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New Basis Points of Geodetic Stations for Landslide Monitoring

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Keywords: basis points, landslide processes, local geodetic network, recalculation of coordinates, the coordinate system.

ABSTRACT. The results of mathematical processing of modern geodetic observations of landslide processes in Dnipropetrovsk on points of observation stations in case of lost basis points are presented. Previous observations were conducted in 1993 using classic geodetic instruments. To provide the required accuracy of observations the local geodetic coordinate system was developed. There were two basis points; using laser range equipment the distance between them was measured with accuracy higher than 0.001 m. New observations were conducted in 2015 using GNSS-technologies and satellite observations in static mode because the traditional methods were impossible to use as the mutual visibility between basis points was lost. The biggest problem in current monitoring was the loss of basis points of monitoring stations. Some suggestions as for choosing the most stable points of network were made. Such points were defined according to previous observations; and the new method of determining the "temporary" basis points by comparing the lengths of lines between points of observation is offered. There were chosen three most stable points with minimal length disparity. Using such method we have transformed satellite observations from WGS-84 to local coordinate system established at the territory of landslide. Such method could be used in case of lost basis points and with considerable number of rather stable observation points. At the same time, we suggest setting the basis points as far from the landslide observation stations as possible. For further observations, we suggest using GNSS-technologies in static mode and setting the new basis points. To improve the accuracy, the observations on basis points will be combined with GNSS and other ground observations.

Introduction. The use of local geodetic networks to monitor landslides has some advantages over the use of public or state ones, especially in cases where precision of information is very important. Local geodetic network is usually created for observation of engineering structures or natural objects. Some of them were created at the time when the GNSS systems were not in use. The application of modern satellite systems is problematic in one local geodetic network and the most significant problem is the comparison of results measured during previous observations without satellite instruments.

It is especially significant when the primary basis points have been destroyed but you need to perform repeated geodetic measurements, and for various reasons, there is no mutual visibility between points of observation, while most of measurements can only be performed using GNSS-receivers. Also, without taking into account the results of previous long-term observations it might be inappropriate and provide incomplete characteristics of the landslide.

Analysis of recent research and publications concerning the problem. There are some modern publications dwelling on the methods of geodetic observations for establishment of geodynamic networks. The publication by Dyshlyk A. [1] is devoted to the methods of geodynamic observations of soil mass of Sudak fortress. The authors have systematized the implementation of methods of geodynamic observations by the accuracy of their methods. There is an example of construction of geodynamic network for observations at the Sudak fortress.

Zuska A. [2] investigated landslide processes in Dnipropetrovsk, including in the area of «Sokil». The findings of the study made the basis for modelling the soil mass changes over time, as of mid-1990.

Works by Tyschuk M. [3] indicate the importance of sharing disparate observations, which is reflected in five papers.

The paper by Khoda O. [4] features monitoring by using GNSS equipment. The author researched the factors that significantly affect the accuracy of measurements, and developed proposals for forecasting the relevant factors. He also suggested the program campaigning GPS-observations on geodynamic polygons to study local deformation of the landslide.

There are many other very important works on the research topic by the following experts Voitenko S., Savchuk S., Trevoho I., Tretyak K., Chernyaha P. etc., however there was no research dedicated to the problem of new observations using GNSS methods when the basis points of local network are lost.

Aim of research. The aim of this research is to determine the methods of selection of new "temporary" starting points by comparing the lengths of lines between points of observation on the results of modern geodetic observations using GNSS equipment for the monitoring of natural landslides in Dnipropetrovsk. This task is dedicated to the problem when the primary basis points of observation stations are not protected.

The main material. Observation of landslides on natural landslide "Sokil" in Dnepropetrovsk were provided by the Department of Geodesy of the National Mining University during 1984-1993. The last series of observations was conducted in autumn 1993. Fig. 1 shows general view of observation points and Fig. 2 – the layout of observation points stations in this area.

To perform the research, the researchers designed the network of microtriangulation, polygonometry and height observation points by using geometric levelling of 2nd class. Additionally, on the slopes of landslide there were set the sedimentary soil rapper, but as of autumn 1993 they were almost lost. The starting points of this network were 16 and 20. The observations were performed in cycles twice a year.

To suspend the landslide in the relevant territory, a retaining wall and drainage systems were built. On this wall, observation points were also established. The shift of the observation points allowed talking about reducing the shear process in general.

Fig. 1. General view of points of tracking station on the section " Sokil "

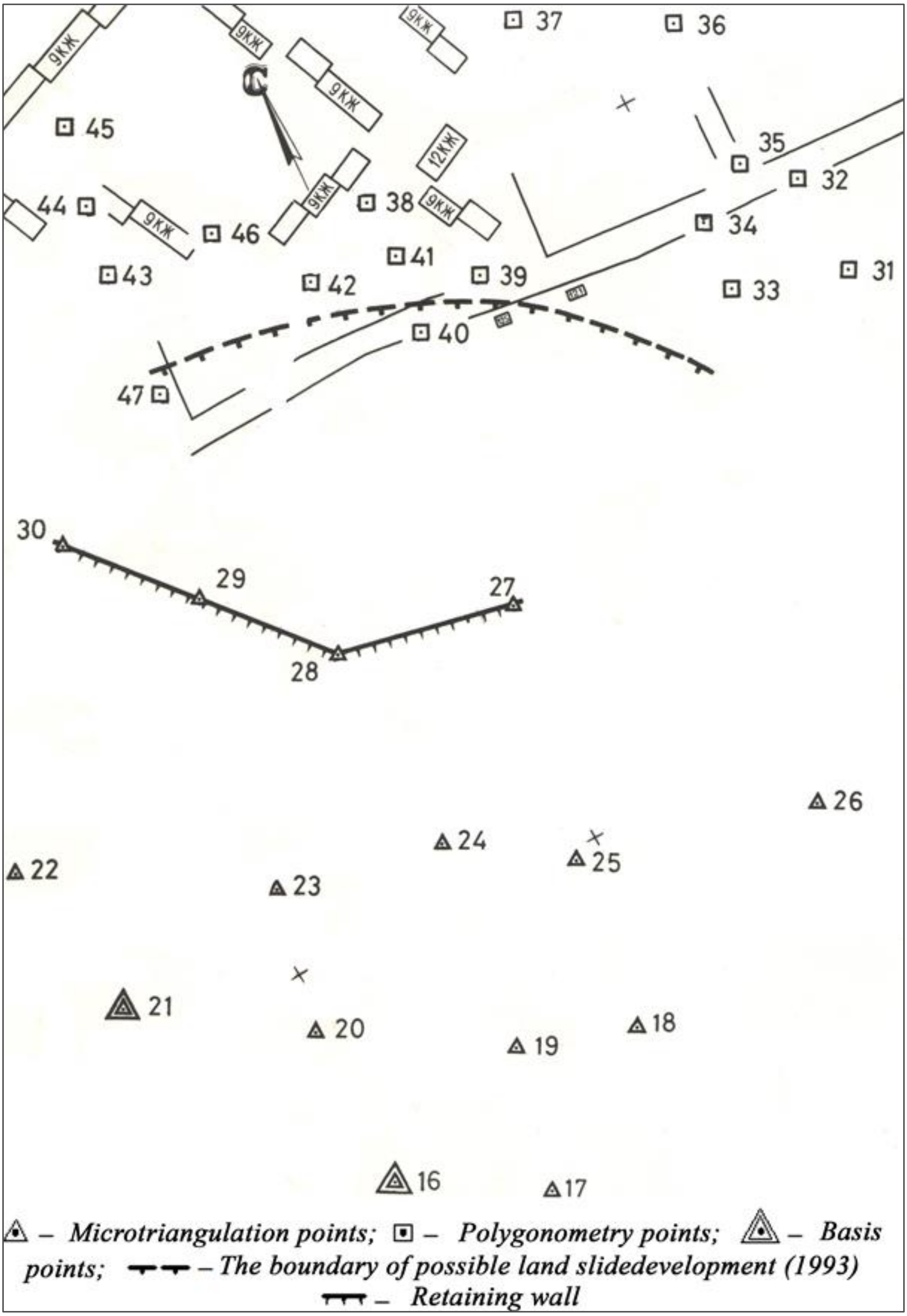

Fig. 2. Scheme of observation station points on the section " Sokil " (Autumn 1993)

In April 2015 the survey at the following areas was made. According to the results of the survey it was established that only the stations shown in Fig. 3 were saved and possible to use.

Fig. 3. Scheme of points available on the section of observation station "Sokil" (Spring 2015)

Station 28 on the retaining wall is not completely preserved, except for its base. Stations 22, 23 and 24 are lost as a result of the widening of the ravine. Stations 16, 17, 20 and 21 are destroyed as a result of human activity.

To receive the results that can be compared with previous cycles of observations the most important was to recalculate the current observations to the local coordinate system. The ideal solution of the problem could be the use of the basis points of previous network 21 - 16, but they were destroyed. Every possible combination of basis points from those remaining were analysed, and the most stable items were selected according to the results of existing geodetic observations from 1984 to 1993. The new basis points are 18, 19 and 41.

The summary of the results of plotted coordinates and elevations of points on the first and the last five cycles with their differences are shown in the table 1. According to the results of geodetic observations of last (seventeenth) cycle in 1993 compared with previous observations, it was established that these points almost did not change their position.

Table 1. Results of planned and altitudinal displacement of points 18, 19, 41

№ point / cycle	Coordinates of points, m			The deviation from previous, mm			The planned shift, mm	The spatial shift, mm
	X	Y	H	X	Y	H		
18/1	83.642	375.013	134.045					
18/13	83.711	375.050	134.040				-	-
18/14	83.722	375.061	134.040	11	11	0	15.6	15.6
18/15	83.731	375.059	134.040	9	-2	0	9.2	9.2
18/16	-	-	134.044	-	-	4	-	-
18/17	-	-	134.045	-	-	1	-	-
19/1	103.024	301.505	136.652					
19/13	103.027	301.506	135.650				-	-
19/14	103.030	301.512	135.649	3	6	-1	6.7	6.8
19/15	103.038	301.509	135.651	8	-3	2	8.5	8.8
19/16	-	-	135.649	-	-	-2	-	-
19/17	103.032	301.506	135.654	-6	-3	5	6.7	8.4
41/1	574.703	432.351	129.944					
41/13	574.691	432.373	129.942				-	-
41/14	574.703	432.362	129.945	12	-11	3	16.3	16.6
41/15	574.701	432.365	129.943	-2	3	-2	3.6	4.1
41/16	-	-	129.945	-	-	2	-	-
41/17	574.738	432.366	129.946	37	1	1	37.0	37.0

In May 2015, observations on saved points of the station "Sokil" were performed by the professors of the Department of Geodesy. The base receiver was installed at point 41, where it worked for the cycle at all observation points. Observations on other points were performed by rapid static method. Time of observations on points ranged from 25 to 35 minutes depending on the geometry of the satellites constellation.

Using the Topcontools software, the coordinates of all observation points were transformed from WGS 84 to the local coordinate system, which was the base for geodetic monitoring of landslides in the past.

The choice of new basis points was performed in the following order. First, the results of GNSS observations in spring 2015 were used to calculate lengths of lines between all points of observation. Then there were calculated the same length of lines according to the results of the last cycle of observations in autumn of 1993. After that the lengths of all lines were compared. The results of this comparison are presented in Table 2 and Fig. 4.

As can be seen from Table 1 and Fig. 4, of all possible lengths of lines between points of observation the distances between points 41, 18 and 19 have the least changed.

As point 41 and points 18 and 19 are located on different sides of the ravine and they are stabile we can use them to make the transformation. But, as can be seen from differences in lengths between other points, landslides are still continuing.

Table 2. Comparison of distances between points of observation stations

N of lengths	Distance from the results of GNSS observations, m	Distance based on observations of last cycle in 1993, m	The difference between the distances, m
18 – 19	76.025	76.043	-0.018
18 – 26	174.262	174.883	-0.621
18 – 27	269.190	269.830	-0.640
18 – 30	460.741	460.938	-0.197
19 – 26	236.679	237.425	-0.746
19 – 27	270.647	271.096	-0.449
19 – 30	415.245	415.481	-0.236
27 – 30	279.698	278.852	0.846
41 – 18	494.322	494.340	-0.018
41 – 19	489.482	489.521	-0.039
41 – 26	424.258	424.652	-0.394
41 – 27	225.232	224.585	0.647
41 – 30	269.867	269.664	0.203

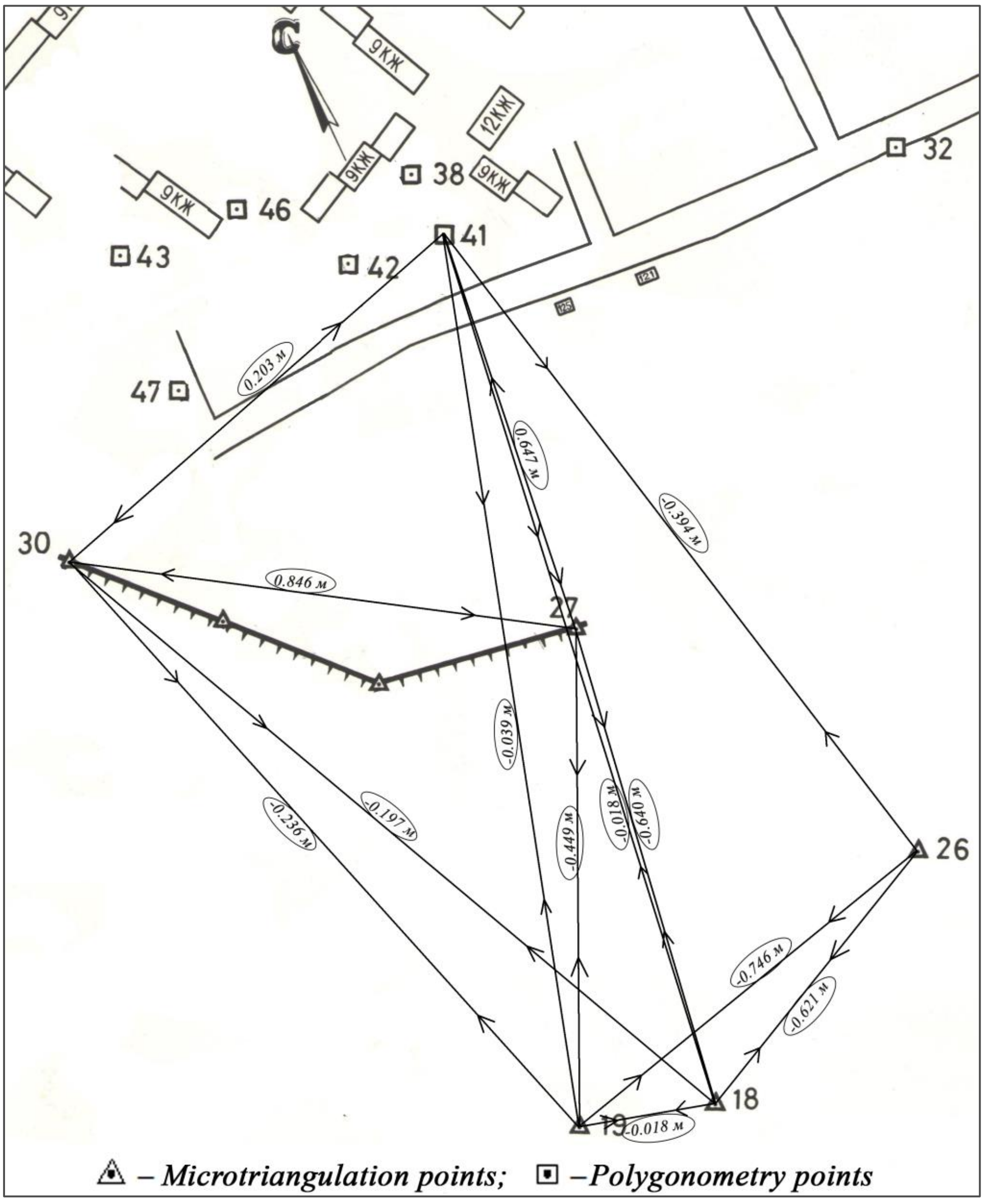

Fig. 4. Directions and changes in distances in the network on the section "Sokil " (Spring 2015)

Conclusions and proposals. Summarizing the information above, the following conclusions can be reached.

1. If the starting points of local geodetic network observations are lost, in order to select new starting points it is proposed to use the method comparing lengths of lines between all points of observation.

2. Application of this method allows using the observations of previous years.

3. To reduce the risks of losing basis points we suggest setting the basis points away from the landslide area. The key demand for new basis points is mutual visibility to provide GNSS and ground observations using all stations.

Further research is aimed at creating a base outside the landslide area, to be set in the state geodetic network UCS 2000 and local coordinate system of Dnipropetrovsk city. Also it is recommended to carry out repeated observations using multifrequency and multisystem GNSS-receivers.

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