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Some Research Results from the Application of Geophysical Methods in Quickly Identifying Shallow Hazards in Dike and Dam Body

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Abstract: Small and shallow caves are frequently found on the dike and dam system inside our country, leading to some risks of subsidence, seepage, even dyke and dam rupture. The handling of this problem is relatively simple if we can accurately identify the location of these hollow caves. The question is how to study and find out the geophysical method to quickly and accurately determine the location and size of these caves for timely treatment in order to improve the efficiency of the survey. This paper presents some new results obtained when studying and applying the Improved multi-electrode (2D and 3D) and Ground penetrating radar methods to rapidly determine the hollow caves at K112+697 position of the Red River right dam in Hà Nội and at K21+900 position of Dao River left dam in Nam Định. The paper also assesses the capability and effectiveness of each method in the determination of this object.

Keywords: Hollow cave, termite, sinkhole, Improved multi-electrode, Ground penetrating radar.

1. Rationale

On the dike and dam system throughout the country, there often exist hidden hazards of small, hollow and shallow caves in the dam body leading to some risks of subsidence, seepage, or even dam and dike rupture. The hollow caves are usually caused by organisms living inside or in the vicinity of dikes, dams, such as mice, civet cat, fox or termite. The handling for the hollow caves is relatively simple if we can accurately determine their location. Many people have been using various geophysical methods to conduct survey and obtain positive results. The question is how to study and find out geophysical method which can quickly and accurately determine the hollow caves for timely treatment.

For many years, we have been working with the Applied Geophysics Department, Institute for Ecology and Works Protection, in studying some geophysical methods to examine shallow, hollow caves to identify them quickly and accurately. In this paper we wish to present some new results obtained from the application of the two methods, i.e. Improved multi-electrode electrical sounding (Improved multi-electrode) method and Ground penetrating radar

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method as well as assess the capability and effectiveness of each method in identifying this object.

2. Research Methodology

2.1. Methodology

- Preliminarily identifying the area with hollow caves on one dike section.

- Using the 2D and 3D Multi-electrode method [1,2,3,4] to determine the hollow caves:

+ For the 2D Multi-electrode method, we measure the parallel lines cutting through the area with hollow caves. The selected measurement array is Schlumberger.

+ For the 3D Multi-electrode method, we measure 4 rows, each row consisting of 14 poles (Figure 1).

The 3D multi-electrode method: Generating the power on 2 poles and collecting the voltage on all remaining double-pole, in turn to the last one.

- Using Ground penetrating radar method [4,5] to determine the hollow caves:

By using Ground penetrating radar method, we will survey parallel lines cutting through the area with hollow caves. When anomalies are identified along the vertical lines, the horizontal lines crossing the anomalous area will be surveyed (Figure 2).

- Checking and assessing the accuracy and effectiveness of each method.

2.2. Data processing

- Data processing of Ground penetrating radar method by Radan 7 software.

In the Ground penetrating radar method, the accurate identification of dielectric constant and the speed of the environment are very important. Meanwhile, to examine small and shallow objects, the general deep point method is nearly impossible to be applied in determining the speed. Therefore, we use the ratio of geometric method to determine the velocity of propagation (V) and dielectric constant of ε (Figure 3).

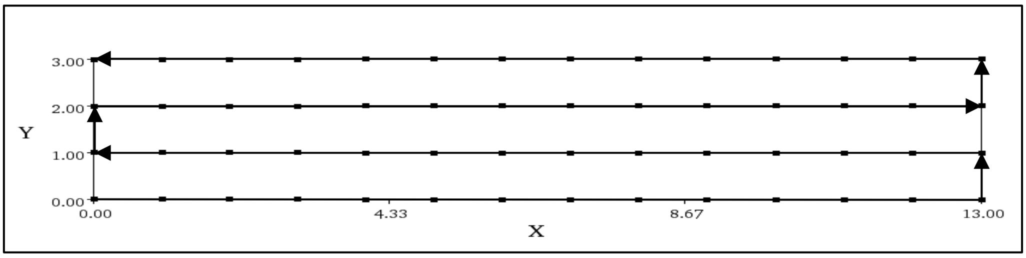

Fig. 1. Layout of 3D Multi-electrode measurement channels.

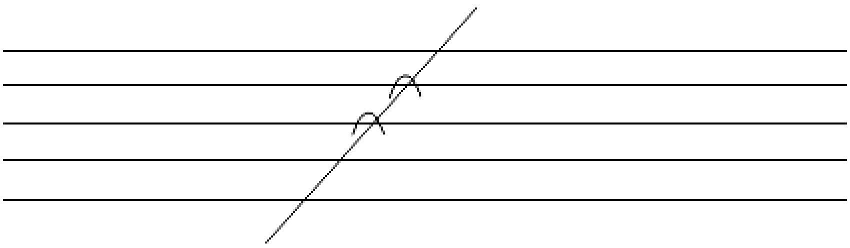

Fig. 2. Arrangement of lines measured by Ground penetrating radar method.

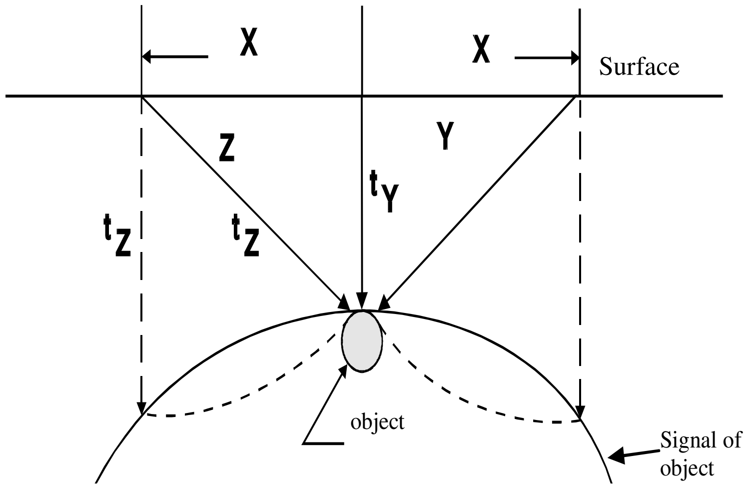

Fig. 3. Geometrical method.

From Figure 3, we have:

$X^2 + Y^2 = Z^2$ (1)

and: $t_y/t_z = Y/Z$

in which:

X - Distance along the surface (m)

Y - Depth of the object (m)

Tz - Transmission time from the hyperbolic swing to the surface (ns)

Ty - Transmission time from the hyperbolic peak to the surface (ns)

Solving the equation (1) we obtain:

$$Y = \frac{X}{\sqrt{\left(\frac{t_z}{t_y}\right)^2 - 1}}$$

After calculating the depth of the object we can calculate the velocity of propagation by the following formula:

$V = 2.Y/t_y$ (m/ns)

Then, we can calculate the dielectric constant using the formula below:

$\varepsilon = c^2/V^2$ or: $\varepsilon = c^2.TT^2$

with: c - The speed of light (3.10^8m/s)

TT - transmission time per length unit (ns/m), calculating from the time the wave reaching the reflecting surface back to the receiving antenna.

From (1) we have:

$$t_z^2 = \frac{X^2}{V^2} + t_y^2 \qquad (2)$$

Performing equation (2) in graph as shown in Figure 4 we have:

$tg\alpha = 1/V^2 \Rightarrow V = \sqrt{1/tg\alpha}$ (3)

After determining the velocity of propagation of the environment we will determine the depth, position and size of the object.

- Data processing of Multi-electrode method by EarthImager 2D and 3D software

The hollow caves inside the earth dike have extremely enormous resistance, while the resistance in the earth dam environment is about 20-80Ωm. So to define the boundary we identify at the position with the largest variability of resistivity.

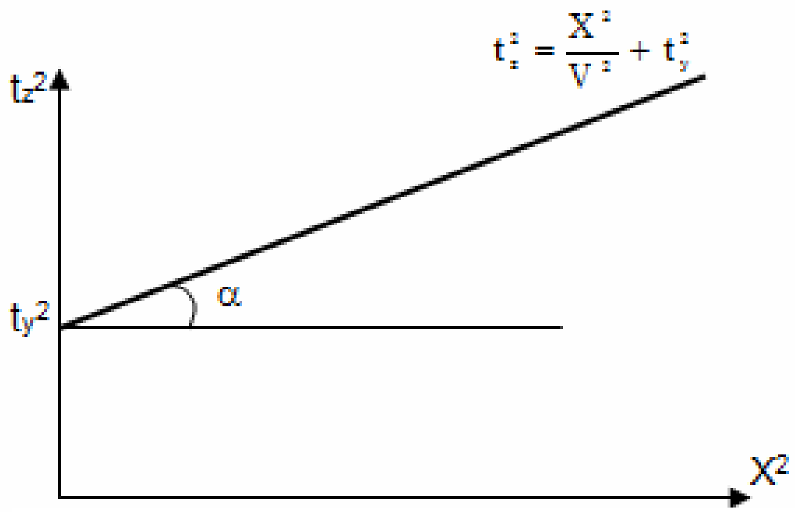

Fig. 4. Transmission time.

3. Survey results

3.1. Survey on termites

3.1.1. The study area and diagram of measuring lines

At position K112+697 of the Red River right dam in Hanoi, there are signs of active termites and this has been defined as the area with termite's nest in this region. Here we have conducted a survey using Improved multi-electrode method and Ground penetrating radar method (Figure 5).

Layout of the measuring lines of Improved multi-electrode method (3D) and Ground penetrating radar method is shown in Figure 6.

3.1.2. Survey results

- *Survey results by Ground penetrating radar method.*

The survey results show that the Ground penetrating radar can identify the anomalies located in the depth of 0.55 m and a width of 0.7 m from position of 6.2 m to 5.5 m. However, the method of Ground penetrating radar cannot determine the bottom of a hollow cave. In our opinion, due to the velocity of electromagnetic waves in the air is much larger than that in the earth and the hollow area is not big enough for using the method of Ground penetrating radar to identify the bottom.

- *Survey Results by 3D Multi-electrode method*

The results of the survey identifying hollow cave by 3D Multi-electrode method show that there exist high resistivity anomalies of more than 200Ωm compared to the average resistivity of the dike, which is 23Ωm. This anomaly is located at the depth of 0.5-1.5 m and along the 7m - 8.5m line (Figure 8, 9). From the results we observe that the 3D Multi-electrode method can determine the 3-dimensional shape of the hollow cave, but the size of the hollow cave anomalies is greater than the hollow cave anomalies identified by the Ground penetrating radar method.

Fig. 5. Identifying the hollow caves by Ground penetrating radar and multi-electrode at K112+697 position of the Red River right dam.

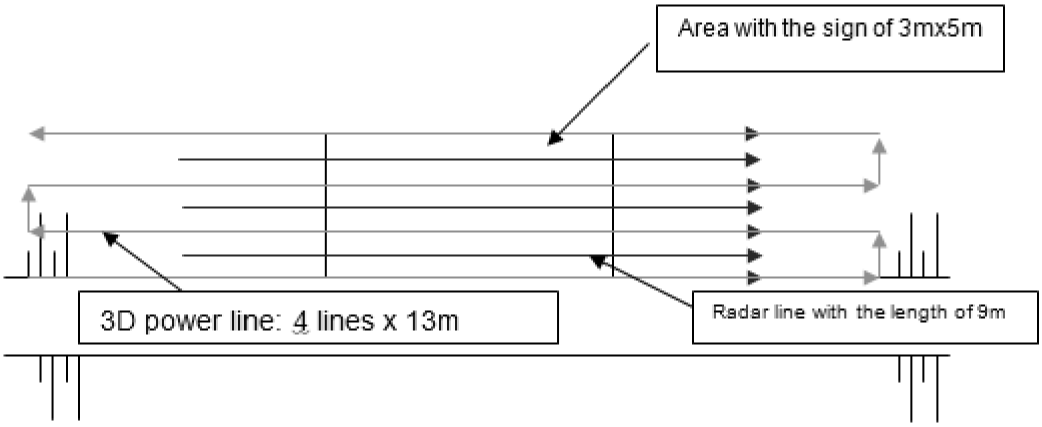

Fig. 6. Layout of the measured lines.

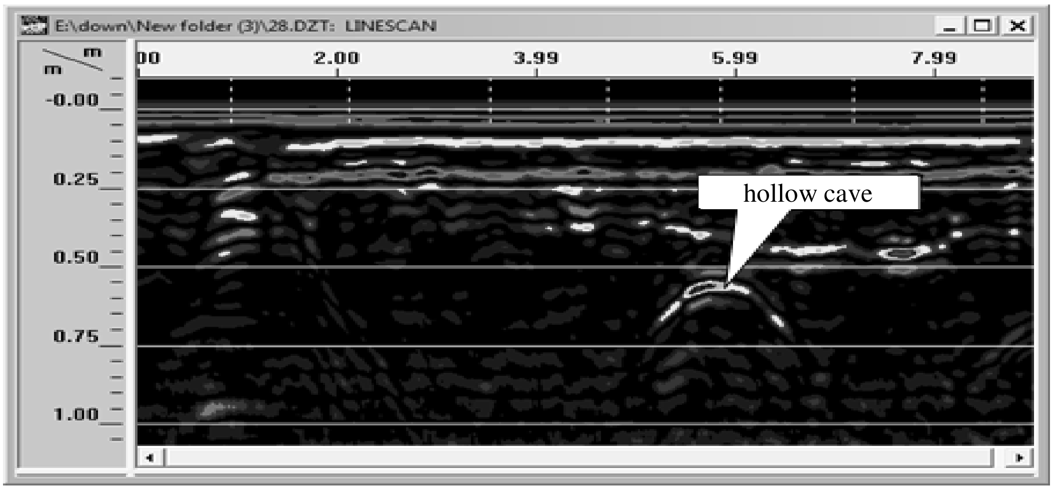

Fig. 7. Survey results for hollow cave using Ground penetrating radar method.

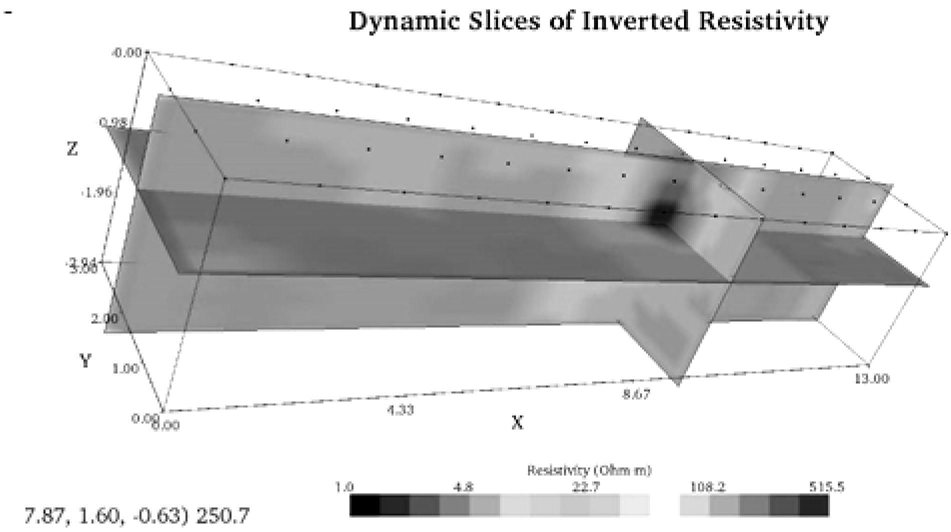

Fig. 8. Resistivity cross-section at the hollow cave area.

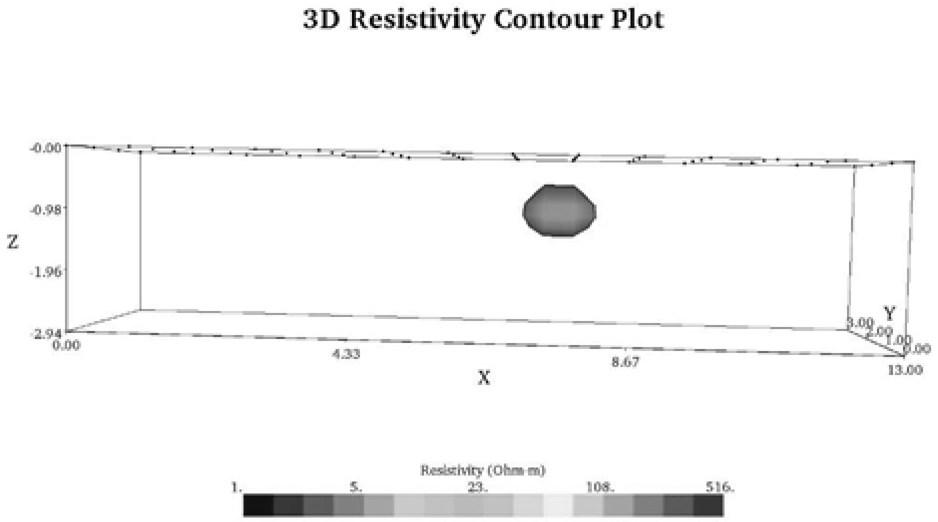

Fig. 9. Results of survey on hollow cave using 3D Multi-electrode method.

- Actual test results

From the survey results by two methods of Multi-electrode and Ground penetrating radar, we drill at anomalous positions, and then we inject clay liquid to fill in the hollow cave. After the clay liquid becomes dry, we conduct excavation to check the accuracy of the survey methods. The result shows that after drilling at the hollow cave area at the width of 0.7m and the depth of 0.55m above the ground, the height of hollow cave is 0.4m (Figure 10).

3.2. Surveying and identifying sinkholes on the dikes

3.2.1. The study area and diagram of measuring lines

On the Dao River left dam in Nam Dinh, at K21+900 positions, there occurs dam face collapse close to the verge of the river (Figure 11). Here, we measure 2 Multi-electrode lines along the dam at the verge of the river and the verge of the field to assess the ability to identify sinkholes by Multi-electrode method and evaluate the extension of the sinkholes; with the Ground penetrating radar method, we measure the edge of the sinkholes from the river to the field, the distance between the line is 0.5m (Figure 12).

Layout of the measuring lines by Multi-electrode method and Ground penetrating radar method is represented in Figure 13.

- The survey results by the Multi-electrode method

The results of the survey using Multi-electrode method for sinkholes on the dike (Figure 14) show that when processing the data with full original measured data, it is very difficult to identify anomalies of sinkholes on the line due to the top layer with a thickness of about 0.5 m and the resistivity roughly equivalent to the anomalies of sinkholes (A). After removing the high resistivity values, then handling, we will obtain sinkhole anomaly with the width 0.8 m and the depth of 0.1 to 0.6 m (B).

- The survey results using the method of Ground penetrating radar

The survey results for sinkholes using the method of Ground penetrating radar (Figure 15) show that this method can identify the sinkholes' location, located at a depth of 0.5 m and a width of 0.7 m.

There fore: According to the results obtained, we see that the Multi-electrode method can only identify the location of shallow and small objects, and it's rather difficult to determine the exact size of them. The value of anomaly's depth is usually incompatible with radar anomalies and reality of the sinkholes.

Fig. 10. Results of checking hollow cave.

Fig. 11. Sinkholes at K21+900 positions on the Dao River right dam in Nam Định.

Fig. 12. Survey for sinkholes on the Dao River the right dam in Nam Định using Multi-electrode and Ground penetrating radar methods.

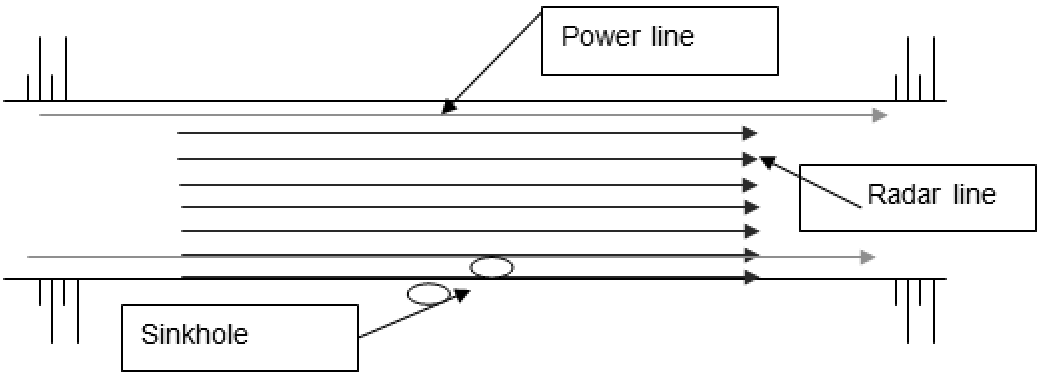

Fig. 13. Layout of the measured lines.

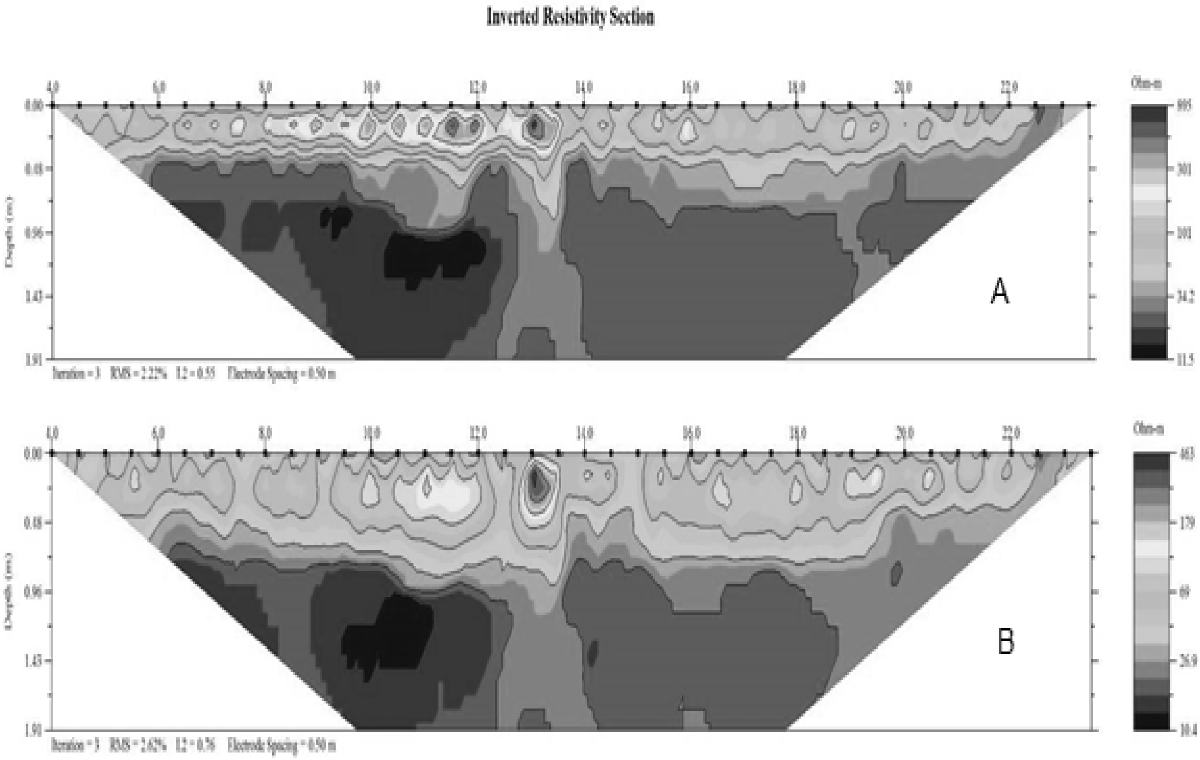

Fig. 14. Survey results for sinkholes using the Multi-electrode method.

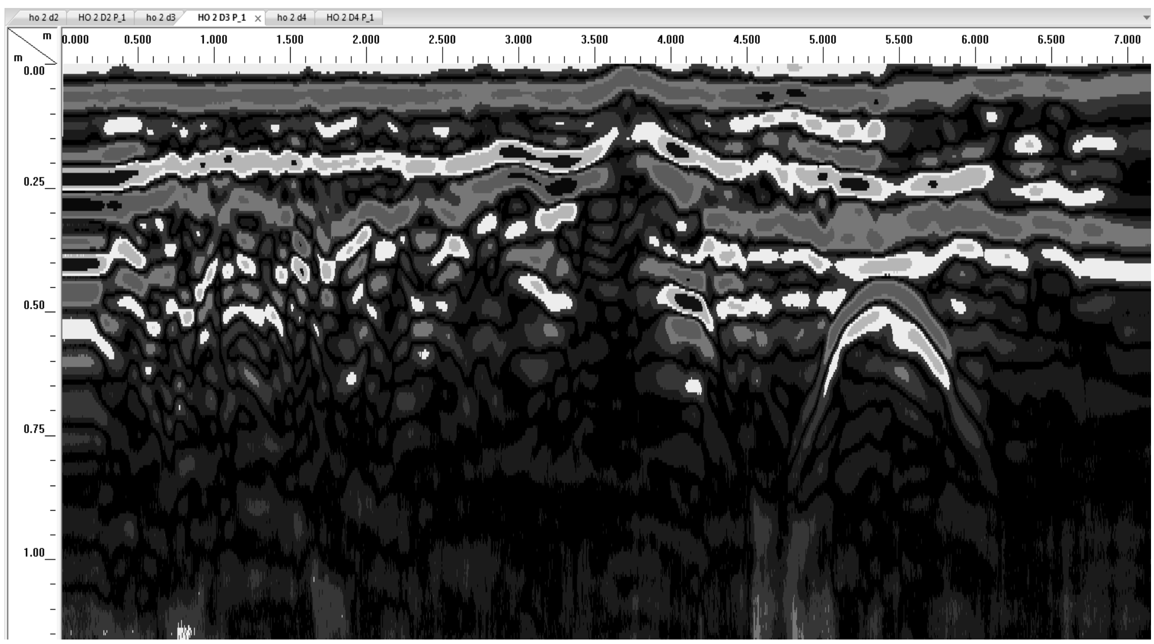

Fig. 15. Survey results for sinkholes by Ground penetrating radar method.

4. Discussing the results

- From the survey results, we find that with both methods of Multi-electrode and Ground penetrating radar, we are capable of identifying shallow and hollow caves. In particular, when the resistivity at the survey area is very low, at around 23Ωm, using Ground penetrating radar method, we can still accurately determine the depth and width of the hollow cave. However, the Ground penetrating radar method cannot identify the bottom of a hollow cave.

- With the Multi-electrode method, we can determine the width, depth and bottom of a hollow cave. However, the size of the anomaly is much bigger than the actual size of the hollow cave and the depth error is relatively big.

- Time for completing the survey of a hollow cave with 10 vertical lines and 3 horizontal lines by the Ground penetrating radar method is 20 minutes (including time for machine installation and adjustment). As for the 3D Multi-electrode method, the time for measurement is 3.55 hours; for the 2D Multi-electrode method, the time for measurements is 60 minutes for 1 measurement channel with 56 poles. Measurement by the Improved multi-electrode method still can save much time.

- From this, we see that with shallow and small hollow cave, we should use the Ground penetrating radar method. The advantage of this method is that it can help us quickly and accurately identify the depth and width of the object. However, to determine the bottom of the object, it should be combined with other methods.

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