Identification of Landslide Potential Using 2D Resistivity Method With Wenner Configurations at Sukawinatan Landfill In Palembang

Siti Sailah[1], Erni[2], Agus Purwoko[3], Hary Widjajanti[4], Muhammad Riko[5], M. Daffa Alfaros Syah[6]

{siti.sailah@unsri.ac.id[1], erni@unsri.ac.id[2], agus_purwoko2002@yahoo.com[3], haryunsri@yahoo.com[4], rikom1963@gmail.com[5], daffaalfarossyah@gmail.com[6] }

Department of Physics, Faculty of Mathematics and Natural Sciences, Sriwijaya University, Indonesia[1,2]
Department of Biology, Faculty of Mathematics and Natural Sciences, Sriwijaya University, Indonesia[3,4]
Student of Physic Department, Faculty of Mathematic and Natural Sciences, Sriwijaya University[5,6]

Corresponding author: siti.sailah@unsri.ac.id

Abstract. Landfill is a place where waste reaches the final management. Sukawinatan Landfill has an area of ± 25 Ha. Every day Sukawinatan landfill receives waste from Palembang city with an average waste volume of ± 600 tons / day. This research was conducted to identify landslide potential in Sukawinatan landfill using the 2-dimensional resistivity method of Wenner configurations with an electrode interval of 2.5 meters. There are 2 measurement tracks with length 60 meters/track. Interpretation used Res2Dinv, and Zondres2D software. Based on resistivity distribution of subsurface resistivity distribution of subsurface, track 1 shows a resistivity value of around 0.0277 Ωm - 15,4 Ωm and track 2 of 0.0258 Ωm - 137 Ωm. The sliding plane of track 1 is identified in the range of 0.416 Ωm - 1.03 Ωm. While from track 2 in the range of 1.02 Ωm - 3,46 Ωm.

Keywords: Landslide, Resistivity method, Wenner Configuration, Sukawinatan Landfill.

1 Introduction

A landfill (TPA) is a place where waste reaches the last stage in its management since it begins to arise from the source, collection, transfer, processing and disposal. Landfill is a place where waste is isolated safely so as not to cause disturbance to the surrounding environment. Therefore, proper facilities and treatment are needed so that security can be achieved properly. Based on SLHI data in 2007 on the condition of landfills in Indonesia, most of them are open landfills, causing pollution problems in the environment. The existence of a landfill (TPA) is indeed needed by an area, because waste is always produced by residents in all their activities. As long as the population continues to grow, waste production is also getting bigger [1]. Sukawinatan landfill (TPA) in Sukajaya Village, Sukarami District has an area of ± 25 Ha.

SICBAS 2023, November 03, Palembang, Indonesia

DOI 10.4108/eai.3-11-2023.2347940

Every day Sukawintan Landfill receives waste from all over Palembang City, the average volume of waste ± 600 tons / day, the height of garbage ranges from 4 meters to 17 meters. The composition of waste in the Sukawinatan Landfill (TPA) is dominated by food and leaf waste at around 67.5%, paper waste by 10.5%, then plastic waste by 7.5% and other waste. The dominance of the types of waste can result in low waste cohesiveness such as organic waste and plastic bag waste [2].

The existence of garbage can cause several problems such as polluting soil, water, causing unpleasant odors, nests of disease and damaging the beauty of the surrounding environment and can even risk landslides if the garbage has accumulated very much [3]. Landslide in landfill often occur in Indonesia, some even claim lives. Some of them occurred on March 17, 2010 at the Galuga Garbage Landfill, Bogor Regency landslide and resulted in four fatalities. Landslide of Panga landfill, North Toraja Regency which damaged residents' rice fields on April 28, 2011. Landslide of garbage pile at Sanggrahan landfill, Temanggung Regency on November 23, 2011. The most concerning landslide event was the landslide of the Leuwigajah landfill which killed 156 residents on February 21, 2005. This incident is a bad history for the people of Bandung. Heavy rain that washed for 3 days caused a landslide of 2.7 million garbage covering residential areas [1]. A landslide is a geological event that occurs due to the movement of soil mass or rocks of various types or types such as the fall of rocks or large lumps of soil. Landslides are also one of the problems that occur on many natural and artificial slopes, because landslides are one of the natural disasters that often occur in Indonesia, especially in the rainy season [4].

The characteristics of rain can trigger landslides that make it difficult to know the magnitude and duration. Partially infiltrated rain is considered as one of factors that play a role in the process of landslides, because it can affect the process of soil saturation to change in the dimensions of space and time. In general, landslide events can be caused by two factors such as drivers and triggers. Driving factors are factors that affect the condition of the material itself, while trigger factors can cause the movement of the material [4]. Landslides are not only influenced by the type of soil, but can also be affected by the stability of the soil. Soil stability is the ability of the soil to maintain its physical properties in all conditions that occur. One of the physical properties of soil that affects soil stability is soil permeability associated with landslides.Permeability is the ability of a rock to pass or escape water. The permeability of a rock greatly affects the amount of groundwater in a layer [5]. Landslides are usually interpreted as the movement of material in an upright, horizontal and tilted direction to its initial position. Garbage slides are often categorized as narrow landslides, namely: Translational slide or rotational slide (slump). Garbage landslides are similar to landslides so they can be viewed from geotechnical science. Theoretically, at different locations of altitude there will be a thrust force making the higher garbage tend to move down. In addition to the force pushing down, there is also a force in the garbage that works to resist the push so that the position of the garbage remains stable. The driving force is in the form of gravity, while the holding force is in the form of shear force, cohesion force and ground shear force. If the driving force is greater than the holding force, then the garbage will begin to collapse along the slip plane so that a landslide occurs [6].

One of the factors causing landslides that is very influential is the slip plane (Slip Surface) or shear plane (Shear Surface). One method that can be used to determine the field of landslide is the geoelectric method, especially resistivity method. This geophysical method is not environmentally damaging and able to detect soil layers to a depth of several meters below the soil surface. Therefore, this method is often used for landslide-prone areas, especially to determine the thickness of potentially landslide layers and lithology of subsurface rock layers. In this study, this method will be used to identify landslide potential especially Wenner 2-D type resistivity geoelectric method.The Wenner *configuration* is used because it is able to identify slip fields on the slopes of the Sukawinatan landfill that have the potential for landslides [7]. A resistivity *mapping* method is a resistivity method used to study resistivity variation of the horizontal subsurface layer. Therefore, in this method the electrode spacing is fixed for all datum points on the surface of the earth. Given the fixed distance between electrodes, Wenner's configuration is quite practical for mapping, because moving the position of the measuring point does not require moving the entire electrode [8]. The purpose of this study was to determine the slip field on the slopes of the Sukawinatan landfill by measuring 2D geoelectric *mapping* Wenner *Configuration* so that the identification of landslide potential was obtained. The benefits of this research result can be used to provide information about the potential landslide at the Sukawinatan landfill site, Sukajaya Village, Sukarami District, Palembang City, South Sumatra, and can be used to increase public awareness of landslide risks to be more vigilant and prepared to face the disaster.

2 Material and Method

To achieve research objectives, measurement was carried out using Nainura Resistivity meter, Electrode, Electrode Connecting cable, Battery 12 Volt, Hammer, Meter, Global Positioning System, Handy Talky, Laptop, and Software of Res2Dinv and Zondres2D. It was conducted at the Sukawinatan landfill slope which consists of 2 measurement passes with Wenner configuration. Then the lateral resistivity value was processed using *RES2DINV software* to obtain a 2D inverse cross-section of the resistivity distribution value and also *ZondRes2D software* for comparison.

Resistivity data collection in the field was carried out by maping measurement method. The maping measurement method used *Wenner configuration* to obtain the resistivity value distribution. Measurement scheme with Wenner configuration is shown in **Figure 1**.

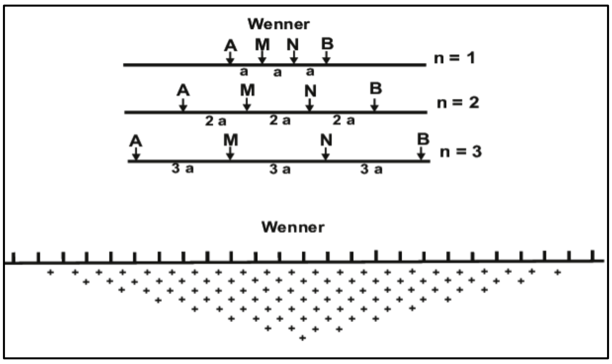

Fig 1. Wenner Configuration Electrode Tuning

Points M, N are as potential electrodes and A, B as current electrodes. Where $AM = MN = NB = a$. The resistivity values for this configuration are:

$$\rho_a = K\frac{\Delta V}{I} \quad (1)$$

Where the configuration factor is $K = 2\pi a$

The Wenner configuration is one of the configurations in geophysical exploration with the electrode arrangement located in a line symmetrical to the midpoint. The Wenner configuration has good vertical resolution, sensitivity to high lateral changes but is weak to current penetration to depth. The Wenner configuration is one of the configurations that is often used in geoelectric exploration with an arrangement of equal length spaced distances (r1=r4=a and r2=r3=2a). The distance between the current electrodes is three times the distance of the potential electrode, the potential distance with the sounding point is 2/a, then the distance between each current electrode and the sounding point is 2/3a. The target depth that can be achieved in this method is 2/a. In field data acquisition, the electrode arrangement of current and potential is laid symmetrically with the sounding point. In the Wenner configuration, the distance between the current electrode and the potential electrode is the same [9].

Identification of potential landslides can be known from estimating the slip surface, The slip plane is something that must be known, the slip plane is a place where a landslide material moves. One of the factors causing landslides that is very influential is the slip plane (Slip Surface) or shear plane (Shear Surface). Material that moves over the slip plane is called an avalanche. In general, the land that experiences an avalanche will move over the slip plane. The slip plane consists of two shapes, the first is the parallel and almost straight slip plane shape called *Translation slip.* The two curved slip planes in the form of circular arcs are circular in nature called *rotational slip.* **Figure 2** shows the various slip planes.

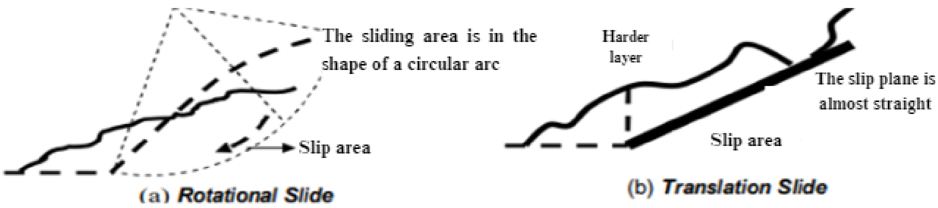

Fig 2. Various slip planes [10]

Figure 2(a) shows a concave slip plane. The rotational slip plane is usually found in an area consisting of weathered layers. **Figure 2(b)** shows a translational slip plane that is flush with the ground surface. Usually, the translational slip plane is between the contrast of type resistance values between layers [11]. The most dominant slip plane shape found in landslides in landfills in Indonesia is the slip plane shape that is close to the circular arc shape (*Rotational Slide)* [6].

The Res2Dinv program is an inversion program widely used in data processing and interpretation of type resistance data based on two-dimensional measurements. This program is equipped with *the iterative method of smoothnessconstrained* and *least-squares* [12] in conducting inversion modeling to produce a picture (map) of 2-D layer formation (two-dimensional) and resistivity values of each rock layer based on pseudo-rock resistivity data. ZonDRES2D Software is one such computer program that automatically can describe or create two- and three-dimensional models of the subsurface from the results of geoelectric survey data.

ZonDRES2D Software is designed to help interpret subsurface resistivity data that visually displays resistivity values based on color [13].

3 Results and Discussion

Geoelectric measurement data at the research location that has been carried out as many as 2 passes with each track having 84 data with a length of 60 meters and a distance from each electrode of 2.5 meters. The data is then *smooting* using excel. Furthermore, data processing is carried out using *RES2DINV* and *ZONDRES2D software* so as to produce 2D cross-sectional results.

3.1 Data Processing Using *RES2DINV*

3.1.1 Track 1

Inversion 2D cross-sectional results

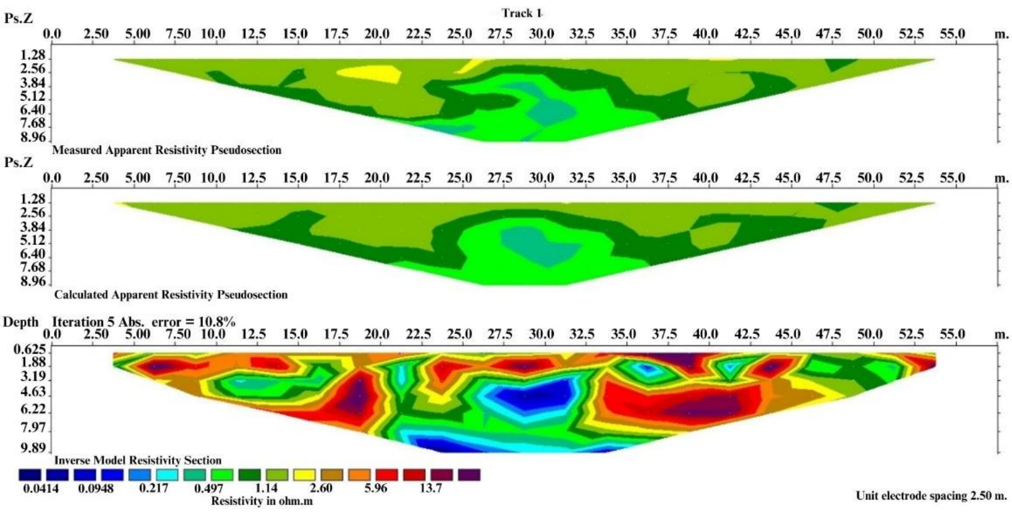

Fig 3. Cross section 2D inversion of trajectory 1 using Res2dinv

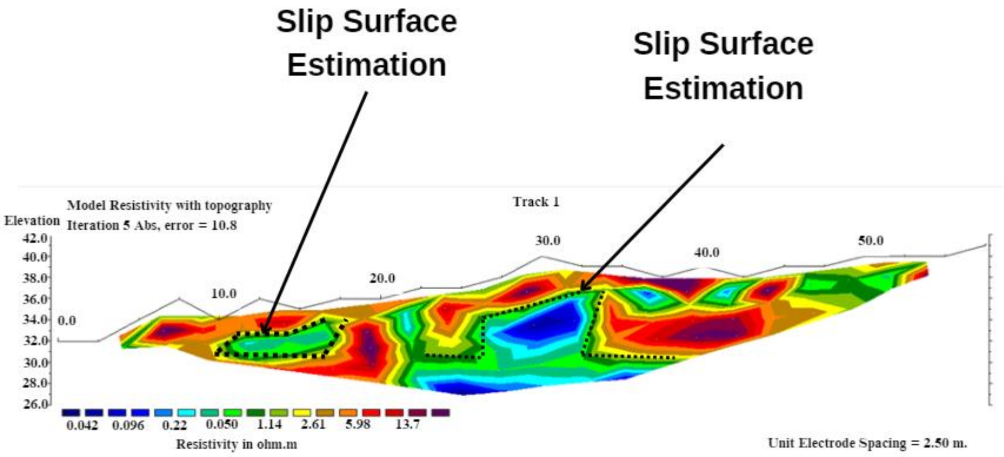

Fig 4. The results of the cross-the-top resensitivity model of the crossing 1 use Res2dinv

Based on the results of the 2D cross-section of trajectory inversion 1 (**Figure 3 and Figure 4**), the resistivity value obtained using *RES2DINV software* is 0.0414 $\Omega.m$ – 13.7 $\Omega.m$ and the error value is 10.8% with 5 iterations. It can be seen that there are zones with low resistivity values with dark blue to light blue layers located at several depths at 1.88 m – 4.63 m and depths of 7.97 m – 9.89 m. In estimating the slip field, it is found that the shift of garbage can occur due to sand that can escape water. Infiltration of uncontrolled water into the garbage body can be a problem for slope stability. The dominance of certain types of waste can result in low waste cohesiveness such as organic waste and plastic bag waste. A very striking resistivity value can also affect and predict the slip plane, can be seen from (**Figure 3 and Figure 4**) which forms a slope in its confinement. So in estimating the slip plane seen from the cross-sectional results in the range of 0.497 $\Omega.m$ -1.54 $\Omega.m$ with the track length in the range of 10 meters to 17.5 m. In supporting the slip plane can be seen from the shape of the layer such as forming a rotational slide which is rotating and (*Translational Slide*) which is moving in a direction which is in a track length ranging from 22.5 meters to 37.5 meters. The results of the interpretation above are briefly shown in **Table 1**.

Table 1. Interpretation Results of Track 1.

Anomali	Color	Resistivity Value (Ω.m)
Fluid	Light Blue – Dark Blue	0,0277 $\Omega.m$ – 0,164 $\Omega.m$,
Garbage on the ground	Light Green – Dark Green	0,497 $\Omega.m$ – 1.54 $\Omega.m$
Garbage on sand	Yellow – Orange	2.61 $\Omega.m$ – 5,98 $\Omega.m$
Metal waste material	Red – Purple	13.7 $\Omega.m$

3.1.2 Track 2

Inversion 2D Cross-sectional Results

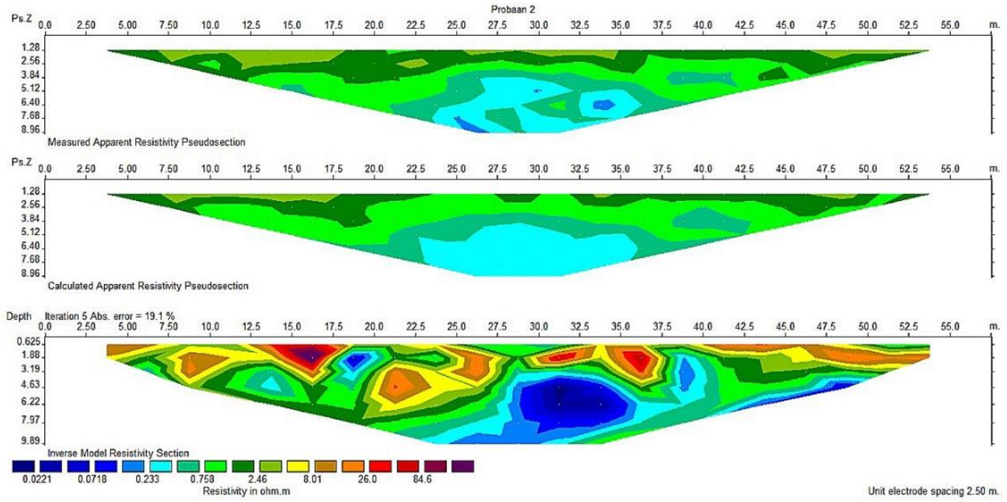

Fig 5. Cross section result of 2D inversion of trajectory 2 using res2div

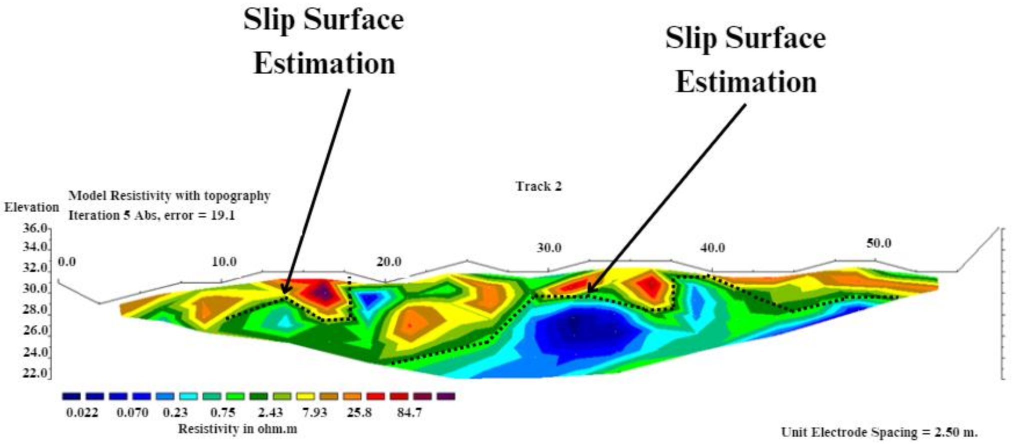

Fig 6. Outcomes of Crossography Topographic Resitivity Model 2 using Res2div

Based on the results of the 2D cross-section of trajectory inversion 2 (**Figure 5** and **Figure 6**), the resistivity value obtained using *RES2DINV software* is 0.0221 $\Omega.m$ – 84.3 $\Omega.m$ and the error value is 19.1% with 5 iterations. It can be seen that there is a zone with a low resistivity value with a dark blue to light blue layer located at some depth at 0.626 m – 9.89 m. Low resistivity values range from 0.0221 $\Omega.m$ - 0.223 $\Omega.m$, these values are indicated as fluid accumulation. The cross-sectional results can be seen based on the results of the resistivity value of 0.758 $\Omega.m$ – 2.41 $\Omega.m$ which is a light green to dark green layer located at a depth of 0.626 m – 9.89 m. This value indicates the presence of garbage on the soil. There are other cross-sectional results based on the results of the resistivity value of 8.1 $\Omega.m$ – 26.0 $\Omega.m$, whose layers are yellow and orange with a depth of 0.626 m – 4.63 m. The value is suspected to be a garbage material metal. As for the high resistivity value of 84.3 $\Omega.m$, whose red to purple layer is suspected as a sand pollutant that has a high resistivity value. In estimating the slip field, it is found that the shift of garbage can occur due to sand that can escape water. Infiltration of uncontrolled water into the garbage body can be a problem for slope stability. The dominance of certain types of waste can result in low waste cohesiveness such as organic waste and plastic bag waste, so in estimating the slip field, it is seen from the cross-sectional results in the range of 0.758 $\Omega.m$ – 2.41 $\Omega.m$ with the track length in the range of 7.5 meters to 17.5 meters and 20 meters to 43 m. In supporting the slip plane, it can be seen from the shape of the layer such as forming a translational slide (*Translational Slide)* which is moving in a department. And the results of the interpretation above are briefly shown in **Table 2**.

Table 2. Interpretation Results of Track 2.

Anomali	Color	Resistivity Value (Ω.m)
Fluid	Light Blue – Dark Blue	0,0221 $\Omega.m$ – 0,233 $\Omega.m$,
Garbage on the ground	Light Green – Dark Green	0,758 $\Omega.m$ – 2,46 $\Omega.m$
Waste Mineral Metals	Yellow – Orange	8,1 $\Omega.m$ – 26 $\Omega.m$
Sand pollutants	Red – Purple	84,3 $\Omega.m$

3.2 Data Processing Using *ZONDRES2D*

3.2.1 Track 1

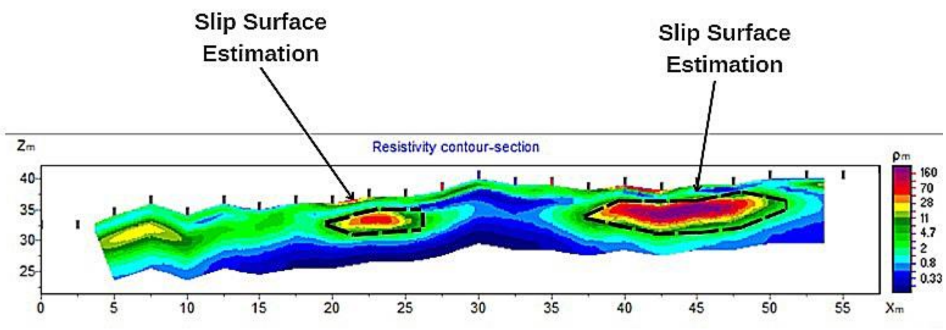

Fig 7. Results of processing track 1 data using Zondres2d

Based on the results of the 2-dimensional cross-section in **Figure 7**, it can be interpreted that there are several layers, namely the first layer with a resistivity value of 0.33 $\Omega.m$ – 0.8 $\Omega.m$ with a dark blue to light blue layer interpreted fluid. Furthermore, a light green to dark green layer with resistivity values of 2 $\Omega.m$ – 11 $\Omega.m$ is interpreted as waste on the soil. Yellow and orange layers with resistivity values of 28 $\Omega.m$ – 70 $\Omega.m$ are interpreted by waste in the sand. A purple layer with a high resistivity value of 160 $\Omega.m$ is interpreted as a pollutant in the sand.

3.2.2 Track 2

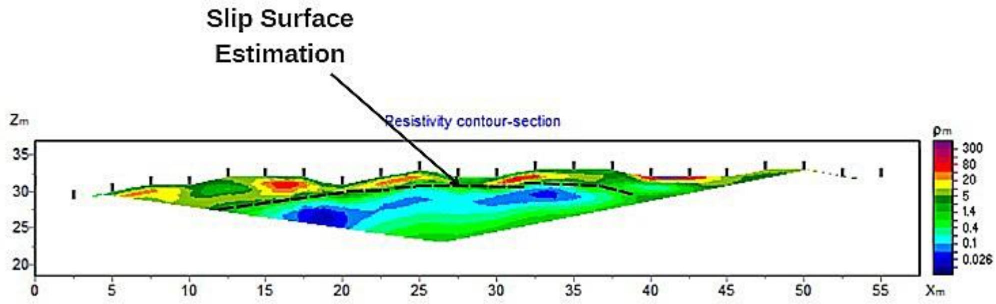

Fig 8. Results of data processing track 2 using zondres2d

Based on the results of the 2-dimensional cross-section in **Figure 8**, it can be interpreted that there are several layers, namely the first layer with a resistivity value of 0.026 $\Omega.m$ – 0.1 $\Omega.m$ with a dark blue to light blue layer interpreted fluid. Furthermore, a layer of light green to dark green with a resistivity value of 0.4 $\Omega.m$ – 5 $\Omega.m$ is interpreted as waste on the soil. Yellow and orange layers with resistivity values of 20 $\Omega.m$ – 80 $\Omega.m$ are interpreted by waste in the sand. A purple layer with a high resistivity value of 300 $\Omega.m$ is interpreted as a pollutant in the sand.

3.3 Discussion

The slip field is marked with a layer that has a resistivity contrast with its surroundings. In general, landslides move over the slip area that is due to the disruption of slope stability. Slip area was formed due to the saturation of water that accumulates and moves laterally over the surface of impermeable soil or rock layers. These impermeable rocks usually have relatively small pores and have a large type resistance value. If water penetrates to the waterproof layer, the waterproof surface will weather, making it slippery. This weathered layer is called the slip plane [7]. The weathered layer will become slippery so that the mass moves along the slope and out of the slope. Rainwater is one of the trigger factors for landslides. The increase in water content increases pore pressure which results in a small waste resistance force so that waste becomes easy to landslide. The low strength of the bond between materials or waste cohesivity is also one of the factors causing landslides. In estimating the slip field, it is found that the shift of garbage can occur due to sand that can escape water. Infiltration of uncontrolled water into the garbage body can be a problem for slope stability. The dominance of certain types of waste can result in low waste cohesiveness such as organic waste and plastic bag waste [4]. Apart from that, the measurement location has the characteristics of waste which is predominantly plastic waste and contains sand. There may be a shift of garbage on the ground that causes slip fields and landslides potential. Based on the characteristics of the dominant waste in the Sukawinatan landfill, it can be assumed that it is a slip field. Garbage experiences weathering so that it can come out of the water causing shifts in the garbage pile**.** Then this can trigger a slip field and cause a landslide. the prediction of the existence of a slip surface can be seen from the shape layer which is thought to act as a slip plane concave shape. Apart from that, the topography of the track. This follows the slope of the slope [14]. Field boundaries avalanche slip is between the waterproof layer and water saturated layer [15].

From the results of data processing using Res2dinv and Zondres2D, the slip field is suspected from a shift in waste on the ground where at that location there is a lot of sand and plastic waste and some waste from food and leaf waste that can be weathered so that it can escape the water and shift from the garbage. Estimation of the slip plane based on the processing result of trajectory 1 shows that there is a very striking resistivity value that can also affect and suspect the slip plane as **Figure 3 and Figure 4** which forms a slope. Then the landslide area is estimated to be in the range of resistivity values of 0.497 $\Omega.m$ - 1.54 $\Omega.m$ with the track length in the range of 10 meters to 17.5 m. The slip plane can be seen from the shape of the layers, such as forming a rotational slide that rotates and a translational slide that moves in a direction that is in a path length ranging from 22.5 meters to 37.5 meters. The estimated slip area resulting from cross-section of track 2 can be seen to be in the range of 0.758 Ω.m – 2.41 Ω.m with track lengths in the range of 7.5 meters to 17.5 meters and 20 meters to 43 m (**Figure 5 and Figure 6**). The slip plane is shown by its presence of the layer forming a *translational slide* which is moving in a department. While in track 1 using Zondres2D software seen from (**Figure 7**) the slip plane support, the resistivity value is resistivity 2 $\Omega.m$ – 11 $\Omega.m$ with a length of 20-25 meters and 37.5-50 meters which forms a rotational slide layer (Rotational Slide) which is rotary. Trajectory 2 is seen from the results (**Figure 8**) of slipping plane support from the results of resistivity values of 0.4 $\Omega.m$ – 5 $\Omega.m$ with a track length of 10 – 40 meters from the shape of the layer such as forming a translational slide which is moving in a department. The estimation of the slip field at the Sukawinatan landfill occurs due to the dominance of wastes that experiences weathering becomes saturated and a lot of waste mixed in sand which can escape water so that there is a shift in waste on the ground. The accumulation of garbage every day can also affect the occurrence of landslides and erosion on the slopes of the landfill and become one of the factors that can cause landslides..

4 Conclusion

The results show that the slip plane is characterized by a layer that has a contrasting type resistance value. From the data obtained using Res2dinv and Zondres2D software, it can be concluded that in estimating the slip field, there is that shifting from garbage can occur due to sand that can escape water. Infiltration of uncontrolled water into the garbage body can be a problem for slope stability. Therefore based on the results of data interpretation, the resistivity value obtained which is a layer of light green to dark green is interpreted as waste on the soil.

References

[1] Rahim I R.: Sosialisasi Keselamatan Kerja dan Mitigasi Bencana Pada Tempat Pengolahan Akhir Sampah (TPAS) Tamangapa, Kota Makssar. Volume 1, No. 1. pp. 11-13 Jurnal Tepat, (2018)

[2] Damanhuri E.: Diklat Landfilling Limbah-FTSL.ITB. Retrieved from http://www.itb/ac/id/ wordpress/wp-content/Bag7P-PenangananLindi.pdf. (2008)

[3] Azizah S N.: Penentuan Penyebaran Lindi Pada Bawah Permukaan Dengan Metode Geolistrik Konfigurasi Wenner-Schlumberger di TPA Sampah Desa Bandengan Kabupaten Jepara (2016)
[4] Wahyono S C., et.al.: Aplikasi Metode Tahanan Jenis 2D untuk Mengidentifikasi Potensi Daerah Rawan Longsor di Gunung Kupang, Banjarbaru., Vol. 8, No. 3. pp: 95-96. Jurnal Fisika Flux, (2011)
[5] Ningtyas G R, Priyantati N, Suprianto A.: Analisis Data Resistivitas Dan Uji Permeabilitas Tanah Di Daerah Rawan Longsor Desa Kemuning Lor Kecamatan Arjasa Kabupaten Jember. Vol. 6, No. 1:7. Journal of Physics, (2016)
[6] Wahyono S.: Mitigasi Bencana Longsor Sampah Analisis Penyebab Dan Upaya Pencegahannya., Vol. 9, No. 2, pp: 6-7. Jurnal Sains dan Teknologi Mitigasi Bencana, (2014)
[7] Wijaya AS: Aplikasi Metode Geolistrik Resistivitas Konfigurasi Wenner Untuk Menentukan Struktur Tanah di Halaman Belakang SCC ITS Surabaya. Vol. 55, No. 19:1. Jurnal Fisika Indonesia, (2015)
[8]] Reynolds JM: An Introduction to Applied and Environmental Geophysics. New York: Jhon Geophysics in Hidrogeological and Wiley and Sons Ltd (1997)
[9] Hakim, Manrulu RH.: Aplikasi Konfigurasi Wenner dalam menganalisis Jenis Material Bawah Permukaan. Vol.5, No.1. pp: 96-98. Jurnal Ilmiah Pendidikan Fisika, (2016)
[10] Wesley LD: Mekanika Tanah, Badan Penerbit Pekerjaan Umum, Jakarta (1977)
[11] Anriani D, Akmam, Amir H.: Estimasi Bidang Gelincir Menggunakan Metode Geolistrik Tahanan Jenis Konfigurasi Schlumberge di Kelurahan Balai Gadang Kecamatan Kototangah. Vol.11, No.1. pp: 33-34. Pillar of Physics, (2018)
[12] Loke MH, Barker RD.: Rapid Least Squares Inversion of Apparent Resistivity Pseudosection by a quasi-Newton Method. Vol. 44. pp: 131-152. Geophysical Prospecting, (1999)
[13] Maay BR, Supit JM.: Interpretasi dan Korelasi Data Resistivitas untuk Menentukan Lapisan Akuifer di RT.002/RW.002 Kelurahan Amban Kabupaten Manokwari Provinsi Papua Barat. Vol. 4, No. 2: 95. Jurnal Penelitian Tambang, (2021)
[14] Jannah L. et al.: Pendugaan Bidang Gelincir Tanah Longsor Berdasarkan Sifat Kelistrikan Bumi Dengan Aplikasi Geolistrik Metode Tahanan Jenis. Vol. 3, No. 1:70. Jurnal Neutrino, (2010)
[15] Dona IR., Akmam, Sudiar NY.: Identifikasi Bidang Gelincir Menggunakan Metode Geolistrik Tahanan Jenis Konfigurasi Schlumberger Di Bukit Lantiak Kecamatan Padang Selatan. Vol. 5, No. 1:1. Pillar of Physics, (2015)