E203

Developing a Simplified Model for Assessing Debris Flow-Induced Pipeline Failure Probability Due to Multiple Independent Source

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Introduction

Debris flows fast-moving landslides. Because of the high mobility characteristics and their consequent large area of impact, long-distance oil and gas transport pipelines passing through certain high-risk mountain areas can be at risk from debris flows. When this happens, natural hazard triggered technological accidents, known as Natechs, may occur (Krausmann, E et al 2017). Moreover, considering the increasing trend in the number of extreme precipitation events due to climate change, rainfall-induced debris flows—as one of most frequent rainfall-induced natural hazards—are expected to become more common. Hence, Natech accidents involving the impact of debris flow on pipelines are also expected to occur more frequently. In view of this increasing trend, pipeline operators could greatly benefit from a methodology to help them assess the risk of pipeline failure with respect to debris flows, in order to identify high-risk hotspots within their pipeline network and better prioritize and allocate resources for maintenance and repair works.

Additionally, the risk assessment process from the determining the initial rainfall to the impact of the debris flow on the pipeline is characterized by many uncertainties. For example, when measuring and simulating soil properties, uncertainty may be introduced due to spatial variation of soil properties, random testing errors, or statistical estimation errors due to a finite number of measurements.

Current research methodologies are technically limited to assuming only one initial source for each debris flow. (Ciurleo, M et al 2021) In reality, however, there may be multiple sources that lead to one debris flow. The uncertainty inherent in the risk assessment process makes the location and number of debris flows source difficult to estimate precisely, which in turn leads to numerous debris flow scenarios being taken into consideration. While operators need to consider every possible and potential scenario which can lead to the pipeline failure. This presents a great challenge in accurately assessing pipeline hotspots for rainfall-induced debris flows.

In a previous study, based on the inventory map of the Mocoa (Colombia) 2017 debris flow event, Su SONG (2021) developed a methodology to assess the pipeline hotspots for rainfall-induced debris flows with the consideration of worst-case scenarios instead of uncertainties. Alvarado-Franco et al. (2017) proposed a quantitative-mechanistic model aimed at assessing the probability of failure along pipelines due to landslides, which offers a method to tackle the aforementioned challenge. Thus, in order to take account of the soil properties uncertainty, this study aims combined a Monte Carlo method with previous methodology (Su SONG 2021) to develop a simplified model for the assessment of the probability of pipeline failure due to rain-induced debris flow triggered by multiple independent sources.

Methodology

The methodology proposed for the assessment of pipeline failure probability includes four phases as shown in Figure 1. These are: (1) data collection of 2017 debris flow event in Mocoa city , (2) debris flow source identification and probability (3) debris flow simulation and (4) pipeline failure determination.

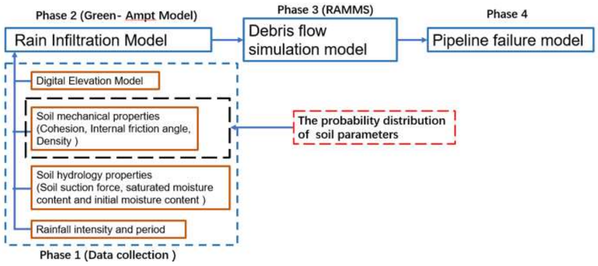

Fig.1 The workflow of the methodology

Phase 1 involves collecting data about the site geomorphology, rainfall and the soil properties. This data serves as input for running the rain infiltration model (Green-Ampt model) in phase 2, to identify the locations of potential debris flow sources, and complete the model validation and threshold safety factor determination. Furthermore, in order to calculate. the probability that an area becomes unstable and can trigger a debris flow, a Monte-Carlo method is employed to sample the soil parameters and inputs them into the Green-Ampt rainfall infiltration model. Phase 3 uses the geometric data and inventory data from phase 1 to complete the simulation and validation of the debris flow using 2D simulation with RAMMS software. Finally, phase 4, we use a pipeline failure model that uses the output velocity, intensity and impact direction from phase 3, to determine the hotspots of potentially exposed pipelines.

For the result of phase 2, areas with probability of becoming unstable are aggregated into groups based on certain probability intervals. Then, the different intervals are combined to create the possible debris flow source scenarios based on the assumption that the areas assigned to each probability interval occurs simultaneously from multiple sources.

Results of trails, discussion and conclusion

To test the proposed methodology, this study obtained the soil parameters from Alvarado-Franco et al. (2017) and conducted a trial based on Mocoa city data. Fig 2 shows the four intervals of probabilities. Fig 3 shows the probability distribution based on the occurrence of one scenario that In the area where the probability located in intervals No.3 and intervals No.4, mass movement occur together. In Fig 3, using Fig2 as input to RAMMS, the significant parameter, debris flow velocity, can be obtained along the pipeline, which is the input for the pipeline model. Fig 2 result shows that most of the probabilities fall within the values of 0.95 and 0.99, and so classifying areas in multiple small intervals is not very meaningful. Moreover, the result is apparently overestimating. Because of the lack of sufficient field data, many large areas are included within our study area. Thus, more detailed field data are needed to improve estimation accuracy.

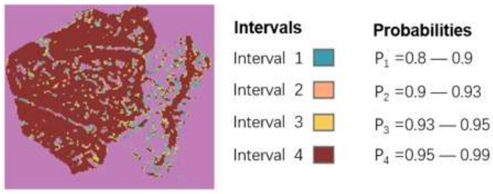

Fig. 2 Integrates areas into probability intervals

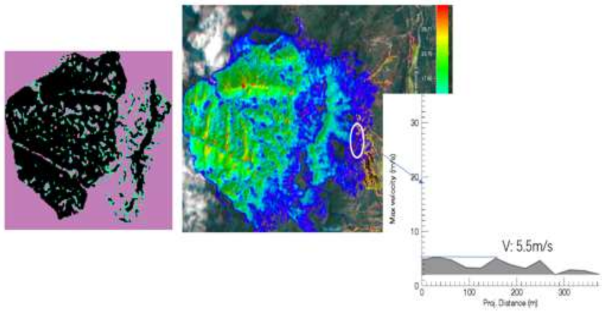

Fig. 3 Intervals 3 and Intervals 4 mass movement occur together and the debris flow simulation.

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