E211

Assessment of Loss of Life Due to Dam Failure Floods Considering Population Distribution and Evacuation

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Introduction

The dam failure is considered a low probability, high consequence event. Although the frequency of dam failures has decreased since the 21st century, the risk of dam failure still exists. Loss of life (LOL) is the most severe consequence of dam failure floods. Assessing potential losses can provide scientific guidance for response in dam emergencies.

The LOL due to dam failure is influenced by various uncertainties. Researchers currently strive to consider as many uncertainties as possible. However, the impact of the spatial-temporal distribution of the population on the results of life losses still needs further investigation.

This study established a population distribution model and a LOL assessment model. By calculating the spatial-temporal changes in life losses during different periods and warning times, the study can provide evacuation guidance for decision-makers.

The population distribution model

The population distribution model (Figure 1) is established based on multi-source data.

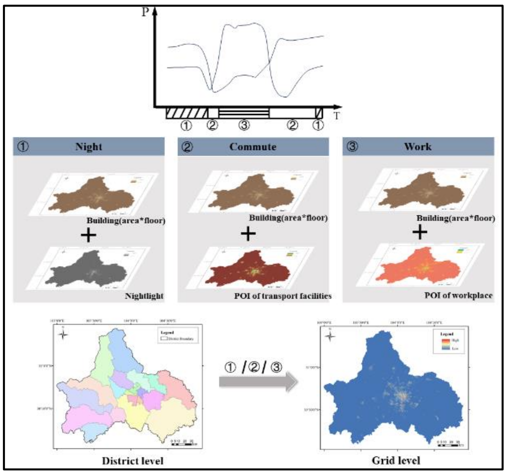


Figure 1 Population distribution calculation model

Population change per unit hour was calculated using the number of end and start orders for shared bikes and the percentage of the population using them. Since the population changes are not significant in some time intervals, a day was divided into three intervals: nighttime, commuting, and working time. The population distribution was downscaled to a 100m grid size using building vector data, point-of-interest (POI) data, and nighttime lighting data.

The dam failure LOL assessment model

The dam failure LOL formation consists of the following six processes (Figure 2).

(1) Generation of population at risk (PAR). The number of PAR is determined by the inundation extent and the spatial and temporal population distribution, which directly affects the LOL results.

(2) Transmission of warnings. Warnings are spread among the population in the downstream through radio, social media etc., with a transmission time of T_{tran}. The time between the issuance of the warning and the occurrence of the dam failure is the warning lead time, T_{war}.

(3) Evacuation preparation process. After receiving the warning, people need time to make decisions on whether, when, where, and how to evacuate. This part of the time is called the reaction time T_{res}.

(4) Vertical evacuation process. When conditions are not suitable for horizontal evacuation, people choose vertical evacuation, i.e., moving vertically upwards inside buildings. People are safe if the building can be stabilized during flooding. The

percentage of population chooses vertical evacuation is R. The percentage of population successfully evacuates vertically is R_{veva}.

(5) Horizontal evacuation process. Horizontal evacuation means the population moves to shelters. The success of horizontal evacuation depends on whether the available time (flood arrival time (T_{arri}), rise time (T_{rise}), etc.) is greater than the required time (T_{eva}). The percentage of successful horizontal evacuation is R_{heva}.

(6) Loss of life formation. The PAR who did not successfully evacuate is called the exposed population P_{exp}, who may lose their lives. LOL is calculated by the formula.

$$LOL = PAR\left[R\left(1-R_{heva}\right)+\left(1-R\right)\left(1-R_{veva}\right)\right]F_M \quad (1)$$

Where F_M is the mortality rate.

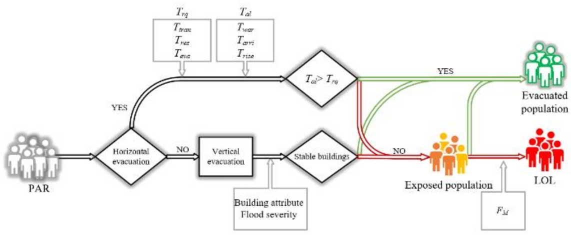


Figure 2 The process of dam break LOL formation

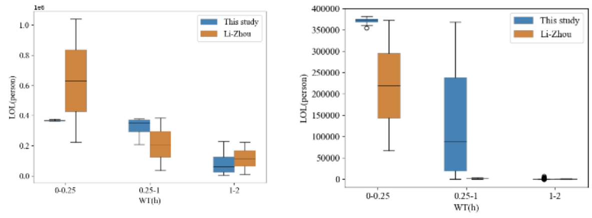
Result

Taking the case of Zipingpu Dam in Sichuan Province, China, the most severe condition is considered. HEC-RAS is used to calculate the dam failure flood evolution process.

(1) Comparison of results

The results of this study were compared with the Li-Zhou method, which is the recommended method of calculation LOL for Chinese dams.

Under two levels of understanding and three WT (time between warning issuance and flooding reaching the PAR) scenarios, the results of this model are within the Li-Zhou method result intervals, or the results are higher than the Li-Zhou method when the level of understanding is clear.



(a) Fuzzy (b) Clear

Figure 3 Comparison of LOL at two levels of understanding

(2) LOL assessment

The value of loss of life varies significantly when dam failure occurs at different times of the day. Since people's reaction ability at night is lower than that in daytime, a longer T_{war} is needed for people to react. Meanwhile, for the dam site similar to Zipingpu, the downstream is the non-central area of the city, due to the population activities, i.e., going to the central city to work during the day and returning home at night, the number of people in the downstream at night is more than that in the daytime, so it should be more concerned about the safety of the dam at night.

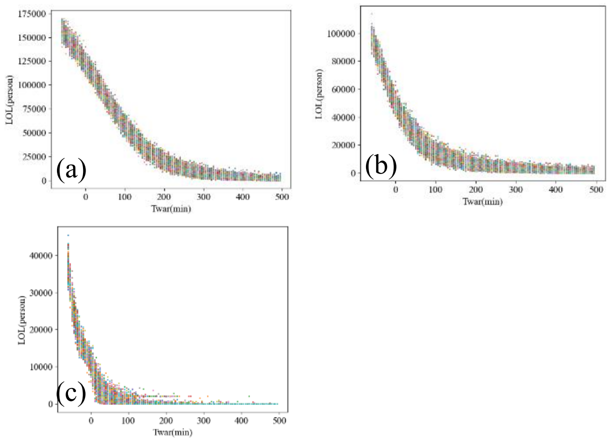


Figure 4 LOL at different T_{war} during different time (a) night time, (b) commuting, (c) working time

Conclusion

This study models the spatial- temporal distribution of the PAR based on multi-source data and analyzes the impact of differences in population distribution under nighttime, commuting, and work hours on the LOL of dam failures. The results provide the latest T_{war} and suggest that managers should pay more attention to the dam status at night.