River Water-Level Recovery Time as an Indicator of Persistent Groundwater Elevation for Disaster Risk Reduction

*Yuya Tonegawa[1], Teruyuki Kikuchi[1], Kyosuke Sasaki[2]

1. Suwa University of Science , 2. Amber Logix Inc.

1. Introduction

Heavy rains and short-duration torrential downpours causing floods and landslides are becoming increasingly frequent. In September 2021, a significant landslide disaster occurred along the Gebazawa River in the Takabe District of Chino City, Nagano Prefecture. While the disaster caused extensive damage, impacting 64 houses, there were no fatalities thanks to successful preemptive evacuation efforts by the local community.

This evacuation was triggered by local traditions stating that evacuation is necessary when "the river makes a rumbling sound" or "the river emits a smell." Furthermore, subsequent water level data from the Gebazawa River revealed that water level fluctuations consistent with the local tradition—"the river water level drops before a *Yamatsunami* (debris flow)"—had actually occurred. Preemptive evacuation is a critical method for minimizing human casualties. However, challenges include the scarcity of information for making evacuation decisions and the difficulty for residents to maintain a constant awareness of disaster risks. To address this, this study installed water gauges to quantify the local tradition that "the water level drops before a debris flow." We established a monitoring network with 14 water gauges and 1 rain gauge in the Suwa region and conducted long-term observation of water levels and rainfall using LPWA (Low Power Wide Area) communication devices.

2. Utilization of River Water Levels

A mechanism for landslide (slope failure) occurrence suggests that if further heavy rain (such as a linear precipitation band) occurs while groundwater levels are already elevated due to prior rainfall, the groundwater level rises further, leading to collapse. However, directly observing groundwater levels is difficult due to cost. Therefore, we aimed to estimate the elevated state of groundwater indirectly by using the amount of change in river water levels and their "recovery time"—defined here as the time required for the water level to return to its normal values after the rain stops.

3. Results

Analysis of long-term measurement data revealed a clear difference between the frequency of rainfall and the number of days required for recovery. When rainfall occurred only once, the average recovery time was 1.9 days. In contrast, when rainfall occurred multiple times consecutively (when the water level rose again due to subsequent rain before returning to the pre-rainfall level), the average recovery time was 23.9 days. This clarifies that it takes an extremely long time for water levels to return to normal compared to single rainfall events.As a specific example, we compared cases in the Noakezawa River with hourly rainfall of 10mm where the water level rose once (Fig.1) versus 14 times (Fig.2). In the single-rise case, the recovery time was 4 days. Conversely, when the water level rise was repeated 14 times, re-elevation due to the next rainfall occurred before the water level could fully recede, resulting in a prolonged state where the water level did not return to normal. Intermittent rain continued thereafter, requiring 39 days for full recovery. Furthermore, investigating the relationship between recovery days and the number of water level rises showed a high correlation with a coefficient of determination R^2=0.861.

4. Conclusion

If the water level remains high and does not return to normal even after the rain has stopped, it can be numerically recognized as a dangerous state where groundwater levels remain elevated. This study demonstrated that the elevated state of groundwater can be indirectly assessed through the recovery

behavior of water levels obtained from water level and rainfall observations. Consequently, water level monitoring can serve as quantitative material for evacuation decisions. Enabling residents to check water level fluctuations on a daily basis is considered an effective means of helping them recognize that dangerous conditions are persisting.

Keywords: disaster prevention, natural disaster, Local traditions

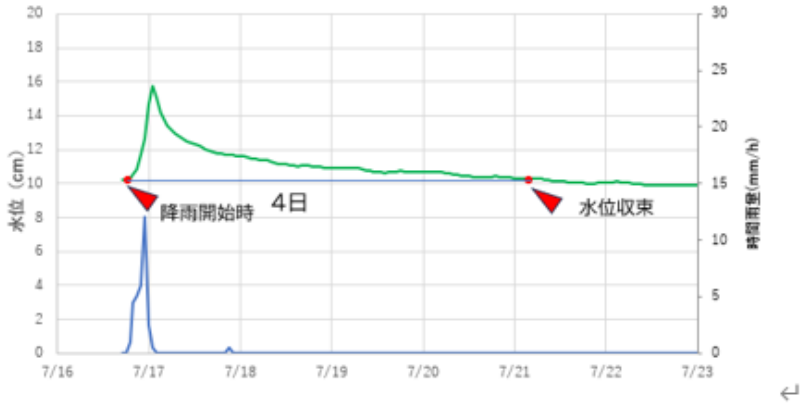

Fig. 1: Case of water level recession after a single rainfall event (Noakezawa River)

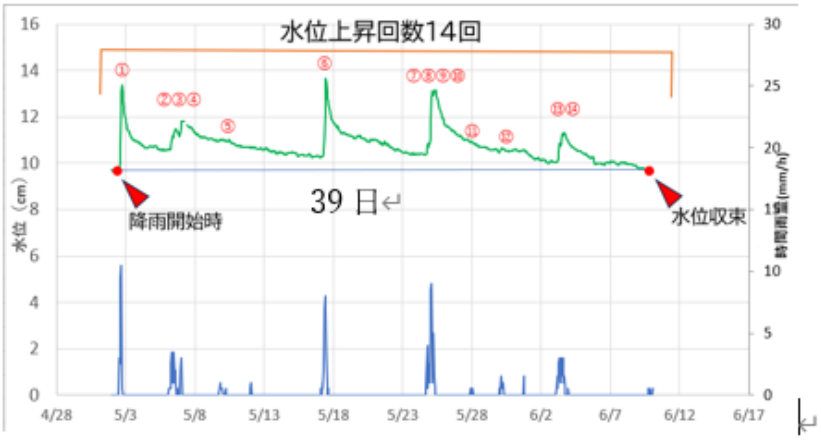

Fig. 2: Multiple rainfall events during the recovery period (Noakezawa River)

