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Numerical Simulation of Overtopping-induced Landslide Dam Breach Process

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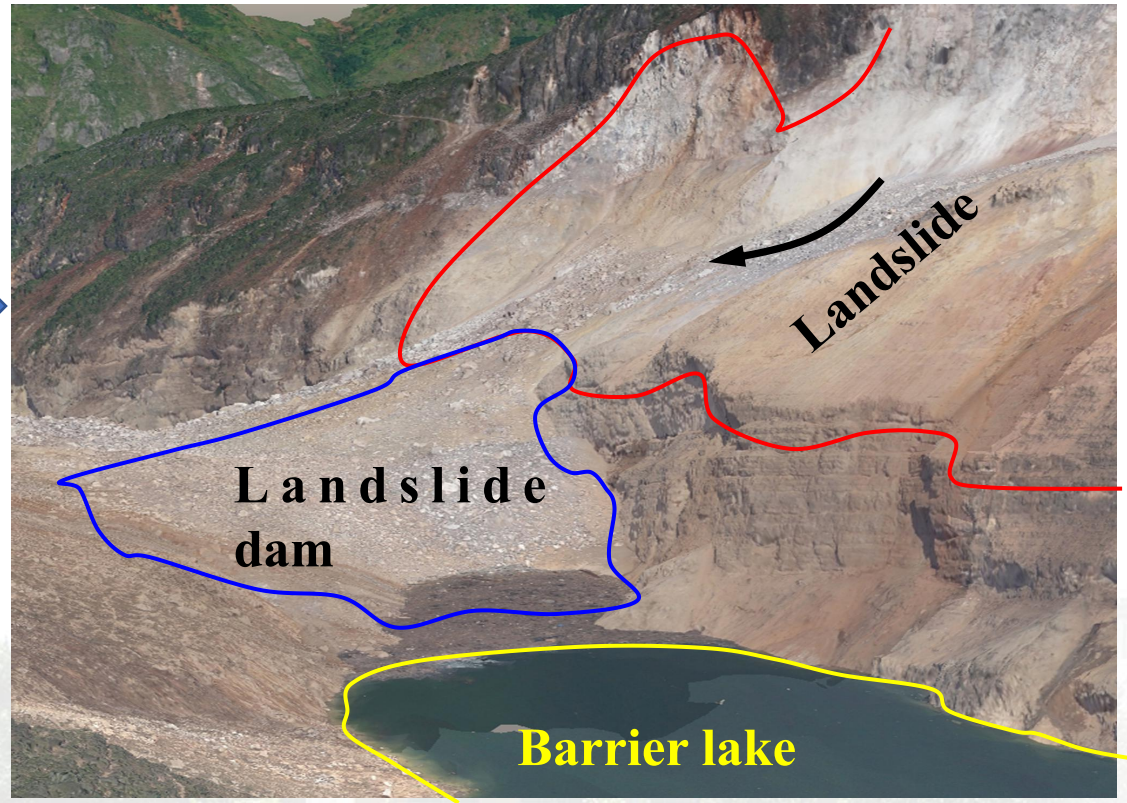
Formation of barrier lake

- According to a statistical analysis of landslide dams worldwide, the most important triggering factors of river-damming landslides were earthquake and rainfall. The resulting landslide is the most frequent form.

Earthquake

Rainfall



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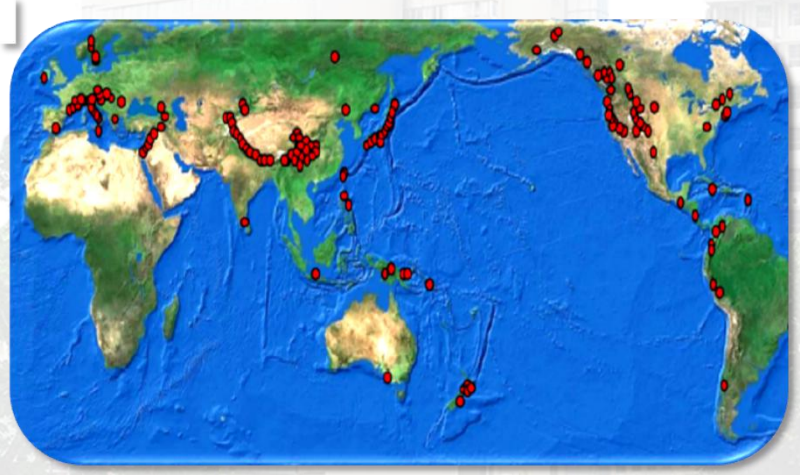
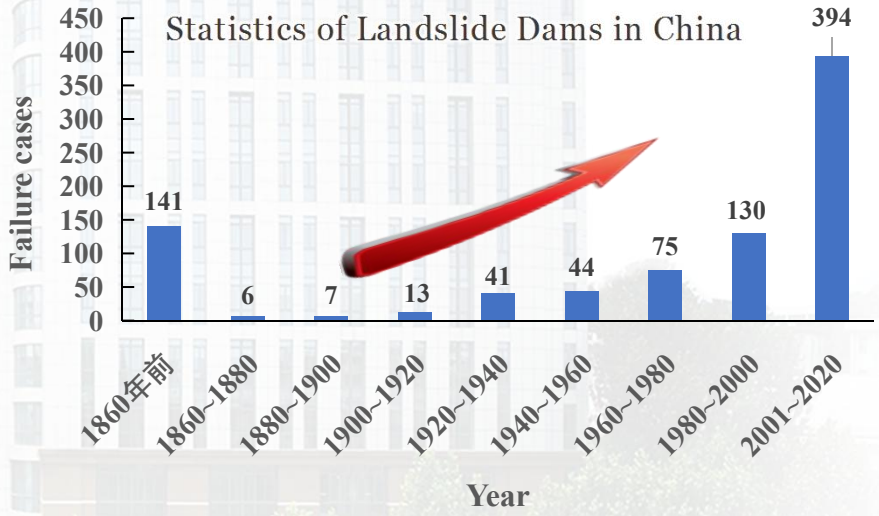
Distribution of landslide dams

- Landslide dams are common worldwide, especially in active mountain regions. They are extremely dangerous phenomena, as they may trigger dam-break floods that can affect large areas downstream.
- They are widely distributed in more than 1400 places all over the world. There are more than 800 cases in China, most of which are located in the upper reaches of the Yangtze River.



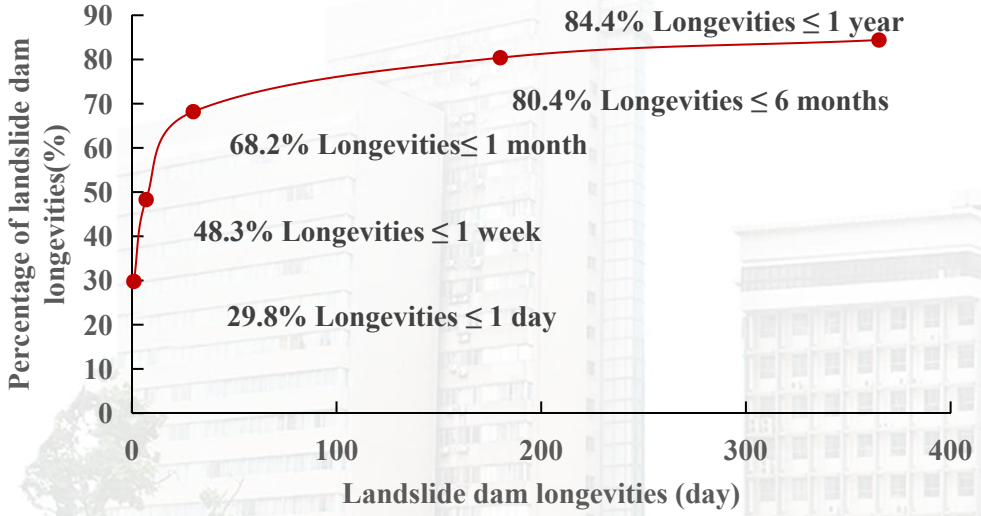
Distribution of large landslide dams in the world

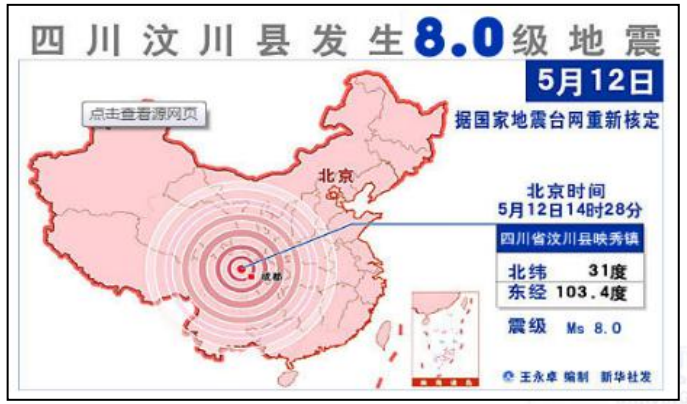
Distribution of classical landslide dams in China



1 Background

- 85% of the landslide dams will breach in one year，so the dam-breaking risk of the landslide dam is much higher than that of the artificial embankment dam.





Yigong landslide dam
2000.04.09-2000.06.10

Tangjiashan landslide dam
2008.05.12-2008.06.10

Baige landslide dam
2018.10.11-2018.10.13
2018.11.03-2018.11.13

Jiala landslide dam
2018.10.17-2018.10.19
2018.10.29-2018.10.31

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Hazards of landslide dams

Once landslide dams breached, massive flooding may occur in a short time, posing a great threat to the lives and properties of downstream residents. So accurate prediction of landslide dam breach process is of great importance for the emergency response.

Tangjiashan Landslide Dam
Failure time: 2008
Peak discharge: 6500 m^3/s
More than 250,000 people were evacuated.

Xiaogangjian Landslide Dam
Failure time: 2008
Peak discharge: 3950 m^3/s
More than 5,000 people were evacuated.

Baige Landslide Dam
Failure time: 2018
Peak discharge: 31000 m^3/s
Nearly 75,000 people were evacuated.

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2 Case Introduction

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● "11.03" Baige Landslide Dam

➢ At 17:21 on November 3, 2018, a secondary landslide occurred on the right bank of the Jinsha River, China.

Parameter	Value
Elevation of dam crest (m)	2,966
Dam height (m)	96
Crest length (m)	200
Dam width (m)	700
Upstream slope (V/H)	1:2.7
Downstream slope (V/H)	1:5.5
Residual dam height (m)	35.75
d_{50} (m)	0.005
e	0.697
C_u	20
C (kPa)	3
φ (°)	35
ρ_s (kg/m^3)	1,591
ρ_w (kg/m^3)	1,000
k_d (mm^3/N-s)	368
τ_c (Pa)	13.6

2 Case Introduction

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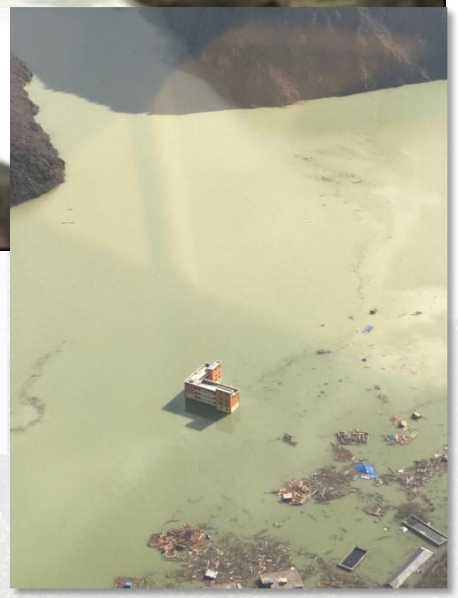
- "11.03" Baige Landslide Dam



A large number of towns in the upper reaches of Boluo Township were submerged!

2 Case Introduction

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● "11.03" Baige Landslide Dam

- Disposal measures :
  - ➢ Non-engineering measures : Transfer upstream and downstream people to avoid risk
  - ➢ Engineering Measures : Spillway excavation

Excavation process of the spillway

2 Case Introduction

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● “11.03” Baige Landslide Dam

➢ Emergency disposal effect

The overtopping flow entered the spillway

The breach gradually expanded until the end

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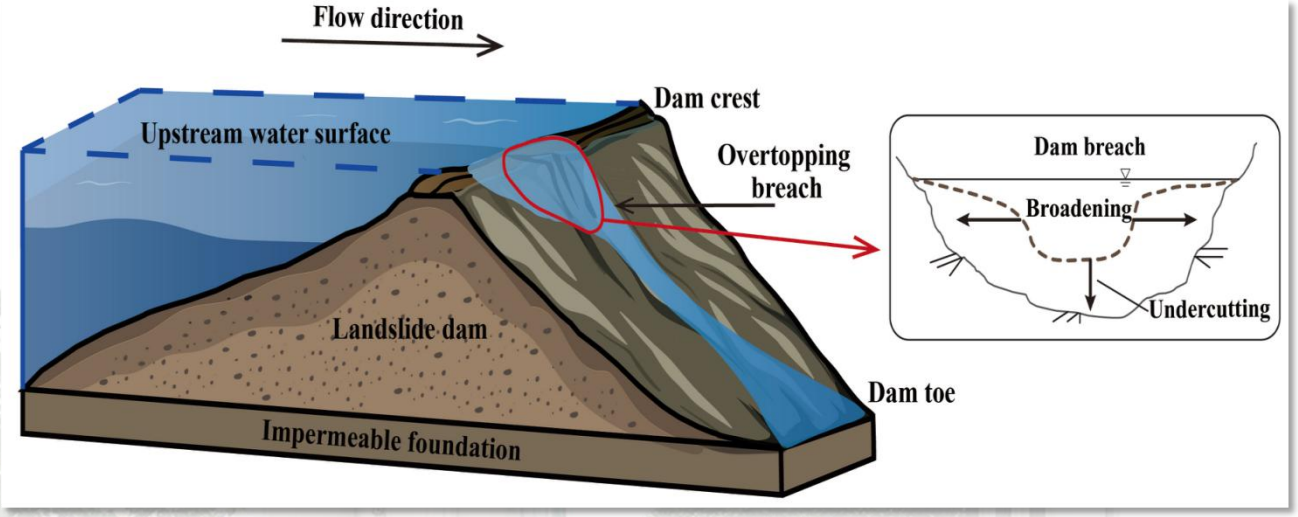
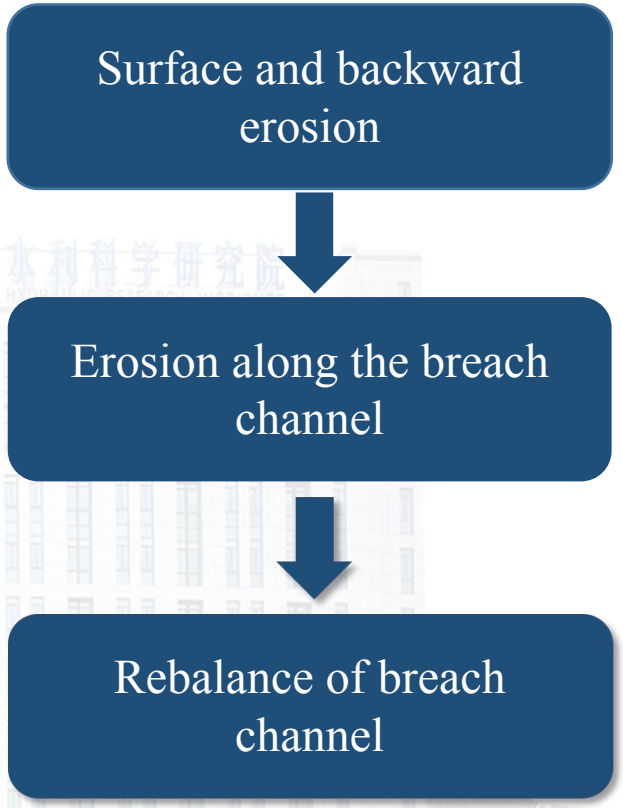
Landslide dam breach mechanism

- The overtopping failure usually occurs at the weak part of the dam crest and downstream surface, forming the initial breach. As the flow increases, the dam breach is continuously undercut and broadened.



Schematic diagram of overtopping-induced landslide dam breach mechanism

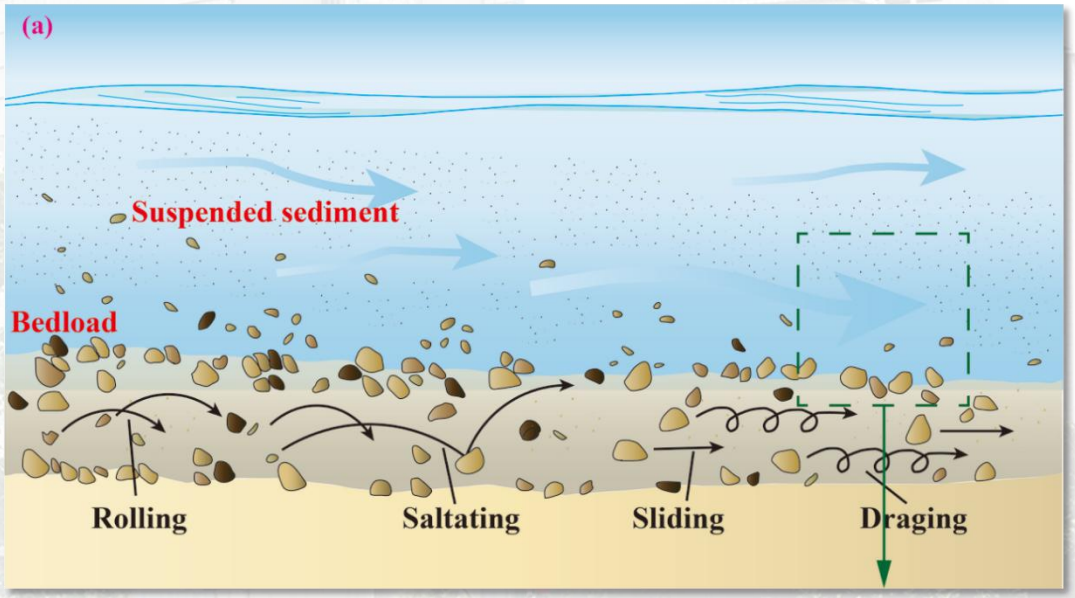


Breach process of overtopping-induced landslide dam

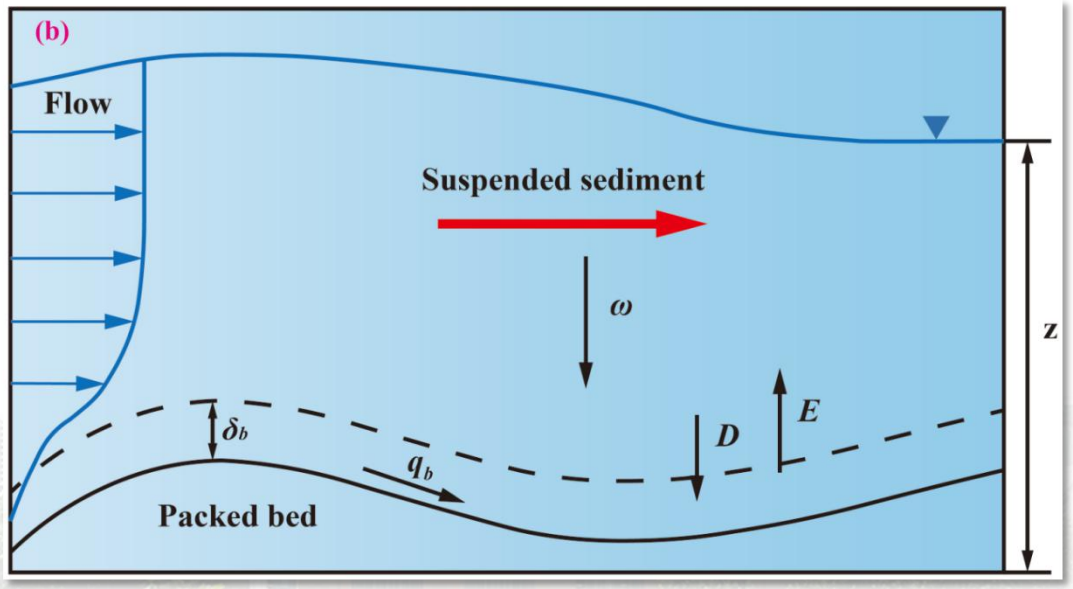
3 Numerical simulation

Numerical model

- The N-S equations and RNG k-ε turbulence model are combined to analyze the breach flow through the complex topography, and the sediment transport equations for bedload and suspended load are employed to better understand the breach evolution.
- The Volume of Fluid (VOF) method is employed to track free-surface flow, and the Finite Volume Method (FVM) is used to solve the governing equations.



Conversion of bedload and suspended load



Morphological evolution in the packed bed

3 Numerical simulation

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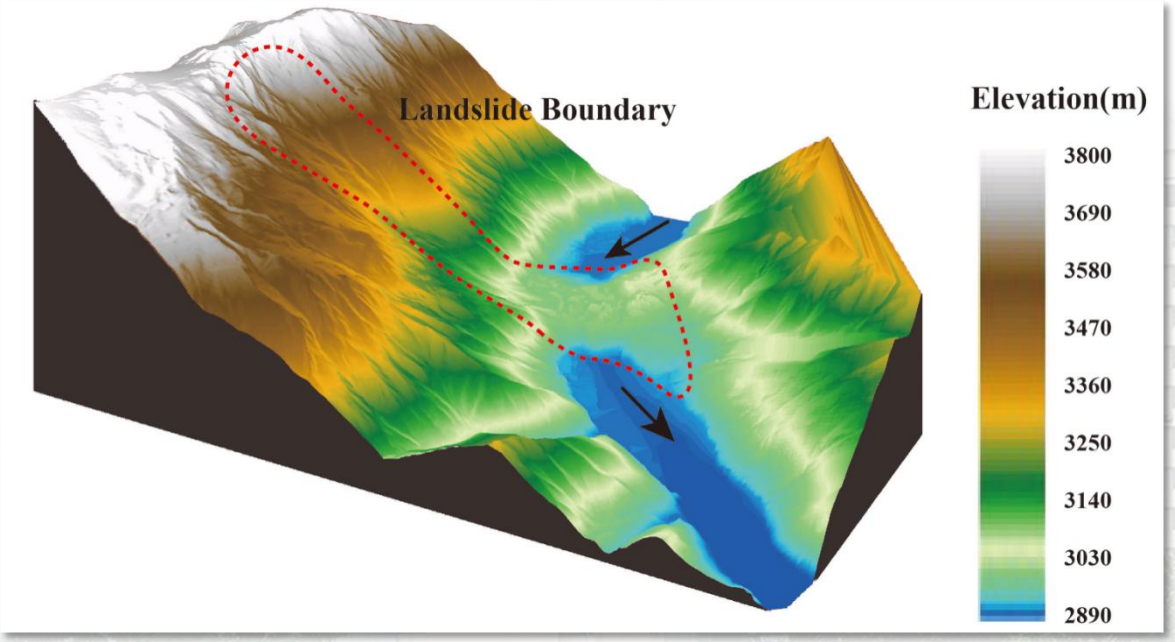
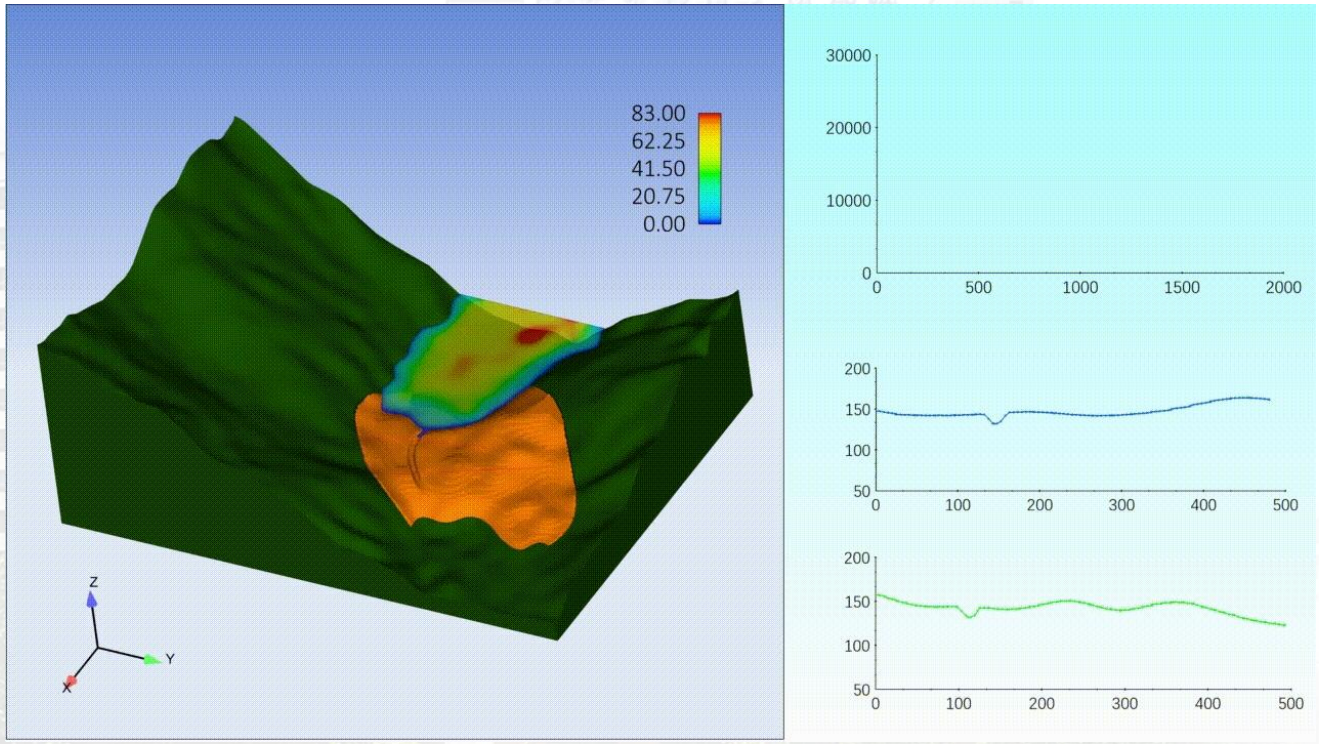
Case study

- Aiming at the "11.03" Baige landslide dam with relatively complete data, the 3D model are reconstructed by using the rapid spatial information processing technology of the combination of geographic information system (GIS) and digital elevation model (DEM).



topographical model



3 Numerical simulation

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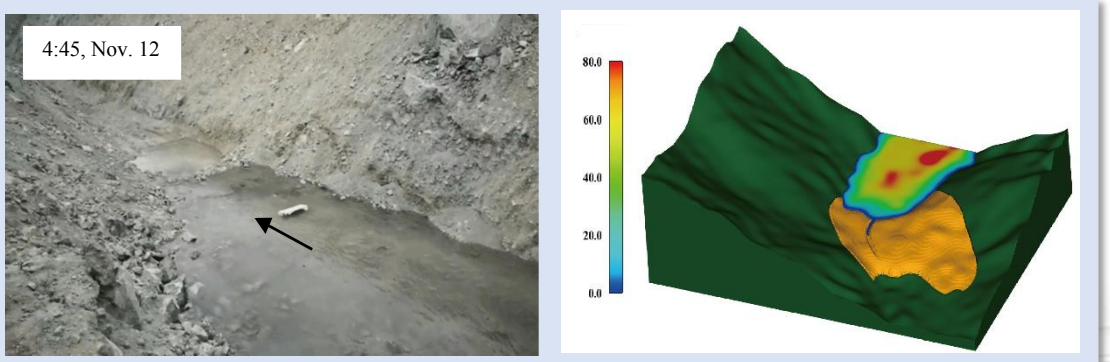
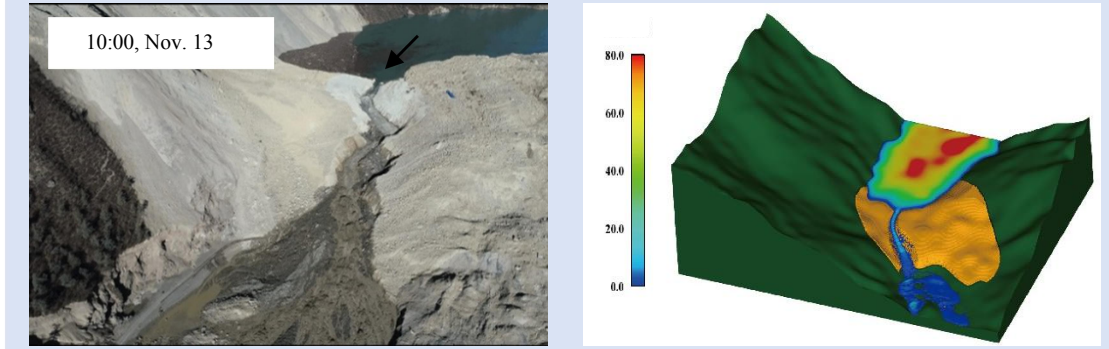
● Results analysis

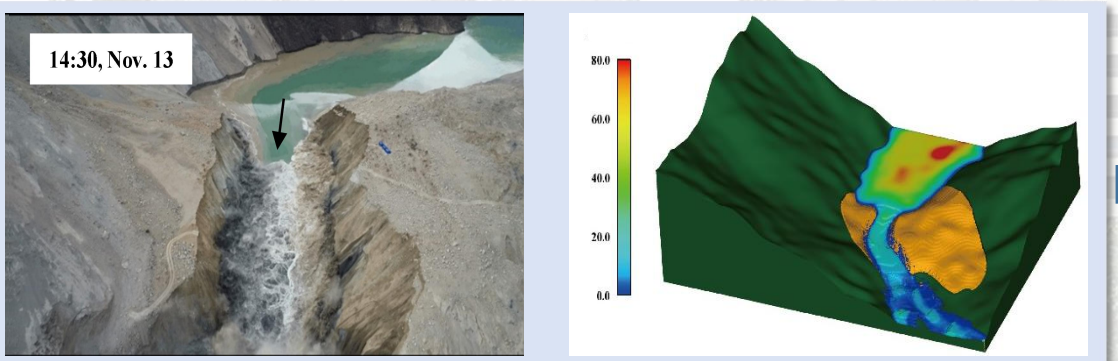
- Comparison of calculated and measured dynamic breach process:



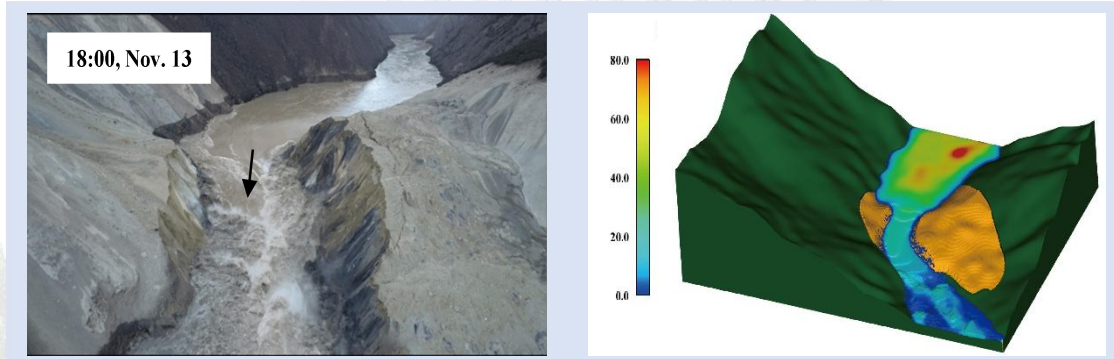
1. Overflow of the spillway



2. Backward erosion



3. Streamwise erosion



4. Rebalance of breach channel

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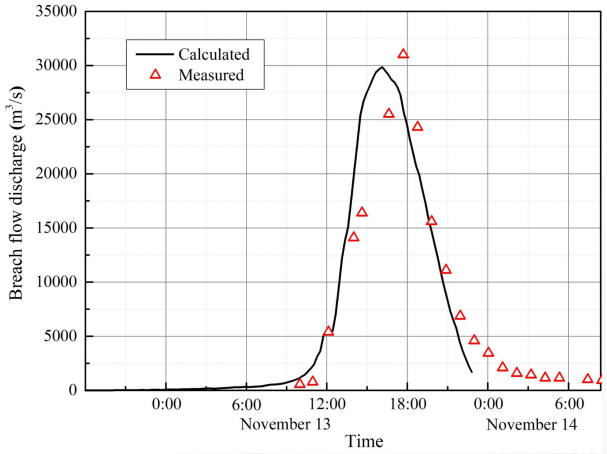
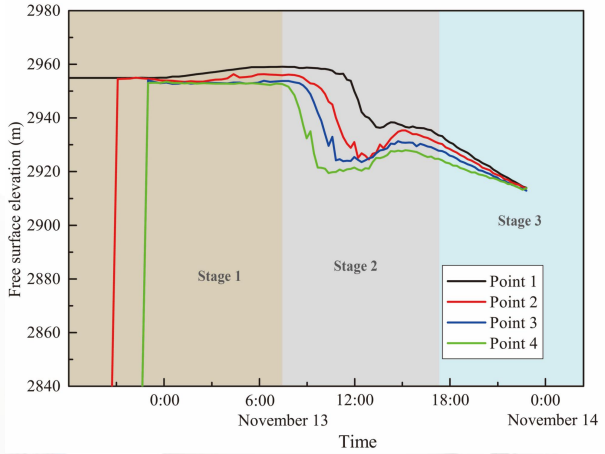
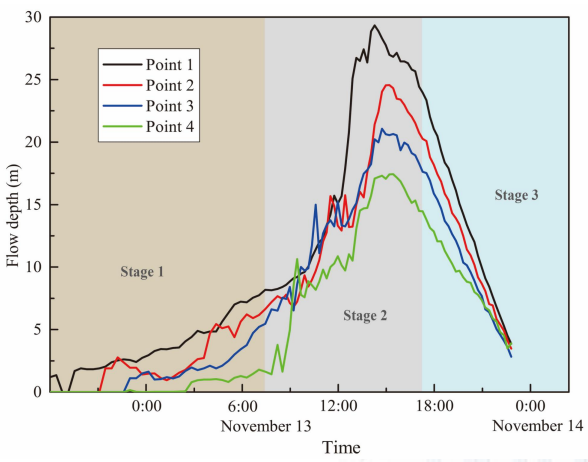
● Results analysis



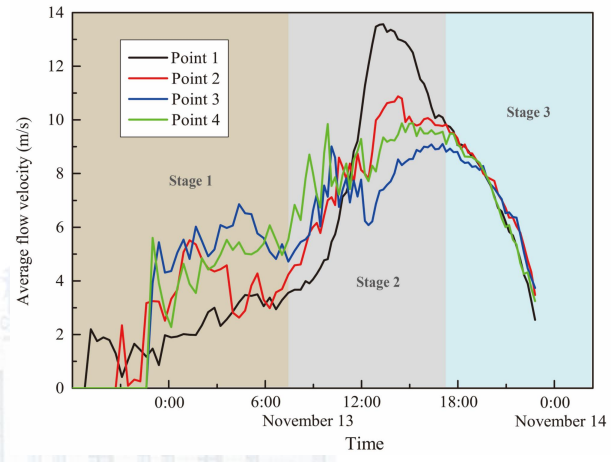
Breach hydrograph



Free surface elevation

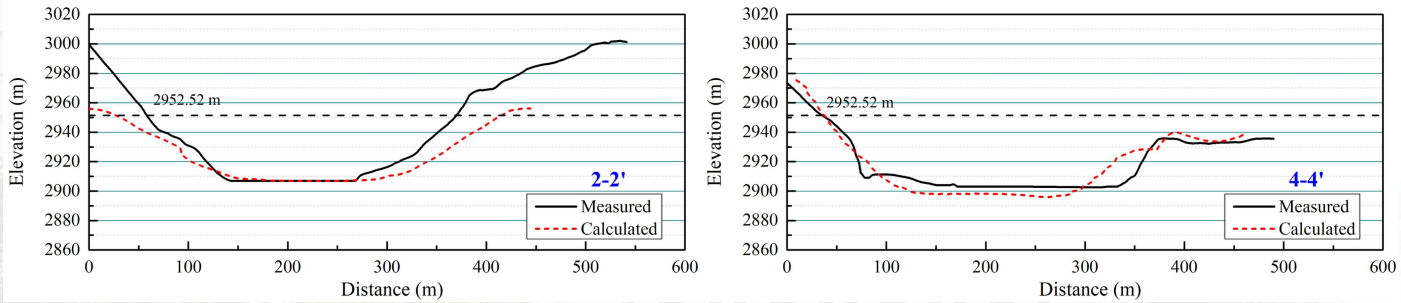


Flow depth



Average flow velocity

The model can reproduce the breach process, and the breach hydrograph is basically consistent with the measured value. The relative errors of the main output breach parameters are all within ± 10 %.



Comparison of the final breach

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4 Conclusions

- There are many influencing factors significantly affect the breach process of overtopping-induced landslide dam.
- Due to the survey data for the analysis of landslide dam breaching, the present numerical model can perform good performance in simulating the whole breach process considering the actual topography.
- In addition, the validity of simulated results is verified through the comparison with the measured data.
- It is expected that the work conducted in this study can give a contribution to the understanding of breach mechanism of landslide dam, and provide a satisfactory guidance for the emergency disposal.

Thank you for your listening !

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