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# The Scope of Reclamation Works for Areas after the Exploitation of Rock Raw Materials

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**Abstract:** This paper proposes a framework to systematize the scope of reclamation works that optimize the agricultural, forest, aquatic, natural, economic, and cultural values of areas after the exploitation of mineral raw materials by mining. The framework describes characteristic reclamation works, which may become the basis for estimating the financial value of reclamation projects and for securing financial means for the implementation of reclamation tasks. Three phases of reclamation are represented in characteristic reclamation works. The preliminary phase includes works related to the development of design-estimate documentation. The scope of these works is the same regardless of the direction and type of post-mining facility. The technical (basic) phase is the completion of earthworks that prepare for the biological (detailed) phase, which includes introduction of biological systems into areas transformed by mining activities. The scopes of works of the technical and biological phases are different, depending on the planned function of the post-mining area and the type of material extracted.

**Keywords:** reclamation; reclamation works; estimation of reclamation costs; rock raw materials

## 1. Introduction

Mining activity, the main purpose of which is the exploitation of minerals, leads to a transformation of the natural environment. As a result of this activity, there are changes in many elements of the natural ecosystem. These changes include landscape transformation, changes in plant and animal environments, and changes in hydrogeological conditions or soils. The landscape transformation is related to the creation of new forms of relief in the shape of excavations or dumping grounds, as well as the destruction of soil within the mine. This disturbance may preclude these areas from restoration to natural ecosystem conditions. In addition, deposit exploitation often involves changes to drainage that significantly affect hydrogeological conditions. The relationships between the various components of the environment are diverse, and the impact of mining activities on each of them may differ. Transformations of different ecosystems also impact on each other, and these changes are not always directly related to the exploitation of minerals. The objective of land management is that transformations of the natural environment through the entire mining activity should be restored as far as possible, and the method of restoration should vary, depending on the nature of the change in the environment.

Therefore, considering changes in the natural environmental, mining entrepreneurs should conduct reclamation activities aimed at compensating for the damage to the environment. In general, these activities should give the reclaimed area new landscape functions. It should be emphasized here that, in the literature, different concepts are used regarding repair activities after mining operations. Kaźmierczak et al. [1] defined terms concerning this issue as follows: restoration means returning the disturbed land to the original state before degradation; on the other hand, rehabilitation aims to

restore the degraded land to its original functions or to give it new utility or natural values. In many countries, these activities are continued until the area is fully equipped/furnished for a particular desired use. However, this is not the case in all countries, such as Poland, where post-mining activities are undertaken in two stages, reclamation and land development. Reclamation involves establishing or restoring the functional and/or natural values of degraded or devastated land by shaping the terrain relief (earthworks, slope reinforcement, etc.), improvement of physical and chemical soil properties, adjustment of hydrological conditions, redevelopment of soil, and reconstruction or construction of necessary roads. In general, reclamation should be understood as the preparation of land for the second stage of development, which is the preparation for sustainable use of the post-mining area. This land development includes targeted measures enabling appropriate use of reclaimed areas in accordance with the objectives of reclamation, (e.g., utilities, buildings, appropriate infrastructure for sports and recreation, etc.). In this approach, it should be emphasized that the mining entrepreneur is responsible for completing the reclamation, and the future user of the area is responsible for the land development [1], which consequently causes the costs of reclamation and land development to be borne by the mining entrepreneur and future user of the reclaimed area, respectively. Such a division leads to the situation where the mining entrepreneur will seek to minimize the value of the reclamation project, which in consequence will maximize the cost of developing the reclaimed area. Conversely, the future user of the land developed will want to maximize the cost of reclamation, which will lead to less investment for land development. In addition, it is also difficult to define a border between reclamation and land development. An attempt to indicate this border by distinguishing the scope of reclamation works as the first stage of revitalization of post-mining areas is, therefore, justified.

A mining entrepreneur conscious of the reclamation commitments should secure financial means for this purpose throughout the mine life cycle from the start of mining operations. Effective planning of revitalization activities at every stage of mining operation minimizes reclamation costs. It should be emphasized here that, in many countries, there is an obligation to secure funds for this purpose. One of the forms of such financial security are bonds, the value of which is usually not commensurate with the real cost of reclamation. This type of financial security is used in countries such as the United States of America (USA), Canada, Australia, and China. Another form of financial security for damage to the natural environment, used in Portugal and Slovakia, may be insurance or bank guarantees [2]. It should be added that the obligation to determine the extent of a financial commitment in the case of reclamation is different for different situations, and should be based on guidelines developed by state institutions or based on a calculation of reclamation costs [3–5]. Such a calculation should be made and the funds secured before a permit for mineral extraction is granted. A different solution is used in Poland. According to the Polish Geological and Mining Law [6], a mining entrepreneur exploiting a mineral using the open-pit method pays the equivalent of not less than 10% of the anticipated exploitation costs into a fund of mining plant closure (FMPC). Funds paid into this account can be used only for liquidation of the mine and, thus, also for reclamation. It should be emphasized that entrepreneurs usually pay the minimum funds required by the legal conditions of the fund at the point of mining plant closure. Because these funds cannot be used for purposes other than for decommissioning mining plants, payments from this fund may be made only after approval of the plan for the mining plant closure. Unfortunately, the problem here occurs because the financial deposits by a mining entrepreneur at the fund of mining plant closure are usually insufficient to conduct reclamation activities. As research showed, they cover approximately several dozen percent of the reclamation costs [7–9]. One approach to supplement the missing financial resources for reclamation may be to adopt the International Accounting Standards (IAS) 37 Provisions, in which contingent liabilities and contingent assets (IAS 37) [10] allow for the creation of additional financial reserves for future events. Creating a provision is possible when an entity has a present obligation (legal or contractual) as a result of a past event. It is probable that an outflow of resources embodying economic benefits will be required to settle the obligation, and a reliable estimate can be made of the amount of the obligation. It should also be emphasized that the provision is a liability of uncertain timing and amount. In the

case of reclamation, this uncertainty results from the price volatility of the reclamation work in time, as well as the variability of outlays for the implementation of reclamation works. In addition, the reclamation commitment is created throughout the entire life cycle of the mine and, therefore, the commitment exists from the beginning of mining operations to its liquidation and reclamation. It is possible to create a reserve for the implementation of reclamation tasks, but only under conditions that are precisely defined, e.g., resulting from documentation of the reclamation works and the schedule of their implementation. Although the preparation of full reclamation documentation and its scheduling across several decades of exploitation may seem difficult, the model incorporated in IAS 37 makes it possible to create financial security for this purpose based on the selected direction of reclamation and estimation of the costs of conducting characteristic reclamation works. Then, these costs can be distributed evenly over all years of the mining operation.

The problem of estimating and forecasting financial security for reclamation purposes may also be a long-term perspective. Considering that, according to Polish regulations, there is no specific deadline for approval of a reclamation objective and process, entrepreneurs do not consider securing financial means for this purpose. The value of financial security for reclamation depends, first of all, on the reclamation objective, as well as the function to be performed by the reclaimed post-mining area. For many years, the options for the reclamation of post-mining areas were discussed in the literature [1]. The most accurate and complete statement of objectives of reclamation and land development of post-mining areas is presented in Table 1. However, it should be emphasized that not only the objective and form of reclamation affect the value of this enterprise. The type and nature of the post-mining objectives are also important here, which are often related to the type of mineral exploited.

Considering the complexity of the problem, first of all, in the case of the division of works into reclamation and land development, it is useful to set out the characteristic reclamation activities. An explicit statement of these activities standardizes the scope of reclamation works conducted in order to define the border between reclamation and land development. It will also facilitate the estimation of the value of reclamation works (aimed at preparing for land development), which is currently very difficult for a country like Poland due to the lack of guidelines for reclamation. The scope of reclamation works was based on literature analysis and a review of reclamation projects.

**Table 1.** Systematic classification of revitalization objectives for post-industrial areas [1].

General Land-Use Objective	Benefits of New Land Use	Specific Land-Use Objectives	Specific Land Use Activities
Agricultural	Agricultural production and agricultural and food processing	Cropping	Arable land: orchards, meadows, permanent pastures, workers' allotment gardens
		Breeding	Breeding: cattle, poultry, finishers, fish, etc.
Forest	Increasing forest resources and plantations	Forestry	At least 0.10 ha of land covered with forest vegetation and related to forest economy
		Protection	Forests recognized as specially protected
		Recreation	Recreation: pedestrian and cycle paths, fitness trails, playgrounds, promotional forest complexes
Aquatic	Increasing water areas, water retention and regulation	Water management	Potable water, flood control, flow-through reservoirs, etc.
		Recreation	Swimming areas, reposing near pools, water sports, waterholes
Natural	Preserving, proper use, and recreating natural resources and elements, especially wildlife vegetation and animals, as well as natural complexes and ecosystems	Nature reserve	Preserving the natural state or slightly altered state of ecosystems, specific animal and plant species, elements of inanimate nature of considerable scientific, natural, cultural, or landscape significance
		Landscape park	Area having natural, historical, and cultural values, aiming at preservation and promotion of these values in the conditions of sustainable development
		Protected landscape area	Areas standing out based on their landscapes of different types of ecosystems
		Species protection	Protecting wildlife vegetation and animals and, especially, rare and endangered species, as well as preserving species and genetic diversity
		Nature monuments	A single living or inanimate object or a group of such objects, characterized by unique scientific, cultural, historical/memorial, and landscape values and individual features distinguishing them among other objects, especially venerable and giant trees and shrubs of native and foreign species, springs, waterfalls, rising spring, rocks, ravines, glacial erratic, caves

Table 1. Cont.

General Land-Use Objective	Benefits of New Land Use	Specific Land-Use Objectives	Specific Land Use Activities
		Inanimate nature documentation site	Documentation site is scientific and educationally important, not emerging on the earth surface or visible on the surface, places of occurrence of various geological formations, fossils accumulations, mineral objects, caverns, rock caves, exploited and discarded opencast and underground workings
		Ecological areas	Worth protecting fragments of ecosystems of significant importance for biodiversity, such as natural water reservoirs, field and forest ponds, groups of trees and shrubs, swamps, peat bogs, dunes, old river beds, rock outcrops, scarps, gravel banks, etc.
		Landscape/nature protected complex	Protection of especially valuable parts of natural and cultural landscape in order to preserve their aesthetical values
		Natura 2000 areas	The areas of specific types of natural habitats and animal and plant species which are considered valuable (significant to preserve the natural heritage of Europe) and endangered within the whole Europe
		Natural succession	Vegetation encroachment through natural succession
		Green areas	Areas covered with vegetation such as parks, squares, clearings, boulevards, botanical gardens, promenades, etc.
Economic	Expanding industrial, communal, and service areas, as well as recreational and sports areas	Housing	Residential, summertime, hotel buildings, etc.
		Industry	Industrial and communal buildings, industrial parks, economic zones
		Services	Service facilities (e.g., storehouses, parking lots, shops, warehouses, etc.) and sports facilities (e.g., sports fields, courts, swimming pools, motorsports, other sports facilities including winter or aviation sports constructions, etc.)
Cultural	Preserving and promoting artistic objects and those connected with the history of industry, memorial sites	Scientific	Forms of protection (historic monuments, culture parks), theme paths, concert and conference halls, laboratories, e.g., natural ones, documentation archives related to the history of industry, monuments and memorial sites, museums (museums of industry: standard, heritage parks, eco-museums)
		Artistic	Exhibitions, exhibition and concert halls, galleries, theaters, stages, cinema theaters, etc.

## 2. Reclamation Phases

The extent and nature of changes occurring in the natural environment during exploitation of mineral resources, i.e., technical parameters of the reclaimed object, as well as the assumed reclamation objective and the function to be performed by the post-mining area, significantly affect the scope of reclamation works.

Reclamation consists of three phases (Figure 1) that follow each other: preliminary, technical (basic), and biological (detailed). Prior to the major works of the technical phase, preliminary works are conducted, aimed at cleaning the terrain by removing extra vegetation, demolishing the remaining parts of buildings, clearing the rubble and debris from the demolished buildings, or storing it in a designated location if it is going to be used to fill the excavations [11–13]. The preliminary phase includes works related to the development of design and cost documentation, which specifies the objectives of the reclamation and the scope of reclamation works, and estimates the value of the reclamation project. The basic (technical) phase consists of earthworks aimed at shaping the relief of the reclaimed terrain, reinforcing slopes, regulating hydrogeological conditions (including the construction of any necessary objects and hydrotechnical structures), constructing or reconstructing access roads, separating toxic deposits, and restoring the layer of fertile soil with the use of technical methods. The detailed (biological) phase is aimed at originating soil-formation processes, restoring biological life, and fertilizing soil. This phase may require agricultural engineering and phyto-irrigation works. These works include mechanical cultivation of the soil, application of mineral and organic fertilizers, restoration of soil with biological methods, introduction of herbs, trees, and shrubs, and maintenance of the plantings. It should be emphasized here that the phase of biological reclamation (detailed) is fundamentally different from land development. The phase of biological reclamation aims to introduce vegetation, whose task is to initiate biological life. However, land development is based on the modification of the reclaimed land to incorporate technical facilities (e.g., arrangement of view places, information boards, benches, buildings, possible exchange of vegetation to the target one—usually in the case of the forest objective).

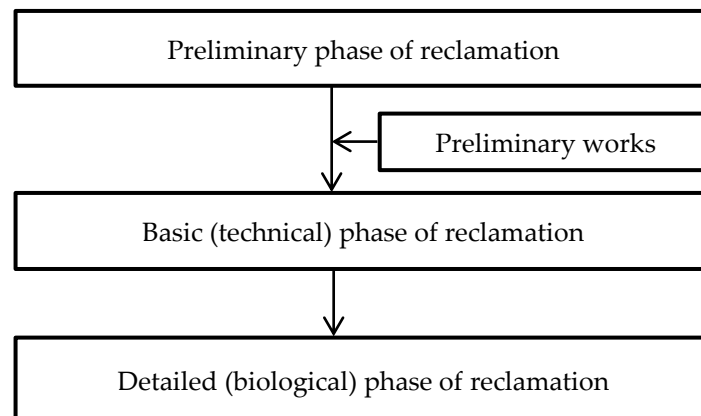


Figure 1. Reclamation phases.

The scope of the preliminary works and preliminary phase are the same for each reclamation direction and type of material. However, the scope of works conducted as part of the reclamation of the technical and biological phase will be different depending on the type of mineral exploited, the reclamation objective, and the function that will be performed by the reclaimed land [13–16].

## 3. Comparison of Reclamation Works in Relation to the Type of Mineral Exploited and the Reclamation Objectives

Classification of reclamation works was made by distinguishing three groups of rock raw materials: clastic (including filtration gravel, sands and gravel, foundry sands, glass sands), clay

(including ceramic clays, clay raw materials for cement production, building ceramics raw materials), and compact (including granite, basalt, dolomites, limestone, sandstone). It should be emphasized here that the scope of reclamation works for clastic rock and clay raw materials will be similar. To present the scope of works, a reclamation classification was used, with division into general and specific objectives (Table 1). An analysis of reclamation works is presented in Tables 2–5. Due to the fact that the works of the preliminary phase of reclamation are the same for all reclamation objectives, they were omitted in the comparison.

### 3.1. Clastic Rock and Clay Raw Materials

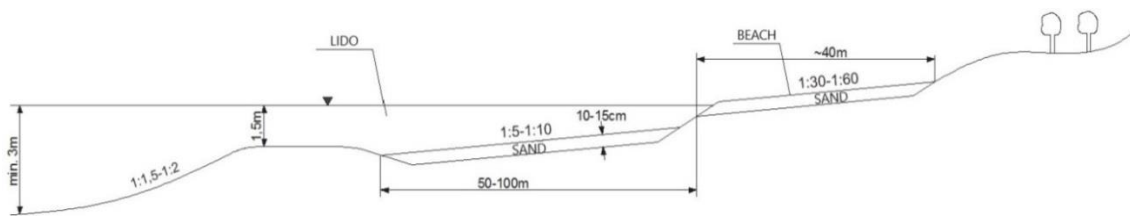
Shaping the slopes of excavation sites is one of the most expensive works performed within the framework of technical reclamation, and it depends on the physical and mechanical properties of the waste rock and soil, as well as on the function of the reclaimed object. The inclination of shaped excavation slopes as part of the reclamation is related to the future accessibility of the reclaimed area, the ease of its use, and geotechnical properties of ground. It should also be emphasized that the slope inclination after the end of exploitation may be different for the clastic rocks and clays. This is due to the greater cohesiveness of soils after exploitation of clay raw materials.

In the case of clastic rocks and clays, slope inclination of excavation sites after the end of reclamation should be 1:3 for agricultural, economic (excluding facilities created for a landfill site), and cultural objectives, while it should be 1:2 for forest and natural objectives of reclamation. At the commencement of technical reclamation of post-mining situations for which natural succession is planned, surface slope modification is not conducted. However, the slope inclination of a future landfill site should be from 1:3 to 1:8 [17]. Therefore, landfill sites can only be located in excavations after the exploitation of clay and clastic rock raw materials. As part of the preparation for the formation of this type of end use, it is necessary to achieve natural or synthetic (using, for example, a geomembrane) isolation (sealing) [15]. In the case of fishponds (agricultural objective), complete water drainage must be allowed, and the bed of the pond must be allowed to dry, which is affected by the level of the groundwater table. Moreover, the pond should have a maximum depth of 2.5 m, and the slope inclination of the bank should be 1:2 or 1:3 for clastic rocks, and 1:2 for clays [18,19].

The method of reclamation of aquatic objective depends on the future function of the reservoir. The construction of a water reservoir with the functions of impounding, flood control, freshwater reservoir, etc. requires the fulfillment of specific formal and legal requirements. For clastic rocks and clays, slope inclination should not exceed 30% (1:3.3) and slopes should have long-lasting stability: a protective buffer zone, with a minimum width of 50 m, is constructed adjacent to the slope [20].

Reservoirs functioning as an element of the landscape and built for aesthetic purposes should have slope inclinations of 1:2 or 1:3 for clastic rocks, 1:1.5 or 1:2 for clays [18,19], and 1:5 for underwater slopes [21]. However, in order to provide a greater diversity of habitats, slopes should be shaped to provide reservoirs with zones of deep and shallow water, as well as islands, bays, and peninsulas. The inclination of underwater slopes in the shore waters should be from 1:8 to 1:10 and should increase with the distance off the shore [22].

A reservoir for recreational purposes, referred to as a lido, can be constructed in pits formed by mining clastic rocks and clays and should comply to water quality standards. Table 2 shows the parameters and guidelines for shaping the slopes of a lido above and below the waterline. Figure 2 shows a profile of a lido created in the pit formed by the excavation of clastic rocks and clays. Reservoirs for recreational purposes typically have a defined beach area, while the remaining area of the reservoir may be used for fishing or water sports, e.g., sailing or diving. The requirements for such objects are varied and mostly depend on the technical, geological, and economic conditions. Recreational water boundaries which are not beaches should have similar slopes as reservoirs functioning as an element of the landscape. Reservoirs for diving should have a diverse bed shape, and reservoirs for sailing should have a considerable depth (several tens of meters) and area (several tens of hectares) [14,16].



**Figure 2.** Profile of a lido in the excavation of rock raw material (own study based on Reference [23]).

Shaping the excavation slopes is one of the elements of shaping the terrain. Another way is filling the post-mining pit. The pit may be filled with the overburden stripped during deposit development or with external material certified as fit for use in governmental regulations. However, it should be emphasized that the overburden deposited on the mine dumps should first be used for soil restoration. Reclamation works aimed at shaping the terrain relief should also include macro-leveling.

The regulation of hydrogeological conditions in the post-mining areas should provide hydrogeological conditions that ensure proper surface water management both in the transformed land and in its surroundings, through regulation of waterways. Reservoirs, to ensure their proper drainage, along with flow and exchange of water, should be equipped with hydro-engineering objects and structures (ditches, canals, weirs, locks, culverts).

Surface exploitation of deposits leads to the removal of a soil layer and results in exposing soilless (denuded) ground. After the end of exploitation, replacement of the soil layer, obtained by covering barren areas with fertile material, should be a part of the reclamation works. In the case of agricultural reclamation, the thickness of this layer should be at least 0.3 m, and, for forest and natural reclamation, it should be at least 0.5 m. When designing recreational facilities such as sports fields or other sports facilities, it is necessary to restore the soil as for the agricultural objective. It should be emphasized that the choice of the thickness of the soil layer also depends on the minimum soil thickness needed for the rooting of plants. In the case of aquatic reclamation, soil restoration in the reservoir area is not needed.

Restoration of the soil layer is possible in two ways. Firstly, the fertile soil layer removed during mine development or materials used to create fertile soil and plant vegetation (materials with a high content of minerals and humus) can be used directly for this purpose. The second method may be the use of a mix of fertile soil with barren soil or the use of stable sludge from municipal treatment plants. In the case when toxic or barren soils are found, the toxic soils should be separated. It is possible by isolating the toxic soils, which is made by covering toxic soil with a layer of productive or potentially productive soil [24]. In this case, the possibility of penetration of plant roots into the toxic layers is important to make the insulation with a thickness sufficient for the introduced vegetation. In addition, the isolation of toxic soils requires that no water enters into the toxic layer. When the toxic soil cannot be isolated, other options include dilution (mixing toxic soil with non-toxic soil) or neutralization (using materials that improve the chemical and physical properties of the soil) [13].

An important issue of basic reclamation works preparing the area for use is the construction or reconstruction of roads (with bridges, culverts, ditches etc.), as well as bicycle and walking paths. Importantly, such works are performed as part of reclamation in all objectives of reclamation, except for the aquatic objective.

A unique specific natural objective of reclamation is natural succession. In such areas, the vegetation comes in naturally. Therefore, only the construction or reconstruction of roads is included in the reclamation works of the basic phase.



**Table 2.** The scope of reclamation works of the technical phase for areas after exploitation of clastic rocks and clays.

Reclamation Objective	Agricultural		Economic		Cultural	Forest	Natural		Aquatic
	Cropping/Breeding	Housing/Services	Industry	Scientific/Artistic	Forestry/Protection/Recreation	Protected Areas*/Green Areas	Natural Succession	Water Management	Recreation
Preliminary works	Removing extra vegetation, demolishing the remaining parts of buildings, clearing of the rubble and debris from demolished buildings, or storing it in a designated location								
TECHNICAL RECLAMATION	Terrain relief shaping	Slope shape at a maximum ratio of 1:3			Slope shape at a maximum ratio of 1:2			Slope shape: 1:3.3	Lido: <ul style="list-style-type: none"> <li>- inclination in the shoreline (beach): 1:5–1:10 (40 m)</li> <li>- inclination of underwater slopes                             <ul style="list-style-type: none"> <li>• descend to the water: 1:30–1:60 (width: 50–100 m), and then 1:1.5–1:2</li> <li>• not a beach: 1:5</li> </ul> </li> <li>- inclination of slopes above water                             <ul style="list-style-type: none"> <li>• not a beach: 1:1.5–1:3</li> </ul> </li> </ul> Fishing, water sports: <ul style="list-style-type: none"> <li>- inclination of underwater slopes: 1:5</li> <li>- inclination of slopes above water: 1:1.5–1:3</li> </ul> Landscape feature: <ul style="list-style-type: none"> <li>- inclination of shoreline slopes 1:8–1:10</li> </ul>
		Landfill site—slope shape: 1:3 to 1:8							Forming the shallows—minimum area of 4 ha and depth of 1.5 m (lido)
		Filling the excavation pit with overburden or with waste as part of the recycling process							Covering beach slopes, descends to water and shallows with sand and gravel—minimum 5 cm
		Macro-leveling							Protective buffer zone width minimum 50 m
		Macro-leveling							Macro-leveling the land adjacent to the pit
Separation of toxic formations	Isolating toxic soil by covering it with a layer of productive or potentially productive soil or by soil deconcentration or by neutralization of contaminated formations								

Table 2. Cont.

Reclamation Objective Type of Reclamation Works	Agricultural		Economic		Cultural	Forest	Natural		Aquatic
	Cropping/Breeding	Housing/Services	Industry	Scientific/Artistic	Forestry/Protection/ Recreation	Protected Areas */Green Areas	Natural Succession	Water Management	Recreation
Soil restoration	Covering barren ground with a layer of fertile soil or with formations stimulating the formation of soil with a minimum thickness of 0.3 m, or using a mix of fertile soil with barren soil or using stable sludge from municipal treatment plants			Covering barren ground with a layer of fertile soil or with formations stimulating the formation of soil with a minimum thickness of 0.5 m, or using a mix of fertile soil with barren soil or using stable sludge from municipal treatment plants					
Regulating the hydrogeological conditions	Constructing canals, draining ditches, hydro-engineering objects (for a fish pond), and irrigation							Constructing canals, draining ditches, and hydro-engineering objects, and filling the pit with water (in mining production with deposit drainage)	
Constructing or reconstructing roads	Constructing a network of access roads, bridges, etc.								

\* Protected areas are nature reserves, landscape parks, protected landscape areas, species protection, nature monuments, inanimate nature documentation sites, ecological areas, landscape/nature protected complexes, Natura 2000 areas.

Table 3. The scope of reclamation works of the biological phase for areas after exploitation of clastic rocks and clays.

Reclamation Objective Type of Reclamation Works	Agricultural		Economic		Cultural	Forest	Natural		Aquatic	
	Cropping/Breeding	Housing/Services	Industry	Scientific/Artistic	Forestry/Protection/ Recreation	Protected Areas */Green Areas	Natural Succession	Water Management	Recreation	
Neutralization of toxic formations	Clastic rocks— isolation with fertile material (toxic soils), allochthonous material (barren formations) Clays—chemical neutralization							Clastic rocks— isolation with fertile material (toxic soils), allochthonous material (barren formations) Clays—chemical neutralization		
Agricultural works and fertilizing	Plowing, employing cultivators, harrowing, applying mineral fertilizers (e.g., nitrogen/phosphorus/potassium (NPK), agricultural limestone) or organic fertilizers (e.g., muck, compost)							Plowing, employing cultivators, harrowing, applying mineral fertilizers (e.g., NPK, agricultural limestone) or organic fertilizers (e.g., muck, compost) of slopes and areas surrounding the reservoir		
Soil restoration using biological methods	Introducing humus-forming plants									
Introducing target vegetation	Agricultural works, introducing agricultural plants (grasses or crops)		Agricultural works, introducing trees and shrubs						Agricultural works, introducing target vegetation on slopes and areas surrounding the reservoir	
Maintenance of plantings	Removing perennial weeds, loosening soil, fertilizing, replacing withered plants with new seedlings							Removing perennial weeds, loosening soil, fertilizing, replacing withered plants with new seedlings on slopes and areas surrounding the reservoir		

\* Protected areas are nature reserves, landscape parks, protected landscape areas, species protection, nature monuments, inanimate nature documentation sites, ecological areas, landscape/nature protected complexes, Natura 2000 areas.

After the completion of the work of the basic phase, works should be conducted aimed at giving biological life to degraded post-mining areas (biological reclamation). In the first instance, in the case of toxic soil, isolation should be achieved by a layer of fertile material or allochthonous material (for clastic rocks), whereas chemical neutralization may be conducted on clay soil [24,25]. After such preparations, the soil is subjected to agricultural works such as plowing, harrowing, applying mineral fertilizers (e.g., nitrogen/phosphorus/potassium (NPK)) or organic fertilizers (e.g., muck, compost), and grasses and legume plants are subsequently introduced. Humus layer formation and soil-forming processes are facilitated by introducing large quantities of plant tissue into the top soil layer. The introduction of plant tissue into the soil often consists of plowing the plants at peak vegetation (fertilizing soil with maximum amount of organic matter).

In the case of agricultural reclamation, the post-mining area is subjected to repeated agricultural engineering works and, subsequently, the intended (target) arable plants (grasses or crops) are introduced. In the case of forest reclamation, after sowing grassy and legume plants, the next step involves the introduction of trees and shrubs [13]. In protected areas qualified for the natural objective, vegetation and other elements characteristic of the desired form are established.

In the case of aquatic reclamation, the biological phase is limited to ensuring slope stability by providing a biological reinforcement lining, as well as initiating and shaping hydrobiological processes. The reinforcement lining of reservoir slopes can be divided into an upper part (typically the steeper portion of the slope) and a lower part. The border between the two parts is defined by the groundwater table. After agricultural works and applying mineral or organic fertilizer, the upper part of the slope and the protective buffer zone are sown with legume plants. In the next step, the slope is covered with xerophilous plants. The aim is to reinforce the soil and prevent its erosion or washing to the reservoir. In the case of the lower part of the slope, only hydrophilous plants are introduced [14,16].

Maintenance of plants is the last task within the biological phase and consists mainly of removing stubborn, perennial weeds, soil fertilization, and loosening the soil around the seedlings, if needed (in order to prevent water evaporation). If some plants wither, they should be replaced with new seedlings.

Biological reclamation in areas with economic or cultural objectives is conducted only on fragments of the reclamation area, on which the introduction of vegetation was designed.

Tables 2 and 3 show the scope of reclamation works of the technical and biological phase for clastic rocks and clays, along with all reclamation objectives.

### 3.2. Compact Raw Materials

The scope of reclamation works in facilities after the exploitation of compact raw materials will cover the same tasks; however, the method of their implementation will be different. Due to the conditions and geometry of post-mining excavations, the slope of the post-excitation pit should have an inclination of between 70° and 80°, and rarely below 70°. In the case of this type of mined materials, slopes have uniform inclination and are only protected against collapse by using, for example, rock rippers or protection meshes and anchors. Additionally, in order to ensure safety in the post-mining area, deep solid rock excavation pits should be protected by constructing barriers or shrubbery fencing.

Toxic formations in compact rock are neutralized chemically and subsequently fertilized with allochthonous material, while, in the case of barren soil, only allochthonous fertilizers are used [24,25]. The other scope of works of basic and detailed phases of reclamation, both for excavations and for the area surrounding the excavation, is the same as for areas after exploitation of the clastic rock and clay raw materials.

An important issue is that, in excavations after the exploitation of compact raw materials, it is not possible to create lids or landfill sites. This is due to considerable difficulties and high costs of shaping slopes in such excavations.

Tables 4 and 5 show the scope of reclamation works of the technical and biological phase for compact rocks for all reclamation objectives.

**Table 4.** The scope of reclamation works of the technical phase for areas after exploitation of compact rocks.

Type of Reclamation Works	Reclamation Objective		Agricultural	Economic	Cultural	Forest	Natural	Aquatic		
	Cropping/Breeding	Housing/Services/Industry			Scientific/Artistic	Forestry/Protection/Recreation	Protected Areas*/Green Areas	Natural Succession	Water Management	Recreation
Preliminary works	Removing extra vegetation, demolishing the remaining parts of buildings, clearing of the rubble and debris from demolished buildings, or storing it in a designated location									
TECHNICAL RECLAMATION	Ripping rock overhangs									
	Terrain relief shaping	Filling the excavation pit with overburden or with waste as part of the recycling process							Ensuring slope stability	
	Macro-leveling									
	Protective buffer zone (minimum width 50 m)									
	Macro-leveling the land adjacent to the pit									
	Separation of toxic formations	Isolating toxic soil by covering it with a layer of productive or potentially productive soil or by soil deconcentration or by neutralization of contaminated formations								
	Soil restoration	Covering barren ground with a layer of fertile soil or with formations stimulating the formation of soil with a minimum thickness of 0.3 m, or using a mix of fertile soil with barren soil or using stable sludge from municipal treatment plants			Covering barren ground with a layer of fertile soil or with formations stimulating the formation of soil with a minimum thickness of 0.5 m, or using a mix of fertile soil with barren soil or using stable sludge from municipal treatment plants					
Regulating the hydrogeological conditions	Constructing canals, draining ditches, and irrigation						Constructing canals, draining ditches, hydro-engineering objects, and filling the pit with water (in mining production with deposit drainage)			
Constructing or reconstructing roads	Constructing a network of access roads, bridges, etc.									
Other works within the technical reclamation	Protection works									

\* Protected areas are nature reserves, landscape parks, protected landscape areas, species protection, nature monuments, inanimate nature documentation sites, ecological areas, landscape/nature protected complexes, Natura 2000 areas.

**Table 5.** The scope of reclamation works of the biological phase for areas after exploitation of compact rocks.

Reclamation Objective		Agricultural	Economic	Cultural	Forest	Natural		Aquatic		
		Cropping/Breeding	Housing/Services/ Industry	Scientific/Artistic	Forestry/Protection/ Recreation	Protected Areas */Green Areas	Natural Succession	Water Management	Recreation	
BIOLOGICAL RECLAMATION	Neutralization of toxic formations Agricultural works and fertilizing	Chemical neutralization and fertilization with allochthonous material					Chemical neutralization and fertilization with allochthonous material			
	Soil restoration using biological methods	Plowing, employing cultivators, harrowing, applying mineral fertilizers (e.g., NPK, agricultural limestone) or organic fertilizers (e.g., muck, compost)					Plowing, employing cultivators, harrowing, applying mineral fertilizers (e.g., NPK, agricultural limestone) or organic fertilizers (e.g., muck, compost) of slopes and areas surrounding the reservoir			
	Introducing target vegetation	Introducing humus-forming plants					Introducing humus-forming plants on slopes and areas surrounding the reservoir			
	Maintenance of plantings	Agricultural works, introducing agricultural plants (grasses or crops)	Agricultural works, introducing trees and shrubs					Agricultural works, introducing target vegetation on slopes and areas surrounding the reservoir		
	Neutralization of toxic formations	Removing perennial weeds, loosening soil, fertilizing, replacing withered plants with new seedlings					Removing perennial weeds, loosening soil, fertilizing, replacing withered plants with new seedlings on slopes and areas surrounding the reservoir			

\* Protected areas are nature reserves, landscape parks, protected landscape areas, species protection, nature monuments, inanimate nature documentation sites, ecological areas, landscape/nature protected complexes, Natura 2000 areas.

#### 4. Summary

Reclamation, which is the last stage of the mine life cycle, is aimed at compensating for changes in the natural environment caused by mining activities and generating new utility or natural values. The scope of reclamation works will differ, depending on the reasoning of the concept of reclamation. Reclamation can be interpreted as a set of activities aimed at preparing the transformed area for optimal use. Another definition defines reclamation as a set of tasks preparing the post-mining area for land development. However, this land development, as the second stage of the process, consists of conducting the target operations preparing for the optimal use of the post-mining area [1]. In the second definition, it is important that the mining entrepreneur is responsible for the reclamation, and that the future user of the site is responsible for the land development. This is important because the costs incurred to conduct the necessary works are allocated to the mining entrepreneur and the future user, respectively. Defining this border between reclamation and land development (and, as a consequence, the scope of reclamation works) is important in order to estimate the amount of financial security required for reclamation works, which a mining entrepreneur should provide. The amount of financial security for reclamation can be held in the form of additional reserves (on the basis of IAS 37), and its value should be determined as the difference in the costs of the reclamation project and the funds accumulated in bank accounts dedicated to the fund of mining plant closure [8,9].

In general, reclamation can be divided into three phases: preliminary, basic (technical), and detailed (biological). In addition, prior to the reclamation process, preliminary works should be conducted, which consist of cleaning the land, removing extra vegetation, demolishing the remaining parts of buildings, etc.

The analysis of the type and scope of reclamation works showed that the scope of reclamation works in the preliminary phase, which consists of the development of design-estimate documentation and determining the objectives of reclamation, is the same for each final land-use objective and area to be reclaimed. However, the scope of reclamation works of the technical and biological phases is different depending on the type of material exploited and the reclamation objective.

The technical phase is aimed at performing earthworks and preparing the area for works related to the introduction of biological life into degraded post-mining areas. The most important difference between the discussed objectives of reclamation for landscapes after the exploitation of clastic rock and clay raw materials is the need to shape the slopes of the excavation to obtain the appropriate inclination. In excavations after exploitation of compact deposits, the slopes are not shaped, but they must be protected against falling overhanging rocks. Particularly noteworthy is the formation of a safe access area for lido. In this case, the expenditures to be borne are likely to be the greatest due to the exacting requirements, for example, the construction of a gradual descent into the water or a shallow zone. Of course, it is not possible to build such reservoirs in all mining excavations, e.g., in excavations after exploiting compact raw materials, which are characterized by steep walls. Soil restoration methods are different for individual reclamation objectives. The thickness of fertilized fertile soil is variable and depends on the minimum necessary for maintenance of the desired vegetation on this land. In the case of compact raw materials, it is also necessary to protect the deep excavations by constructing barriers or shrubby fencing.

The scope of work of the biological reclamation phase may vary depending on the requirement for neutralization of toxic soils, as well as depending on the characteristics of the reclaimed landscape and of the introduced target vegetation.

Considering that there are no detailed solutions for reclamation documentation in the literature, the solutions proposed here in Tables 2–5 can be adopted as guidelines for the detailed design of technical and biological reclamation in surface mining of different rock raw materials. In addition, these guidelines may be a useful source for estimating the value of financial security for future events, such as reclamation of post-mining areas. This value should be determined at the stage of the mining investment feasibility study.

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