SUBSURFACE CHARACTERIZATION USING GEOPHYSICAL METHODS AT THE PROPOSED SITE OF BLOCK 11 AND BLOCK 12, UNIVERSITI TEKNOLOGI PETRONAS

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ABSTRACT

Subsurface study is an essential component not just in the oil and gas industry but also in the construction engineering industry. Geophysical methods are among the approaches that could be applied to map the subsurface conditions such as electrical resistivity imaging (ERI) and seismic refraction surveys. Four lines of ERI survey and two lines of seismic refraction survey had been carried out at the proposed site of the academic blocks (Block 11 and Block 12), Universiti Teknologi PETRONAS (UTP) to investigate the shallow subsurface condition and bedrock identification. The shallow subsurface tomography profiles were produced by using the Res2DInv and GeoGIGA Software for the ERI and seismic refraction respectively. Based on the results of both methods, relating to the geophysical parameters and the borehole data. Generally, three subsurface layers were found which are alluvium, weathered bedrock (parent material) and bedrock. The alluvium consists of water saturated zone and compacted layer indicated with resistivity range and seismic velocity of 30-200 ohm.m (except for the compacted layer; 800-1000 ohm.m) and 1500 m/s respectively. The second layer which is moderately weathered bedrock consists of 150-800 ohm.m resistivity range and a seismic velocity of 3000 m/s. The bottom layer is a fresh sedimentary bedrock with the value of 800-2500 ohm.m resistivity range and a seismic velocity of >3000 m/s. Both profiles have shown a good result, particularly when it ties identically to the borehole data.

Keywords; electrical resistivity Imaging, Seismic Refraction Tomography, bedrock

INTRODUCTION

The new academic complex of Universiti Technology PETRONAS (UTP) should be built in the shape of a 5-pointed star made up by 5 semi-circles and the first phase construction was completed in 2004. During the first phase, instead of 23 proposed blocks, only 16 blocks were constructed according to cost optimization and the current needs. The missing blocks are from Block 6 up to Block 12 and the establishment of Block 11 and Block 12 will complete the 4th semi-circle. In order to proceed with the second phase construction of the academic complex (Block 11 and Block 12), UTP management needs the subsurface information on the proposed site in terms of the foundation's safety. The two methods of geophysical approaches were carried out namely, electrical resistivity and seismic refraction surveys to characterize the shallow subsurface of the proposed site to come out with an approximate thickness estimation of alluvium and bedrock. Electrical resistivity imaging and seismic refraction tomography are some of the common geophysical techniques which are used in the study of subsurface especially in terms of construction and building foundation investigation. Borehole data are usually used to calibrate the geophysical profiles in order to reduce the uncertainties of the lateral and vertical variation.

STUDY AREA

Located in Seri Iskandar, Perak, Universiti Teknologi PETRONAS geological background is related to the Kati Formation which covers most of the Perak Tengah region. Figure 1 shows the exact location of the study area which is situated at the southern part of Block 13, Department of Civil Engineering Building, UTP. These two buildings will provide both academic and research facilities for the two departments. Namely, Department of Petroleum Engineering and Department of Geosciences.

reddish brown to purplish carbonaceous shale, siltstone, mudstone and rare sandstone with minor conglomerate and carbonaceous limestone deposited in deep waters [2]. Kati Beds is then renamed to the Kati Formation since it was interpreted equivalent with the Kubang Pasu Formation [3]. Thermal metamorphism seems to be occurred on this area based on the evidence of granite intrusion, but [4] stated that this formation is less affected by thermal metamorphism, but it is mostly affected by the regional metamorphism. It is hard to determine the thickness of the bed since some of the beds are highly folded [1]. Therefore, the Kati Formation thickness is measured by studying the outcrops available. For example, an outcrop in Seri Iskandar which is estimated to be 780 m thick [5]. The formation represents as one of the Palaeozoic clastic formation of the western zone and the extension can be found which is exposed in the southern part of Kinta Valley which includes Seri Iskandar, Bukit Tunggal and Parit [6].

Figure 1 Study area - On the right side, the yellow region is Western belt of Peninsular Malaysia. The red box shows the location of UTP. On the left side, the red circle is the proposed site of Block 11 and Block 12 in UTP.

The Kati Formation is part of Palaeozoic rocks formed on the Western Belt of the Peninsular Malaysia. Foo (1990) stated that Kati Beds are located around Kuala Kangsar area and it extends southward along the western bank of Sungai Perak into Kinta Valley. The Kati Beds lithology are composed of metamorphosed

METHODOLOGY

Electrical Resistivity Survey

The Electrical resistivity surveys involve injecting current into the ground from two electrodes and measuring the voltage difference between two other potential electrodes. For nearly a century, these surveys have been used to perform one-dimensional profiling (detection of lateral changes in underground electrical properties by moving a fixed electrode array along a survey transect) or sounding (detection of vertical changes by expanding an electrode array about a fixed location). Electrical resistivity imaging system using the ABEM SAS4000 terrameter including ES10-64C Electrode selector is mainly carried out with a multi-electrode resistivity meter system. Such surveys use a number (usually 41 to 61) of electrodes laid out in a straight line with a constant spacing. A computer-controlled system is then used to automatically select the active electrodes for each measure [7].

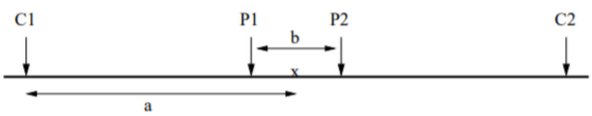

Figure 2 Schlumberger array

is much more complex as the spacing between the current electrodes not equal to the spacing between the potential electrodes (Figure 2). For the survey, the system is connected to 41 steel electrodes which lays out on a straight line of 240 m with a constant spacing of 6 m via multi-core cables. A microcomputer unit is connected to the switcher unit then automatically selects four active electrodes used for each measurement (Figure 3). The resistivity method basically measures the resistivity distribution of the subsurface materials. In general, the potential electrode spacing is negligible compared to the current electrode spacing for this type of array. From the array, the apparent resistivity can be calculated by using Equation 1 and later create a resistivity profile by using the Res2DInv software.

$$\rho_a = \pi\left[\left(\frac{a}{b}\right)^2 - \frac{1}{4}\right]\frac{V}{I} \qquad (1)$$

Where;

ρ_a = apparent resistivity, a = distance from C1 to center, b = the gap between two potential electrodes, V= voltage, I=current.

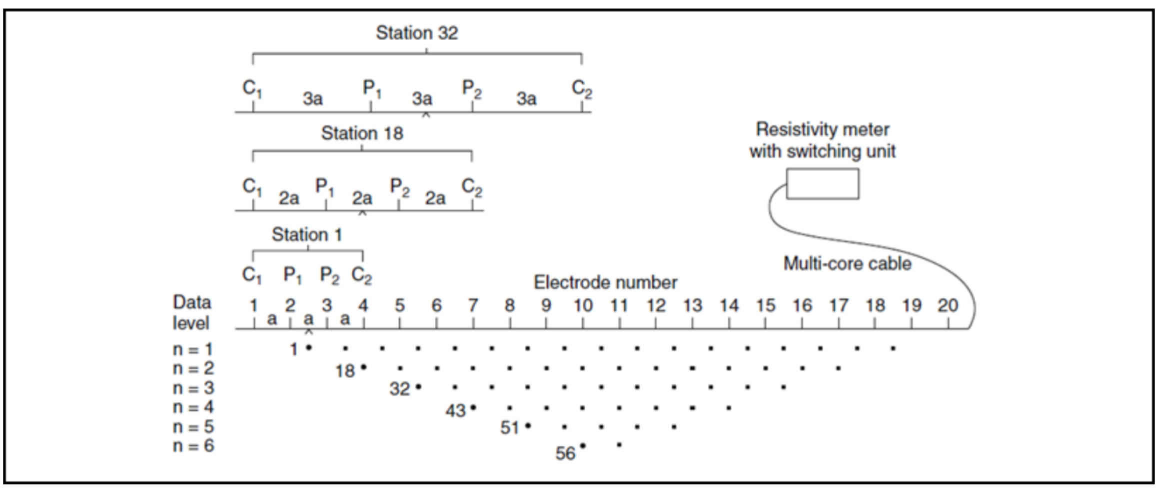

Figure 3 The arrangement of electrodes for a 2D electrical resistivity survey and the sequence of measurement used to build up a pseudo section

In the resistivity survey, there are various electrode configurations that can be used. The apparent resistivity measured by the array depends on the geometry of the electrodes. Most of resistivity surveys use a two current electrodes and two potential electrodes. The array configuration will be used is the Schlumberger array. The Schlumberger array

Seismic refraction method is commonly used in shallow depth investigations. This method is based on the measurement of the travelling time of the seismic waves refracted at the interfaces between the subsurface layers of different velocity created by hitting a steel plate with a hammer on the surface. When the shots are fired, the acoustic waves propagate into the subsurface at a velocity dependant on the elastic properties of the material on how the wave travel. When the waves reach an interface where the density or velocity changes significantly, a portion of the energy is reflected back to the surface and the remainder is transmitted into the lower layer. A part of the energy also will be refracted when the velocity of the lower layer is higher than the upper layer. Critically refracted waves travel along the interface at the velocity of the lower layer and continually refracting energy back to the surface. The refracted and reflected waves will be recorded by the geophones (Figure 4). The data were recorded on a seismograph and later downloaded to the computer for analysis of the first arrival times to the geophones from each shot position.

Seismic refraction equipment used during this investigation consisted of ABEM MK8 Terraloc, 14 Hz vertical geophones, two refraction cables with 12-foot takeout, a sledgehammer, weight drop and an aluminium striker plate. Each seismic line is consisted of one overlapping geophone for each spread are nominally spaced 5 m for a total spread length of 240 m for all the seismic lines. Nine shot point locations were used per spread which consists of four offset shots and five in line shots with an off-end shots located at a distance far enough to image the deepest refractor. The fundamental of the seismic survey layout is shown in Figure 5. Picking of the first arrival times of the seismic data and processing of the seismic refraction data was processed using GeoGIGA. Table 1 shows the resistivity values and seismic velocity values of rocks and soil types as a reference. Figure 6 shows the layout of four resistivity lines and 2 seismic lines on the proposed site. Both

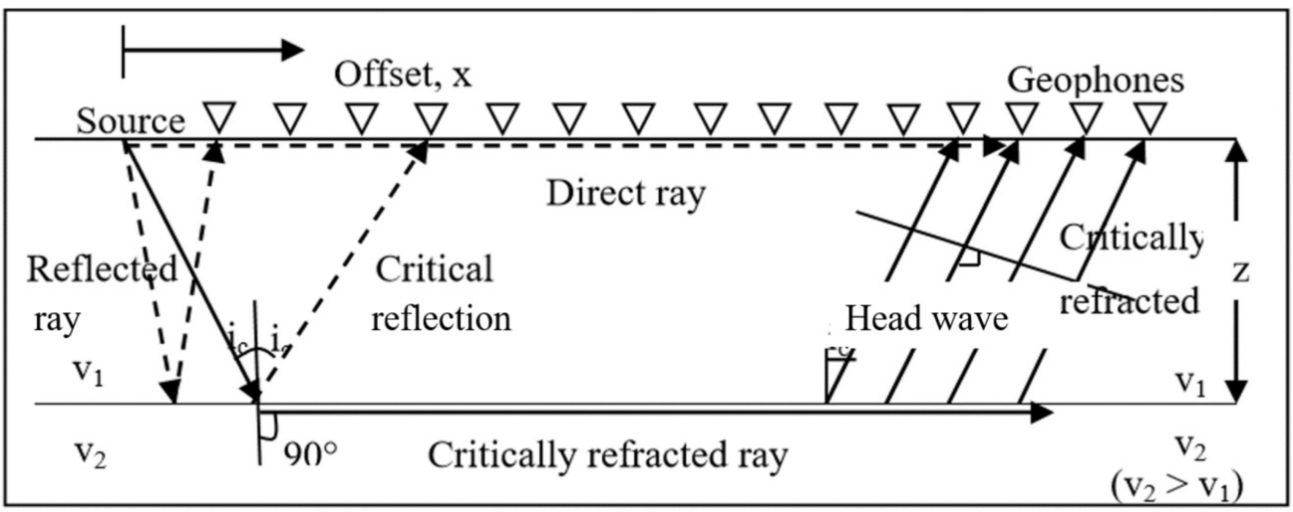

Figure 4 Ray path diagram showing the respective paths for direct, reflected and refracted rays [8]

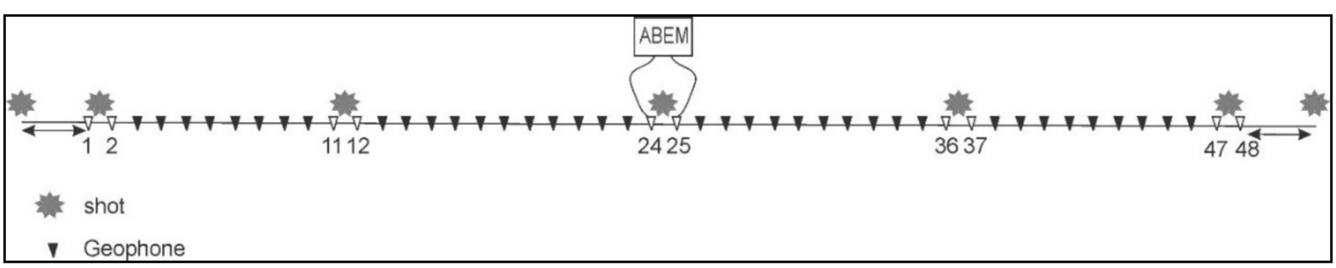

Figure 5 Five in line shots and two offset shots that will be done for each proposed line

seismic and resistivity survey lines were oriented from Southwest to Northeast based on the structure geology information of Alkhali et al. [5].

Table 1 Resistivity and velocity of some common rocks and minerals [9]

Material	Seismic (m/s)	Resistivity (Ohm-m)
Sediments		
Sandstone	1830 - 3970	8 - 4 x10^3
Shale	2750 - 4270	20 - 2 x10^3
Unconsolidated sediment		
Clay	915 - 2750	1 - 100
Alluvium	500 - 2000	10 - 800
Marl		1 - 70
Clay (wet)		20
Groundwater		
Fresh water	1430 - 1680	10 - 100

RESULTS AND DISCUSSION

Figure 7 to 10 shows the electrical resistivity imaging profiles and Figure 11 and 12 are the seismic tomography profiles. The resistivity profiles show the penetration depth is around 55 m from the surface and the deepest interface for the seismic profiles is around 64 m. Based on the results of both methods, relating to the geophysical parameters and borehole data. Generally, the three subsurface layers were found which are alluvium, weathered bedrock (parent material) and bedrock. The alluvium consists of water saturated zones and the compacted layer indicated with the resistivity range and the seismic velocity of 30-200 ohm.m (except for the compacted layer; 800-1000 ohm.m) and 1500 m/s respectively. The second layer which is moderately weathered bedrock consists of 150-800 ohm.m resistivity range and a seismic velocity of 3000 m/s. The bottom layer

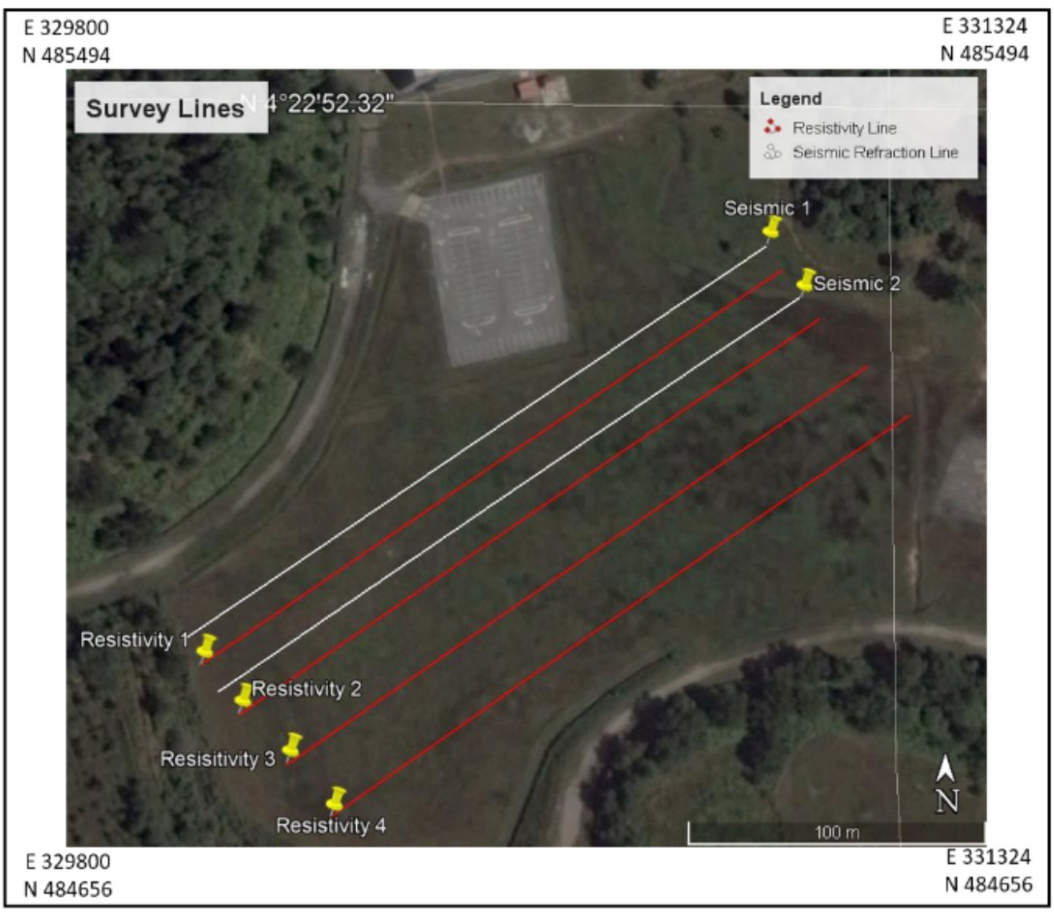

Figure 6 Two seismic refraction lines (white) and four resistivity lines (red)

is a fresh sedimentary bedrock with the value of 800-2500 ohm.m resistivity range and a seismic velocity of >3000 m/s. A borehole data was used as a reference for correlation as it shows the thickness of alluvium and weathered sedimentary rock are around 25 m and 55 m respectively.

The Figure 7 to 10 shows the vertical variation of the subsurface based on the electrical resistivity properties. The bedrock is close to the surface and the dipping structures are clearly observed as it goes to the northeast part while the water saturated layer zone of alluvium is thinning from northwest to southeast.

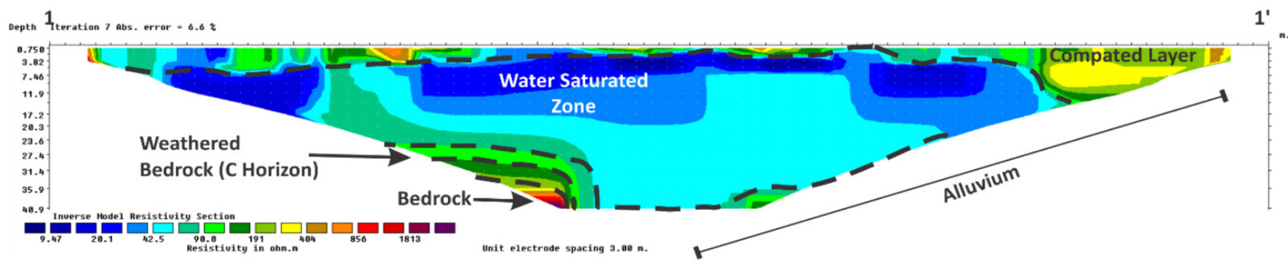

Figure 7 Resistivity Profile of Line 1

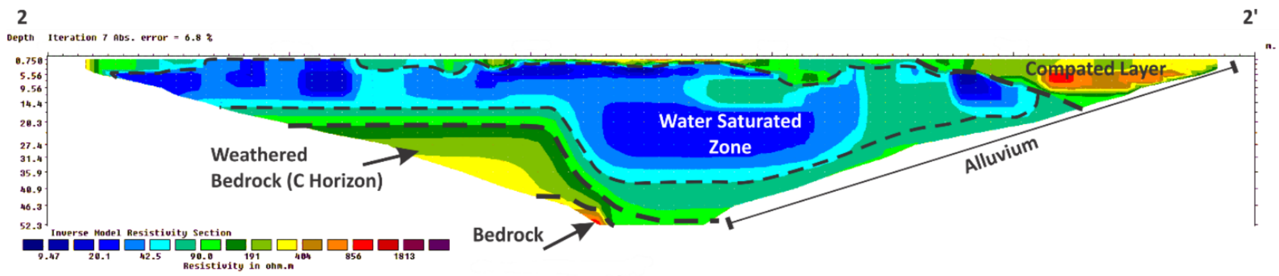

Figure 8 Resistivity profile of Line 2

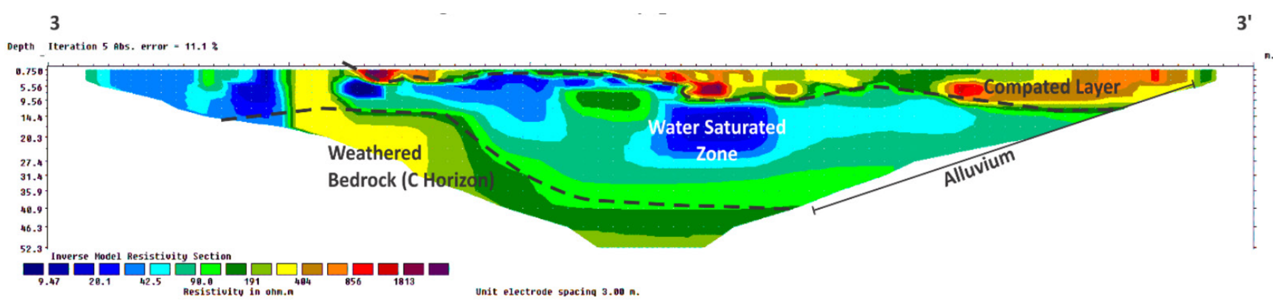

Figure 9 Resistivity profile of Line 3

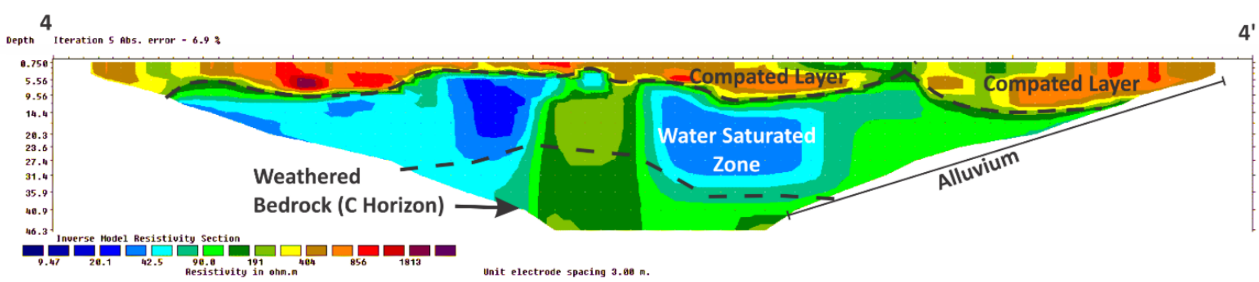

Figure 10 Resistivity profile of Line 4

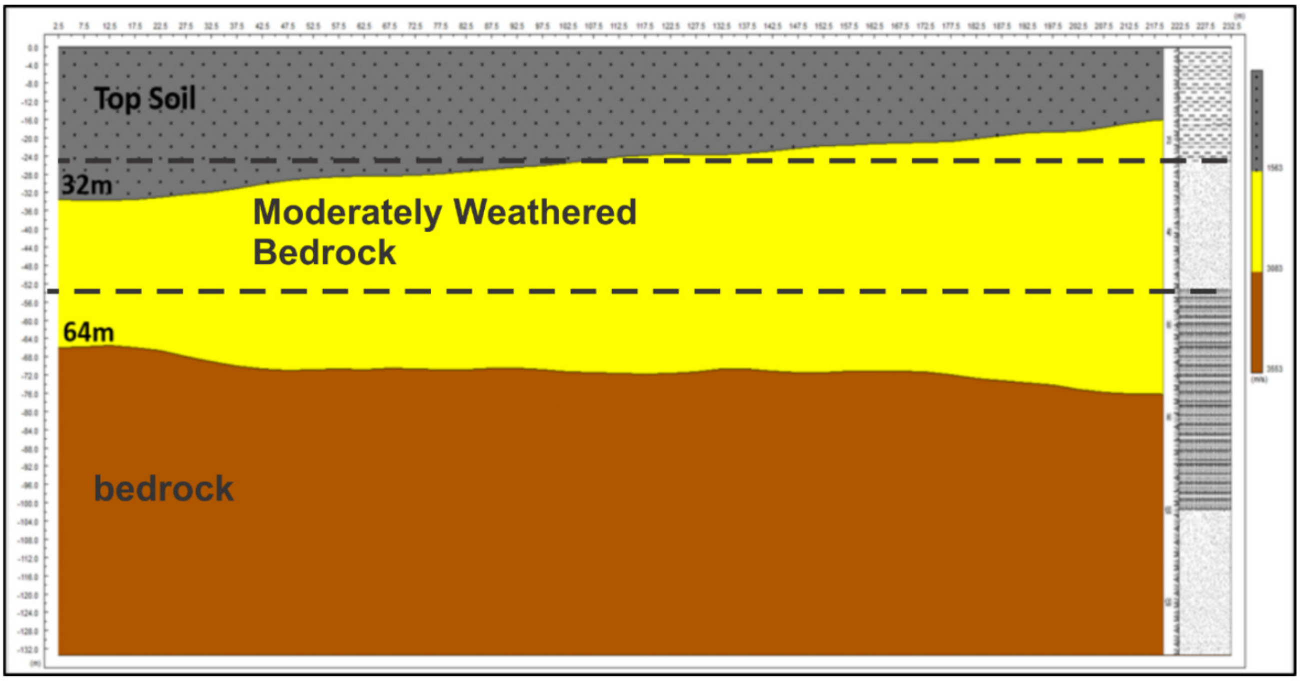

Figure 11 Seismic Tomography profile of Line 1 and borehole data.

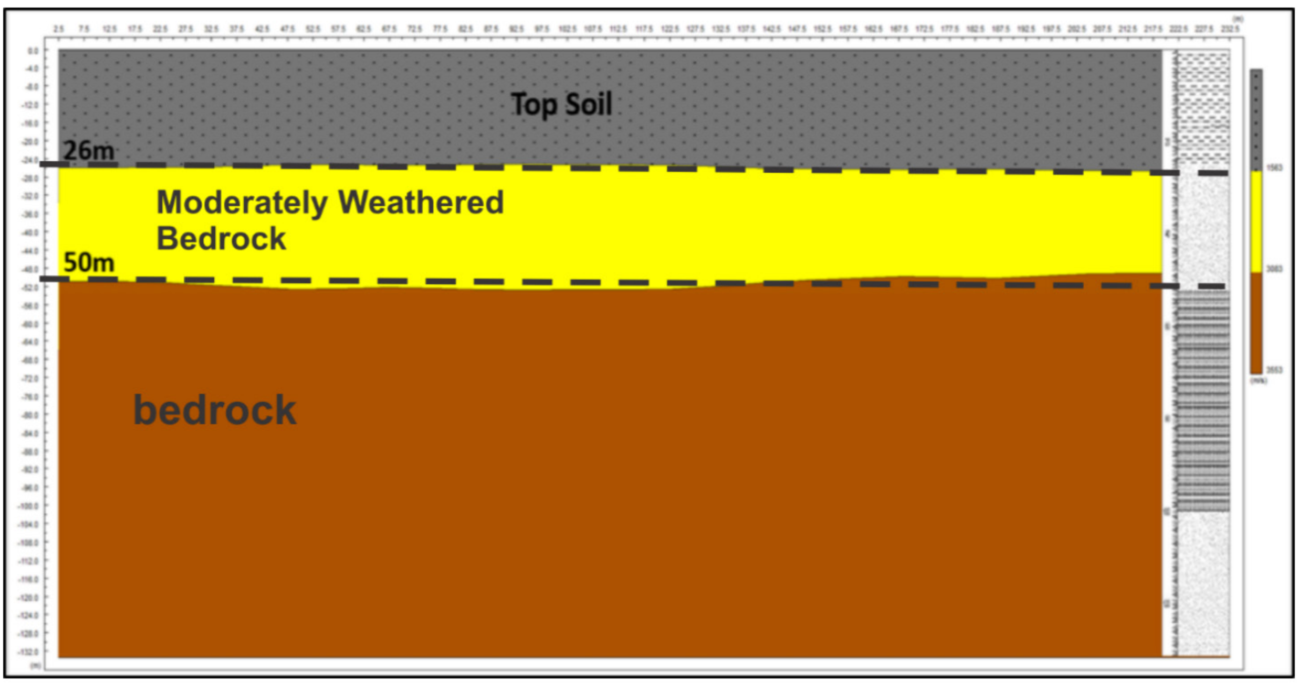

Figure 12 Seismic Tomography profile of Line 2 and borehole data.

These were happening probably due to the granite intrusion (Kledang granite) during the Permian-Triassic age that uplifts the sedimentary rocks of Kati Formation dipped towards northeast region. The compacted zone on the northeast part is due to the compacted ground during the previous construction. Figure 13 shows the combination of four resistivity lines on the location map as well as a 3D resistivity model for vertical and lateral resistivity distribution evaluation on Figure 14.

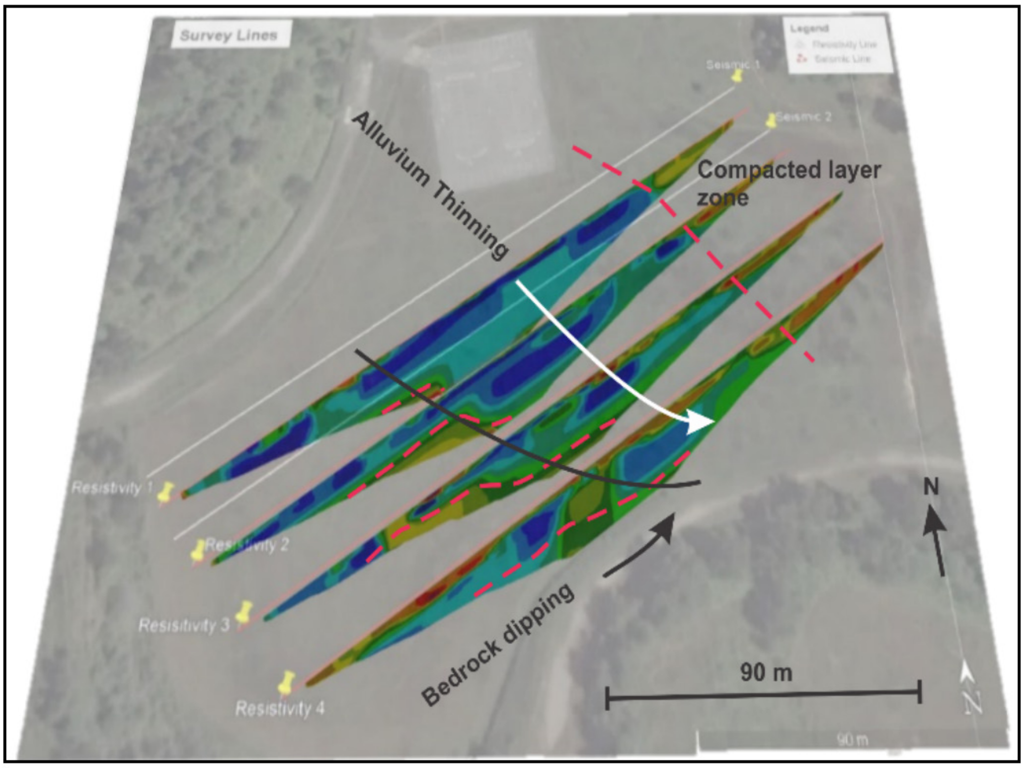

Figure 13 The resistivity profiles on the location maps

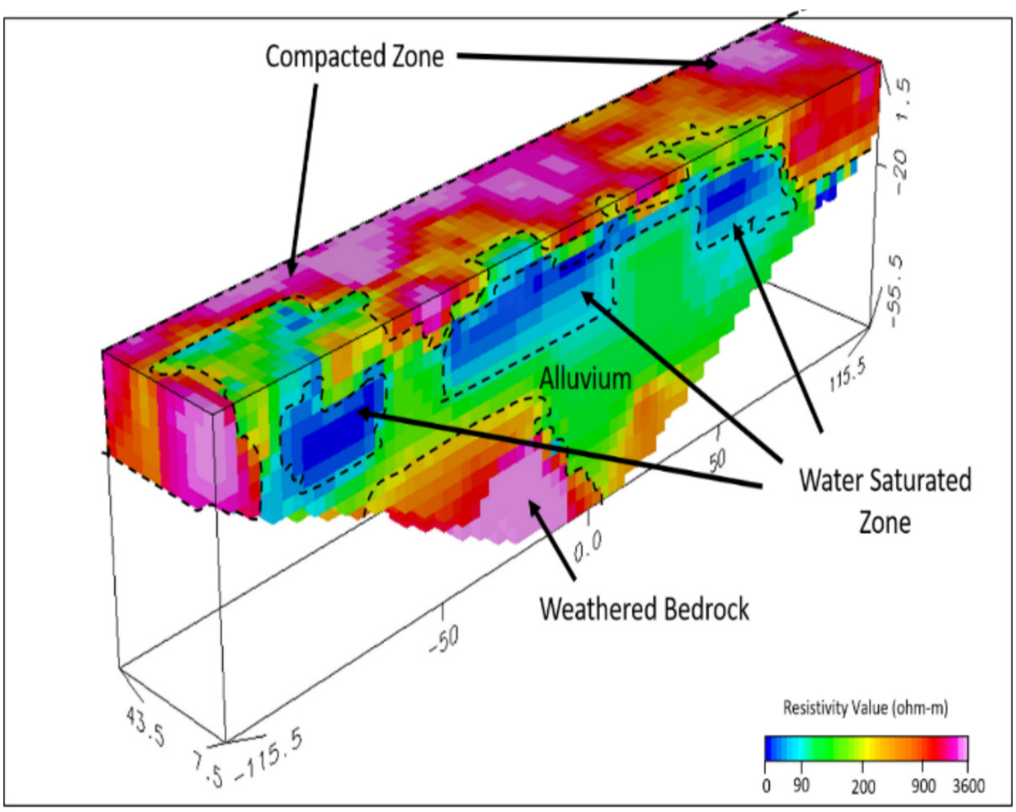

Figure 14 3D models of resistivity

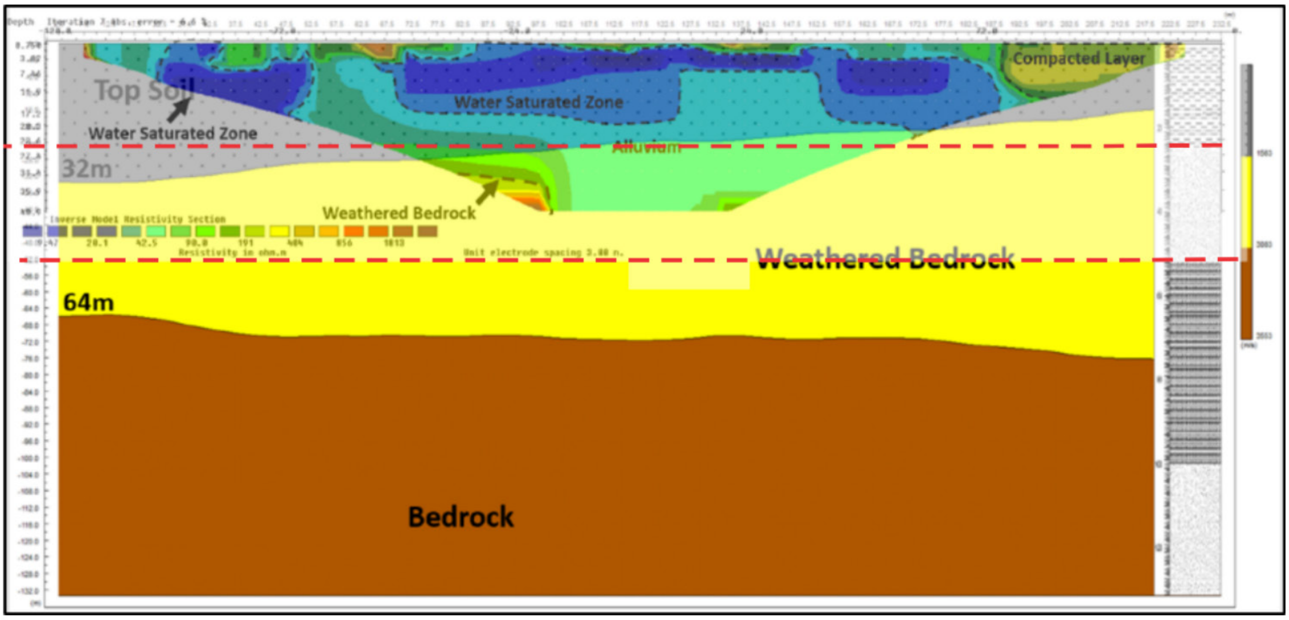

Figure 15 Integrated section of the resistivity profile 1, seismic tomography profile 1 and borehole data

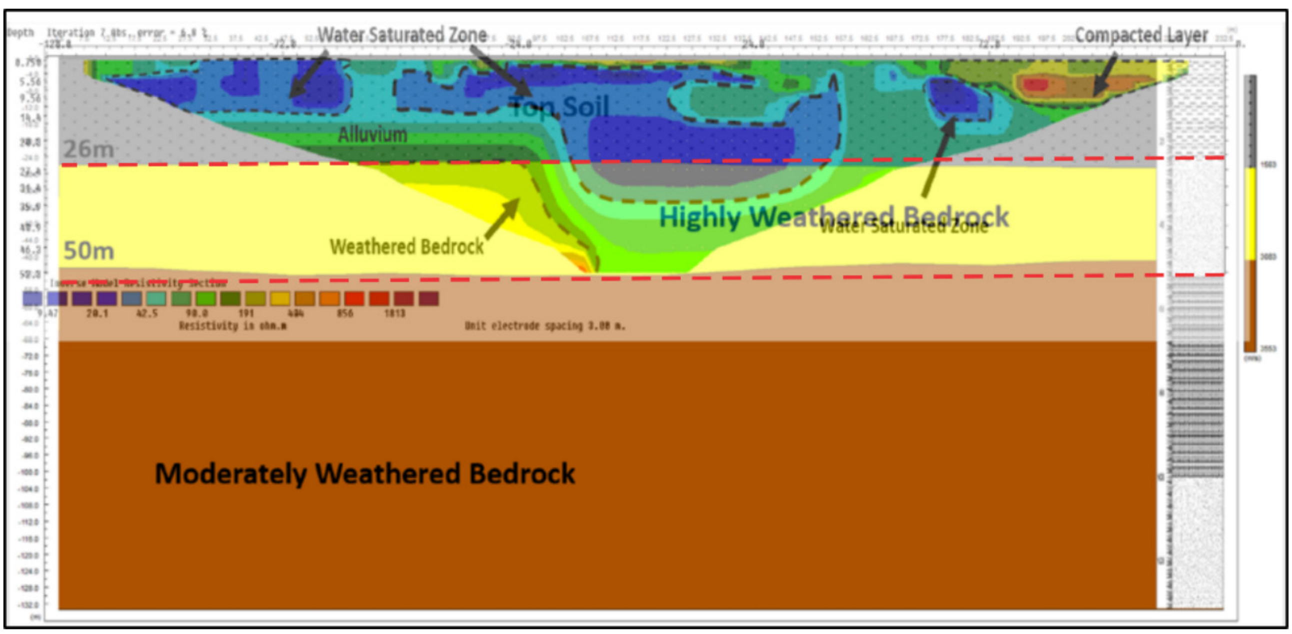

Figure 16 Integrated section of the resistivity profile 2, seismic tomography profile 2 and borehole data

CONCLUSION

An intensive foundational study on the shallow subsurface for construction is very crucial to evaluate the underneath unknown condition. Without a comprehensive study, many possible disasters may happen, such as sinkhole and ground instability. Geophysical methods are a common approach when it comes to the subsurface evaluation because it gives a good potential subsurface profile. The integration of resistivity profiles and seismic tomography with a borehole data on this study presents excellent results, where three main layers are identified namely alluvium, moderately weathered bedrock and sedimentary bedrock. These three layers can be classified through the resistivity ranges of 30-200 ohm.m (except for the compacted layer), 150-800 ohm.m and 800-2500 ohm.m respectively. For the seismic velocity, alluvium, moderately weathered bedrock and sedimentary bedrock layers are classified into the velocity value of 1500 m/s, 3000 m/s and 3500 m/s respectively. The alluvium is thinning, and the bedrock is closer to surface as these go the southeast. Moreover, the bedrock is dipped to the north eastern part because of the igneous intrusion at western area. The bottom line, the proposed site is safe from any critical issues near the subsurface conditions based on two factors; high velocity and high resistivity alluvium at the top layer, and shallow bedrock at 25 m (in average) from the surface. These indicate a good subsurface condition for building foundation.

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