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SLOPE STABILITY ANALYSIS USING GEOELECTRIC IN ROAD DUAPITUE DISTRICT, SIDRAP REGENCY

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Abstract

Research has been carried out on lanslide slip area of landslide of the road in Duapitue Sidrap. This study aims to determine the slip field using geoelectricity which is suspected as the cause of slope stability / landslide disturbance in terms of resistivity values in each layer and to determine the structure and coating of subsurface soils in the Kampale sub-village, DuaPitue. Information about the structure and coating of the land is used to determine the limits of soil instability that can be used as a reference in the planning of cliff / slope strengthening on the intended road. From the cross section of the material resistivity, it can be seen that the weak zones on the shoulder and the road body are more than 10 meters deepth. Most of the overburden is unconsolidated fill material, covered by alluvium material with a fairly large air composition with a thickness of 5-10 meters. Slip area of lanslide formed at an average depth of 12 meters between the weak zone of the embankment material layer and the water-saturated alluvium layer with relatively solid alluvium and sandstone material beneath it.

Keywords: slope stability, slip field, geoelectric and lithology

A. Introduction

Population growth and economic development in Sidrap Regency are rapidly increasing, requiring the government to prepare and organize transportation infrastructure so that regional resources can be utilized optimally. One of the infrastructure development activities on the road in Kampale Hamlet, DuaPitue Subdistrict, requires further investigation to overcome the problem of soil stability, and the symptoms of soil movement on the road section. In principle, the stability of the soil is disturbed when the driving force on the slope is greater than the holding force. Retaining forces are generally influenced by rock strength and soil density. While the driving force is influenced by the magnitude of the slope angle, water, load and density of rock soil.

Factors causing landslides include rain, steep slopes, less dense and thick soil, less strong rocks, type of land layout, vibration, lake or dam water level shrinkage, additional burden, erosion/erosion, presence of pile material on cliffs, old landslides, and discontinuity areas. Several methods can be used in assessing landslide problems such as geophysical methods to identify slides, geotechnical methods to predict slope stability, GeoComputation methods (satellite imagery and overlays) for interpretation of landslide vulnerability, geochemical methods to identify clay content, and so on. (Souisa, Hendrajaya, & Handayani, 2018). In this study, a geoelectric method was used to determine the slip field suspected as the cause of slope stability/landslide disturbance in terms of resistivity values in each layer and to determine the structure and coating of subsurface soils in the Kampale sub-village, DuaPitue.

The geoelectric resistivity method is one of the geophysical methods that is used for various purposes to determine the description of geological conditions under the surface of the soil by utilizing the resistivity properties of rocks and shallow exploration activities (Santoso et al, 2015). In a previous study which done by Ardhi et al (2017) explained that several parameters can be used to analyze the stability of slopes, in this case, the study of the Kaliwadas limestone in Kaliwadas, Kebumen, Central Java, using several parameters including a) physical and mechanical properties of rocks consisting of weight weights, cohesion, and deep friction angles; b) groundwater level; c) earthquake vibration coefficient; d) Depth of fracture. Information about the structure and coating of the land is used to determine the limits of soil instability that can be used as a reference in the planning of cliff/slope strengthening on the intended road.

B. Methodology

1. Research Design

In this study using the geoelectric resistivity method. The geoelectric method that commonly used as one method in the geophysical to comprehend the nature of the flow of electricity in the earth by detecting it over the surface of the earth (Hendrajaya, 1990 in Firdaus et al, 2016). Surface detection involves measuring the potential, current and electromagnetic fields that occur both naturally and as a result of injecting currents into the earth. In this study, the discussion is devoted to the type of geoelectric resistivity method. In the geoelectric resistivity method, an electric current is injected into the earth through two current electrodes (located outside the configuration). The potential difference that occurs is measured through two potential electrodes in the configuration. From the results of current measurements and potential differences for each particular electrode distance, it can be determined variations in type of resistance of each layer below the measuring point. Information about the structure and coating of the land is used to determine the boundaries of soil instability that can be a reference in the development of the regions, especially roads in Duapitue Subdistrict, Sidrap Regency.

2. Instruments

The tools used in this study consist of field measurement tools and data processing tools. Field measurement tools consisting of:

a. S-Field automatic multichannel tool used to measure currents and electrical potential differences.

Figure 1. S-Field automatic multichannel resistivity tool

The virtue of the tool:

1) Full automatic measurement for 1D (sounding), 2D and 3D (profiling) data
2) Output 2D file format is compatible with Res2Dinv software
3) Multi electrodes (standard 16 electrodes and can be increased to 32/64/128 multiples of 16 to 1000 electrodes)

4) Current 100 mA (current sources)
5) Data stored in ASCII format is compatible with Res2Dinv software
6) Long-life battery
7) Anti-short circuit
8) Field settings are controlled by a Laptop PC
9) It can be used for sounding measurements or profiling/resistivity mapping

b. The S-Field instrument can be upgraded with two geological Induced Polarization / IP Hammer gauges, used to install stakes and electrodes into the ground.
c. Hydraulic Drill for underground rock sampling per meter to a specified depth.
d. Numbered bamboo stakes are 16 pieces, used to determine the distance that has been measured.
e. 12-volt battery (dry element), as a current source.
f. Roll Meter, used to measure distances.
g. As many as 16 electrodes, used as a conductor of current and potential difference
h. The cable chain is set per 7 meters, used to flow current into the ground.
i. Compass, used as a determinant of the measurement trajectory
j. Connecting cable, used as a connector between the resistivity and the battery
k. GPS (Global Positioning System) is used to measure the coordinates of the starting point and endpoint
l. Writing stationery, used to write the measurement results into a prepared table
m. Digital cameras, used for shooting when conducting data acquisition in the field

Data Processing Tools

The tool used for data processing is a set of computers with some supporting software for data processing, namely the excel, notepad, re2DinV, ArcGIS programs. This research was conducted in two stages, namely the fieldwork phase and the post-work field stage.

a) Field Work
   i. Preparation phase
      In conducting data acquisition in the field, a free test/calibration is carried out on the equipment.
   ii. Geoelectric Data Collection
      Geoelectric data retrieval using the following procedure:
      1) Determination of measurement locations on the field map
         Noteworthy here are geological, topographic, and other factors related to research.
      2) Placement of measurement point locations in the field
         The measurement points that have been determined on the field map are correctly located. In determining or placing the measurement point is attempted on a horizontal or sloping surface and has a straight path.
      3) Data acquisition in the field or resistivity measurement:
      a) Determine the representative position for geoelectric measurements and plots using GPS, then record the measurement time and position.
      b) Plugs 16 electrodes into a fixed position. The electrodes are plugged by hammering them into rocks/soil until they are about 5-10 cm high.
      c) Each electrode is given a distance under the desired depth (meters) with other electrodesIn this study used 7 meters of space.
      d) Install a cable that has been set per 7 meters on each electrode that has been plugged into the ground. Then connect to a PC and geoelectric device for data retrieval.
      e) Then connect the geoelectric device to the battery as a source of electric current.
      f) Pinch / tie each cable to the electrode which has been electrically charged.
      g) Connect the USB on the battery to the computer, then run the software "GEORES" on the computer to conduct data acquisition.
      h) Furthermore, it is included in the data processing.

b) Post-Field Work

This stage includes determining the value of geometric factors (K), resistivity (R), and apparent resistivity (Pa) as well as data analysis for map-making and final report preparation. The data is processed based on a predetermined formula while the subsurface section is created using Res2DinV Software. From the results of data analysis, geological structure, rock stratigraphy, and groundwater distribution will be obtained in the form of a map. In this case, the processing will be fully carried out using the software. Some things done in this regard are: At this stage, the data obtained must be processed first by using Microsoft Excel so that the values of geometric factors, type resistivity, apparent resistivity, in the form of text files will be used as input to the next process using Res2DinV or Res3DinV. The steps of data analysis using Excel are as follows:

1) Activate the excel program on the computer
2) Copy and paste the results of.DAT data from the geoelectric data storage folder on the PC to Excel.
3) Analyze the numbers displayed, make sure all data columns are filled.
4) Save back to the.DAT or TEXT data form.

After the data file field is contained in a text or.DAT file and follows the Res2DinV data format, then an inverse is performed to display the subsurface cross-sectional image of the survey area. After the field data file is contained in the text file or. DAT and follow the Res2DinV data format, then the inverse is performed to display cross-sectional images below the surface of the survey area.

3. Technique of Data Analysis

The interpretation of this data analysis is carried out from some field analysis data in the 2D inversion geoelectric cross-section of mathematical calculations performed in Res2DinV or Res3DinV software. The results of this interpretation are presented in the form of cross-section type resistors, and geoelectric interpretation of type resistors, as well as maps of the slip field analysis of the subsurface lithology arrangement at the measurement location. 2D inversion results are analyzed based on the resistivity value. The variations in earth material resistivity are shown in the following table:

Table 1. Variations in Earth Material (Rocks) (Santoso 2002: 108)

Materials	Resistivity (Ωcm)
Air (on earth)	$2 \times 10^6 - 5 \times 10^7$
Water	
Distillation	2×10^7
Surface	$3 \times 10^3 - 10^5$
Mining	$40 - 6 \times 10^4$
Sea	21
Copper	
Pure	1.7×10^{-6}
Ore	0.1
Iron	
Pure	10^{-5}
Meteorite	3×10^{-4}
Mineral	
Calcite	5.5×10^{15}
Galena	0.001 – 0.25
Magnetic	0.008 – 0.5
Pyrite	0.002 – 9
Quartz	4×10^{12}
Saltstone	$10^4 - 10^7$
Sulfure	$10^{14} - 10^{17}$
Rocks	
Granite	$5 \times 10^5 - 10^9$
Gabro	$10^5 - 10^8$
Gneis	$2 \times 10^7 - 10^9$
Schist	$10^3 - 3 \times 10^9$

Materials	Resistivity (Ωcm)
Limestone	$6 \times 10^3 - 3 \times 10^5$
Sandstone	$10^2 - 10^5$
Shales	$2 \times 10^3 - 10^5$
Clay and Soil	$10^2 - 10^6$

Table 2. Resistivity of igneous and metamorphic rocks (Telford et al. 1976: 454)

Rocks	Resistivity (Ωm)
Granite	3×10^2 - 10^6
Granite porphyry	4.5×10^3 (wet) – 1.3×10^6(dry)
Feldspar porphyry	4×10^3 (wet)
Albite	3×10^2 (wet) – 3.3×10^3 (dry)
Syenite	$10^2 - 10^6$
Diorite	$10^4 - 10^5$
Diorite porphyry	1.9×10^3 (wet) – 2.8×10^4 (dry)
Porphyrite	10 – 5×10^4 (wet) – 3.3×10^3 (dry)
Carbonatized porphyry	2.5×10^3 (wet) – 6×10^4 (dry)
Quartz porphyry	$3 \times 10^2 - 3 \times 10^5$
Quartz Diorite	$2 \times 10^4 - 2 \times 10^6$ (wet) – 1.8×10^5 (dry)
Porphyry (various)	60×10^4
Dacite	2×10^4 (wet)
Andesite	4.5×10^4 (wet) – 1.7×10^2 (dry)
Diabase porphyry	10^3 (wet) – 1.7×10^5 (dry)
Diabase (various)	20 – 5×10^7
Lavas	$10^2 - 5 \times 10^4$
Gabbro	$10^3 - 10^6$
Basalt	10 – 1.3×10^7 (dry)
Olivine norite	$10^3 - 6 \times 10^4$ (wet)
Peridotite	3×10^3 (wet) – 6.5×10^3 (dry)
Hornfels	8×10^3 (wet) – 6×10^7 (dry)

Table 3. Sediment rock resistivity (Telford et al. 1976: 455)

Rocks	Resistivity (Ωm)
Consolidated shales	20 – 2×10^3
Argillites	10 – 8×10^2
Conglomerates	$2 \times 10^3 - 10^4$
Sandstone	1 – 6.4×10^8
Limestone	50 – 10^7
Dolomite	$3.5 \times 10^2 - 5 \times 10^3$
Unconsolidated wet clay	20
Marls	3 – 70
Clay	1 – 100
Alluvium and sand	10 – 800
Oil sands	4 – 800

C. Findings and Discussion

1. Findings

This research was carried out in a landslide section in Kampale Hamlet, DuaPitue Subdistrict which shown in **Figure 2,** using the Geoelectric resistivity method on two trajectories of 150 meters each with a depth of 22 meters. Line 1 has a North-South direction with a zero-point stretch in the south direction, while Line 2 has a relatively east-west direction. The two fields intersect at the 90 meters stretch on field 1 and the 40 meters stretch on field 2.

The geological research area is composed of alluvium material which shown in **Figure 3**, which is river sediment with mud, clay, sand, and gravel/crust material. The thickness of alluvium deposits in areas ranging from a few meters to 150 meters. Roads in the study area are those that are prone to disturbance of slope stability due to being on the edge of a river bend (meander) which is very actively experiencing erosion, shown in **Figure 4**. Installation of slope reinforcement with gabions on the riverside becomes ineffective because there is still erosion through water insertion from under the gabion towards the inside of the gabion side, as well as due to water saturation on the road section due to the influence of rainwater. Both roadside and roadside contact are still in contact with the eroded river and river water. Through a cross-section of the resistivity, measurement results can be shown an estimate of the direction of the slip field. The resistivity value of the slip field is 150-1000 ohms with a depth of 12-15 meters it is estimated that this layer is sandstone.

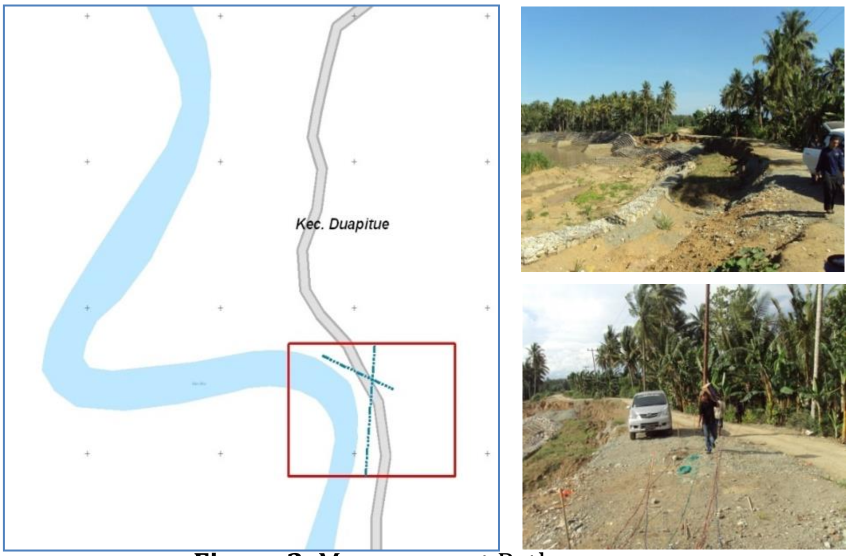


Figure 2. Measurement Path

Figure 3. The appearance of subsidence on the road of the study location

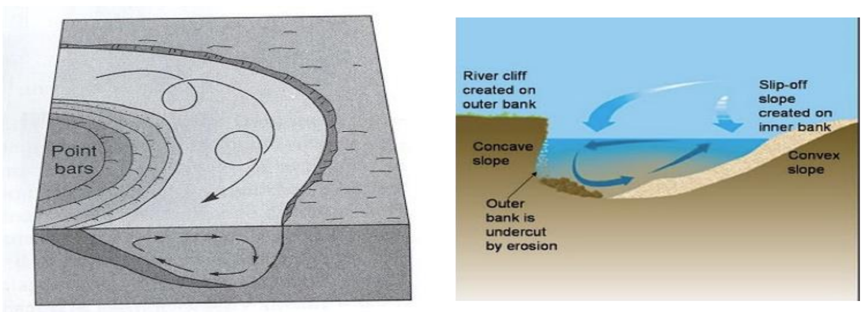


Figure 4. Erosion diagram of the Meander Riverbank
(Source: https://www.slideshare.net/Kaium3g/running-watergeomorhology-chapter)

2. Discussion

2.1 Crosssing Section in Track 1

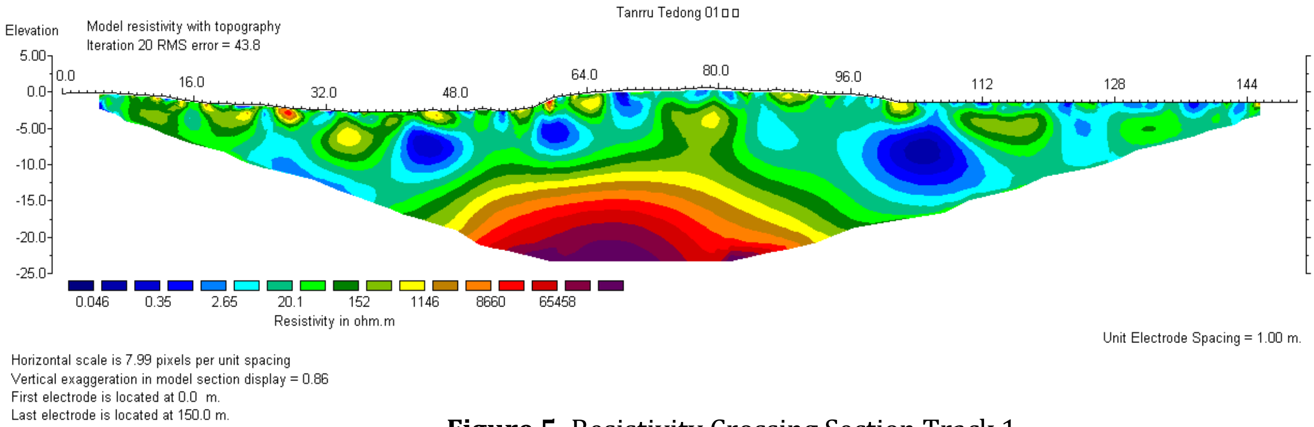
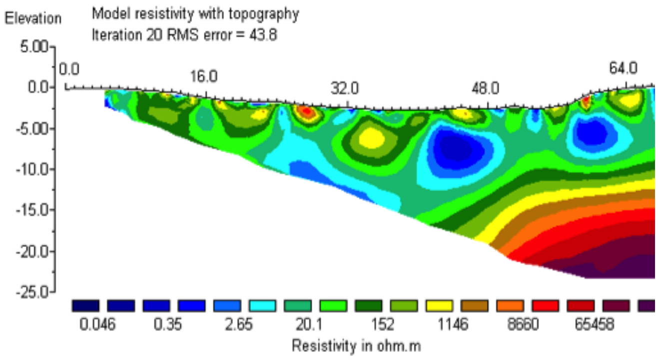


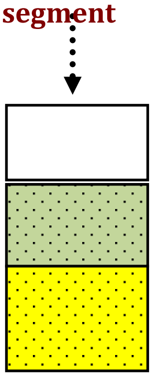
Figure 5. Resistivity Crossing Section Track 1

Resistivity value of the measurement results as shown in the cross-section shows that in the measurement path along the 150 meters south-to-north m (N 185 E), can be distinguished in 3 types of layers, as follows:

1. The first layer is a layer of loose material (unconsolidated) which is estimated to be a pile of material from alluvium, clay, sand, to hard rocks (granule, pebble, boulder). In the cross-section, it can be seen that this layer is in the form of pockets locally with the value of resistivity varying from 10 - 1000 ohm m. In some places also seen hard rock lumps with resistivity values of more than 1000 ohm m. This layer is at a depth of 0 - 5m. If it is focused on the segment where the subsidence occurs at a stretch of 6-60 meters, then the pile material layer is at a depth of 0-8 m, with an average thickness of 5 meters.
2. The second layer, the alluvium layer, wet clay, and sand, containing water in the form of bags with a fairly large dimension, namely with a stretch of 1-10 meters with a thickness of 1-10 meters. The layer resistivity value is at the value of 0.1-25 ohms m. This layer is generally located at a depth of 2-12 meters, at several places at a depth of 5-15 meters. In the subsidence segment (span 6-60m), this layer is at a depth of 5-15 meters, with a thickness of 5-10 meters.
3. The third layer, the alluvium and sandstone material layer which is relatively more compact, is the lowest layer which is in the vertical segment of this road section. This layer is shown with a resistivity value greater than 150-ohm meters. In the lowest layer up to more than 1000 ohm m. This layer is at a depth of under 10 meters. In the subsidence segment, this layer is below a depth of 12 meters.



Subsidence segment



Description

Unconsolidated/ Stacking Material: alluvial, clay, sand, to hard rock (granule, pebble, boulder), local pockets, the resistivity of 10 - 1000 ohm. The depths are 0-8 m, with an average thickness of 5

Alluvium, wet clay, sand: Indicated contains water locally with a sufficiently large dimension. The layer resistivity value is 0.1-25 ohm, with the depth are 5-15 meters, with a thickness of 5-10 meters.

Alluvium, sandstone: relatively compact, resistivity value greater than 150 ohms. Bottom layer up to more than 1000 ohm. The depth is over 12 meters.

Figure 6. Layers of rock in the subsidence zone Track 1

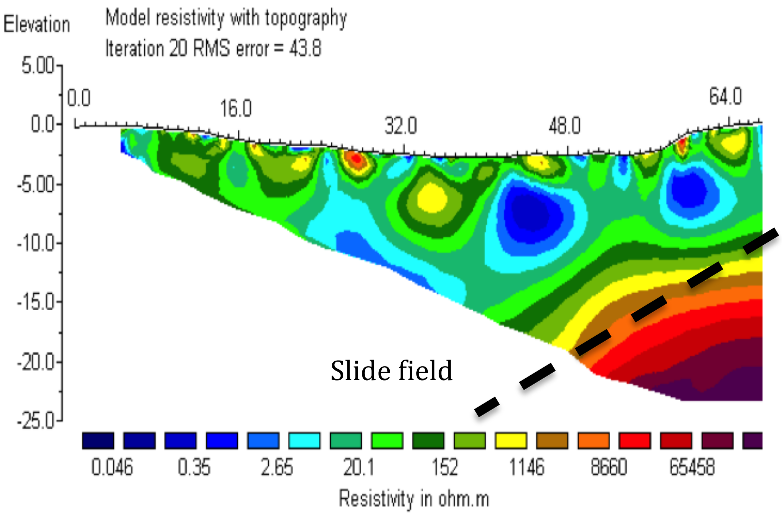


Figure 7. Slide Field Diagrams in Track 1

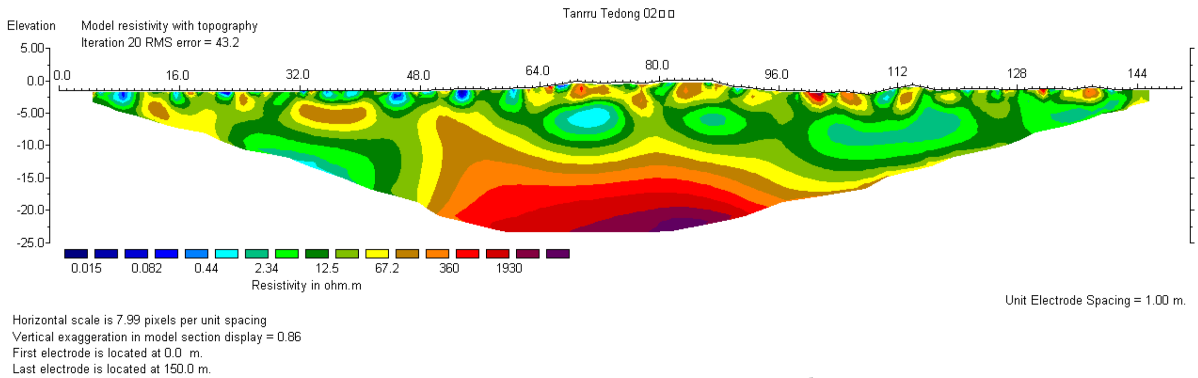
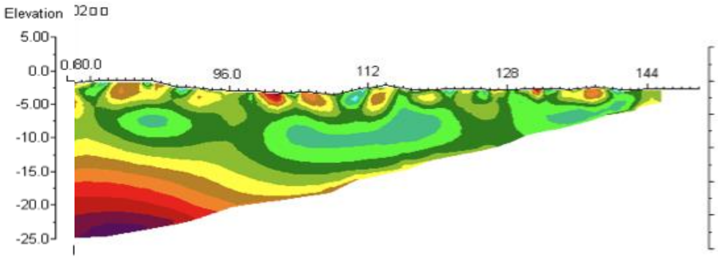


Figure 8. Resistivity Crossing Section Track 2

Resistivity value of the measurement results as shown in the cross-section shows that on the measurement path along the 150 meters that head west to east (N 95 E), can be distinguished in 3 types of layers, as follows:

1. The first layer is a layer of loose material (unconsolidated) which is estimated to be a pile of material from alluvium, clay, sand, to hard rocks (granule, pebble, boulder). In the cross-section, it can be seen that this layer is in the form of pockets locally with the value of resistivity varying from 10 - 1000 ohm m. In some places also seen hard rock lumps with resistivity values of more than 1000 ohm m. This layer is at a depth of 0 - 5m. If it is focused on the segment where there is subsidence, ie at a stretch of 87-150 meters, then the pile material layer is at a depth of 0-5 m, with an average thickness of 5 meters.
2. The second layer, the alluvium layer, wet clay, and sand, contains water in the form of bags with a fairly large dimension, namely with a stretch of 1-15 meters with a thickness of 1-7 meters. The layer resistivity value is at the value of 0.1-25 ohms m. This layer is generally located at a depth of 2-15 meters, in some places at a depth of 5-15 meters. In the subsidence segment, this layer is at a depth of 5-10 meters, with a thickness of 5-10 meters.

The third layer, the alluvium and sandstone material layer which is relatively more compact, is the lowest layer which is in the vertical segment of this road section. This layer is shown with a resistivity value greater than 150 ohmmeters. In the lowest layer up to more than 1000 ohm m. This layer is at a depth of under 10 meters. In the subsidence segment, this layer is below a depth of 12 meters.



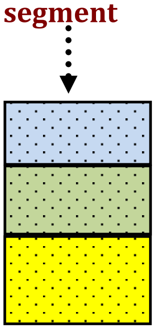
Subsidence segment	**Description**
	**Unconsolidated/ stockpile**: alluvium, clay, sand, to hard rock (granule, pebble, boulder), pockets locally, resistivity 10 - 1000 ohms m. depth of 0-8 m, with an average thickness of 5 meters. **Alluvium, wet clay, sand**: indicated to contain water locally with a large enough dimension. The resistivity value of the layer is at the value of 0.1-25 ohms m, found at a depth of 5-15 meters, with a thickness of 5-10 meters. **Alluvium, sandstone**: relatively more compact, resistivity value greater than 150-ohm m. The lowest layer is more than 1000 ohms. Depth of more than 12 meters.

Figure 9. Layers of rock in the subsidence zone Track 2

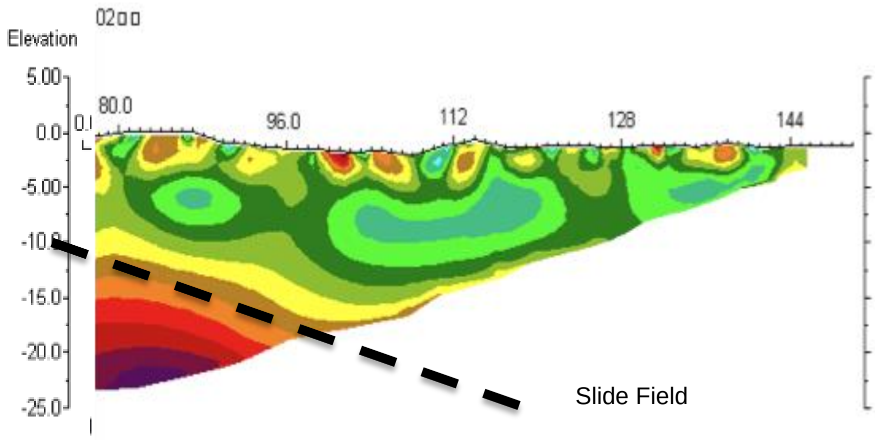


Figure 10. Slide Field Diagrams in Track 2

D. Conclusion

Based on the results obtained, it can be concluded that the existence of horizontal and vertical flow vortices (vortices) caused by meandering river conditions on the environment that can erode riverbanks. This flow is able to erode the river bank through the bottom of the gabion and penetrate the inside of the gabion which is directly adjacent and also a buffer from the shoulder of the road. From the cross-section of the material resistivity, it can be seen that the weak zones on the shoulder and the road body are more than 10 meters deep. Most of the overburden is unconsolidated material, covered by alluvium material with a fairly highwater content with a thickness of 5-10 meters. Skidding fields are formed at an average depth of 12 meters between the weak zone of the embankment material layer and the water-saturated alluvium layer with relatively solid alluvium and sandstone material beneath.

Acknowledgments

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