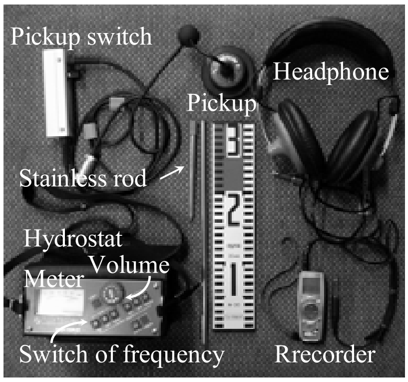
Detection of Groundwater Aeration Sound and Occurrence of Collapse in the Aftermath

Disaster Prevention Research Institute Kyoto University ○Yasuyuki Tada, Masaharu Fujita, Taizo Tsutsumi,
Faculty of Agriculture, Tottori University Takenobu Okumura, Naomasa Honda, Kan Koyama, Takayuki Kawai

1. Overview

There have been many stories regarding precursory phenomenon related to springs since long ago. For example, the following have been pointed out: (1) Stoppages of springs. (2) Blow off of springs. (3) Turbidity of springs. (4) Traces of water flow at collapse area, etc. There is thought to be some relationship between springs and the incidence of collapse, but there is little at the site which clearly shows the relationship between them. This is due to the fact that there is no way to discover the location of groundwater flow routes, referred to as water paths, which exist underground in difficult to access mountain districts.

This study (1) developed a method to easily identify the location of a water path from the sounds produced from groundwater flow; and (2) applied this method to a collapse area to compare the locations of water paths with the collapse positions. In addition, (3) the correspondence between the distribution of groundwater aeration sounds and the collapse positions generated by typhoon activity in 2004 was studied and the relationship between the collapse and the water paths was investigated.



Picture 1 Groundwater Aeration Sound Measuring Device

2. Measurement of Groundwater Aeration Sounds and Properties

2.1 Measurement of Groundwater Aeration Sounds

We estimated the locations of water paths by the loudness of groundwater aeration sounds. Groundwater aeration sounds include not only sounds produced from water flow but also other noises (wind noise, friction sounds of earth and gravel, etc.). However, by selecting the frequency band of sound, extraneous noise can be muted. The groundwater aeration sound measuring device is shown on Picture 1 and a schematic depiction of measurement is shown on Figure 1. To pick up groundwater aeration sounds, a stainless rod attached to Pickup is inserted into the ground surface and Hydrostat is used to cut noise and amplify sounds, which can be heard through headphones. In addition, the level of loudness of groundwater aeration sounds can be read by a level meter.

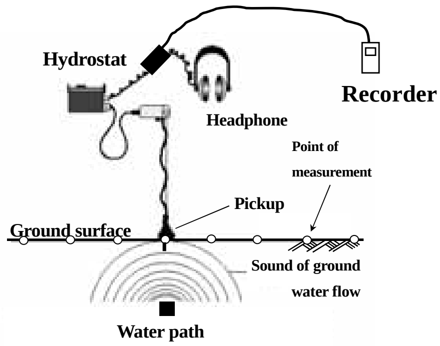


Figure 1 Schematic Depiction of Groundwater Aeration Sound Measurements

2.2 Properties of Groundwater Aeration Sounds

We carried out the following experiments to find out properties of groundwater aeration sounds. A porous pipe was placed in the middle of a model soil layer shown in Figure 2 (depth of 35 or 62 cm). 6 kinds of water flow (50 to 300 mL/sec) were used from Q_{in} to measure groundwater aeration sounds at ground surface. The level of loudness of the groundwater aeration sounds measured on the ground surface is shown on Figure 3. The following points can be understood from the figures: (1) The groundwater aeration sounds are loudest directly above the water path and the further from the water path, the weaker the sound. (2) If the water paths are at an equal depth, the larger the amount of water flow, the louder the underground sound pressure. (3) If the amount of water flow in the water path are equal, the shallower the water path, the larger the peak of groundwater aeration sound. We carried out the same kinds of experiments on natural slopes and obtained a similar result which showed that the groundwater aeration sounds become louder directly above spring points.

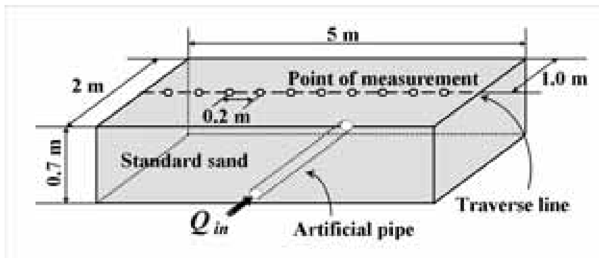


Figure 2 Model Soil Layer

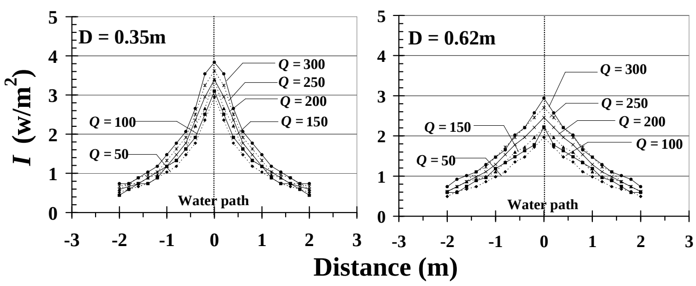


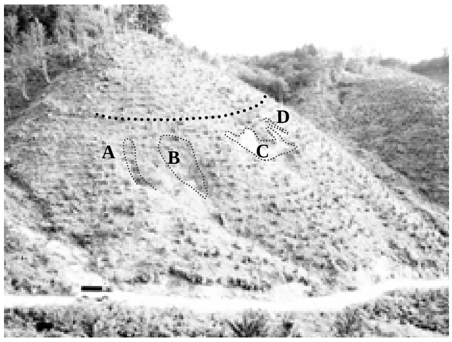
Figure 3 Examples of Groundwater Aeration Sound Measurement Results

3. Relationships between Water Paths Locations and Collapse positions

We investigated groundwater aeration sounds, targeting collapses occurring on natural slopes and forest road slopes. Here, we look at examples of shallow landslides which occurred on natural slopes in north Okayama prefecture and slope landslides which occurred on forest roads within Tottori prefecture.

[Natural Slope]; There were collapses at 4 places on 30° ridge type slopes, of granite geology (Picture 2). The character of each collapse is as follows. (1) Collapse A; width

2 m, depth of collapse 1.0 m. There is 1 spring. (2) Collapse B; width 6m, depth of collapse 1.0 m. There are 2 springs. (3) Collapse C; width 12m, depth of collapse 2.0 m. There is no spring. (4) Collapse D; width 2 m, depth of collapse 1.0 m. There is no spring. Figure 4 shows the distribution of groundwater aeration sounds measured at locations indicated by dashed lines in Picture 2. In addition, the hatched areas in the Figure indicate areas of collapse. The peak of groundwater aeration sounds and the collapse positions are aligned.



Picture 2 Appearance of Natural Slope

[Road Cut Slope]; There are collapses at 4 places (A to D) at slopes reinforced with planting shotcrete (Picture 3). The character of each collapse is as follows. (1) Collapse A: width 2 m, depth of collapse 1.0 m. There is no spring. (2) Collapse B: width 4 m, depth of collapse 1.0 m. There is no spring. (3) Collapse C: width 6 m, depth of collapse 1.0 m. Spring occurred during heavy rainfall. (4) Collapse D: width 4 m, depth of collapse 1.0m, there is no spring. The results of groundwater aeration sound measurements are shown in Figure 5. The collapse positions and peak of groundwater aeration sounds are aligned.

➔➔ Collapses occur at areas where the subsurface water is concentrated.

4. Monitoring of areas where peak of groundwater aeration sounds were confirmed.

There are peak levels of groundwater aeration sounds, equivalent to the level of the collapse area but there are also slopes where no collapse occurred. We monitored subsequent geomorphic changes of these slopes where peak of groundwater aeration sounds were detected. For the road cut slope described above, groundwater aeration sounds were measured on July 12, 2004. After that, typhoon No 21, which hit between September 29 through 30, 2004 brought great quantities of rainfall and collapse occurred. The appearance of the slope on October 1 after the typhoon had passed is shown on Picture 4. A collapse occurred on a scale of 30 m width and 1.5m depth. Compared to the appearance before the collapse (Picture 3), the left side of slope, area in (a) of Picture 3, has largely collapsed. Figure 6 maps this collapse position layered on Figure 5. The collapse occurred at the area where 3 peaks of groundwater aeration sound were detected.

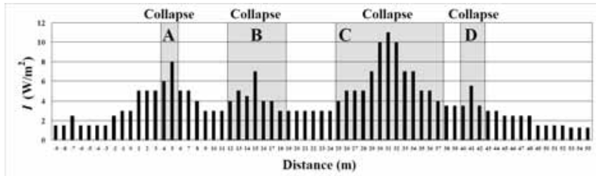
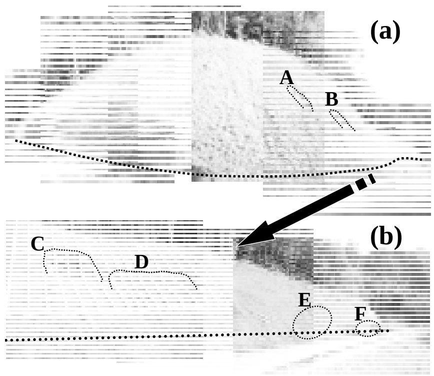


Figure 4 Correspondence of the Loudness of Groundwater Aeration Sounds and the Collapse Positions



Picture 3 Appearance of Road Cut Slope

➔➔ On the slope, there are areas (water paths) where subsurface water routinely concentrates and great quantities of subsurface water are delivered to those areas in heavy rainfall and thus collapses occur.

5. Conclusion

This study revealed the following:

(1) We developed a new method which easily investigates locations of water paths using groundwater aeration sounds. We confirmed that groundwater aeration sounds were the loudest directly above the water path. (2) We measured groundwater aeration sound on natural slopes and slopes and studied the relationship between groundwater aeration sounds and collapse positions. We confirmed that groundwater aeration sounds were strong at areas where collapses occurred and collapses occurred at points of subsurface water concentration. In addition, (3) Slopes where peak of groundwater aeration sounds were confirmed were monitored, and the results showed those points collapsed due to heavy rainfall. We can draw the conclusion that on slopes, there are areas (water paths) where subsurface water routinely concentrates and great quantities of subsurface water are fed into those areas by heavy rainfall, which leads to collapse.

In the past, it was observed that even though they have similar topography and geology, there are some slopes which collapse and there are some slopes which do not and the reasons were often not able to be clearly understood. As a result of this study, we were able to understand that water is fed in fundamentally different ways to slopes which collapse and slopes which do not collapse. When investigating disasters in the future, we should also turn our eye to

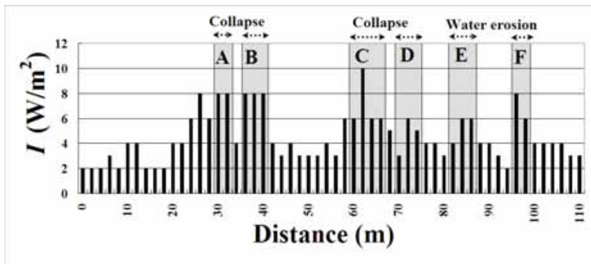


Figure 5 Correspondence of Groundwater Aeration Sounds and Collapse Position

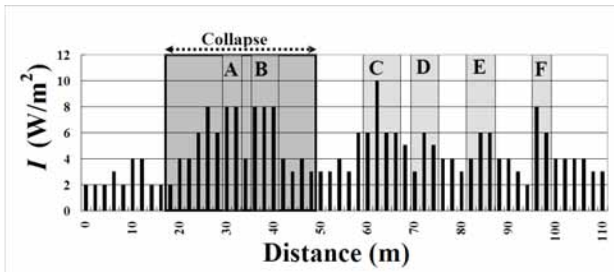
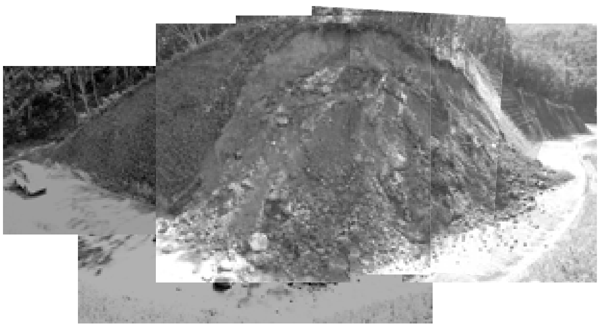


Figure 6 Comparison of Distribution of Groundwater Aeration Sounds and Positions where Collapses occurred


Picture 4 Slope Collapse Caused by Typhoon

these differences in the ways water is fed.