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Investigation of landslide zones with geoelectric methods for disaster mitigation in Pamekasan

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Abstract. Madura is one of the islands in Indonesia. This island had a landslide in 2016. The occurrence of this landslide resulted in the Madura community being mentally and financially burdened. The results of this study were that the soil layer consists of six types of soil, namely clay, clay, sandstone, sandstone with clay stones, quartz and limestone. Crossing types of clay and sandstone was the top layer with an average thickness of ± 1.2 m-6 m. quartz and limestone layers were bed rock rocks that were in depths of more than 10 m. While the slip plane was a field that becomes the basis of moving the ground mass. The soil layer which is the slip plane was clay and sandstone with slope 8^0-25^0. This soil layer has a low resistivity with a depth of ± 9.5 m - 11.5 m. The higher the slope of a layer, the faster the time needed for the avalanche to occur. For the evacuation route the batumarmar was heading north because the landslide direction was heading west and east, the springs were heading eastward because the landslide direction was heading west, proppo was heading north because the landslide direction was heading north to the east and south to the west, go east and west because the landslide was heading west and east. The results of the Community outreach on our research were the increasing readiness for landslides.

1. Introduction

Indonesia is a country surrounded by oceans. The country is also surrounded by active volcanoes andnon-active so that the effects of frequent natural disasters include tsunamis, earthquakes, volcanic eruptions, and landslides. In 2004 to 2007 various natural disasters have occurred which claimed thousands of lives and the biggest occurred in the Aceh tsunami and earthquake. In 2014 the Kelud mountains in East Java also caused victims of property and soul. In the last year, there have been earthquake disasters in Lombok, Palu, Sigi, Dongala, and Madura. Almost every year in Indonesia there are always natural disasters, therefore researchers in Indonesia try to maximize knowledge to find solutions and determine the point of natural disasters. This is useful for researchers to predict the occurrence of natural disasters that can only be predicted and anticipated to minimize the victims of these events. So the researchers began to maximize this knowledge as early mitigation of natural disasters, pre-natural disaster mitigation, and post-natural disaster mitigation.

Madura Island in 2018 caused an earthquake even though there were no fatalities. But the community is concerned that a bigger aftershock will occur. The Madura Islands have four districts namely Bangkalan, Sampang, Pamekasan and Sumenep. Just as in 2016 in Pamekasan district a natural disaster, namely a landslide, occurred. After the landslides in Pamekasan district, the government issued a letter to researchers to examine landslides and issue illustrations of landslide-prone disaster maps. However, the map is still not detailed about the constituent rocks, rock density and slope so there is a need for follow-up to get more satisfyingresults. This study describes four areas in Pamekasan about constituent rocks, rock density, and slope. The results obtained can be used to strengthen the landslide disaster mitigation information in Pamekasan.

One natural phenomenon has a high socio-ecological impact and loss of life is a landslide. To determine landslides requires a multidisciplinary approach. One multidisciplinary is geotechnical, geography, geology and geophysics [1]. Geography Science to determine landslide disaster mitigation by 6 factors. These 6 factors are the movement of soil, constituent rock, rock density, rock type, slope, and many plants. Geological science determines the type of rock globally. Geophysical science determines constituent rocks, rock density, and slope. This paper reviews the "Investigation of Landslide Zones using geophysical science".

Geophysical science to determine landslide zones is the geoelectric method. Geophysics is used in superficial investigations using computer technology and numerical methods [2][3]. To determine landslide zones or skidding midwives requires an analysis of morphological geological conditions and geophysical survey methods [4]. Landslide investigations can use the tomographic electrical resistance method (ERT) [5]. ERT can show the existence of a conductive zone by determining the landslide zone [6]. Geoelectric engineering to study hydraulic landslide processes [7][8][9][10][11]. ERT measurement and self-potential (SP) can determine landslide zones with the geometry of the Drainage system [12]. ERT and GPR measurements are applied to find the thickness and structure of landslides [13]. Surface exploration to determine landslide areas and geological settings using Electric Resistivity Tomography (ERT) [14]. To illustrate the geometry of landslides using electrical resistivity [15]. There are 4 types of geoelectric configuration methods, namely pole-pole, Wenner, dipole-dipole, and Schlumberger configurations [16]. To determine the landslide zone we use a dipole-dipole configuration. Dipole-dipole configuration is very efficient to determine landslide zones.

2. Method

This research method was a combination of 3 sciences, namely geophysical science, information systems science and scientific approach to society (humanities). The location of the studywas in Pamekasan Regency, there were four locations of this study, namely Batumarmar, Pakong, Proppo and Galis sub-districts (Figure 1).

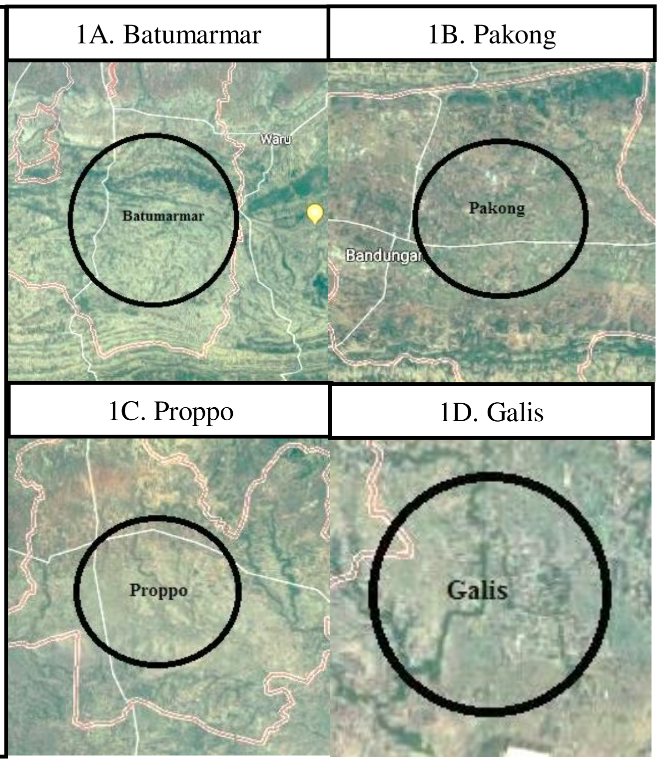

Figure 1. The research location consists of 4 sub-districts

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Geophysical scientific method uses several tools, namely Resistivity Meter 64 Channel serves to determine potential values and currents, 64 crocodile clamps function to clamp cable roll, 1 cable roll serves to connect 64meters resistivity Channel with 64 electrodes, 64 electrodes function to channel current and receive current, 1 geological compass serves to determine the slope, 1 geological map to determine the type of rock, 2 roll meter serves to determine the distance of 64 electrodes, 1 GPS serves to determine the point of the research location, 4 hammers function to plug electrodes and 1 battery serves to source electricity 64 Channel resistivity meter. Data acquisition uses a geoelectric method with 2 lines at each location. The length of each line is 300 meters, spacing 10 meters, N = 25 with a target depth of 78.8 meters. This method is very important to determine the landslide zone because it can see in detail the constituent rocks, moving rocks and rock density.

Information systems scientific method to determine safe paths during landslides. This scientific method uses hardware tools namely computers, Matlab software for numerical methods and photoshops software functions to combine geoelectric data and district maps of Pamekasan to describe landslide points and be able toengineer evacuation during landslides.

The scientific method of community approaches uses the human readiness approach before landslides, during landslides, and after landslides. This study requires interviews, discussions, and socialization of landslide mitigation.

3. Results and Discussion

3.1 Geoelectric Science

After data acquisition at 4 locations, Batumarmar, Batubintang, Proppo and Galis sub-districts. The results of processing data obtained a 2D cross-section of each track as in the following figure:

From the results of the 2D cross-section, it was found that the surface rock resistivity in Batumarmar subdistrict from 23.3 Ωm - 624 Ωm on line 1, rock resistivity surface on line 2 from 12.5 Ωm - 746 Ωm (Figure 2). Pakong sub-district surface rock resistivity from 25.6 Ωm - 1376 Ωm for line 1, surface rock resistivity from 27.8 Ωm - 2424 Ωm for line 2 (Figure 3). Proppo Subdistrict surface rock resistivity from 26.5 Ωm - 826 Ωm for line 1, resistivity surface rocks from 28.9 Ωm - 4946 Ωm for line 2 (Figure 4). Kecamatan Galis resistivity of surface rocks from 25.4 Ωm - 722 Ωm for line 1, surface rock resistivity from 25.5 Ωm - 885 Ωm for line 2 (Figure 5).

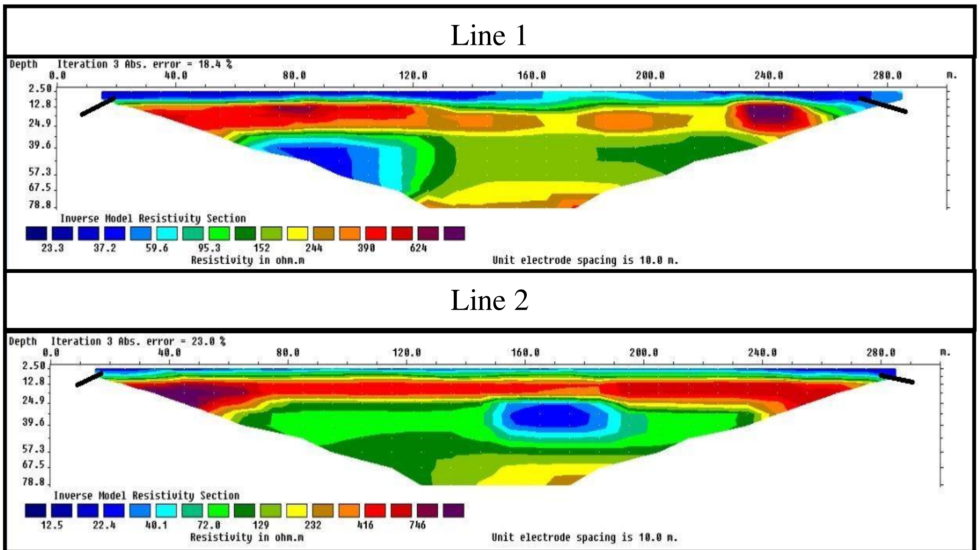

Figure 2. Results of Line 1 and Line 2 Measurement in Batumarmar

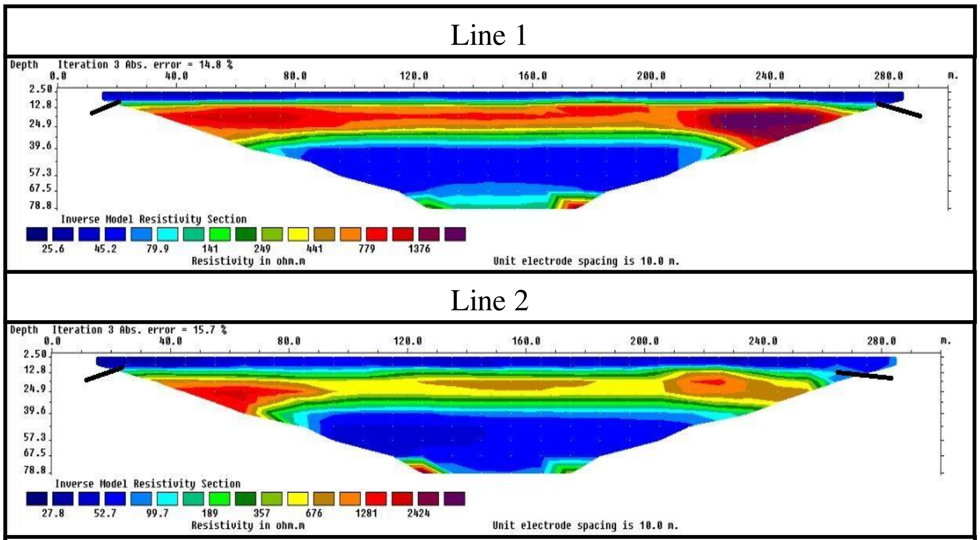

Figure 3. Results of Line 1 and Line 2 Measurement in the Pakong

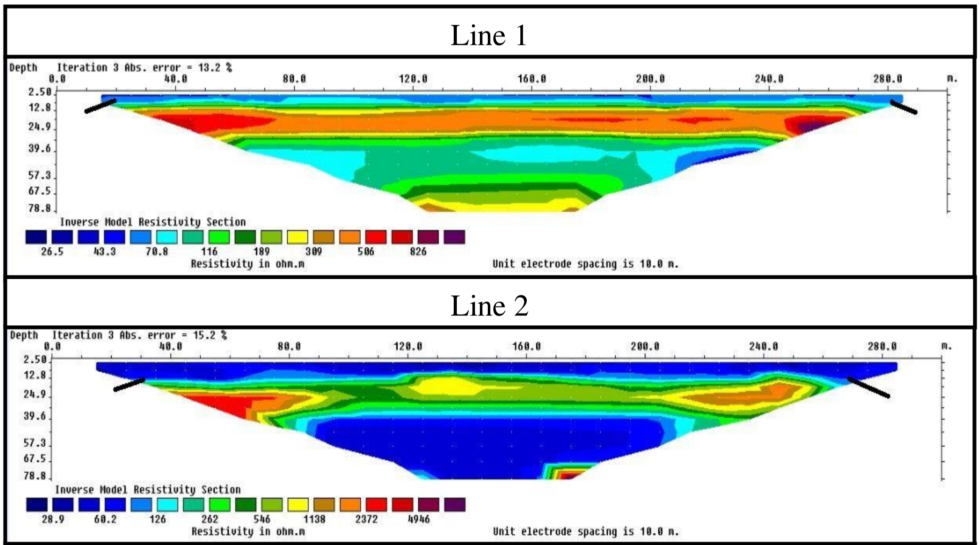

Figure 4. Measurement Results Line 1 and Line 2 at Proppo Locations.

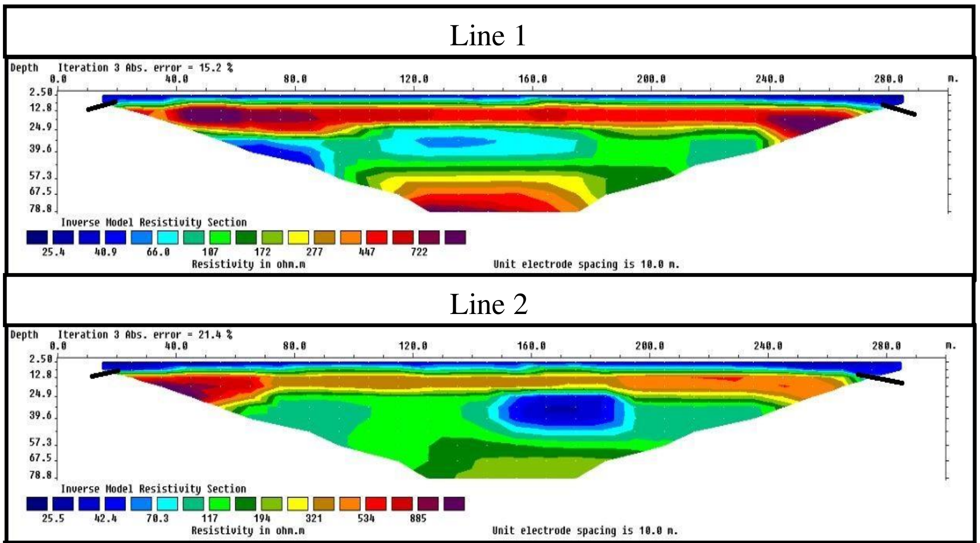

Figure 5. Line 1 and Line 2 Measurement Results in Galis Location.

From the results of the 2D cross-section, it was found that the surface rock resistivity in Batumarmar subdistrict from 23.3 Ωm - 624 Ωm on line 1, rock resistivity surface on line 2 from 12.5 Ωm - 746 Ωm (Figure 2). Pakong sub-district surface rock resistivity from 25.6 Ωm - 1376 Ωm for line 1, surface rock resistivity from 27.8 Ωm - 2424 Ωm for line 2 (Figure 3). Proppo Subdistrict surface rock resistivity from 26.5 Ωm - 826 Ωm for line 1, resistivity surface rocks from 28.9 Ωm - 4946 Ωm for line 2 (Figure 4). Kecamatan Galis resistivity of surface rocks from 25.4 Ωm - 722 Ωm for line 1, surface rock resistivity from 25.5 Ωm - 885 Ωm for line 2 (Figure 5).

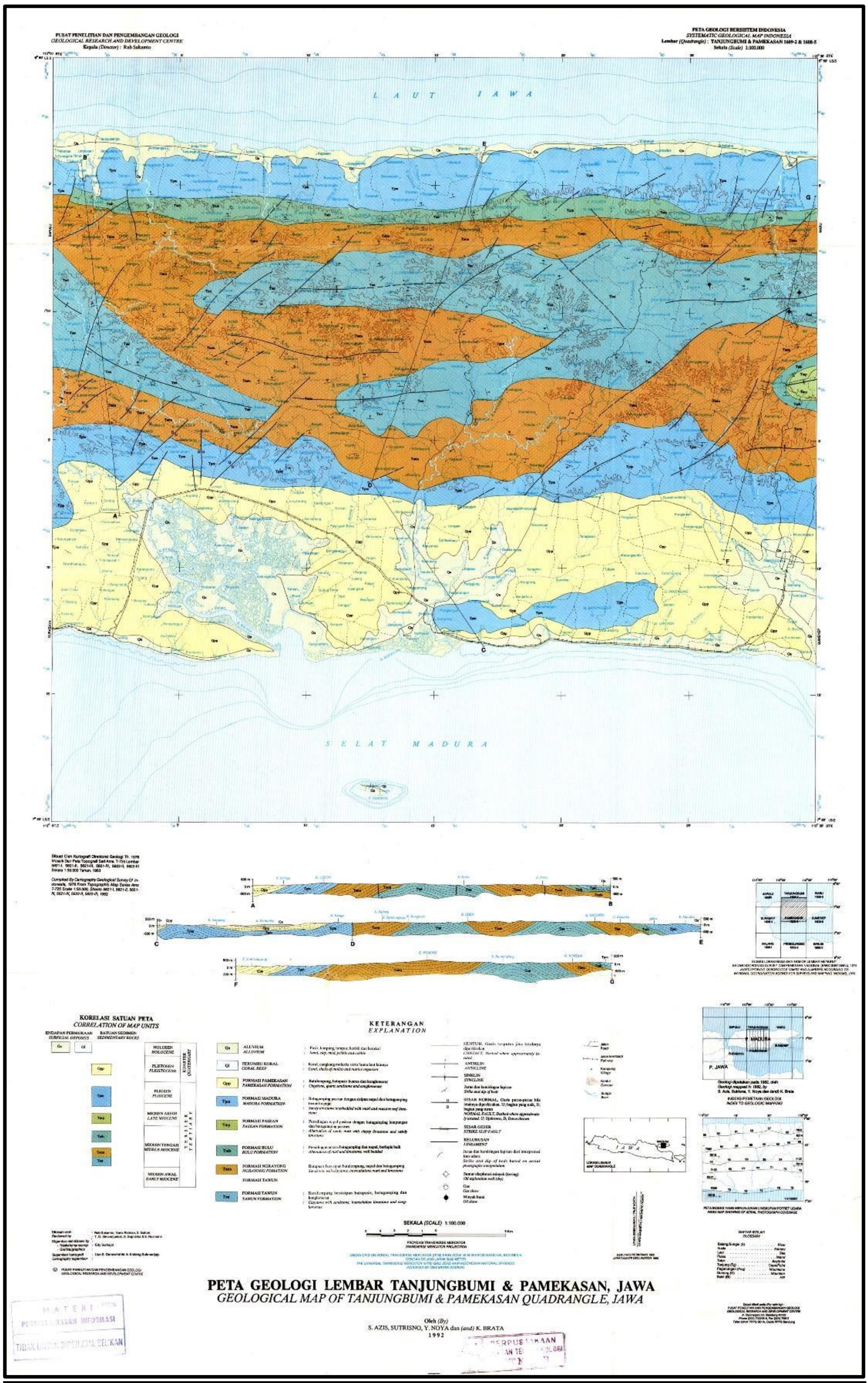

Figure 6. Geological Map of Pamekasan Sheet.

Based on lithology of four sub-districts, it has similarities. The similarity offour sub-districts is located in the soil layer carrying the slip plane. the existence of a slip field is in the first layer with a resistivity value of 20 Ωm to 50 Ωm. this layer is a clay layer with a slope of 25º Batumarmar sub-district, 23º Pakong sub-district, 8º Proppo sub-district, and 7º Galis sub-district. this means that the Batumarmar sub-district and Pakong sub-district have the potential to move or shift the land. However, it does not rule out the possibility that the Proppo sub-district and Galis sub-district have the potential to have a potential land shift. Due to the results of the study, the data obtained from the Proppo and Galis sub-districts have a layer of rock constituent similar to the Batumarmar and Pakong sub-districts. Supported by the results of the research [17]the episodic tilt movement consists of debris flow, rotational slide, soil material, and shallow translation. The slope value results in instability of the subsurface so as to cause landslides, The slope causes the soil to move so that it causes landslides [18].

In the cover for the four sub-districts, it has similarities. A composite layer of rock cover in the form of soil and gravel soil with different thickness. For Batumarmar sub-district on line 1 from 7 meters - 10 meters with a thickness of 3 meters, on line 2 from 5 meters - 11.5 meters with a thickness of 6 meters (Figure 2). For Pakong sub-district on line 1 from 12.7 meters - 15.9 meters with a thickness of 3.2 meters, on line 2 from 16.3 meters - 19.5 meters with a thickness of 3.2 meters (Figure 3). For Proppo sub-district on line 1 from 11.7 meters - 12.9 meters with a thickness of 1.2 meters, on line 2 from 18.4 meters - 21.2 meters with a thickness of 2.8 meters (Figure 4). For Galis sub-district on line 1 from 9.3 meters - 10.8 meters with a thickness of 1.5 meters, on line 2 from 12.1 meters - 13.9 meters with a thickness of 1.8 meters (Figure 5). From this explanation, the thickest cover layer is in Batumarmar sub-district with a thickness of 3 meters line 1 and 6 meters line 2.Supported by geological maps (Figure 6).

With the presence of sandstone limestone content, sandstone inserts with clay, clay rock and sandstone found in the four sub-districts. This indicates that the Batumarmar subdistrict has the most potential to be prone to mass movements because the very low inter-grain bond between the soils with an average depth of 12 meters causes the sub-district to be prone to erosion. The amount of soil erosion in these four sub-districts is grassland and forest land which results in these four sub-districts prone to erosion. Supported by research [19] the amount of soil erosion in the second highest grassland and the third highest forest land.

The existence of limestone rocks of sand and sandstone with claystone inserts indicates that the sub-district has skid areas that can cause landslides, plus in the area, there is a lack of vegetation cover land. However, it does not rule out the possibility of landslides in the Pakong, Proppo, and Galis sub-district because of the results of the research, there are slippage fields that cause landslides from clay rock and sandstone, plus there is a lack of land cover vegetation in the subdistrict. This means that these four sub-districts have the potential to be landslides and added to the observations in the field there are visible in some places there are soil cracks, this soil crack is very likely to cause landslides. Supported by research results [20] release of landslides caused by sandstone. in the landslide zone, there is solid sand that moves the soil [21]. Low permeability bedrock formations that cause landslides, The types of compilers of moving soil carrying the occurrence of landslides are sandstone and clay or clay rock [22]. clay sand causes landslides [23]. Land cover is very necessary to reduce the movement of soil from landslides, One of the factors that cause landslides is rock density [24].

3.2 Information Systems

The result of the lack of an information system is to determine the evacuation route on. The red color is the direction of a landslide, the blue color is the line of research on line 1 and line 2, the green color is the evacuation route during the landslide (Figure 7). The evacuation route at the Batumarmar location headed north due to the direction of landslides heading west and east (Figure 7A). The evacuation route at the Pakong location is heading east due to the direction of the landslide heading west (Figure 7B). The evacuation route at the location of the Proppo heading northwards because of the direction of the landslide heading north towards the east and south turn to the west (Figure 7C). Evacuation routes at the Galis location head east and west because of the direction of landslides heading west and east (Figure 7D).

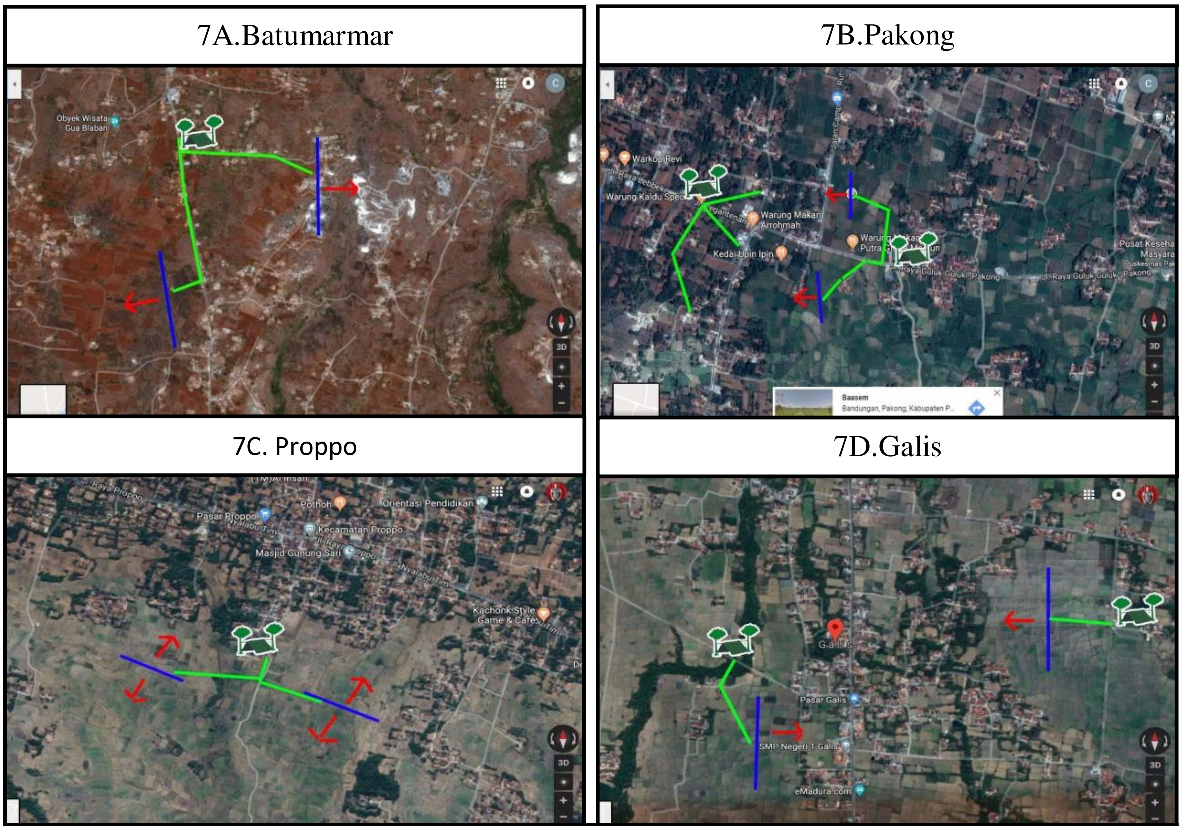

Figure 7. Evacuation Route

3.3 Community Approach

Based on the results of the interview with the community in the four research locations. The readiness of the Batumarmar, Pakong, Proppo and Galis communities about landslides is stillminimum. However, from the results of the socialization of the Community into these four sub-districts, our research using the Town Watching method has succeeded in preparing everything such as landslides. This method is presented in two stages; they are the learning process and department promotion.This method can increase public understanding of natural hazards and preparedness in the face of disasters[25].

4. Conclusion

These four research districts have the potential to a landslide, but the biggest landslide potential was in Batumarmar sub-district. The results of the research in these four sub-districts were Batumarmar Subdistrict from 23.3 Ωm - 624 Ωm on line 1, On this line from 7 meters - 10 meters with a thickness of 3 meters. surface rock resistivity on line 2 from 12.5 Ωm - 746 Ωm, at this line from 5 meters - 11.5 meters with a thickness of 6 meters. Pakong Subdistrict surface rock resistivity from 25.6 Ωm - 1376 Ωm for line 1, at this line from 12.7 meters - 15.9 meters with a thickness of 3.2 meters. Surface rock resistivity from 27.8 Ωm - 2424 Ωm for line 2, at this line from 16.3 meters - 19.5 meters with a thickness of 3.2 meters. Proppo Subdistrict surface rock resistivity from 26.5 Ωm - 826 Ωm for line 1, at this line from 11.7 meters - 12.9 meters with a thickness of 1.2 meters. Surface rock resistivity from 28.9 Ωm - 4946 Ωm for line 2, at this line from 18.4 meters - 21.2 meters with a thickness of 2.8 meters. Galis sub-district surface rock resistivity from 25.4 Ωm - 722 Ωm for line 1, at this line from 9.3 meters - 10.8 meters with a thickness of 1.5 meters. Surface rock resistivity from 25.5 Ωm - 885 Ωm for line 2, at this line from 12.1 meters - 13.9 meters with a thickness of 1.8 meters.

The existence of a slip field was in the first layer with a resistivity value of 20 Ωm to 50 Ωm. this layer was a clay layer with a slope of 25° for Batumarmar sub-district, 23° forPakong sub-district, 8°

for Proppo sub-district, and 7° for Galis sub-district. the greater the degree of slope, the more potentially landslide. So from the results of this study, the possibility of landslides was the Batumarmar sub-district.

Evacuation routes at the Batumarmar location was head north due to the direction of landslides heading west and east. The evacuation route at the Pakong location was heading east because of the direction of the landslide heading west. The evacuation route at the location of the Proppo was heading to the north because of the direction of the landslide heading north towards the east and south turn to the west. The evacuation route at the Galis location was heading east and west because of the direction of landslides heading west and east.

The results of interview withcommunity in four research locationswas the readiness of the Batumarmar, Pakong, Proppo and Galis communities about landslides was still very minimal. However, from the results of the socialization of the Community to these four sub-districts, our research has been successful so that the readiness of the community has increased.

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