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THE EVOLUTION OF GEOTECH: 25 YEARS OF INNOVATION

The schematization of soil properties in mathematical modeling in engineering geology and geotechnics.

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Paper #: RICAB34

Introduction

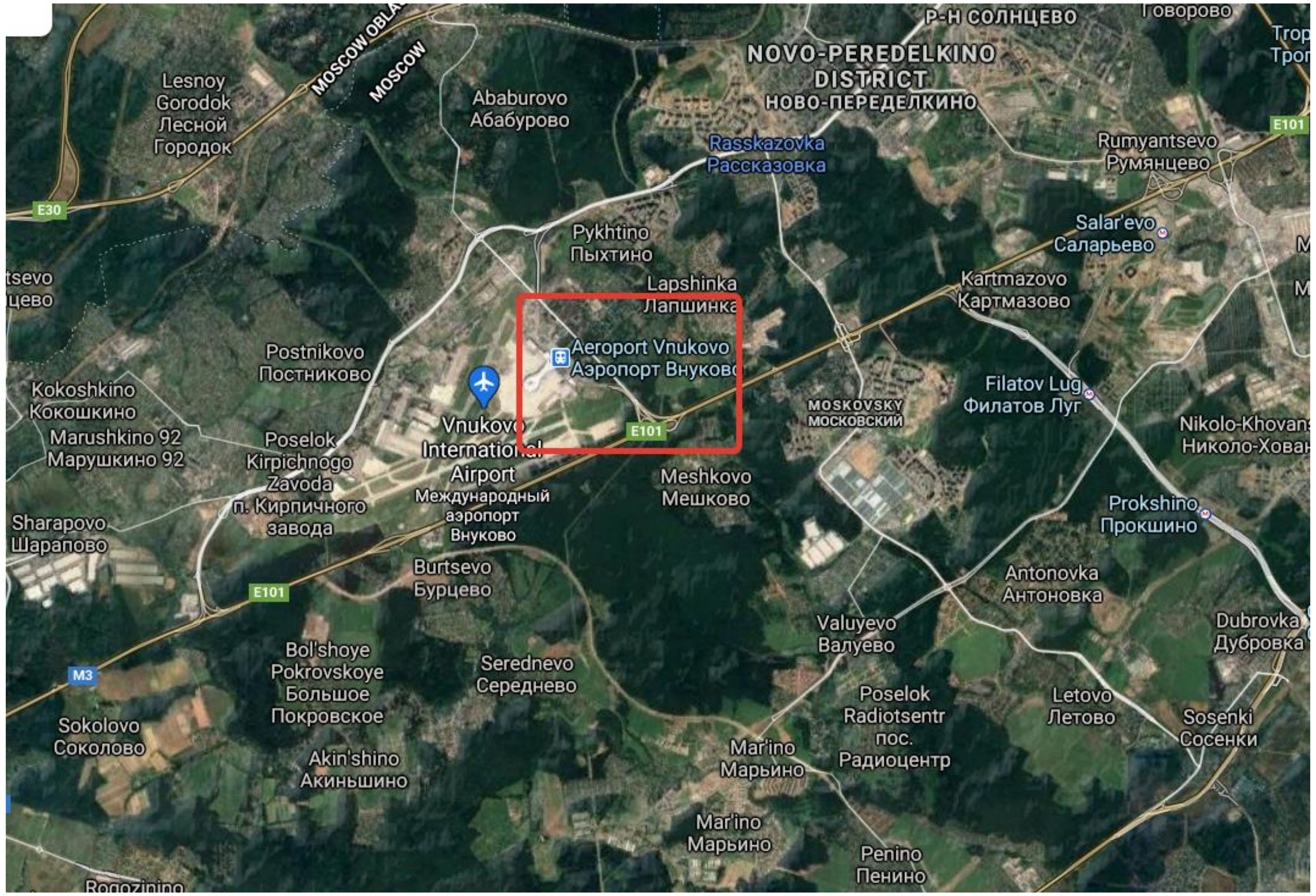
The geological engineering schematization is based on the concept of engineering geological element (EGE). According to Russian standards (SP 446.1325800.2019) (2) EGE - the main soil unit used in the creation of an engineering-geological model of a soil array. It includes some volume of the soil of the same type (subtype) and varieties when changing values the characteristics of the soil within the element randomly or under the observed pattern of change in the characteristics of the soils with the coefficient of variation for the physical characteristics of the soil ≤ 0.15, for mechanical ≤ 0.30.

Despite the fact that the random nature of the distribution of properties in the EGE is present in definition, until recently, this fact wasn't paid to the construction of geological engineering models. The statistical processing of the properties of the soil was performed before creating a model. The model was itself usually deterministic character.

In recent years, the situation has changed. Analysis of Russian and foreign experience allows you to distinguish four basic models describing the distribution of soil properties in mathematical modeling in engineering geology and geotechnics.

Consider them on the example of solving the problem of assessing the stability of slopes by the limiting equilibrium method (LEM) based on the criterion of the strength of Mohr-Coulomb.

Object of research



When carrying out engineering and geological work on the territory under study, the activation of the slope processes was noted.

Administratively, the plot of work is located in pos. Lapshinka, Moscow.

In the geological structure quaternary sediments represented by technogenic soils, alluvial, coating, glacial and chalk sediments, are taking part in the explored depth of 20 m. In the limits of the research area technogenic soils are the foundation of the dump and are represented by the brown, poorly compacted, loam. They were opened when carrying out drilling in all wells. Power of technogenic soils up to 12.0 m.

Modeling methodic. Estimated schemes

The task was solved in flat setting. The assessment of the slopes stability was carried out on the basis of Morgenstern-Price and Yanbu methods belonging to the class of LE methods. In the calculations an elastoplastic model Mohr-Coulomb was used. The mathematical model Mohr-Coulomb combines elastically ideal plastic behavior and linear criterion of soils strength.

The following models for schematization of soil properties used in the calculations :

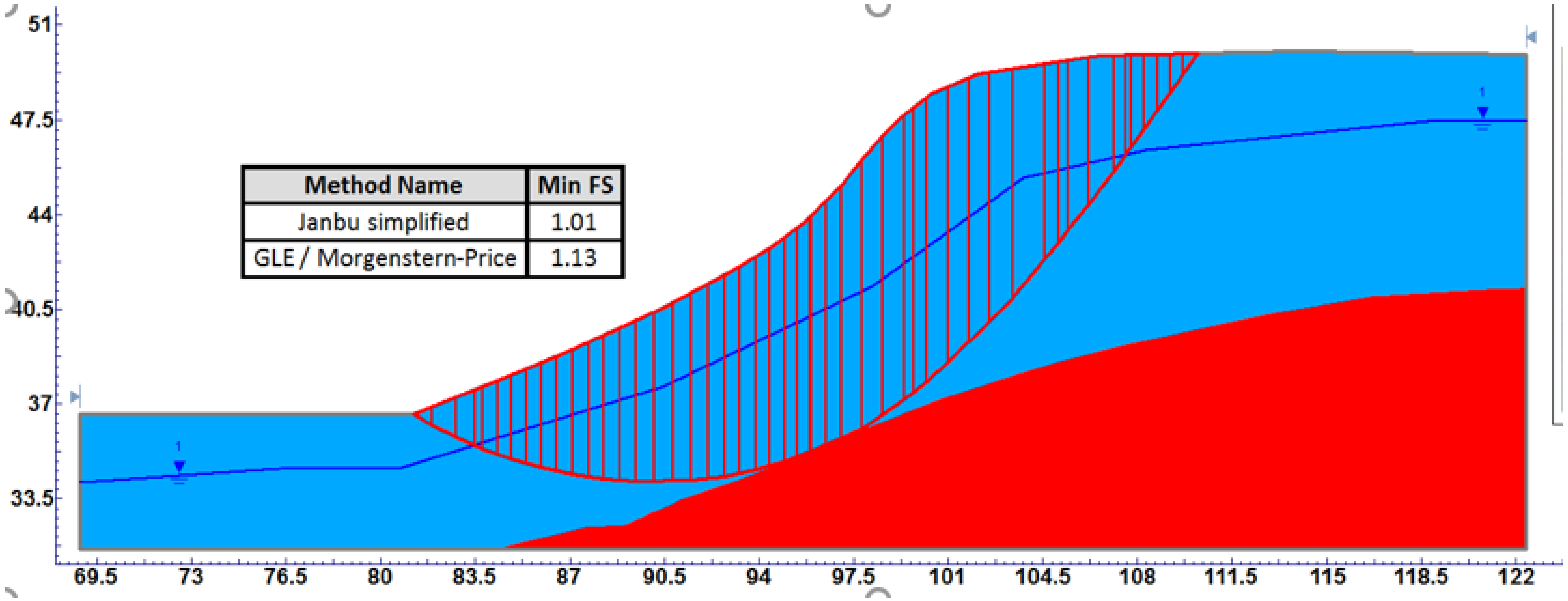
Scheme 1 – Deterministic model of distribution of properties
Scheme 2 - Interpolation model of distribution of properties
Scheme 3 - Probabilistic model of distribution of properties
Scheme 4 - Variation model of distribution of properties

Results and discussion

Scheme 1 - Deterministic model of distribution of properties

The initial parameters is the scalar values of the properties of the soils for each EGE: density, specific clutch, internal friction angle.

The modeling result is determining the minimum value of the stability coefficient (also scalar value) and the position corresponding to it the slide surface.



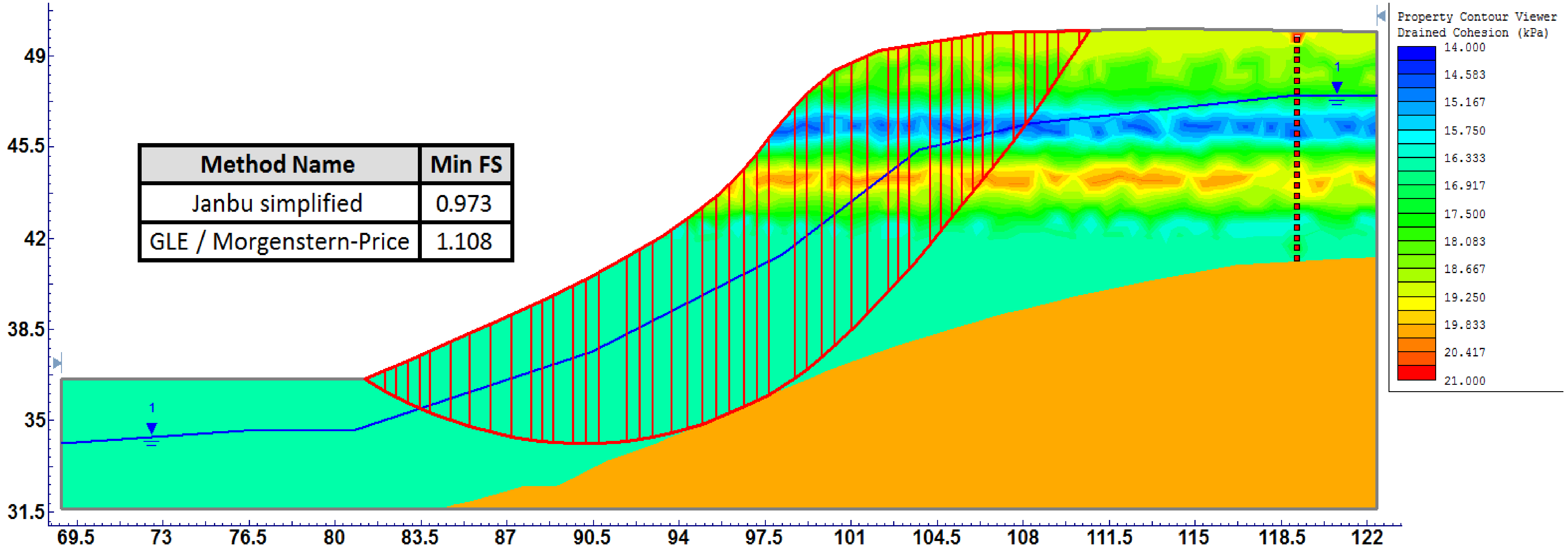
The result of calculating the stability of the slope

Results and discussion

Scheme 2 - Interpolation model of distribution of properties

The initial parameters are numerical arrays defined for each EGE, including the properties of the soil (density, specific clutch, internal friction angle) and the coordinates of the sampling site for defining properties. Based on this information the properties distribution field is built using interpolation methods (with geostatistics methods) for each EGE.

The modeling result is determining the minimum value of the stability coefficient and the position of corresponding to it the slide surface. However the result depends on the choice of the method of interpolation of the properties of the soils and the sampling grid.



Method Name	Min FS
Janbu simplified	0.973
GLE / Morgenstern-Price	1.108

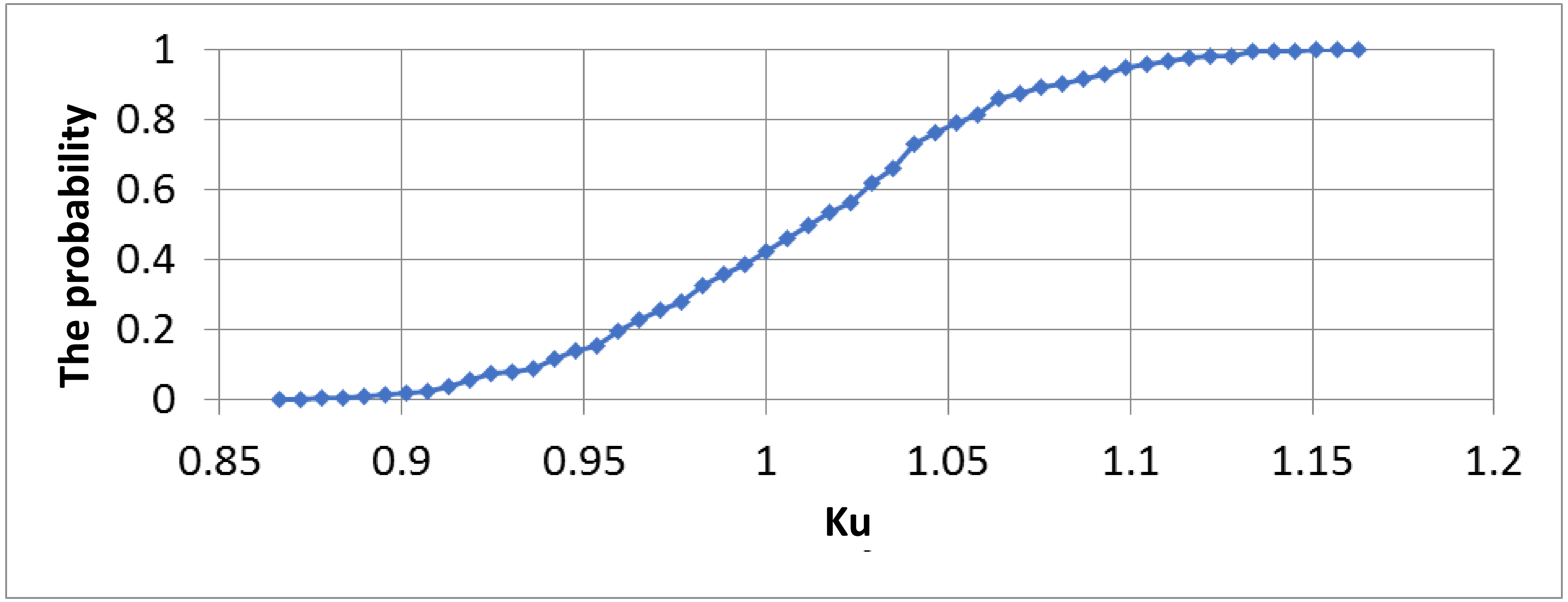
The result of calculating the stability of the slope. Ku lower than in the deterministic model

Results and discussion

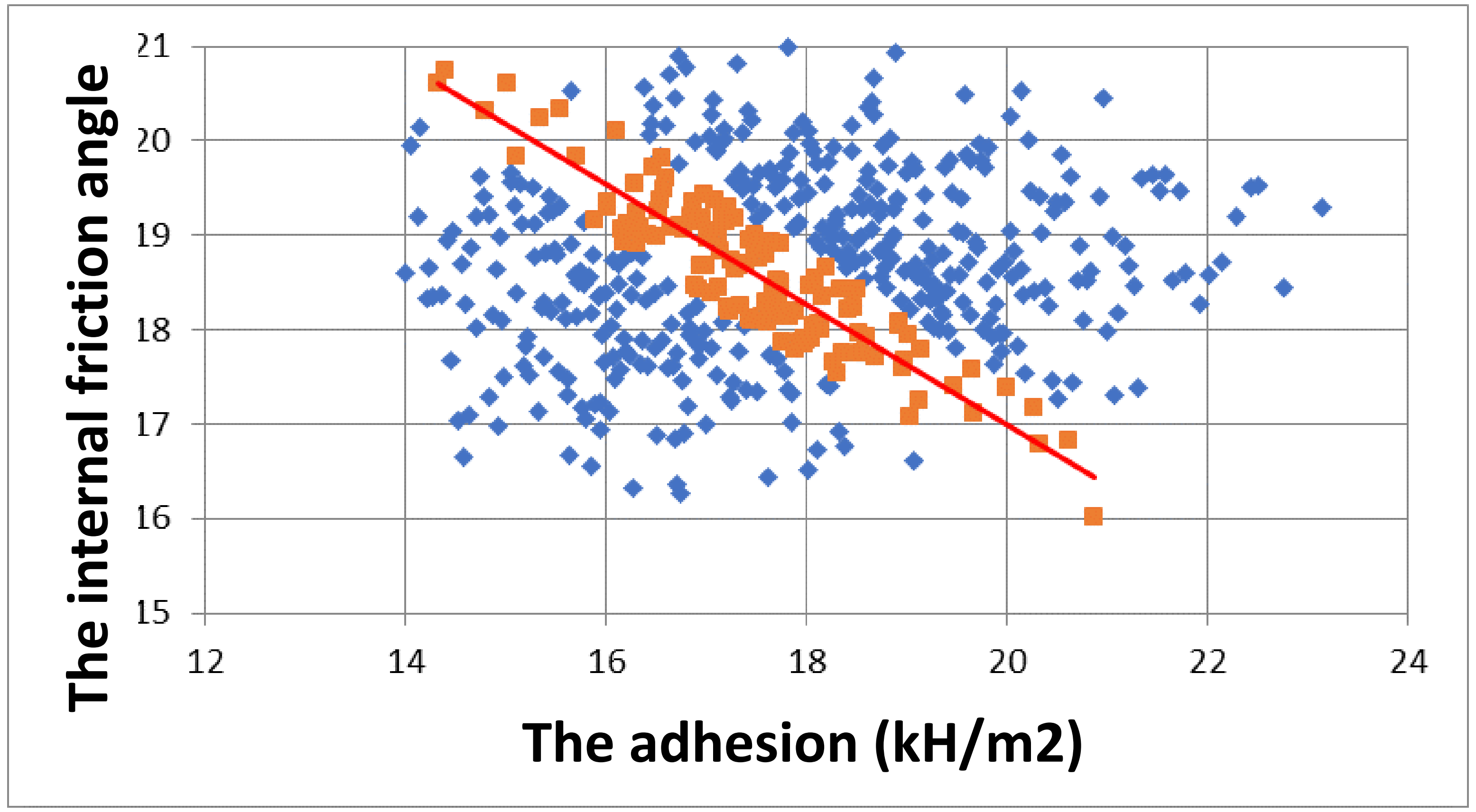
Scheme 3 - Probabilistic model of distribution of properties

The initial parameters is the functions of the probabilistic distribution of the properties of the soils defined for each EGE.

The modeling result is a probabilistic function of the distribution of Ku, on the basis of which it is possible to determine the likelihood of the development of the landslide process.



The integral function of the Ku distribution (the probability of the development of the landslide process is 42%).



Two-factor sensitivity analysis for the simulated slope. The red line is the dependence of the internal friction angle from the adhesion at which the Ku slope is 1.

Results and discussion

Scheme 4 - Variation model of distribution of properties (variability model)

The spatial variability of the properties of the soil can be modeled using the theory of random fields, according to which in any area of EGE the soil properties are a random variable characterized by a probabilistic distribution function and correlating with the values of the soil properties. The spatial correlation of the properties of the soil is determined based on the function of the autocorrelation. It can be assessed from the measurement results of the parameter at various points according to the results of field or laboratory tests using the Markov correlation coefficient function:

$$R(\tau_x, \tau_y) = \exp\left\{-\sqrt{\left(\frac{2\tau_x}{\theta_x}\right)^2 + \left(\frac{2\tau_y}{\theta_y}\right)^2}\right\}$$

where $R(\tau_x, \tau_y)$ –the coefficient of autocorrelation, τ_x and τ_y - absolute distances between two points in horizontal and vertical directions, θx и θy - correlation distances with horizontal and vertical directions.

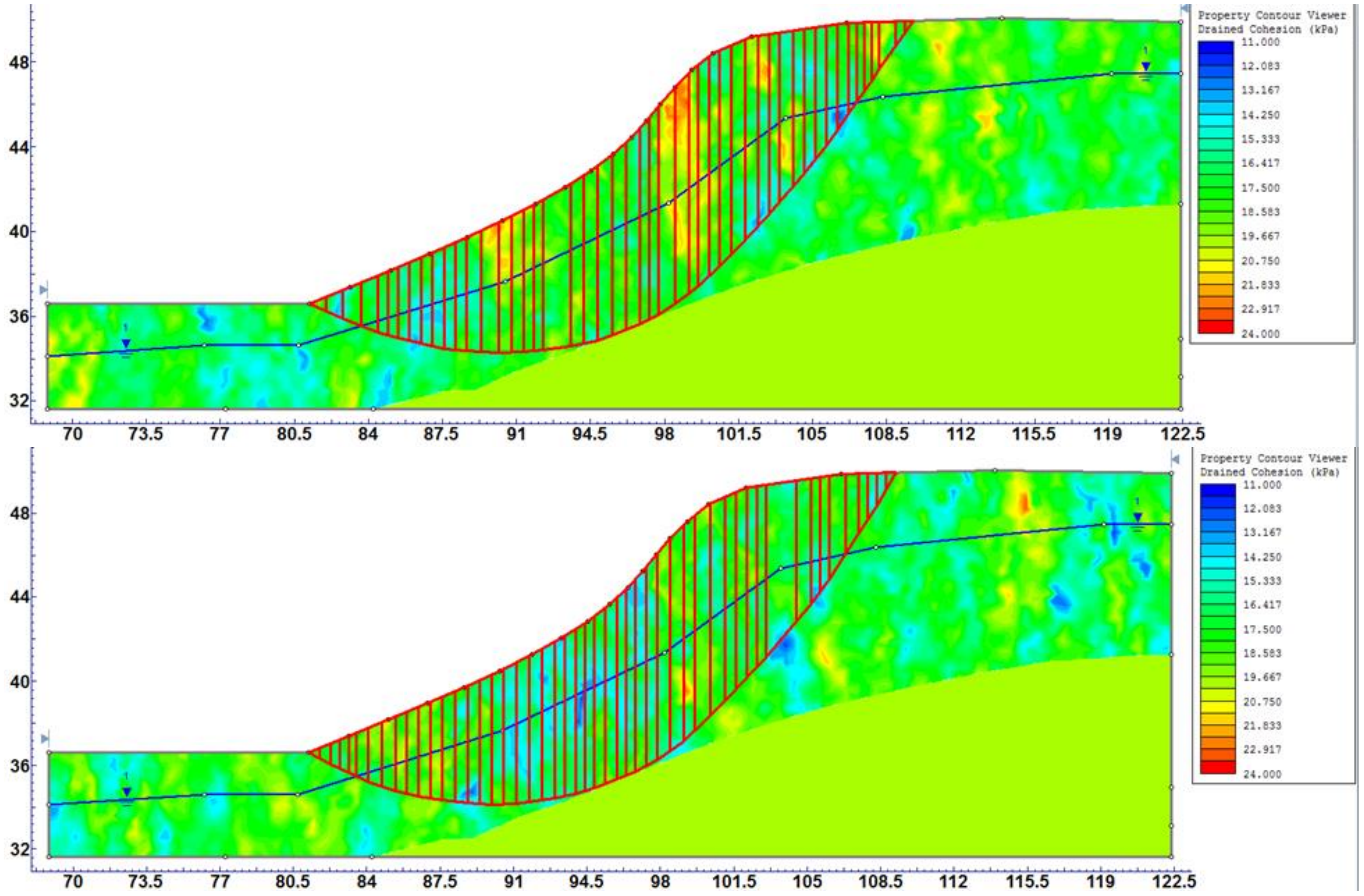
Thus, the necessary initial parameters for the variability model in addition to the functions of a probabilistic distribution of soil properties is the correlation distance values.

Results and discussion

Scheme 4 - Variation model of distribution of properties (variability model)

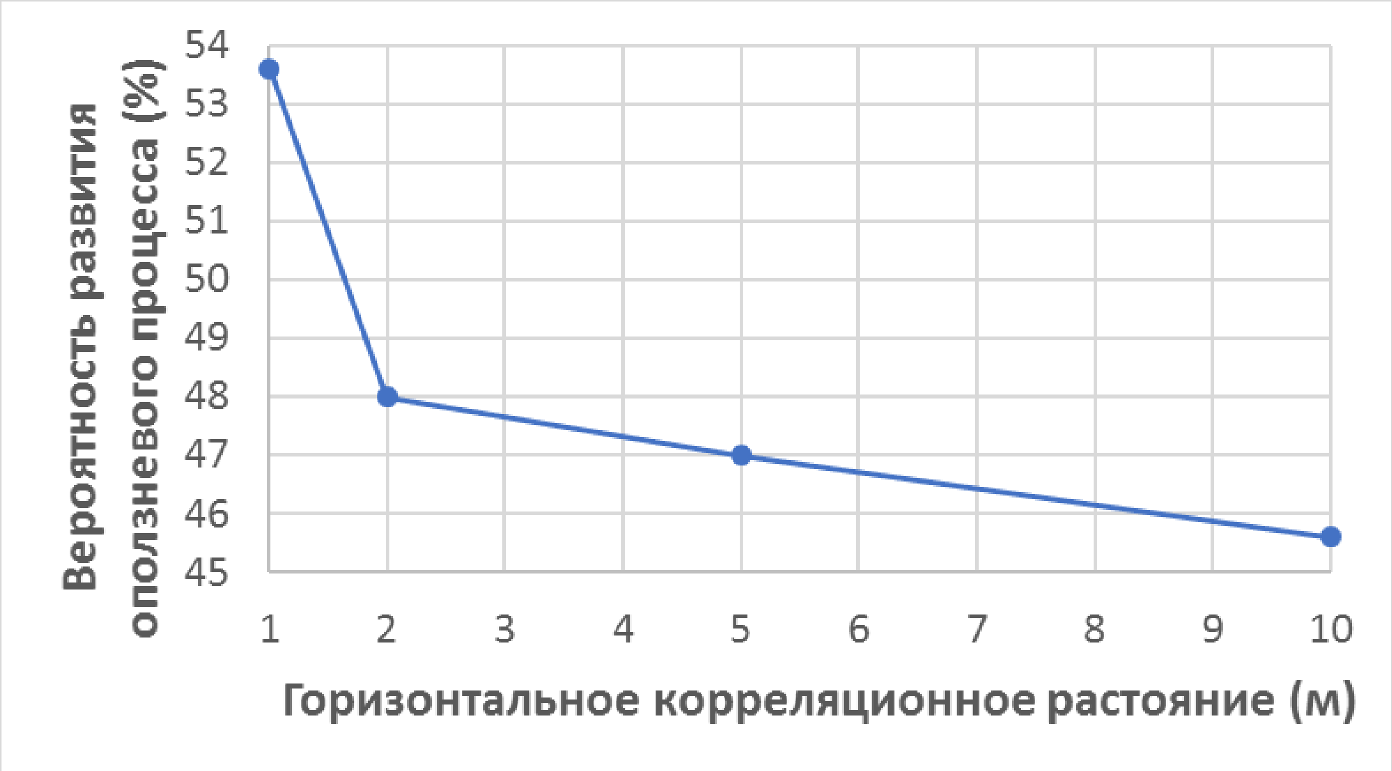
A random method of limiting equilibrium (LEM) was used to study the effect of the spatial variability of the strength parameters of the soil on the likelihood of destroying the slopes of the dam.

The modeling result is the likely models for the distribution of soil properties for a given correlation distance and the function of the distribution of Ku.



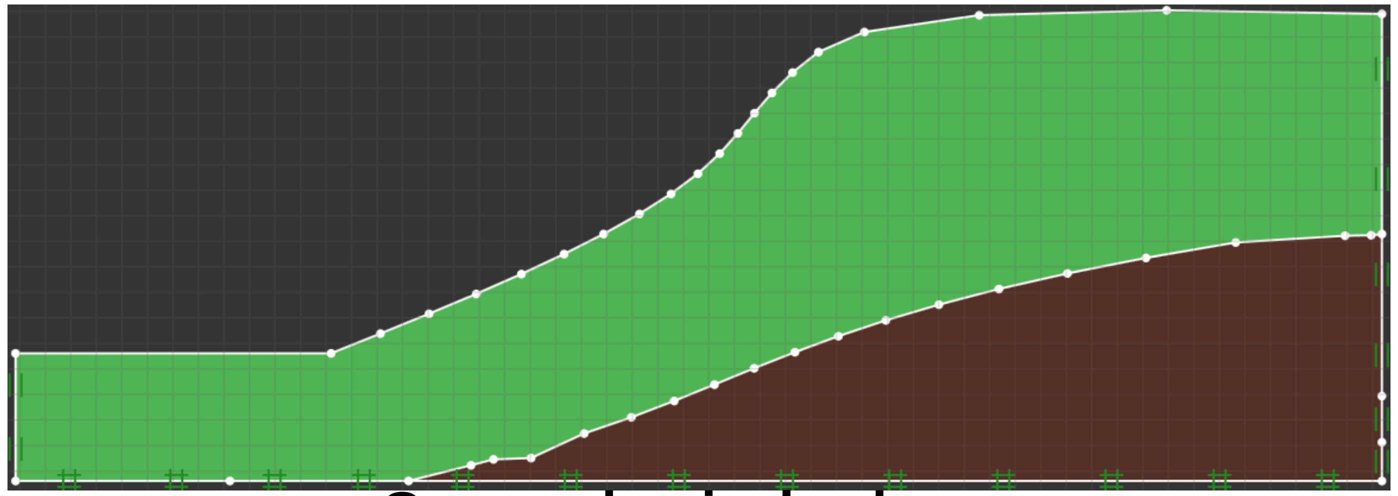
Model of the distribution of the specific adhesion for: a) the mean value of Ku =1.01; b) the minimum value of Ku =0.97. The horizontal correlation distance is 1 m, the probability of a landslide process is 53.6%.

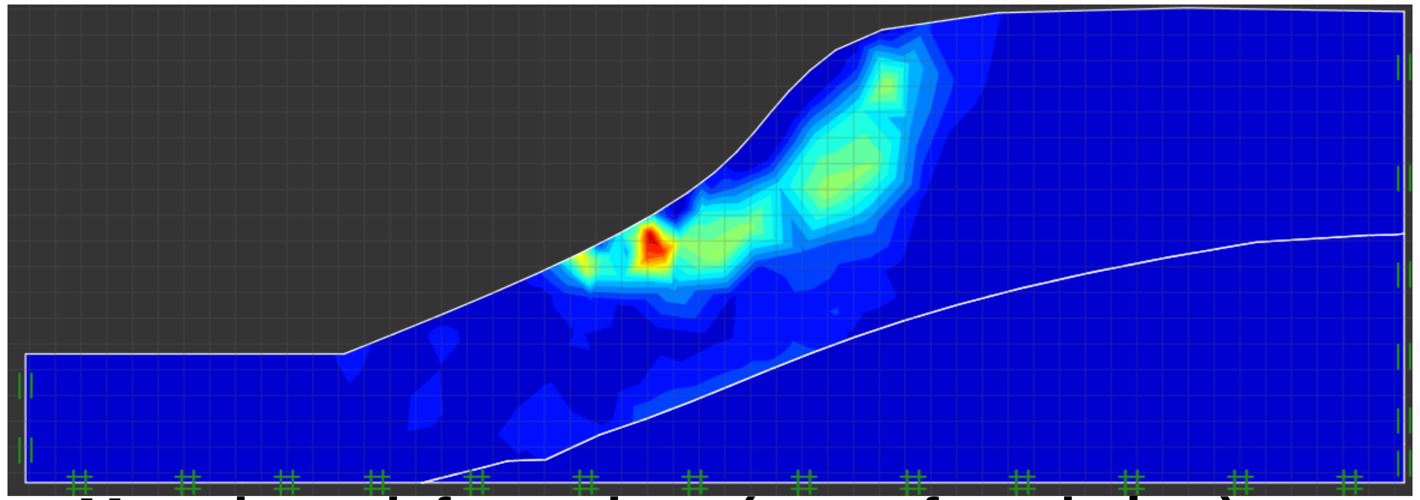
The dependence of the probability of developing a landslide process from the horizontal correlation distance.

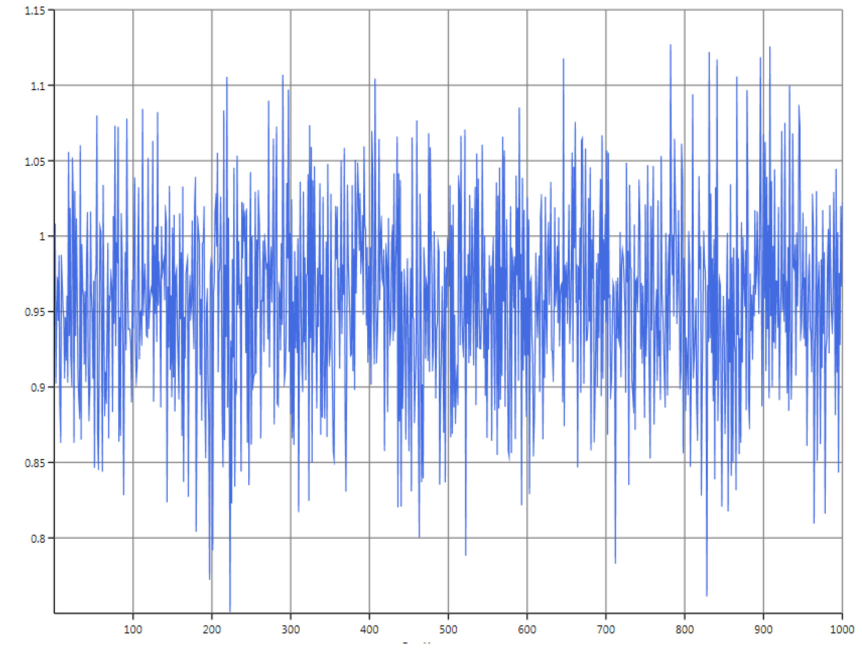


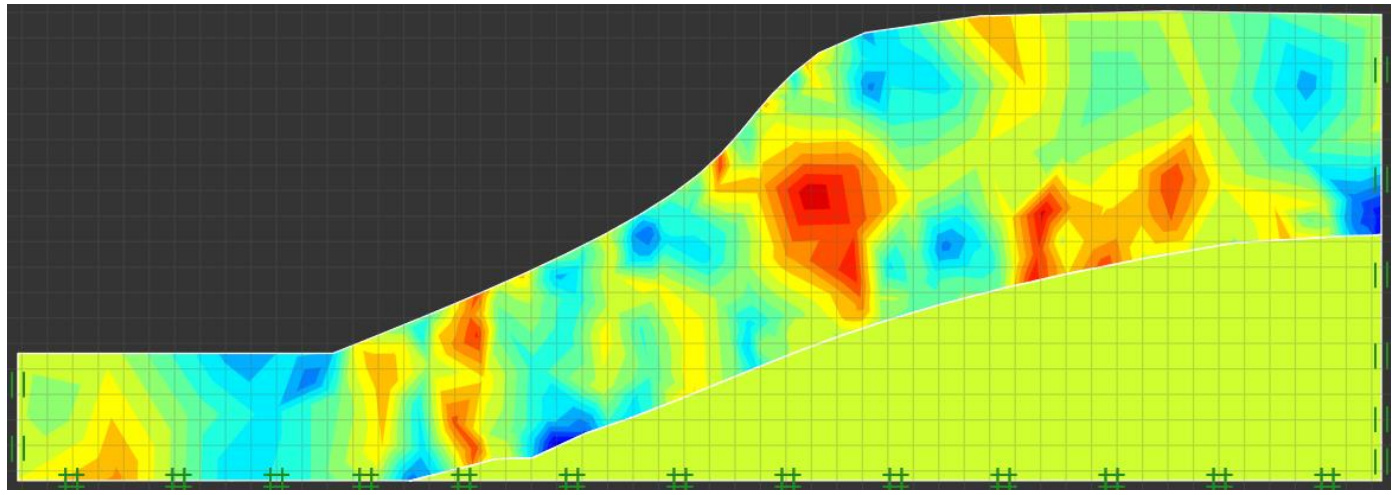
Analysis of the results of the calculation showed that the correlation distance does not affect the Ku of the slope (for all cases, the average FS - 1.01). However, the likelihood of the development of a landslide process with a change in the correlation distance varies changes. At the same time, with a decrease in the correlation distance and, as a result, with an increase in inhomogeneity in the soils, the probability of developing landslide increases.

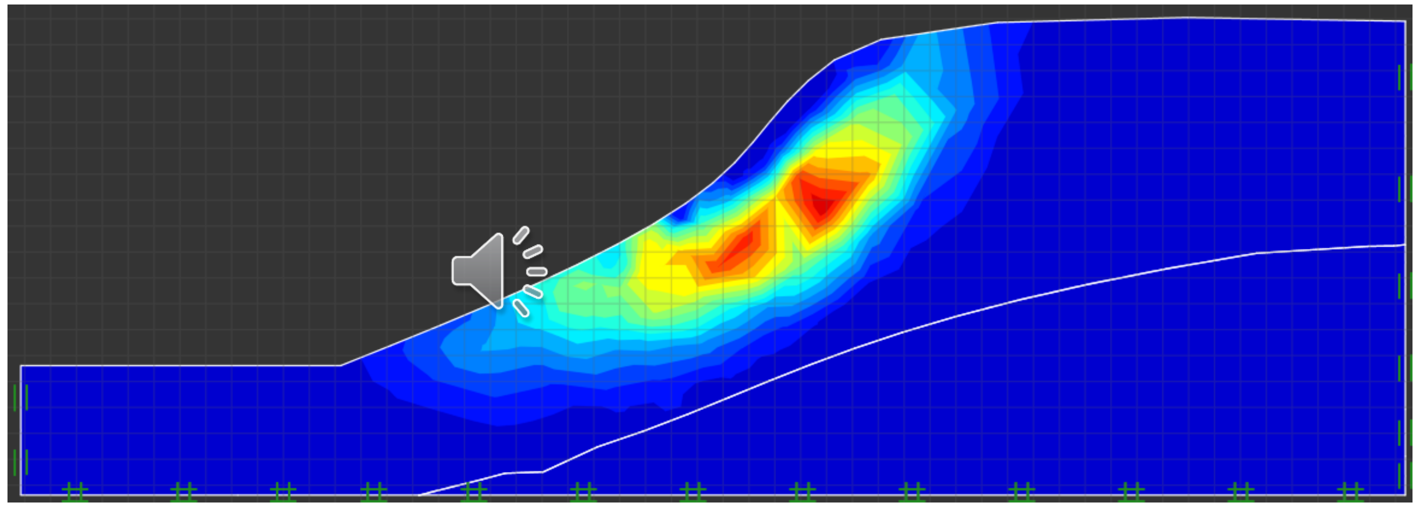
Random Finite Element Method (RFEM)

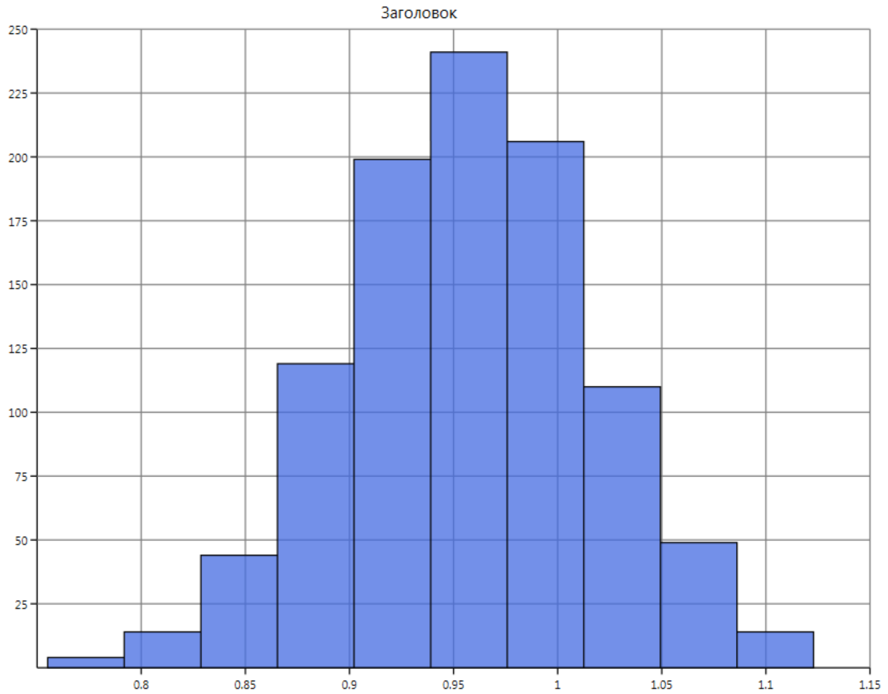

Geomechanical scheme


Max shear deformations (score from below)

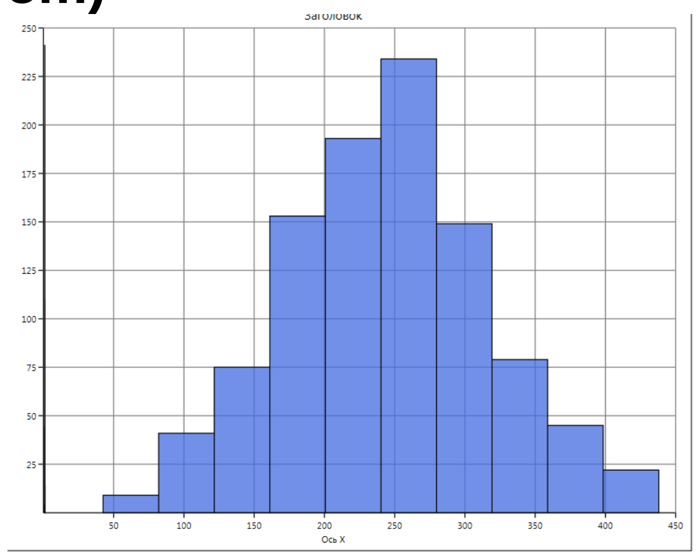

Changing Ku by the iterations (score from below)

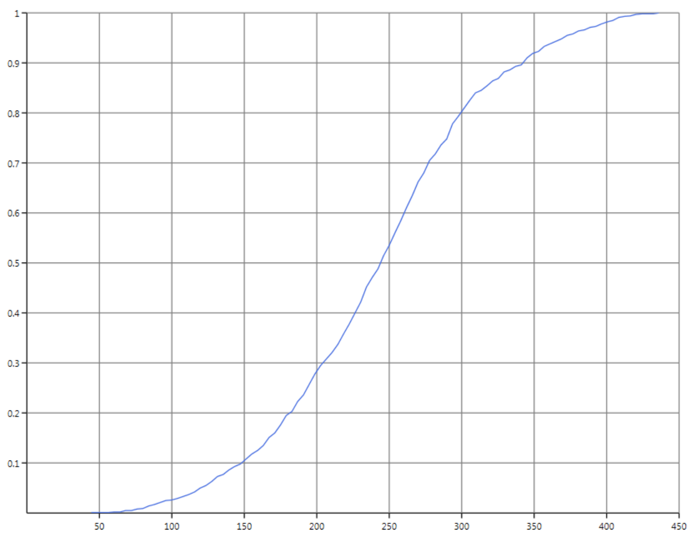

Distribution of the angle of internal friction (correlation distance along x = 1m, along y = 5m)


Max shear deformations (grading from above)



Histogram Ku (score from below)


Landslide size histogram (score from below)


Integral function of landslide size (score from below)

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Conclusion

Modeling the processes of the most different nature faces, as a rule, with the problem of approximation, inaccuracies and incompleteness of data on the simulated system with it's uncertainty. One of the main stages of constructing a mathematical model is the schematization. In Russian practice, the basis of the engineering geological schematization is the concept of engineering geological element (EGE). Accounting for foreign experience we distinguish 4 basic models describing the distribution of the properties of soils in mathematical modeling in engineering geology and geotechnics:

- Deterministic model of distribution of properties
- Interpolation model of distribution of properties
- Probabilistic model of distribution of properties
- Variation model of distribution of properties

First, the use of a model determines the necessary set of input data, and on the other, determines the set and quality of information obtained as a result of modeling.

Analysis of the results of the study showed that under the conditions of uncertainty, the slope isn't a reliable parameter characterizing stability. In particular, as a result of using RFEM, it is shown that with an increase in the inhomogeneity of the soils, the sloping slope array, the average Ku doesn't change. However the likelihood of the development of a landslide process increases.

Mathematical modeling is performed in the program Slide 2. The Department of Engineering Geology at MGRI is part of the Rocscience academic program.

The schematization of soil properties in mathematical modeling in engineering geology and geotechnics.

Thank you! Any questions?