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Sub Surface Geoelectrical Imaging for Potential Geohazard in Infrastructure Construction in Sidoarjo, East Java

Prihadi Sumintadireja[1,2] and Diky Irawan [2]

[1] Applied Geology Research Division, Geology Study Program, Institute of Technology Bandung, Jl. Ganesha 10, Bandung 40132, Indonesia
[2] Laboratory Application and Modeling of Geosciences (LVG), Geology Study Program, Institute of Technology Bandung, Jl. Ganesha 10, Bandung 40132, Indonesia.
Email: prihadi@gc.itb.ac.id

Abstract. Mud volcano remnants are identified in Surabaya and adjacent areas. The people in East Java based on historical report are custom and able to adjust with the natural phenomena within their areas. Sidoarjo mud volcano phenomena which coincident with drilling activity in 29 May 2006 is making people and government anxious for development a new infrastructure such as high rise building, toll road etc. An understanding of a geological hazard which can be single, sequential or combined events in their origin is the main key importance in subsurface imaging. Geological hazard can be identified by geophysical, geological, geotechnical method. The prompt selection of geophysical method to reveal subsurface condition is very important factor instead of survey design and field data acquisition. Revealing subsurface condition is very important information for site investigation consists of geological, geophysical and geotechnical data, whereas data analysis will help civil engineer design and calculate the construction safety.
Keywords: geoelectrical, mud volcano, geological hazard

1. Introduction

Geophysics is an application of physics sciences which measured the rock/earth properties in order to image the subsurface condition. Subsurface depth penetration result is depending on geophysical method selection and survey design. Regional scale subsurface condition can be used potential field method or passive geophysical method such as: gravity and geomagnetic. On the other hand for shallow and high resolution results are using active geophysical method which need generated source, such as: geoelectrical, georadar, control source audio magnetoteluric (CSAMT), seismic refraction/reflection etc.

Geoelectrical method is widely used in subsurface imaging due to simple and fast result for site investigation in infrastructure civil construction and development [1]. Commonly, well known as electrical direct current (DC) method which measured earth/rock electrical property, electrical direct current is injected to the earth, whereas the potential differences due to physical property measured within the earth. The measured geoelectrical potential differences value is depend on electrode array configuration and earth/rock medium as resistivity. The earth/rock resistivity value is highly correlated with porosity, fluid resistivity in pore, mineral content, water saturation, etc. [2]. Therefore, the geoelectrical method is one of the best geophysical methods for prediction geological subsurface imaging based on resistivity medium distribution.

The mud or clay with high porosity will represent as low resistivity features and clearly identified from the modeling. Subsurface mud volcano feature and distribution can be shown as map with geoelectrical method and interpreted as geological section. In this paper we elaborated the application of geoelectrical method for high rise building construction with deep foundation and vulnerable risk area in toll road relocation construction adjacent to recent mud volcano area in East Java province.

2. Mud Volcano distribution identification

There are many mud volcano found in East Java special Surabaya and adjacent area. At least a 14 has identified (Figure 1). There are many references elaborating and modeling the occurrences of mud volcano such as [3-8].

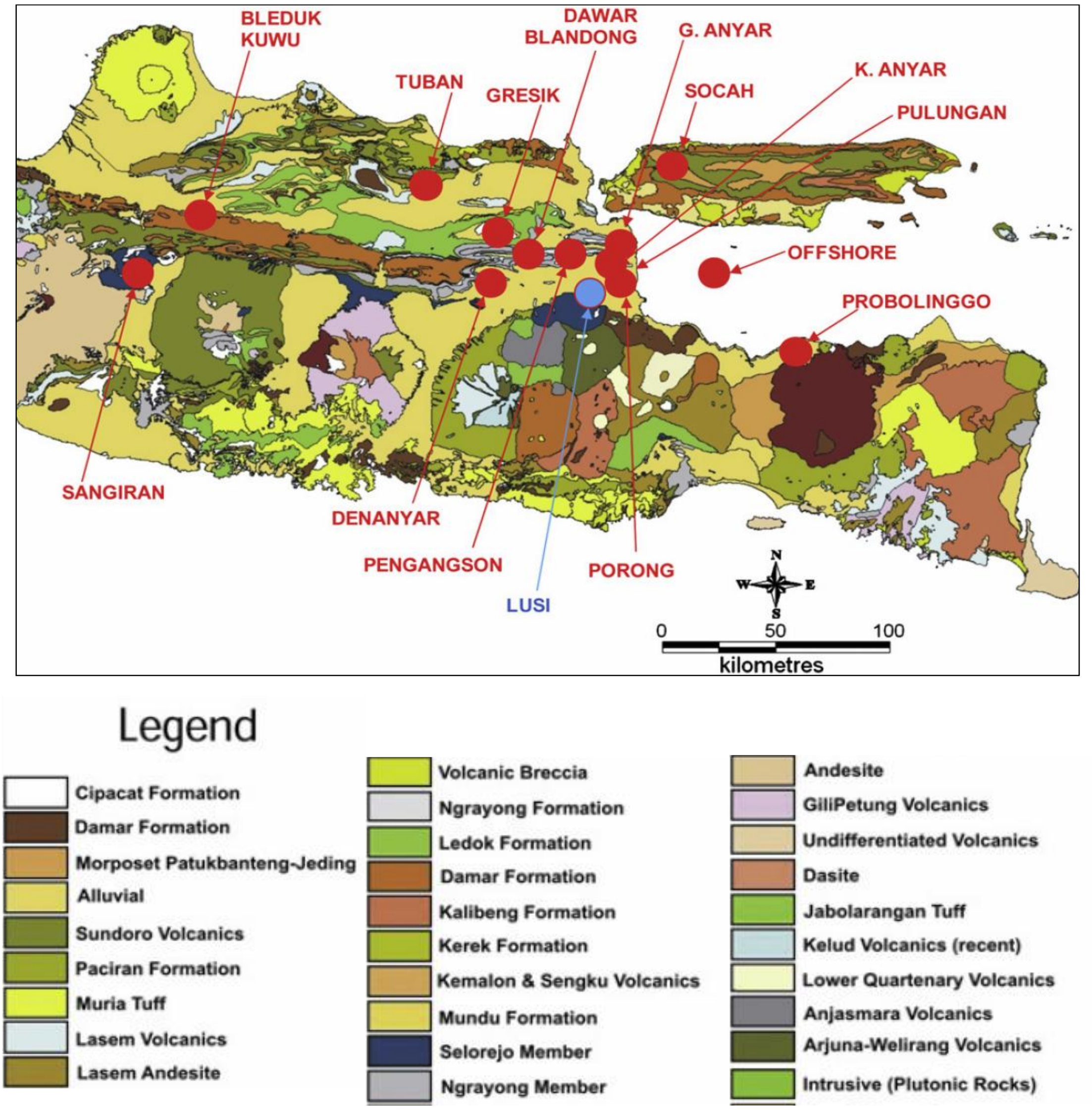


Figure 1. Geological map and mud volcano distribution in East Java [9].

The structural configuration of the East Java Basin includes two main structural lows of NE-SW and E-W orientation depocenters which are bounded by Bawean Arc to the northwest and North Madura Platform to the northeast directions. In the offshore part of the basin, the basement configuration is formed by northeast-southwest structural grain comprises a series of well define basement ridges with intervening grabens containing Tertiary sediments up to 18,000 feet in thickness. Two distinctive trends are recognized: the NE-SW orientation, parallel to the coastlines of East Kalimantan and West Sulawesi which form the flanks of the basin which continue towards SW direction into the East Java Basin where they define major sub-basins such as Central Basin and Muria Trough.

The origin of rifting in NE Java basin is interpreted to be relating to the onset of the NW subduction of oceanic crust along the SE margin of Kalimantan during the Early Cretaceous. The subduction is thought to have shifted with time in the southward in Eocene. The present location of the subduction trench runs parallel to the east-west striking wrench zone, which was reactivated in the Neogene period.

3. Case study 1: high rise building

Planning for high rise construction building is necessary to obtain special sub surface information better than ordinary building. Specific information dealing with soil/formation must be elaborate all of geology, geophysics and geotechnical data as hard data in order to mitigate risk and safety of the construction site. The anxiety people adjacent to center of mud volcano remnant must be consider as a stake holder who need clear explanation for both risk and safety of the construction related within their populated areas. Recent phenomena for mud volcano in May 2006 is located at Sidoarjo area East Java, make people worried if due to man-made construction will trigger mud volcano activity on their backyard.

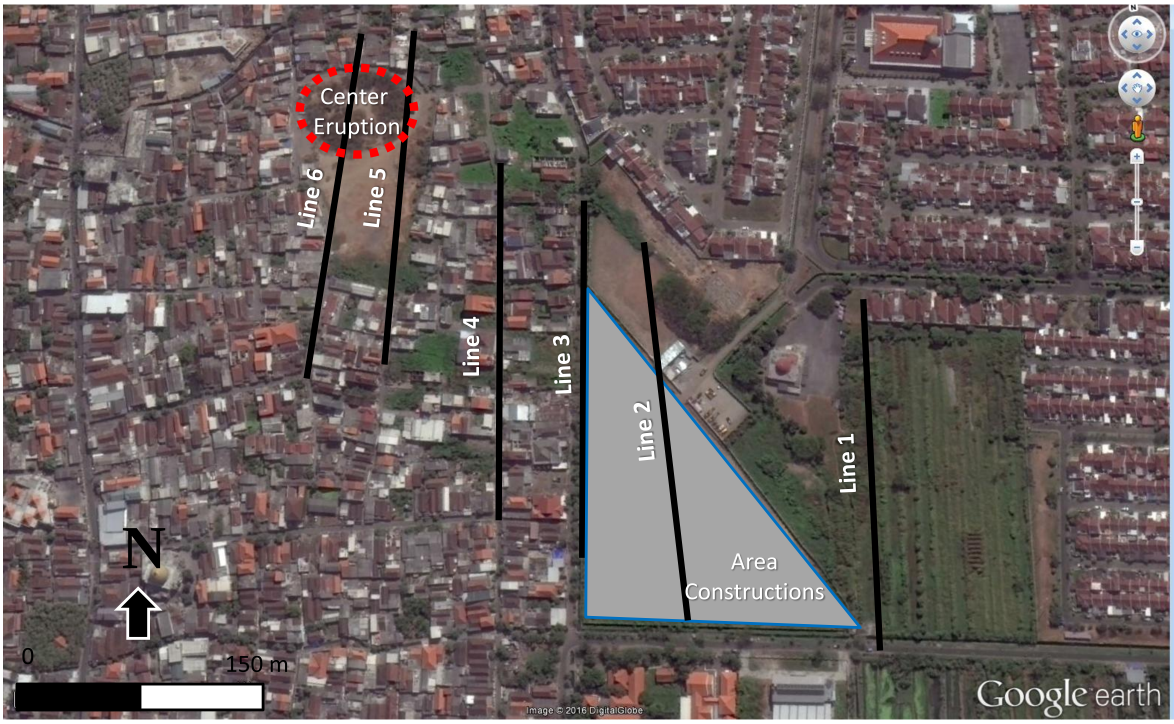


Figure 2. Geoelectrical Measurement Line.

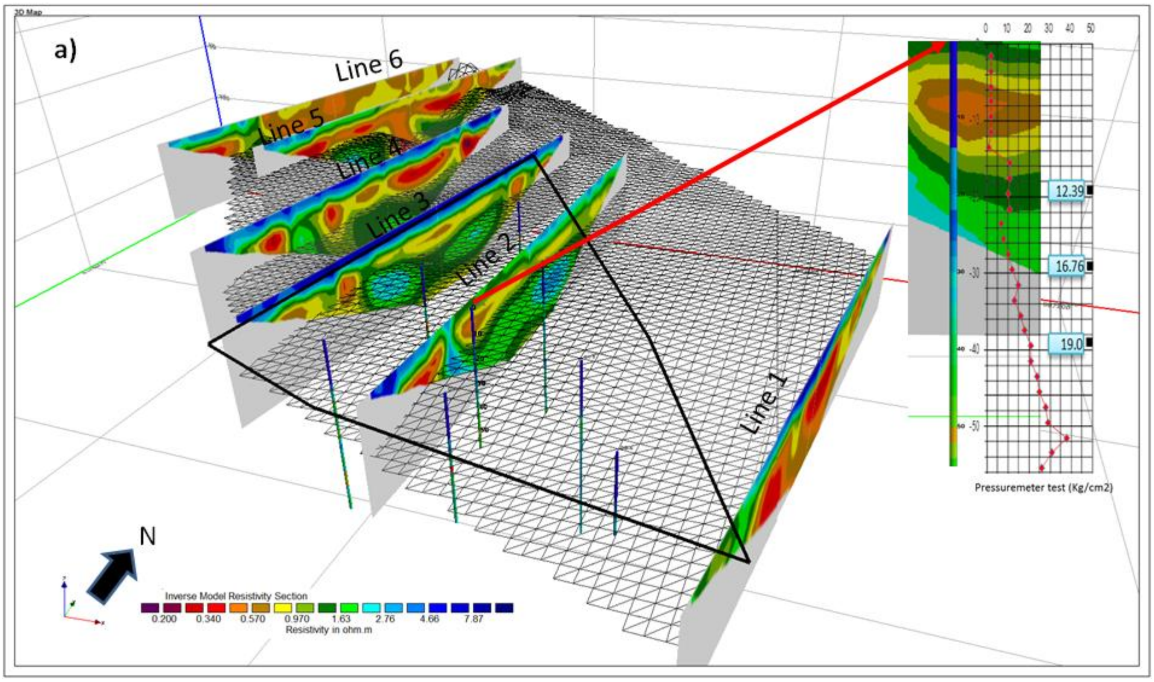
Six geoelectrical lines @ +235 m with 5 meter interval for 48 electrodes are designed as shown in Figure 2. The subsurface imaging is intended to convince people surrounding construction area about geohazard mud volcano potential due to high rise building construction plan.

Based on 2D geoelectrical model and well data, the survey area consists of 3 anomaly sub surface classification: landfill, very soft silty clay associated with mud volcano eruption and soft silty sand clay.

Resistivity 2D geoelectrical data for lines 5 and 6 (Figure 3) showing distribution of very soft silty clay (red-yellow) which thickening toward north part in western investigated area. Therefore, subsurface data indicated abundance clay deposit material of very soft silty clay which related with center of mud volcano extrusion in past. In the eastern part, upper layer interpreted as land fill (blue) as recent consolidated layer. All of 2D resistivity data showing thinning distribution of silty clay away from eruption center as shown in Figure 3a, whereas mud volcano distribution is shown in Figure 3b.

The geoelectrical model result is reflected lateral distribution of mud. Chronological sequence model for very soft silty clay is started from fault weak zone as mud pathways of mud volcano which the product found in site plan of the construction building (Figure 4).

Interpretation results based on resistivity subsurface imaging indicated that mud volcano adjacent to construction site is directly influence within 50 meter radius from center of mud eruption. On the other hand, the construction site is ±300 m away from the center is acceptable as long as civil engineering team select best foundation type and technique during building construction. Both geoelectrical and drilling data showing a good data match such as: characteristic of mud volcano deposits as very soft silty clay with high plasticity, still containing natural water with low SPT value (standard penetration test). Thickness of this layer is about 15 meter. Base of engineering bed rock is ranging between 65 and 145 meter below the surface.



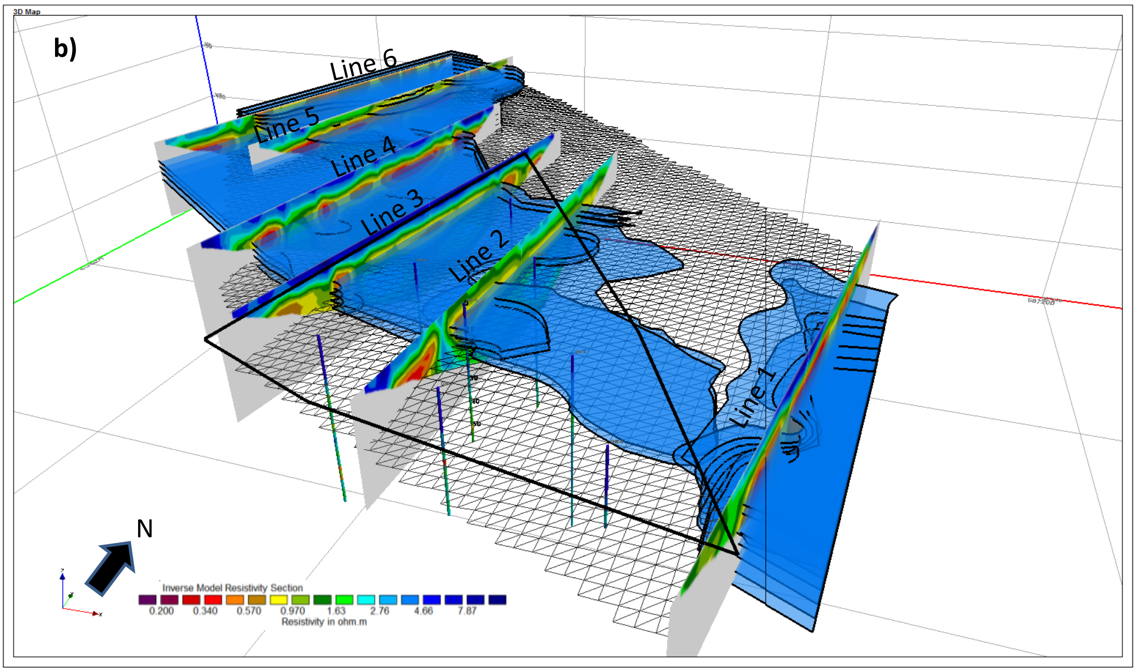


Figure 3. 2D Geoelectrical Model, well data and subsurface interpretation of lower boundary mud volcano product (a); Interpretation of mud volcano product distribution (b).

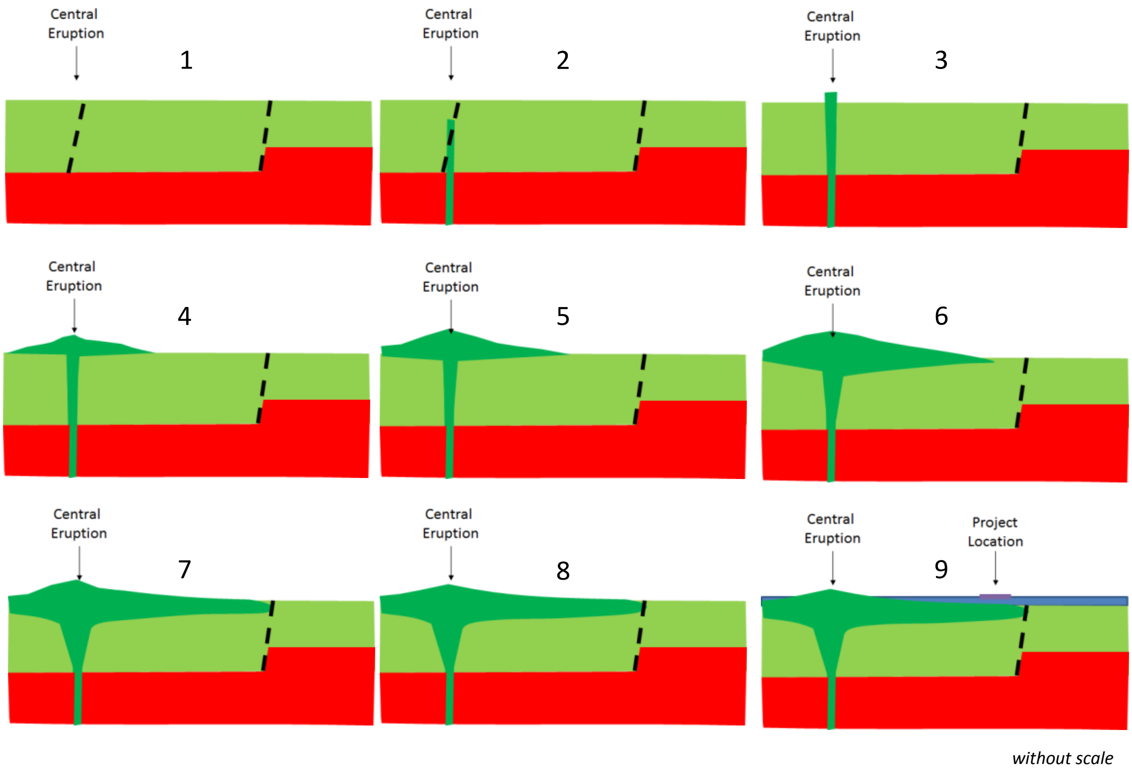


Figure 4. Chronological model very soft silty clay deposit erupted from weak zone of fault which is as mud pathways.

4. Case Study 2 Weak zone identification at toll road plan design

Mud extrusion at Porong, Sidoarjo, and East Java occurred 29 May 2006, about 150 m southwest of Banjarpanji 1 (BJP-1) Lapindo Brantas exploration well. Mud extrusion is still continuing until today (Figure 5).

Figure 5. Mud Extrusion Sidoarjo 28 Augusts 2009.

Based on analysis results carried out by [9 and 10], there is a possibility that the new toll road route planned within low deformation vulnerability zone. Therefore, deformation on the previous occurrence due to mud overburden surrounding can be found in the future. The presences of fault make a vulnerable potential for new source of mud extrusion since there is an indication weak zone as an active fault.

Geoelectrical using Wenner configuration of DC resistivity data acquisition carried out with 96 electrodes with 5 meter interval about 475 m length [11]. The objective is subsurface imaging about 30 meters depth with total 8 km line (Figure 6) The low resistivity features (red) in Figure 7 is consistently appears until + 27 meter depth in the northern part investigation area. Interpretation for the anomaly is a discontinuity of weak zone as fault within the adjacent area. The geoelectrical measurement result is confirming with geological survey agency study result [11-13]. Monitoring and special civil engineering construction around these areas must be considered the finding of the fault as identified previously.

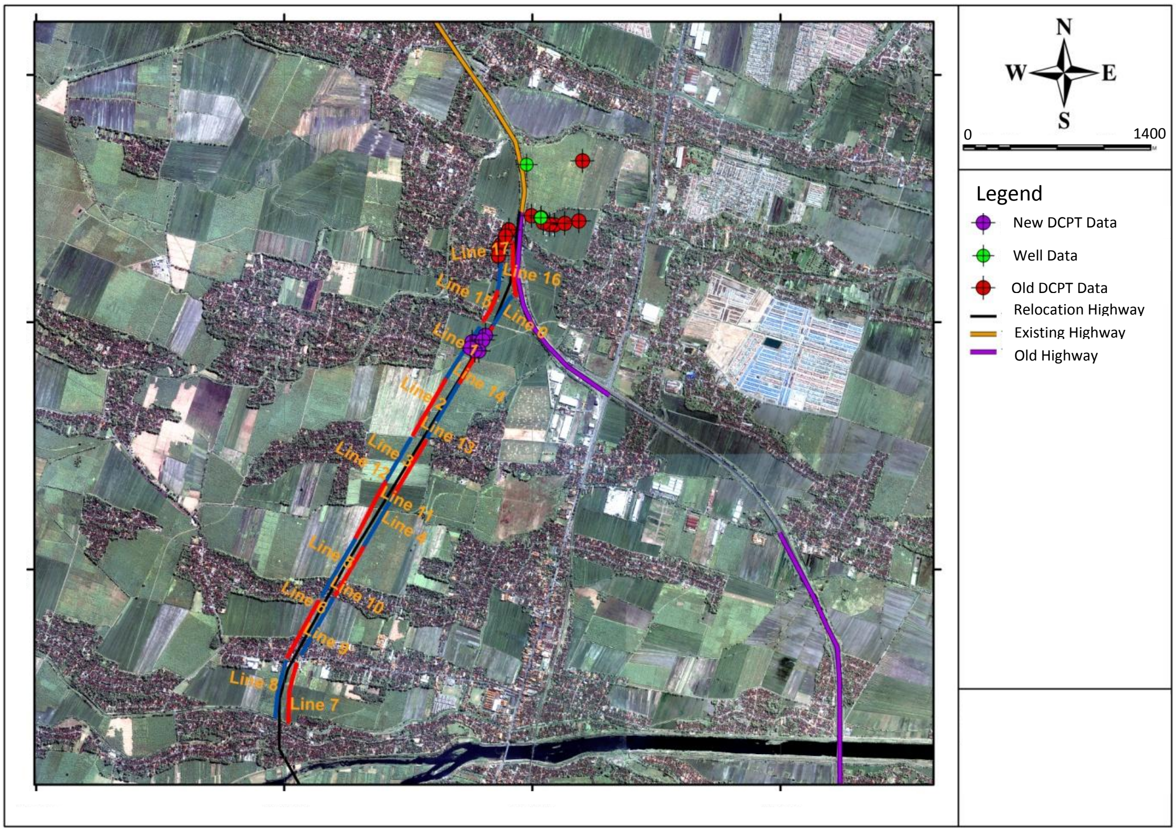


Figure 6. Geoelectrical line measurement [11].

Features of cross section compilation of 2D geoelectrical modeling as lateral resistivity is shown in Figure 7.

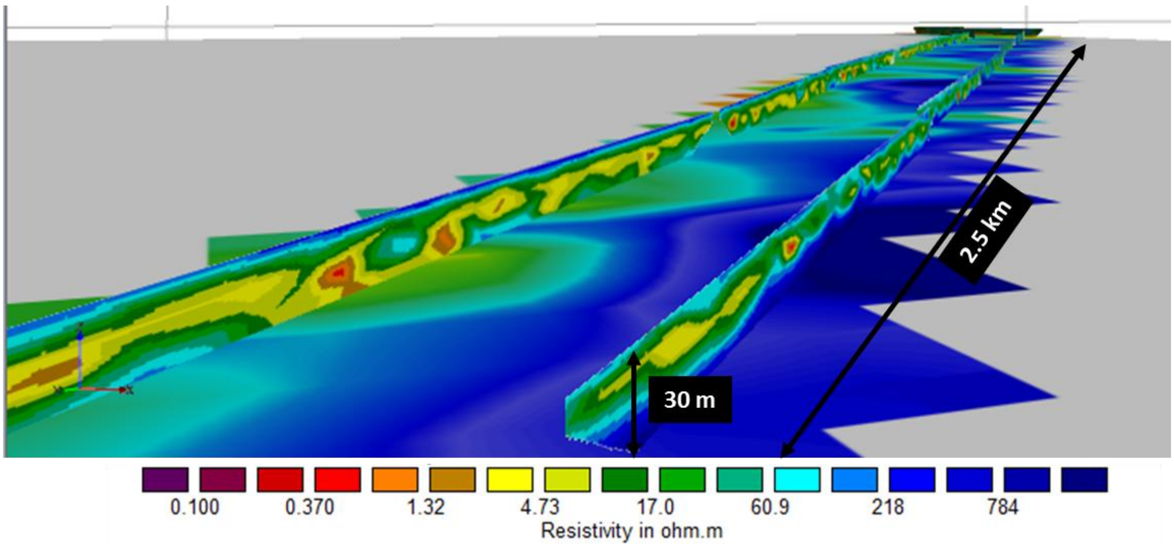


Figure 7. 3D Image of Lateral Resistivity Distribution.

5. Concluding Remarks

Based on two case study of planning high rise building and toll road which applying geoelectrical measurement and combine with well data is a powerful method subsurface imaging for both lateral and vertical of rock resistivity property distribution. The geoelectrical measurement is relatively give a very good result for shallow subsurface imaging, especially if combine with geotechnical data. It is easily to understand for common people to image distribution of rocks beneath their areas. Therefore, the contribution of the study results will help the stake holder who did the activity surrounding the area to explain their development/construction activity.

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