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Analysis of Environmental Conditions in the Andesite Mining Area of Kokap District, Kulon Progo Regency, Yogyakarta, Indonesia: Implications for Environmental Damage Prevention Monitoring

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Abstract

In this study, an analysis of environmental conditions in andesite mining areas was conducted as a form of monitoring in the prevention of environmental conditions. The methods used in this research are survey, mapping, and analysis methods using scoring that refers to the Decree of Gub. DIY Prop. No. 63 Year 2003. Field observations were conducted to find out information on environmental conditions and determine the areas to be mapped. While mapping is carried out using GPS (Global Position System) tools with medium accuracy of 3-5 meters that are stable. Based on the measurement results seen from the image map, it shows that it has a distance of less than 359.62 meters. The relief of the excavation base with a height tolerance of less than 1 meter, the slope of the excavation cliff with a tolerance reaching an angle of less than 18 degrees, the height of the excavation cliff with a height tolerance of less than 3 meters. The results of data processing and analysis of environmental damage that occurs in andesite stone mining show that the physical environment at the mining site is at a severe level of damage with a total score of 42. The physical environment at the river location is at a moderate level of damage with a total score of 8.

Keywords: analysis; environmental conditions; environmental damage prevention; mining area; monitoring

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INTRODUCTION

Monitoring environmental conditions is crucial for preventing environmental damage and ensuring sustainable development. Regular monitoring helps detect pollution early, allowing for prompt action to mitigate its impact (Jan et al., 2021; Watlet et al., 2020). Identifying the sources of pollution enables targeted measures to address the root causes. Data from monitoring programs inform the development of effective environmental policies and regulations. Monitoring ensures that industries and communities comply with environmental standards, and helps enforce regulations (Chafa et al., 2022).

Monitoring environmental conditions in mining areas is essential to mitigate the negative impacts of mining activities on the environment (Chen et al., 2021; Jha et al., 2020). Not only air and water quality monitoring, assessing soil for the presence of heavy metals and other contaminants is also important. In addition, monitoring soil stability to prevent subsidence and other geological hazards is a measure of whether the environmental conditions in the mining area are good or not (Dong et al., 2020; Gheibi & Hedayat, 2020; Umar Kura et al., 2013).

Recently,remote sensing and geographic information systems have been developed to monitor the environmental condition of mines. One of them is monitoring using satellite imagery. Satellite imagery is a remote sensing technology for monitoring changes in land use, vegetation cover and water bodies. Other monitoring methods such asgeographic information systems (GIS) are also used tointegrate various data sources to create comprehensive maps and models for environmental assessment (Al-Khashman et al., 2017; Bhat et al., 2018; Okoli & Kabaso, 2024; Sujitapan et al., 2024; Watlet et al., 2020; Xu & Wang, 2021).

Andesite Stone Mining activities use an open mining system (surface mining) with a side hill mining method. Andesite stone products can later be used for the construction sector, especially infrastructure such as bridges, irrigation, dams, road facilities, residential buildings, and so on. In planning mining activities, there are several aspects that are taken into consideration to determine whether or not the mining plan is feasible, including technical, environmental and economic feasibility studies (Nugraha et al., 2019). The operational activities of andesite stone mining broadly include land clearing, unloading, loading, and transporting, which produce physical impacts on the environment due to mining activities carried out without proper planning.

In this study, an analysis of environmental conditions in andesite mining areas was conducted as a form of monitoring in the prevention of environmental conditions. The methods used in this research are survey, mapping, and analysis methods using scoring that refers to the Decree of Gub. DIY Prop. No. 63 Year 2003. Field observations were conducted to find out information on environmental conditions and determine the areas to be mapped.

METHOD

In solving this problem, by combining theory and field data, especially primary data obtained from the company, soon both of them will obtain an approach. The method used in the study of physical environmental damage due to andesite mining in Gunung Kukusan Village, Hargorejo Village, Kokap District, Kulon Progo Regency, is namely by surveying, mapping, and analyzing methods. The method used in this study is the survey, mapping, and analysis method using scoring, which refers to Kep. Gub. DIY Prop. No. 63 of 2003.

The results of field observations were carried out to determine information on environmental hue conditions and to determine the area to be mapped. While mapping is carried out using a GPS (Global Positioning System) tool with an intermediate accuracy of 3-5 meters, stable or uniform, map creation is carried out in the studio using the Arc View program equipped with 3D Analyst, Image Analyst, in addition to additional extensions such as Geo Processing, Xtools, Edit Tools, and Register and Transform, as for the sequence of research work.

Research on environmental damage in Kalumata Village was carried out in several locations. Mining activities are carried out in a conventional or manual way and in a mechanical way, namely using heavy equipment such as rock breakers and backhoes. Mining is carried out manually and mechanically initially by cleaning/peeling the covered soil first. After the cover soil has been peeled off then the andesite is dug up using mechanical equipment. The excavated proceeds are then collected and ready to be sold and transported by trucks.

Research conducted in the field to obtain data from measurements and observations of conditions in the field. Data obtained from the determinants of environmental damage from mining activities include 1. Excavated edge boundary, 2. The boundary of the depth of excavation from the initial soil surface, 3. Relief of the excavated bottom, 4. Excavated cliff slope boundary, 5. Excavation wall height, 6. Road conditions, 7. Distance from bridges and river buildings. This data will be used to analyze the extent of damage and impacts caused by mining activities. The following is a map of the environmental situation at the CV Central Stone Perkasa andesiite stone quarry, Kokap District, Kulon Progo Regency, Yogyakarta Special Region which can be seen in **Figure 1**.

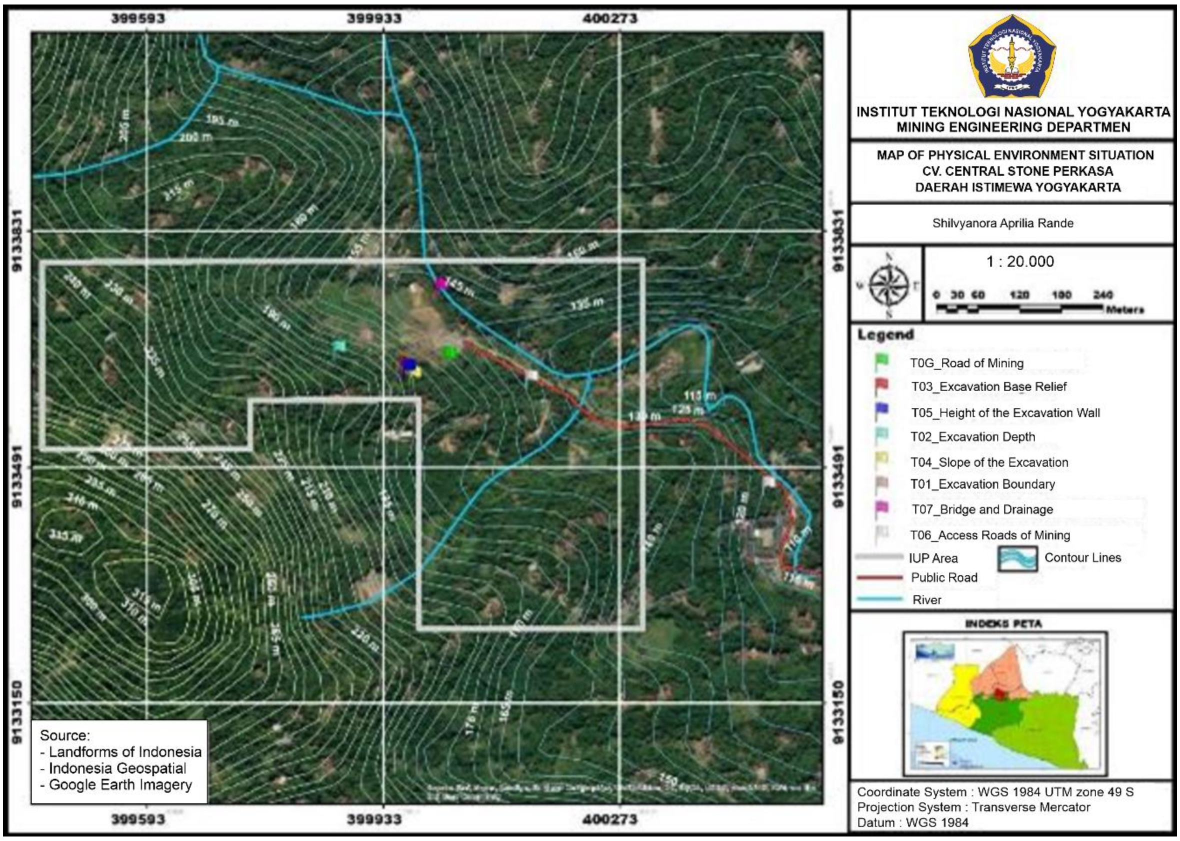

Figure 1. Situation Map of the Physical Environment Andesite Mining, Kokap District, Kulon Progo Regency, Yogyakarta, Indonesia

RESULTS AND DISCUSSION

Based on the results of the analysis, the environmental damage at the edge of the excavation in the field reached 4.7 meters. Documentation and measurements at the edge of the excavation can be seen in **Figure 2**. An excavation pit is a hole formed by mining excavated soil, while the depth of the excavation pit is the vertical distance from the Initial Land Surface to the field surface to the bottom of the excavation pit. The determination of the tolerable excavation depth limit for each land use is determined by the location of the groundwater table (Ibrahim, 2019; Luo et al., 2018; Umar Kura et al., 2013). The groundwater table is the boundary between the water-saturated soil layer and the water-unsaturated soil layer. The location of this layer varies depending on place and season. Lowlands generally have a shallow water table, while in higher areas the water table is deeper. During the rainy season, the water table is usually shallower than during the dry season. From the field measurements, the average depth of the excavation pit is 3 meters. This can be seen in **Figure 3**.

Figure 2. Documentation Excavated edge boundaries

Figure 3. Documentation The boundary of the excavation depth from the initial soil surface

Based on the results of the environmental damage analysis, the base relief of the excavation in the field reached 2.4 meters. Measurement of the relief of the excavation base formed is carried out by measuring the distance between the ground surface around the bottom of the excavation and the pile of residual material at the mining site (Chen et al., 2021; Czinder & Török, 2021). The measurement method of the excavation base relief can be seen in **Figure 4**. In determining the slope of the excavated cliff slope, 2 measurement points were taken that represented the slope of the slope at the research location, then the slope value was averaged. Slope data obtained from measurements using a geological compass and GPS have units of degrees (o) which can be converted into percent (%) where a slope of 45 degrees equals 100%. Measurement of the slope of the excavated cliff was carried out as shown in **Figure 5**.

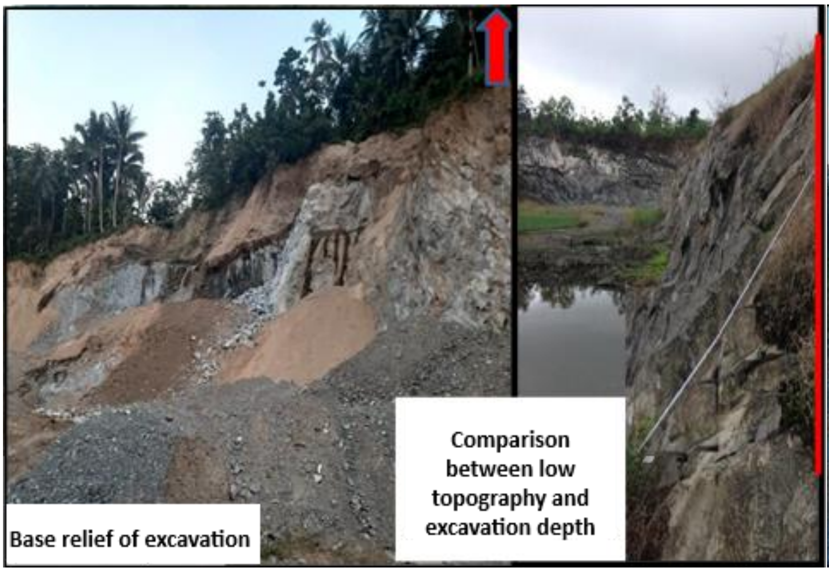

Figure 4. Documentation Relief of the excavated base

Figure 5. Documentation Excavated cliff slope boundary

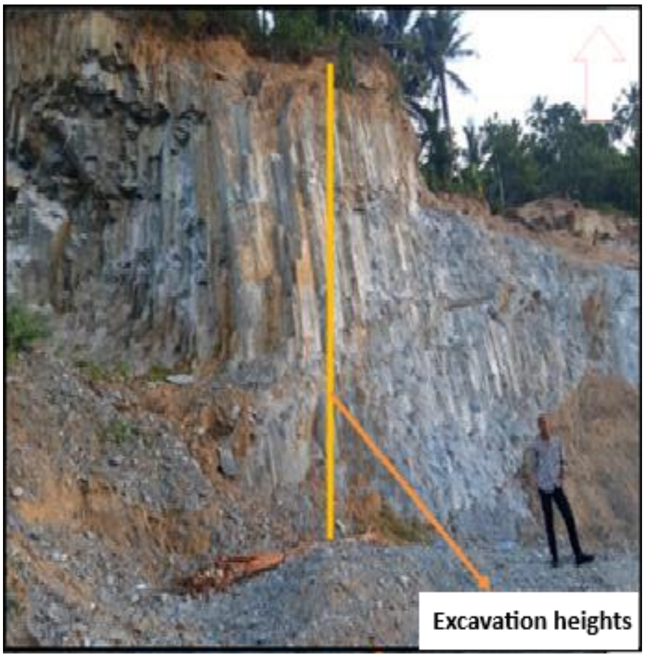

Figure 6. Documentation Excavation wall height

Figure 7. Documentation Conditions A) Mine driveway, B) mine inner road, C) mine outer road

Based on the results of the environmental damage analysis, the height of the cliff excavated in the field shows that it reaches (7-8) meters. Measurement of slope height using the trigonometric equation in **Figure 6**. Measurement of cliff height in the field can be done in 2 ways. Firstly, if the slope is steep, the measurement can be done directly from the bottom of the excavation (toe) to the top of the cliff (crest) (Mustofa et al., 2024; Pérez-Labrada et al., 2024). Second, if the slope is relatively gentle. The road used to bring material from the mine site to order is deliberately made for smooth transport. The condition of the road needs to be considered because it involves the risk of road damage. Road conditions at the mine site, both from the mine entrance to the road in the mine, have moderate criteria, with a distribution area of < 30% on the road in the mine, so that the mine entrance road is only bumpy. Documentation of road conditions can be seen in **Figure 7**.The results of the analysis of environmental damage at a distance from bridges and river buildings in the field reached 359.62 meters. for road condition documentation can be seen in **Figure 8**.

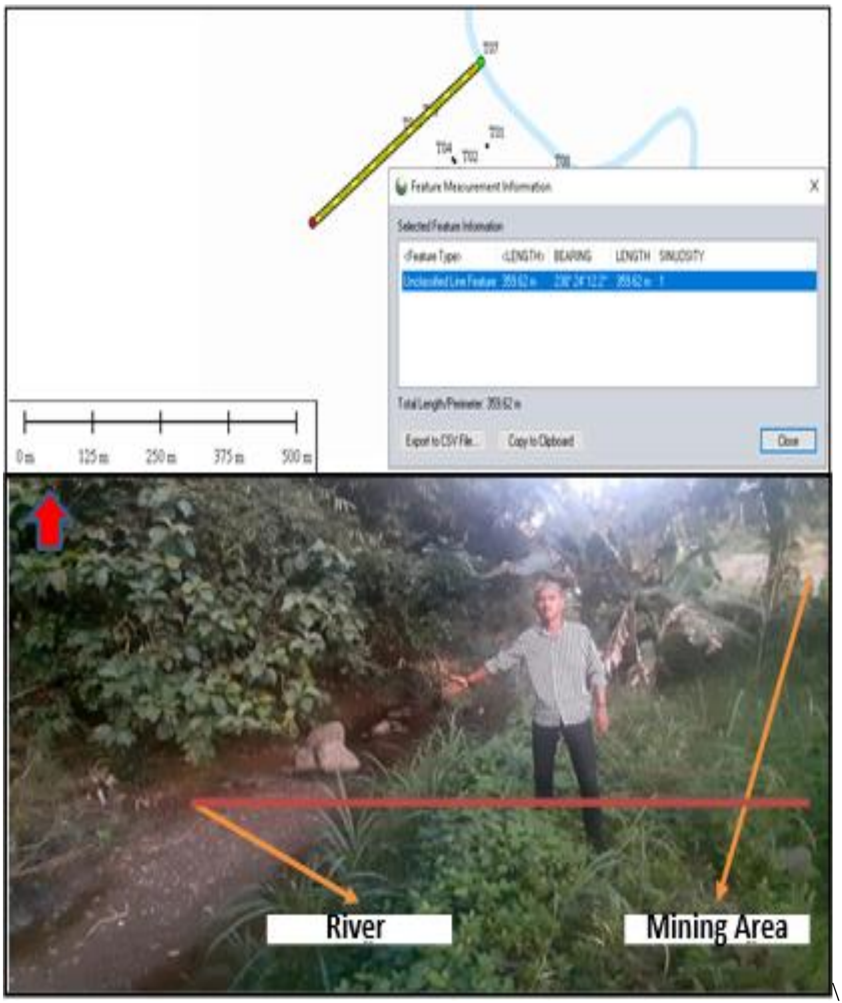

Figure 8. Documentation Distance from bridges and river buildings

Classification of Damage Rates due to Mining of Andesite Commodities

Criteria for physical environmental damage due to mining activities of andesite stone commodities in hamlet of Gunung Kukusan, Hargorejo Village, Kokap District, Kulon progo Regency, Yogyakarta Special Region Province is determined by the assessments of each damage-determining parameter as outlined in **Table 1, Table 2 and Table 3**. From the results of the data on these seven parameters, most of the parameters studied have criteria for damage with land conditions that have changed towards land damage.

Table 1. Classification of the Level of Environmental Damage and its Symbols

Classification	Sum of the total score range	Symbols

Light Damage	15.00 – 25.00	Δ
Medium Damage	26.00 – 35.00	ȼ
Heavy Damage	36. 00 – 45.00	ϒ

Table 2. Damage Criteria for Each Parameter at the Mining Site

Variable	Weight	Criteria	Score	Observation Result	Score Result
Excavation edge boundaries	1	Good, if the excavation edge > 5 meters	1	In the measurement, the edge of the excavation was 4.7 meters long.	2
		Moderate, if the excavation edge limit is 3 - 5 meters	2		
		Damaged, if the excavation edge limit < 3 meters	3		
Excavation depth limit from ground level	2	Good, if the excavation depth limit is between 0.5 - 1 meters above groundwater level	1	Excavation depth 3 meters	4
		Moderate, if the excavation depth limit is > 0.5 meters above groundwater level	2		
		Damaged, if the excavation depth limit < 0.5 meters above the groundwater level	3		
Excavation base relief	2	Good, if the excavation relief height is the same as the surrounding topography	1	Excavation relief height 2.4 meters	6
		Moderate, if the excavation relief height < 1 meters with the surrounding topography	2		
		Damaged, if the excavation relief height is > 1 meters with the surrounding topography	3		
Excavation cliff slope limit	4	Good, if the slope of the excavation cliff is < 15 degrees	1	The slope of the excavation cliff is 85 degrees	12
		Moderate, if the slope of the excavation cliff is between 15 - 30 degrees	2		
		Damaged, if the slope of the excavation cliff is > 30 degrees	3		
Excavation wall height	4	Good, if the excavation wall height is < 3 meters	1	Excavation wall height is 10.9 meters	12
		Medium, if the height of the excavation wall is between 3 - 4 meters	2		

		Damaged, if the height of the excavation wall is > 4 meters	3		
Road conditions	2	Good, if the road is not rutted and bumpy	1	The road has potholes with a proportion of >30%	6
		Medium, if the road has potholes with a proportion of < 30%	2		
		Damaged, if the road has potholes with a proportion of > 30%	3		
		Total Number			**42**
		Classification			**Heavy Damage**

Table 3. Damage criteria of each parameter on the location of the river.

Variable	Weight	Criteria	Score	Observation Result	Score Result
Distance from bridges and river buildings	4	Good, if the distance is > 500 meters upstream and > 1000 meters s downstream	1	359.62 meters	8
		Medium, if the distance is between 350 - 500 meters upstream and between 850 - 1000 meters downstream	2		
		Damaged, if the distance is < 350 meters upstream and between < 850 meters downstream	3		
		Total Number			**8**
		Classification			**Medium damage**

The results of the analysis of this research discussion are sought to obtain results that are relevant to the objectives of this study, namely: a. Influence due to Andesite mining activities on damage to the physical environment; b.How big is the assessment rate of environmental damages due to Andesite mining.

Analysis of the Influence of the Physical Environment

Hargorejo Village is a highland area with an altitude of 135-315 masl, with a slope of >15%. Based on rainfall data obtained from the Yogyakarta Special Region Public Works, Housing, and Energy Mineral Resources Office, Hargorejo Station for 10 years (from 2011-2020), the rainfall value in the study area ranges from 65-275 mm/year. Air temperature ranges between 25-30ºC, and air humidity between 60-80%. Thus, the study area includes areas that have high rainfall. Research on physical environmental damage due to andesite commodity mining at the mine owned by CV. Central Stone Perkasa, Gunung Kukusan hamlet, Hargorejo village, Kokap sub-district, Kulon Progo district, Yogyakarta Special Region Province.

The edge of the excavation is the area between the outer limit of the excavation pit and the land around the mining area. From field measurements, the excavation edge of 4.7 meters has not met the requirements of the excavation edge limit according to the provisions, which is at least 5 meters. The distance between the edge of the excavation becomes a buffer area for the surrounding environment. If an avalanche occurs on an excavation cliff that has a narrow excavation edge, it will threaten the land and community facilities located close to the mining site. For this reason, technically, efforts can be made to increase the distance of the edge of the excavation to a minimum of 5 meters and advise the community to stop digging on the cliff wall, which results in a smaller edge of the excavation.

An excavation pit is a hole formed by mining, while the depth of an excavation pit is the vertical distance from the surface of the field to the bottom of the excavation pit. The determination of the tolerable excavation depth limit for each land use is determined by the location of the groundwater table. The groundwater table is the layer of soil that is saturated with water and the layer of soil that is not saturated with water. The measurement results in the field show that the limit to the pit varies because the mine site has been flooded and the measurement process must go down into the pit, starting from a depth of 3 meters above the highest water level, so it has good criteria, with a value of 1 based on the DIY Governor Decree No. 63 of 2003.

The relief of the excavation base is the difference between the depth of the excavation and the lowest topographic height in the vicinity (Meju & Le, 2002). The recommended excavation depth difference should be less than 1 meter; this is so that the depth of the excavation does not make it difficult for further land use or in accordance with its designation. Based on the results of observations and measurements made from the measurement points, the lowest excavation relief measurement ranges from 2- meters to 3- meters below the lowest surrounding topography, so the condition of the excavation relief is included in the classification of Damaged or with a grade/score of 3.

Mining activities with cliff slopes above 50% are very risky for landslides and can threaten the safety of miners. Based on the results of observations and measurements in the field, each slope of the excavation cliff at the point at the mining site was found to be a vertical slope condition. The measurement results obtained the average slope of the excavation cliff at 85º at the mining site; the slope of the cliff is >50% based on the Decree of the Governor of Yogyakarta No. 63 of 2003, so that the rating of this parameter is declared damaged or with a value/score of 3.

The height of the excavation wall is the edge of the excavation hole as a whole from the surface to the bottom of the hole. To maintain the stability of the excavation wall, it should be tiered to prevent landslides. The height of the excavation wall was measured by using a meter. Based on the measurement results from fifteen points in the mining location, the result of the excavation wall height has a value of 10.995 meters. Giving a score of 3, based on the Decree of the Governor of Yogyakarta in 2003, the height of the excavation wall at the mining site is damaged.

Roads are very important infrastructure for smooth travelling, both using motorbikes and cars. While at the mine site, roads are also very important for mobilizing vehicles to transport excavated materials at the mine site to be marketed. From the observations in the field, the mine road is not asphalted and uses the soil at the mine site itself to be stockpiled and used as a mine road. The road conditions at the mine site are slightly bumpy and do not endanger the drivers themselves. So that the road conditions at the mine site are still included in the medium benchmark, or score 2.

Distance from bridges and river buildings upstream is a measure of length (meters) between the outermost point and the nearest point of the upstream boundary. Measurements are made by measuring the distance from the mine pit to bridges and river buildings; the distance from bridges and river buildings upstream is recommended at a minimum if the distance is >500 m upstream and >1000 m downstream from the bridge/river building. Based on the measurement results seen from the image map, it shows that it has a distance of less than 359.62 meters from the mining site. This means that the value is moderate and/or with a value/score of 2.

Recommendations for Improving the Level of Physical Environmental Damage Due to Andesite Commodity Mining

The condition of the excavated cliffs at the location of the former mining land has exceeded the tolerance limit, so there needs to be an arrangement of excavated cliffs that needs to be carried out with reference to existing provisions. Efforts to arrange the cliffs are carried out by setting the slope of the cliffs not to exceed 26.60 and the allowable cliff height of less than 3 meters. The repair of the excavated cliffs is carried out mechanically using heavy equipment used to work, namely the Backhoe. Based on observations, the height of the excavated cliffs reaches 10,995 meters. According to the existing provisions the height of the excavated cliffs is a maximum of 4 m. Therefore it is technically set to 2.9 m by forming cliff terraces such as bench terraces. The width of the terrace is at least 6 meters apart referring to Kep. Gub. DIY Prop. No. 63 of 2003. The boundary of the edge of the excavation is the area between the outermost boundary of the excavation pit and the land around the mining area. From field measurements, the excavation edge limit of 4.7 meters has not met the requirements for the excavation edge limit according to the provisions, namely a minimum of 5 meters. The distance between the boundary of the edge of the excavation becomes a buffer area for the surrounding environment. If there is an avalanche on the excavated cliff that has a narrow excavation edge boundary, it will threaten community land and facilities close to the mining site. For this reason, technically, efforts that can be made are to increase the distance of the edge of the excavation to at least 5 meters and advise to no longer excavate the cliff walls resulting in smaller the boundary of the excavated edge.

Former mining land tends to be irregular and undulating due to the remnants of excavated material that is no longer being used. The remaining excavated material at the observation site that forms the relief of the excavation base, needs to be handled by placing it in a certain location so that it does not make it difficult when land use efforts are made. The arrangement of the relief of the excavated bottom is necessary to prepare a stable land for plant planting activities. From field measurements, the relief of the excavation base formed varies between 1 meter and 2.4 meters. Most of the remaining excavated material is in the form of large chunks of rock. With the creation of a cliff terrace, it will reduce the height and slope of the excavated cliff, which is able to reduce the speed and volume of surface flow and also allow more water to be infiltrated, so that damage can be minimized. In the next observation, damage occurred to the road condition, The road condition observed has a hollow condition with a hole distribution area of >30% from before there was mining, but the road is still accessible, but this must be repaired in order to reduce the damage that has occurred, referring to Kep. Gub. Prop. DIY No. 63 of 2003 that road conditions must be improved so that road conditions are not hollow and bumpy. The point of this improvement recommendation will help in repairing the environmental damage that has occurred, here is an assessment of the results of the recommendations for improving the level of physical environmental damage due to mining of andesite commodities which can be seen in **Table 4**.

Table 4. Recommendations for Fixing the Damage Criteria for Each Parameter at the Mining Site

Variable	Weight	Criteria	Score	Improvement Result	Score Result
Excavation edge boundaries	1	Good, if the excavation edge > 5 meters	1	6 meters	1
		Moderate, if the excavation edge limit is 3 - 5 meters	2		
		Damaged, if the excavation edge limit < 3 meters	3		
Excavation depth limit from ground level	2	Good, if the excavation depth limit is between 0.5 - 1 meters above groundwater level	1	Excavation depth 3 meters	4
		Moderate, if the excavation depth limit is > 0.5 meters above groundwater level	2		
		Damaged, if the excavation depth limit < 0.5 meters above the groundwater level	3		
Excavation base relief	2	Good, if the excavation relief height is the same as the surrounding topography	1	The excavation relief height is the same as the	2
		Moderate, if the excavation relief height < 1 meters	2		

		with the surrounding topography		surrounding topography	
		Damaged, if the excavation relief height is > 1 meters with the surrounding topography	3		
Excavation cliff slope limit	4	Good, if the slope of the excavation cliff is < 15 degrees	1	The slope of the excavation cliff is 25 degrees	8
		Moderate, if the slope of the excavation cliff is between 15 - 30 degrees	2		
		Damaged, if the slope of the excavation cliff is > 30 degrees	3		
Excavation wall height	4	Good, if the excavation wall height is < 3 meters	1	Excavation wall height is 2.9 meters	4
		Medium, if the height of the excavation wall is between 3 - 4 meters	2		
		Damaged, if the height of the excavation wall is > 4 meters	3		
Road conditions	2	Good, if the road is not rutted and bumpy	1	The road is not rutted and bumpy	2
		Medium, if the road has potholes with a proportion of < 30%	2		
		Damaged, if the road has potholes with a proportion of > 30%	3		
		Total Number			**21**
		Classification			**Light Damage**

CONCLUSION

Based on the results of field measurements the most influential damage criteria are irregular relief reaching 2.4 meters, the height of the excavated cliff reaching 10.995 meters with the slope of the cliff reaching 850. In accordance with the provisions, the boundary of the excavated edge has a tolerance of more than 5 m, the boundary of the excavation depth of the initial soil surface with a depth tolerance of more than 1 m, the relief of the excavation bottom with a height tolerance of less than 1, the slope of the excavated cliff slope with a tolerance reaches an angle of less than 180, the height of the excavated cliff with a height tolerance of less than 3 meters, and road conditions have tolerance if the road is not hollow and bumpy and at the location of the river at the distance parameter from the bridge and river building has a tolerance when the distance is >500m upstream and > 1000m downstream from the bridge/river building. The results of processing and data analysis of environmental damage that occurred in the hamlet of Mount Kukusan, Hargorejo Village, Kokap District, Kulon progo Regency, Yogyakarta, Indonesia showed that the physical environmental condition at the mining site was at the level of damage with a total score of 42 including the weight category and the physical environmental conditions at the river location were at the level of damage with a total score of 8 including the medium category.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest concerning the publication of this article. The authors also confirm that the data and the article are free of plagiarism.

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