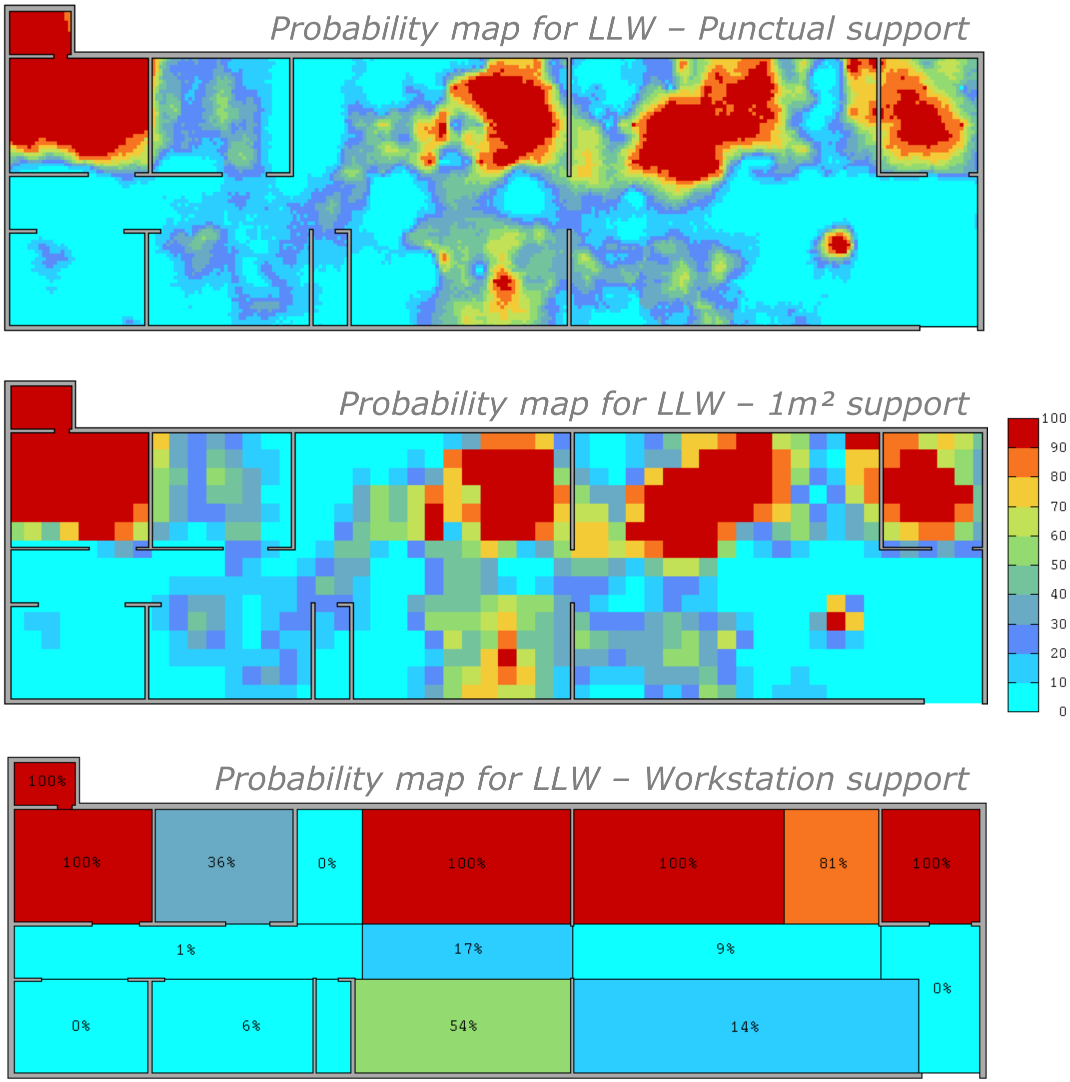


Data Analysis & Modeling

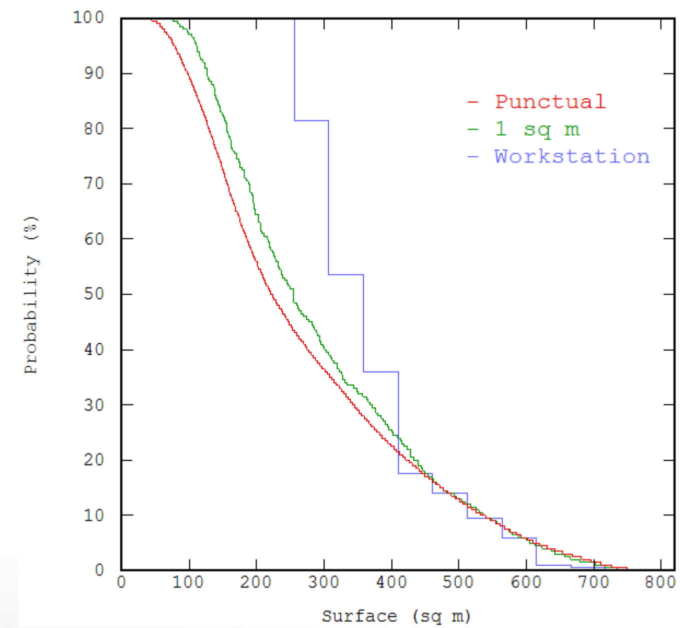
- Use of the geostatistical multivariate approach
  - Integration of all relevant information and data
  - Description of the spatial correlation between two variables:
    → Cross-variogram
  - Use of surface radiation data so as to improve the estimation of activity levels (uncertainty reduction)



Risk Analysis & Estimation Support



- Taking the decision support into account:
  - Punctual → Hot spots
  - Block → Waste category
- Impact on categorisation surfaces (averaging)



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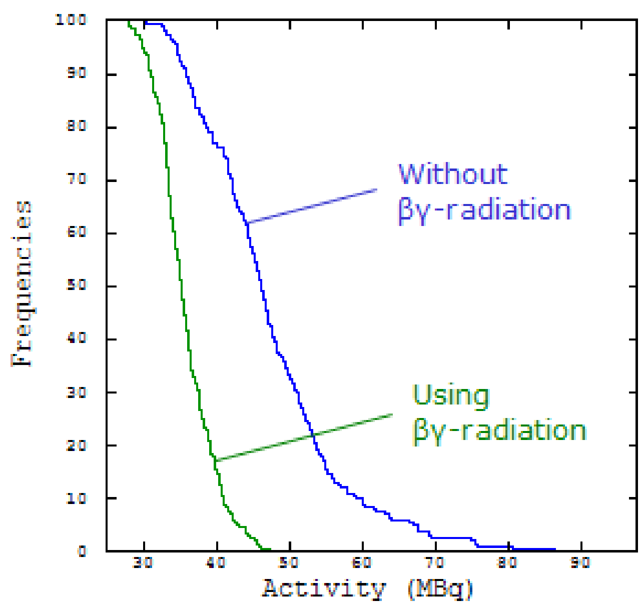
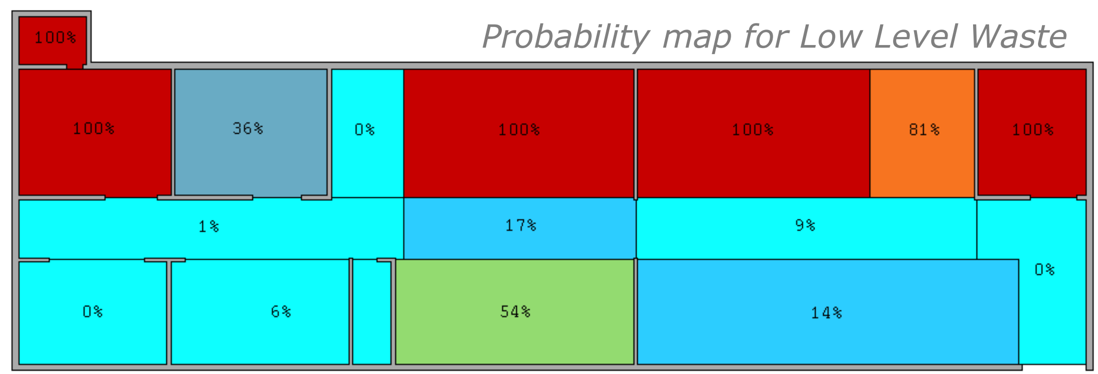
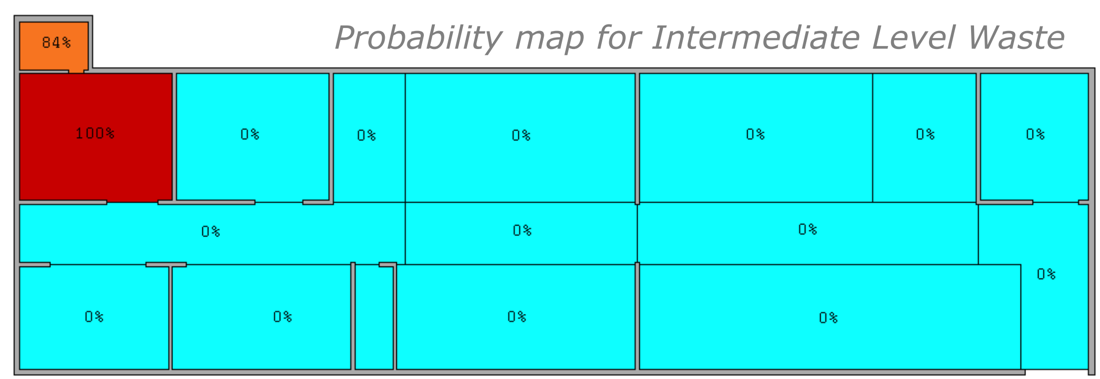
Radiological Categorization

- Decision-making tools for decontamination process:
  - Waste segregation according to activity levels and risk levels
  - Average activity per "decontamination unit"
  - Accumulation (total amount of activity)





Probability map for Low Level Waste



Probability map for Intermediate Level Waste

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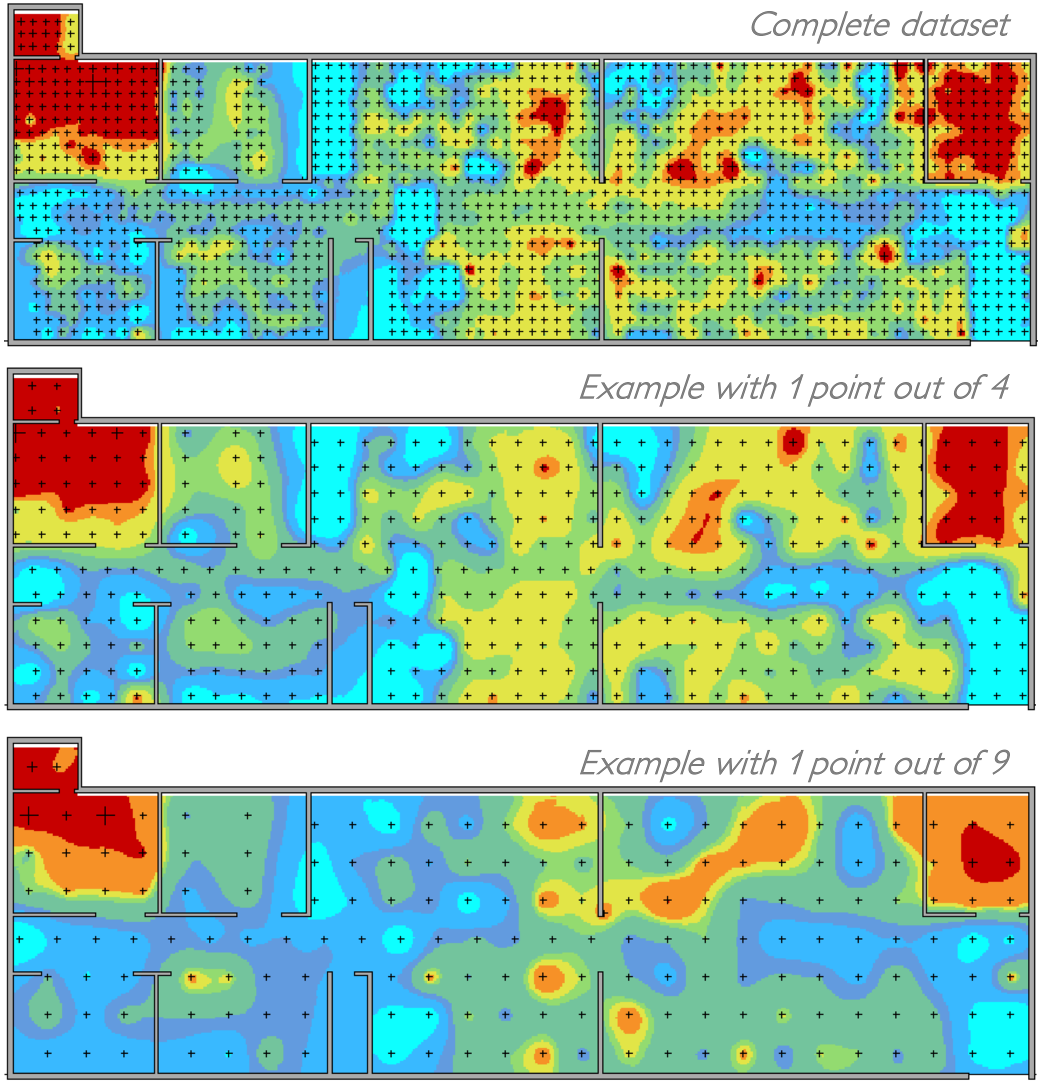
Sampling Optimization

- Impact of the initial mesh on the estimation maps:
  - 0.66m, 1.3m, 2.0m
- What is your objective?
  - Hot spots
  - Average dose rate
  - Waste zoning
  - …



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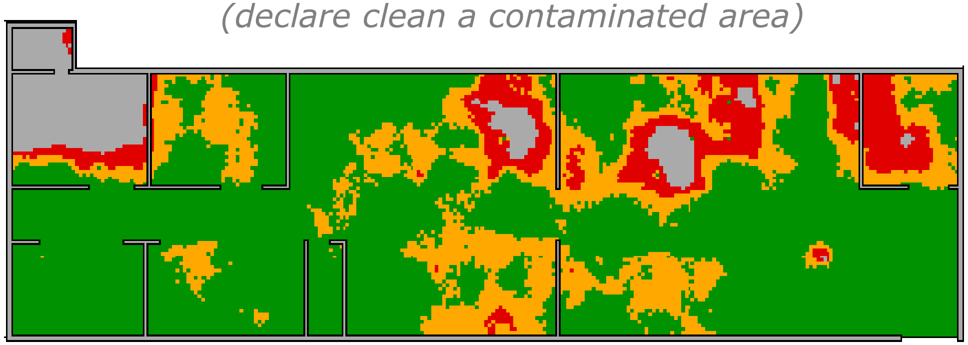
Sampling Optimization

- Integration of the geostatistical analysis of values to optimize the number and location of data points
    - Initial mesh determination (feedback on spatial structures)
    - Defining additional points (on risk maps)
    - Positioning samples on radiation maps (use of the correlation between values)

Map of the false negative risk

(declare clean a contaminated area)



- *Low risk*
- *Intermediate risk*
- *High risk*
- *Declared above the threshold*

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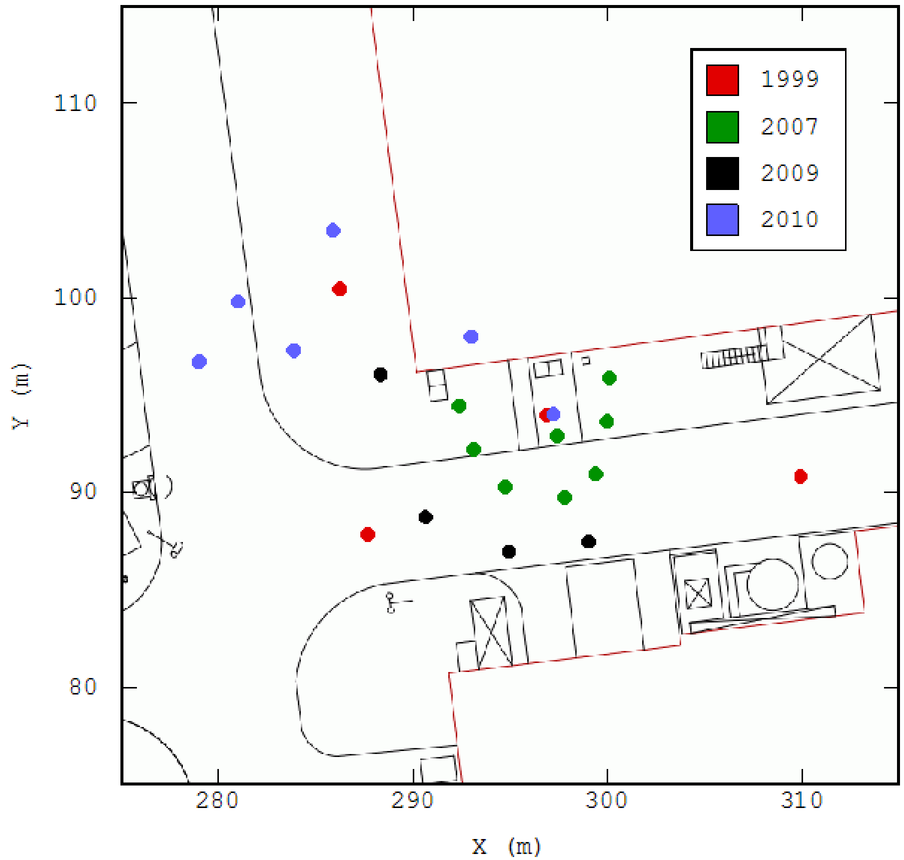
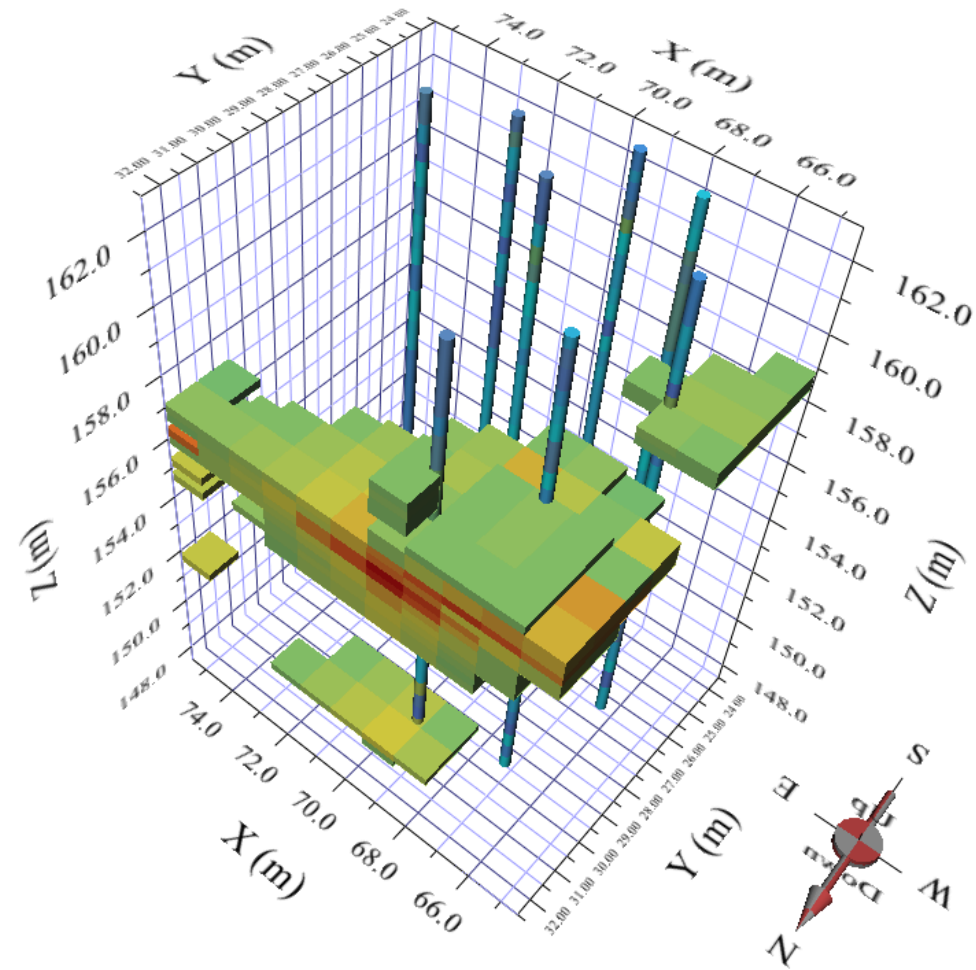
A Deep Contamination Example

- 4 drilling campaigns



- First data analysis (in 2007)



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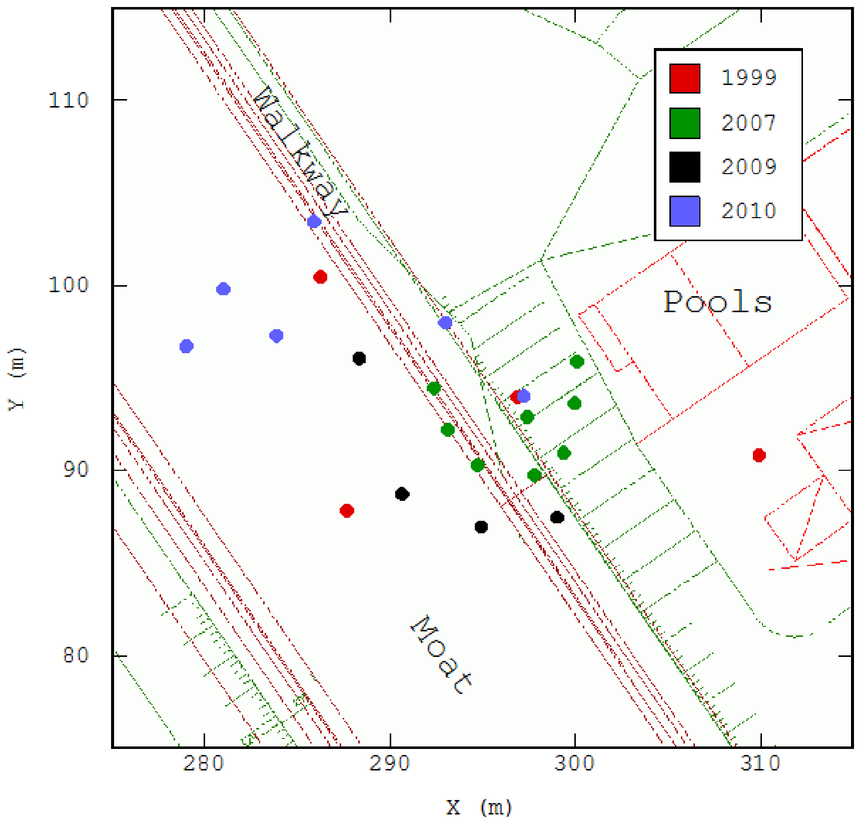
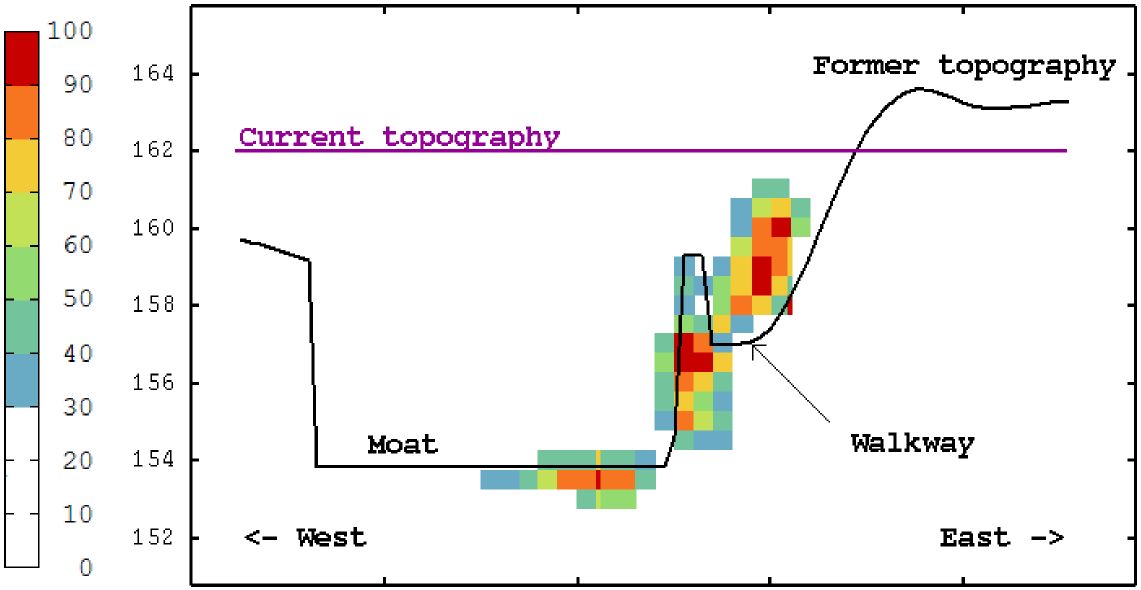
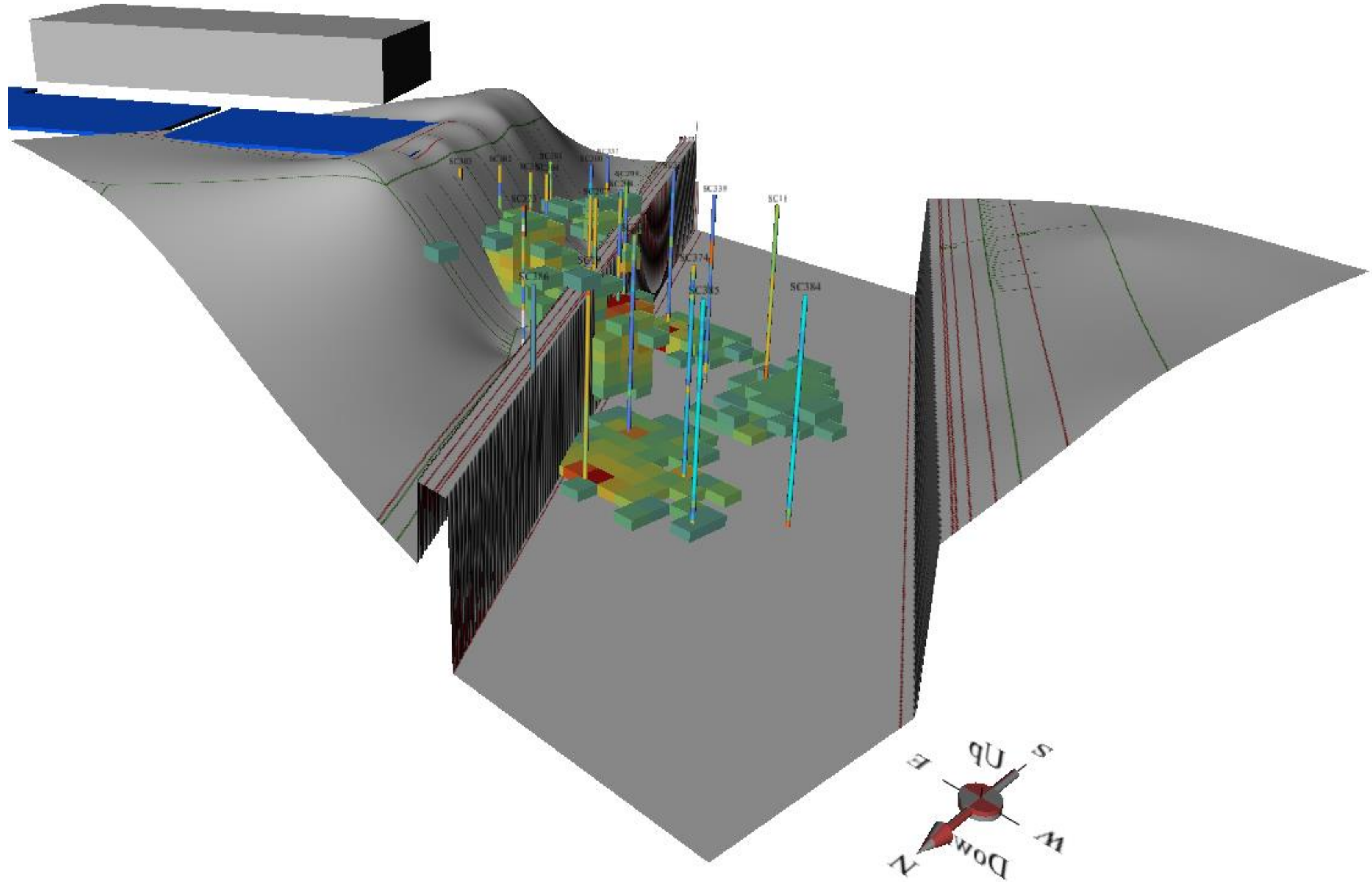
Integration of Historical Information



- Topography of the former military fortification (first generation of installations)
- Correct interpretation of contaminated areas



3D Representation



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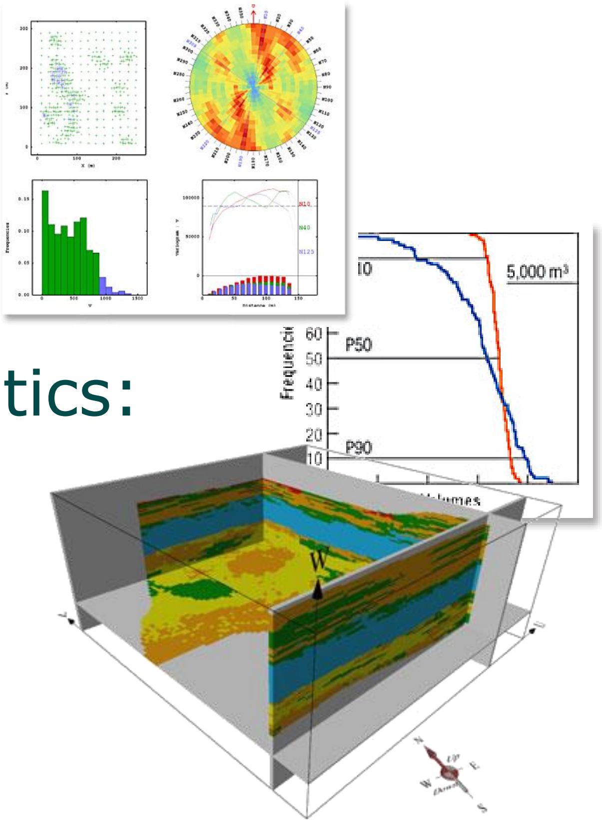
Added Value of Geostatistics

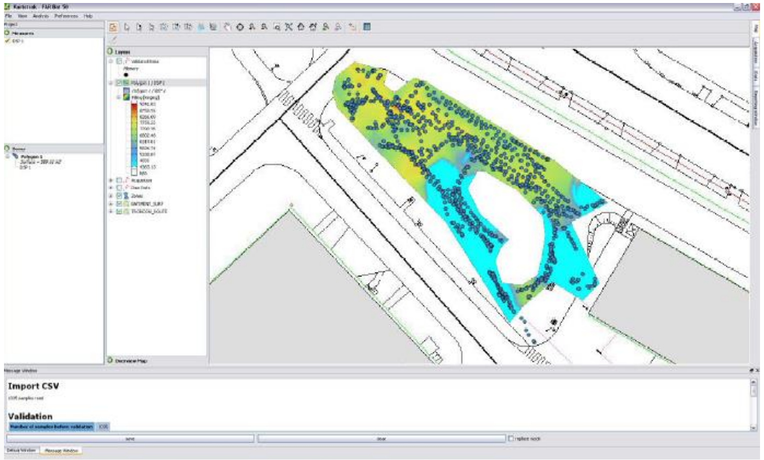
- Explore and valuate collected data
  - Data cleaning and validation / Handling data anomalies and outliers…
- Get a reliable mapping of the radiological contamination
  - Take the spatial behavior (variographic analysis) into account
  - Assess the precision of the estimation map
  - Refine the estimation map using correlated data (destructive / in situ) and indirect information (historical knowledge)
- Quantify uncertainties on contaminated volumes (or surfaces)
  - Compute the probability of exceeding a radiological threshold
  - Assess the uncertainty on the volumes
- Optimize the investigation effort / sampling strategy

Geovariances in brief…

- World leader in advanced geostatistics
- The most complete solution in geostatistics:
  Innovative Methodologies,
  Experts & Software packages



- Kartotrak all-in-one software solution for contaminated site characterization
  - GIS-based with sampling optimization
  - Real-time contamination mapping
  - Risk assessment for decision-making process (2D and 3D modeling)



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