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HYDROLOGICAL ASPECTS OF ESTIMATION OF CONSEQUENCES OF SUBSIDENCE OF TERRITORIES DUE TO LARGE-SCALE MINING WORKS

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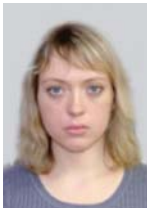

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Possible variations of hydrological conditions of a small water flow located in the territory of working-out mine field are analyzed. Usolka river in the territory of SKRU-1 mine field of "Uralkaliy" OJSC was considered as an object for investigation. In order to obtain correct estimations, an imitation quasi-1D hydraulic model of Usolka river in Sen-Venan mode, realized in HEC-RAS 4.1.0 software complex, was used. Initial data about current relief were scanned from the large-scale topographic maps, wile the data about land subsidence in the territory of SKRU-1 mine field were presented by "Galurgiya" OJSC. ArcMap v.9.3 software complex has been used for processing of topographic data. Influence of land subsidence processes on variation of hydraulic conditions of Usolka river was analyzed. Necessity of execution of concrete measures on minimizing of negative consequences is estimated.

Key words: *land subsidence, strata working-out, Usolka river, quasi-1D hydrodynamical model, calculation of average flow speed, relief of river bottom.*

Introduction

Large-scale underground mining of the minerals may lead to settling of the ground over the mined fields. Change of morphological parameters of the earth's surface inevitably reflects hydraulic conditions of the fields and correspondingly hydrologic regimen of the nearby water objects. So, for minimizing of possible negative consequences it is very important to estimate, at the stage of projecting, possible expected scale of the changes. Because of mining of Verkhnekamsk deposit of potassium salt (VKDPS) above mentioned task is very important for towns Beresniky and Solikamsk and for small water courses located on their territory. Usolka-river may be considered as typical water object, located within the bounds of the worked mine field. Above mentioned task has become especially important in connection with preparing of the project of working of the field of the mine SKRU-1 where the water course is located.

Usolka-river is left-bank tributary of the Kama-river (Kamsky storage pond). It flows in Kama-river near the town Solikamsk at the distance 919 kilometers from the mouth. Its lower flowing is located within the bounds of investigated territory. Amplitude of fluctuation of the water level in the middle flowing is 1.5–2 meters. In lower flowing it may reach 3–3.5 meters. Minimum river discharge, with probability 95%, is 1.01 m^3/s. Average annual discharge for many years is 4.8 m^3/s. Average rate of flow is 0.3 m/s.

In period of examination width of the river changed from 7.9 meters near the eastern border of the studied area (15.6 kilometers from the mouth) to 31 meters in the range at the distance 7.3 kilometers from the mouth. Average depth of the river on the studied area was 1.2 meters. Territory of the watershed is subjected to influence of the people's activity. It is covered with the forest tracts alternating with agricultural lands.

Small temporary water-course flows into Usolka-river from the left bank at the distance 15.5 kilometers from the mouth along the studied length. In period of prospecting the flow was absent. Chernaya-river flows into Usolka-river from the right bank at the distance 13.3 kilometers from the mouth and Klestovka-river — at the distance 9.5 kilometers from the mouth.

Large areas with stagnation zones have not been found in course of prospecting of Usolka-river. Erosion of the banks and accumulation of alluviums have not been found too. Morphological parameters of the bed of Usolka-river are uniform along the studied length.

Materials, methods of examination

Estimation of the possible change of hydraulic regimen of Usolka-river has been carried out on the base of the modern hydrodynamic models of the river-bed flows. In accordance with conduction of considered task heterogeneity of hydrodynamic parameters along the width of the flow is inessential. So, the model of water-course in one-dimensional approach has been considered in the Sen-Venan arrangement [1].

Today the number of the software products has been worked up in our country and abroad. They allow simulate hydrodynamic processes in the river-bed flows:

- River, worked up in NIIES;
- "Wave of the break" and "MMM", worked up in "VNIG named by Vedeneev B.E." JSC [2];
- MIKE 21, worked up by the Danish Hydraulic Institute (DHI), official Russian dealer of DHI Software is NKF "Volga" (http://www.volgaltd.ru);

• EMS-I. SMS.v.9.2, worked up to order and with participation of the Centre of hydraulic investigations (HEC) of the Corp. of military engineers of US army (USACE) and Federal administration for roads of USA (FNWA) (www.ems-i.com);

• HEC-RAS 4.0, worked up by HEC for USACE (www.hec.usace.army.mil).

All above mentioned software products have been worked up on the base of numerical solution of the Sen-Venan system:

$$\partial Q/\partial t + \partial/\partial x(\alpha Q^2/F) + gF(i - \partial h/\partial x) = gQ|Q|/FC^2R;$$

$$\partial Q/\partial x + \partial F/\partial t = q, \quad (1)$$

Q — water consumption; F — area of cross-section; q — specific consumption of the side inflow (tributary); h — depth; α — Bussinesque coefficient; C — Shezy coefficient.

$$C = R^{0,5}/n \quad (2)$$

n — coefficient of roughness (according to Manning); R — hydraulic radius, calculated by the formula $R = F/\varphi$, where φ — moistened perimeter of the river-bed cross-section.

Difference of above mentioned software products consists of the numerical methods of solution of the equations system (1) and very often — only of the interface of their software envelops.

Analysis of software products, including criterion of cost of software (HEC-RAS is free of charge software and it may be easily distributed) and its efficiency, has conditioned usage for simulation of software product HEC-RAS 4.1.0. It is the system of detailed hydrodynamic simulation of the different surface water objects and is intended for description hydrodynamic processes of the river-bed flows in one-dimensional approach. It permits to solve non-stationary and stationary tasks. Above mentioned software product has been tested in course of calculation of the waves of the break in emergency situation at GTS in the Perm territory, for calculation of the zone of flood for settlements and for solution of another tasks.

Simulation of the quasi-one-dimensional model has been worked up in software complex HEC-RAS 4.1.0 for analysis of influence of settling of the earth's surface on hydrological regimen of Usolka-river.

Prognostic estimations of change of the earth's surface relief for appointed calculated periods are topographic basis for construction of hydraulic models of Usolka-river.

Calculation has been carried out for two periods:

• finishing of process of extraction at the mine field SKRU-1 (2039)

• finishing of the process of moving (settling) of the rock.

Initial information was the data about relief in the

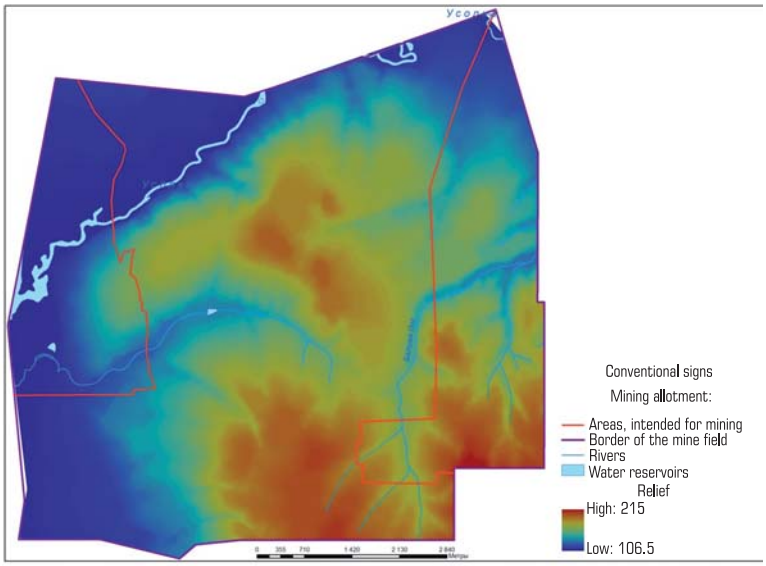

Fig. 1. Numerical model of the relief for 2012

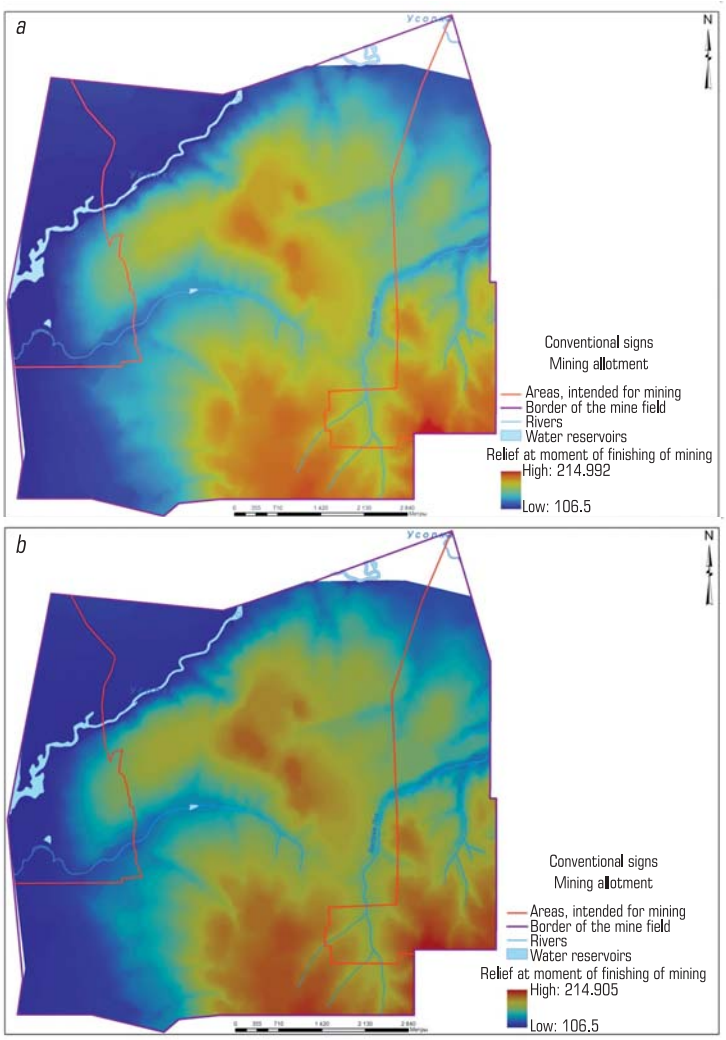

Fig. 2. Numerical model of the relief for moment of finishing of mining (*a*) and settling (*b*)

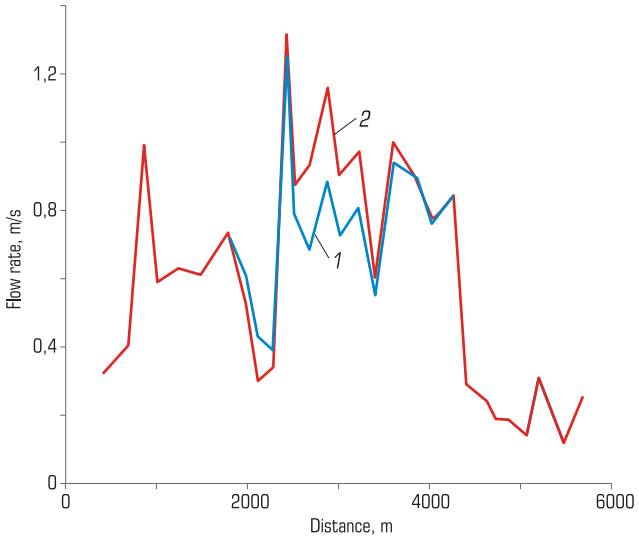

Fig. 3. Rate of flowing of Usolka-river in period of finishing of mining (*1*) and finishing of process of settling (*2*)

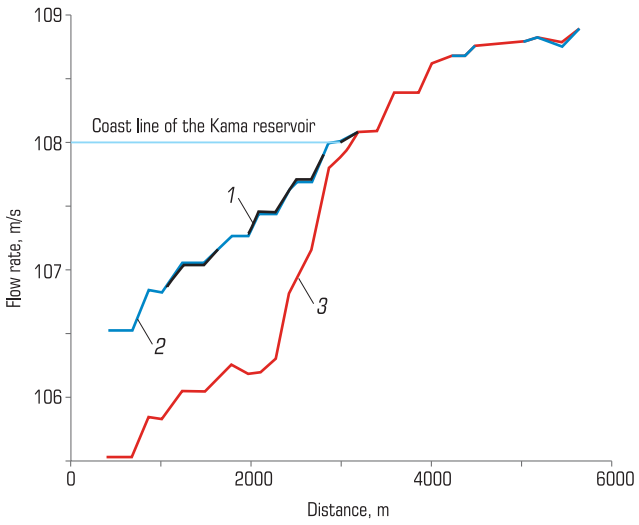

Fig. 4. Profile of the bottom of Usolka-river in 2012 (*1*), in period of finishing of mining (*2*) and finishing of process of settling (*3*)

current period (relatively to 2012), obtained from the large-scale topographic maps, and the data about the ground settling on the territory of the mine field of SKRU-1. The last ones were given by "Gallurgy" JSC in form of the map-scheme of the isolines of settling of the earth's surface. For all this it has been taken into account all mining-technical measures for decrease of settling of the earth's surface.

Initial topographic data have been coordinated with territory and transformed into numerical form. Software complex ArcMap v.9.3. [3] has been used in the work. Later on the base of initial data it has been constructed so-called TIN-models transformed then into the raster form (image) (GRID). Spatial resolvability of GRID them is 1 meter. Numerical model of the relief for 2012 is given at the Fig.1.

Later the instrumental set "Raster calculator" of the software complex ArcMap v.9.3. has been used for calculation of numerical model of the relief taking in account settling of the earth's surface for the set periods (Fig. 2).

Model of the relief, obtained in result of superposition, is the basis for subsequent analysis of consequences of the ground settling on the territory of the mine field of SKRU-1.

On the next stage with usage of functional of the module HEC-GeoRAS it has been plotted on the parameters minimally necessary for calculations: borders of the left and right flood-lands of Usolka-river, fairway, water edges and transversal profiles. After that module HEC-GeoRAS has calculated automatically geometric parameters of the profiles and conversion of the last ones into the format HEC-RAS. Above mentioned parameters have been loaded into HEC-RAS and it has been calculated parameters of water flow passing through transversal section of the river-bed.

Discussion of obtained results

Results of fulfilled work are the diagrams of change of the rate of water flow (Fig. 3) and mark of the bottom of Usolka-river at the studied plot (Fig. 4). It is obvious that it is not observed significant changes in the rate of water flow for conditions of the relief of the bed of Usolka-river in period of finishing of mining processes and settling of the surface. Changes within the limits of 10–20 % will not influence significantly on parameters of water flow and its ecological state. Analysis of settling of the bottom of Usolka-river shows that large areas with stagnant zones are not formed here.

Conclusion

On the base of the data about probable settling, presented by "Gallurgy" OJSC, it has been created the numerical models of the relief for two control periods: finishing of mining of the field of SKRU-1 and finishing of settling of the earth's surface.

It has been found that settling of the earth's surface, connected with finishing of extraction at the mine field of SCRU-1, will not influence appreciably hydrologic regimen of Usolka-river. So, it is inexpediently to work out measures for preservation of the surface water objects at the given stage.

Significant changes in the rate regimen of the water flow are not observed in period of finishing of process of settling. Analysis of settling of the bottom of Usolka-river shows that big areas with the zones of stagnation are absent. Besides, the river-bed in the lower flowing is propped up by the Kama storage pond. So, settling of the bottom will lead to increase of the depth. But it will not change principal parameters of the water objects.

References

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