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Geophysical and Geoelectric Studies of Dry Dam against Flood

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ABSTRACT

Water shortage has always been one of the fundamental problems in society. For this reason, dams play an important role in the country's water crisis. Among the dams, embankment dams are the most common type of dams that local materials can be used for their construction. Because embankment dams are susceptible to cracking, the extension of crack should be prevented in them with necessary measures. In this study, geophysical studies of dry dam were proposed. For this purpose, geoelectric method has been used to study and identify different layers of the dam, identify cracks as well as the water surface in the dam body and the results show the layering separation based on soil specific resistance.

1. INTRODUCTION

Dams are structures that can store large amounts of water for drinking and agricultural consumptions or flood control behind them. Successful construction of a dam requires various stages including location, site assessment, design, construction and maintenance. Not paying enough attention to each of these stages exposes the dam structure at risk and scour. For this reason, experienced specialists and contractors are needed to construct the dam. Embankment dams are the most common type of dams. Local materials can be used to construct these dams. The biggest disadvantage of these dams is their destruction when water overflows. This issue should be considered in the design and the risk of overflow should be avoided by implementing proper overflow. Among problems of these types of dams can be referred to the emergence of longitudinal and transverse cracks in the crown on the upstream and downstream slope. These cracks may not have wide spread and it can prevent them from spreading them with little measures and sometimes by filling in the gaps. But if ignored, they will be expanded over time and may cause irreparable damages. For this purpose, identifying the geometric shape of the rupture and depth of its extension is one of the important issues in the cure studies of dams that face this problem [2].

2. GEOPHYSICS

Geophysics is simply the knowledge of the study of earth using physical methods and it is a science that follows the laws of physics and the geological principles. Geological knowledge analyzes the composition and historical transformations of these formations and recognizes the earth using direct observations of earth surface formations with drilled boreholes, while geophysics tries to study and identify inaccessible areas in the earth by physical measurements at the surface or above the earth and interpreting these measurements. Today, this method is used in the studies of oil, gas, water exploration and identifying the location of buried faults and old buried rivers, as well as specifying earth layers and studying soil corrosion, determining the boundaries of saline and fresh water, the studying geotechnical properties of embankment and rock materials of earth and determining the oil and rock dynamics properties. Geophysicists can measure the elastic and magnetic properties, density, and temperature inside the earth by using seismic waves and measuring gravitational and magnetic fields. There are various methods in geophysics, including the following: [1]

- Geophysics- Seismography method
- Geophysics- Magnetometry method
- Geophysics- Gravimetric method
- Geophysics- Geoelectric method

Each of these methods is applied in specific cases and has advantages and disadvantages. In this project, geoelectric method has been used to determine the layers, water surface and depth of crack extension in the dam body.

2.1. Geoelectric

Generally geoelectric is a branch of geophysics based on the revelation of surface effects created by crossing electric current through the earth. In geophysical studies by measuring some physical properties (wave velocity, electrical resistivity, magnetic capability, specific gravity, temperature, intensity of radioactive emission, etc.) that has a clear difference with the surrounding environment is used as a criterion for identifying the water resources of hydrocarbon reservoir mines of geology (cavity, crack, fracture, fault, etc.). Each of the geophysical methods has a specific application that geoelectric in addition to the most use in the exploration of water resources can also be used in engineering geological studies (dam, fault, crushed zones, landslides and power plants). . The

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advantages of this method are the saving of time and low cost.

Figure 1. Geoelectric device

In this method, by applying different methods of resistivity survey, inductive polarization and self-potential, it can determine the material, thickness and the way of placing the ground layers. Geoelectric is one of the practical parts of the science of physics. In general, electrical methods are divided into two general categories [1].

2.1.1. Natural electrical methods

Natural electrical methods include three methods, self-potential or SP method, telluric current method or TC method, magneto telluric method or MT method.

2.1.2. Artificial electrical methods

Electrical methods including four methods, electrical resistivity or RM method, electromagnetic method or EM method, induced polarization or IP method, Wellogin method or WM method

In all these cases, the purpose is to reveal the surface effects (measurements on the surface of the earth) resulting from crossing current or electric field inside the earth. I.e, if a field or electric current passes through the earth, how can reveal these effects by devices on the surface of earth?

2.1.3. Effective depth range of electrical methods

Low depth (less than 100 m) SP method, average depth (up to 1 km) special resistance methods and IP and TC, high depth (up to the earth's crust) MT and wellogin methods.

3. GEOGRAPHICAL LOCATION OF THE PROJECT SITE

Project site of embankment dam of dry dam of Namin's flood in Ardebil Ardebil is located in 20 km northeast of Ardabil city. The project site is located at geographical coordinates of 48˚22″46 eastern longitude, 38˚23″55 north latitude. Satellite images from the project area and the dry dam of flood are shown in Figures 2 and 3 [1].

Figure 2. Satellite image of the project area

Figure 3. Satellite image of the dry dam of Namin's flood

4. THE PURPOSE OF THE PROJECT

The purpose of project is to specify the type and length and width extension of the various layers in the dam body, to determine the water level in the body and the foundation of dam, to specify the geometry of the crack in the dam body using geoelectric explorations.

5. GEOLOGICAL DESCRIPTION

Since the basis of the interpretation of geophysical data, especially data obtained from geoelectric excavation, is based on the specific resistivity of the earth's structure, and given that each soil or rock has its own specific resistivity range that is revealed through the flow from the layer and in order to obtain a correct and rational interpretation and to separate noise and errors during field harvesting, awareness from the geological status of the project site and material used in the dam body is essential.

5.1. Geology of the project scope

Study area in terms of geological structure according to zoning [3] is located in western zone of Alborz-Azerbaijan and according to zoning (Aga Nabati, 2000) is located in northern position of Gondwana, Azarbayjan zone and sub-zone of Alborz-Azarbayjan located magmatic community zone of Alborz. Table (1) presents the structural pattern according to zoning of Agha Nabati.

Table 1. Structural pattern of (Agha Nabati, 2000)

Supercontinent	Position	Main zone	Sub zone
Eurasia	South margin of Eurasia (Turan Sheet)	North (Turan Sheet)	South Caspian extensional basin
			Compressive zone of Kope Dagh
Paleo-Tethys remnants			
Gondwana	North margin of Gondwana (Turan Sheet)	Middle (Turan Sheet)	Sanandaj-Sirjan
			Alborz-Azarbayjan
			Zone of Tabriz-Saveh Zone of Sabzevar Microcontinent of Central including: -Block Yazd -Block Posht Badam -Block Tabas -Block Lut
			Eastern mountains
	Neo-Tethys remnants		
	South margin of Gondwana (Turan Sheet)	South (Turan Sheet)	Thrust zagros Fold zagros Dezful Embayment Abadan plain

5.2. Geology of dam location

The dam location, following the geology of the area, is part of the West Alborz Zone of Azerbaijan and it has geological features and lithostratigraphic and tectonic features. The dam is generally located in the middle section of the Ardabil plain and most of the Quaternary alluvial sediments are visible in the area. The height of dam location is about 1280 meters above sea level and the area is characterized by flat plains with hills. The thickness of the plain sediments is about 100 meters and often fine silt and clay and coarse sediments of sand mixture can be seen [1].

6. DAM TECHNICAL SPECIFICATIONS

In order to specify the path of cracks and to know the material and depth of materials used in the dam body, the geometrical and engineering specifications of the dam implemented are briefly presented in Table (2).

Table 2. Geometrical and engineering characteristics of dry dam of Namin's flood

	Characteristics of dam
Embankment with clay core	Dam
Maximum 7 and minimum 2 m	Height (m)
About 1050 m	Length of crown (m)
6m	Width of crown (m)
1:3	Upstream slope (Horizontal: Vertical)
1:2.5	Downstream slope (Horizontal: Vertical)
Valve	Discharge system

6.1. Geophysical studies in the dam

In general, geophysical operations have been conducted in the area to achieve the following objectives:

- Separating different layers of dam from each other
- Determining the thickness of the clay core
- Determining of water level in the dam body
- Examining the material status of shell and core materials
- Determining the status of cracks [4]

6.2. Dam problems

- Water permeation from downstream of the dam
- Water permeation around the water drainage system
- Occurrence of longitudinal crack in the dam crown

7. THE METHOD USED

Generally, in geophysical studies based on the physical properties of different layers and classes and according to the physical properties of adjacent formations and structures and project goals, the appropriate method is selected. Regarding the aforementioned, geoelectric method has been recognized suitable among the geophysical explorations due to its fast and easy efficiency and easy interpretation of results and low cost in the study area. Different arrays can be used in determining the specific resistivity, and the desirable array is selected according to the geographical location and need and topography. The project uses the Schlumberger array [4].

The Schlumberger array is one of the most commonly used electrode arrays in performing electrical sounding. This array is more efficient and more accurate in separating horizontal layering compared to other arrays. The Schlumberger array, like other arrays, is symmetric compared to the center of array (site of electrical sounding). In performing the electrical sounding with the Schlumberger electrode array, by increasing the electrode distance of current, the potential electrode distance is kept as constant as possible until the electrical potential difference values have the required accuracy and when the potential difference values are smaller than the measured limit, the potential electrode distance increases, so that they always consider the current electrode distance more than five times the potential electrode distance. When increasing the potential electrode distance, the measurment of the specific resistivity is repeated for the same distance of current electrodes. This action informs the operator from the correct trend of changes curve of the apparent special resistance or its incorrectness. Based on the apparent special resistivity relationship and according to the distance of electrodes in the Schlumberger array, the values of geometric coefficient and apparent special resistivity in this array can be calculated using the following equations [5]:

$$K = \frac{2\pi}{\frac{1}{AM} - \frac{1}{BM} - \frac{1}{AN} + \frac{1}{BN}}; \ AM = BN; \ AN = MB \Rightarrow \qquad \text{Equation 1}$$

$$K = \frac{\pi\, AM.AN}{MN}; \qquad \text{Equation 2}$$

$$\rho_a = \frac{\pi\, AM.AN}{MN} \cdot \frac{\Delta V}{I}$$

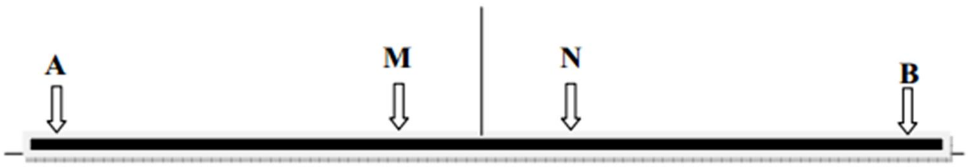

Figure 6. Arrangement of electrodes in the Schlumberger array

According to the form of electrodes A and B called current electrode, the amplified current by device is injected into the ground and received the return voltage from the ground by the M and N electrodes and sent to the device. In this project, according to the consultant's request from the depth to depth 15 meters or in other words, AB= 25, the wires have been opened and studies have been conducted.

7.1. Position of sounding and profiles

According to the position of the study area and the appearance of crack in the dam crown, and considering that dam embankment operations was completed and the possibility of better improvement of current in the dam body materials, these studies are conducted in longitudinal profiles on the dam crown and at the site of longitudinal crack extension that the location of profiles and sounding is seen in the following images (Mamariyan, 1998).

Figure 8. Position of sounding at the dam site

8. EQUIPMENT AND TECHNICAL STAFF

Depending on the project needs, the equipment is presented as follows.

1- A portable electrical resistance measuring device with sensitivity 0.01 mw with a current amplifier of 50 to 500 watts that automatically generates and transmits square current intensity.

2- 12V 12Ah battery for device
3. The reels and cables related to length 100 meters for the device
4- Copper electrodes and a high-sensitivity stainless steel
5- Two experts with full knowledge of the device and high experience a superior expert of geophysics with full knowledge of Geoelectric interpretation and analysis software
6- Two simple workers
7- A car
8- One GPS universal positioning device
9. A high-speed computer device for interpreting results and adapting to the ground

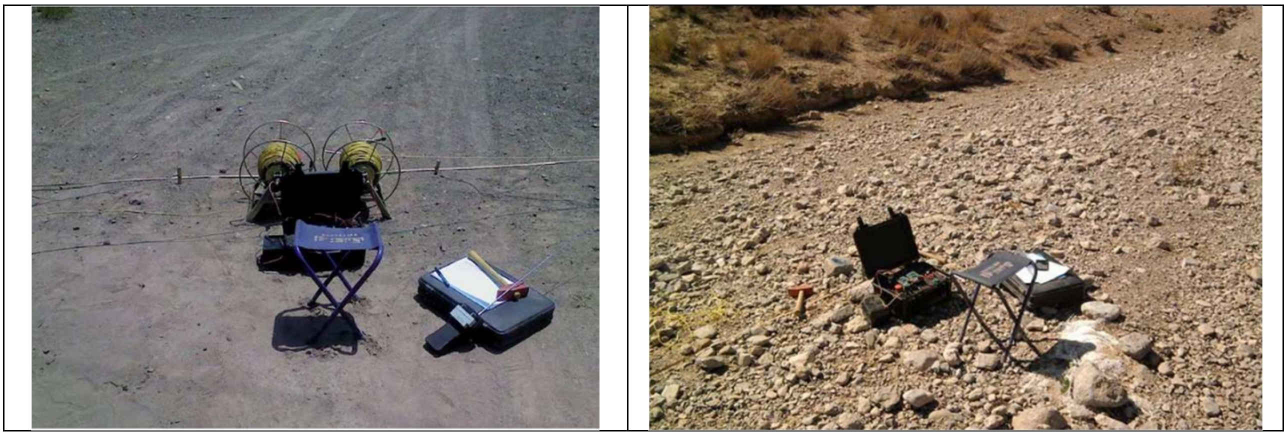

Figure 7. A view of the geoelectric equipment in the study area

9. GEOELECTRIC CURVES

The result of geophysical investigations are as the diagrams that their vertical axis (Y) is the specific resistance value of materials (ρ) and the horizontal axis (X) is half the distance of the current electrodes (AB/2). It can determine the depth and thickness of the layers with different specific resistance by interpreting these curves using standard curves (Abak). In describing the depths of the layers, it is worth noting that the final depth is the final depth of the studies (15 m). Geologically, the separation and type of layer is specified. The following results can be deduced from the interpretation of the electrical sounding curves.

9.1. Description of geoelectric sections

Based on the results of geophysical studies and interpretation of the diagrams of special resistivity in software, (W-GeoSoft/win sev), the material of layers at the location of sounding according to their specific resistance value is separated and geologically, the type of layer is specified.

9.2. Interpretation of electric sounding curves

According to geophysical surveys, the water level in the boreholes is located in depth 6 to 6.5 m, this is due to water subsidence below the dam, and likely groundwater level is not natural (aquifer). The results of geophysical surveys show that a layer with high special resistance about 1 m is located from the surface to depth (37 to 58 ohm) which indicates a mixture of sand, clay and silt.

Also, a layer with specific resistivity of 19 to 13 ohms is observed from depth of 1 to about 5.5 m which indicates a low density of clay, and a significant decrease in resistance indicates significant minerals (lime and plaster) in the clay. A layer with a resistance of 7 to 11 ohms can be seen from depth of about 5.5 to 11 meters which indicates a high density of clay. A layer with a resistance of 3 to 7 ohms is seen from a depth of 11 to 15 meters with a very high density. Survey of geoelectric sounding curves show that its resistance loss and abrupt change in depth 1 m is due to fracture from zero to about 1 m, then at lower depths, the curve becomes fracture and sudden changes at upstream and boundary of crust indicates the rapture or openings up to 5 to 20 mm that it is due to the loss of shear strength during fracture. The geometry of rapture during geophysical investigations is with flat surface and will be observed in the crown if not improved as transitional drifts or slump. The change in the resistance of the clay layer can be due to the change in the density of the layer and the presence of soluble materials such as plaster and lime in the clay. Figure (9) shows the geoelectric sounding curves.

The figures below shows the geoelectric curves for each geoelectric sounding and separation of the layering based on soil specific resistance. As it can be seen in these diagrams, the sharp drop in resistance and increasing slope of the diagram indicating the impact of the water surface can be seen in most of sounding at a depth of 6 to 7 meters, as well as Figure (10) shows two profiles A and B related to the geoelectric sounding.

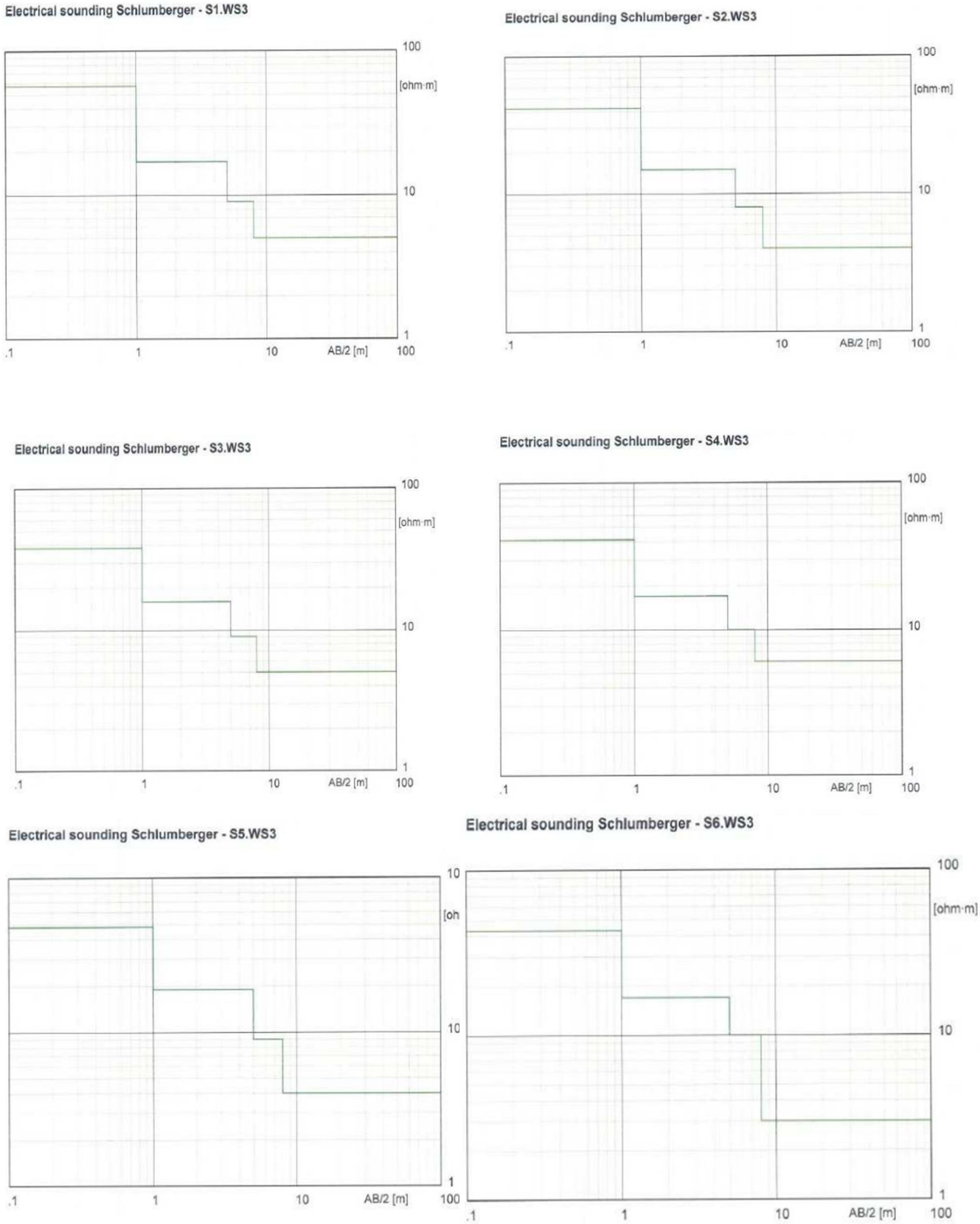

Figure 9. Geoelectric curves plotted for each geoelectric sounding

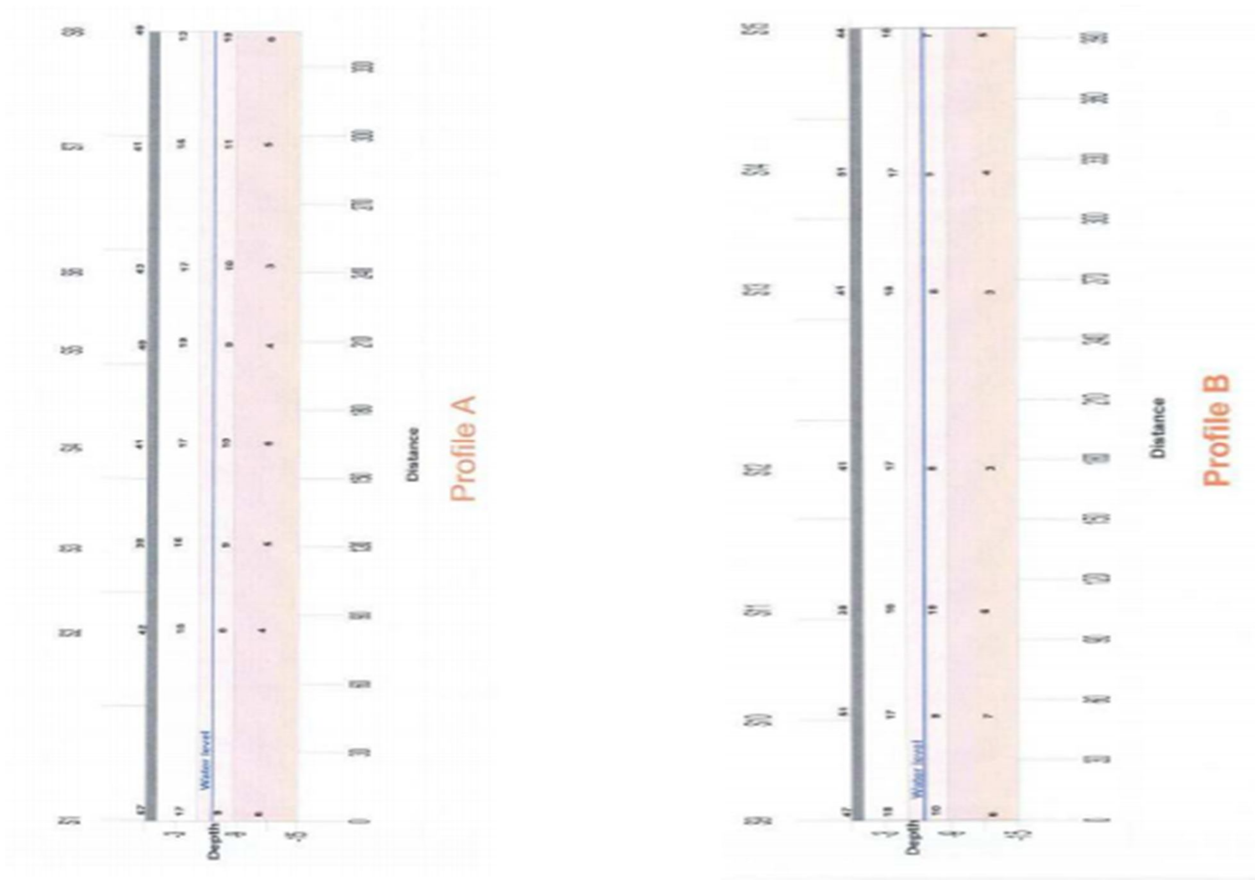

Figure 10. Profile plotted for each geoelectric sounding

9. DISCUSSION AND CONCLUSION

Dams are structures that can store large amounts of water for drinking and agricultural consumptions or flood control behind them. Successful construction of a dam and its durability require geophysical evaluation of the site, careful design and implementation as well as its repair and maintenance. Among the dams, embankment dams are the most common type of dams that local materials can be used to construct them. It is important to note that these dams are always faced with many problems, including demolition of water overflow from the dam and cracking of the dam crown. In this study, a geophysical method was used to separate the different layers of the dam, to identify the cracks and also the water surface in the dam body. Among the geophysical methods, the geoelectric method was used to save time and cost. And then the results obtained from the geoelectric method showed the separation of the layers based on their specific resistance, the water level in the dam body as well as the cracks in the dam crest. Also, the geoelectric curves showed that in the diagrams, a sharp drop in resistance and increasing slope of diagram indicating a collision with the water surface in most of the soundings at depths of 6 to 7 meters can be seen.

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