

Four-dimensional electrical resistivity tomography of the groundwater in a landslide zone

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Abstract

This study developed a four-dimensional electrical resistivity tomography (4-D ERT) method and verified the method by field test. The 4-D ERT method is based on 3-D ERT technique to evaluate the variation of the groundwater in a landslide due to rainfall and time lapsing. It is required that fixed electrode array is arranged in a special layout in the field. The 3-D ERT measures were performed from time to time for 8 times in about a year. The method is helpful to engineers for understanding the spatial and temporal distribution of groundwater when performing landslide investigation.

Keywords: electrical resistivity tomography (ERT), groundwater, landslide

1. Introduction

In recent years, the monitoring of electrical resistivity (ER) has become an increasingly common geological investigation technique. Zhang (2008) monitored ER when studying the subterranean structure of a mud volcano in Wusanto, Tainan County, and the activity of the Qishan Fault. In this work, Zhang (2008) also incorporated the four-dimensional (4D) concept. He measured the mud volcano at four different times to examine how the subterranean structure changes over time.

This study developed a 4D ERT approach in which time series of 3D electrical resistivity tomography (3D ERT) were performed. The 3D ERT utilizes a two-dimensional system to scan special electrode arrays, collect data, and perform inverse calculations (Geotomo Software, 2009).

We applied the 4D ERT to understand how groundwater changes over time and associated with rainfall in a landslide. The results obtained were compared with the data from a report by Soil and Water Conservation Bureau, Taiwan (2013). This technique can be used in landslide-prone areas or where landslides have already occurred. We hope to gain a better understanding of groundwater changes in landslides by studying temporal changes in electrical resistivity in landslides.

2. Methodology

We selected a landslide area as the research site. The site was next to Meihua Elementary School in Meihua Village, Jianshi Township, Hsinchu County, Taiwan (see Fig. 1).

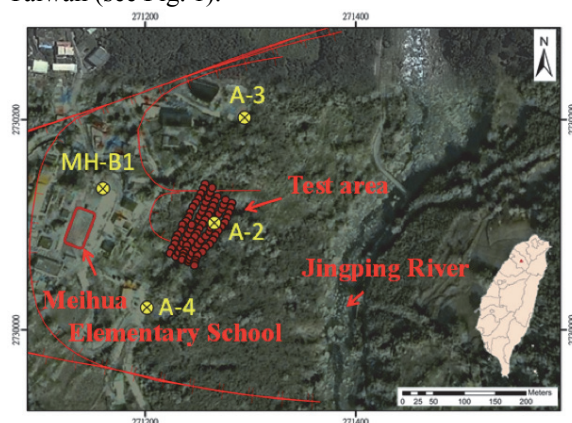


Fig. 1 The study site in Hsinchu prefecture, Taiwan

Five test lines were laid out. The locations of the test lines are shown in Fig. 2. Each of which included 16 electrode arrays were positioned five meters apart. The layout of the electrodes and their number codes are as follows: first test line (01-16), second line (17-32), third line (22-48), fourth line (49-64), and fifth line (65-80).

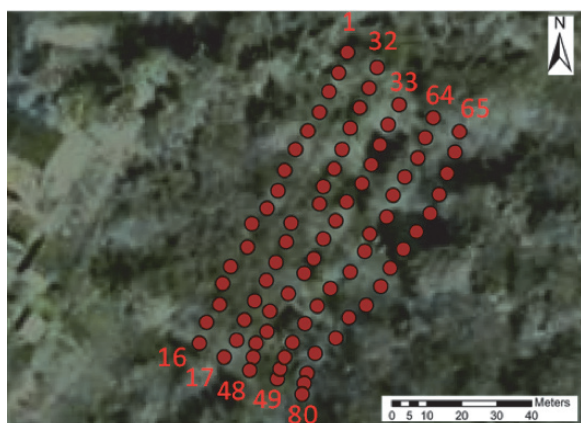


Fig. 2 Layout of the test lines and electrodes (numbered 1~80)

3. Results and discussion

The 3D ERT was tested a total of eight times. The test dates, and data file numberings are provided in Table 1.

Table 1 Information of the eight 3D ERT tests

| Test no. | Test date | Data file no. |
|---------------|-------------------|-----------------|
| Test 1 | 2013/01/25 | McOHM961 |
| Test 2 | 2013/03/01 | McOHM962 |
| Test 3 | 2013/03/15 | McOHM965 |
| Test 4 | 2013/09/11 | McOHM102 |
| Test 5 | 2013/09/25 | McOHM104 |
| Test 6 | 2013/10/09 | McOHM106 |
| Test 7 | 2013/11/06 | McOHM121 |
| Test 8 | 2013/12/04 | McOHM222 |

Among the eight 3D ERT test results, we selected three test results to in Figures 3-8. The three tests are Tests 1, 5 and 8 which are marked in bold in Table 1. In addition, rainfall records and typhoon of the test site were plotted in Fig. 9.

Our first ERT test was conducted on 25 January, 2013, the results of which were used as a reference to compare with the other tests. There had been no rainfall for one week prior to the test date of Test 1, wherefore (Figs. 3 and 4) the shallow zone in the images appears somewhat dry and ER is at approximately $600 \Omega \cdot m$. This was adopted as an “initial value” in this study.

Typhoon Usagi September 20-23, 2013 brought total rainfall of 89.8mm. Test 5 was conducted on September 25, 2013, two days after the meteorological effect on Taiwan of Typhoon Usagi had ended. However, the rainfall was very light during these two days, September 24-25, measuring only 0.4mm. The similarity in the ER results in Figs. 4 and 6 indicate that most of the groundwater drained away rapidly after the Typhoon Usagi in two days.

This can be attributed to severe weathering, fissures and high permeability in the research site where is in a displaced landslide zone.

Test 8 (Fig. 8) preformed on 4 December 2013 presented conditions drier than those obtained on 9 September 2013 (Fig. 6). This is due to the fact that no rainfall occurred in the week prior to the test date, thereby increasing ER.

In summary, groundwater was shown to drain away from the colluvium of landslide zone within a matter of days, possibly due to highly fractures materials and thereby very high permeability in the landslide zone.

4. Conclusions

Based on the techniques developed for 3D ERT, this study used fixed electrode arrays and time series measurements to study the spatial and temporal distribution of groundwater in a landslide area. The research site, Meihua Village in Hsinchu, Taiwan, is classified as a landslide prone area. Our primary focus was on the changes in groundwater over time in the landslide zone. Fixed electrodes arrays and test lines were setup prior to the first test on January 25, 2013. Our results demonstrate that groundwater drains away from this landslide area within just a few days after typhoon/rainfall, possibly due to highly fissured and high permeability in the landslide zone. The proposed 4D ERT testing method provides a indication of changes in groundwater caused by rainfall over time and could therefore be highly valuable to engineers seeking to identify the location and behavior of groundwater to assist in assessing the risk of landslide disasters.

Acknowledgements

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References

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method. User's manual, published by Geotomo Software, Penang, Malaysia.

Inverted Resistivity Image

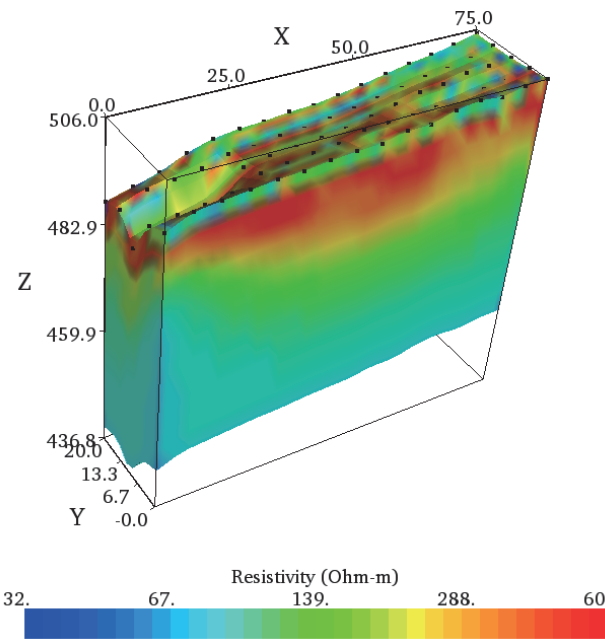


Fig. 3 Test 1 (2013/01/25) 3D ERT Image

Inverted Resistivity Image

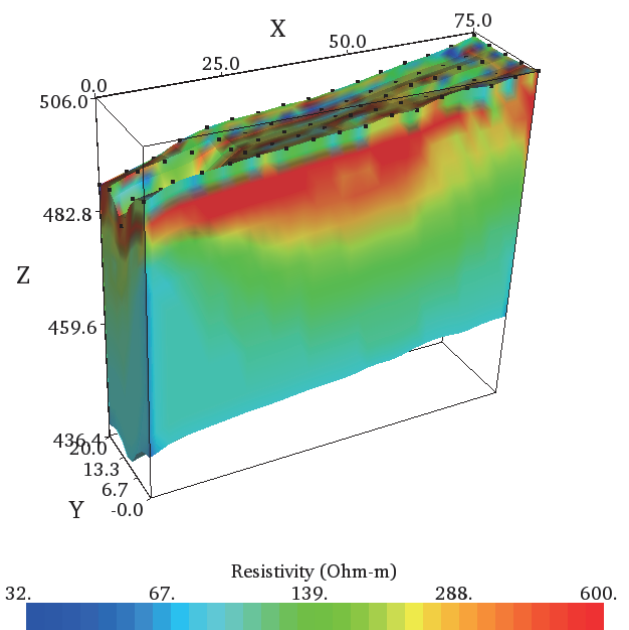


Fig. 5 Test 5 (2013/09/25) 3D ERT Image

X Slices of Inverted Resistivity

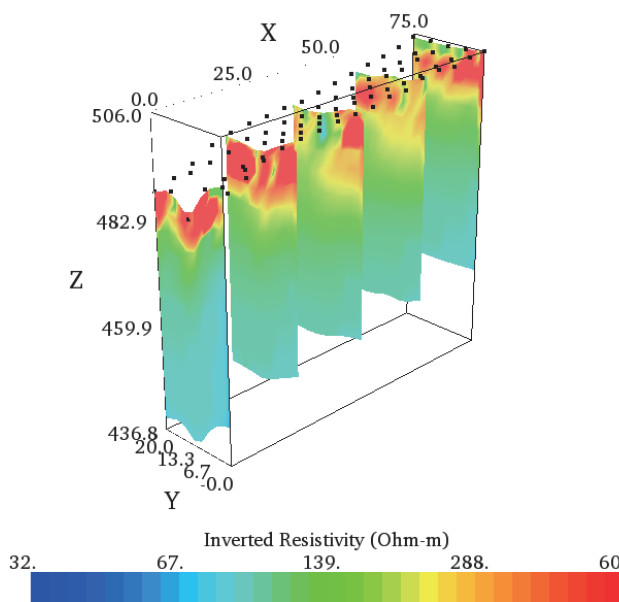


Fig. 4 Test 1 (2013/01/25) - Vertical slice of 3D ERT Image

X Slices of Inverted Resistivity

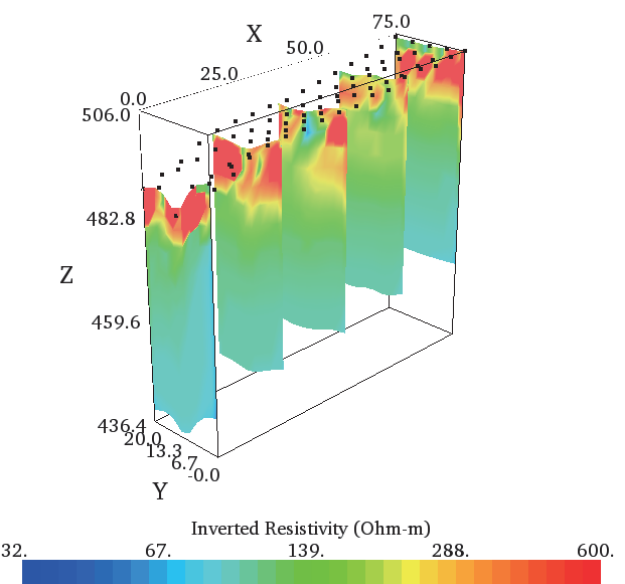


Fig. 6 Test 5 (2013/09/25) - Vertical slice of 3D ERT Image

Inverted Resistivity Image

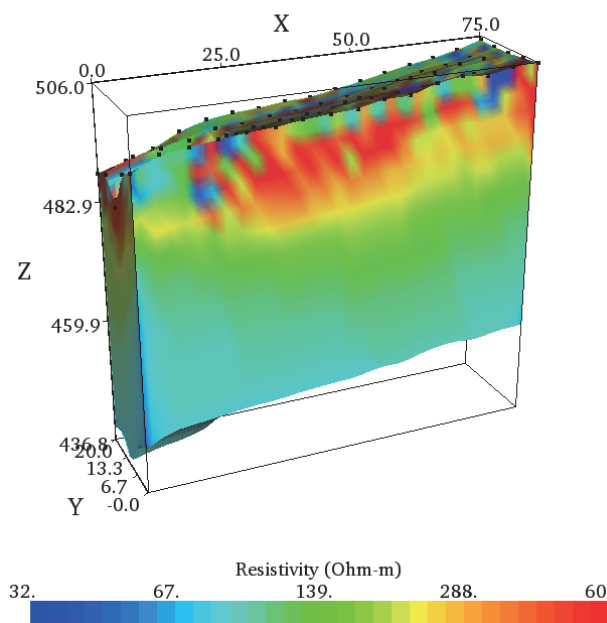


Fig. 7 Test 8 (2013/12/04) 3D ERT Imag

X Slices of Inverted Resistivity

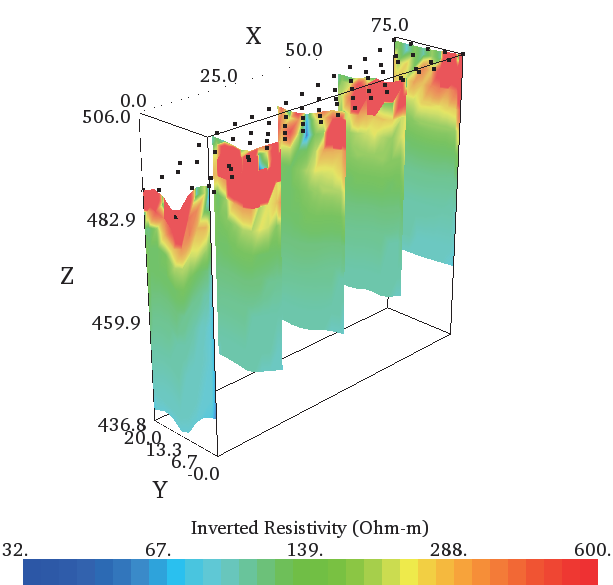


Fig. 8 Test 8 (2013/12/04) - Vertical slice of 3D ERT Image

Rainfall (mm/day)

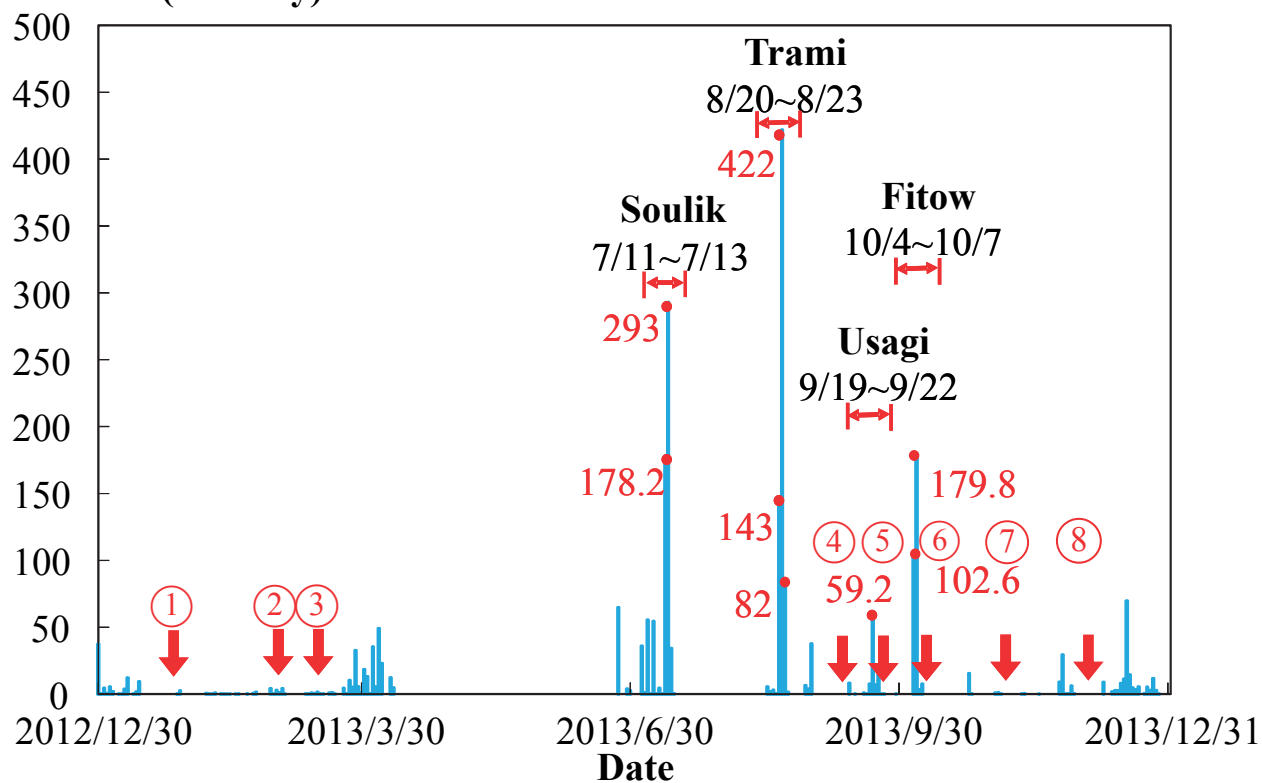


Fig 9 Rainfall records and typhoon durations of the test site (Ref: Soil and Water Conservation Bureau, 2013); Timings of the 8 tests performed were indicated as ①~⑧. (Typhoons: Soulik; Trami; Usagi; Fitow)