International Journal of GEOMATE, Sept. 2022, Vol.23, Issue 97, pp.97-105
ISSN: 2186-2982 (P), 2186-2990 (O), Japan, DOI: https://doi.org/10.21660/2022.97.3261
Geotechnique, Construction Materials, and Environment

STUDY OF SUBSURFACE CONDITIONS OF SOUTHERN CROSS ROAD USING THE WENNER-SCHLUMBERGER METHOD FOR DISASTER MITIGATION

*Alamsyah M. Juwono[1], Adi Susilo[1], Sunaryo[1], Faridha Aprilia[1] and Farizky Hisyam[1]

[1]Geophysical Engineering, Faculty of Mathematics and Science, Brawijaya University, Indonesia

*Corresponding Author, Received: 27 Jan. 2022, Revised: 20 June 2022, Accepted: 02 Aug. 2022

ABSTRACT: A study using the geophysical resistivity method, as a part of a disaster mitigation attempt, has been carried out in the Southern Cross Road (JLS), in the area of Gedangan District Malang Regency, East Java. The study was conducted to investigate the geological disaster potentials, such as fractures, land discontinuities, and ground movements, which exist along the road, that now is a popular route amongst tourists and travelers. The research was conducted using the Wenner-Schlumberger configuration, where a distance of 20 m between adjacent sounding points was chosen. The data obtained were processed by the inversion method to obtain 2D subsurface resistivity cross-sectional features. From five locations surveyed, various low resistivity values, ranging from 2.5 to 30 Ωm, were obtained, which indicate the presence of seawater intrusion or underground water flows that fill the subsurface cavities. Limestone discontinuities were also observed, indicated by resistivity values ranging from 25 to 70 Ωm, which were suspected as an indication of faults. High resistivity (150-700 Ωm) zones, where there is no limestone present significantly, were also detected at some points, which indicate the embankment of the road construction materials. The overall study also confirms that the resistivity method, especially with the Wenner-Schlumberger configuration, is useful for identifying the geological disaster potentials, which, in turn, will be useful in conducting the risk analysis for the Southern Cross Road or similar roads.

Keywords: *Resistivity, Geoelectric method, Wenner-Schlumberger, Southern Cross Road, Geological DisasterPotential, Mitigation*

1. INTRODUCTION

Indonesia is located in a very active tectonic zone, with a complex confluence of the Eurasian, Indo-Australian, Pacific-Philippine plates. As a result, Indonesia often experiences geological disasters, earthquakes, or ground movements, triggered by active local faults, that, cause infrastructure damage. Furthermore, it also, commonly, results in other kinds of disasters, such as hydrometeorological ones, including floods, landslides, subsidence, and extreme weather.

Malang Regency is one of the Indonesian regional areas, which, is prone to natural disasters. Based on the statistical data, throughout the year 2016, there were 56 natural disasters occurred in Malang Regency [1]. The most often occurring natural disasters are landslides and other kinds of land motion, which occurred in several areas in the regency [2]. Moving lands occur in the area, were due to the geological conditions of Malang Regency, as well as in the nearby areas, such as Blitar Regency.

The Southern Cross Road (The JLS) is a national project road, which extends along hundreds of kilometers, of the southern mountaineering coastline of Java Island. The part of the JLS, which passes through Malang Regency, has, recently, become a vital infrastructure [3]. This road is the economy's lifeblood and is an important route for agricultural product transport from surrounding areas to Malang City. The road is, also, a popular route for tourists, who visit the beaches, which are, now, new tourist destinations.

While offering the attraction of beach beauties, the coastline of South Malang, which is part of the Indian Ocean, has great geological disaster potential. The most obvious, and the most possible disaster to occur, is an earthquake, which, may be followed by a tsunami, or not. Other possible disasters could be landslides, which could cover, or even, break the JLS, especially on the far side of the road, which has a fairly steep slope. Road subsidence is, also, a real issue, since the road was built along the karst area, where underground rivers naturally exist almost anywhere in the area. Furthermore, floods and sinking lands are also possible disaster potentials in the targeted area.

The area, where this research was conducted, is on the southern coast of the eastern part of Java Island, which is located nearby the collision zone of the Indo-Australian and Euroasian tectonic plates, where medium and large magnitude earthquakes quite often occur, with or without tsunami.

Geological disasters, which may commonly occur in the Indonesian islands, accompany the construction of roads, may be such as land movement, landslide, fault development, land subsidence, flood, etc. A moving land is known to be a manifestation of clay unstable morphology, which is prone to any trigger, such as vibration due to an earthquake. Such a vibration, when it happens, can, in turn, develop cracks below the earth's surface, and might even trigger a landslide [2]. Flood may occur due to inappropriate irrigation systems which may be due to wrong design, or structural changes caused by the construction of the road.

Due to the above-mentioned geological disaster potentials, a disaster risk analysis for the JLS needs to be done, to mitigate the impacts they may cause. One effective method to provide data to conduct such a risk analysis is the geophysical geoelectric method. The method can provide an overview of subsurface resistivity, which is non-destructive, and environmentally friendly. Analysis of the geophysical resistivity data, therefore, may lead to conclusions regarding the existence of fault structures, land voids/cavities, underground water bodies, and the kinds of materials that constitute the under-surface structures. Previous disaster studies, employing similar resistivity methods were carried out, including fault analysis in Pohgajih, Blitar [2], and an investigation of the fractures and possible seepage zones in the Sutami Dam [4]. The same method was also employed previously, for investigating the damages in the subsurface of the main Alue Naga road, Banda Aceh [5], or in the study of landslides occurring, due to limestone fractures, along the Ankara-Kirikkale toll road and railroad, Central in Turkey [6].

This research aims to identify the geological disaster potentials existing along the JLS part, in the Gedangan District, by employing the geoelectric method. Results from this study can be used to construct comprehensive disaster risk analysis by the governmental agents, or other relevant parties. The results can, also, be used as basic information for mitigating geological disasters, and for formulating the land-use policies, in the targeted areas, as well as in any other similar regions.

2. GEOLOGICAL STUDY OF INVESTIGATION SITES

Physiographically, the research area is located in the Southern Mountains Zone, which stretches from West to East, in the southern part of Java Island [7]. In general, the physiography of the area is composed of carbonate sediments mixed with tertiary volcanic rocks [8]. The morphology of this area is categorized into four units, namely, the volcanic cones, high hills, low and wavy hills, and swampy plains.

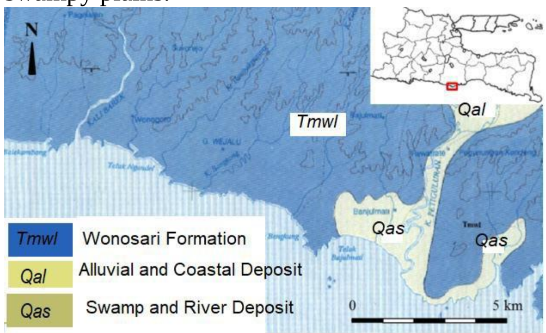

Fig. 1 Regional geological map of the research site [9]

Based on the geological map of the Turen sheet [9], the oldest formation, that, composes the lithology of the research area is the Mandalika Formation, which is from the late Oligocene to early Middle Miocene age. This formation is composed of andesite lava, basalt, tracite, dacite, and prophesized andesite breccia. This formation, also, has members of the Mandalika Formation tuff, which is composed of andesite-rhyolite-dacite tuff and pumice tuff breccia. The Mandalika Formation is intruded by granite, diorite, and andesite rocks. Above the Mandalika Formation, the Wuni Formation (Tmw) is deposited, in an early Miocene age, with the composition of andesite-basalt breccia and lava, tuff breccia, lava breccia, and sandy tuff. Furthermore, the Nampol Formation (Tmn) of the Middle Miocene age was unconformably deposited above the Wuni Formation, with a composition of tuffaceous, or calcareous, sandstone, black claystone, sandy marl, and calcareous sandstone. The Wonosari Formation (Twml), with a Middle Miocene-Late Miocene age, which is composed of limestone, sand marl, and claystone inserts, overlaps unconformably the Wuni Formation. Meanwhile, the youngest layers observed along the coast of the study area, are the alluvium deposits and coastal deposits (Qal), with the composition of gravel, gravel, sand, and mud. In addition, there are, also, swamp and river deposits (Qas), in the form of gravel, sand, clay, and plant remains. These swamp and river deposits are mainly found around Bajulmati Bay, where the estuary of the Penguluran River is located.

In contrast to the eastern part of the region, as indicated in the geological map of the Turen sheet, which consists of Tertiary volcanic rocks, its western part is an area with carbonate rock dominance. During conducting this research, not all the formations contained in the geological map of the Turen sheet were found. The exposed rocks in the research areas are the Wonosari Formation and alluvial deposits, as presented in Fig. 1 [9]. The Miocene Wonosari Formation is known to undergo tectonic uplift, accompanied by the process of the dissolution of karstification, which formed the karst landscape in the form of karst cones, karst hills, karst ridges, closed basins, valleys, and narrow plains [10]. The formation of karst landscapes is influenced by the geological structures that develop in the area. The extensive dissolving process occurs in the fracture zones. This indicates, that, the local geological structures had played an extensive role in this area during the previous lifting process. Some of the geological structures in the areas can be observed by faults that pass through the Penguluran River [9].

Tectonic processes in the research area are estimated to have occurred since the Late Oligocene. Magmatic activity due to the subduction of the Indian Ocean plate, under the Eurasian plate, resulted in magmatic activity in the Miocene. The uplift continued into the Plio-Pleistocene. As a result of the tectonic activity, amongst other things, is the existing slope of the sedimentary rock layer to the south, and the presence of the various faults, in the research areas. In general, the faults in the research area consist of normal faults lying in northeast-southwest, and northwest-southeast directions [9].

3. METHODS

The research was carried out in several stages. The data acquisition was conducted on the 25-27 July 2019, along the Southern Cross Road (JLS), in the Gedangan District. The district of Gedangan borders with Bantur District in the west, and Sumbermanjing Wetan District in the east, as indicated in Fig.2. The morphological conditions of the research location, in general, are coastal and karst areas, facing directly to the Indian Ocean.

Fig. 2 The JLS is in Malang, on the southern coastline of East Java. Red dots are the measurement sites, which are located in Gedangan District.

This research was conducted by employing a resistivity method, for which several configurations can be chosen. Fig. 2 shows the location of each measurement point, which was determined based on the direct pre-observations in the area.

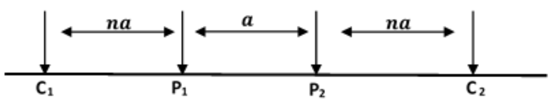

Fig. 3 The Wenner-Schlumberger Electrode array.

Considering the geomorphological conditions of the location, the configuration of Wenner-Schlumberger, as indicated in Fig. 3, with a 5-meter distance in each n shift was considered to be the most appropriate one, and hence, was chosen. The distance between two sound points was taken to be 20 meters.

The Wenner-Schlumberger configuration is a modification of the Schlumberger and Wenner configurations by adjusting the electrode system resulting in a fixed spacing (Fig. 3). The parameter "n" is the ratio of the C1-P1 (or P2-C2), electrode distance, to the P1-P2, the potential electrode distance. Thus, this configuration is quite sensitive to vertical structures as well as horizontal structures. Compared to the Wenner configuration, the Wenner-Schlumberger configuration, in general, has better lateral coverage. Meanwhile, the penetration depth of the Wenner-Schlumberger configuration is about 10% greater than that of the Wenner configuration [11].

Theoretically, by following the Wenner-Schlumberger configuration, the apparent resistivity value is obtained by using Eq. (1)

$$\rho_a = \pi n(n+1)a\,\frac{\Delta V}{I} \qquad (1)$$

where ρ_a is the pseudo-resistivity (Ωm), n is an integer, a is the space length (m), ΔV is the potential difference (V), and I is the current (A).

The data were collected using an OYO McOhm type resistivity meter. The data was processed by employing the Res2Dinv software, to produce a 2D subsurface resistivity model. The results of the data processing are presented in colored contours, representing the subsurface resistivity values, with logarithmic intervals. The interpretation stage is carried out by correlating the subsurface resistivity section with the rock resistivity values, which have been available. The interpretation of the results was also done by involving available relevant geological information, and direct field survey results obtained previously.

4. RESULT AND DISCUSSION

This survey targeted five measurement points, for which all measurements were successfully done. Inversion processes, which were employed in the data processing, with five to seven times iterations, produced 2D resistivity profiles, with absolute uncertainties of 4, 5, and 15. The estimates of the penetration depths range from 20 m to 25 m. The selected results will be discussed one by one in the next section.

4.1 MT 03

Point MT 03 is located at coordinates of 112^o 38' 23.14" E and 08^o 25' 54.40" S with a track of the length of 140 meters, which constituted eight sounding points. Based on the field observations, this point is adjacent to a brackish water pool, whose water may seep into the embankment, which is the foundation of the road. Such seepage, in due time, may deteriorate the road's stability. In addition, about 80 meters to the east of the point MT 03, there is an outcrop of hill slope of limestone, that seems to have been cut, and used as part of the road construction. This, to some extent, may cause instability, due to the characteristic differences between parts of the road, which were built by rock pilling, and that part that was built from hill slope cutting.

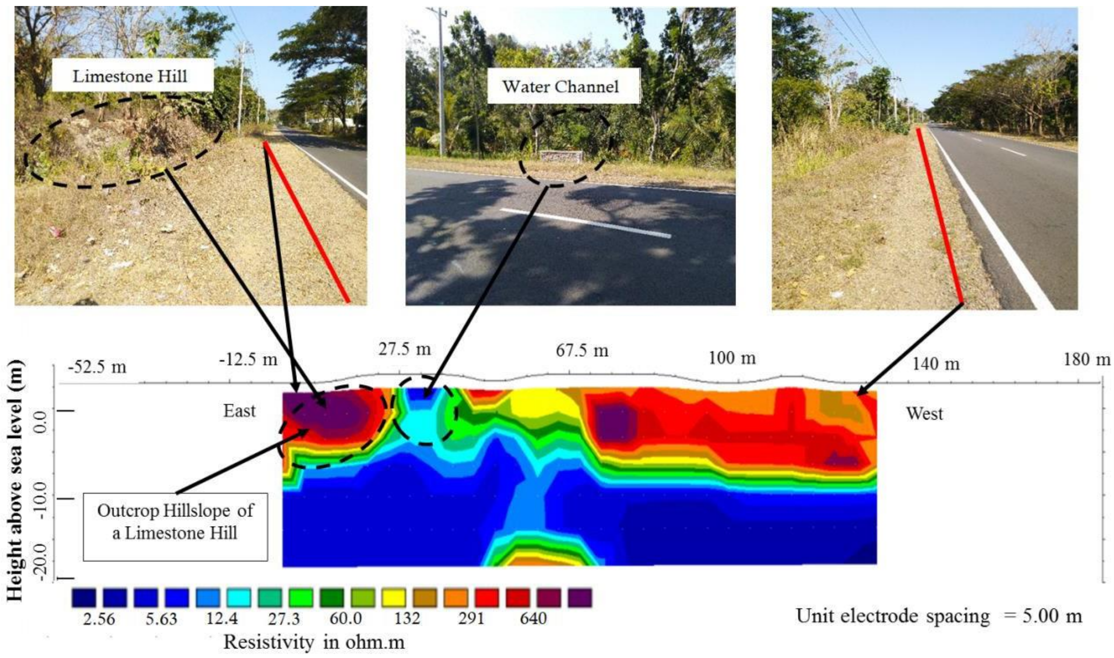

Fig. 4 The results of a 2D subsurface resistivity profile at point MT 03. The Red line in each photograph is the measurement line

Based on the 2D data processing results, a cross-section of the subsurface resistivity distribution of point MT 03 is shown in Fig. 4. As can be seen in Fig. 4, in the eastern part of the measurement line, a zone with a 300-700 Ωm subsurface resistivity was observed. By correlating the available data, this zone is interpreted as the limestone hill slope cut, used as part of the road construction. Furthermore, there is an anomaly with a low resistivity value (2.5-30 Ωm) on the surface to a depth of 2.5 m from the surface marked by a black dotted circle. This anomaly is associated with a small river, that, flows perpendicular to the highway.

In the western part of the track, there are zones with high resistivities (150-700 Ωm) on the surface, just similar to those in the eastern part of the track. Since there are no limestone rocks in the area, the high resistivity on this side of the track is considered to be related to the embankment of the construction materials. This embankment material may come from the cut limestone hills, because it has resistivity similar in value to that of the limestone hill, in the eastern part of the track. At a depth of 7.5-20 meters, in the western part of the track, a zone with low resistivity values (2.5-15 Ωm) was found This zone is interpreted as loose material, which was filled with water so that its resistivity value becomes very low. In such a case, if the water filling is brackish water, the resistivity of the material would be lower. Another interpretation, that, may be taken, is that the low resistivity is, perhaps, due to seawater intrusion. It is considered so because the point of MT 03 was located only about 100 meters from the seawater line.

4.2 MT 04

Point MT 04 is located at the coordinates 112° 37' 53.90" E and 08° 25' 41.96" S, with a track length of 120 meters, and seven sounding points. This point is adjacent to a brackish water river, which raised concern that it may disturb road stability when water seeps into the road foundation, similar to what happened with Point MT 03, as previously discussed. Meanwhile, 30 meters to the east of Point MT 04, limestone hills that were exposed due to the road construction, were found. Fig. 5 shows a cross-section of the subsurface resistivity of the MT 04 point in 2D, resulting from the data processing.

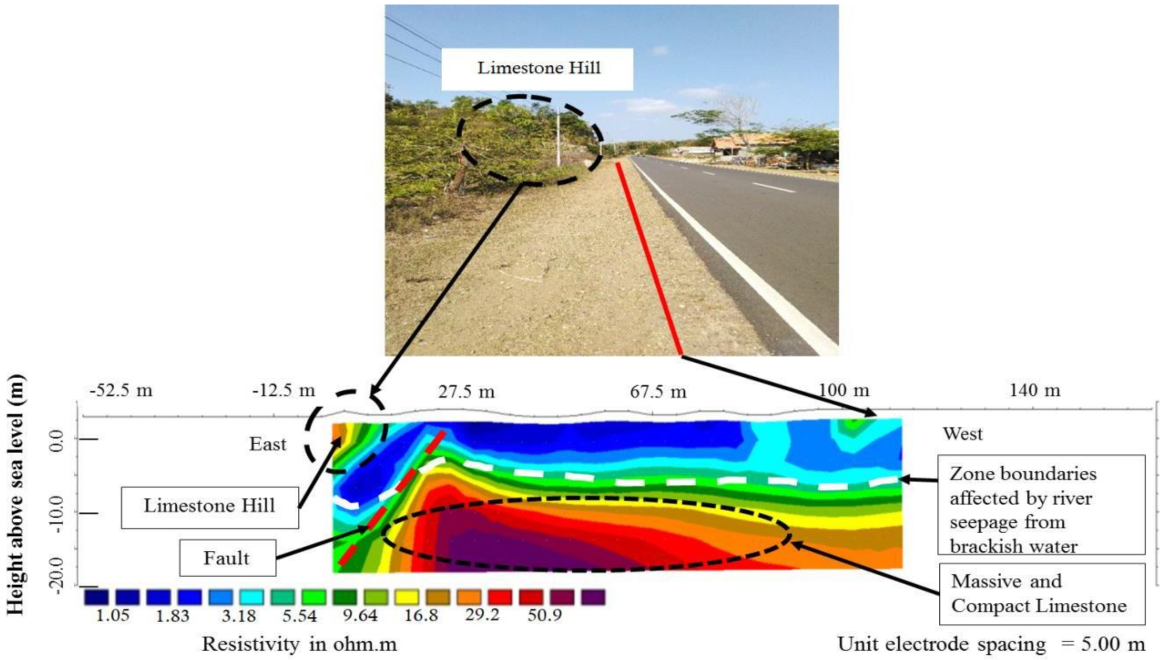

Fig. 5 The MT 04 measurement point along with the 2D subsurface cross-section resistivity MT 04 measurement point along with the 2D subsurface cross-section resistivity. The Red line in the photograph is the measurement line

In general, the subsurface resistivity values at point MT 04 are lower than those of point MT 03. The cross-section resistivity shows a zone marked with a low resistivity value (2-16 Ωm) and is interpreted as a zone affected by seepage from the nearby brackish water river. Brackish water may seep as this zone comprises accumulated materials, or lose weathered limestone, making the water prone to percolate. This zone was found to be at a depth of up to 5 meters. Meanwhile, other zones with relatively high resistivity (25-70 Ωm) were observed in the area of Point MT 04, and are interpreted as rocks, which are unaffected by brackish water seepage, because they are more compact and massive. The contact between the two zones is marked with a white dotted line in Fig. 5

As indicated in Fig. 5, it appears that the high resistivity zone does not continue on the east side of the track, as marked with the dashed red line. This discontinuity seems to be related to the presence of fault and fractures, which become the water percolation pathway, making this zone more prone to weathering. Right, at the eastern end of the track, the rock's resistivity values on the surface tend to be high again (8-30 Ωm). From direct field observations, these high resistivity values may be associated with the limestone outcrops on the road cliffs.

4.3 MT 05

Point MT 05 is located at the coordinates of 112^o 37' 26.19" E and 08^o 25' 37.81" S with a track thegth of 100 meters, and six sounding points. At this point, a cavity was found, at the depth of 13-15 meters from the road surface. In addition, we observed a cracked foundation barrier, which was considered to be from undetected cavities at the soil surface, which is a river channel that flows into the sea, and which also acts as a tidal river. During the rainy season, the river overflows due to excessive rainwater and tidal water

The results of data processing in the form of a subsurface cross-section resistivity at point MT 05 are shown in Fig. 6.

The modeling results, as presented in Fig. 6, show a zone with low (6-20 Ωm) resistivity, at a depth of about 15 meters from the surface. This zone is interpreted to be composed of fine-sized sedimentary material saturated with water, due to an underground river whose flow boundary is shown as a light red bold dashed line (Fig. 6). Meanwhile, high resistivity anomalies with a range of 150-350 Ωm, were found at a depth of 10-15 meters. By comparing the resistivity values from other points, it is assumed that the anomaly is a massive limestone boulder. Based on field observations, limestone boulders were also found, which were used as natural foundations for the construction of JLS. Due to the cracks in the foundation barrier, it is suspected that the water flow cavity continues to 5-10 meters from the surface.

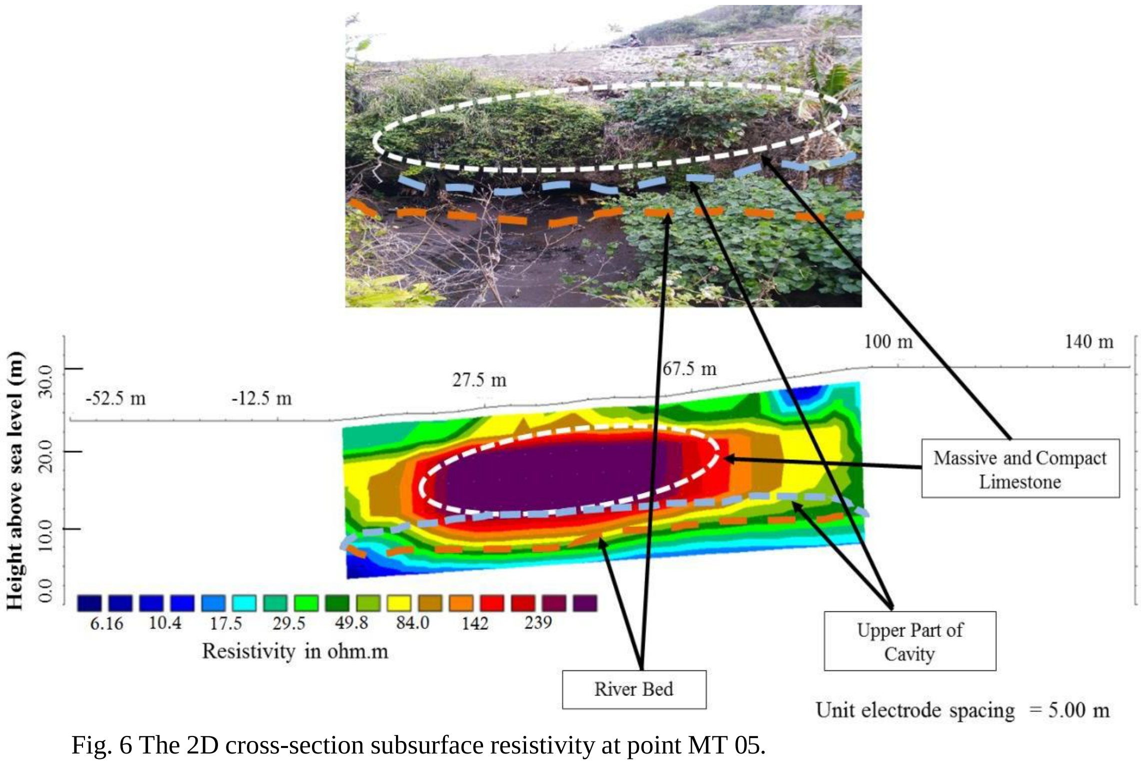

Fig. 6 The 2D cross-section subsurface resistivity at point MT 05.

4.4 MT 08

Point MT 08 is located at the coordinates of 112^o 35' 57.11" E and S 08^o 24' 03.61" S. The track length of point MT 08 is 100 meters, with six sounding points. Across the area of Point MT 08, we found a sloping structure, which, maybe a potential landslide in the JLS.

Fig. 7 is a modeling of the results in the form of a 2D cross-section representing the subsurface resistivity values at point MT 08.

The resistivity modeling in Fig. 7 shows, that, there is an anomaly of high resistivity (150-350 Ωm) in the east of the track. The direct field observations on the surface show, that, structure that is existing in the east of this track is a limestone hill, which was cut and used for JLS construction. The high resistivity, associated with this compact limestone seems to continue downward, below the surface. Thus, limestone is found to be the dominant lithology along this track.

However, at the depth of 15-20 meters, there is a low resistivity anomaly, ranging from 25 Ωm to 60 Ωm, which, is considered to be a cavity filled with water; or a shallow aquifer.

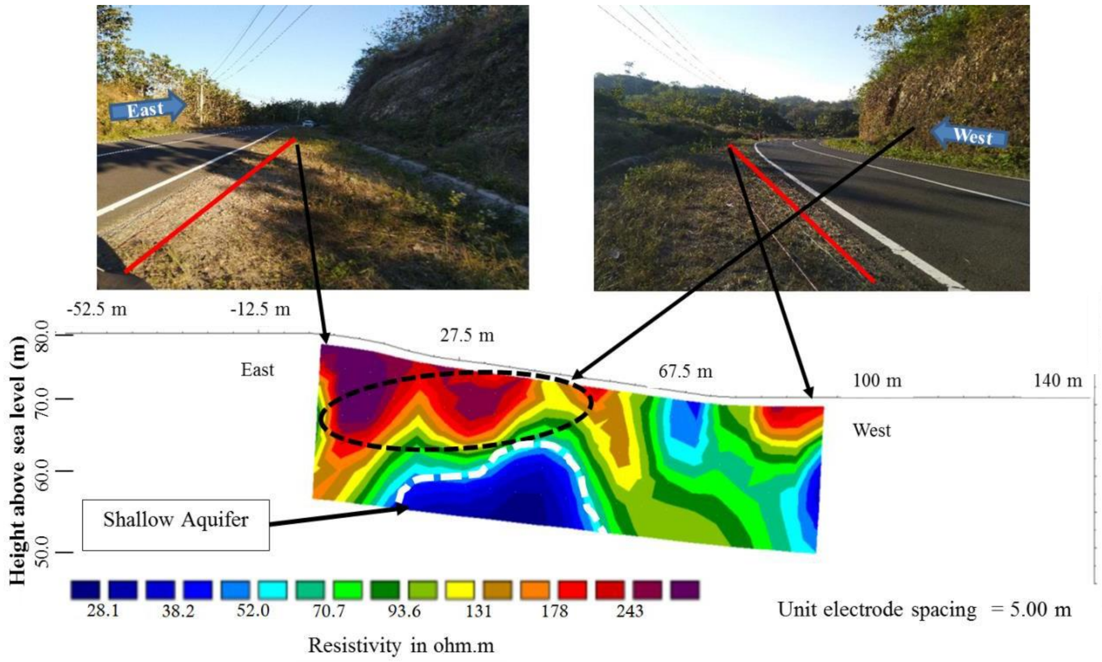

Fig. 7 The results of 2D subsurface resistivity modeling at Point MT 08 and field photos. The Red line in each photograph is the measurement line.

It is, therefore, important for everyone in the area, to be aware of its possible enlargement, due to water erosion, and its possible damaging effect on road construction. On the other hand, the water in the cavity may offer a shallow groundwater source.

.

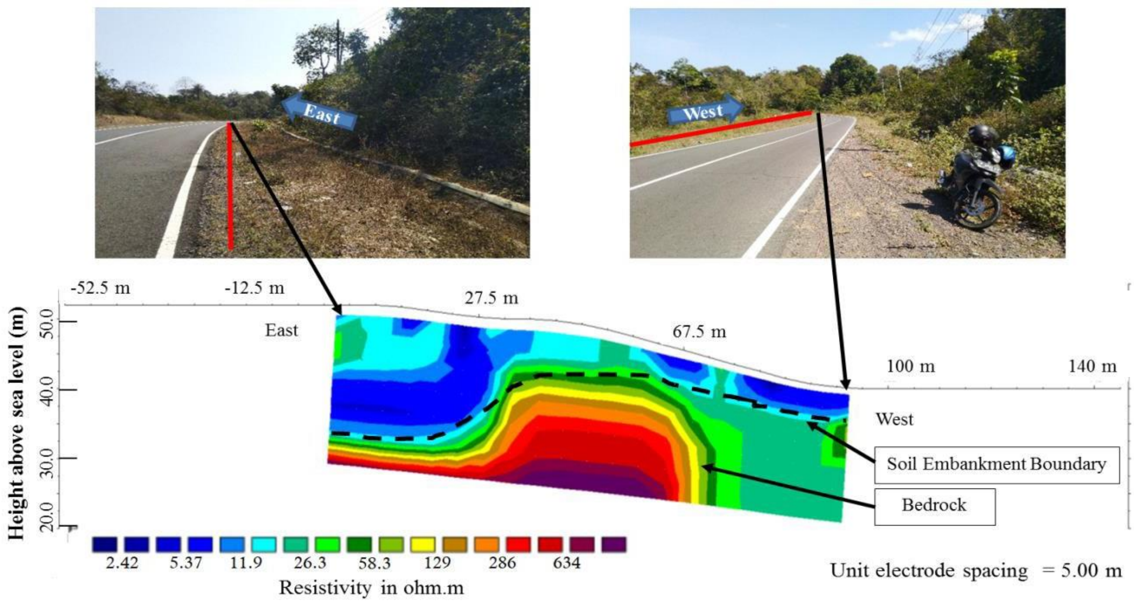

Fig. 8 The sections of 2D subsurface resistivity at point MT 10 along with several field photos. The Red line in each photograph is the measurement line.

4.5 MT 10

Point MT 10 is located at the coordinates of 112° 33' 08.74" E and 08° 23' 39.88" S, which has a track length of 100 meters with six sounding points. Observations in the field show, that, this point has ground motion indicated by a tilted electric pole. The ground movement was observed up to 200 meters to the east of a tilted electric pole. Consequently, the resistivity survey conducted at point MT 10 needs further attention, and to be aimed to investigate the potential for moving land.

The results of data processing of a 2D cross-section subsurface resistivity at point MT 10 is shown in Fig. 8.

Along the resistivity section of point MT 10, there is a low resistivity (2-30 Ωm) zone in the eastern part of the track. Field observations show, that, the area to the east of the track, is a soil embankment, as in the previous points. This zone maybe a soil embankment was obtained from the area around the measurement point with its low resistivity value. This soil embankment is loose or decomposed with good porosity but poor sorting. Meanwhile, at 5-7 meters below the surface, there is an anomaly with high resistivity values (129-700 Ωm). This value range is the same as that of limestone resistivity values at other measurement points. Thus, it is interpreted as a bedrock. The black dashed line in Fig. 8, is interpreted as the contact between bedrock and soil embankment

The overall results of measurements, observations, and interpretations, from all measurement sites, with their corresponding possible disastrous effects, are summarized, and presented, in Table 1. They, together with all data from measurements, can be used as the bases for formulating mitigation policies and practical strategies, such as determining the sites for warning signs.

Table 1: Observed/detected indicators from measurement sites, and the corresponding possible effects they may cause or indicate.

Site	Observed/Detected Indicators	Disastrous effects which may be caused or indicated
MT03	Brackish water pool	Water may seep into the foundation of the road, and, in due time, may deteriorate the road's stability
	Different materials used, i.e., between a rock pilling and rock/soil from hill slope cutting	May cause road instability, due to the characteristic differences between parts of the road foundation
	Seawater intrusion	Road instability
MT04	Nearby brackish water river	Water seeps into the road foundation and disturb road stability
	Presence of fault and fractures	Strong weathering on road construction materials, which may shorten the lifespan of the road
MT05	Cavities or cracks at the depth of 13-15 meters, which may form water channels	Road instability or cracks
MT08	Sloping structure	Landslides on the sides of the road
	WateThe water-filled or shallow aquifer (15-20 m)	Damages on the road construction
MT10	Ground creeping	Landslides
	Loose soil embankment	Weak road structures

5. CONCLUSION

Based on the results of the resistivity survey and field reviews of the areas along the JLS, Gedangan District, and Malang Regency, it is interpreted that the resistivity value of 300-700 Ωm corresponds to compact limestone lithology. Meanwhile, a low resistivity value (2.5-15 Ωm) is considered to be a material in wet conditions, possibly affected by the presence of brackish water. The discontinuity, which is observed in a zone within site MT04 whose resistivity value is 25-70 Ωm, is considered to be of a crack (a fracture or a fault). The low resistivity value of around 2.5-30 Ωm, may also correlate with the loose embankment material.

At point MT 05, a cavity filled with flowing water was detected. Likewise, at point MT 08, there is a low resistivity, which is considered to be a cavity filled with water that can trigger subsidence. The geoelectric data analysis results at the point MT 10 can be used as supporting data for further analysis of the suspected ground motion at this location, where the boundary between the bedrock and the weathered material, or embankment material above it, can act as a slip plane.

Overall results of this investigation are presented in Table 1, which shows various observed/detected indicators, and the corresponding effects they may cause or indicate.

The Wenner-Schlumberger configuration geoelectric method has been able to provide good subsurface images, which, can be used for the initial prediction of potential geological disasters, in an area.

6. REFERENCES

[1] Yodha, A. M., 2017. Potensi Bencana Geologi di Kabupaten Malang. Metronews.com https://nusantara.medcom.id/jawa-timur/peristiwa/0kpJG5qN-potensi-bencana-geologi-di-kabupaten-malang retrieved 25 January 2021.

[2] Susilo, A., Sunaryo, Fitriah, F., and Sarjiyana. Fault Analysis in Pohgajih Village, Blitar, Indonesia Using Resistivity Method for Hazard Risk Reduction. International Journal of Geomate, 14(41), 2018, pp. 111-118.

[3] Nana, 2018. Pembangunan Jalan Lintas Selatan Balekambang-Blitar Segera Dimulai. MalangTimes.com.https://www.malangtimes.com/baca/24811/20180208/171954/pembangunan-jalan-lintas-selatan-balekambangblitar-segera-dimulai retrieved 25 January 2021.

[4] Sunaryo and Susilo, A. Seepage Zone Identification at Sutami Dam using Geoelectrical Resistivity Data. IOP Conference Series: Earth and Environmental Science, Vol. 75, No. 1, 2017, p. 012011.

[5] Syukri, M., Taib, A. M., Fadhli, Z., and Safitri, R. Geophysical investigation of road failure in the case of the main street of Alue Naga, Banda Aceh, Indonesia. In IOP Conference Series: Materials Science and Engineering, Vol. 933, No. 1, 2020, p. 012056.

[6] Yilmaz, S. A case study of the application of electrical resistivity imaging for investigation of a landslide along the highway. International Journal of Physical Sciences, 6(24), 2011, pp. 5843-5849.

[7] Van Bemmelen, R. V., The Geology of Indonesia. Vol. IA: General Geology of Indonesia and Adjacent Archipelagoes. US Government Printing Office, 1949.

[8] Surono, Litostratigrafi Pegunungan Selatan bagian Timur Daerah Istimewa Yogyakarta dan Jawa Tengah, Geo-Sciences, JSDG, Vol. 19, No. 3, 2009, pp. 209-221.

[9] Sujanto, R. H., Kusnama, R. C. R. Baharudin, 1992. Geologi Lembar Turen–Jawa (Geologic Map of The Kebumen Quadrangle–Jawa).

[10] Sitinjak, A. E., Rayes, M. L., and Agustina, C. Morfologi dan Klasifikasi Tanah pada Berbagai Macam Sub-Landform Karst di Formasi Wonosari Kecamatan Gedangan, Kabupaten Malang. Tanah dan Sumberd. Lahan, 6, 2019, pp. 1055-1064.

[11] Loke, M. H., Electrical imaging surveys for environmental and engineering studies. A practical guide to, 2, 1999.Moghal A. A. B., Dafalla M. A., Elkady T. Y., and Al-Shamrani M.A., Lime Leachability Studies on Stabilized Expansive Semi-Arid Soil. International Journal of GEOMATE, Vol. 9, Issue 18, 2015, pp.1467-1471.