# Landslide potency at Trangkil, Gunung Pati based on the groundwater flow pattern and the value of safety factor

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# Landslide potency at Trangkil, Gunung Pati based on the groundwater flow pattern and the value of safety factor

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**Abstract.** One of strategic approaches in landslide disaster mitigation atTrangkilsettlement area, Gunungpati, Semarang is through the prevention of soil and rock saturation. The investigation of soil and rock saturation is determined based on the shallow groundwater flow pattern and the value of safety factor.The location which prone to landslide on the eastern part with slower groundwater flow is reinforced by the rock characteristic's analysis result which show its permeability value is 8.8 x $10^{-7}$ cm/s. The slow groundwater flow withinin the loam lithology makes the rock mass is greater, while its lithology could rests on an impermeable claystone. This condition makes the incompact silty loam and peeble mass could easily slide along the claystone surface and based on the analysis of rock characteristic's result on the eastern part, the permeability value is smaller than on the western part. The value of safety is 1.372 indicates that the eastern part is an area prone to landslide.

**Keyword** : Groundwater Flow, Landslide, Trangkil

## 1. Introduction

The study observed that the morphology of the research location was an undulating hill area with slope ranging from 15$^{o}$ to 45$^{o}$. Structural landform unitdenudational step hill lithology constituent sandstones, conglomerates, carbonates clay, and breccia [1]

Geological factors will determine the vulnerability of the avalanche area. These factors are the topography is steep, rock types are volcanic young and not yet perfect compact, condition lithology relative has happened weathering strong, stratigraphy mutually alternating between rock impermeable (lava) with a layer of rock layers vulcanoes more, the number of discontinuous form of fracture / fault [2].

Unconfine water is a contributing factor to groundwater, leadingto the loss of land shift strength when it has been abandonedin the landslide area. Water saturation as the position of watertable has a significant effect on the slope stability. Therefore, thisposition is important to find out the slope stability of particulararea.

Boundary equilibrium analysis is a method of equilibrium analysis of mass potentially moving down the slope by comparing the driving force and the holding force along the plane of the avalanche. The comparison of the two styles will result in an F (safety factor) value. In this study, the slope stability criteria in the equilibrium limit analysis were determined as follows: F value ≤ 1 shows the

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slope in unstable condition, while the F> 1 value indicates the slope in stable condition. Furthermore, a value of 1 <F <1.2 indicates a slope in critical condition and an F value of ≥ 1.2 indicates a slope in a safe condition [3][4]

Research was conducted to determine the landslide prone area by using groundwater flow method and the value of safety factor(F) was done in the residential area of Trangkil Gunung PatiSemarang.

## 2. Review of Literature

***a.*** *The Geology of Research Location*

The morphology of the research location, Trangkil Settlement, is part of undulating hill composed of tertiary sediment and quarter volcanic formation. Field observation and shallow drilling revealed that the area had three lithological units (Figure. 1.), i.e. clay, breccia, and granule-silt. The clay was located in the lowest stratigraphy layer with dark gray, compact, fairly soft, and breakable features. The breccia unit was characterized by dark gray color, medium-to-soft sand matrices, 5-30 cm fragments, and andesite. The granule-silt unit was characterized by browned-gray color, composed by gravel and clod features. According to the drilling data, the lithology was observed in a rather spreading condition, containing timber, waste, red brick, can, and suffering from erosion, in particular in the northeast direction. A geoelectrical analysis explains that such lithology has a thickness from 1 to 2 m in the north and 2-15 m in the south[5]. According to physical condition and lithological distribution, such gravel unit is caused by a landfill during the land use for settlement.

The clay in the study area according to themegascopical appearance is gray color, clay-sized grain (<1/256 mm), contain carbonaceous cement as it emits foam while dropped by HCL, severe weathering condition. This rock distributesabout 10% located at the east of study area. This unit is exposed beneath the volcanic breccia close to seasonal riverwhich only filled during the rainy season. Clay is an impermeable rock due to its inability to passing through water which may lead to landslidesurface and cause landslide.

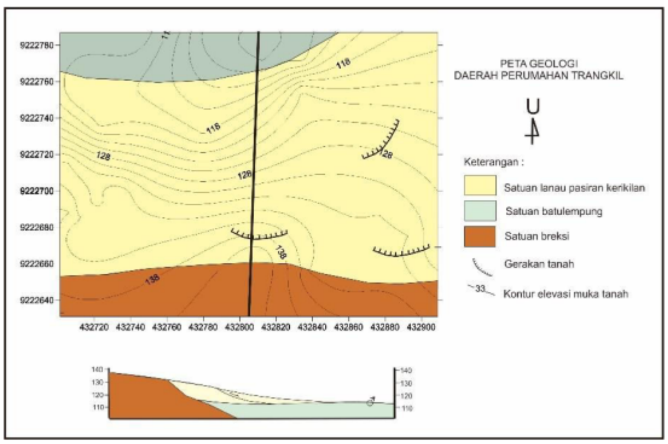


**Figure 1.** The Geology Map ofTrangkil Residence [6]

***b.*** *The Analysis of Slope Stability*

The safety factor (F) of the slope can be calculated by various methods. The landslide with slip surface, F can be calculated by slicemethod according to Fellenius or Bishop. The required data to find the value of F as follows:

a. Slope data(required particularly for making cross-section slope) which includes: slope angle, slope height, or slope length from each slopes.
b. Soil mechanics data
   - deep sliding angle (φ; degree)

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- unit weight of wet soil content (γwet; g/cm$^3$ or kN/m$^3$ or ton/m$^3$)
- cohesion (c; kg/cm$^2$ or kN/m$^2$ or ton/m$^2$)
- groundwater content (ω; %)

The soil mechanics data should be taken from undisturbed soil sample. The groundwater content ( ω ) is required mainly in the computer-based calculation (mainly when it requires γdry data or unit weight of dry soil content), i.e. : γdry = γ wet / ( 1 + ω ). On the slope which affected by the groundwater levelthe value of F (by the slice method, Fellenius) as follows:

$$F = \frac{cL + \tan\phi \sum(W_i \cos\alpha_i - \mu_i \times l_i)}{\sum(W_i \sin\alpha_i)}$$

c = cohesion (kN/m$^2$)
φ = deep sliding angle (degree)
α = the slip surface angle on each incisions (degree)
μ = pore water pressure (kN/m$^2$)
l = the slip surface length on each incisions (m);
L = the total number of the slip surface length
$\mu_i$ x $l_i$ = pore water pressure on each incisions (kN/m)
W = the width on each incisions (m$^2$)
Based on the researches and thorough studies of the slope's collapse, it is subsequently divided into 3 groups of Safety Factor (F) in terms of the landslide intensity [7],

**Table 1.**The Correlation between the value of Slope Safety Factor and Landslide Intensity:

| The Value of Safety Factor | Landslide Occurrence / Intensity |
|---|---|
| F<1,07 | Landslide occur regularly/often (unstable slope) |
| 1,07 < F < 1,25 | Landslide occur once before (critical slope) |
| F>1,25 | Landslide rarely occur (relatively stable slope) |

The degree of landslide vulnerability is also affected by the groundwater position against the slip surface, if the groundwater level is above, the soil will be saturated and heavier so that the safety factor decreases.

***c.*** *The Flow of Shallow Groundwater*
The groundwater level has high influenceon the slope stability. Therefore, the groundwater position is very important to discovering the slope stability at certain area.

Groundwater is water flowing between the spaces of soil grains or rock's fractures and filling it in. Groundwater flow includes in a series of hydrological cycle's process. The main source of groundwater is infiltrated rainwater, minus evaporation from the soil surface and transpiration.

The existence of groundwater is highly dependent on the nature of the underlying rock layers. A layer of rock which is easily passed by water is called 'permeable layer', consists of loose rocks, namely gravel or sand. This layer is also referred as 'aquifer layer'.

The layer which unable to be passed by water is called 'impermeable layer' or 'aquitard layer' consists of clay-textured soil. The existence of these different layers resulted in differences of water storage.

The areas which containconsiderable amount of groundwater (aquifers) are alluvial plain, inter-volcano areas, limestone areas, and delta/sandbanks. In coastal areas, freshwater water is often found on the former coastal shelf or natural embankment (natural levee). This land is usually used for residential areadue to itsavailability of fresh shallow groundwater.

Naturally, the groundwater level will fluctuate but remain in a balanced state. Fluctuation on the groundwater surface occur because of :

- The groundwater's extraction activities for household, industry, and agriculture consumption

- The seasonal change, on the rainy season the water levels is arising, but on the dry season it tends to declining gradually.

Groundwater has main role to the existence, on the other hand it can also trigger the occurrence of landslide at various locations.

## 3. The Method of Research

The research was conducted by composing (1) geological map of research area, The result is presented in a geological map which provides an overview or information about geological conditions including geomorphology, stratigraphy, lateral-vertical spreading and clustering, weathering, seepage symptoms and fracture pattern analysis (2) creating a groundwater flownet's map based on shallow groundwater's map, and determining the flow direction of shallow groundwater, (3) determining the value safety factor of landslide vulnerability. By analyzing the physical properties of rocks in the laboratory, the permeability, cohesion and sliding angle are known can be further used to determining the value of safety factor, this value is used to determining the vulnerable areas.
Overall, this method is described in the diagram as in Figure 2.

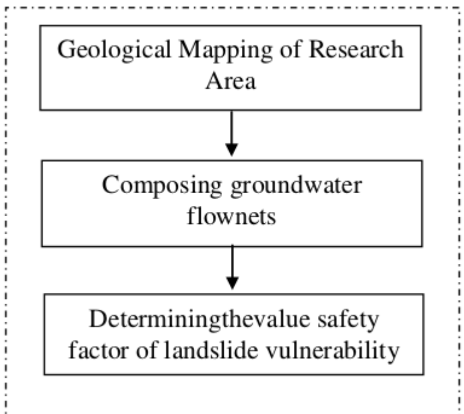


**Figure 2.**Research's Stages

## 4. Discussion

*a. Groundwater flow pattern and landslide prone locations*

Locations of the former land movement area in the past and signs of the potential landslides are illustrated in Figure. 3. One part in the middle-south and two parts in the west were considered landslide prone. The field observation proved that the land movement as lengthened cracks was in a curvy form. Such symptom was mostly found in the west, which had a slow groundwater flow. The slow groundwater flow in the clayey silt lithology cause greater rock mass weight, while this clay depends on impermeable clay. Such condition made the non-compacted clayey silt with granulelithology to be easy to slide following the clay rock surface (Figure. 3.). In rainy season, water absorb into the water through the existing cracks, downward to the surface of the clay, causing stronger water flow. Erosion then occurred in the rock mass above the unit. The increase in water content will weaken the physical-mechanical properties of the soil and decrease the value ofSafety Factor [8].

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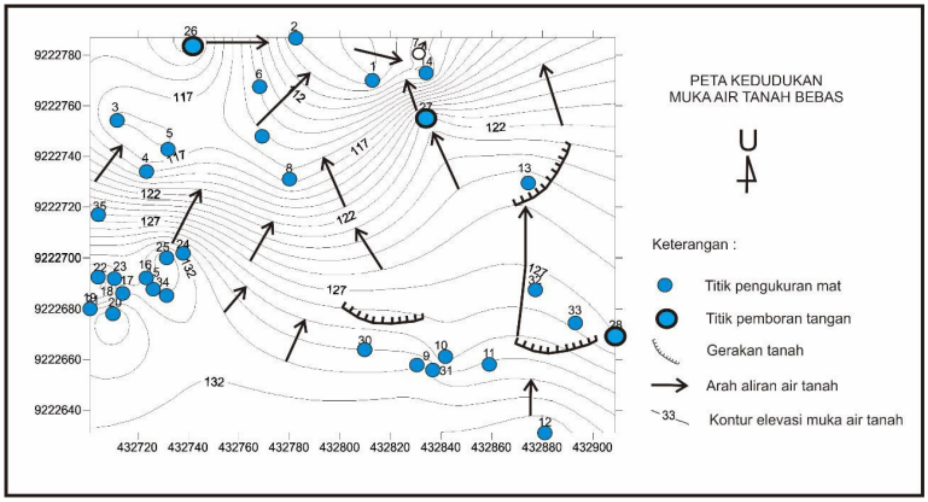


**Figure 3**. Unconfined groundwater flownet in the research area

*b. The Analysis of Rock's Technical Properties*

Based on data analysis of mechanical soil laboratory, the upper lithology of study area is clayey siltwith permeability 8,8 x $10^{-7}$ cm/secon the eastern part and clayey silt with sand has permeability 4,5 x $10^{-4}$ cm/sec western part. Great permeability on the western part indicates that the ability of rocks to passing through water is greater than the eastern part. This supports the groundwater flownet above that is the western partthe waterflows more swiftly than the eastern part. The small permeabilityon the eastern part cause the water within is difficult to passing through, thus increasing the load and increasing the occurrence of landslide.

Data on the technical properties at the upper part shows that the western part has cohesion 0,28 kg/cm2 with deep sliding angle 18°, while the eastern part is 0,11 kg/$cm^2$with deep sliding angle 26°. Analysis of slope stability with value F >1,5 means there isn't any landslide occurance with the slope result 43 %, the safety value on the western part is1,772 (Figure4.) which means landslide has not happened yet. While on the eastern part with the same slopes provide safety value 1,372 (Figure 5.) which indicates an immediate occurance of landslide. The value of the Safety Factor (F)> 1.25 on a slope is interpreted as a slope with an avalanche rare or is referred to as relatively stable [7]. To mention a stable slope, a safe boundary value should be set other than F = 1.25, since it indicates that landslide events have occurred (though rarely). It is proposed that the value of F> 2 as a safe value for the slope (stable slope). As a comparison, the value of F = 2 or F = 3 is usually used for the safe value (safety factor) for soil carrying capacity for various shallow foundations.

The value of F can be attributed to a decreased holding force or / and increased driving force.The holding strength of the slope body may decrease due to rising ground water content. Groundwater levels increase due to increased rainfall [9].

The analysis is conducted bytaking the groundwater sample under the landslide surface. It will become more vulnerable if the groundwater level is over the landslide surface, due to its soil saturation and become heavier. Based on the description, on the eastern part is very vulnerable to landslide.

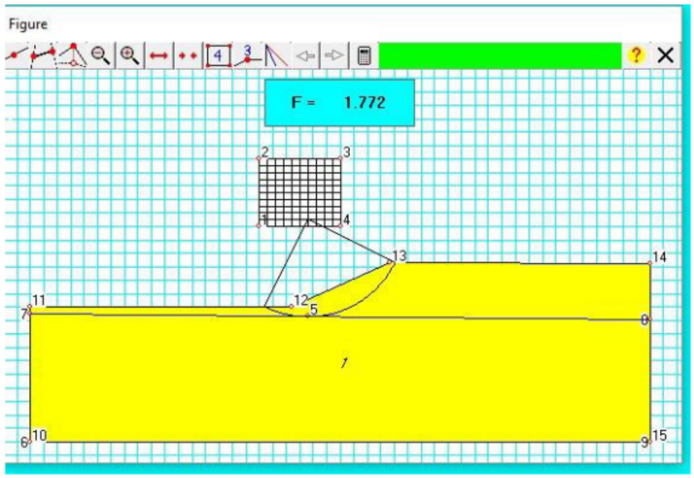


**Figure 4.**The analysis result of slope stability on the western part shows SFvalue 1,772 which meansthere isn't any landslide occurance

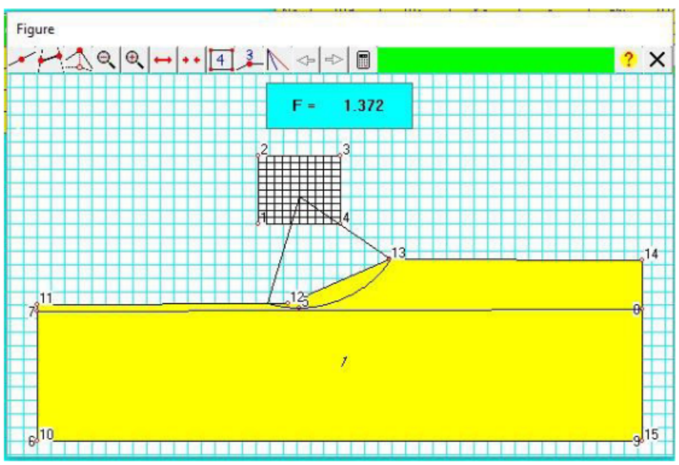


**Figure 5**. The analysis result of slope stability on the eastern part shows Fvalue 1,372 which means there is a landslide occurance

## 5. Conclusion

Unconfined groundwater at the study area which flows from south to north and from southwest to northeast which eventually into the springs. Taking into account the contour'sdensity, the flow on the western part is greater than on the eastern part. It meansthewestern partflows more swiftly. Upon the lithology of superficial drilling, it is seen that in the western part consists of silt, pebble, gravel has permeability 4,5 x $10^{-4}$ cm/sec. While the eastern part which tends to silty consistency and granuly sand with gravel has permeability 8,8 x $10^{-7}$ cm/sec, a great permeability on the western part indicates that the ability of rocks to escaping water is greater than the eastern part.

The potential location of larger ground movements is on the eastern part which its groundwater flows slowly. The slow groundwater flow in the lithology clayey silt makes the soil load greater, while it rests on the impermeable clay and thevalue of safety factor is1,372 shows that the area is prone to landslide. This condition makes the clayey silt with gravel masswill easily sliding along the clay surface.

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