The effective way to mitigate landslide by groundwater survey measuring ground temperature

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Abstract

Recently, there are many natural disasters such as landslide caused by heavy rain fall, which supply groundwater to make slope unstable and landslide occur. The groundwater especially subsurface flow can raise water pressure to lift the bottom face of landslide, and also may move landslide block. Consequently, it's very important to know how the groundwater which is related to the landslide flows. So we have surveyed the ground water flow in landslide area measuring ground temperature. This measuring method is called the ground temperature measuring survey which mainly consists of 1m depth temperature measurement and Multi temperature logging. In this paper, we are explaining the ground temperature measuring survey method and its principle firstly, then introducing a case study of the landslide survey using this method, and finally, considering its effectiveness for landslide survey and mitigation work.

Keywords: landslide, groundwater, ground temperature, groundwater vein stream, 1m depth ground temperature measurement, Multi temperature logging,

1. Introduction

Landslide is caused by heavy rain fall, which supply groundwater to make slope unstable and landslide movement occur. The groundwater especially subsurface flow can raise water pressure to lift to the bottom face of landslide, and also may move landslide block. Consequently, it's very important to know how the groundwater which is related to the landslide flows. So, we have surveyed the ground water flow in landslide sites measuring ground temperature. This measuring method is called the ground temperature measuring survey which mainly consists of 1m depth temperature measuring and Multi temperature logging. In this paper, we will introduce the method, a case study and will consider its effectiveness of surveying and mitigation work for landslide.

2. Landslide and Groundwater

Landslide is generally classified into some categories by type of movement and material. In narrow meaning, it is defined as mass movement on slope, where is, in depth, a distinct zone of weakness that separates the overlying soil mass that is landslide block from stable underlying soil or rock. Fig.1 shows schema of groundwater flow around landslide block (Yasuda and Takeuchi, 2012). Groundwater flows into the zone to develop pressure to lift the mass and make it slide. If the pressure of groundwater that is groundwater level is lowered by withdrawing it, the lifting force will be decreased and, consequently the landslide movement will be stopped or stabilized . Fig.2 shows schema of making landslide more stable by withdrawing groundwater from where groundwater flows (Yasuda and Takeuchi, 2012). That makes groundwater level lower and landslide more stable.

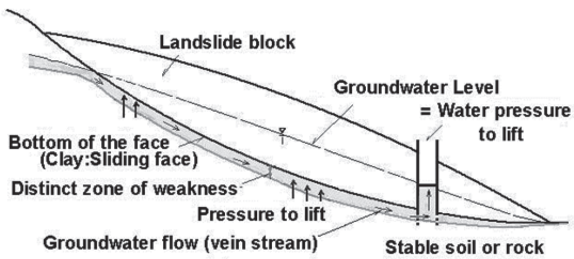

Fig. 1 Schema of groundwater flow in landslide block

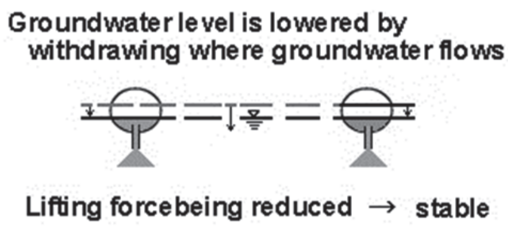

Fig. 2 Schema of landslide stabilization by withdrawing groundwater

3. Groundwater Survey

3.1 Ground temperature measuring

Here, we introduce the groundwater survey measuring ground temperature. If groundwater temperature is different from ground temperature, it can be known where groundwater flows. To know distribution of planar groundwater flow, it is effective to measure distribution of ground temperature. On the other hand, to know that of vertical groundwater flow, it is meaningful to detect the groundwater vein stream in a borehole by Multi temperature logging. Generally in landslide area, groundwater doesn't flow uniformly but streams like a vein (Takeuchi, 1996). So we call it groundwater vein stream.

3.1 1m depth ground temperature measurement

If the depth of measuring is 1m, the temperature condition is considered constant within a few days. This is reason why 1m depth ground temperature measurement is general method of ground temperature measurement. Fig.3 shows theory of 1m depth ground temperature measurement (Takeuchi, 2013). In principle, normal 1m depth ground temperature is higher/lower than groundwater temperature in summer/winter respectively. Groundwater vein stream is detected by the difference between the ground temperature and the groundwater temperature. In case of implementing the measurement should be done as follows;

[1] Calibrating sensor.
[2] Measuring ground temperature
[3] Estimating normal 1m depth ground temperature:
[4] Measuring groundwater temperature.
[5] Rectifying deviation due to land condition

Then the planar distribution of groundwater vein stream is obtained by drawing isothermal lines on a planar figure.

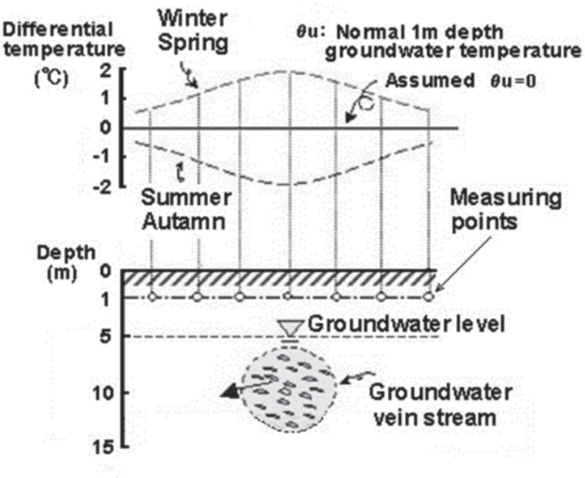

Fig. 3 Theory of 1m depth ground temperature measurement

3.2 Multi temperature logging

Multi temperature logging is an advanced groundwater exploration in a bore hole to detect the depth of groundwater vein stream by measuring temperature as shown Fig.4. The implementation of the logging is as following;

[1] Measuring temperature of natural state in the hole.
[2] Pouring hot water into the hole
[3] Putting the probe with sensors in the hole.
[4] Adjusting temperature of each depth to be equal.
[5] Measuring every 1 to 5 min for half an hour

Then, the relation of temperature returning rate to depth is obtained. The rate is equal to {(The temperature at 0min – The one at certain time) / (The one at 0min – The one of natural state)}. The groundwater vein stream is detected as the point of faster turning back to natural state, which means high returning rate on the graph. The rate being more than 60% per half an hour is reliable evidence of groundwater flowing (Takeuchi, 1996).

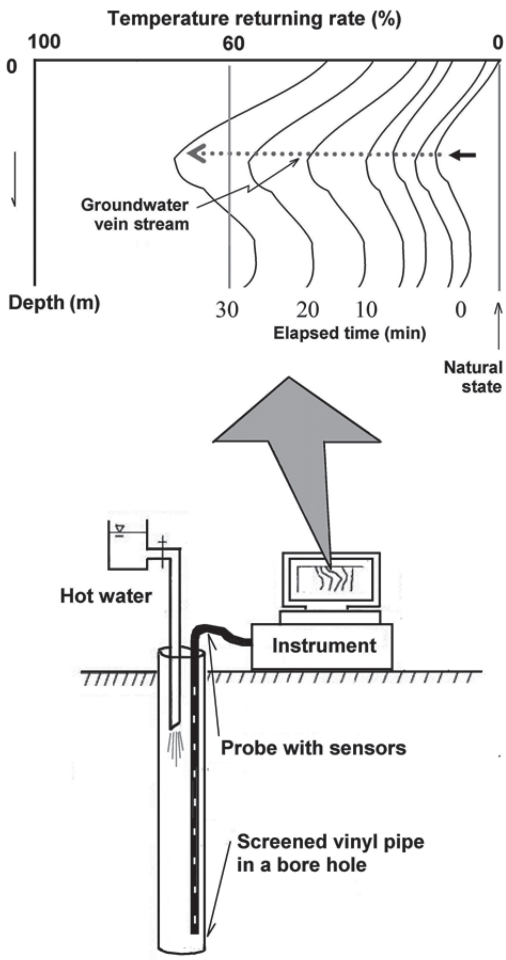

Fig. 4 Multi temperature logging and graph obtained from measurement

4. Case Studies

We introduce case studies of the survey and also introduce its mitigation work using the result of the measuring survey method (Yasuda et.al., 2009).

4.1 The case 1

The landslide situates in the mountain area, 42°30' north latitude and 140°40'east longitude, the Hidaka district, Hokkaido Japan. Geology of bed rock is Kamuikotan metamorphic rocks group such as hard metamorphic green rocks. The landslide became active in the summer of 2003 after heavy rainfall which precipitation was reported 215mm for 3 days until the rain stopped. Crack opening was 20 cm per month. The exploring map and the landslide profile are as shown in Fig.5 and 6, respectively.

They are reflected the result from core boring and geophysical exploration. The landslide consists of several blocks. The 1m depth ground temperature measurement was conducted in autumn within the lower right area (Small 2 block) where fountain is found at the end of the slope. The result of the measurement was shown in Fig.7. The normal 1m depth temperature was 11.0 ℃ and groundwater temperature was 8.0 ℃. Multi Temperature Logging was also done in bore hole of this area, and the result was as shown in Fig.8. The groundwater flew as a vein stream and connected to the fountains at the end of the slope. The depth was about 10m where the zone of weakness and the sliding face existed. By these measurements, the information of groundwater flowing was obtained.

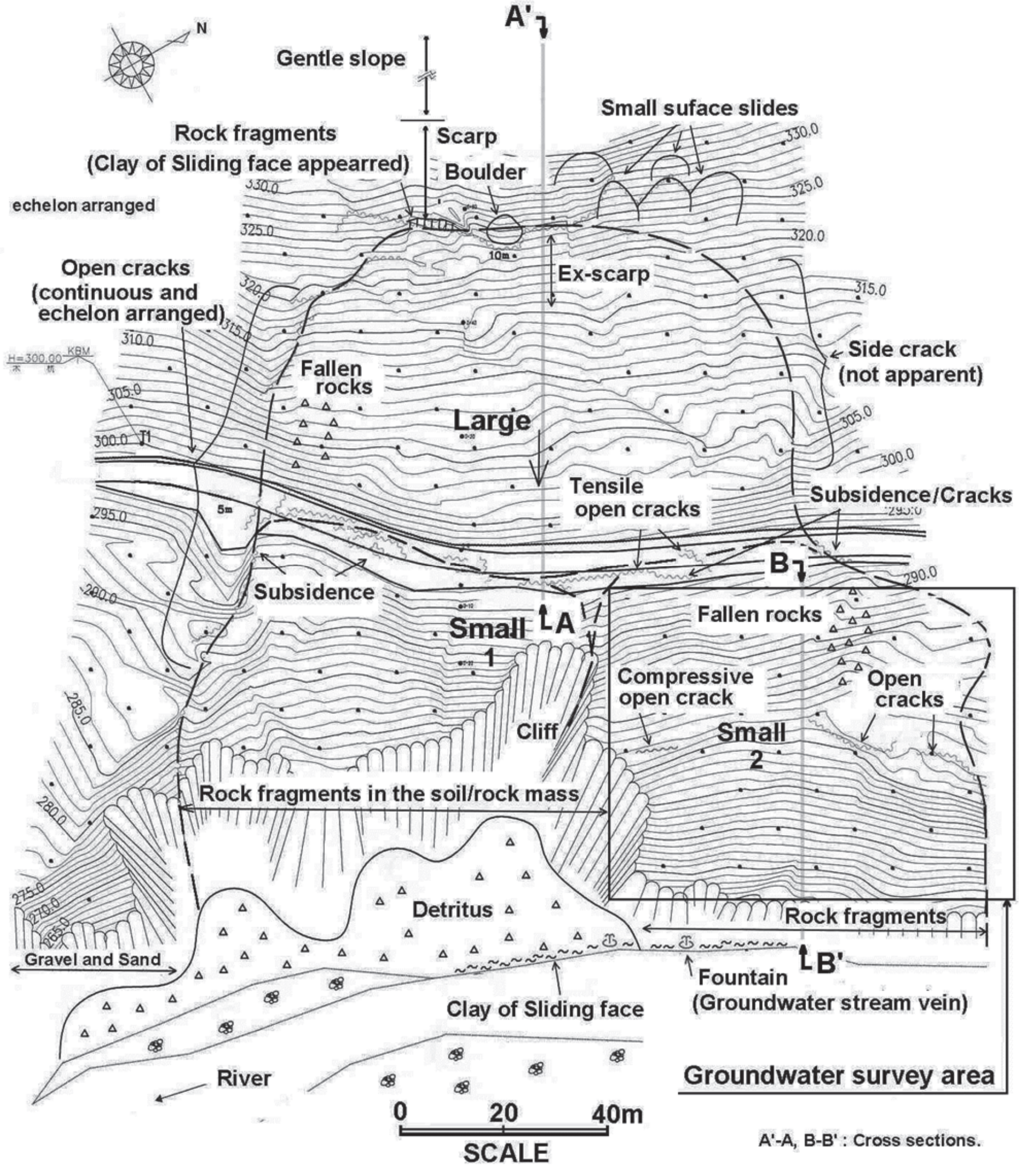

Fig .5 The exploring map of the site

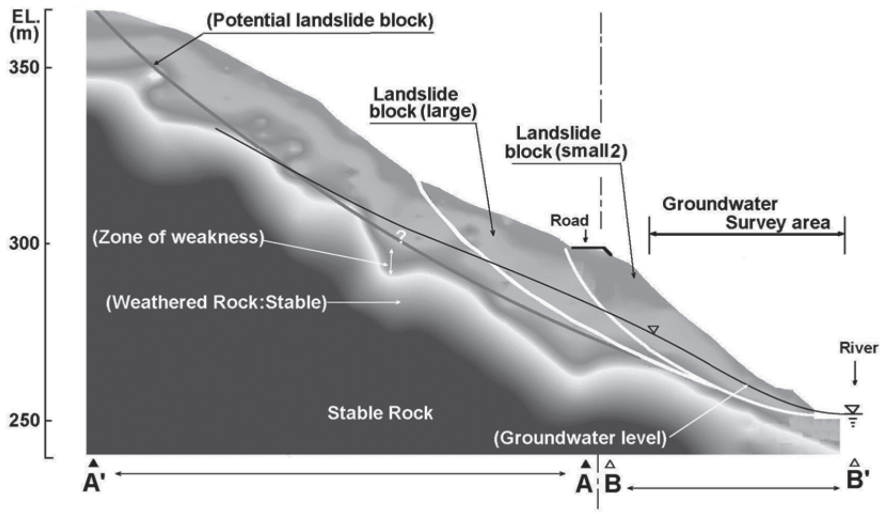

Fig. 6 The landslide profile (A'-A/B-B' cross section)

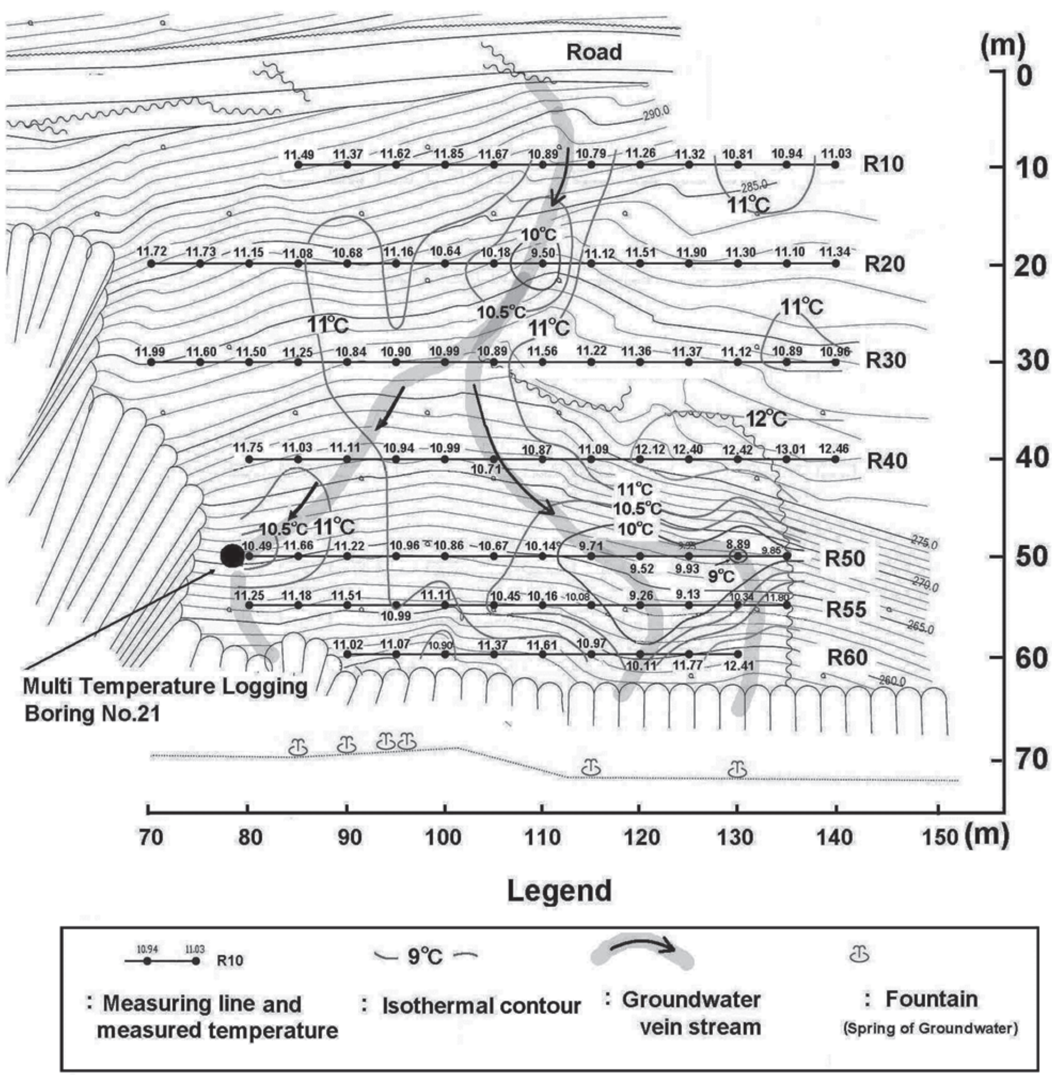

Fig. 7 The planar distribution of 1m depth ground temperature.

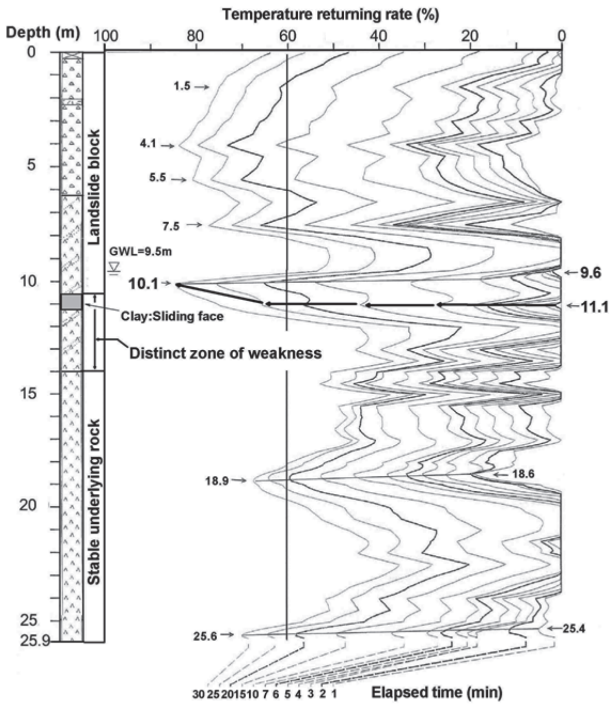

Fig. 8 The result of Multi Temperature Logging

According to the information got from the groundwater survey, the mitigation work such as withdrawing groundwater by drainage boring and well was conducted, as shown in Fig.9. The concrete protection work against river erosion was also constructed. The location was where groundwater vein stream was found. The groundwater withdrawing work was arranged along the groundwater vein stream. After the mitigation work was constructed, excessive groundwater drained off, and consequently active landslide stopped and became stable. The landslide has been stable since the mitigation work for more than ten years.

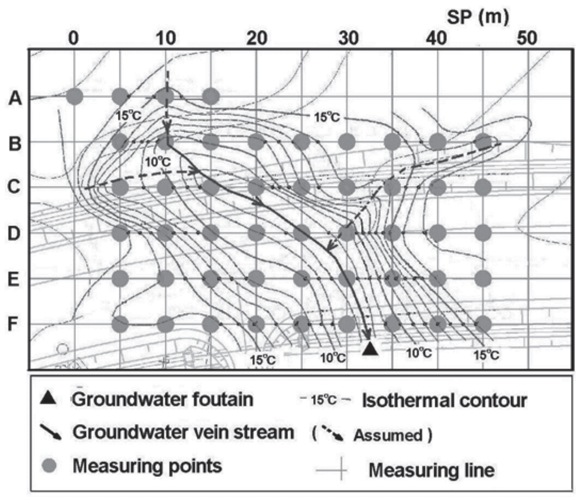

Fig. 10 Ground temperature distribution and groundwater vein stream

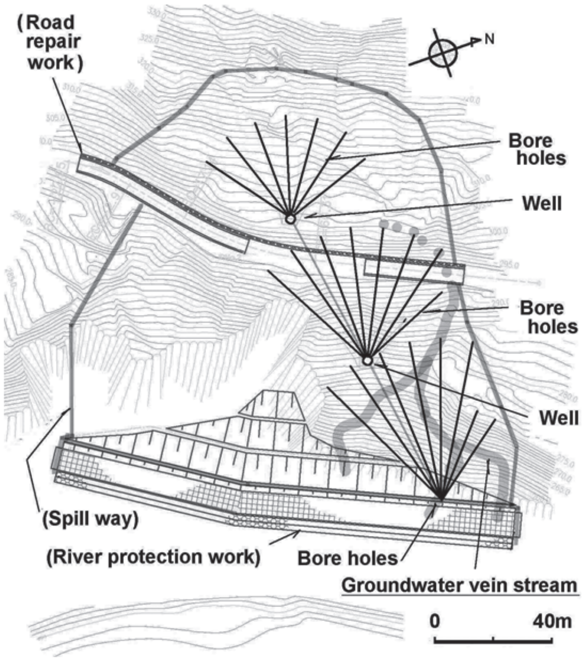

Fig. 9 Schema of the mitigation work

4.2 The case 2

The site situates at the end of earth flow, at an altitude of 10m, 45°10' north latitude and 141°20'east longitude, the Soya district, Hokkaido Japan. Geology of bed rock is volcanic rocks and debris overlies it. The 1m depth ground temperature measurement was conducted in simmer in order to find the underflow that could be affected by road construction. The results are as shown in Fig.10 and Fig11, respectively. The normal 1m depth temperature was 16.5℃ and groundwater temperature was 7.7℃. In Fig.10, groundwater vein stream was estimated as a narrow line connecting to fountain, while Fig.11 shows the lowest peak of the temperature that is groundwater vein stream of each line. It means the ground temperature measurement can considerably provide accurate location of groundwater vein stream, as shown in Fig.12.

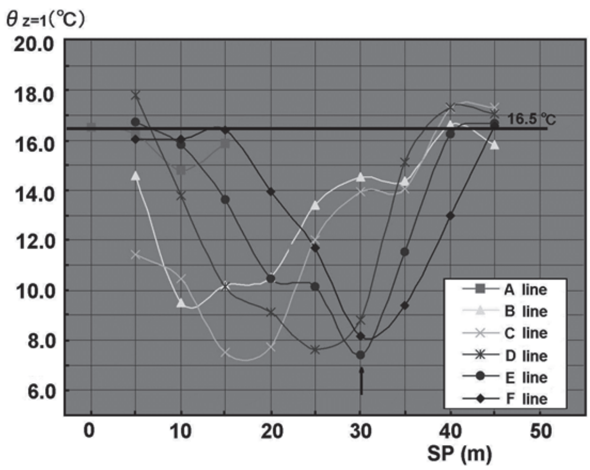

Fig. 11 Ground temperature distribution of each line

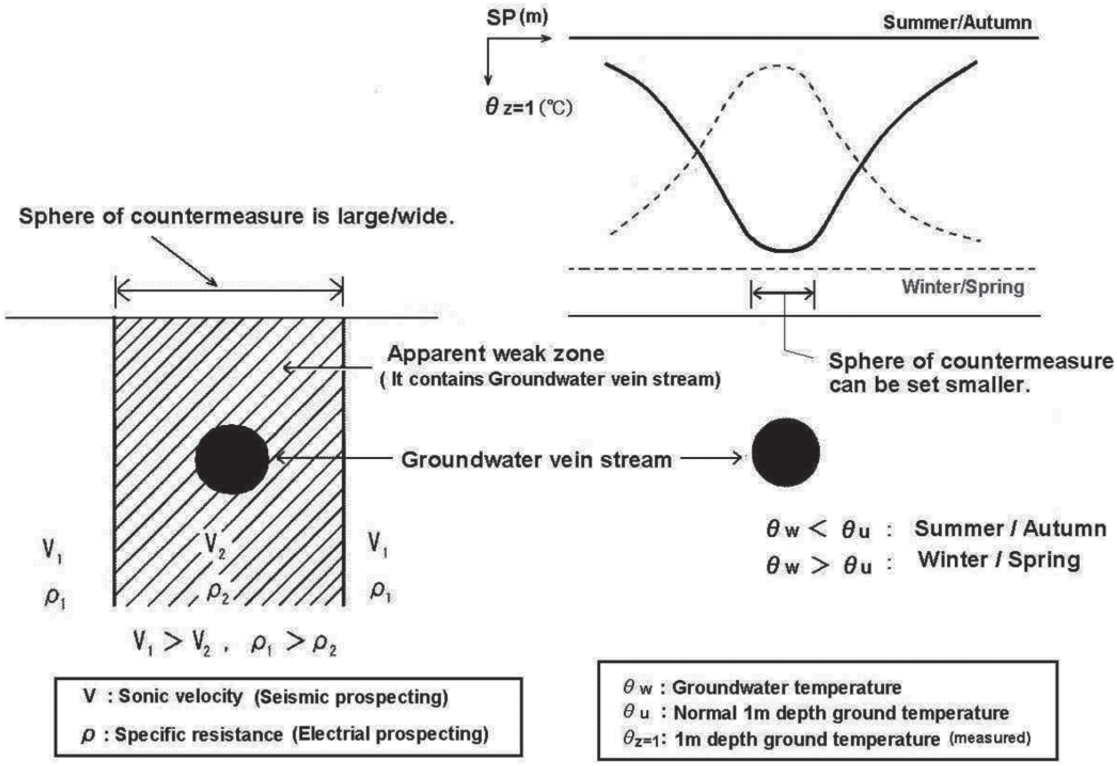

Fig. 12 Result comparing of Seismic/Electrical prospecting and 1m depth ground temperature measurement

5. Discussion and Conclusion

The general groundwater measure is electrical prospecting and sometimes seismic prospecting may be included. As shown in Fig.12, 1m depth ground temperature measurement can considerably provide accurate location of groundwater vein stream while the general groundwater measure such as electrical or seismic prospecting can detect only apparent weak zone which could contain groundwater and groundwater vein stream (Takeuchi, 2013). 1m depth ground temperature measurement is more effective that it can narrow sphere of countermeasure much smaller than the general groundwater measure. Multi temperature logging can detect the very point/depth of groundwater vein stream in a borehole.

As mentioned above, the groundwater survey measuring ground temperature can provide information of planar distribution of groundwater vein stream by 1m depth ground temperature measurement and that of vertical one by Multi temperature logging accurately. In case of landslide being found, it is effective to perform the groundwater survey measuring ground temperature because it can indicate exactly where to do countermeasure such as withdrawing excessive groundwater using well and bore hole.

These are the reason why the groundwater survey measuring ground temperature is effective for mitigating landslide.

Acknowledgements

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