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Maindam Stability Analysis of Retarding Basin TR-01 Flood Control Project Das Sanggai 1A Advanced KIPP IKN Region East Kalimantan

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ABSTRACTS

Infrastructure development on KIPP-IKN East Kalimantan area faces challenges such as flooding and the unavailability of raw water. To address these issues, a Retarding basin is being built to address these issues. However, the engineering geological conditions in the basin and surrounding area can vary significantly, impacting the construction process. Further research is needed to understand these conditions and safety factors for slope stability and seepage in the main dam building. The research method used is the surface and subsurface geological mapping method to analyze engineering geological conditions as well as simulating the stability of the main dam using data from laboratory analysis. The research area consists of residual soil classified as Class D and mudstone as Class Middle, with fair-poor quality rocks. Slope stability simulations show that the area meets minimum requirements and is safe from landslides. Additionally, seepage stability simulations show that the TR-01 retarding basin's seepage discharge is below maximum permitted discharge requirements and is included in the safe category.

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INTRODUCTION

Infrastructure development in the State Capital Government Center Core Area (KIPP-IKN) located in Sepaku District, North Penajam Paser Regency, East Kalimantan is a strategic initiative that aims to accelerate economic development, improve connectivity, and optimize resource potential throughout Indonesia. However, in its development there are still many problems, one of which is flooding which always occurs every year due to high rain intensity and long rain duration and the unavailability of raw water and water control that is not optimal so that it needs to be handled properly. One of the solutions to the above problems is to build a Retarding basin in the watershed around the KIPP-IKN area (Syafrudi, 2021).

A retarding basin is a pond or reservoir that stores rainwater for a certain period of time. Its function is to cut flood peaks that occur in water bodies or rivers (Jenderal Cipta Karya, 2017). Retarding basins will function in runoff control surface and rainwater conservation in maintaining groundwater accumulation. In other words, retarding basins function to store and hold water temporarily before it flows into the river so that flood peaks can be reduced. In addition to its main function as flood control, another benefit of retarding basins is as a water facility and water conservation. In the construction of retarding basins, one of the buildings that requires special attention is the maindam building because it is the main building that functions to hold and control the water entering the retarding basin. (Astuti, et al. 2015).

Geological conditions and engineering geology around retarding basins can vary significantly depending on factors such as soil and rock types, geological structures, and local hydrological characteristics can have a major impact on retarding basin buildings. Therefore, based on the description above, it is necessary to conduct research on the Maindam Stability of the TR-01 Retarding basin in the Sanggai 1A Watershed Flood Control Project Advanced KIPP IKN Area.

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METHODS

This research used the methods of engineering geological mapping, core drilling, and soil and rock sampling for laboratory testing. Engineering geological mapping was conducted to obtain information related to surface engineering geology in the retarding basin area. In this engineering geology mapping, data taken in the form of lithological data, geological structures, soil and rock distribution and rock classes. Then rock core drilling was carried out to collect data to determine the characteristics of subsurface rocks. In core drilling, several data were collected on the geological conditions of the subsurface rock technique to determine the rock class, as well as the calculation of Rock Quality Designation (RQD).

Soil and rock sampling is carried out to analyze characteristics through several types of tests. The sampling method is carried out by taking large rocks from the excavation results to represent the existing lithology types, and for the soil, the sampling method is carried out by taking large rocks from the excavation results to represent the existing lithology types data were collected in the inundation area and borrow area that will later be used as the foundation of the dam on the retarding basin

Then the analysis is carried out by determining the subsurface rock class zone and rock mass quality, as well as analyzing the data from laboratory testing, as well as evaluating earthquake conditions and modeling slope stability and seepage discharge at the research site using Slope / W and Seep / W Geostudio 2018 software.

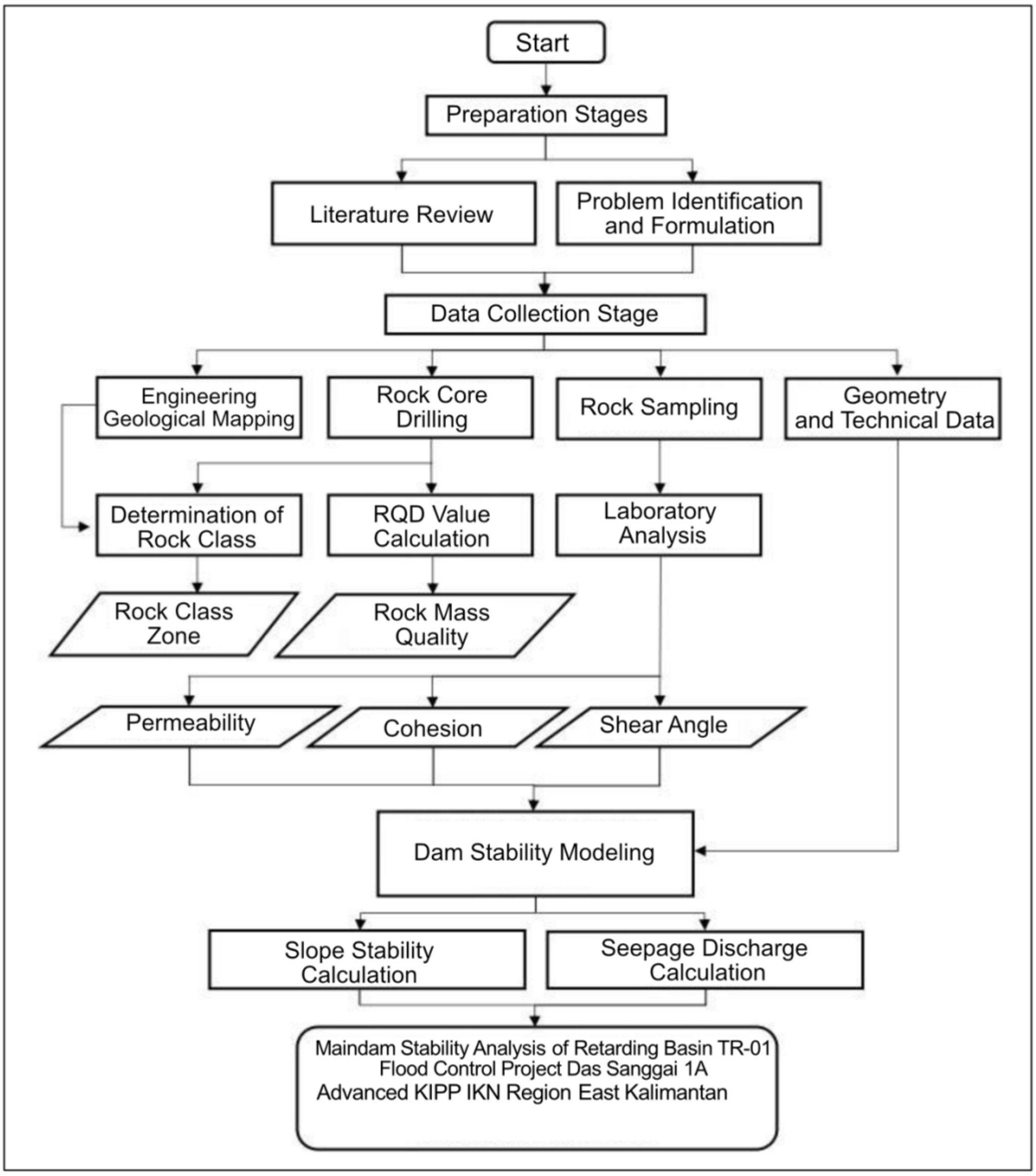

Figure 1. Research Flowchart

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RESULTS AND DISCUSSION

Engineering Geology of Research Area

Engineering geology data was collected through surface mapping and rock core drilling in the TR-01 retarding basin building area of the Sanggai 1A Advanced Watershed flood control project. The station map displays the distribution of research stations, with 9 observation and sampling stations and 3 core drilling stations.

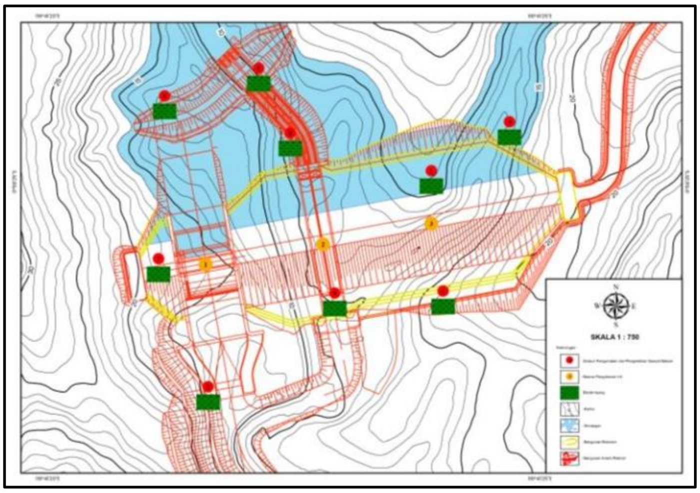

Figure 2. Map of research station at retarding basin TR-01

Surface Mapping

In surface mapping activities, observations and sampling were carried out at 9 location points around the maindam body building plan to determine the geomorphological conditions, and stratigraphy in the research area.

Geomorphology of the Research Area

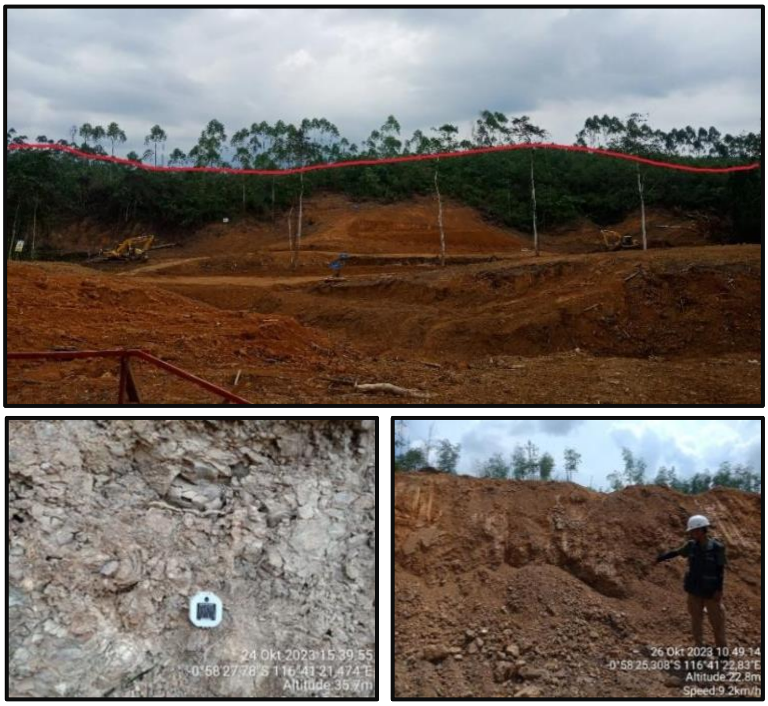

Figure 3. (A) Appearance terrain with photo direction N 132^0 E, (B) chemical weathering in the form of spheroidal weathering on rocks, (C) Appearance of residual soil from rock weathering with a thickness of 3 meters

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Based on direct observation in the field, the study area has a relatively undulating appearance with an altitude of about 29 meters above sea level, so it is concluded that the study area is a lowland area. The formation of this landscape unit is included in the denudational morphological unit with the dominant process of weathering and erosion. The weathering process that occurs is biological and chemical weathering. Biological weathering characterized by the presence of tree roots that penetrating the rock makes the rock no longer extant and eventually becomes soil. Chemical weathering is characterized by spheroidal weathering caused by the release of pressure due to changes in pressure.

The level of weathering found is quite high as evidenced in several places where residual soil from the weathering of the underlying rocks is found with a thickness of 1-5 meters. The soil color is light brown to dark brown with vegetation types such as trees and shrubs. So based on the results of the above observations, it can be seen that the geomorphology in the research area is included in the denudational lowland landscape unit.

Stratigraphy of the Research Area

The grouping and naming of rock units in the study area is based on unofficial lithostratigraphy. Based on interpretation and direct observation in the field, the stratigraphy of the study area consists of mudstone units.

Figure 4. Outcrop claystone with photo direction N 180 E

The field appearance of this unit in the fresh state is blackish gray and in the weathered state is brown with clay grain size (<1/256 mm), good sorting, closed packing, layered structure, carbonatan chemical composition, moderate plasticity, strong cementation, homogeneous structure, rather dense relative density, very low water graduation, very hard firmness. So based on its physical characteristics, the name of this rock is claystone (Wentworth, 1972).

Rock Core Drilling

In core drilling activities, sampling was carried out at 3 points along the maindam body building with a depth of 15 m. Based on observations of the samples from each drill point, the study area consists of two layers as follows:

1. **Residual Soil**

Megascopically it has a brownish yellow appearance, very fine grain size, moist water content, medium cementation, relatively dense density, verylow water graduation, hard firmness. Based on its physical characteristics, it is clayey soil resulting from the weathering of existing rocks.

2. **Claystone**

Megascopically it has a gray-black appearance,medium plasticity, very fine grain size, moist water content, strong cementation, homogeneous structure, relatively rather dense density, very low water graduation, very hard firmness. Based on its physical characteristics, this rock is mudstone.

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Figure 5. Claystone samples at drill point BH-01 at a depth 4-15 meter

Based on the correlation results of each layer at the core drilling point, the subsurface rock layer in the TR-01 retarding basin can be seen in the following table:

Table 1. Depth of rock layers at core drilling points

No	Drill Point	Depth (m)	Lithology
1	BH-01	0 - 3	*Residual Soil*
		3 - 15	*Claystone*
2	BH-02	0-3	*Residual Soil*
		3-15	*Claystone*
3	BH-03	0-1	*Residual Soil*
		1-15	*Claystone*

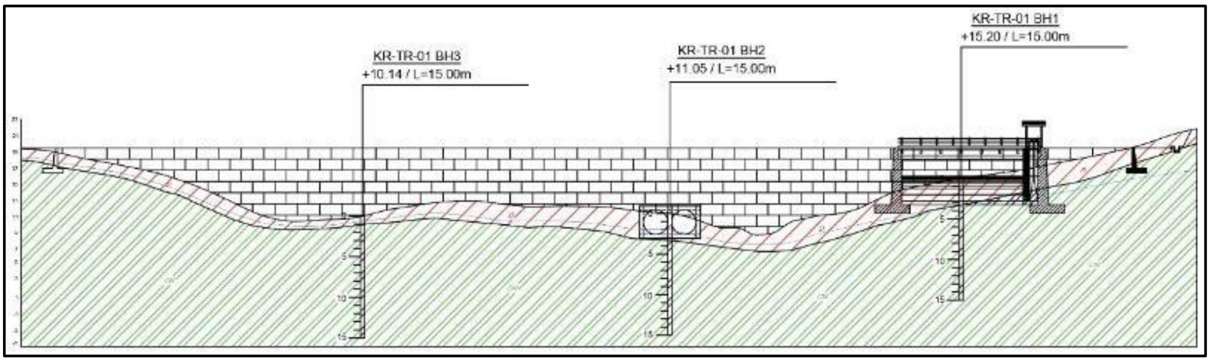

Figure 6. Engineering geological cross section of retarding basin TR-01

Rock Quality Designation (RQD)

Calculations are carried out on each core run at each core drilling point to determine the strength of the rock and its relationship to the construction of the building above it.

Table 2. RQD calculation results at core drilling points

No	Drill Hole	Depth	Lithology	RQD	Class
1	BH-01	0 - 3	*Residual Soil*	-	-
		3 - 15	*Claystone*	53	*Fair*
2	BH-02	0-3	*Residual Soil*	-	-
		3-15	*Claystone*	51	*Fair*
3	BH-03	0-1	*Residual Soil*	-	-
		1-15	*Claystone*	37	*Poor*

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Based on the relationship between the RQD index and rock quality (Bieniawski, 1989), the subsurface rock quality at BH-01 and BH-02 falls into the fair quality class, while that at BH-03 falls into the poor quality class.

Rock Class

The determination of rock class zonation is obtained from samples of core drilling results based on the CRIEPI classification (1992) by considering factors such as hardness based on sound reaction when hammered with a geological hammer, the level of mineral/rock weathering and fault characteristics. The criteria for layers in the study area are :

- Residual soil layer is categorized as D (Decomposed) or very soft rock.
- Claystone layer, it is included in the CM (Class Middle) rock type or semi-soft rock.

Maindam Stability Analysis

The stability analysis was conducted by calculating the earthquake evaluation in the study area, as well as modeling the slope stability and seepage discharge in the maindam body using Geostudio 2018 software.

Earthquake Evaluation

In the evaluation of the calculation of the earthquake load value, the influence of the level of damage and the level of risk of the dam, as well as the calculation of the earthquake coefficient in the study area, were analyzed.

Dam Risk Level

Analyze the risk level of the dam at Retarding basin TR-01 as follows :

Table 3. Risk Level factors for dams

No	Risk Factor		Category	Value
1	Capacity (FRk)	361.050 m3	Moderate	2
2	Height (m) (FRt)	12.76 m	Low	0
3	Evacuation Need (Number of People) (FRe)	0	Low	0
4	Downstream Damage Level (FRh)	Moderate	Moderate	4

Determination of earthquake load criteria by determining the risk class using the formula :

$$FRtot = FRk + FRt + FRe + FRh$$
$$FRtot = (2) + (0) + (0) + (4)$$
$$= 6$$

From the results of the above calculations, it can be seen that the risk level of the dam in the TR-01 Retarding basin TR-01 belongs to the type of risk class I (Low).

Damage of Level Dam

The classification of damage levels can be made based on the maximum earthquake acceleration (PGA) using the earthquake zone map in accordance with the previous risk class

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classification, which uses a 100- year return period for OBE earthquakes and a 1000- year return period for MDE earthquakes.

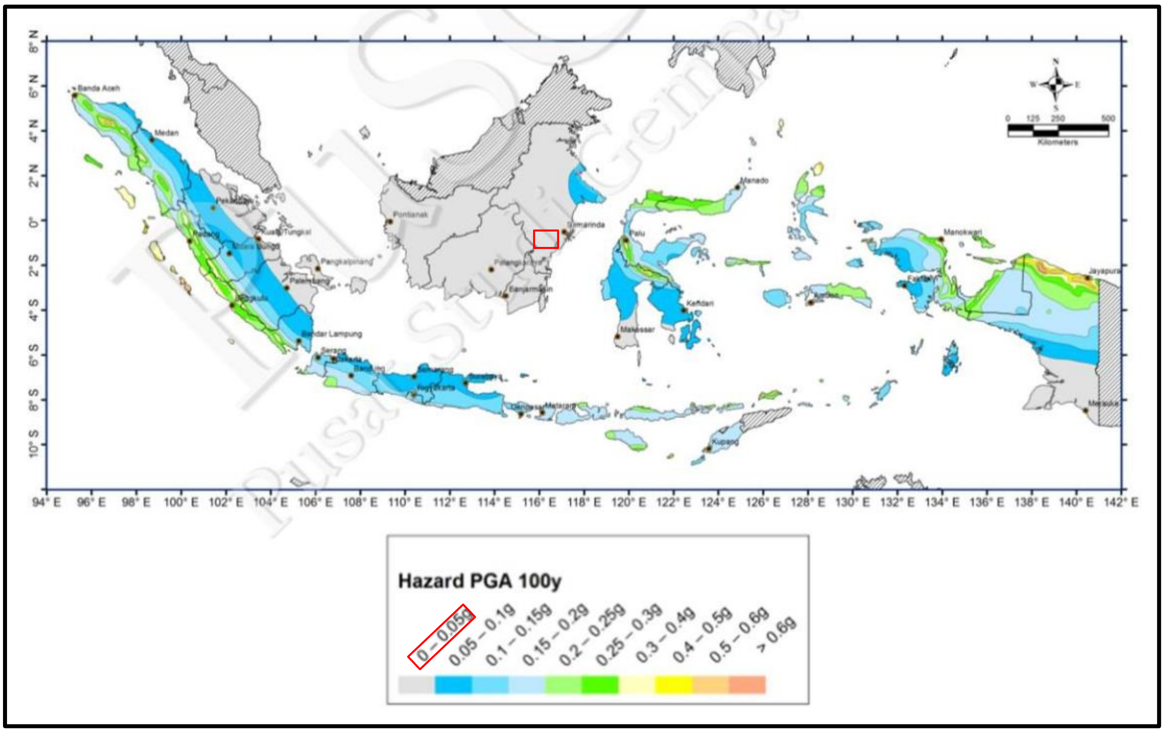

Figure 7. 100-year earthquake acceleration map (Pusgen, 2017)

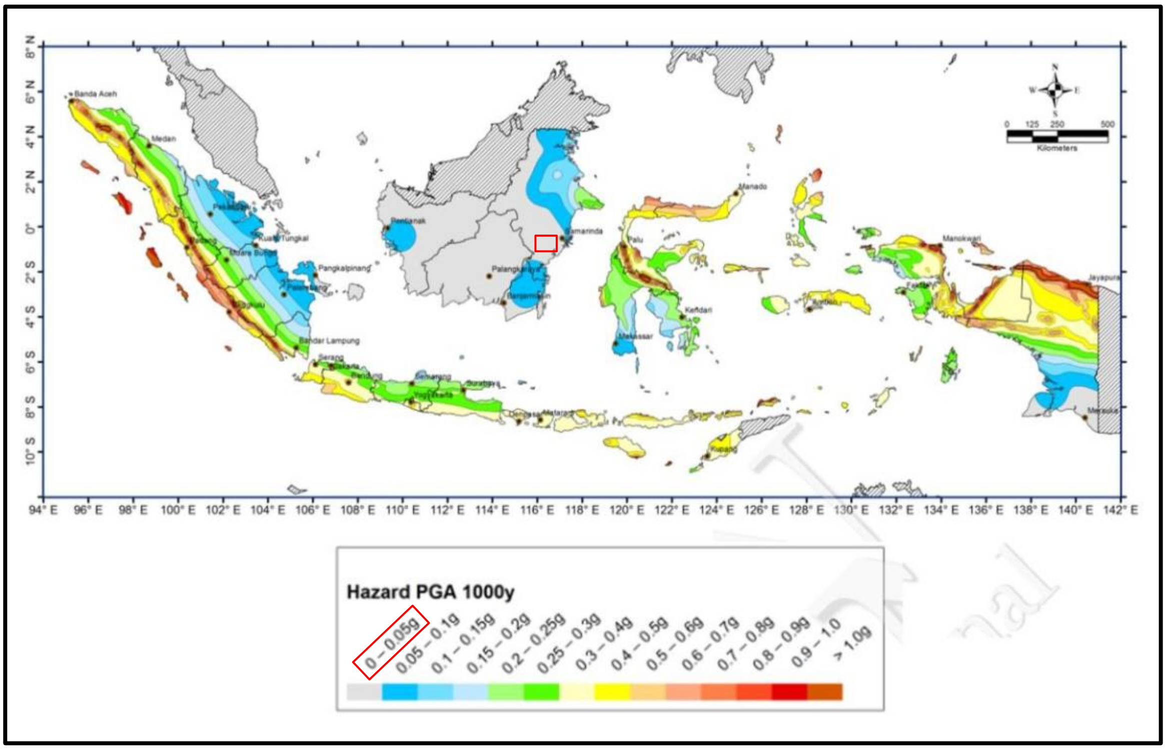

Figure 8. 1000-year earthquake acceleration map (Pusgen, 2017)

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Damage of Level Dam

The calculation of the earthquake coefficient is carried out using the modified earthquake coefficient method, where the MDE calculation with a PGA value of 0.05g is as follows:

$a_d = 0.05$

$g = 0.981$ dm/s2

$\alpha = 0,5$ (Earthfill Dam)

$K_h = \frac{ad}{g}$

$K_h = \frac{0,05}{0.981}$

$K_h = \frac{0,05}{0.981}$

$= 0.051$

$K_o = \alpha \times K_h$

$K_o = 0.5 \times 0.051$

$= 0.0255$

The value of the earthquake coefficient at depth Y from the dam crest is different. This is because the higher the place under review, the greater the earthquake shaking. Calculations were performed at y/H 0.25; 0.5; 0.75; and 1 (Imron et al., 2017).

On y/H 0,25 :

$K = K_o \times (2,5 – 1,85\ Y/H)$

$= 0.0255 \times (2,5 – 1,85 (0.25))$

$= 0.0519$

On y/H 0,5 :

$K = K_o \times (2,0 – 0,6\ Y/H)$

$= 0.0255 \times (2,0 – 0,6 (0.5))$

$= 0.0433$

On y/H 0,75 :

$K = K_o \times (2,0 – 0,6\ Y/H)$

$= 0.0255 \times (2,0 – 0,6 (0.75))$

$= 0.0395$

On y/H 1 :

$K = K_o \times (2,0 – 0,6\ Y/H)$

$= 0.0255 \times (2,0 – 0,6 (1))$

$= 0.0357$

From the results of the above calculations, it can be seen that the earthquake coefficient at the research location is as shown in the table below :

Table 4. Risk Level factors for dams

Return Period (T)	K_o (g)	K_h (g)	K_h on y/H				Ket
			1	0.75	0.5	0.25	
1000	0.0255	0.051	0.0357	0.0395	0.0433	0.0519	MDE

Slope Stability of Retarding basin TR-01

Calculation of slope stability on the TR-01 Retarding basin weir body was carried out using SLOPE/W Geostudio software. Calculations are carried out in 4 conditions, namely conditions after construction is completed (After Construction), Maximum Water Level, Normal Water Level and Rapid Draw Down then analyzed in a state without Earthquake Load and added MDE Earthquake Load before with the following data properties :

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Table 5. Properties data of residual soil layer

Layer	Unit Weight Wet (kN/m³)	Unit Weight Saturated (kN/m³)	UU		CU		Koef. Permeabilitas
			Cohesion (kPa)	Shear Angle (°)	Cohesion (kPa)	Shear Angle (°)	
Residual Soil	18.211	19.054	120.32	8.9	21.921	14.1	2.213E-07

Table 6. Properties data of claystone layer

Layer	Unit Weight (kN/m³)	Cohesion (kPa)	Shear Angle (°)	Koefisien Permeabilitas
Claystone	25.525	35.23	21.349	6.590E-08

Table 7. Technical data of retarding basin TR-01

Type	: Earthfill Dam
Maximum Height of Dam	: +9.00 m from the riverbed
Elevasi Puncak Bendungan	: +19,50 mdpl
Peak Dam Elevation	: 145 m
Dam Crest Width	: +4.00 m
Minimum Water Level	: +14.00 m
Normal Water Level	: +16.00 m
Maximum Water Level	: +17.49 m
Riverbed Elevation	: +14.00 mdpl
Total Storage Volume	: 361.05 x 10^3
Discharge Inflow	: 93.10 m^3/s

1. After Construction Condition

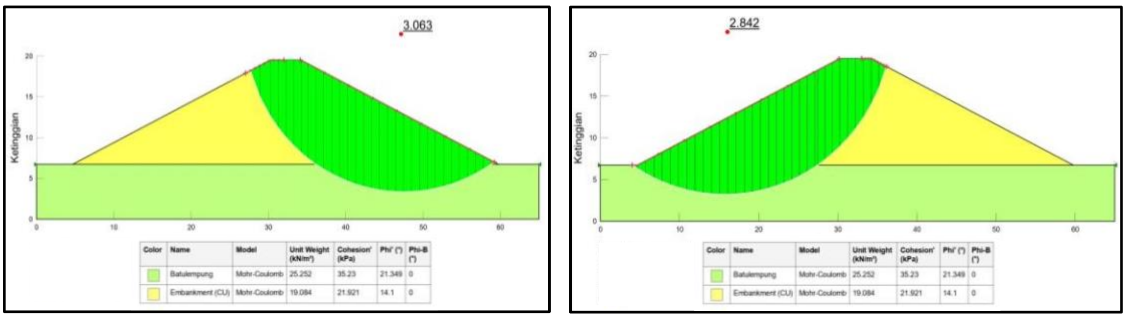

Figure 9. Simulation of downstream slope stability in after construction condition

Table 8. Results of Slope Calculation in After Construction Condition

Bagian Bendungan	Tanpa Beban Gempa pada y/H				Syarat FK	Beban Gempa pada y/H				Syarat FK
	1	0.75	0.5	0.25		1 0.0357	0.75 0.0395	0.5 0.0433	0.25 0.0519	
Udik (U/S)	3.102	5.011	8.967	17.14	1.30	2.842	4.549	8.028	14.93	1.20
Hilir (D/S)	3.205	5.568	8.385	12.94	1.30	3.063	5.053	7.517	11.59	1.20

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From the results of the calculation of slope stability in the table above, it can be seen that the dam in this condition meets the requirements of the safety number and is categorized as safe from landslides.

2. Maximum Water Level Condition

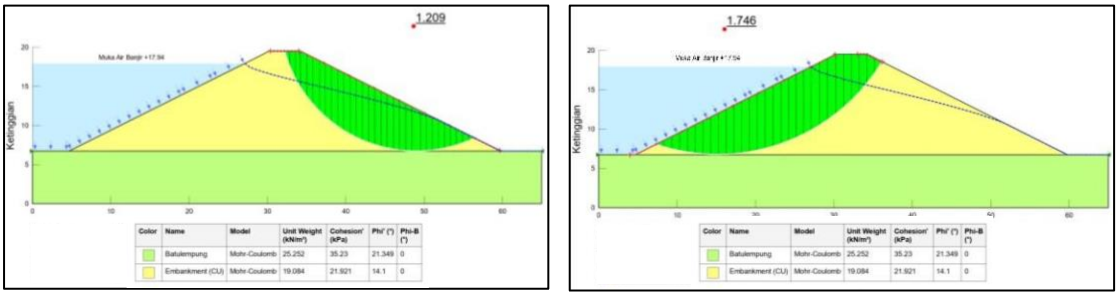

Figure 10. Simulation of slope stability in maximum water level condition

Table 9. Results of Slope Calculation in Maximum Water Level Condition

Bagian Bendungan	Tanpa Beban Gempa pada y/H				Syarat FK	Beban Gempa pada y/H				Syarat FK
	1	0.75	0.5	0.25		1 0.0357	0.75 0.0395	0.5 0.0433	0.25 0.0519	
Udik (U/S)	2.024	2.213	2.973	4.176	1.50	1.746	1.902	2.548	3.578	1.20
Hilir (D/S)	1.240	1.347	2.081	3.003	1.20	1.209	1.318	1.868	2.730	1.20

From the results of the calculation of slope stability in the table above, it can be seen that the dam in this condition meets the requirements of the safety number and is categorized as safe from landslides.

3. Normal Water Level Condition

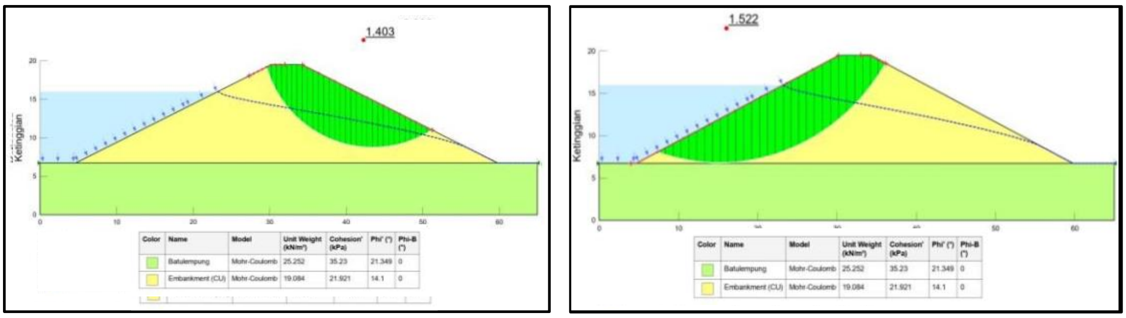

Figure 10. Simulation of slope stability in Normal Water Level condition

Table 9. Results of Slope Calculation in Normal Water Level Condition

Bagian Bendungan	Beban Gempa pada y/H				Syarat FK	Tanpa Beban Gempa pada y/H				Syarat FK
	1	0.75	0.5	0.25		1 0.0357	0.75 0.0395	0.5 0.0433	0.25 0.0519	
Udik (U/S)	1.724	1.840	2.358	3.837	1.50	1.552	1.625	2.108	3.344	1.20

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Hilir (D/S)	1.296	1.541	2.186	3.003	1.20	1.210	1.403	1.980	2.662	1.20

From the results of the calculation of slope stability in the table above, it can be seen that the dam in this condition meets the requirements of the safety number and is categorized as safe from landslides.

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From the results of the calculation of slope stability in the table above, it can be seen that the dam in this condition meets the requirements of the safety number and is categorized as safe from landslides.

4. Rapid Draw Down Condition

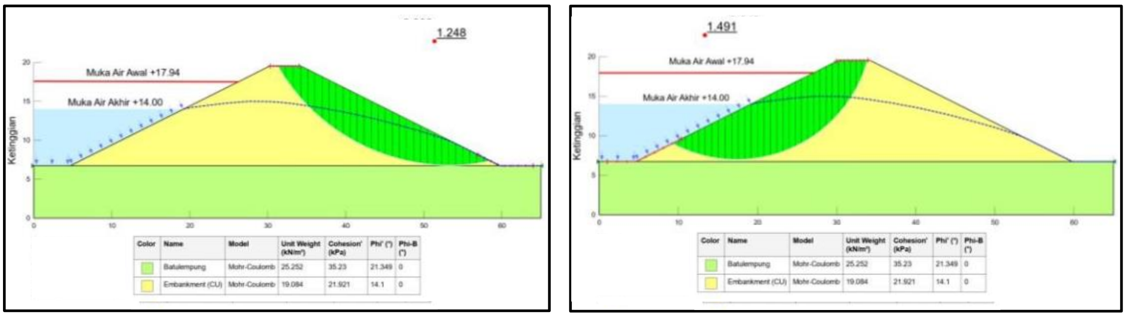

Figure 11. Simulation of slope stability in rapid draw down condition

Table 10. Rapid Draw Down from Maximum Water Level to Minimum Water Level

Bagian Bendungan	Waktu Penurunan (Hari)							Syarat FK
	0	0.5	1	2	3	4	5	
Udik (U/S)	2.098	2.016	1.937	1.794	1.669	1.543	1.491	1.30
Hilir (D/S)	1.219	1.221	1.222	1.226	1.229	1.232	1.248	1.20

Table 11. Rapid Draw Down from Normal Water Level to Minimum Water Level

Bagian Bendungan	Waktu Penurunan (Hari)							Syarat FK
	0	0.5	1	2	3	4	5	
Udik (U/S) dengan Gempa	1.635	1.607	1.580	1.530	1.484	1.442	1.402	1.20
Udik (U/S) tanpa Gempa	1.770	1.737	1.706	1.648	1.595	1.547	1.503	1.30
Hilir (D/S) dengan Gempa	1.205	1.205	1.206	1.206	1.207	1.208	1.209	1.20
Hilir (D/S) tanpa Gempa	1.277	1.277	1.277	1.278	1.279	1.280	1.281	1.30

From the results of the calculation of slope stability in the table above, it can be seen that the dam in this condition meets the requirements of the safety number and is categorized as safe from landslides.

Seepage of Retarding basin TR-01

The calculation of seepage discharge in the body of the TR-01 Retarding basin weir was carried out using SEEP/W Geostudio software. Calculations were carried out in 3 conditions, namely conditions of Maximum Water Level, Minimum Water Level, Normal Water Level.

1. Maximum Water Level Condition

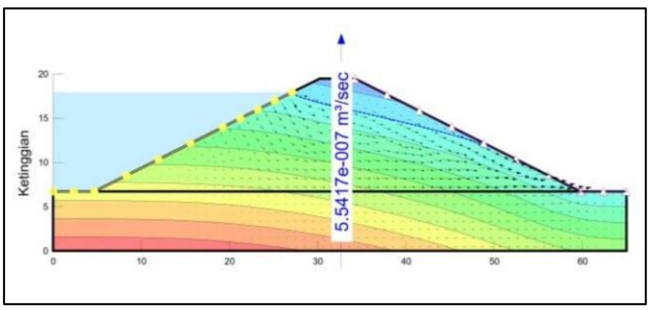

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Figure 11. Seepage Discharge Analysis on Maximum Water Level Condition

Based on technical data Retarding basin TR-01 has a peak length of 145m so that the total seepage is as follows.

Qtotal = 5,5417 x 10-7 x 145
= 8,0354 x 10-5 m3/dt

2. Normal Water Level Condition

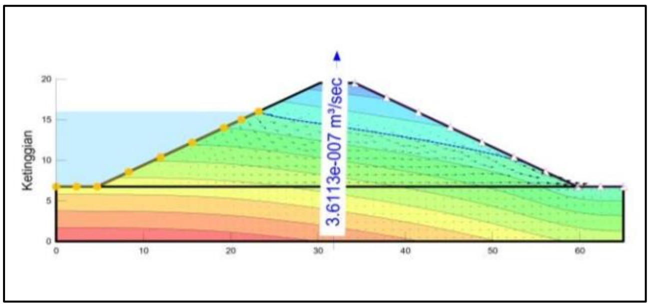

Figure 12. Seepage Discharge Analysis under Normal Water Level Condition

Based on technical data Retarding basin TR-01 has a peak length of 145m so that the total seepage is as follows.

Qtotal = 3,6113 x 10-7 x 145
= 5,2363 x 10-5 m3/dt

3. Minimum Water Level Condition

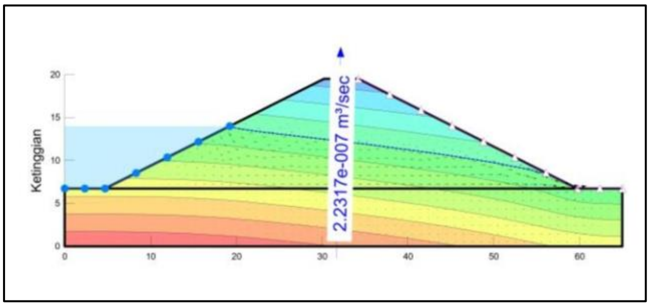

Figure 13. Seepage Discharge Analysis under Minimum Water Level Condition

Based on technical data Retarding basin TR-01 has a peak length of 145m so that the total seepage is as follows.

Qtotal = 2,2317 x 10-7 x 145
= 3,3259 x 10-5 m3/dt

Based on the retarding basin data collected, it is known that the inflow discharge in the TR-01 retarding basin is 93.10 m3 / d. Then in the 2005 Grouting Guidelines for Dams book which refers to the limitations that apply in Japan, it is stated that the value of seepage discharge that occurs (Qizin) in the dam body should not be more than 1% of the average river discharge that will enter the dam.

Q_{izin} = 0.01 x Discharge Inflow
= 0.01 x 93.10
= 0.931 m^3/dt

From the above calculations, it can be seen that the seepage discharge that occurs (Qizin) in the TR-01 retarding basin cannot be more than 0.931 m3/s.

Table 12. Seepage Discharge in each Condition

Condition	Discharge	Syarat
Maximum Water Level	8,0354 x 10^{-5} m^3/dt	< 0.931 m^3/dt
Normal Water Level	5,2363 x 10^{-5} m^3/dt	< 0.931 m^3/dt
Minimum Water Level	3,3259 x 10^{-5} m^3/dt	< 0.931 m^3/dt

From the results of the analysis that has been done, the seepage discharge value obtained in each water level condition has a value smaller than Qizin so that the seepage discharge in the TR-01 retarding basin can be said to be safe.

CONCLUSION

Based on the results of research and analysis that has been carried out at the research location, it can be concluded that the geological conditions in the research area consist of residual soil which is included in the type of rock class D (Decomposed) or very soft rock and claystone which is included in the type of rock class CM (Class Middle) or rather soft rock. As for the quality of rocks in the research area, it is included in the quality of moderate (fair) - poor (poor).

From the results of the slope stability analysis that has been carried out in the after construction condition, the maximum water level, normal water level and rapid draw down have a safety factor value (1.29- 17.14) which meets the minimum requirements and is included in the category of safe from landslides.

From the results of the seepage discharge analysis that has been carried out in the conditions of maximum water level, normal water level, and minimum water level, the seepage discharge value (3.3259-8.0354 x 10-5 m3 /dt) is still below the maximum permissible discharge requirement so that seepage that occurs in the TR- 01 retarding basin is included in the safe category.The conclusion should indicate the results obtained, the advantages and disadvantages, and the possibility of further development. The conclusion can be in the form of a paragraph, but it should be in bullet points using numbering or bullets.

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