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GEODETIC MONITORING OF RESHAPING OF VALLEY-RIVERBED RELIEF ELEMENTS OF RIVERS IN THE CARPATHIAN REGION

B. Volosetskyy

Lviv Polytechnic National University

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Statement of the problem.

The study of the dynamics of the processes of natural objects involves periodic monitoring of displacements of certain points that occur under the influence of natural and technogenic factors. Depending on the type of objects, their parameters and the character of the acting factors, these changes are slow, as in the case of modern crustal movements, or fast enough, as in the case of reshaping (deformation) of river valley-riverbed relief or collapse-landslide geological processes.

Quantitative characteristics of such phenomena are determined in the process of geodetic monitoring that involves observation, measurement and determination of parameter values of displacements of points of natural objects in a particular coordinate system for a certain period of time.

Significant morfoform changes (deformations) of the river valley-riverbed relief in the Carpathian region occur under the action of water flows during floods with extremely high levels and great water discharges. Such floods cause destruction of engineering facilities and damage to economic systems that are functionally linked to the watercourses and are located on near-valley sites of the relief.

During the passage of extreme floods in the rivers, there occur channel transformative processes in the river valleys, which are manifested in the change of valley-riverbed relief elements. Since the manifestations of the impact of the energy of water flows are reflected in the changes of the morphometric parameters of the channel and of the river valley relief, the main methods to determine the elements of the reshaping (deformation) of the valley-riverbed morfoforms are periodic geodetic measurements that ensure adequate detail and accuracy of these parameters.

Analysis of the studies and publications dedicated to the solution of this problem.

Works on monitoring the dynamics of geological and geomorphological processes, changes (deformations) of the river valley-riverbed relief have been done by several authors [1-3, 5-7]. For instance, hydrological aspects of these phenomena are discussed in [5], and the dynamics of geomorphic processes is analyzed in [6]. The results of geodetic monitoring of the dynamics of valley-riverbed relief are presented in [1-4]. A detailed bibliographic review and analysis of the impact of natural and anthropogenic factors on changes in topography of the earth's surface is offered in [5-7].

Changes in the forms of valley-riverbed relief in rivers of Transcarpathia and Prikarpattya occur during extreme floods, which are enhanced by anthropogenic impacts: deforestation of mountain slopes, quarrying inriverbeds, melioration in river valleys. Catastrophic floods in the Carpathian region are caused by the interaction of natural and anthropogenic factors. Investigations of the deformations of the valley-riverbed relief elements of many rivers in Transcarpathia and Prikarpattya after the passage of extreme floods indicate significant horizontal reshaping whose values reached from 10 m to 100 m and more, and the vertical deformation, in particular, the accumulation of gravel-pebble deposits, reaches 0.5 to 2.0 m [6]. Such repositioning of rivers and reshaping of valley-riverbed formations are caused not only by natural causes, but to a large extent, by anthropogenic factors, including: construction of various facilities on the floodplains and river beds, construction of reservoirs, ponds, river-bed quarrying [5, 6].

Significant deformations of riverbeds in the Carpathian region occur due to the extraction of large amounts of gravel-pebble deposits in river-bed quarries. For example, extraction of millions of cubic meters of the deposits from the Stryi River bed over the years has led to erosion of the bed and lowering of the bottom marks in the lower river by 0.25 to 0.4 m per year [6]. This has resulted in destruction of protective and regulating structures on the river, flood damage of many bridges and pipeline crossings, washing away of rock underneath bank protection structures. Similar deformation occurred on the Limnytsya River where due to the same causes the expansion of the channel and lowering of the bottom was about 3 m, and the slope of the Prut River bottom in some areas increased 1.5-fold. Similar processes occur in other rivers of the Carpathian region.

Irreversible deformations of fluvial valley morfoforms are observed in the Bistrica Nadvirnianska River [6], where riverbed deepening reached 2 meters or more. Reshaping of the riverbed topography is observed in the river within Ivano-Frankivsk, where there were washouts of the river bottom and horizontal displacements of the riverbed within the floodplain. Accumulation of sediment is observed in addition to reshaping of channel forms associated with erosion. Sediment accumulation is due to the small tributaries carrying out the material washed off from sloping plots of plowed fields, ravines, etc. Similar changes in valley-riverbed relief also occur in rivers of Transcarpathia: the Tisza and the Teresva [2-4].

Statement of the task

Deformation values of valley-riverbed relief elements can be determined based on the results of periodic geodetic observations: monitoring the spatial position of morfoform points in a fixed coordinate system. Monitoring movements of the Earth's surface points involves instrumental measurements of the components of the differences of spatial positions of relief points in a particular geodetic observation system. The magnitudes of displacements of the corresponding points are determined in the process of instrumental observations carried out at certain time intervals.

The position of any point M of the Earth's surface can be specified by coordinates X, Y, Z. For a certain moment of observations T_1 the position of the point will be M_1 (x_1, y_1, z_1). As a result of the deformation displacements at moment T_2, point M will shift to position M_2 (x_2, y_2, z_2), where $x_2 = x_1 + \Delta x$; $y_2 = y_1 + \Delta y$; $z_2 = z_1 + \Delta z$. (1)

Therefore, in order to determine the magnitudes of displacements Δx, Δy, Δz of earth surface points, it is necessary to carry out repeated (with a certain time interval) geodetic measurements of the spatial positions of these points. Unambiguous determination of the displacements is only possible in a fixed coordinate system, the starting points of which remain unchanged during all periods (cycles) of observations.

The main material

Based on research findings of the dynamics of valley-riverbed relief on the rivers of the Carpathian region, in particular the Stryi, the Svicha, the Tisza, and the Teresva [1-3], we can conclude that extreme floods cause significant riverbed movements (meandering) within a fluvial valley. In addition, significant deformation and reshaping of valley-riverbed relief morfoforms are observed as a result of side and bottom erosion and sediment transport and accumulation processes.

According to the monitoring studies of erosion processes on the Stry River carried out in 2003 and 2011, significant destruction of the bank part of the river bed and erosion of the bottom of the channel were revealed, which were caused by heavy floods in 2008. These processes are accompanied by the transfer of gravel-pebble deposits in the lower part of the river bed. It is estimated that about 1.5 million m^3 of gravel and pebble rocks were washed away from a 3 km long study area during the 2003 – 2011 period. Gravel and pebble quarrying in the the lower part of the river bed and floodplain of the Stry may be among the factors contributing to the processes of erosion and movement of these sediments.

Geodetic monitoring of the dynamics of valley-riverbed relief of the Tisza River under flood was carried out in the area between the settlements of Vylok and Hetynya, Transcarpathian region [1]. Geodetic measurements were carried out on a more than 20 km long section of the river where forty one cross sections had been marked.

The monitoring studies were based on the reference horizontal and vertical moves, whose points were laid on the right-and left-bank dams of of the river valley embankment. The horizontal framework was created by means of 1st-category polygonometry moves according to the requirements of [8]. All the points of the horizontal framework are fixed by long-term storage centers У15Н. The starting points for the polygonometry network were the existing State Geodetic Network of Ukraine points and GPS points of classes 2-4. The elevations of the benchmarks were determined by class IV leveling. The existing II-III class leveling points were the initial data for the vertical networks.

Repeated geodetic observations were carried out in order to determine the magnitudes and nature of the reshapings of the valley-riverbed relief elements. Measurements were carried out on transverse profiles (cross-sections) having lengths within 0.5-2.0 km and relying upon the benchmarks of the main horizontal and vertical moves. The cross-stctions were marked with stations, every 100 m, and plus-point.

The theodolite moves laid along the cross-sections that relied on the polygonometry points were the surveying basis for the study of changes in the horizontal positions of the relief points. The elevations of the station and plus points were determined by means of a technical leveling of high accuracy (allowable discrepancy did not exceed 30 mm $\sqrt{L}$ where L is move length in km).

The depths of the bottom of the river bed were measured using a special rack and the plan positions of the surveying points were determined by means of the alignment-linear method. An electronic tacheometer was used for shallow areas of the river.

Changes in shape of the river bed and valley-riverbed relief morfoforms occur under the action of water flows during heavy floods. Heavy floods were observed in 2001 and 2008. Fig. 1 is a fragment of the map done in scale 1:10000, which shows the positions of cross sections and change of the position of the bed of the Tisza River (light color for before the flood, dark color for after the flood). The magnitudes and direction of riverbed meandering were studied in [1]. Transverse profiles were made on the corresponding cross-sections based on the results of geodetic measurements. Analysis of changes in elevation of relief points and of the bottom of the river bed before and after the flood makes it possible to evaluate the magnitudes of deformation of valley-riverbed relief elements. Changes in the position of the riverbed can be considered as characteristic quantities. Such changes in position of the axis of the riverbed occurred in almost all areas studied, reaching values of 100-400 m.

Important parameters can be determined from the longitudinal profile of the river plotted based on the channel depth measurements and observations of the characteristics of flood water flows. Such a generalized longitudinal profile has been plotted for the investigated area of the Tisza River (Fig. 2). The profile shows elevations of the bottom, of the water edge, the crest marks of the right bank and left bank dams as of 2009 determined from the geodetic measurements. It also shows the heights of the water level during the 2001 flood and estimated water level heights for a flood of 1% probability. Analysis of the data on the longitudinal profile makes it possible to make a conclusion about the probability of flooding of the relevant parts of the territory during floods of varying intensity.

Monitoring studies of the changes in the valley-tiverbed relief morfoforms of the Svicha River, a tributary of the Dniester River, caused by the 2008 flood were carried out in 2010. Geodetic measurements were carried out on 70 transverse profiles (cross-sections) within an about 30 km long segment of the river [2]. The main horizontal-vertical moves laid on both sides of the river were the basis for the instrumental observations. Measurements were carried out in accordance with the 2nd-class polygonometry regulatory requirements. All the polygonometry points are fixed by long-term storage centers of У15Н type, benchmark elevations were determined by class IV leveling.

The reshapings of relief elements of the riverbed and river valley were examined on marked transverse profiles (cross-sections) which relied on the benchmarks of the main moves located on the right-and left-bank embankment dams. The cross-section lengths range from 05 to 1.3 km. Stations are marked down every 100 m on the transverse profiles, the characteristic points of the relief are fixed with plus points. All the points on the cross-sections were assigned temporary signs. Theodolite moves were laid along the cross-sections to observe the situation, and the elevations of all the relief points were determined from leveling. The transverse profiles of the river bed were determined from surveying works. The previous cycle of observations on the Svicha River was carried out during 2000-2005.

Fig. 3 shows a fragment of the Svicha River valley plan executed on a scale of 1:5000, where riverbed movement (meandering) is clearly visible. The riverbed offset values reach 100-300 m on average [2].

Conclusions

The data of monitoring observations and the results of their processing revealed significant changes in the positions of riverbeds in the Carpathian region after floods. Analysis of the results, in particular, of the transverse and longitudinal profiles makes it possible to draw conclusions about the existence of flood-prone areas along the river beds.

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Geodetic monitoring of the rivers valleys changing in the Carpathians region

B. Volosetskyy

The results of the geodetic monitoring of the rivers valley-relief changing in Carpathian region is considering. The repeated geodetic observations reveal the displacements of rivers valleys and its deformation due to freshets. The displacements of the river valleys and positions of potentially hazardous freshets are determined.

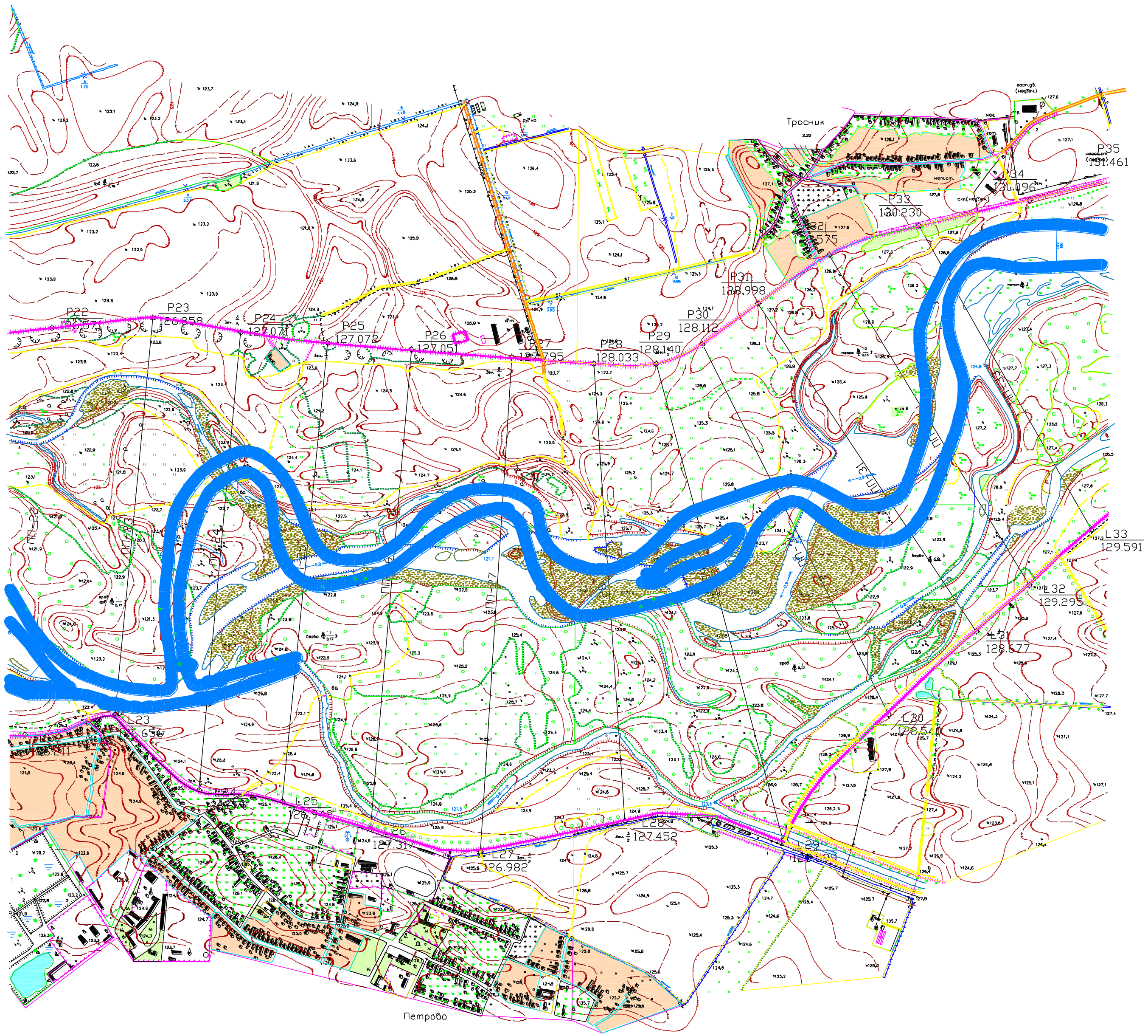

Fig. 1. A fragment of the Tisza River valley plan

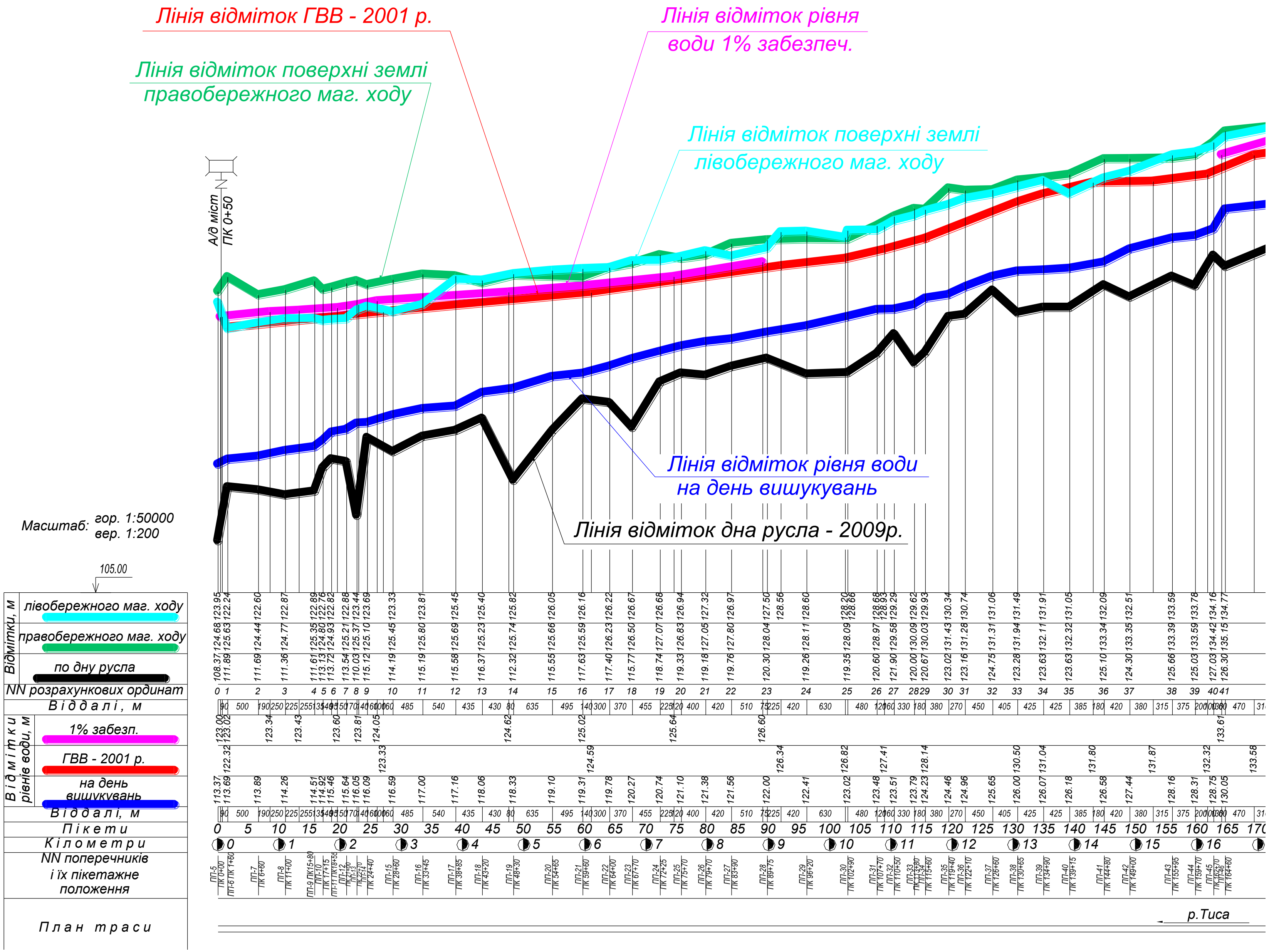

Fig. 2. Longitudinal profile of the Tisza River in the area under study

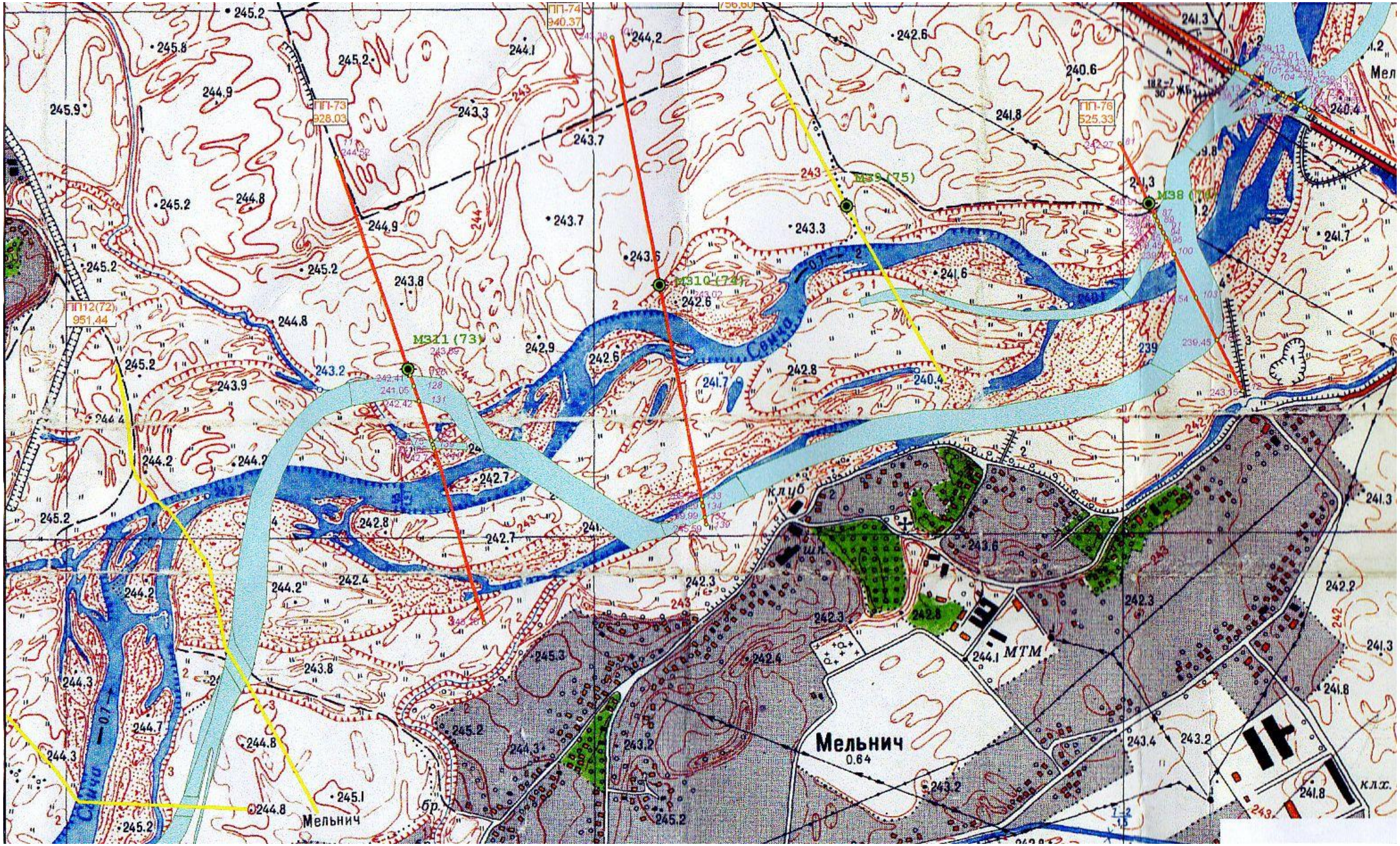

Fig. 3. A fragment of the Svicha River valley plan