Russian State Geological Prospecting University named after Sergo Ordzhonikidze (RSGPU)

Landslides hazard of Moscow cultural heritage sites

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The faculty has 35 teachers and more than 600 students are studying. This is also our team!

Landslides hazard of Moscow cultural heritage sites

Russian churches were traditionally built on high places with a good panorama of the surrounding area. It is not surprising that in Moscow a number of large churches were built near the edge of high slopes, many of which are landslide-prone. But such a placement naturally entails an increased threat in case of activation of landslide processes.

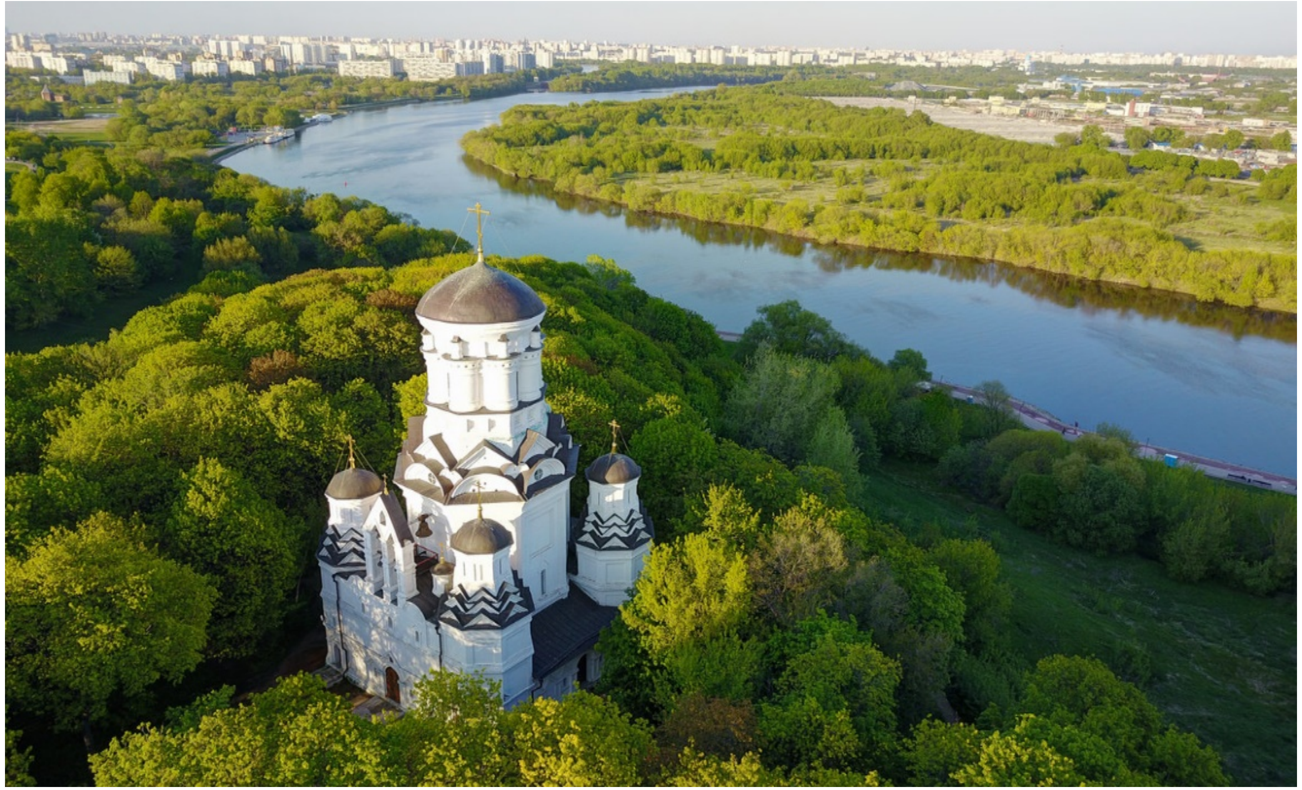
To date, in the city of Moscow, deep block landslides have been identified at 12 sites on the slopes of the Moskva River valley.

Church of the Ascension in Kolomenskoye (built in 1532)

Landslides hazard of Moscow cultural heritage sites

In the history of Moscow churches, the destruction associated with landslides has been recorded for a long time. According to the record of 1649, there was a church of the Protection of the Virgin, which then disappeared. According to legend, it completely went underground (obviously, as a result of a landslide).

The main reason of landslides origin was undercutting of the Moscow river bank. Since 1770 six floods with water rise of about 7,5 – 8,8 m were recorded – almost every 20-30 years.



Church of the Beheading of John the Baptist in Kolomenskoye (built in the 2nd half of the 16th century)

Holy Trinity Church in Khoroshevo

White Stone Holy Trinity temple stands on the high bank of the Moskva River for more than four centuries. It is one of the jewels of Russian architecture of XVI century.

The first mention of the movement of soil near the temple dates back to the 18th century.

In 1877, a new threat of landing slip near the temple perturbed parishioners.

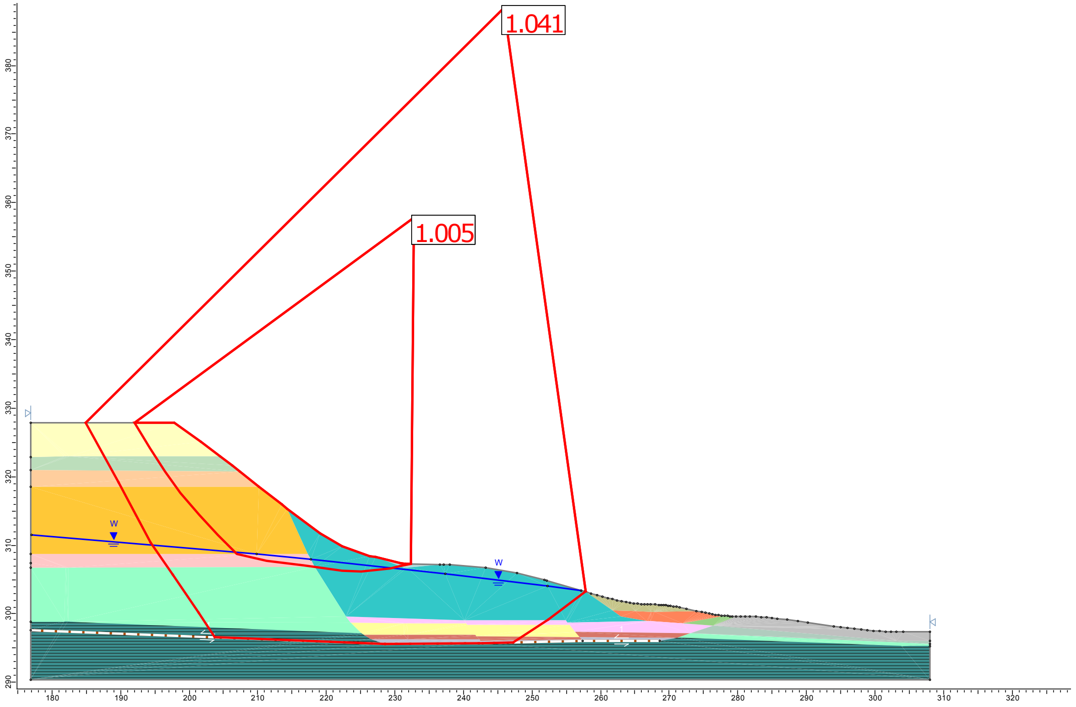
Regular observations took place since 1975 and lasts until now. Until 2006 some minor mudslides occurred. High accuracy observations lasts since 1977 until 1984. The highest mean displacements (86-91 mm) were near the river and decreased upslope up to 45-46 mm close to the top of the slope. Noticeable signs of deep deformations were not noticed.

The main landslide displacement took place in 2006 it was about 300 m long and vertical displacement was 0,5-1,0 m, which then increased up to 3 m. Displacements occurred about 5 m from one of the cottages and 15 m from the church. It threatens to their safety.

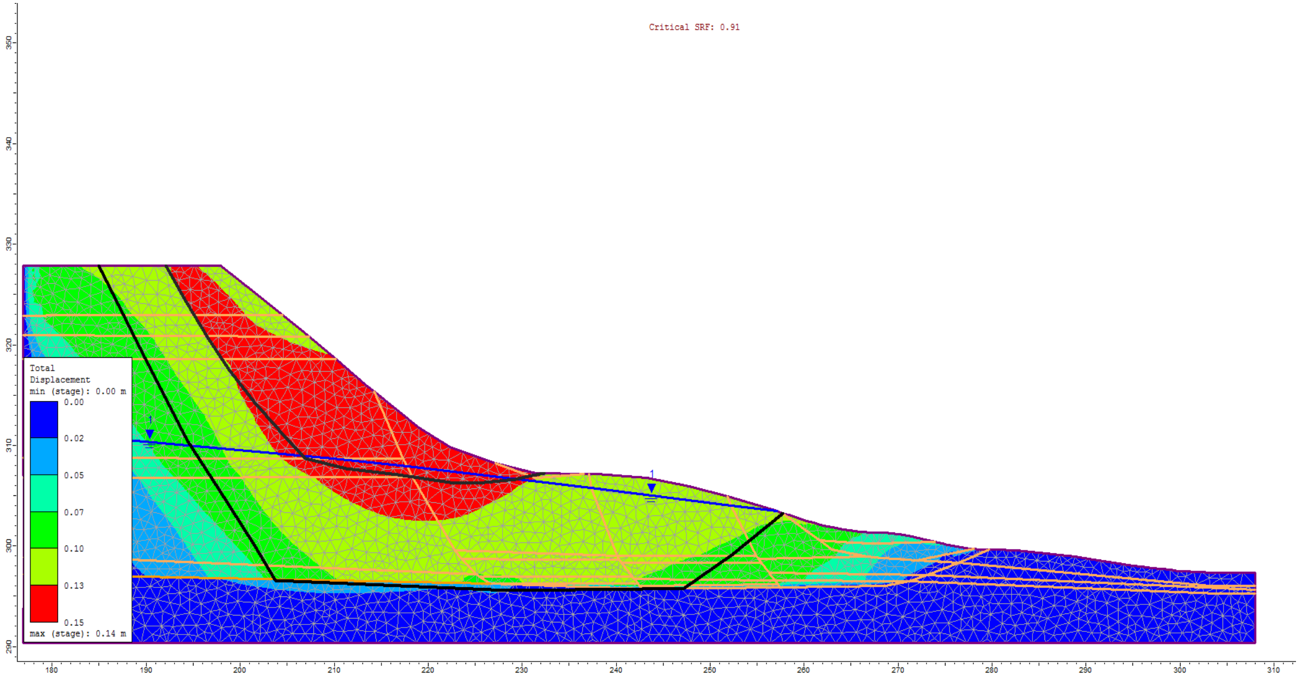
The intensification of the landslide process coincided with the construction of the Zhivopisniy bridge, namely with the driving of piles for temporary supports in the southwestern part of the Khoroshevsky straightening. At the end of 2007, displacement rates decreased to 2 mm per month, but immediately after the opening of traffic on the bridge on January 7, 2008, they increased 4 times, reaching 2 mm per week. Thus, one of the reasons for the activation of the landslide process can be man-made impacts.

Quantification of slope stability

The class of limit equilibrium method (Spenser) and finite elements method (FEM) were used along the estimates. These methods applies for heterogeneous slopes.



The results of slope stability assessment with the definition of stability factor (S_f) (Spenser method).

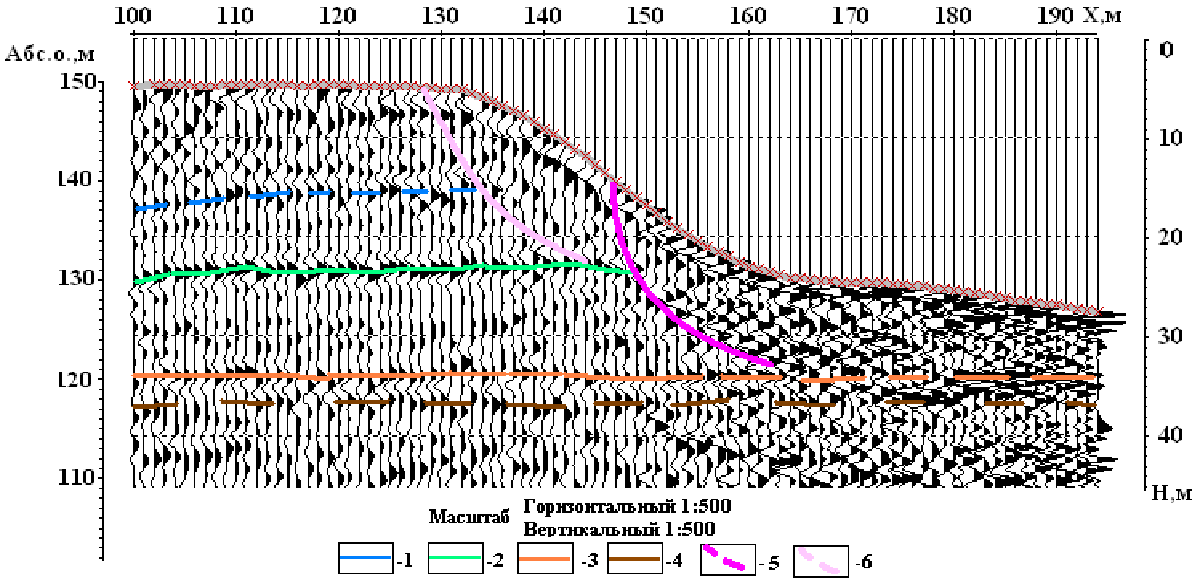


The estimation result by FEM method (Fs – 0.91). Black lines are the sliding surfaces estimated by Spenser method.

The analysis of data allows making a conclusion that there are two possible variants of sliding deformations.

First scenario

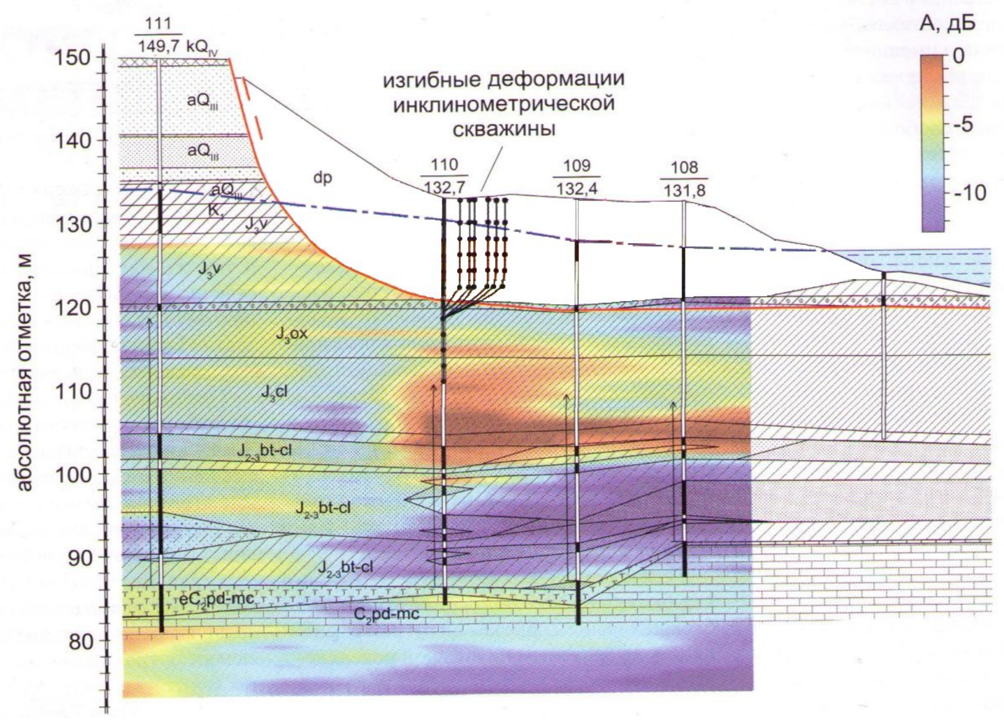
According to the first variant the secondary landslide forms on the slope (Fs-1.005). Such scenario was proved along the geophysical investigations.



Deep seismogeological profile. 1 – the roof of the Cretaceous deposits, 2 – the roof of the Volgian sediments; 3 – the roof of the Oxford clays; 4 – the roof of the Callovian clays; 5 - existing surface displacement; 6 – potential surface displacement

Second scenario

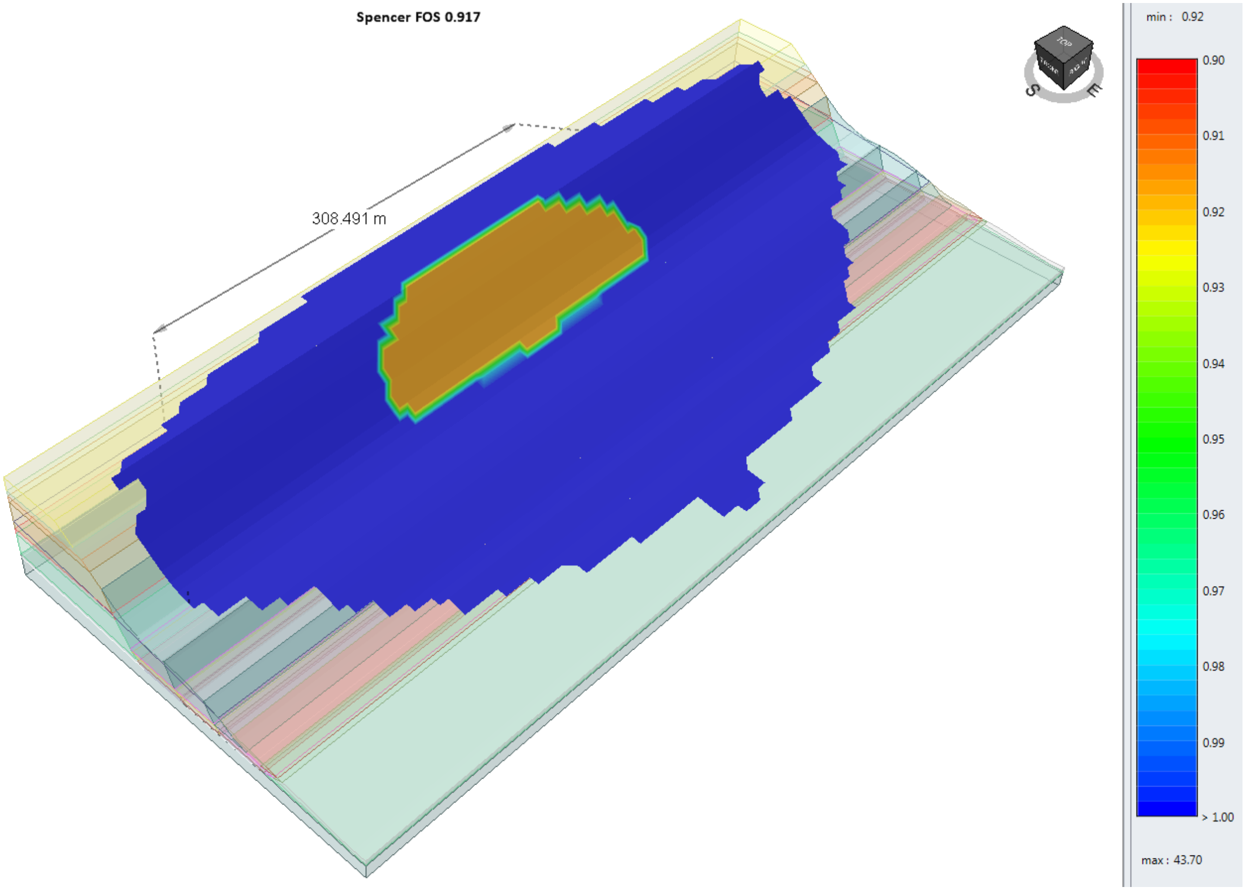
In concordance with the second variant, a new sliding block forms on the slope (Fs -1.04). Its sliding surface arranged to Upper Jurassic clays of Oxford stage. This variant was proved along inclinometric observations.



Geophysical profile and the results of inclinometric observations.
A – Amplitude of microseismic oscillation

3D slope stability calculation

3D stability assessment realized for evaluation of the extent development the sliding process (by the limit equilibrium method (Spenser)).



Estimated results about the landslide width (308 m) are coordinated well with the field data obtained by the engineering-geological investigations (300 m).

Further tasks

1. Conduct reconnaissance surveys of the entire bank of the Moskva River within the city of Moscow in the fall of 2019 and in the spring of 2020.
2. Reveal the new most dangerous landslide sites.
3. Carry out a preliminary calculation of the stability coefficient based on field data and archival materials.
4. Update an existing landslide hazard map.
5. To conduct a first landslide hazard assessment for the temples of the city of Nizhny Novgorod.
6. To elaborate the structure of a landslide hazard catalog (database) of the objects of cultural heritage of Russia.

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Thank you for your attention