Justification of reclamation parameters for lands disturbed during the development of gold placers

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Abstract. The article deals with the issue of reclamation of lands disturbed during the development of gold placers. Using the results of surveys and studies of the rocks composing the surface layer, the authors compare the present state of disturbed lands and the technogenic relief designed by technical documents on the development of alluvial placers. The discrepancy between actual and design data is analyzed. The conditions of natural vegetation restoration are studied. Results of observations of the natural vegetation restoration within loose deposits are presented. Recommendations on flattening angles depending on the length of slopes and elevation differences between the bottom and crest of technogenic embankments are given. The design results for reclamation of disturbed lands based on preliminary surveys and mining project data are compared. Methods for reducing the amount of reclamation works are substantiated.

1. Introduction

In 2019, the Government of the Russian Federation issued two decrees (No. 800 of July 10, 2018 and No. 244 of March 7, 2019) on land reclamation according to which land reclamation projects can be implemented after land surveys, including surface surveys, field and laboratory studies of soil conditions, engineering and geological surveys have been completed. The requirements of these decrees make it possible to make rational technical decisions on reclamation of disturbed lands taking into account actual rather than design data.

Thus, development of a land reclamation project is preceded by long-term land surveys. Remote sensing and laser scanning reduce the duration of technogenic topography [1,2]. When preparing source materials for reclamation of disturbed lands, aerial surveys followed by computer processing of data obtained were carried out.

Field surveys revealed discrepancies between actual and design conditions of disturbed lands. Moreover, the actual conditions of disturbed lands had better reclamation indicators than those provided for by the projects.

2. Methods and results

When developing mineral deposits, deviations from projects occur due to both objective and subjective factors. Since projects are aimed at choosing the most rational technological schemes and optimal parameters for deposit development and reducing negative effects on land resources, any deviations can complicate reclamation works.

However, our experience in the development of several projects on the reclamation of lands disturbed during the development of alluvial deposits has shown that the actual amount of reclamation works is smaller than the design one. Figure 1 shows transverse profiles of the disturbed land surface...
according to the technical design (1a) and surface surveys after mining operations have been completed (1b).

![Diagram](image)

**Figure 1.** Project (a) and actual (b) transverse profiles of the anthropogenic relief along one of the drill lines.

According to half of the reclamation projects, the actual area of the disturbed surface turned out to be smaller than the design one due to unsubstantiated reserves along placer contours, changes in the routes of drainage facilities, and parameters of external dumps. In 75% of such cases, the fragmentation of the disturbed area was less than the design one; in some cases, it was less by 24.5 m and 16.9 m. The latter significantly affects the technology and the amount of reclamation works. The reduced fragmentation is due to the fact that mining projects do not take into account that almost all sand washing tailings are stored in the waste area which is partially filled. Secondly, peat from a safety jacket and diluting rocks from the opencast sides, as well as peat from the excavator-car overburden and rocks used for the construction of hydraulic and engineering structures are stored in the waste area which is also not taken into account.

There were a lot of irregularities (small embankments, excavations) with elevation differences of up to 3-5 m. According to the design decisions, all these irregularities have certain flattening angles. In fact, levelling of these irregularities does not have positive effects and sometimes deteriorates the self-
organized vegetation. On the uneven surface, in small depressions and furrows, seeds are better fixed and rock moistening is better as well. Young shoots are protected from winds and covered with snow in winter.

During the development of placers, only loose sediments are mainly disturbed. They are fertile lands which are suitable for natural reforestation in the taiga zone. The reforestation process is regulated by the Order of the Ministry of Natural Resources and Ecology of the Russian Federation No. 375 of June 29, 2017. According to Clause 3, reforestation is carried out by natural, artificial or combined methods. Natural reforestation is carried out by natural processes and reforestation measures (preservation of the undergrowth, mineralization, fencing).

In accordance with Clause 12 of the Reforestation Rules, natural reforestation is planned in the zone of near-tundra forests and sparse taiga, the taiga zone, the zone of coniferous-deciduous forests and the South Siberian mountain zone. Most placers are located in these zones.

Soft, well-moistened sediments in the floodplains of rivers disturbed during the development of placers contribute to rapid natural vegetation restoration.

Factors intensifying the natural reforestation are as follows:
1. The presence of adjoining insemiinating forests which will serve as a natural source of seeds.
2. Conformity of the soil to GOST 17.5.1.03-86 Classification of overburden and host rocks for bi- ological land reclamation which can be referred to potentially fertile sedimentary non-cemented rocks, having humic inclusions (according to the results of laboratory studies of granulometric composition).
3. Compliance of technical parameters of the areas with GOST 17.5.3.04-83 General requirements for land reclamation, according to which dump heights and slope angles depend on the stability of constituent rocks and the use of their surface preventing natural erosion processes.

In addition, it should be noted that in summer, the heat supply of industrial lands is much higher than the natural one. On technogenic lands, temperatures of the root layer are 3–7 degrees higher than on natural ones, which can increase productivity of the vegetation cover [3].

Natural restoration of vegetation within loose sediments increases the biodiversity [4,5,6] and productivity of the vegetation cover.

Intensity of natural vegetation restoration depends on a number of factors: the content of fine soil in the upper layer (up to 20 cm), the proportional ratio of the height and size of the dump, the presence and proximity of natural seedlings. At a 6-7% fine soil content in the upper layer of the dump substrate, a 1:10 ratio of the height and areal size of the dumps and a landfill width not exceeding 200 m, the vegetation restoration is satisfactory, there are no depleted species composition and reduced ecosystem productivity compared to the natural restoration [7-10].

Long-term experience of exploration and development of placers in Irkutsk region has confirmed that the disturbed land is covered with grass, shrubs, and then with deciduous and coniferous trees. After 15–20 years, a dense forest cover with a butt diameter of birch and larch trees of more than 10 cm is formed [9,11].

Thus, the previous studies [7–11] confirm that after 15-20 years, the natural vegetation cover can restore and negative effects of technogenic factors on the environment can weaken.

For most factors determining the self-organized vegetation process, vegetation restoration conditions are satisfactory (the height and angle of slopes of the dumps, the depth and angles of pit walls). A number of factors should be considered favorable for the self-organized vegetation: a relatively small average width of disturbed areas; general characteristics of the surrounding landscape (the taiga piedmont zone), the presence of organic matter in the surface layer, a general view of the surface topo-ography and the type of surrounding vegetation (mixed forests). Areas characterized by poor conditions for self-organized vegetation are slopes of excavator dumps and pits. In this regard, the natural reforestation of disturbed lands may be long, accompanied by negative impacts (e.g., water erosion) in the adjacent areas. Therefore, to accelerate the self-organized vegetation of disturbed areas, it is necessary to carry out fragmentary reclamation and flatten dump and pit wall slopes up to 23-28° filling ephels, silts, gravel dumps, and outcrops of rock formations with overburden rocks, eliminating possi-
ble foci of water erosion and flooded areas and ensuring the natural flow of surface water from the disturbed area or creating artificial reservoirs.

Restoration of channels of permanent and temporary watercourses is of particular importance for the reclamation of disturbed lands. The restored riverbeds and streams should be formed close to the thalweg of the reclaimed land which will prevent the long-term erosion process caused by the gradual return of surface watercourses to the lowest surface elevations.

The results of field studies on disturbed lands of Irkutsk region and the Trans-Baikal Territory showed that in areas with differences in elevations of up to 5 m, there is no significant change in intensity of self-organized vegetation (apart from mounds and dumps). Figure 2 shows measurement results for woody self-organized vegetation density (pcs/m²) at different slope angles and lengths. Given the fact that on long slopes the vegetation density decreases with increasing elevations, the density was studied in the central part of the slope on land plots with an area of 9 m² (3 m x 3 m).

![Figure 2. Dependence of woody self-organized vegetation density on disturbed lands 8-11 years after the deposit development on the slope angle (α) and the slope length (L): at slope angles α up to 10° - «Δ»; α = 10-20° - «ω»; α = 20-30° - «+»; α = 30-40° - □.](image)

At the same time, in [12-18] and reclamation instructions and guidelines [19-22], the limiting slope angle of the reclaimed surface is 23-28°; this angle does not depend on the slope length or differences in elevations between the crest and the bottom. Therefore, when designing reclamation works, one limiting angle is set (see Fig. 1a).

### 3. Conclusions and recommendations

Exclusion of flattening works on small embankments and backfilling shallow troughs (with a height or depth of up to 3.0 m) with slope angles of 28-35° will reduce the amount of reclamation works. Moreover, under conditions of natural vegetation restoration, this will not deteriorate the self-organized vegetation of disturbed lands. Given that the reclamation process begins after mining operations have been completed, complete flattening will destroy the vegetation in areas disturbed during the first period of deposit development and delay the natural vegetation restoration.
Taking into account the above factors, the amount of design reclamation works was reduced by 70% compared with the data of mining projects; the reclamation works are planned to be completed during one season.

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