# THE SLOPE STABILITY OF WATER CANAL AND LANDSLIDE MANAGEMENT AT DADAHUP WATER CANAL CONSTRUCTION IN CENTRAL KALIMANTAN

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# THE SLOPE STABILITY OF WATER CANAL AND LANDSLIDE MANAGEMENT AT DADAHUP WATER CANAL CONSTRUCTION IN CENTRAL KALIMANTAN

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**Abstract**

Dadahup Swamp Irrigation Area in Central Kalimantan Province has a land area of 21,226 Ha which carries out the water management system of Barito River, Kapuas Murung River and Mangkatip River. The site has many waterways that are parts of the Food Estate national strategic program which is aimed to supply the food demand. Dadahup Swamp Irrigation Area also has secondary canal that drains and supplies the water to rice fields. A slope failure occurred during the construction of new waterways nearby the traffic access road. The landslide site was in Bina Jaya Village, Jalan DIR Dadahup, Central Kalimantan Province. PLAXIS software was used in slope stability analysis. Seen from the soil characteristics, particularly at the canal bottom and canal slopes, soft clay soil dominated to a depth of 20 meters from the surface. Soft clay has a small shear strength and slides when triggered. Sheet piles of 18 meters long was selected as the slope reinforcement to handle the landslide around the Sluice Gate construction area. The sheet pile reinforcement improved the slope stability as seen from the value of the safety factor which exceeded the minimum requirements set in SNI 8460 of 2017.

Keywords : Swamp Irrigation, Water ay, Slope Stability, Sheet Pile

## Background

Dadahup Swamp Irrigation Area in Central Kalimantan Province was built on a land area of 21,226 Ha to regulate the water management system of Barito River, Kapuas Murung River and Mangkatip River. There are many water channels there which contribute to the Food Estate national strategic program to supply food for the community. Dadahup Swamp Irrigation Area also has secondary canal that supplies water to rice fields.

Dadahup Swamp Irrigation Area plays significant role to the surrounding area as it overcomes tidal flood and drought. During the rainy season, the tide level is higher than the land elevation, while in the dry season, the water level is below the land level. This condition is the basis for the need for a floodgate.

At the onset of the water gate construction, a slope failure occurred along the traffic access road adjacent to Bina Jaya Village. Figure 1(1,b,c) visualizes the current condition of the landslide area. Figure 2 illustrates the design of sluice building to be constructed in close proximity to the landslide site.

Right before the commencement of the water gate construction, a landslide suddenly occurred nearby. This paper provides a thorough analysis of slope stability and the slope reinforcement model which results would be significantly useful to be used as an insight in water gate construction.


(a)


(b)


(c)

Figure 1 The Landslide Site

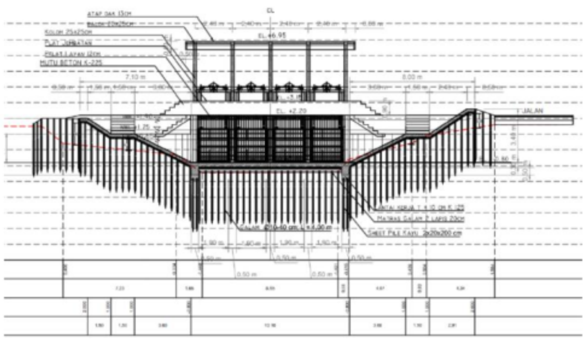

Figure 2 Cross Section of Sluice Construction

**Slope Failure**

Various factors can cause slope failure and researchers have been intrigued in investigating about it further. Results of studies in this topic are quite useful for the development of science, especially related to slope stability Kaya (2017) and Kumar et al. (2017) have conducted studies on slope failure and discovered that steep slopes can increase thrust and trigger landslides. Therefore, slope stability analysis is necessary to conduct in order to prevent casualties from landslides. Hou et al. (2018) found that water infiltration in soil can significantly reduce its shear strength and lead to slope instability. Fattahi (2017) noted that the safety is the factor that plays a crucial role in determining the stability of a slope. Slopes that do not meet the safe slope value require soil repair or soil reinforcement. Soil reinforcement effectively increases the safety factor of slope stability. Slope stability analysis uses a combination of several methods to develop effective soil reinforcement technique. Kassou et al. (2020) found the use of vertical drains in soil reinforcement can increase the factor of safety. Meanwhile, Fazelabdolabadi and Golestan (2020) developed a Bayesian framework for micro-scale quantification of porous structures to increase the factor of safety for slope stability.

In addition to direct techniques, indirect techniques and simulations have been developed for research on slope failures. Qiu et al. (2018) discovered that simulation and observation of local topography can enhance the safety factor of slope stability which significantly influences the size of the landslide area. Additionally, Wang and Xiong (2020) proposed a numerical analysis to establish a model of shear strength and determine the angle of inclination of reinforcement with anchors, which greatly affects the shear strength of soil slopes.

## The Comparison between the Methods used to Estimate the factors that affect the slope stability.

In slope stability analysis, the Limit Equilibrium method and the Finite Element method are available to use on Plaxis software. Adolphe et al. (2022) compared these two methods and found that the safety factor is overestimated in the Limit Equilibrium method compared to the finite element method. However, under certain conditions, Limit Equilibrium method is better. In addition, the simplified Bishop's method, among the Limit Equilibrium methods, provides the highest value of the factor of safety in most of cases being studied. This inconsistency should be further addressed.

## Method

The study was carried out at the canal landslide site in Bina Jaya Village, Jalan DIR Dadahup in the Central Kalimantan Province. The treatment done in this study comprised four stages; preliminary survey, soil investigation (including field and laboratory tests), analysis of the cause and treatment, and conclusion.

### a. Preliminary Survey

Field observation were conducted and secondary data were also collected to support the primary data. At this stage, preliminary information about the general characteristics of the landslide area, such as the location and size of the landslide, the type of landslide, and the possible causes of the landslide were collected. In this stage, the extent of the damage that has been inflicted in the area and other relevant information were examined.

### b. Soil Analysis

At this stage, the soil characteristics of the site were examined. Soil investigation was carried out through Sondir test and deep drilling tests in addition to the NSPT test. Soil samples were collected from different depths through deep drilling. The data were then analyzed in the laboratory. The data obtained from both the field and laboratory tests served as the primary supporting data for the analysis of the slope stability and determination of the appropriate solution to the problem.

**c. Analysis of Factors Causing the Landslide**

PLAXIS software was used to calculate the slope stability factor. Several slope stability simulations were carried out to examine the initial slope stability, reinforcement of the slope stability, and slope stability after the construction of the Watergate.

The PLAXIS software helped the researcher to analyze the slope safety figures using the following equation (Liu et al., 2014).

$$SF_{slope} = \frac{\tau}{\tau_d}$$

where :

SFslope is the factor of safety for slope stability, τ is the available soil shear strength, and τd is the pushing force of the soil that slides.

The minimum safety factor value refers to the guidelines of SNI No.8460 of 2017 concerning Geotechnical Design Requirements as follows.

Table 1 Safety Factor Value for Slope

| Biaya dan konsekuensi dari kegagalan lereng | Tingkat ketidakpastian kondisi analisis | |
|---|---|---|
| | Rendah[a] | Tinggi[b] |
| Biaya perbaikan sebanding dengan biaya tambahan untuk merancang lereng yang lebih konservatif | 1,25 | 1,5 |
| Biaya perbaikan lebih besar dari biaya tambahan untuk merancang lereng yang lebih konservatif | 1,5 | 2,0 atau lebih |

[a]Tingkat ketidakpastian kondisi analisis dikategorikan rendah, jika kondisi geologi dapat dipahami, kondisi tanah seragam, penyelidikan tanah konsisten, lengkap dan logis terhadap kondisi di lapangan.

[b]Tingkat ketidakpastian kondisi analisis dikategorikan tinggi, jika kondisi geologi sangat kompleks, kondisi tanah bervariasi, dan penyelidikan tanah tidak konsisten dan tidak dapat diandalkan.

In reference to SNI 8460 of 2017, the required factor of safety for soil slope stability analysis is shown in Table 1. The cost of the project and the potential consequences of slope failure under varying degrees of uncertainty was also included. According to conference, the minimum value for the slope stability factor was set at SF = 1.5.

In addition, at this analysis stage, the slope modeling was proposed based on the measurements of the geometry of the slopes in the field, and used a road traffic load of 12 kN/m2. This is based on recommendations from the DPU (2001) as follows:

Table 2 The Traffic Burden of the Stability Analysis (DPU, 2001) and Non-road Stability

| Kelas Jalan | Beban lalu lintas (kPa) | Beban di luar jalan [(*)] (kPa) |
|---|---|---|
| I | 15 | 10 |
| II | 12 | 10 |
| III | 12 | 10 |

Keterangan: [(*)] Beban dari bangunan rumah-rumah sekitar lereng

**d. Concluding Stage**

The data from the soil investigation results and the results of the analysis and handling of slope failures, conclusions are drawn as follows.

**Results and Discussions**

1. **Data Interpretation and Soil Investigation**

Soil investigation using deep drill and NSPT test and Sondir tests were conducted successfully. Table 3 and Figure 3 describe the soil for the study location. Based on Table 3 and Figure 3, the soil at the study site is dominated by soft clay from the ground surface to a depth of 20 meters. At further depths, a layer of sandy loam of medium consistency was found. moderate consistency up to a depth of 26 m. Meanwhile, dense sand and highly dense composition started at the depth of 26 meters.

Table 3 Description of the Land Around the Site

| Kedalaman (m) | Deskripsi | Konsistensi |
|---|---|---|
| 00.00 - 11.40 | Lempung | Sangat Lunak |
| 11.40 - 11.80 | Lempung berpasir | Lunak |
| 11.80 - 16.80 | Lempung | Lunak |
| 16.80 - 17.20 | Lempung berpasir | Lunak |
| 17.20 - 19.60 | Lempung | Lunak |
| 19.60 - 21.20 | Lempung berpasir | Sedang |
| 21.20 - 24.40 | Lempung | Sedang |
| 24.40 - 24.60 | Lempung berpasir | Sedang |
| 24.60 - 25.00 | Pasir berlempung | Lepas |
| 25.00 - 25.40 | Pasir berlempung | Sedang |
| 25.40 - 26.00 | Pasir | Sedang |
| 26.00 - 26.80 | Pasir | Padat |
| 26.80 - 27.00 | Pasir | Sangat Padat |

Source : Soil Investigation Report (2021)

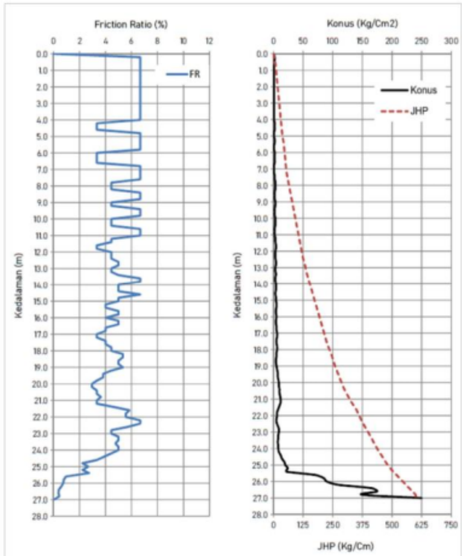


Figure 3 Sondir Graph

## 2. Stability Analysis

Prior to the stability stability using Plaxis software, it was essential to develop a slope geometry model based on field measurements (as depicted in Figure 4) and utilize soil parameters derived from both field investigations and laboratory test results (see Table 4). The result of the Plaxis calculations, as shown in Figure 4, the resulting deformation and factor of safety do not meet the slope stability safety requirements (SF < 1), implying that the slope is susceptible to sliding.

Table 4 Summary

| Layer | Jenis Tanah | Kedalaman (m) | | | NSPT | Undrained (kN/m2) | | | Drained (kN/m2) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Cu | ϕ | Eu | c' | ϕ' | E' |
| 1 | Lanau Abu Abu | 0 | - | 15 | 1 | 5 | - | 500 | - | - | 300 |
| 2 | Pasir halus | 15 | - | 25 | 8 | 35 | - | 5000 | - | - | 3000 |
| 3 | Pasir halus | 25 | - | 30 | 34 | - | 25 | 18000 | - | 35 | 10800 |
| 4 | Pasir berlempung | 30 | - | 40 | 29 | 100 | 30 | 16000 | - | 30 | 9600 |

At the site, the canal bottom and slopes are predominantly composed of soft clay soil. Soft clay soil has a low shear strength which reduces the soil's ability to retain slope's stability. Due to the soil's weight, gravitational force usually causes the soil mass to move towards lower elevations. Moreover, in this study, the landslide slope was also influenced by the vibrations and load of vehicles, as well as the excavation of canals for the sluice gate area, which further compromised the slope's stability.

If we look at the characteristics of the soil in the study location, especially in the area of the canal bottom and canal slopes, it is dominated by soft clay soil. The nature of soft clay is that it has a small shear strength. If this is related to the conditions in the field, the ability of the soil mass to hold on to the slope is very low. Soil masses tend to move to the lowest elevation following the gravitational force due to the soil's own weight. Especially in this study where the position of the landslide slope was also triggered by the load and vibration of the vehicle, as well as the digging of canals for the area of the sluice gate.

In a similar case, Vannee Sooksatra and Pawinee Jinga (2016) indicated that the reduction in the shear strength of soil is attributed to an increase in water content and seepage force. This condition make s soft clay loses its strength, leading to a decrease in the safety factor of the flood embankment made of soft clay.

Jorge Yannie (2012) stated that factors associated with drained soil must be taken into consideration as well, especially in the transition from in-situ conditions to stable conditions after excavation. In addition, the nature of partially drained or undrained soil in the bottom area of the excavation according to the method and time of construction were demanded at high price,

The PLAXIS modeling illustration is shown in Figure 4 below, where the slope stability analysis was carried out under the actual conditions with certified that there were wooden reinforcements with a length of 4m, a diameter of 10cm, and a spacing of 30cm.

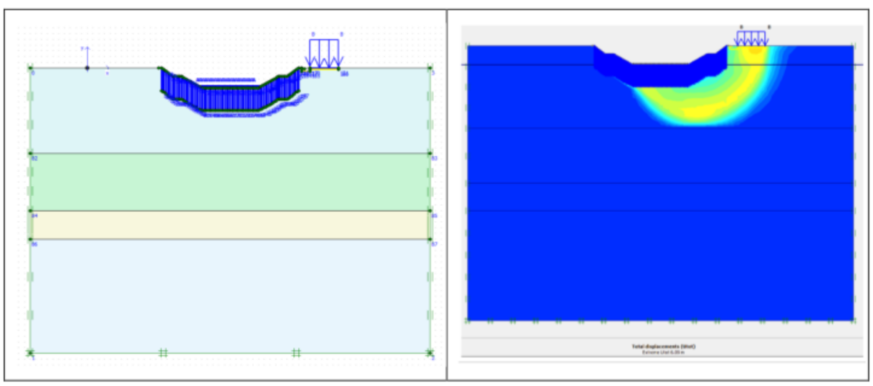

Figure 4 The Modelling and Output of Slope Stability Output in the Deformation era and the Factors related to Safety during the landslide SF<1 (Soil Body Collapse)

### 3. Landslide Management

The landslide management at the site vary, including the installation of sheet piles, installation of soldier piles, reinforcement with mini pilales, installation of geotextile walls, sloping slopes, and others. As seen from the consideration of considerations, in this study the handling of landslides is by using plaster or sheet pile. The type of sheet pile chosen is type GU 18-400 steel material with the following specifications:

| Section | Width | Height | Thickness | | Sectional area | Mass | | Moment of inertia | Elastic section modulus | Static moment | Plastic section modulus | Class[1)] | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | b mm | h mm | t mm | s mm | $cm^2/m$ | kg/m of single pile | $kg/m^2$ of wall | $cm^4/m$ | $cm^3/m$ | $cm^3/m$ | $cm^3/m$ | S 240 GP | S 270 GP | S 320 GP | S 355 GP | S 390 GP | S 430 GP | S 460 AP |
| **GU sections** | | | | | | | | | | | | | | | | | | |
| **GU 7-600** | 600 | 309 | 7.5 | 6.4 | 100 | 47.0 | **78** | 11350 | **735** | 435 | 890 | 2 | 2 | 3 | 3 | - | - | - |
| **GU 8-600** | 600 | 309 | 8.5 | 7.1 | 110 | 51.8 | **86** | 12690 | **820** | 485 | 995 | 2 | 2 | 2 | 2 | - | - | - |
| **GU 9-600** | 600 | 309 | 9.5 | 7.9 | 121 | 57.0 | **95** | 14060 | **910** | 540 | 1105 | 2 | 2 | 2 | 2 | - | - | - |
| **GU 12-500** | 500 | 340 | 9.0 | 8.5 | 144 | 56.6 | **113** | 19640 | **1155** | 680 | 1390 | 2 | 2 | 2 | 2 | - | - | - |
| **GU 13-500** | 500 | 340 | 10.0 | 9.0 | 155 | 60.8 | **122** | 21390 | **1260** | 740 | 1515 | 2 | 2 | 2 | 2 | - | - | - |
| **GU 15-500** | 500 | 340 | 12.0 | 10.0 | 177 | 69.3 | **139** | 24810 | **1460** | 855 | 1755 | 2 | 2 | 2 | 2 | - | - | - |
| **GU 16-400** | 400 | 290 | 12.7 | 9.4 | 197 | 62.0 | **155** | 22580 | **1560** | 885 | 1815 | 2 | 2 | 2 | 2 | - | - | - |
| **GU 18-400** | 400 | 292 | 15.0 | 9.7 | 221 | 69.3 | **173** | 26090 | **1785** | 1015 | 2080 | 2 | 2 | 2 | 2 | - | - | - |

The moment of inertia and section moduli values given assume correct shear transfer across the interlock.

The aforementioned plaster specifications are used in slope modeling with reinforcement in the Plaxis software. In the initial modeling attempt, the sheet pile length was set to only L=12m. Figure 5 illustrates the outcome of the slope stability analysis calculation with reinforcement utilizing a 12m long sheet pile. The results demonstrate that the safety factor remains below 1.0 (SF <1.0), indicating that there is still a potential for further slope failure.

This condition occurs because the deposit of soft clay found in the study area is quite thick and exceeds the planned sheet pile length. This condition resulted that the sheet pile construction with a length of L=12m was unable to provide resistance to the thrust that caused the avalanche that occurred. The thrust value of the avalanche that will occur is greater than the opposing force value generated by the sheet pile construction L=12m. As explained by Yannie (2012), that the length of the sheet pile embedded in the soil greatly affects the stability of the slope, where if the penetration of the sheet pile is close to the excavation hole, the shear strength of the soil in that area has decreased significantly, then the safety factor does not produce a value that meets the safe requirements.

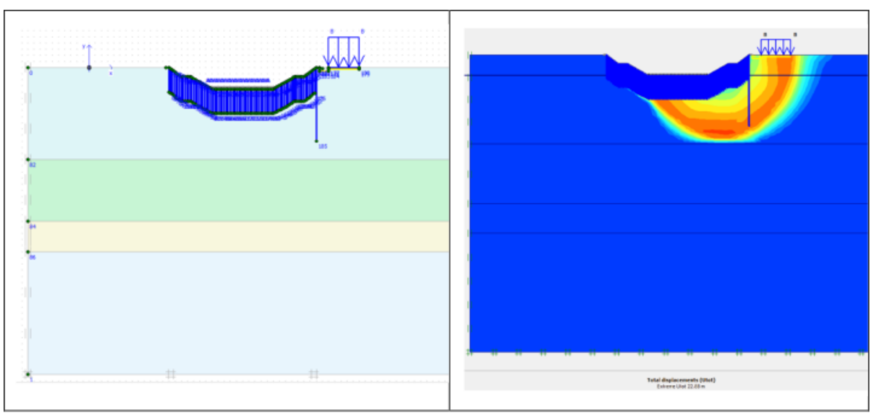

Figure 5 Permodelan dan Output Pada Plaxis Menggunakan Sheet pile L=12 m

Figure 6 displays the outcome of the Plaxis modeling for slope stability analysis utilizing sheet pile reinforcement with a length of L=18 meters. By providing sheet pile reinforcement with a length of L=18 meters to the slopes at the study site, the safety factor for slope stability would increase to SF=2.1>1.0. This indicates that the slope's stability with sheet pile reinforcement (L=18m) is secure, averting the risk of slope failure.

According to Kurniawan et al (2017) that slopes reinforced with sheet pile can significantly increase the safety factor of slope stability. This is because the slope loads and slope forces received will be resisted by the sheet pile reinforcement. Sheet pile reinforcement has the ability to cut off the slip circle from the failure plane that occurs.

The increase in the safety factor for slope stability after being reinforced with a long sheet pile of L=18m indicates that the sheet pile construction generates a greater opposing force than the thrust that displaces the slope. A sheet pile length of L=18m satisfies the requirement to intercept the slope failure circle that may occur. Figure 6 displays a different deformation pattern from those in Figures 7 and 8. The deformation pattern in Figure 7 appears more sloping, and the critical slump circle has been intercepted by an appropriate sheet pile length.

Sheet pile is designed to resist soil pressure laterally (horizontally) since the change in soil height, that exceeds the internal shear angle. The lateral earth pressure behind the retaining wall depends on the angle of friction in the soil (φ) and cohesion (c). Lateral pressure price increases from the top to the very bottom of the retaining wall. If not properly planned, soil pressure will push the retaining wall causing construction failure and landslides (Hastuty, et al 2018 and Roesyanto, et al, 2018)

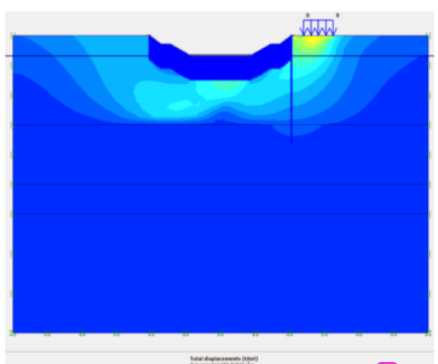

Figure 6. The Output Sheet pile walls are specifically designed to resist lateral (horizontal) soil pressure that occurs when there is a change in soil height that exceeds the internal shear angle.

The amount of lateral earth pressure exerted on the retaining wall is determined by the angle of friction in the soil (φ) and the cohesion (c). As the height of the retaining wall increases, the lateral pressure on the wall also increases. If the retaining wall is not properly planned and constructed, the soil pressure may cause the wall to fail, leading to potential landslides (Hastuty et al., 2018; Roesyanto et al., 2018).

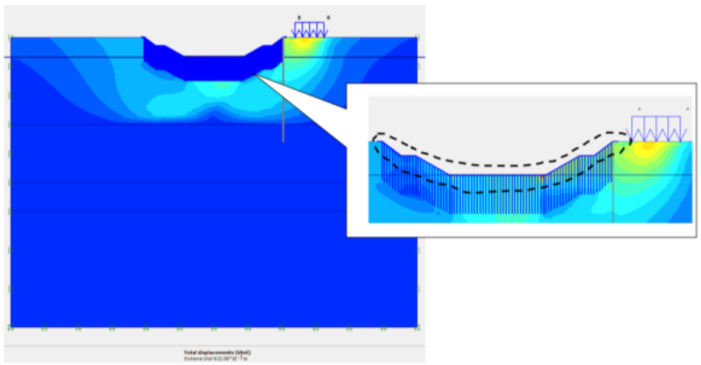

Figure 7 Slope Stability with Sheet Pile Reinforcement Revoked and in the Slope Area There is already a Floor Plate / Stairs Strengthening with a safety factor SF = 1.4

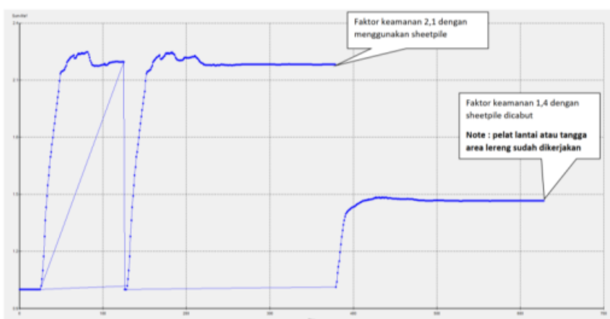


Figure 8 The Curve of the Slope Stability and Safety

**Conclusion**

The thick soft clay deposit is one of the factors that trigger canal avalanche in Dadahup Irrigation System in Central Kalimantan Province. This soft clay has small shear strength and it slides easily if there is a trigger. Slope reinforcement using sheet pile with a stake length of 18 meters was determined as the effective method in the landslide management at this site. The sheet pile reinforcement has been able to increase the value of the safety factor for slope stability which exceeds the minimum requirements for the safety factor based on the SNI 8460 of 2017.

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