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DETERMINATION THE CAPACITY OF MINING EQUIPMENT IN THE DESIGN PHASE OF RECLAMATION

Summary. The technologies of opencast mining, alongside with economy and safety, should be considered with the following requirements: the duration of the period between the pit closure and carrying out land reclamation - ground improvement works must be as little as possible; the post-mining area must be minimum from point of view of wise land-use. The closed pit and post-mining space must be adapted to reclamation project decision according to the accepted direction of further land usage. The technological decisions have to be aimed at leaving a minimum post-mining area by the means of backfill mining method.

Keywords: opencast mine, waste piles, topsoil, reclamation.

WYZNACZANIE ZDOLNOŚCI PRODUKCYJNEJ URZĄDZEŃ GÓRNICZYCH W FAZIE PROJEKTOWANIA ZAGOSPODAROWANIA TERENÓW POGÓRNICZYCH

Streszczenie. W artykule przyjmuje się założenie, że określenie technologii wytwarzania w górnictwie odkrywkowym, wraz z wymogami ekonomicznymi i normami bezpieczeństwa towarzyszącymi produkcji górniczej, powinno uwzględniać długość okresu pomiędzy zamknięciem kopalni a rozpoczęciem prac nad zagospodarowaniem terenu pogórniczego. Działania naprawcze na powierzchni powinny być przeprowadzane na jak najmniejszą skalę, a rozpiętość terenu pogórniczego powinna być ograniczona do minimum, z uwagi na konieczność zapewnienia racjonalności eksploatacji górniczej. W artykule zwraca się także uwagę na konieczność dostosowania wszystkich działań naprawczych do lokalnych i regionalnych planów zagospodarowania terenu.

Słowa kluczowe: kopalnia odkrywkowa, hałdy, skutki produkcji górniczej, zagospodarowanie terenów poprzemysłowych.

1. Introduction

According to the current legislation, companies mining mineral and turf deposits, carrying out geological exploration, engineering survey, construction and other types of works on agricultural, forest and other lands must, after their works are finished, at their own expense bring the lands to the condition, suitable for agricultural, forestry, fishery, construction or any other use[1]. While carrying out these works, the companies must conduct topsoil stripping, preserve and apply top-soil and potentially rich rocks on the developed or under-productive lands.

Reclamation works on the lands damaged by opencast pit mining should be conducted according to a special project, developed taking into account the physical and geological settings of the area, economic, socio-economic and sanitary-hygienic conditions of the region, technology of reclamation works, its economic feasibility and social effect of the reclamation and align with the state supervision bodies[2].

Reclamation works have to be technologically consistent with the structure of complex mechanization of mining operations, working lifespan and open pit mine development stages[3].

The most costly part of reclamation is the mine-engineering stage, including reclamation leveling, benching, top-soil stripping, application of top-soil and other mining operations. Currently the development of reclamation projects and the choice of technology depends on the prospects of land-use planning[4].

Reclamation projects for the areas damaged during mineral resources extraction have to provide a minimal land transfer for the shutdown of a mining enterprise, preservation and rational use of the top-soil, maximal reclamation of the damaged lands and their return to the landowner. The approved reclamation project is a subject to compulsory implementation for the purposes of rational land-use at every mining enterprise.

Technical reclamation, carried out during the operation of open pit mine, allows conducting reclamation works at the expense of the main activity of the enterprise, decreasing rental payments, emissions of harmful substances and reclamation costs[5].

According to the fundamental principles of land reclamation, top soil must be compulsory preserved in the areas damaged by open pit mining[6]. Therefore, top-soil and, if necessary,

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[1] Smetanin, V.I.: Reclamation and improvement of disturbed lands/V.I. Smetanin. – M.: Kolos, 2003, p. 94.

[2] Agapov A.E.: Science mined-land reclamation near shut down mining enterprise/A.E. Agapov A.M. Navitniy, Y.G. Semikobyla - M.: Rosinformugol, 2003, p. 285.

[3] Fomin S.I.: Rational use and reclamation of the damaged lands/S.I. Fomin, E.L. Ubugunov, V.L. Ubugunov. – Ulan-Ude: publishing house of Buryat scientific center SB RAS, 2012, p. 87.

[4] Marinin M.A. Technical and economic evaluation of technical reclamation projects/Marinin M.A.//GIAB. – 2014, No. 3, pp. 401-405.

[5] Marinina, O.A.: Improving methods of assessing reclamation/O.A. Marinina, M.A. Marinin//Summary of 11th international scientific-practical conference "Development of Northern Mineral Resources: Problems and Solutions". 11-12 April 2013, pp. 566-570.

[6] Methodology instructions on organization and monitoring of mining reclamation of lands, damaged by open pit mining [electronic resource]. – M.: Federal Mining and Industrial Inspectorate of Russia, No. 7, 1993. access mode: http://www.bestpravo.ru/rossijskoje/lq-instrukcii/y0p.htm.

potentially rich rocks should be timely disposed of the mining claim as well as the areas occupied by rock dump, tailing dump, plant facilities, autoroutes etc.

The removal of topsoil is the first step in the process of mine technical reclamation phase. Conducting these tasks by using bulldozers of different models is the most common method. At the mine reclamation stage it is advised to actuate the equipment used on the basic technological processes, which allows reducing operating and capital costs[7].

As a calculation basis of the main equipment used during reclamation one uses "Unified performance standards of open pit mining works for mining enterprises" (1989), "Technological design standards for non-ferrous enterprises with an open-pit mining method " (1986), "Technological design standards for non-ferrous enterprises with an underground mining method" (1987), "Unified performance standards of land reclamation works for the coal industry" (1981), "Unified performance standards for placer deposits development with an open-pit mining method" (1991)[8].

2. Productivity of bulldozing equipment for mine reclamation works

The attention must be paid to the number of tours per day, which is accepted by the working regime, and the number of working days per month and year, excluding weekends and holidays, the necessary amount of time to conduct preventive, scheduled preventive, current and other repairs when it determines performance of the equipment[9]. The following parameters affect the performance of the bulldozer: category of the developed soil, its humidity, moving speed, depth of the shear layer, range of soil movement, magnitude of the slope and the shape of the knife. The productivity of bulldozer is decreasing with the increasing distance of soil movement[10].

The performance of bulldozer at work on the topsoil removal and relocation is[11]:

$$Q = V \cdot \frac{60}{T_ц} \cdot k_{укл} \cdot k_n \cdot k_u, \ \mathrm{m}^3 / \mathrm{h} \tag{1}$$

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[7] Fomin, S.I.: Appraisal of man-made impact of mining enterprises on the environment/S.I. Fomin, A.A. Faul, M.A. Marinin//Environmental geology: scientific, practical, medical, economic and law aspects. Summary of international conference, 6-10 October 2009, pp. 189-192.

[8] Unified performance and time standards or placer deposits development with an open-pit mining method. - Magadan: Severovostok-Zoloto, 1991, p. 395.

[9] Perelygin V.: Russian bulldozers in open-pit mines/V. Perelygin//Fixed assets, No. 11, 2006, pp. 52-57.

[10] Doronenko E.P. Reclamation of lands, damaged by open-pit mining/E.P. Doronenko. - M.: Nedra, 1979, p. 253.

[11] Fomin S.I.: Rational conditions for opencast shovels/Fomin S.I., Donchenko T.V., Ivanov V.V.//Scientific and industrial magazine Cement and its application. – Spb.: 6/2007, pp. 23-25.

where the variables are:

Q – bulldozer performance at the recess and moving, m^3/h,

V – bulk up of soil displacement per the working cycle, m^3,

$T_ц$ – cycle time,

$k_{укл}$ – factor, which takes into account the slope on the working acreage,

$k_п$ – coefficient of the soil loss during the movement,

$k_и$ – coefficient of the bulldozer reclaiming during the working time.

The bulk up of ground movements per working cycle is:

$$V = q \cdot k_н, \text{ m}^3 \tag{2}$$

Where the variables are:

q – volumetric capacity of culm bank, m^3,

$k_н$ – coefficient of culm bank charging.

In calculating the theoretical capacity of a bulldozer for the volume of soil moved per the working cycle a dump capacity is adopted. The performance of each working cycle depends on the properties of the soil, so there is the coefficient of dump crowding, which is introduced for the correction, Table 1[12].

Table 1

The correction coefficient of dump crowding

Conditions of soil displacement		The coefficient of dump crowding, $k_н$
simple conditions	A complete soil dump is moved as bondless ground. Unconsolidated sandy soil with low water content, ordinary soil, stacked material	1,1 - 0,9
conditions of average complexity	Bondless loose soil, but moving all dump is impossible. Gravel, sand, fine gravel containing soil.	0,9 - 0,7
conditions of high complexity	Crater with a high water content, sand with a breakstone content, meagre crater and natural ground.	0,7 - 0,6
conditions of extremely high complexity	Shot rock or large clasts	0,6 - 0,4

Source: http://www.komatsu.ru/

[12] Fomin S.I.: Rational conditions for opencast shovels/Fomin S.I., Donchenko T.V., Ivanov V.V.//Scientific and industrial magazine Cement and its application. – Spb.: 6/2007, pp. 23-25.

The duration of the bulldozer operating cycle (moving, turning and shifting) is:

$$T_{ц} = \frac{D}{F} + \frac{D}{R} + Z \tag{3}$$

Where the variables are:

D – conveying distance, m.,

F – speed of forward stroke m/min.,

R – speed of backward stroke, m/min.,

Z – time required for transmission shift, min.

When calculating the theoretical capacity of a bulldozer, for the forward stroke it takes the speed of movement 3 - 5 km/h and for the backward stroke 5 - 7 km/h.

When moving clay, the slope surface has an impact on the performance of a bulldozer, considering the terms of the dipping drift coefficient. The performance of a bulldozer during mining extraction and moving the topsoil is:

$$Q = q \cdot k_{н} \cdot \frac{60}{\frac{D}{F} + \frac{D}{R} + Z} \cdot k_{укл} \cdot k_{п} \cdot k_{и} \tag{4}$$

Figure 1 shows the graphs of the functional connection of productivity of a number of bulldozers made-in-Russia models with thickness of cutting off the topsoil in the Northern conditions.

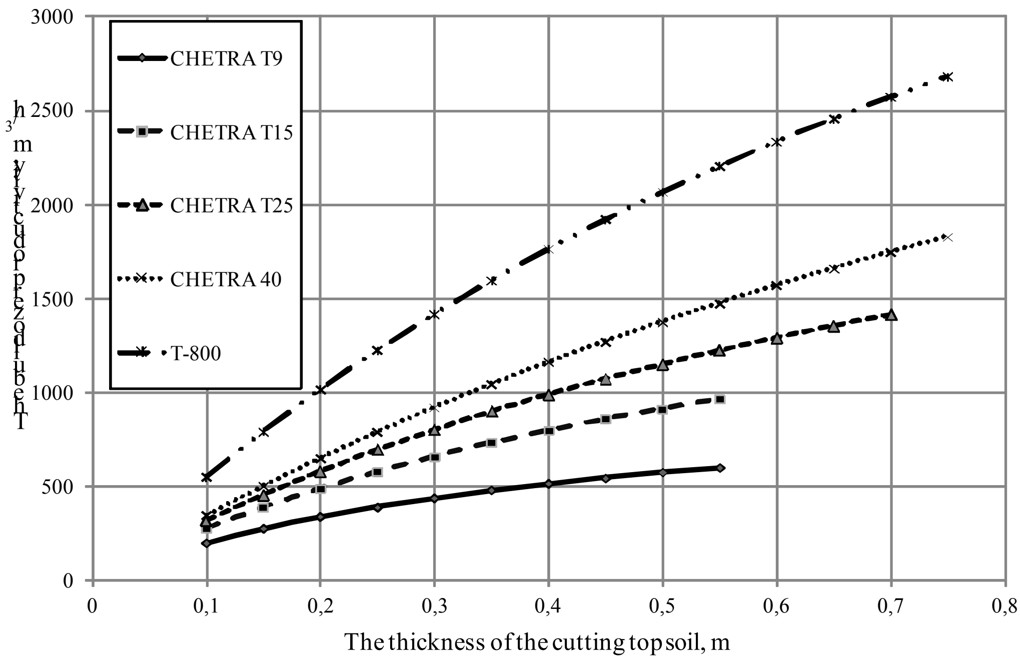

Fig. 1. The graphs of the functional connection of the bulldozer productivity with the thickness of cutting off the topsoil

Rys. 1. Wykres zależności funkcyjnej między wydajnością spychacza a grubością zebranej wierzchniej warstwy gleby

Source: own work.

The analysis of the data presented in Figure. 1 shows that the bulldozer performance increases with the thickness expansion of the fertile layer to the level of maximum dump penetration.

Figure 2 shows the graphs of the functional connection of the bulldozer productivity with the distance of soil transporting. Depending on the bulldozer equipment usage for the main technological processes or for the mine technical reclamation the productivity will be different.

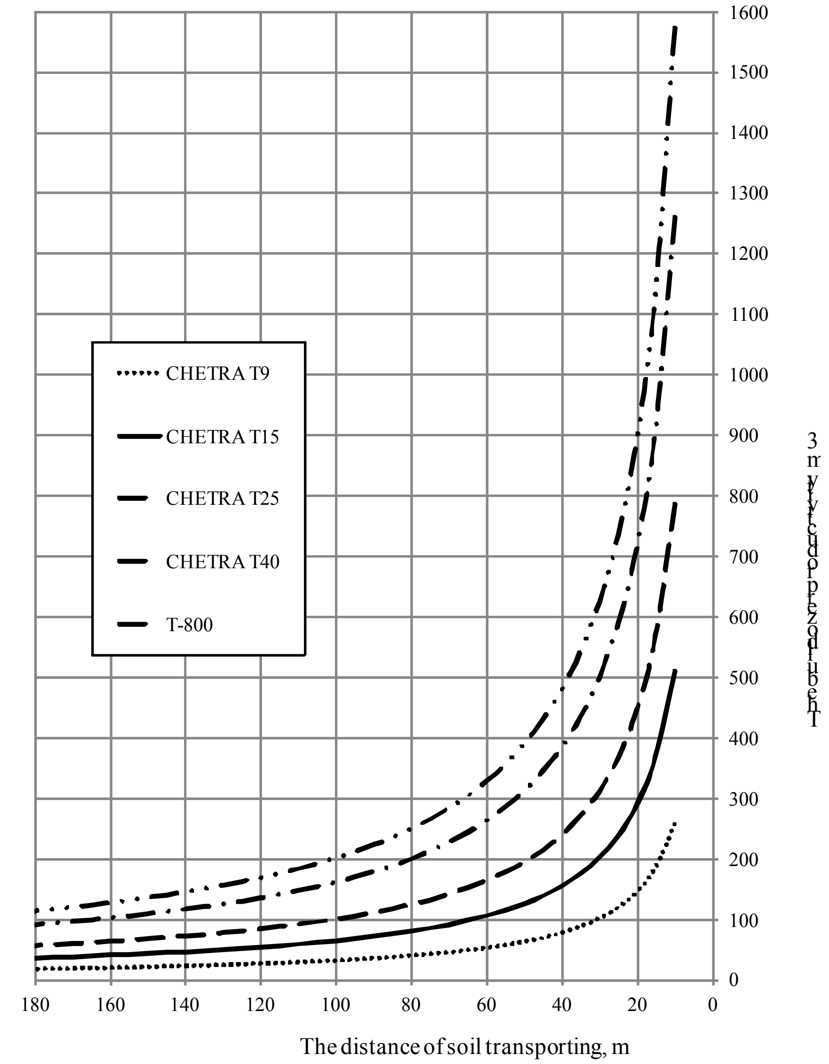

Fig. 2. The graphs of the functional connection of the bulldozer productivity with the distance of soil transporting
Rys. 2. Wykres zależności funkcyjnej między wydajnością spychacza a odległością transportu gleby
Source: own work.

Figure 3 shows the graphs of the functional connection of the productivity coefficient (dependency of bulldozer equipment productivity employed in the mine technical reclamation, with different topsoil thickness, and the bulldozer equipment productivity functioning on the basic technological processes) with the topsoil thickness. Analysis of the data presented in Figure 3 shows that the productivity of bulldozer equipment employed for the mine technical reclamation (cutting off and planning the productivity of the fertile layer), in connection with the productivity of the same equipment for the main processes can be increased by 1.5 - 3 times, depending on the increasing thickness of the fertile layer. For the minimum thickness of the fertile layer - up to 0.3 m, the productivity of the equipment employed in the basic technological processes above, or slightly different.

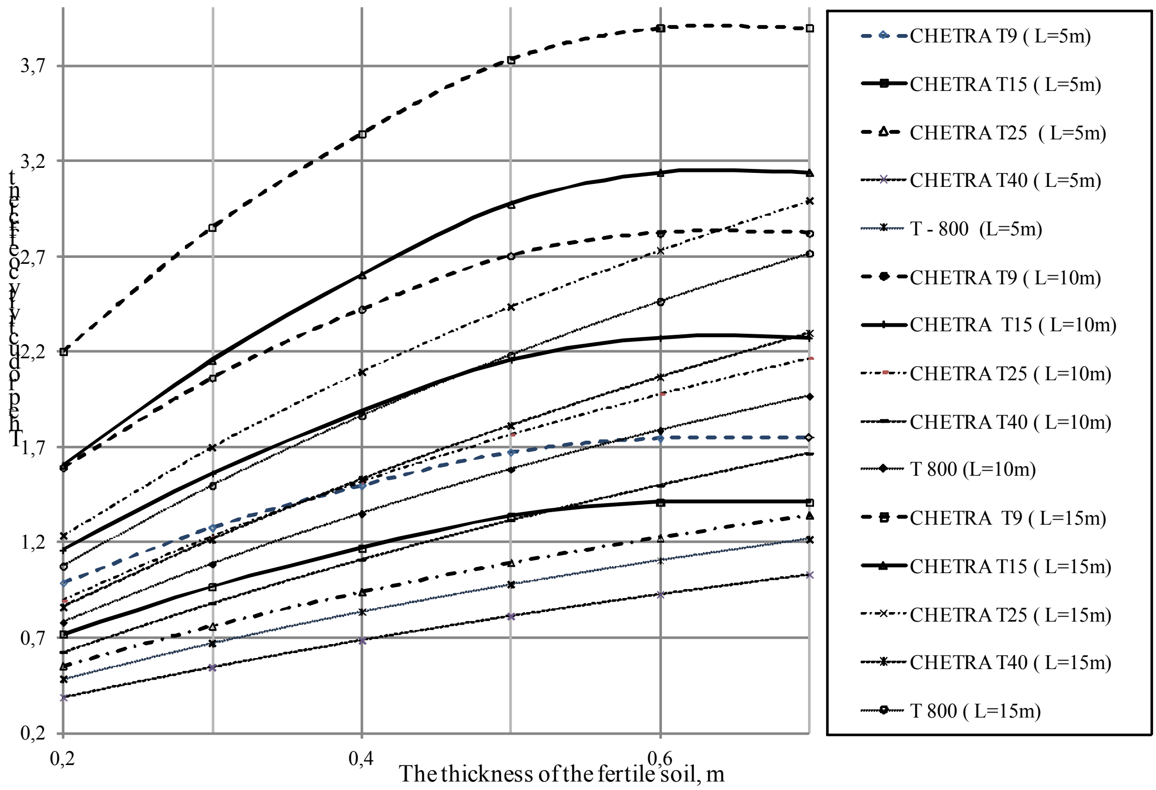

Fig. 3. The graphs of the functional connection of the productivity coefficient of bulldozer equipment productivity with the fertile soil thickness
Rys. 3. Wykres zależności funkcyjnej między współczynnikami wydajności wyposażenia spychacza a grubością gleby
Source: own work.

It is advisable, when calculating the productivity of bulldozer equipment employed in the mine technical reclamation, to introduce the correcting coefficient of productivity from 1 to 3 depending on the equipment type and capacity of the fertile layer.

3. Productivity of bulldozing equipment for mine reclamation works in the North

The work of mining equipment in the Northern regions is accompanied by an adverse impact of natural climate factors of the external environment, which has influence on a lower level of reliability and the use of machines, increasing the costs of operating appliances. The weighted average coefficient of mining equipment usage in the North is: for mining excavators - 0.52; loading machines - 0.54; drilling rigs - 0.47; bulldozers - 0.43[13].

It results from the analysis of the actual productivity of the bulldozer equipment that the usage of high-productive bulldozers is not expedient when thickness of the fertile layer is 0.3m, in spite of the fact that the Theoretical capacity is higher. When reclamation is conducted with mining equipment used in the main productive processes, it is necessary for the calculation of operational productivity to introduce a correction lowering coefficient of selective fertile layer cutting-off, which depends on the thickness of cutting-off layer:

$$k_{М} = f(m_{ПС}), \tag{5}$$

Where the variables are:

$k_м$ – coefficient of selective fertile layer cutting-off,

$m_{пс}$ - thickness of the fertile layer, m.

Thus for the cutting-off the fertile layer with the thickness $m_{пс} \geq 0{,}2$ m (the general case, recommended for cutting and storage in instructions for the mine technical reclamation), Km = 1, for cases where the thickness of the fertile layer $m_{пс} < 0{,}2$ m (as for the considered conditions of the North), $k_м = 0{,}7$. Therefore, to determine the operational productivity of the bulldozer at the cutting-off of the fertile layer in the North is necessary to use the correction lowering coefficients $k_и$ and $k_м$, taking into account the effect of low temperature on the operating reliability and the cutting-off thickness of the fertile layer.

$$Q_{экспл} = Q_{теор} \cdot k_{И} \cdot k_{М} \tag{6}$$

Where the variables are:

$k_и$ – coefficient of mining equipment usage.

The lower layer Northern coefficient k_c is:

$$k_{С} = k_{И} \cdot k_{М} \tag{7}$$

[13] Fomin S.I.: Productivity of opencasts and demand for mineral raw materials/Fomin S.I.//. S-Pb., publishing. „Tema”, 1999, p. 169.

As the result of analysis and processing of careers are analog data the average weighted value of lowering coefficient kc = 0,42 was obtained.

It is established that under the northern conditions during the cutting-off the fertile layer, shaping clamps and transferring the fertile layer to the planned surface, the most rational is to use a maneuverable medium and low-productivity mining equipment excavator - bulldozer. The necessity of introducing the lowering coefficient is proved in the calculation of theoretical productivity of bulldozer equipment, employed for mine technical reclamation in the Northern conditions.

4. Summary

The following requirements should be presented for the technologies of the opencast mining, alongside with economy and safety: the duration of the period between pit closure and carrying out land reclamation - ground improvement works must be as little as possible; the post-mining area must be minimum from point of view of wise land-use. The final pit and mined out space must be adapted to reclamation project decision according to the accepted direction of further use-lands. The technological decisions have to be aimed at leaving minimum post-mining area by the means of backfill mining method.

The article takes into consideration the functional connection of productivity of a number of bulldozers made-in-Russia models with the thickness of cutting off the topsoil in the Northern conditions and the functional connection of the bulldozer productivity with the distance of soil transport. Depending on the bulldozer equipment usage for the main technological processes or for the mine technical reclamation the productivity will be different.

The functional connection of the productivity coefficient with the topsoil thickness is determined. It is established that under the northern conditions during the cutting-off the fertile layer, shaping clamps and the fertile layer transport to the planned surface, the most rational is to use maneuverable medium and low-productivity mining equipment excavator - bulldozer. The necessity of introducing the lowering coefficient is proved in the calculation of the theoretical productivity of bulldozer equipment, employed for mine technical reclamation in the Northern conditions.

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Omówienie

Podczas przeprowadzania zagospodarowania terenu przy użyciu urządzeń górniczych wykorzystywanych w głównych procesach produkcyjnych, w celu obliczenia produktywności operacyjnej konieczne jest wprowadzenie pomniejszającego współczynnika korygującego dla selektywnej obróbki wierzchniej warstwy gleby, co zależy od grubości gleby poddanej obróbce. W celu obliczenia produktywności sprzętu buldożerowego dla przeprowadzenia

likwidacji szkód górniczych, możliwe jest dokonanie korekty o wartość czynnika od 1 do 3, w zależności od rodzaju urządzeń i grubości wierzchniej warstwy gleby.

Technologia górnicza w przyszłości musi umożliwić obróbkę wierzchniej warstwy gleby na zdegradowanych terenach. Odległość od wierzchniej warstwy gleby, która będzie w przyszłości zagospodarowana, do górnego poziomu wydobycia (niższej warstwy hałdy na powierzchni) nie powinna przekraczać szerokości obrabianego poziomu (lub poziomu hałdy) o więcej niż warstwę odkrytej gleby (nagromadzonej hałdy) w ciągu roku. Wierzchnia warstwa gleby oraz skały potencjalnie zasobne w surowce są odkrywane osobno. Wierzchnia warstwa o grubości mniejszej niż 10 cm nie może być odkryta na terenach zalesionych oraz na obszarach, na których mikrorzeźba nie pozwala na obróbkę mechaniczną. W tym ostatnim przypadku wierzchnia warstwa gleby musi być odkryta razem z ukrytymi, potencjalnie zasobnymi skałami.