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Surface contamination activity reconstruction based on measurements of ambient dose equivalent rate

Workshop on Current and Emerging Methods for Optimizing Safety and Efficiency in Nuclear Decommissioning, 7th–9th February 2017, Sarpsborg, Norway

Objective

Find the transition method from air kerma rate $\dot{K}_{air}(x,y)$ (or ambient dose equivalent rate ***Ḋ***) to the density of surface contamination ***A***

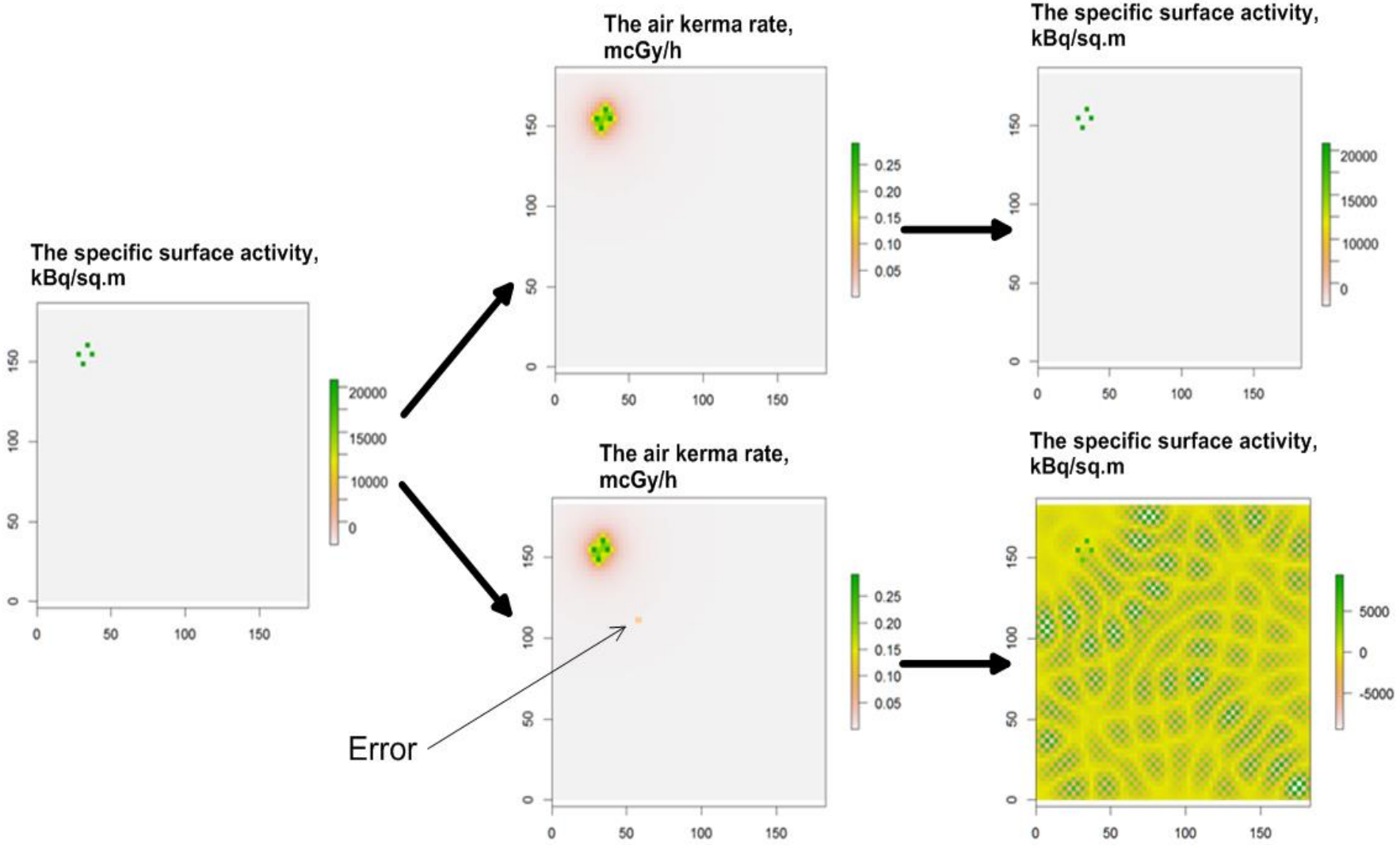
The well-known method used: method of conversion coefficients

$$\dot{K}_{air}(x,y) = DRFK \cdot A$$

$$\dot{K}_{air}(x,y)/DRFK = A$$

Where ***DRFK*** – dose-rate factor for kerma.

Example of an error in solving a system of linear equations for activity



New method developed

New method is based on the solution of Fredholm equation of first kind :

$$\dot{K}_{air}(x,y) = \int\int Q(x,y,\acute{x},\acute{y}) \cdot A(\acute{x},\acute{y})\, d\acute{x} d\acute{y}$$

$Q(x,y,\acute{x},\acute{y})$ is a kernel of the equation:

$$\boldsymbol{Q(x,y,\acute{x},\acute{y}) == \frac{K_\gamma}{H^2 + (x-\acute{x})^2 + (y-\acute{y})^2} \cdot exp(-\mu_a \cdot \sqrt{H^2 + (x-\acute{x})^2 + (y-\acute{y})^2})}$$

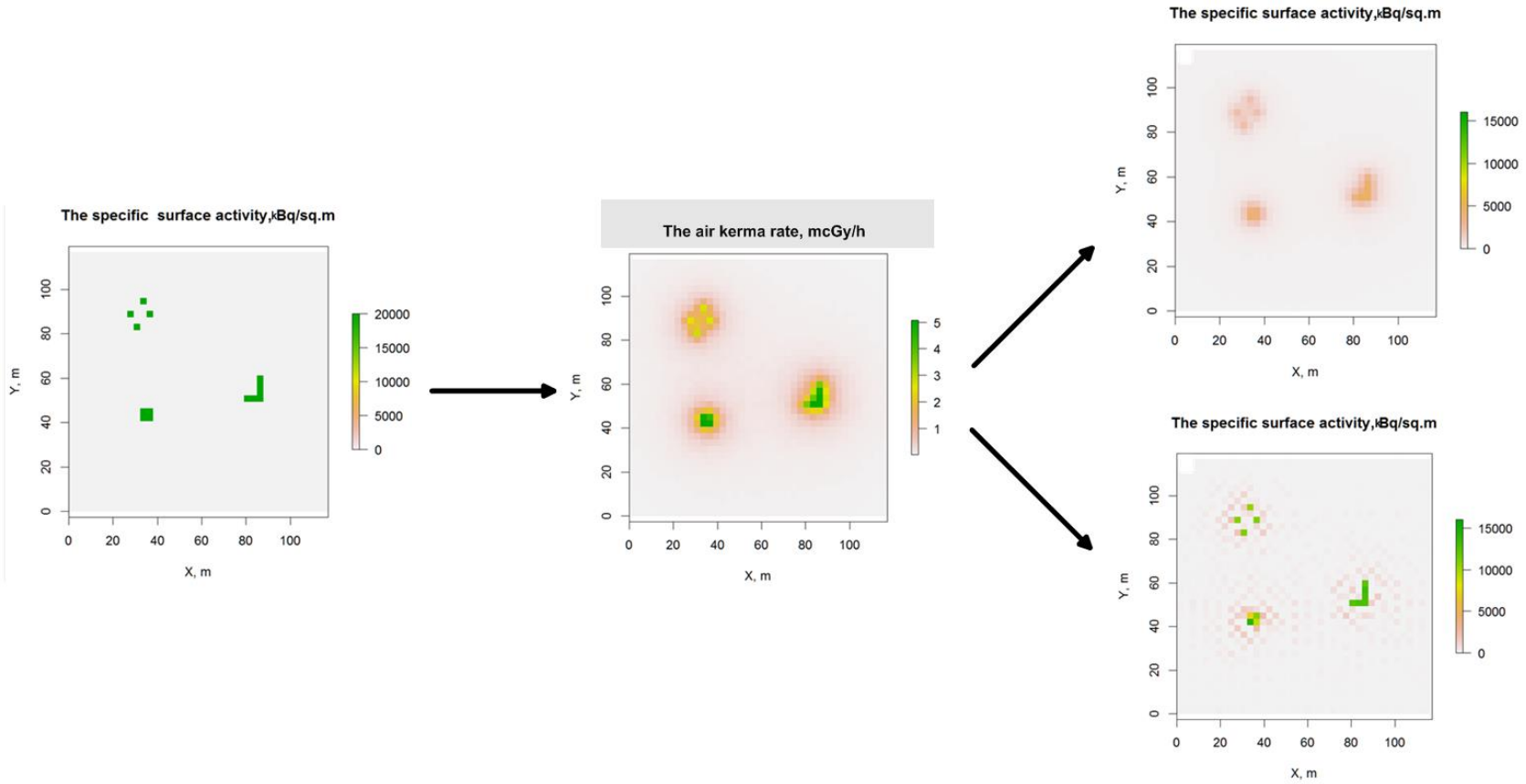
Finite-dimensional approximation

$$\dot{K}_{air}(x_m, y_n) = \sum_{j=1}^{m}\sum_{i=1}^{n}(Q\left(x_m, y_n, \acute{x}_i, \acute{y}_j\right)\Delta\acute{x}\Delta\acute{y}A\left(\acute{x}_i, y_j\acute{y}\right))$$

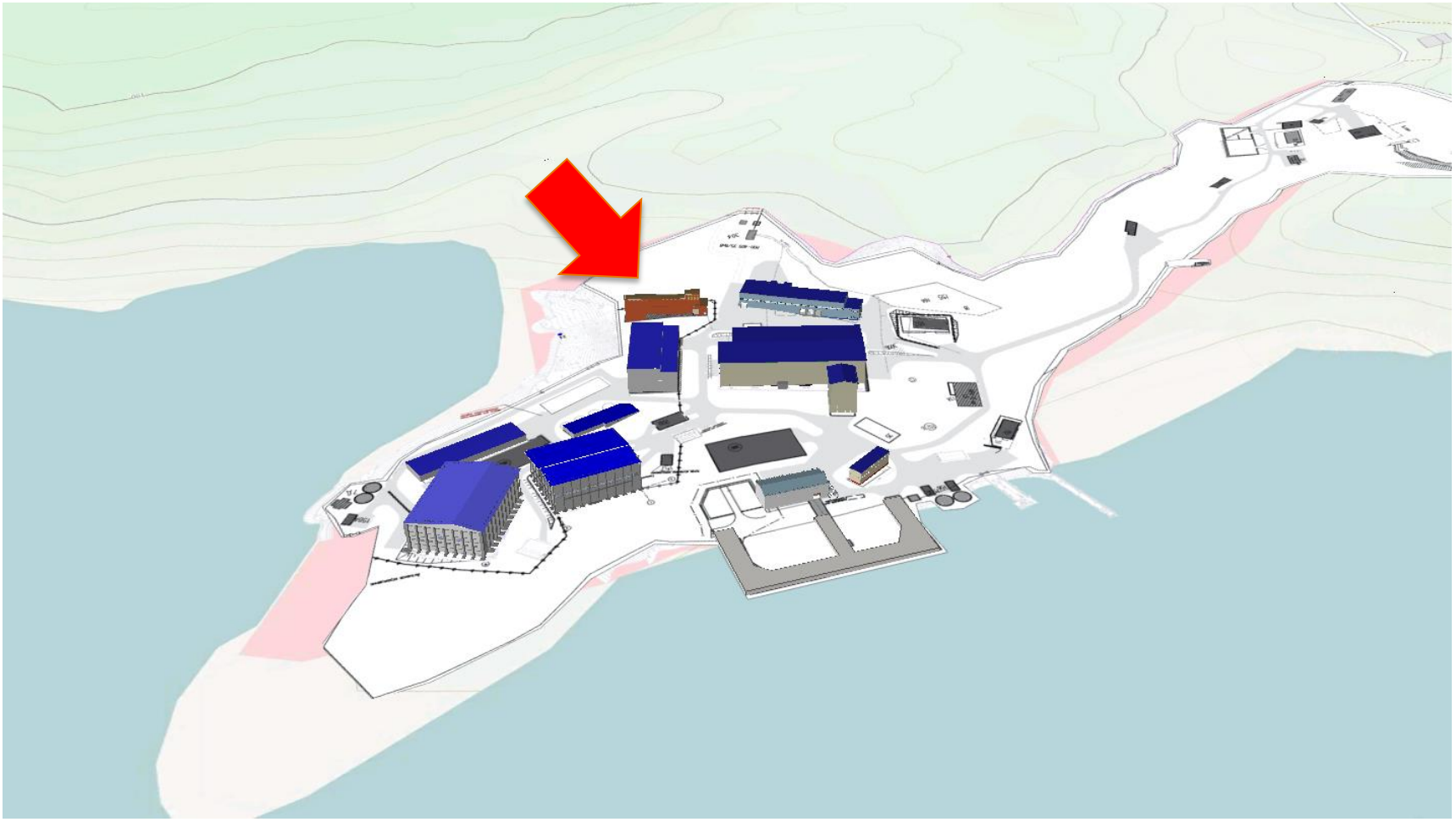
The equation is solved by numerical methods: transition from the integral equation to a system of linear equations.

Example of the surface activity reconstruction

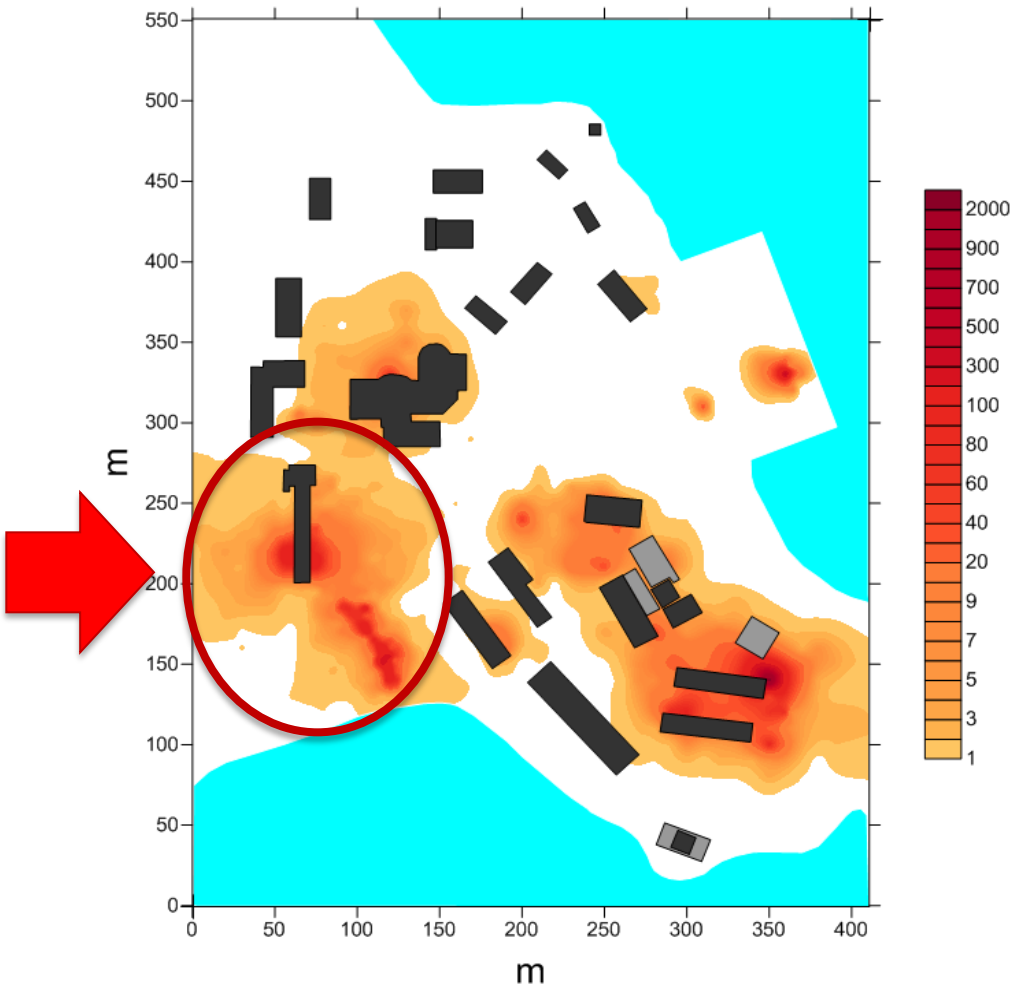
Comparison of results: method of conversion coefficients (upper right fragment of the figure) and the method of solving Fredholm equation of 1st kind (bottom right fragment)



3D view of the industrial site

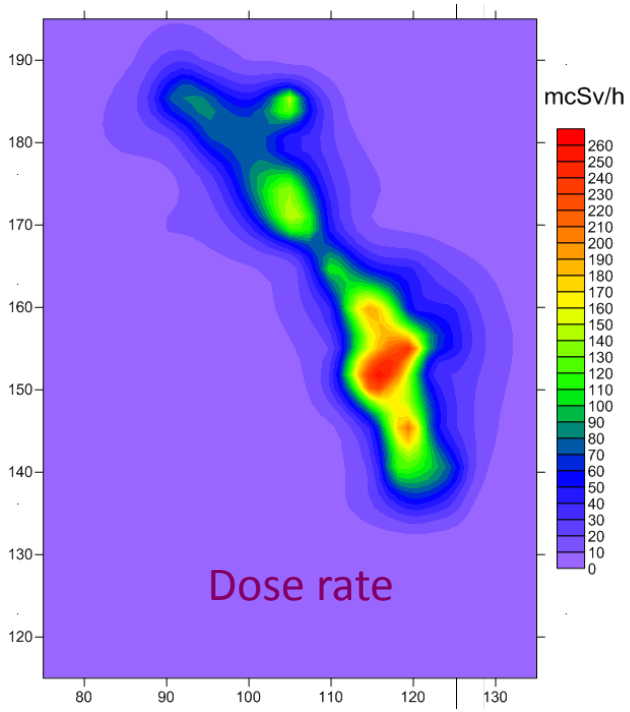


Radiation situation at Andreeva Bay in 2002 (ADER in µSv/h)

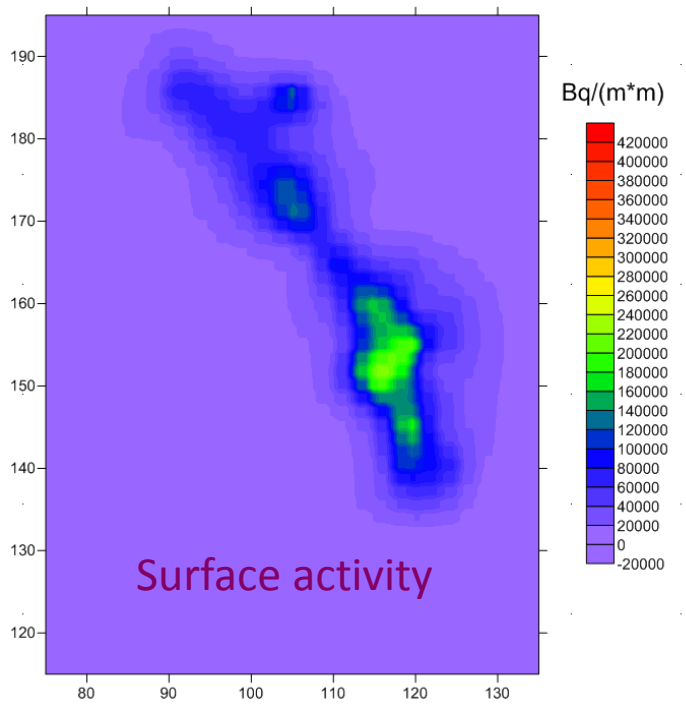


Logarithmic kriging interpolation

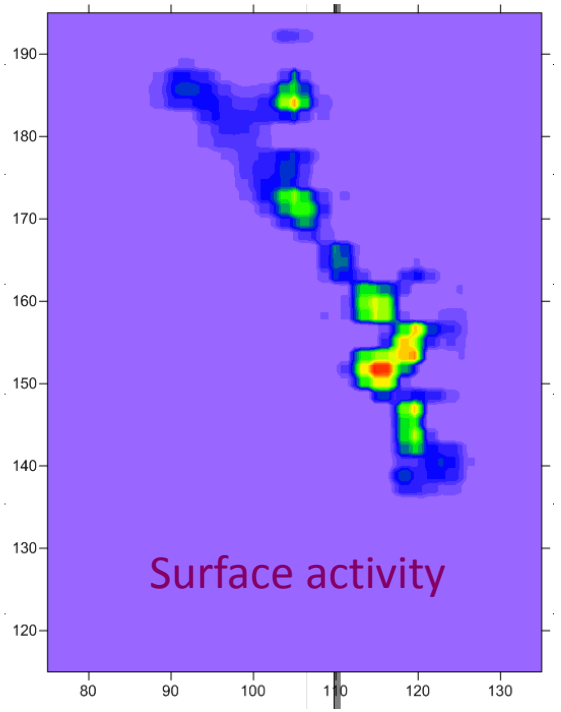
Conversion coefficients and new method results comparison



Dose rate

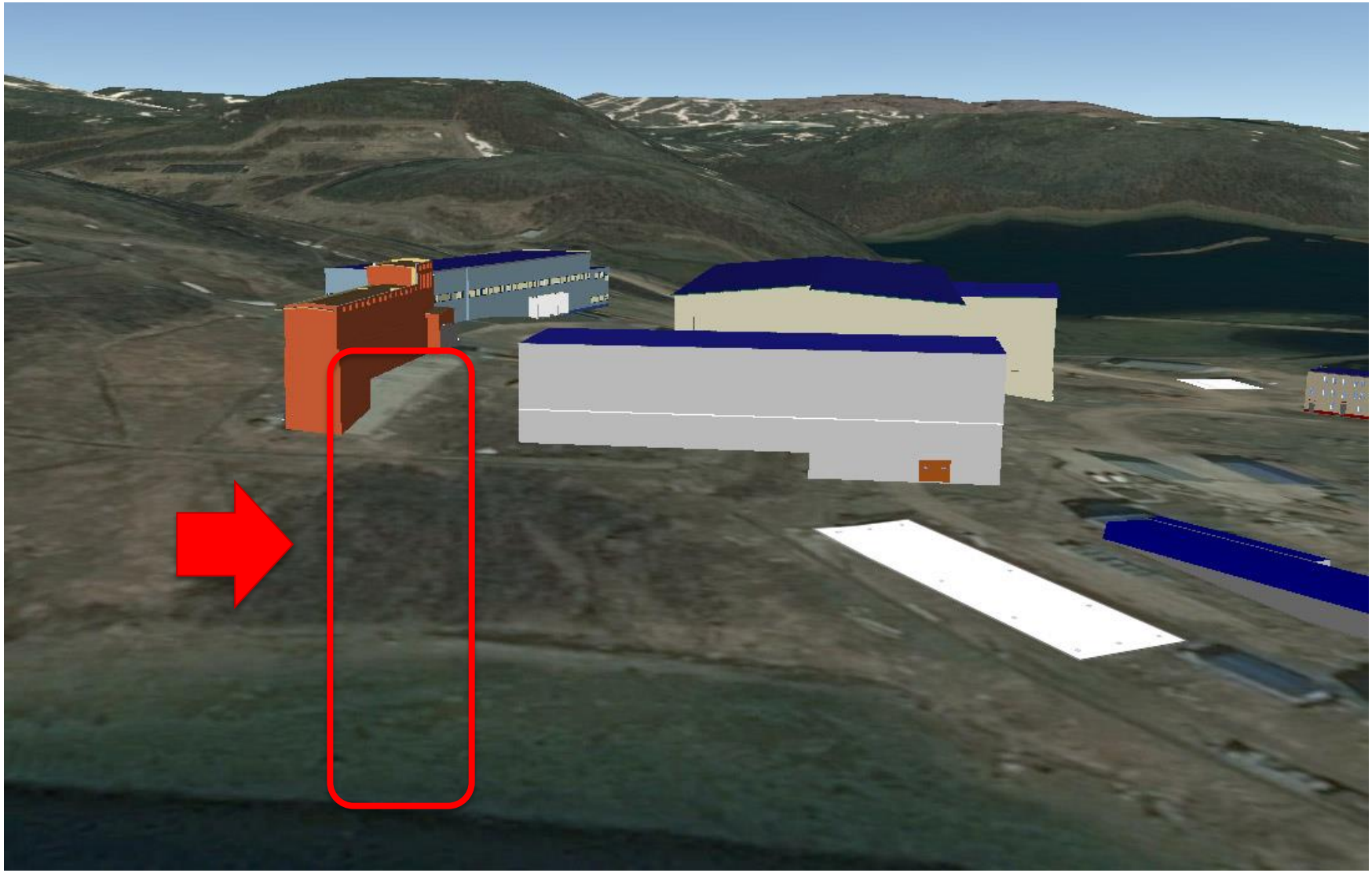


Method conversion coefficients

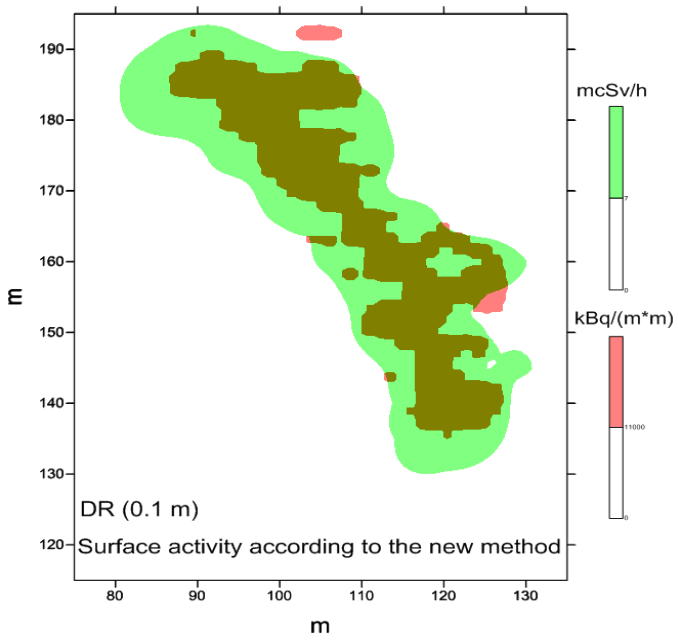


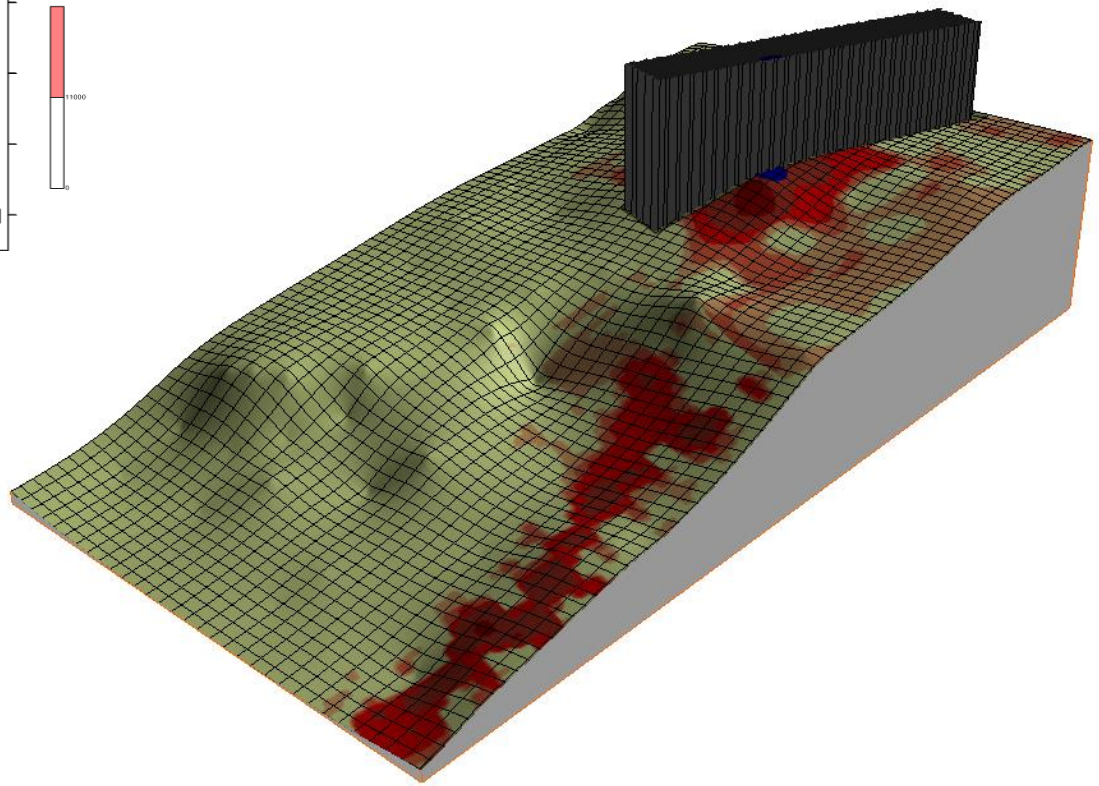
New method. $\alpha=10^{-9}$

Example for building 5 leak

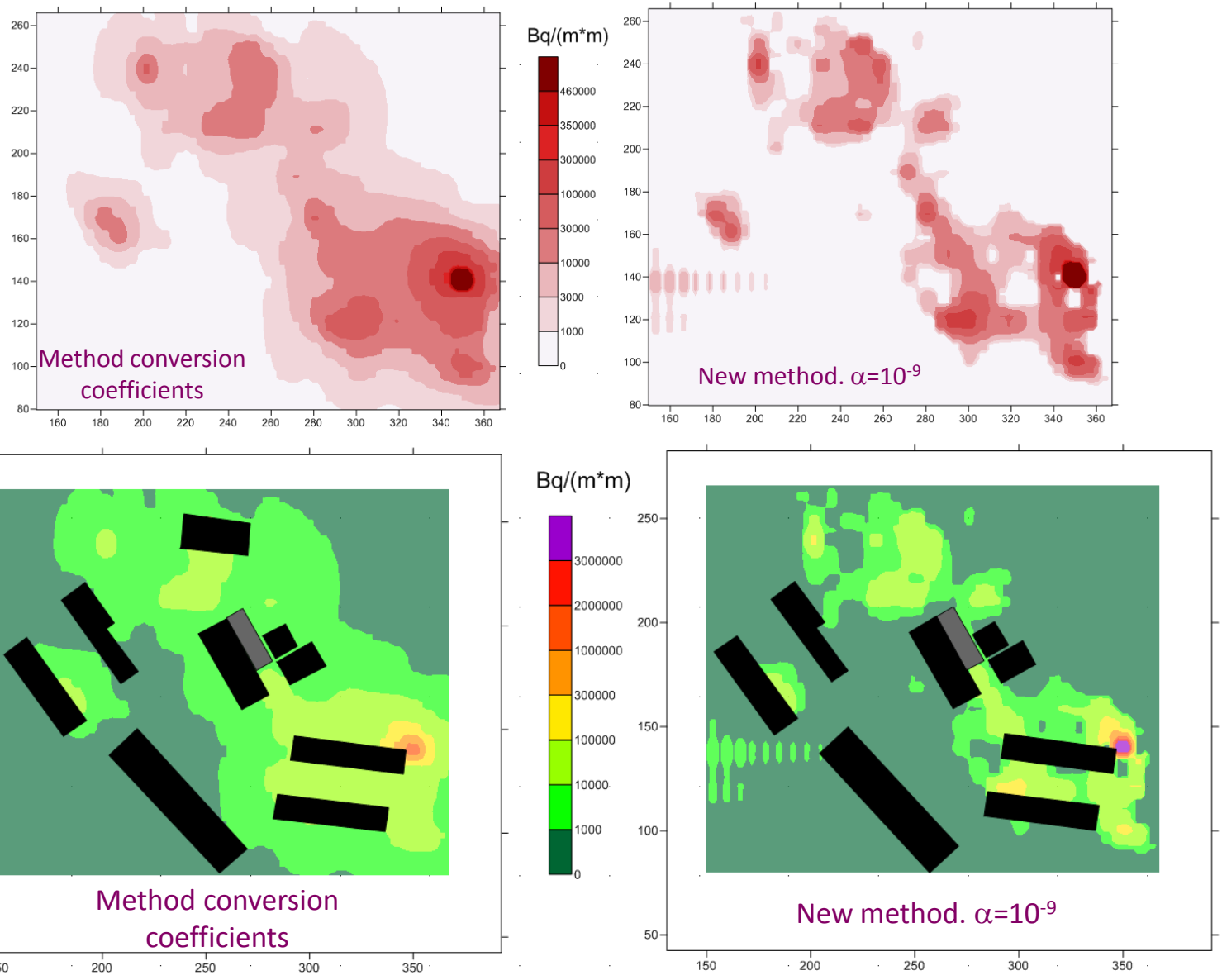


Example for building 5 leak, 3D model



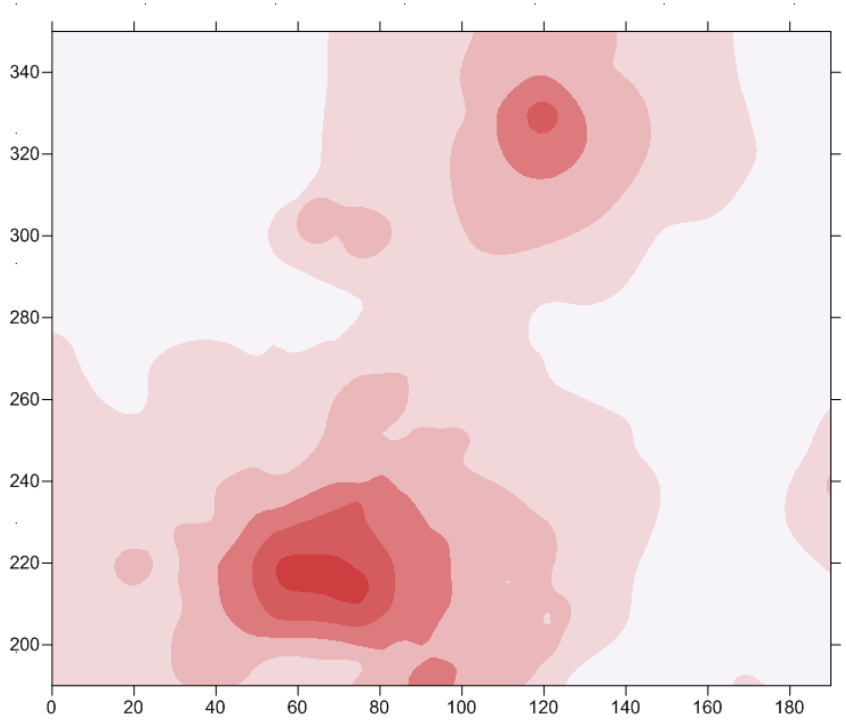


Surface contamination activity reconstruction

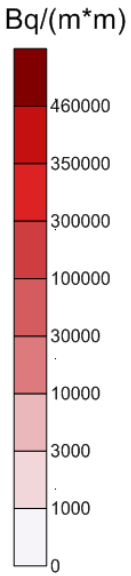


Surface contamination activity reconstruction for building 5 and dry storage unit

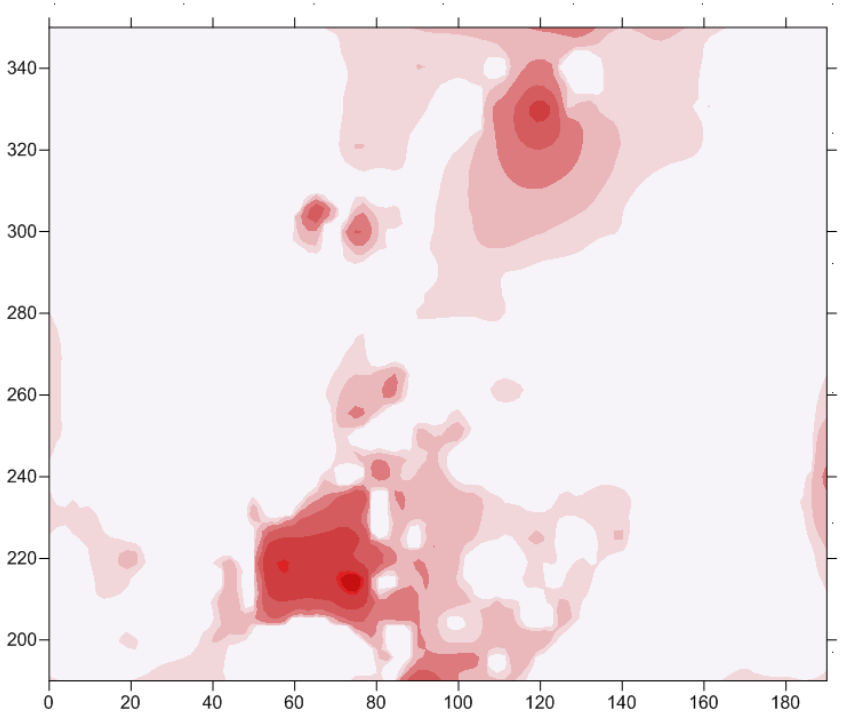
Method
Conversion coefficients



A_{max}=149 kBq/m^2



New method. $\alpha=10^{-9}$

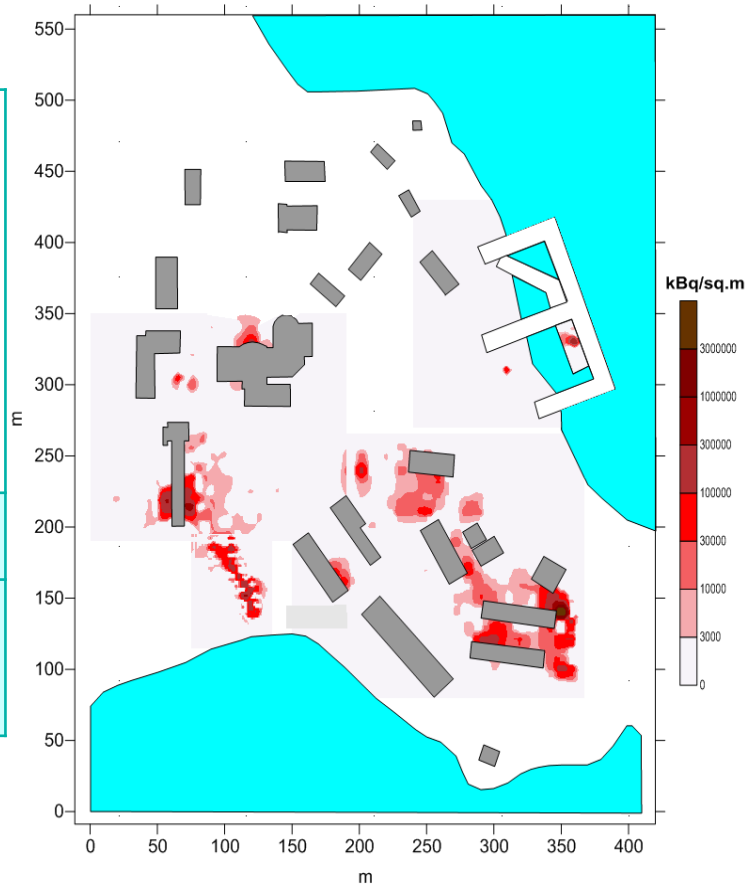


A_{max}=441 kBq/m^2

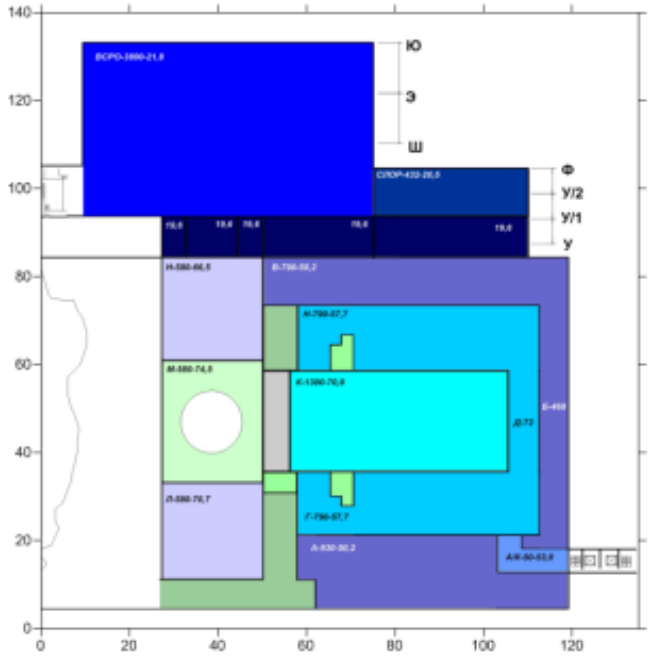
Surface contamination map for Andreeva Bay

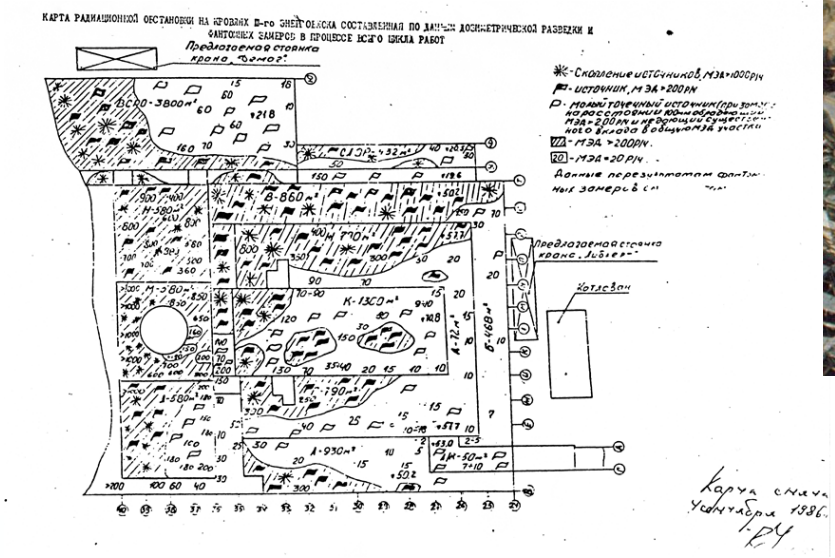
Percentage of activity in the area (%) where the specific surface activity is more than 30,000 Bq/m^2.

Method	The area of the zone where the threshold is exceeded, m^2	Integral activity in zones, where the threshold is exceeded, KBq	Integral activity for industrial site in total, KBq	%
MCC	$3{,}8 \cdot 10^2$	$2{,}2 \cdot 10^8$	$6{,}39 \cdot 10^8$	34,4
New method	$3{,}1 \cdot 10^2$	$4{,}5 \cdot 10^8$	$6{,}49 \cdot 10^8$	69,3



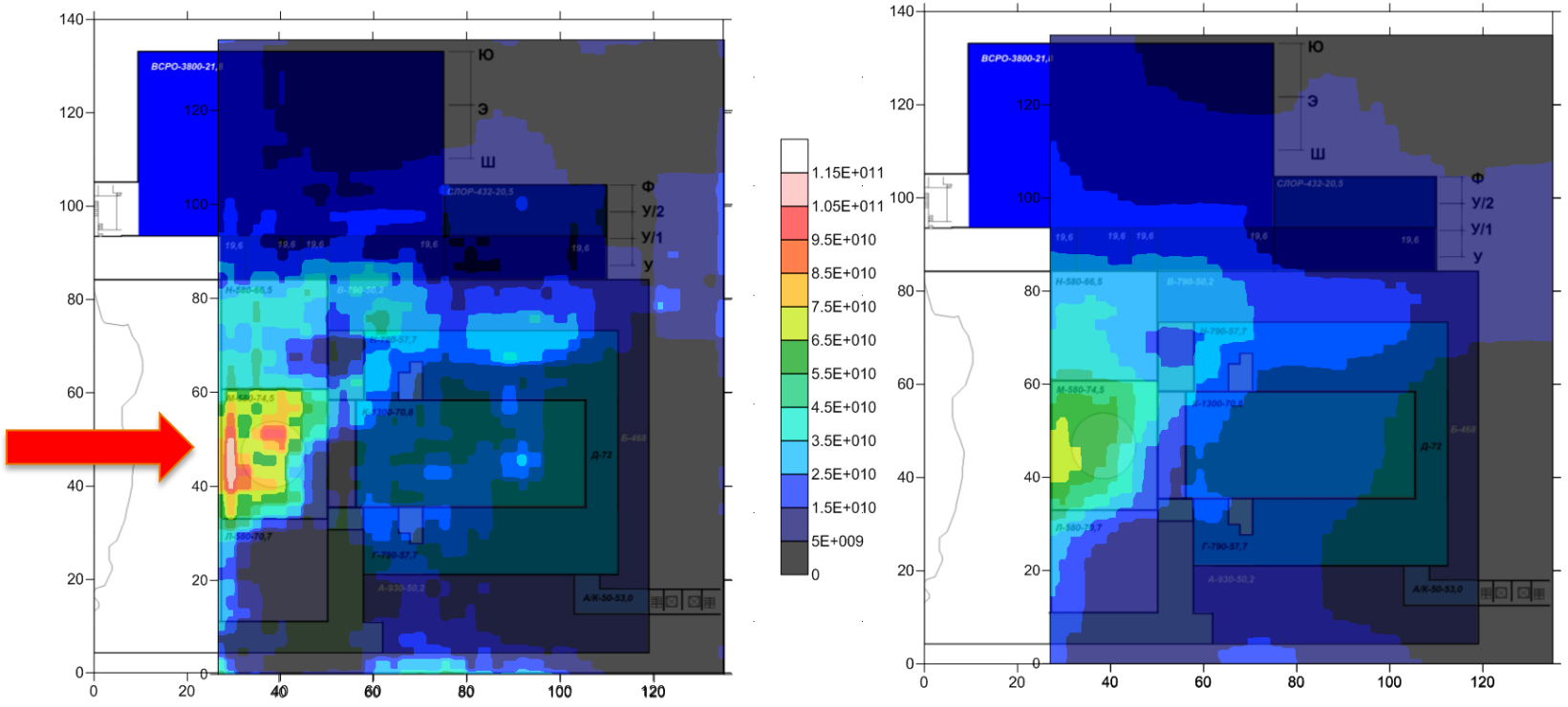
Initial data for the recovery of surface activity on roofs of ChNPP





ChNPP roofs, august 1986

Total activity on the roofs: (1.57 - 1.78) * 10^{14} kBq or ~5 MCi



New method,
$\alpha=10^{-9}$

Method conversion coefficients

Conclusions

- The method of surface contamination activity reconstruction based on measurements of ambient dose equivalent rate was developed.
- The new method gives a more accurate result of surface activity distribution that the method of conversion coefficients. This allows to plan a more effectively work on the decontamination
- Using the developed method experts of radiation safety services could use both types of tools (software) for dose assessment based on dose rate measurements data and based on information about the location of radioactive sources and their activity.

Thank you!

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