In-situ radiation measurements and GIS visualization / interpretation

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Outline

- Intro NSIL
- Need for radiological monitoring
- Some features inherent to in-situ measurements
  - Compliance to needs
  - Effective sampling
  - Spatial distribution of radiation
  - GPS readings
- Measurement and Interpretation
  - Comparability of data
  - Data validation
  - Interpolation
  - Probability maps

NSIL: Nuclear Science and Instrumentation Laboratory

Spectrometry

Instrumentation

Mission: Assisting Member States in introducing and extending the use of nuclear instrumentation and radiation spectrometry techniques

- Training
- Research aimed to improve analytical performance and to extend applicability (Adaptive Research)
- Provision of analytical services (MS and other IAEA units)

Regular Budget Activities

Major programme 1. Nuclear Power, Fuel Cycle and Nuclear Science

Programme 1.4 (D) Nuclear Science

Subprogramme 1.4.3 (D.3) Accelerators and Nuclear Spectrometry for Material Science and Analytical Applications

PROJECTS (2016 - 2017):

1.4.3.3 Facilitating experiments with accelerators (*Particle and Synchrotron*)

1.4.3.4 Nuclear Instrumentation *(for Environmental and other Applications)*

TC Budget Activities

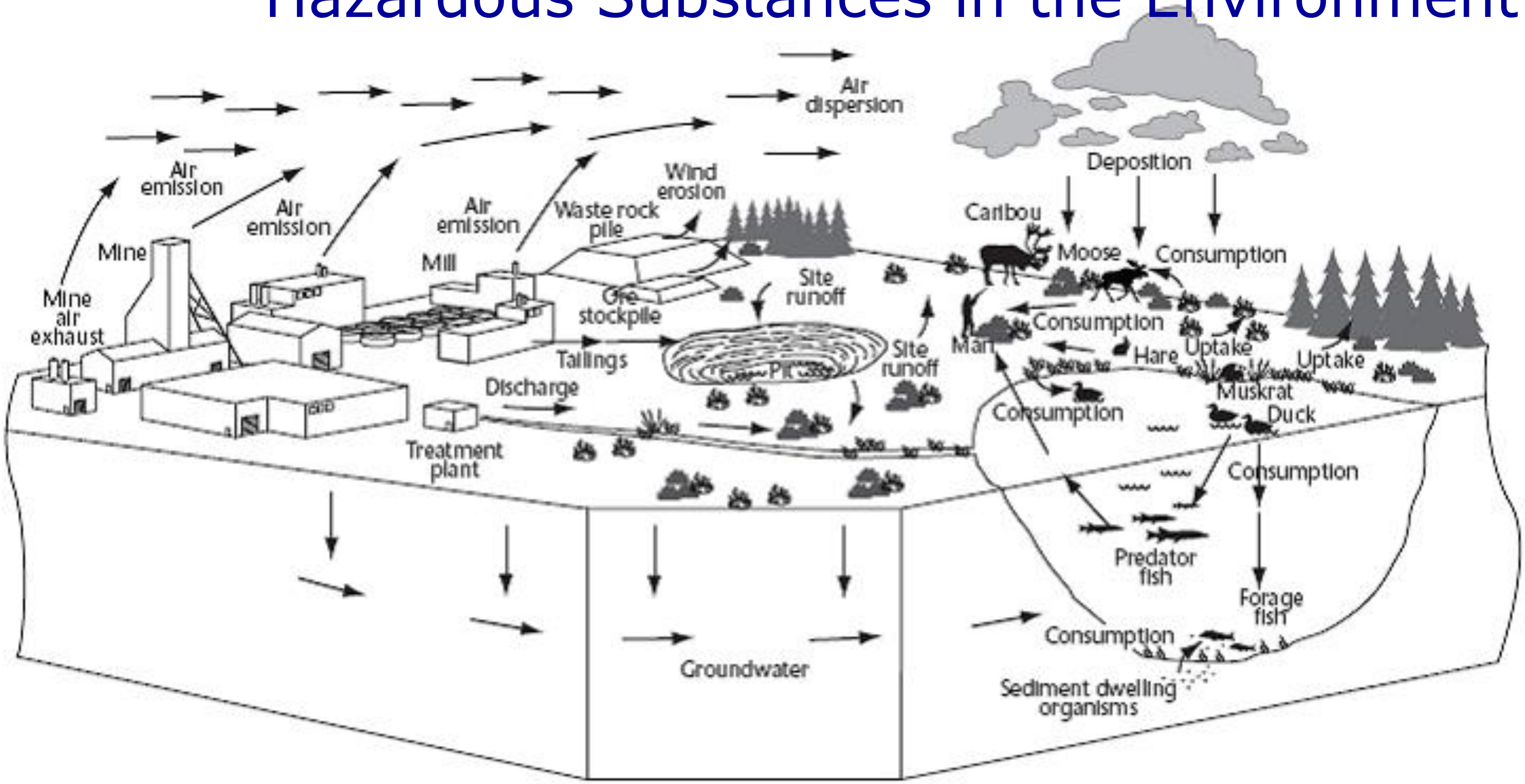
- National, Regional and Interregional projects

- Technical backstopping
  - Concepts and designs review
  - Implementation
    - Procurement
    - Expert missions
    - Regional Training courses
    - Fes and SVs

- Around 20 fellows month trained at NSIL

ERA monitoring

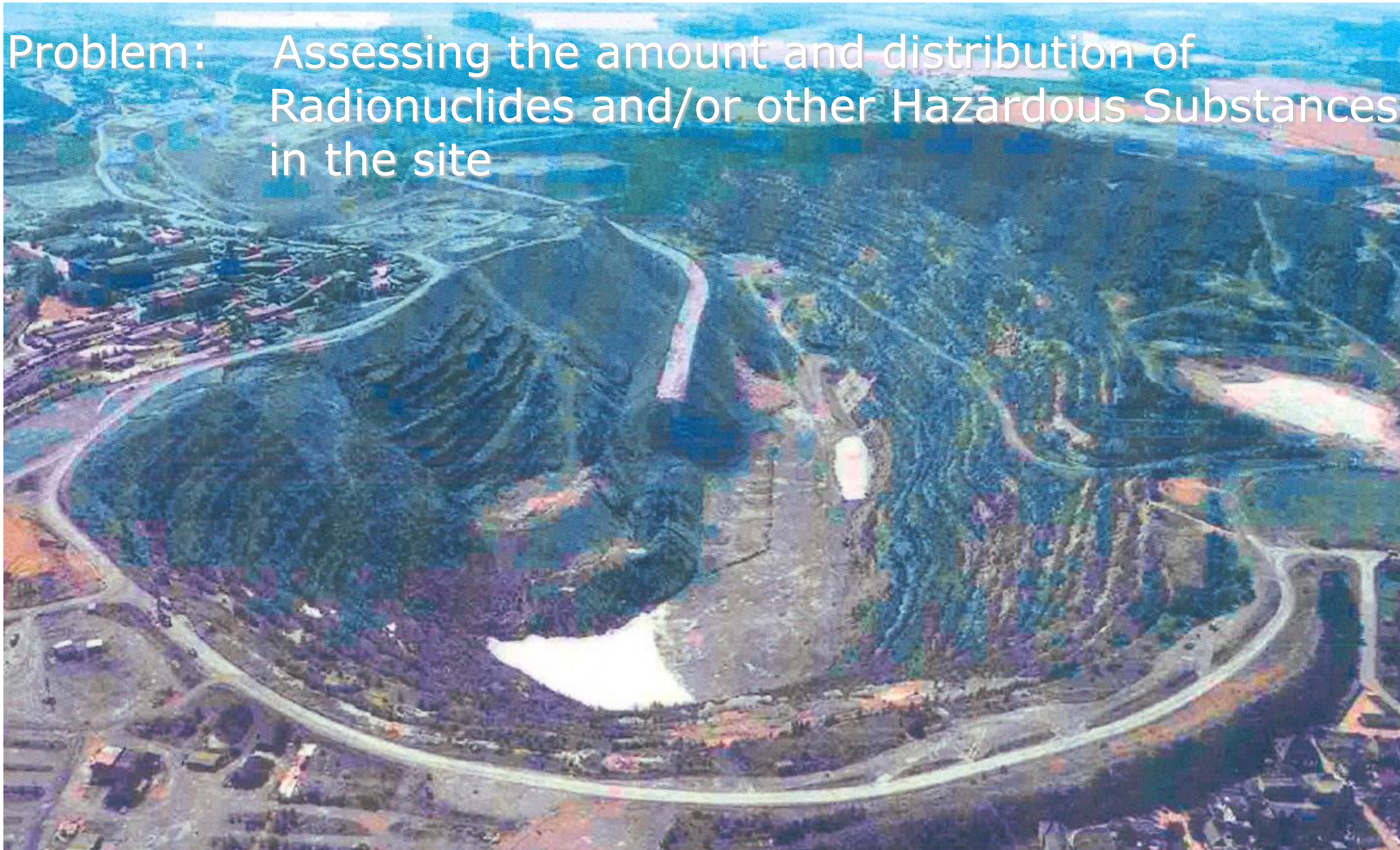
Problem: Monitoring of Radionuclides and/or other Hazardous Substances in the Environment



Example of conceptual model for a mining / milling site

Characterization of sites for remediation

Problem: Assessing the amount and distribution of Radionuclides and/or other Hazardous Substances in the site



Typical cases of radiologically affected sites include:

- Uranium mining / milling sites
- Sites with increased amounts of NORM
    - mining of phosphate rocks, REE, bismuth, zirconium, titanium, oil exploitation
- Sites affected by discharges (accidental or planned) of radionuclides
- Nuclear weapons test areas
- Military sites
- Nuclear industry or other radiological facilities accidents

Site characterization challenges

- Samples may differ by composition and aggregation
- The concentration of contaminants of concern (abundance) is unknown
- Heterogeneous spatial distribution of the COC
- Need to analyze different compartments (soil, water, biota)
- Large amount of samples required to evaluate the status and extent of the contamination

Balanced order of priorities in site characterization

- Is there contamination (Y/N)
    - Trigging level corresponding to established (or to be established) regulation
        - Presence or not
- How to assess the extent (spatial distribution) of the contamination?
        - Knowledge of previous activities + logic sampling campaign
        - In-situ fast screening
- Accuracy required for the results…
    - High? Poor? Acceptable?
- Additional needs:
    - To avoid misclassifications (false positives/ negatives)
    - To minimize hazardous exposure
    - To reduce costs
    - To shorten time delay for decision taking

An ideal analytic technique...

- Sensitivity
  - The response to the inspected property (measurand, analyte)
    - highest possible !
    - Lowest DL !
- Specificity
  - To which extent the measured signal reflects only of the presence (qualitative) and amount (quantitative) of the analyte
    - Interference free !
- Accuracy of the measurement result
  - To which extent the result is true and precise
    - Better possible accuracy !

An ideal analytic technique...

- Uncertainty of measurement result
  - Uncertainty is the parameter associated with the result of a measurement that characterizes the dispersion of the values that could reasonably be attributed to the measurand
    - Minimal possible uncertainty !
- Time delay in obtaining the results
    - Immediate !
- Cost
    - Minimal !

In real life what matters is...

- Fitness for purpose
  - To which extent the analytical method fulfils the expectations in regard to the results of analysis

- Analytical Problem definition
  - What my sample is?
    - Matrix type
    - Homogeneity of distribution of the property
  - What do I need to assess in it?
    - Analytes (COC)
  - What is the expected level of presence of the analyte?
    - Mass fraction, activity concentration
  - How accurate and uncertain can be the results?
    - Depends on the purpose of the characterization

Laboratory vs. in-situ

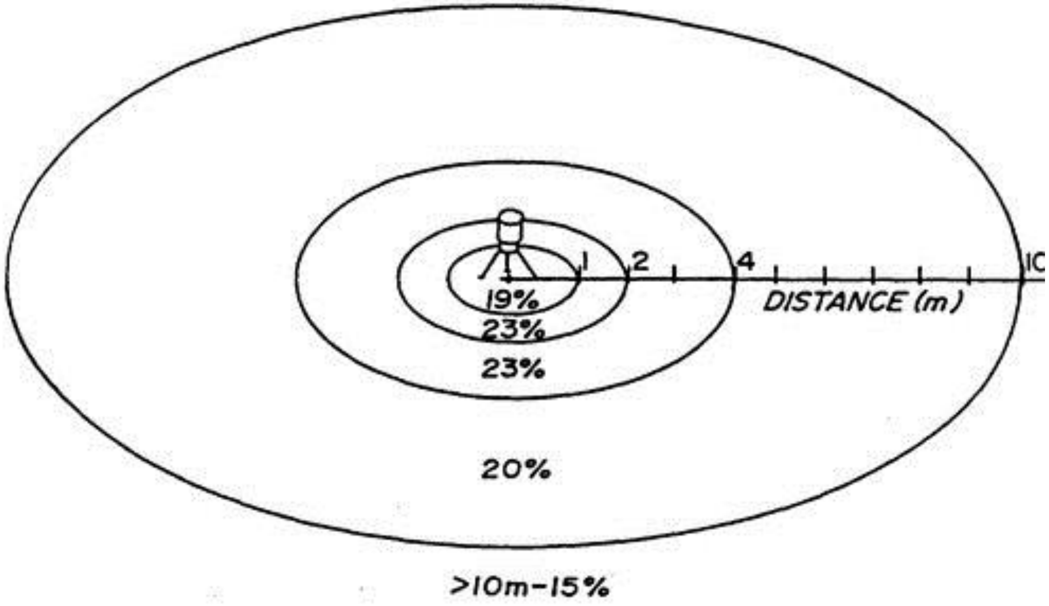
Gamma spectrometry: Sample size

- Appropriate sampling
  - representative
- Highly accurate analysis
- Mostly for soils, biota, foodstuff

Marinelli beaker: ~ 1 dm^3

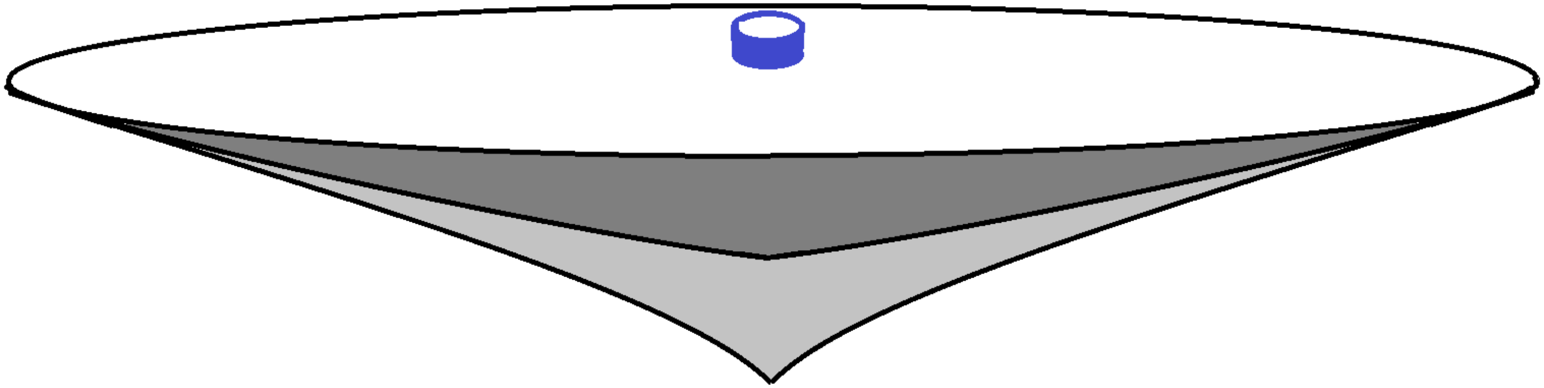
In-situ

Gamma spectrometry: Sample size



In-situ

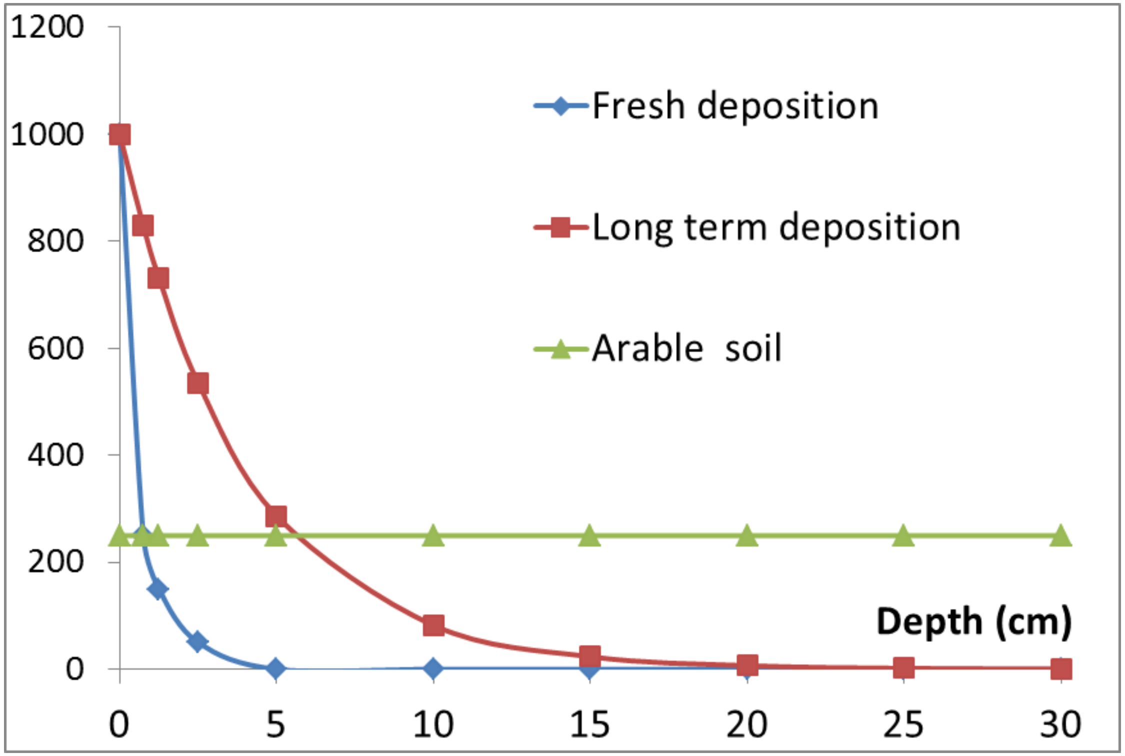
Effective Volume shape (85 %)   10 m x 0.3 m ~ 3 m^3



- The measured signal is integrated over large volume
- Suitable for large scale estimation

In-situ

Depth distribution



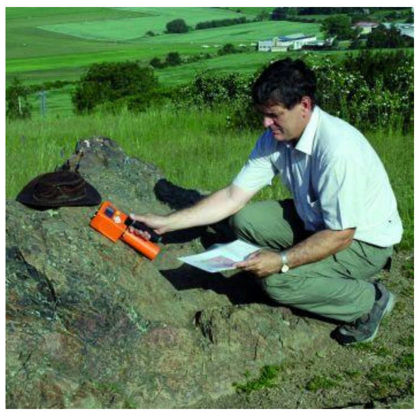
Compliance to requirements

- Sensitivity
  - Similar to laboratory (even shorter measurement time per spot !)
- Specificity
  - Sufficient for most cases (improved res. Scintillators)
- Accuracy and uncertainty of the measurement result
  - Worst for individual measurement, but at large scale characterization, better
- Time delay: immediate
- Cost: Much less !!!

Surface radiological assessment

Surface measurements:
Shift from Gas-filled (GM / PIC / PC) to
Low resolution gamma spectrometry (Scintillation detectors)

NaI(Tl), BGO, CeBr CdZnTe CsI

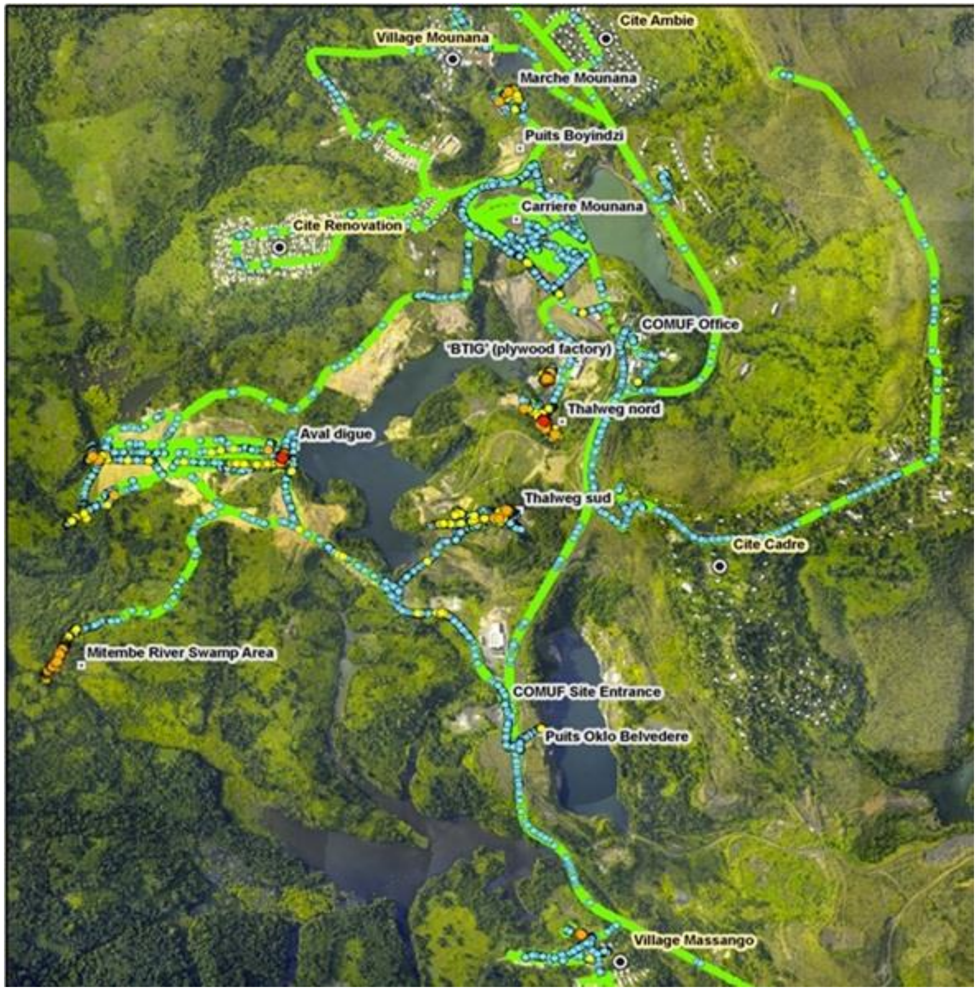




Measurement time:
For dose rate ~ 1 s
For radionuclide activity concentration ~ 1 – 5 min.

Surface radiological assessment

- 114 165 measurements
- 2 ½ days of measurements

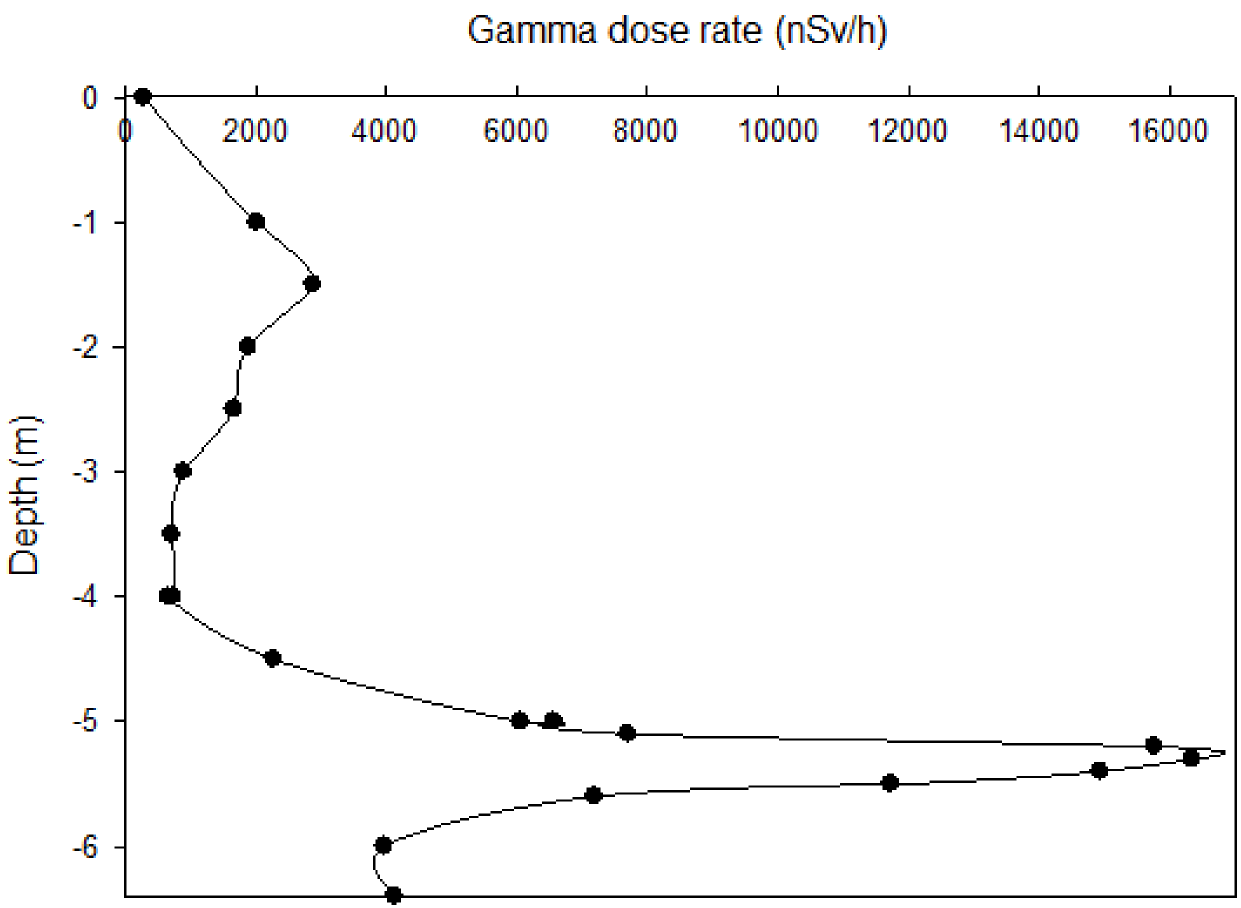
Dose rate (nSv/h)	Nr	(%)
10 - 114	61 267	56.7
114 - 250	24 771	22.9
250 - 500	11 660	10.8
500 - 1140	5 283	4.9
1140 - 10400	5 036	4.7



In-depth radiological assessment

Bore hole measurements:
High density Scintillation detectors (BGO)

In-situ techniques for radiological assessment



Dose rate depth profile in a repository of uranium tailings

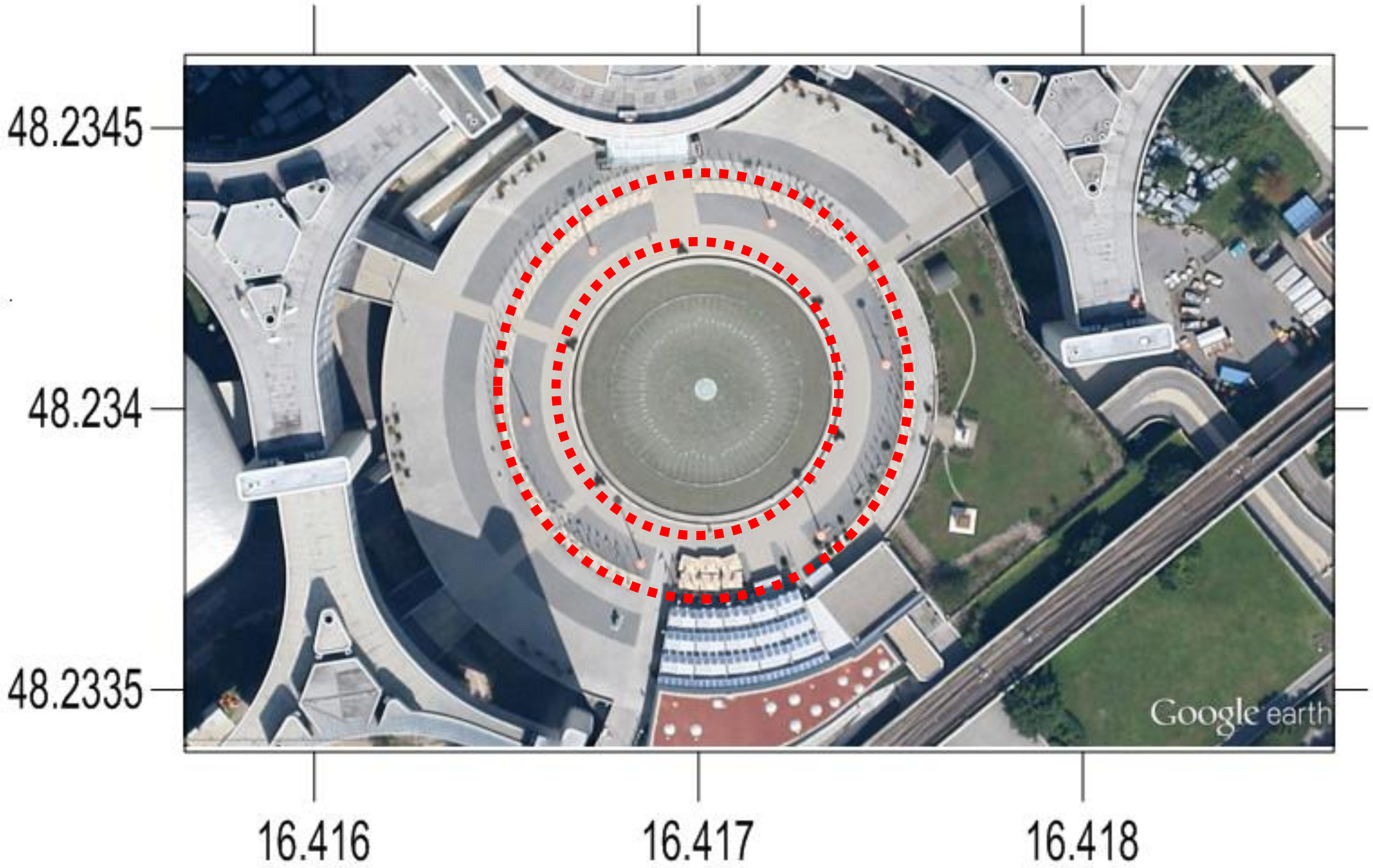
GPS coordinates

Accuracy:

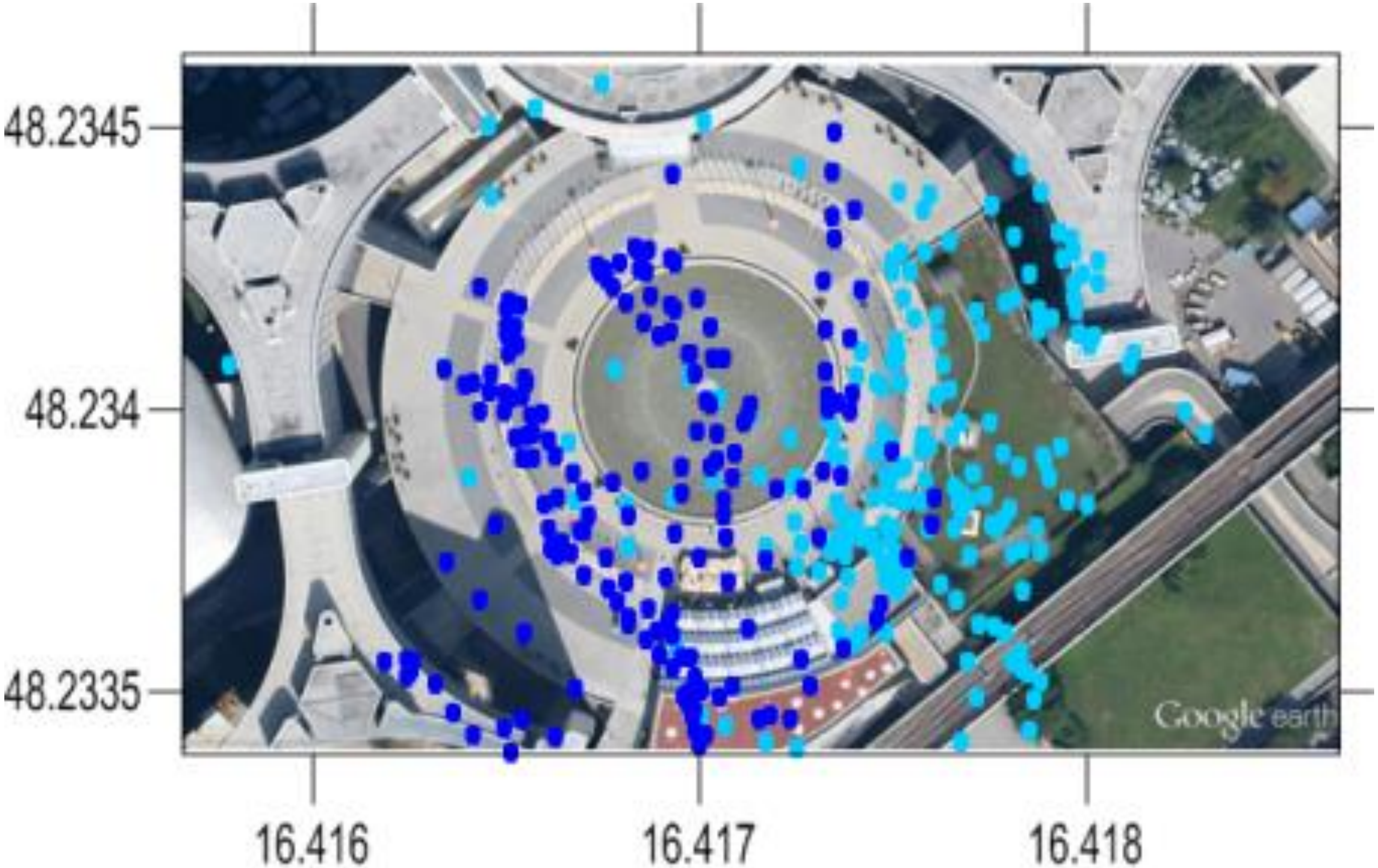
- For out of shelf (non-expensive devices) in the order of 5 – 10 m
- Open space (not covered areas)
- Effects from multiple reflections at buildings or topography (cliffs, high buildings) can bias the coordinate readings

Effect of reflections

Effect of reflections



Effect of reflections



GPS coordinates

- **Higher precision data is also available**
  - **OmniSTAR** is a satellite based augmentation system (SBAS) service provider. OmniSTAR correction signals are proprietary, and a subscription must be bought
  - **Differential Global Positioning System (DGPS)** Reference radio beacon systems network of fixed, ground-based reference stations to broadcast the difference between the positions indicated by the satellite systems and the known fixed positions

Usability of data

- Several instruments might be used at once
- Each instruments has different calibrations

Rescaling readings:

- It is recommended to use at least one instrument having calibration made by an accredited laboratory. The measurements obtained with other instruments can be re-scaled to the values of the calibrated instrument

Usability of data

- Several instruments might be used at once
- Each instruments has different calibrations

Rescaling readings:

- Compare readings among the different instruments at locations where different dose rate levels are found. Differences not exceeding 25 % can be re-scaled to those of the instrument selected for reference

Data validation:

- Coordinate validation: The data sets have to be thoroughly examined to correct positioning errors if any, in combination with background map or visual localization.
- Incorrect values: To exclude the cases presenting missing or wrong values (probe saturation or probe failure for instance).
- Detection limits: Shall be considered as valuable information. Depending on the intended processing algorithm, be replaced by either the DL, or by different fractions of the detection limits (in Geochemistry to use half of the DL)
- Duplicates: Measurements performed within a distance less than the targeted spatial resolution in a grid plan) must be removed or replaced by a single value (the minimum, the maximum or the average of the defined cluster

Data analysis and interpretation:

- Base maps are needed
- Simple statistical treatment.
- Correlation among different variables, if more than one has been measured).
- Understanding the spatial variability of data.
- Interpretation and representation of the results

Base maps:

- Base maps: Maps from the surveyed areas have to be available and properly geo-referenced. The measurement results have to be represented in such maps.

- Option 1: Use professional software or free ware packages

- Option 2: Recalibrate aerial imagery

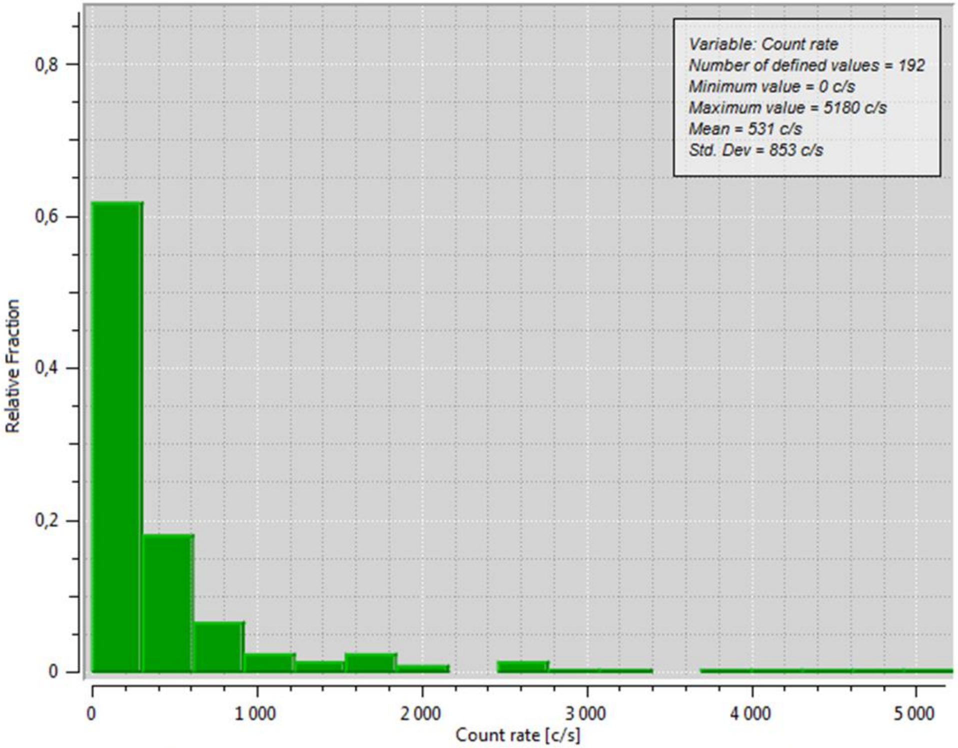
Reference points used to compare the GPS readings and to calibrate the map

Base maps:

- Base maps: Maps from the surveyed areas have to be available and properly geo-referenced. The measurement results have to be represented in such maps.
  - Option 1: Use professional software or free ware packages
  - Option 2: Recalibrate aerial imagery
  - **Option 3: Contact Frank Albinet**

Simple statistics:

- Simple statistical treatment, to reveal minimum and maximum values, as well as the variability of the data.
- Correlation among different variables, if more than one has been measured).

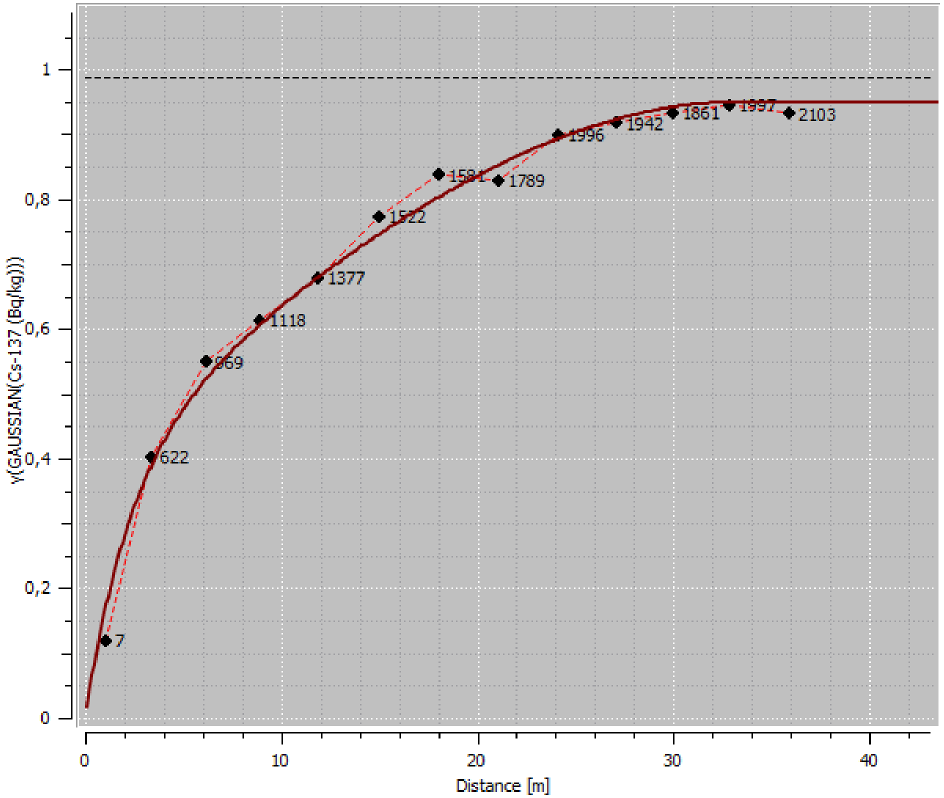


The histogram displays adjacent rectangles that are erected over an interval, with an area equal to the frequency of the measure corresponding to this interval.

Courtesy of Mr. Julien Attiogbe, Geovariances, France

Spatial variability:

- Understanding the spatial variability of data.
- Experimental variograms represent the variability of the measurement values according to the distance between each pair of data points
- *To infer some information from the spatial structure of the data set, if there is any*
- *to assess if an adequate sampling plan has been performed*



Experimental Variogram

Courtesy of Mr. Julien Attiogbe, Geovariances, France

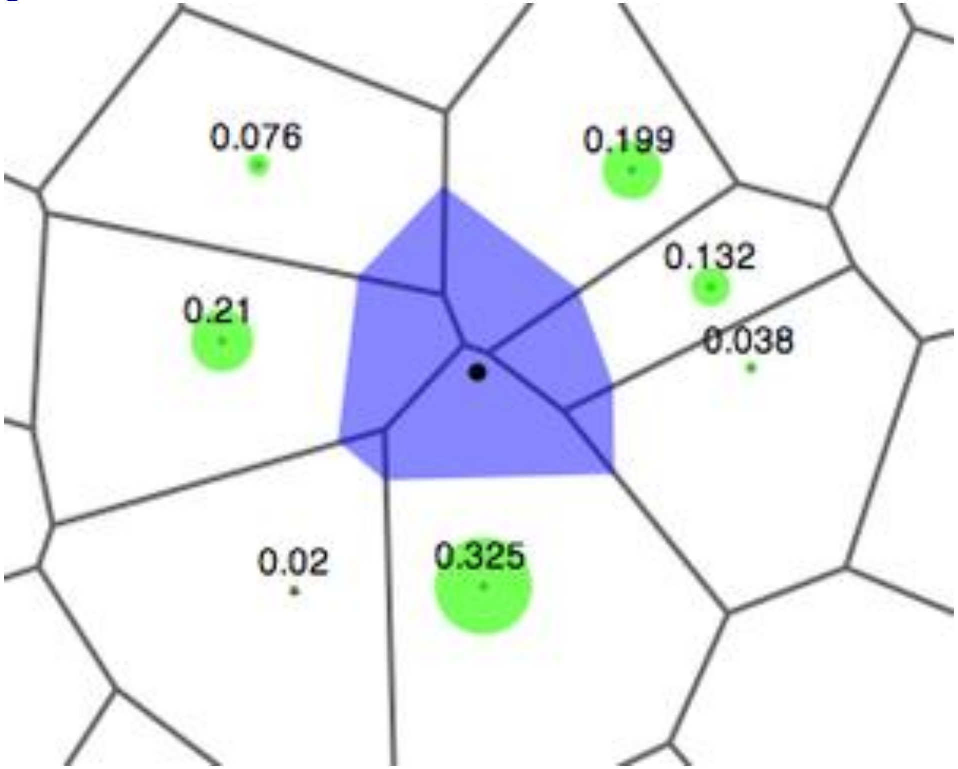
Pathway measurements:

Measured cells: 22, total area: ca. 7.7 ha
Average length of each followed path: 6.5 km

Interpolation: Natural Neighbor

- Natural neighbor: weighted average of the neighboring observations, where the weights are proportional to the "borrowed area" of Thiessen polygons

$$NN(x,y) = \sum_{i=1}^{n} w_i M(x_i, xy_i)$$

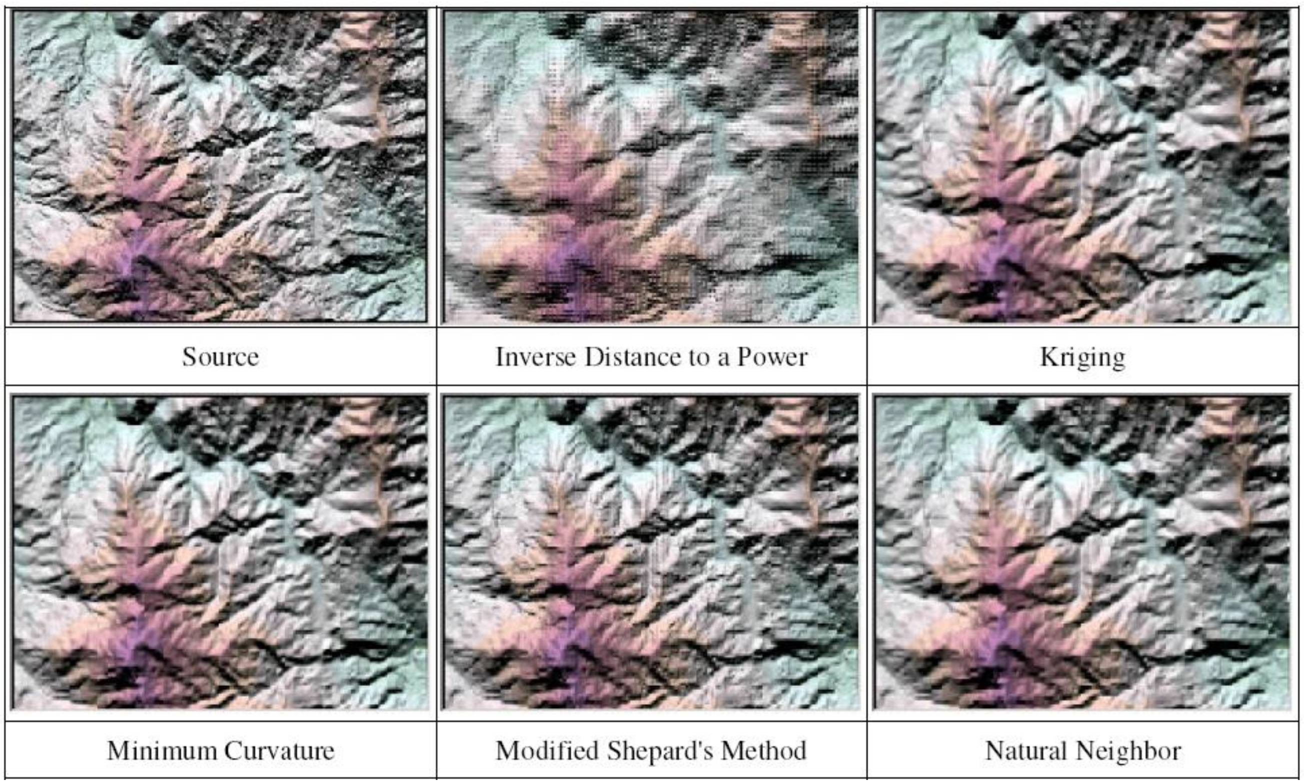


Kriging:

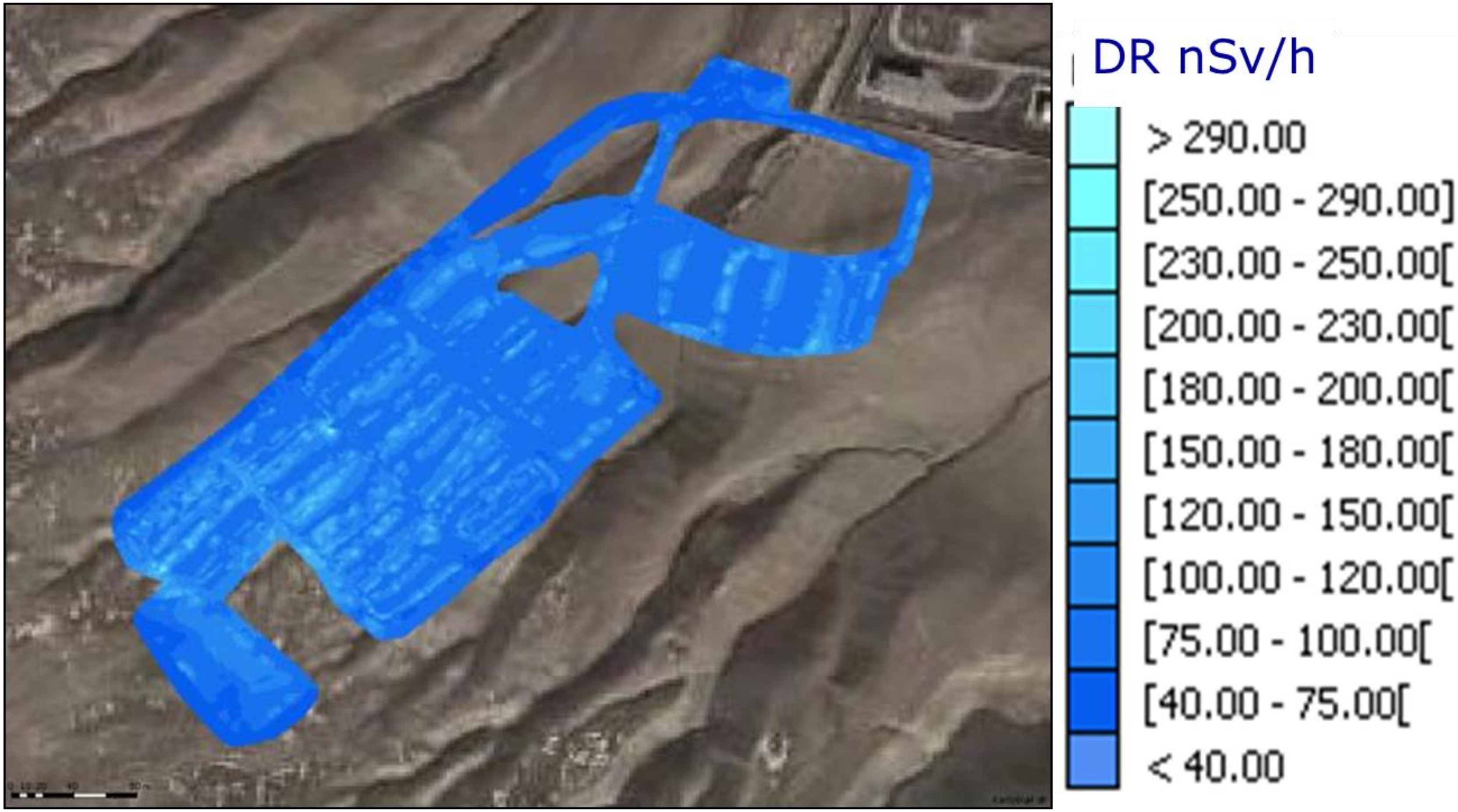
- The interpolated values are modeled by a Gaussian process governed by prior covariances.
- Kriging predicts the value of a function at a given point by computing a weighted average of the known values of the function in the neighborhood of the point
- Allows calculating the uncertainty of the prediction (based on variogram results)
- Possibility to calculate the probability of exceeding a given acceptance value (based on Gaussian distribution)

Comparison: Experimental interpolation

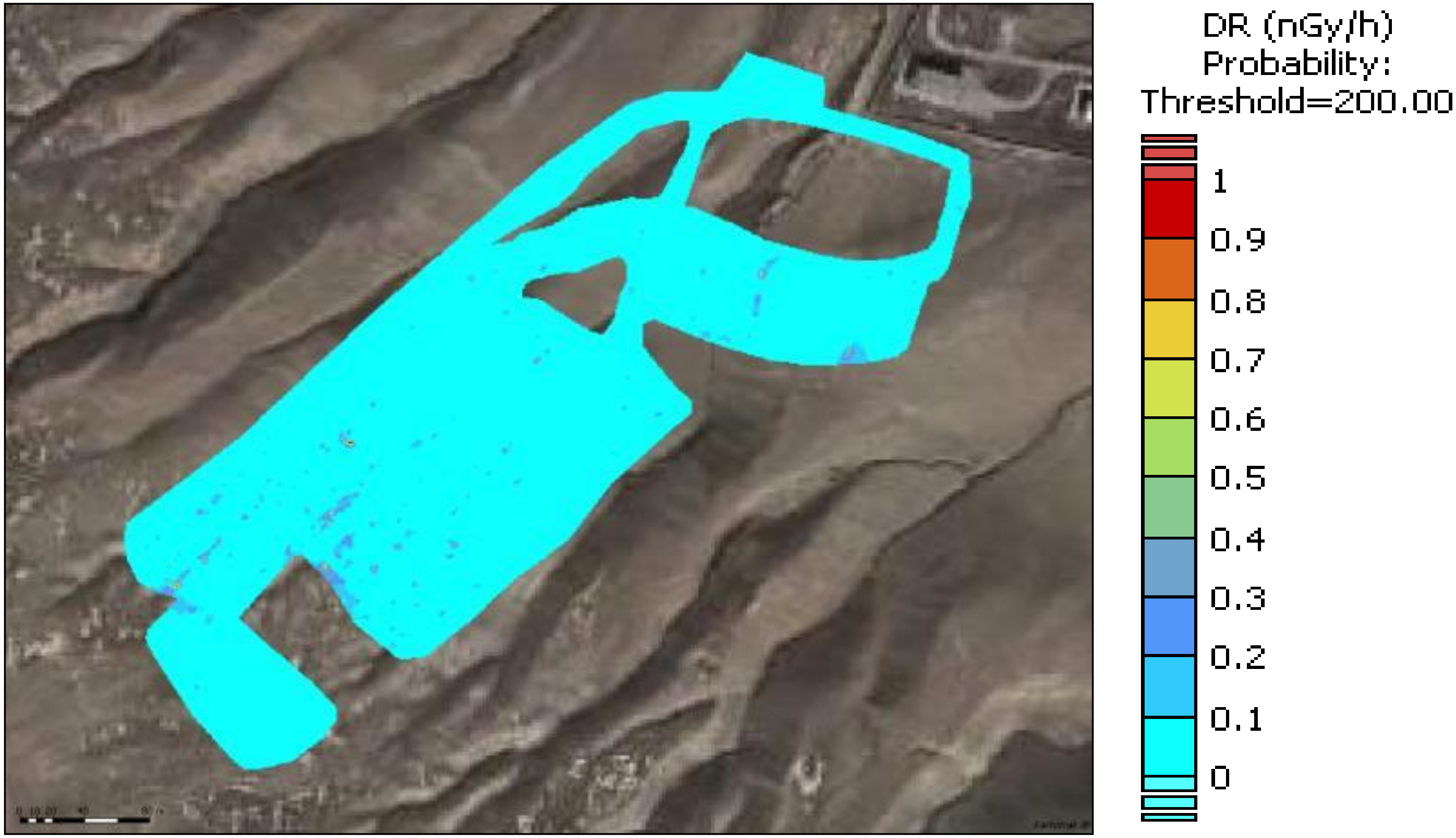
- Source data: Altitude in digital terrain model (5 m grid)
- Data set was taken with a 40 m separation
- Interpolation was made as to create a 5 m grid



Interpolation by Krigging:



Probability:



Data analysis and interpretation:

- Interpretation and representation of the results
  - Background info

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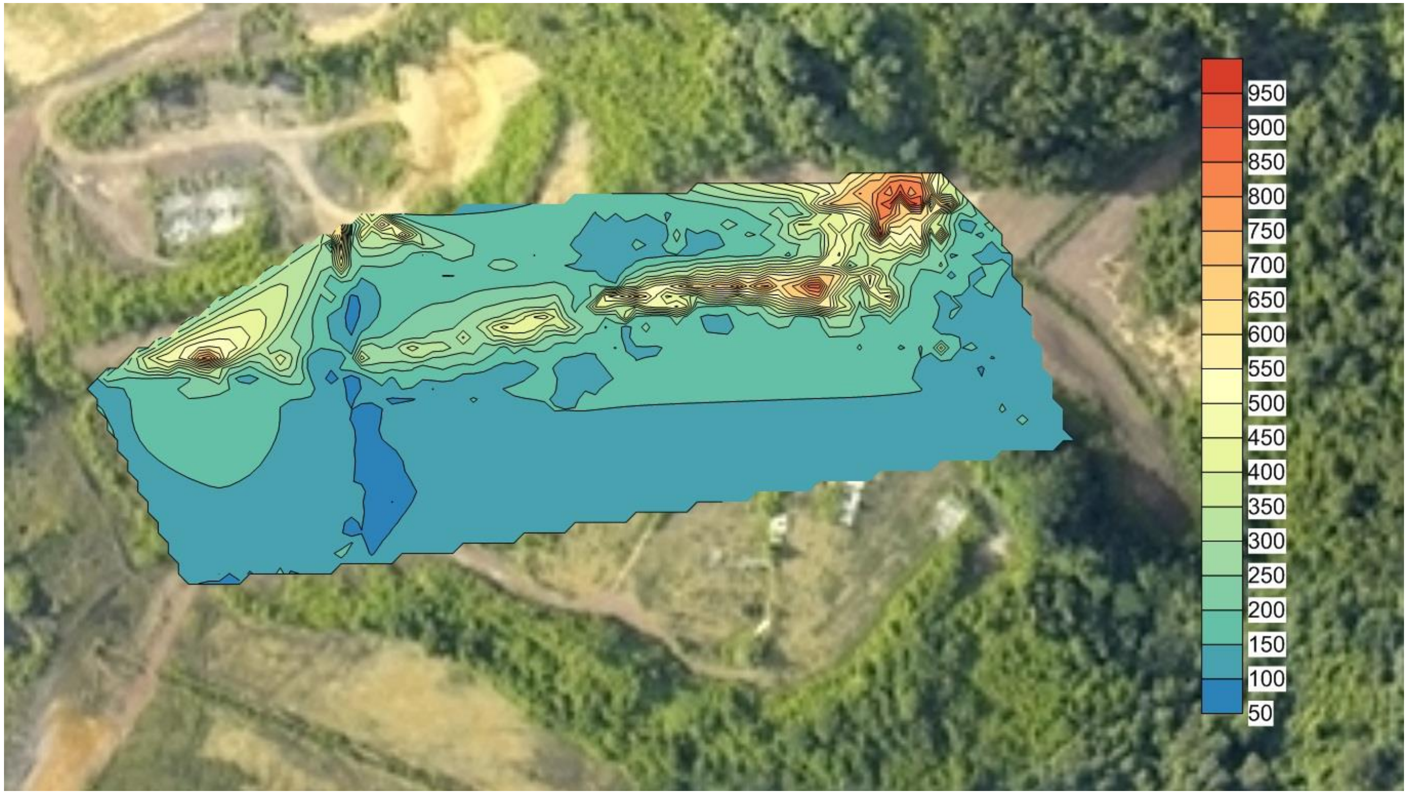

IN-SITU Working Group:

- Harmonization of procedures for site characterization, depending on the radiological impact.
- Comparison of the performance of detectors and sampling heads. For example, probes for bore-hole analysis can be useful for soil depth profile studies, whereas special sampler designs could be useful for measuring activity concentration in water bodies at different depths.
- A comparison of the performance of different statistical approaches for interpretation of the results is required. Such evaluation shall be made for data sets representing different types of contamination.

https://nucleus.iaea.org/sites/connect/ENVIRONETpublic/Pages/default.aspx

Thanks for your time and attention…