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MONITORING OF "DEALUL MARIA" MARBLE PERIMETER, RUSCHIȚA, CARAȘ-SEVERIN COUNTY

Ovidiu Marcel SÎRBU[1], Clara-Beatrice VÎLCEANU[2], Anca Maria MOSCOVICI[2], Alexandru-Iulian ILIESCU[3], Remus CHENDEȘ[2], Otilia-Maria ANDERCA[2]

[1]Politehnica University Timisoara, Faculty of Management in Production and Transportation,
14 Remus Street, Timisoara, Romania
[2]Politehnica University Timisoara, Civil Engineering Faculty,
2 Traian Lalescu Street, Timisoara, Romania
[3]University of Agronomic Sciences and Veterinary Medicine of Bucharest,
Faculty of Land Reclamation and Environmental Engineering,
59 Marasti Blvd, District 1, Bucharest, Romania

Corresponding author email: beatrice.vilceanu@upt.ro

Abstract

Soil excavation represents a fundamental step in the construction and development of infrastructure. Despite the widespread application of best practices and regulations, accidents in the construction industry are comparatively higher than those in other industries. Deep excavations have the potential to cause adverse effects on the stability of the soil and nearby structures. Thus, in addition to ensuring safety, it is necessary to assess and monitor the environmental impact of deep excavations during construction processes. An eloquent example is represented by monitoring the marble resources exploitation from the quarry located in the "Dealul Maria" perimeter, in the town of Ruschița, through topographical surveys realized with a view to determine volumes, carried out quarterly, for a period of 5 years. The achieved 3D modeling highlights the differences between the initial shape of the natural land before the start of exploitation, the resulting shape of the land at different stages of the exploitation and the final shape as well as supports a proposal to green the exploited area by restoring the exploited land to a form as close as possible to the original one.

***Key words**: 3D modeling, deep excavations, environmental impact, BIM, topographic survey.*

INTRODUCTION

Building Information Modeling (BIM) involves a working methodology that uses digital models of a building to record and consistent manage the spatial information and data relevant to its life cycle and the exchange between the specialists involved (Pescari et al., 2022).

BIM aims to provide improved visualization of project variants, a significant reduction in planning errors, and easier construction based on collaboration and computer-aided simulation. The BIM concept (Figure 1) emerged as a need to improve the way buildings are designed, constructed and operated (Wu et al., 2015). The main problems that this concept solves are: reducing design time, eliminating the need for redesign, improving coordination between disciplines, the possibility of exploration and simulation within the model in order to detect design problems at a low cost, increasing the quality and level of trust for deliverables (they are uniquely connected to the 3D model, and the risk of inconsistencies is practically null) (https://bimmda.com/en/what-is-bim).

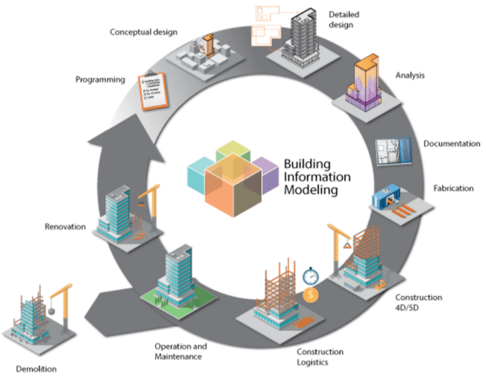

Figure 1. BIM definition
(https://bimmda.com/en/what-is-bim)

The main advantage of BIM is to increase the level of coordination and collaboration between the members of all the teams involved in the project (architects, specialized engineers, manufacturers, executors, beneficiaries) throughout its duration (concept, technical design, execution details, manufacturing, construction, maintenance) (Badea, A.C. & Badea, G., 2022).

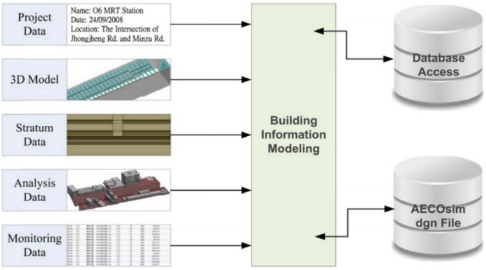

Figure 2. Data sources to be integrated in BIM (Wu et al., 2015)

For the industry to converge to the use of three-dimensional, object-oriented models such as BIM, three essential elements need to work together: computational power, a platform for a common database, and a network with sufficient bandwidth (Figure 2). The system shown in Figure 2 is based on commercial hardware and software comprising the Bentley AECOsim Building Designer, which supports visualization of a 3D model with some capabilities for 3D object manipulation and information query with Application Programming Interfaces (API) for functionality extensions (Wu et al., 2015). BIM can be interpreted through the aspects that define it.

A first aspect concerns conceptual design as it is commonly perceived. The conceptual design is the most creative part of the design work and brings into focus all aspects of the project in terms of function, cost, construction methods and materials, environmental impact, cultural and aesthetic considerations and more. During it, the entire knowledge and experience of the members of the design team is activated and put to use (Oprea et al., 2014).

A second aspect concerns the use of BIM for the design and analysis of building systems. Analysis means, in this case, the operations of simulating and measuring the fluctuations of the physical parameters that are expected from the real construction (Kim et al., 2012).

The third aspect is the classical one, regarding the use of BIM for the development of construction information at the level of execution details (Marcuta et al., 2020).

BIM provides detailed 3D visualization and the ability to organize large volumes of building-related data for management. Different scientist (Hsieh & Lu, 2012) demonstrated that a visualization system allows users to interpret monitoring data effectively and intuitively, reduces misinterpretation, improves communication efficiency, and facilitates effective decisions that are supported by collected monitoring data. On the other hand, other researchers (Kim et al., 2012) focused on monitoring and visualizing aggregated and real-time states of various energy uses represented by location-based sensor data collected within the city, in particular referring to building.

Design representations are no longer 2D drawings. Instead, designers use 3D BIM models that are assembled in the same manner a building is constructed. BIM can be used in construction companies to better reuse accumulated management information (Oprea et al., 2014) (Figure 3).

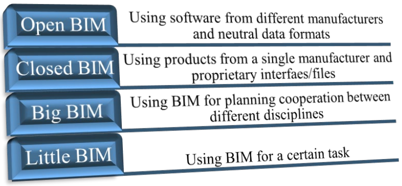

Figure 3. Different types of BIM

Employing spatial information within the BIM model (Figure 4) enables everyone on the project team to make better and more informed decisions throughout the entire lifecycle of construction and infrastructure projects.

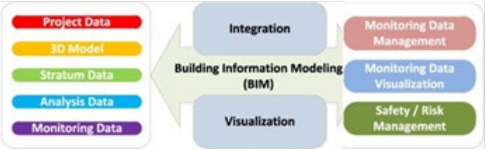

Figure 4. Logical diagram of a BIM-based monitoring system development project (Wu et al., 2015)

In terms of understanding the current state of safety planning in built-up areas, an in-depth understanding of previous research studies is summarized as safety planning practices related to excavation pits in the construction industry. Inadequacies in contemporary safety planning have been addressed with advanced BIM-based design for safety concepts. Research works on rule-based safety planning and BIM are thoroughly reviewed and the need for the proposed safety rule-based automated excavation modeling approach is established (Buza et al., 2001).

An eloquent example is represented by automatic modeling of safety excavation, regulatory compliance and safety best practices, using visual programming and BIM technologies for the safety management process. The more specific objective of the study was to develop an automated BIM-based safety planning tool specific to construction excavation that can identify potential hazards related to falls, pits and safety exits together with a 3D model visualized with a built-in prevention solution for hazard recognition. As a limitation it is mentioned that this solution does not take into account the whole hazard related to geotechnical activities. Therefore, the scope of the study is limited to the major types of potential hazards, including but not limited to fall and exit hazards (Khan et al., 2019).

Thus, academic researchers as well as industry professionals are currently paying vital attention to ensuring construction safety even from the project stage. To this end, various algorithms to increase safety in the pre-construction phase have been developed. These algorithms focus on analysing potential risks, checking the BIM model for fall risks and limiting access to areas where masonry wall constructions are being carried out. Using programming languages, such algorithms automatically generate geometric conditions in BIM and visualize potential risks and adoption of safety measures, along with quantity calculation and optimized locations.

This paper presents the monitoring process of the marble resources exploitation from the quarry located in the "Dealul Maria" perimeter, Caraș-Severin County, Romania. This objective represents an eloquent example of assessing and monitoring the environmental impact of excavations which have the potential to cause adverse effects on the stability of the soil and nearby structures and could be successfully further integrated into BIM. By implementing such an approach, it brings added value to the entire process of safety planning in construction (Sălăgean et al., 2017).

MATERIALS AND METHODS

The purpose of environmental impact assessment is to highlight both the negative, as well as the positive effects of a planned activity or an ongoing one (in the case of development or modernization projects of existing capacities) on the environment.

From an administrative point of view, "Dealul Maria" exploitation perimeter is located outside the built-up areas of Rușchiţa locality, Rusca Montană commune, Caraş-Severin County, 2 km from Rușchiţa locality and 25 km northeast of Oţelul Roşu town (Figure 5). Access to the exploitation perimeter is realized from Caransebeş - Haţeg national road, on the partially modernized county road Voislova - Rusca Montană - Ruschiţa, then on an industrial road to the exploitation perimeter "Dealul Maria", at an elevation of +800 m above Black Sea 1975 level.

Figure 5. Location of the “Dealul Maria” exploitation perimeter (© Google Earth)

The exploitation activity in the "Dealul Maria" quarry was expected to be in progress over a period of 11 years (2010-2021). Thus, a concession license for exploitation has been issued by the National Agency for Mineral Resources, as well as additional documents 2 and 3 to this license. The key deciding element in what concerns the granting of the exploitation licence is represented by the accomplishment of the planned production during the validity period of the license through the systematization of the quarry in the perspective of the continuation of the exploitation beyond the year 2021.

Marble exploitation from "Dealul Maria" deposit will be carried out on all 12 levels, starting with level 1 and up to the last level +780 m elevation, level 12, partially.

The total expected production for the period of validity of the exploitation license will be 3,224,215 tons, respectively 39,401 tons of industrial extraction in the first year of exploitation, reaching 279,696 tons per year of industrial extraction at the end of the license, in the last year of exploitation (S.C. Omya Calcita S.R.L. Bucureşti, Report, 2010).

The following types of waste result from the activities that have been carried out within the objective:

- plant (organic) waste, sawdust, plant residues etc. derived from forest vegetation clearing works;
- topsoil and technological waste resulting from the deposit discovery works and exploitation losses;
- household waste.

Vegetable waste from vegetation clearing works consisting of sawdust, wood scraps etc. will be completely collected, ground and utilized.

The topsoil will be stored separately from the sterile rocks, in a temporary topsoil dump, so that at the end of the exploitation license period, respectively at the end of the exploitation activity, it will be used for environmental restoration works (Herbei et al., 2021). The dump will be located in the northern area of the exploitation perimeter, between elevations +890 m and +910 m. The amount of topsoil from "Dealul Maria" perimeter that is to be stored in the landfill until the end of the validity of the exploitation license is 20,000 m^3 (1,176 m^3/year).

The hydrographic network of the area is represented by "Valea Morii" stream and "Raci" stream, the left tributary of the "Padeşului" valley. The rugged relief in the area with steep slopes and narrow valleys, with relatively poor vegetation, contributes to the oscillating flow of the "Padeş" River. The closest watercourse to the site is "Valea Morii", about 400 m away.

From a hydrogeological point of view, the geological research carried out did not indicate the existence of permanent or temporary aquifer layers, holes or underground voids with possible accumulations of water.

Forest soils are spread in the areas where forest vegetation develops, the dominant type being the Preluvosol, as a subtype-the typical Preluvosol that appears on the highest, well-forested ridges. Because of these soils’ weaker physical and biochemical properties, compared to chernozems and faeozems, they are much more exposed especially to physical and chemical degradation. Located in regions with higher slopes, when the forest is cleared, these lands are exposed to intense erosion. On large areas, on steep slopes, due to the marked degradation of the land, regosols-class protosols (unevolved soils) developed on a parent material originating from unconsolidated rocks and maintained close to the surface by slow and long geological erosion, but especially the erodisols, are also found caused by accelerated erosion.

From a geotechnical point of view, the land shows no indications of geodynamic phenomena existence that could affect the stability of the site.

The final slopes of the quarry will have an established slope so that, under normal conditions, landslides will not occur.

The quarry is located far from towns, in an area without traffic or permanent activity, without industrial objectives or networks (electricity, gas, water, roads) to protect.

Under these conditions, for 5 years monitoring of the definitive slopes of the quarry, the following measures have been taken:

- placement of levelling benchmarks at the base of the definitive slopes;
- semi-annual monitoring by precision levelling of slope stability combined with GNSS planimetric measurements;
- recording the measurement results in a special register.

RESULTS AND DISCUSSIONS

In this section, the geodesy-specific methodology and technology used for monitoring the marble resources exploitation from the quarry located in the "Dealul Maria" perimeter in the town of Ruschița, are presented. The topographic surveys have been realized quarterly, over a period of 5 years, with a view of determining the volumes and creating the 3D models of the terrain. The 3D modeling will highlight the differences between the initial shape of the natural land before the start of exploitation, the resulting shape of the land at different stages of the exploitation, the final shape and a proposed model to green the exploited area by restoring the land to a form as close as possible to the original one.

The first measurements session was carried out in October 2016 on the new area proposed for exploitation. The measurements were performed after clearing of the mentioned area initially covered by forest vegetation and represent the basis for realizing the layout plan and the 3D model of the terrain, which will be considered as the reference for future calculations. The equipment used for the topographic surveys consists in a GNSS receiver, STONEX S10A, using the RTK (Real Time Kinematics) method; the services of the ROMPOS (Romanian Position Determination System) RTK system were used to determine the detail points.

Topographic surveys have been realized in adequate temperature and environmental conditions. Processing of the measurements with a view of obtaining the 3D model and volume calculation of the exploited marble implied using TopoLT and AutoCAD software.

The reference measurement included representation of forced slope change lines required for 3D terrain modelling (Figure 6) using the TopoLT software, consisting of existing topographical details on the quarry site such as: slopes, determined by slope shoulder and slope foot, roadsides, ditches etc.

In addition to the studied area for the marble exploitation, the area in the vicinity where dust pollution from the cutting and sectioning process could occur was also identified during the first session of measurements.

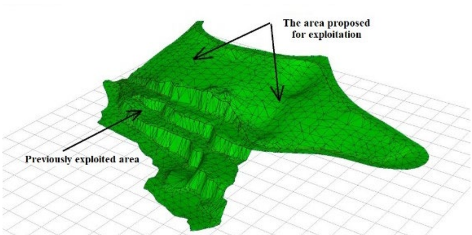

Figure 6. The 3D model of the terrain resulting from processing of the first measurement session carried out on 30.10.2016

The preparation of the levelling plan (Figure 7) necessary for the specialized works related to the exploitation is based on generating the contour lines with TopoLT software.

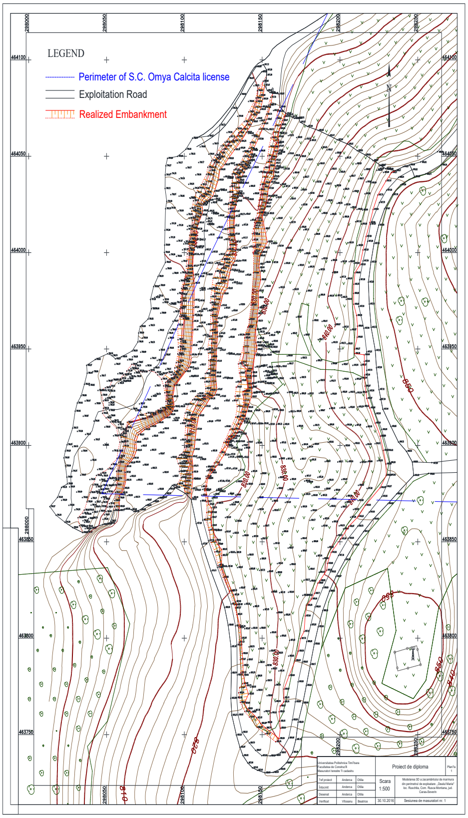

Figure 7. Layout plan of the marble quarry in the "Dealul Maria" perimeter (First session of measurements)

Analysing the levelling plan, one can see that the maximum elevation reaches 850 m starting from 780 m, in the area where exploitations have been previously realized. Also, another conclusion is that terraces are formed in the exploited area with a 10 m level difference between. In this measurement, the three terraces are at an elevation of 800 m, 810 m, respectively 820 m.

From the measured coordinates, we also studied the positioning of the first locality near the marble exploitation, which is less than 4 km from the first inhabited houses. We have identified the areas where air monitoring sensors will be installed. The interest in this aspect is increased and the results are centralized to find solutions to reduce pollution.

Next, from all the quarterly measurement sessions, session number 10 realized on 29.12.2018, respectively the last measurement session, namely session 20 on 30.05.2021, have been selected to be discussed in this paper.

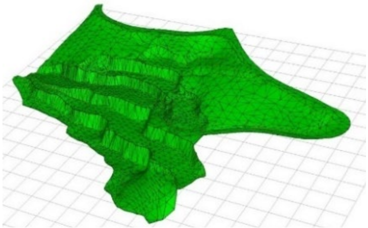

Figure 8. The 3D model of the terrain resulting from processing of measurement session no.10 carried out on 29.12.2018

Data processing has been performed in the same manner as for the first measurements session, realizing both the 3D models (Figure 8 and 11) and the layout plans (Figure 9 and 12).

Analysing Figure 9, one can identify the new areas where marble exploitations have been carried out. We noticed that the exploitation on the 830 m contour line were expanded and the topographic surveys were realized for the 840 m contour line. At this elevation (840 m), the transverse profiles were made and the slope of the ramp was identified. It was also found that, in the northern part, the transition from the contour line 820 m to 830 m was made without keeping the buffer zone.

The volume calculation of the exploited marble was carried out using the TopoLT software. This application allows users to calculate the volume between different measurement sessions by computing the difference between 3D models.

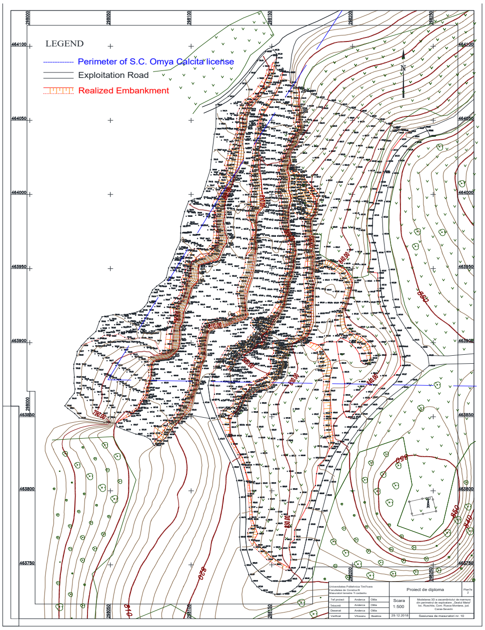

Figure 9. Layout plan of the marble quarry in the "Dealul Maria" perimeter (measurement session no.10)

Figure 10 shows the volume calculation between measurement session 1 and session 10.

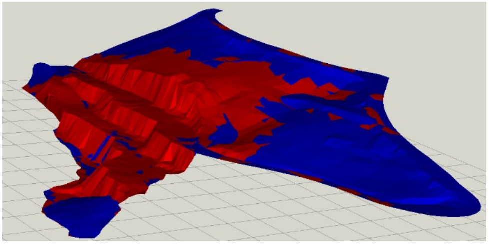

Figure 10. Volume calculation between measurements session 1 and session 10 and representation of the exploited area

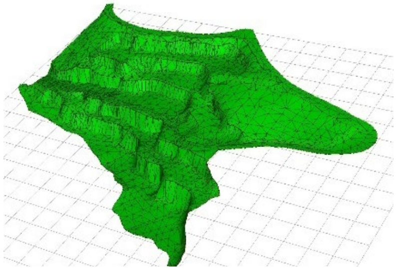

Figure 11. The 3D model of the terrain resulting from processing of measurement session no.20 carried out on 30.05.2021

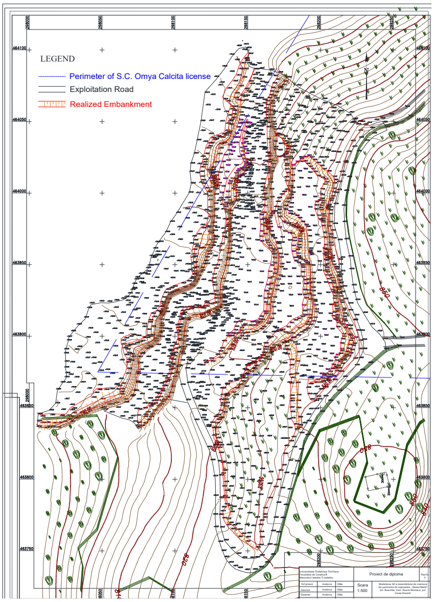

Figure 12. Layout plan of the marble quarry in the "Dealul Maria" perimeter (measurement session no.20)

Figure 12 shows the exploited area at 840 m elevation. From the resulting plan, the five benches of exploitation and their interval by elevation were also identified. The first step is between +785 and 800 m, the second step between 800 and 815 m, the third step starts from 815 to 825 m, the 4th step is between 825 and 835 m, and the last step is identified at +835 m to 845 m.

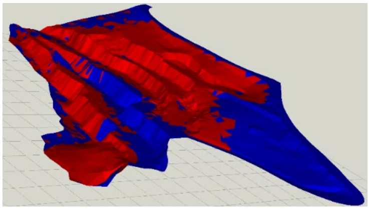

Figure 13. Volume calculation between measurements session 10 and session 20 and representation of the exploited area

In Figure 13 the volume calculation between measurement sessions 10 and 20 is represented. Table 1 summarizes the volume calculation between the 3 surveying sessions which spread over a 5-year period. As it can be seen, the value of the exploited marble is lower than the initial estimated value of 279,696 tons per year of industrial extraction.

Table 1. Volume calculation of the exploited marble

Measurement session	Volume calculation [m³]	Volume calculation [tons]
Session 1 Session 10	+93,427.87	252,255.249
Session 10 Session 20	+80,928.88	218,507.976

A future exploitation is proposed for the final period of the license, in the sense of greening the area simultaneously with the marble excavation process. Slope excavation is established between the slope foot lines of the existing steps, in order to avoid filling works in view of minimal greening costs. In other words, following the proposed exploitation, the quarry will be directly greened (Figures 14 and 15).

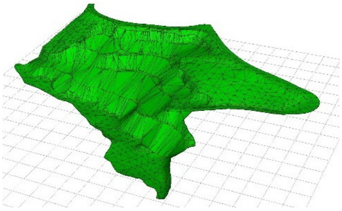

Figure 14. 3D model after greening the exploited area

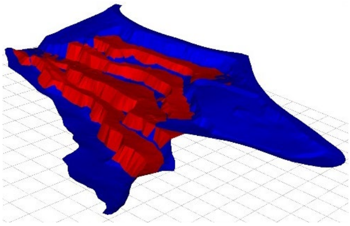

Figure 15. Marble volume calculation remaining to be exploited according to the greening proposal

CONCLUSIONS

Despite the vital development of BIM technologies for construction safety planning, the current practice of excavation safety planning is still manual and based on conventional methods. To address this problem, both internationally and in Romania, automatic excavation safety planning tools must be developed and tested.

The topicality of this research is given by the fact that assessing and monitoring the environmental impact of excavations which have the potential to cause adverse effects on the stability of the soil and nearby structures can be successfully further integrated into BIM.

The implementation of such an approach also brings added value to the construction process, as optimal decisions can be adopted with regard to streamlining time and costs.

The potential of BIM for excavation safety planning and modelling in the pre-construction stage has been ascertained and confirmed through real case studies (Herbei et al., 2022).

Various studies have demonstrated the usefulness of a BIM of deep excavation projects to integrate a 3D model and relevant spatial information regarding the retaining walls, excavation and adjacent buildings; and then visualized all the analysis and assessment results to present the likely locations and degrees of risk and safety in different situations. These facilities enable users to interpret monitoring data effectively and intuitively, reduce misinterpretations, improve communication efficiency, and facilitate effective decisions that are supported by the collected monitoring data.

As regards "Dealul Maria" objective, its exploitation consisted in carrying out the activity of extracting the marble reserves from the quarry fronts, loading the material into dump trucks and transporting it to the primary crushing plant located outside the exploitation perimeter. At the end of the activity, works will be carried out to close the objective in order to return to the initial environmental conditions, which will consist of: evacuation of machinery and equipment, proper evacuation and storage of any waste, correcting the slopes and covering the horizontal surfaces of the quarry with topsoil and seeding with grass the surfaces covered with vegetable soil, applying fertilizer.

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