河道凸岸地形對土石流運移影響以花縣 DF024 為例

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摘　　要　113 年 4 月 3 日花蓮大地震造成大量崩塌發生，共計新增崩塌地 1942 處，面積 1521 公頃，以秀林鄉新生崩塌面積 1481.05 公頃最為嚴重。本研究以花縣 DF024 土石流為研究區域，於今年 6 月 21 日因土石流湧浪災害致火車出軌，其集水區新生崩塌面積達 31.73 公頃、崩塌率達 6.0%，後續受降雨再度誘發土石災害可能性極大。再者，由於河道凸岸地形對於水流及土砂運移等造成影響，為探討凸岸地形對土砂運動及構造物可能造成的威脅，本研究以 Hyper KANAKO 2D 土石流模式進行模擬評估。模擬結果顯示受凸岸地形影響，使水流集中於左岸側並造成淤積且衝擊橋台，同時土石流數值模式可協助評估重現期 50 年設計事件對工程構造物之致災性，有效模擬土石流土砂流動影響範圍，俾作為相關單位防災應變決策參據。

關鍵詞：凸岸地形、土石流、設計事件、Hyper KANAKO 2D

The Influence of the Convex Bank on Debris Flow Movement

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Abstract　The Hualien Earthquake resulted in numerous landslides on April 3, 2024. Satellite images identified 1,942 new landslides, covering a total area of $15.2*10^6$ m^2. The Hsiulin district was particularly affected, with new landslides covering an area of $14.81*10^6$ m^2. This research takes Hualien DF024 as the study area, where the train derailed by debris flow on June 21, 2024. A new landslide area of $31.73*10^4$ m^2 was identified and the ratio accounting for 6% of the total catchment area, could trigger debris flows by further rainfall events. The convex bank effects can influence the debris flow path, which could damage engineering structures. The Hyper KANAKO 2D is applied to investigate the influence of channel convex bank on flow patterns and sediment transport processes. The focus is on the potential risks to bridge approaches due to excessive sediment deposition. The results indicate that Hyper KANAKO 2D can assist in assessing the impact on engineering structures under 50-year design event conditions. The numerical model can identify the area impacted by debris flows and provide valuable information for the authorities.

Keywords: Convex bank, Debris flow, Design event, Hyper KANAKO 2D

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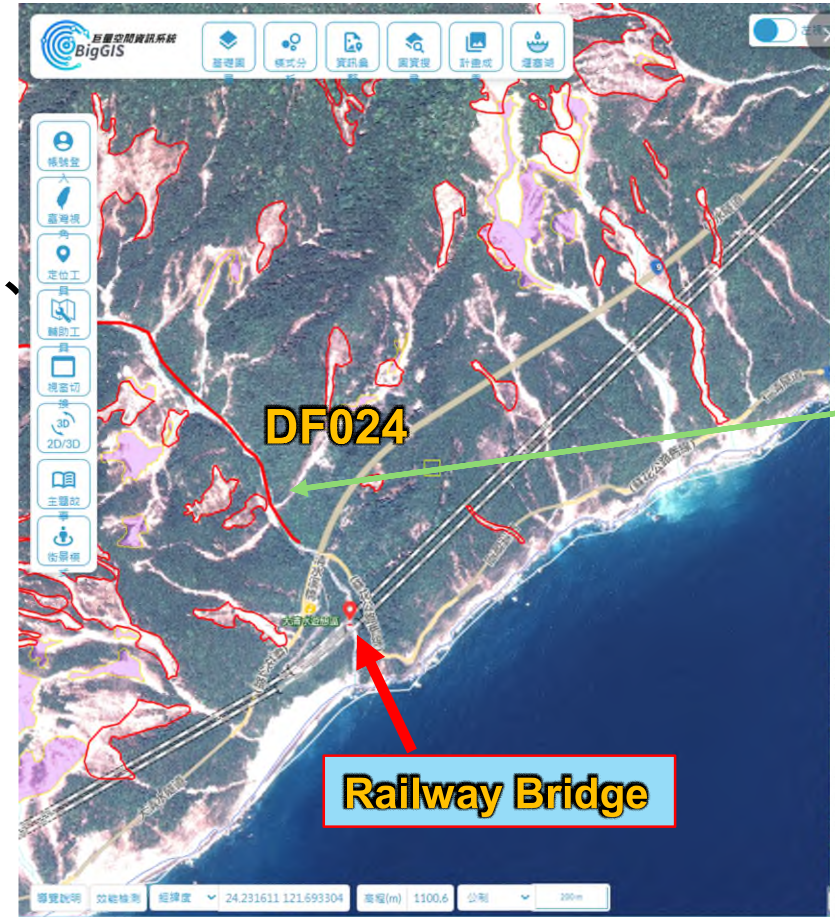
Outline

- □ The Hualien Earthquake Event
- □ Study Area
- □ Event Narrative
- □ Numerical Simulation
- □ Conclusions

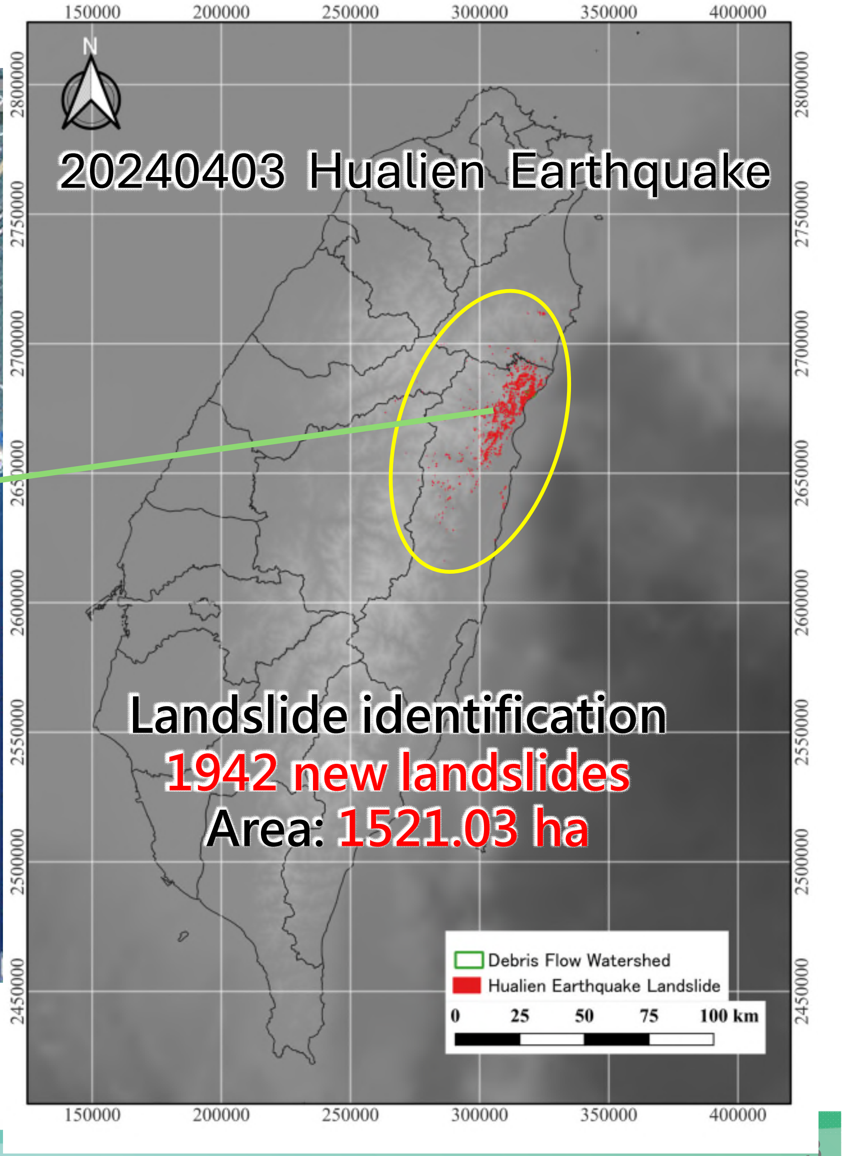
The Hualien Earthquake Event

Landslide Identification

- **Hualien County (HSIU-LIN、WAN-RONG、FENG-PIN、SHOU-FENG、CHI-AN);**
- **Yilan County (NAN-AO、TA-TUNG、SU-AO);**
- **Nantou County (JEN-AI);**
- **Taichung City (HE-PING)**
- **1,942 New Landslides**
- **Landslide Area: 1521.03 ha**



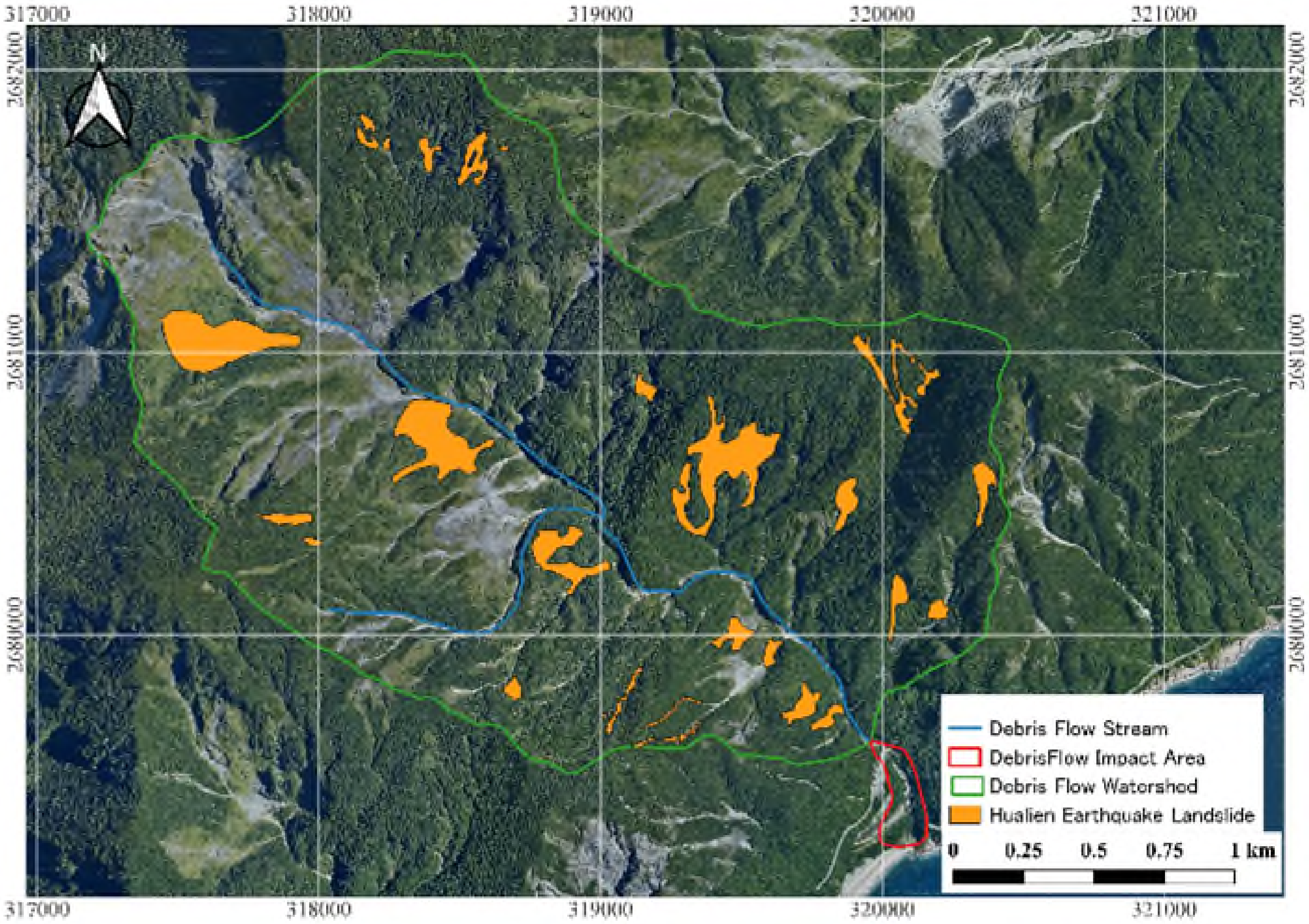
Hualien Debris Flow No.024



Study Area

Hualien Debris Flow No.024

- Location: Hsiulin district, Hualien County
- Debris Flow Catchment Area 5.29 km^2
- Debris Flow Impact Area: 43.9 ha
- 25 New Landslides
- New Landslide Area: 31.7 ha
- New Landslide ratio: 6%
- Average slope: 50%



Hualien Daqingshuishi Creek (DF024)

Event Narrative

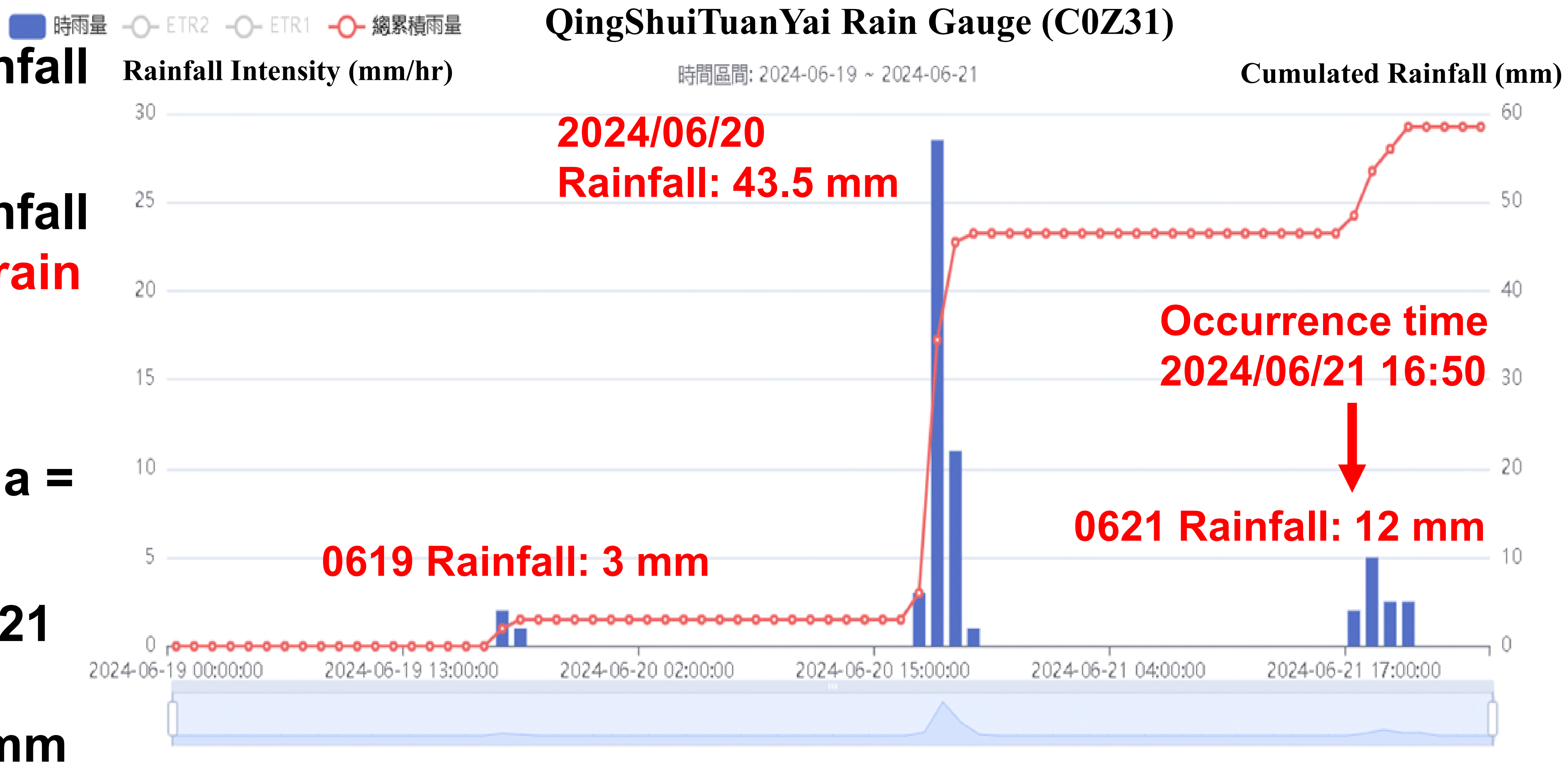
2024/06/21

- **Taiwan Express Train Derailment**
- **Debris Flow outburst:**
  - 2024/06/21 16:30
- **Train Derailment**
  - 2024/06/21 16:50
- **Location: The Hualien Daqingshuishi Creek**
- **Casualty: 9 People Injured and train damage**

Rainfall

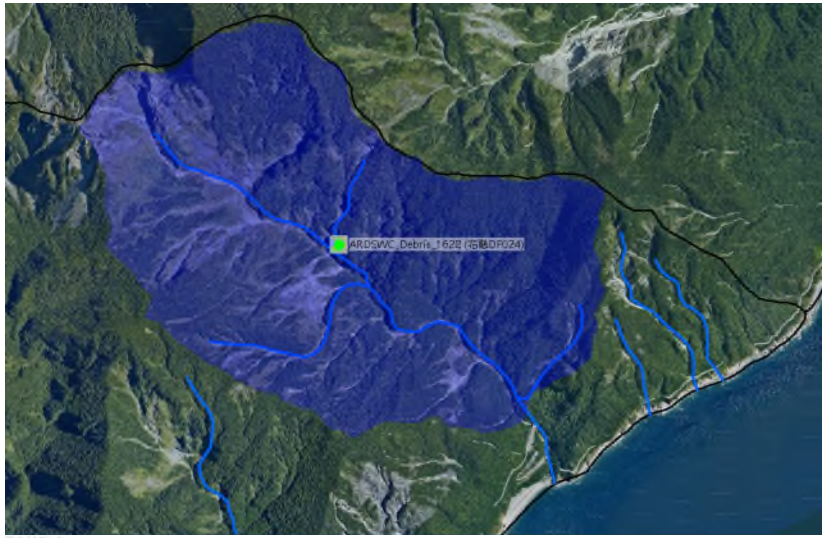
Gauge	District	10 mins	1hour	3hour	6hour	12hour	24hour
大農 (C1T97)	KuangFu	-	-	-	12.0	12.0	12.5
清水斷崖 (C0Z31)	HsiuLin	-	-	5.0	12.0	12.0	12.0

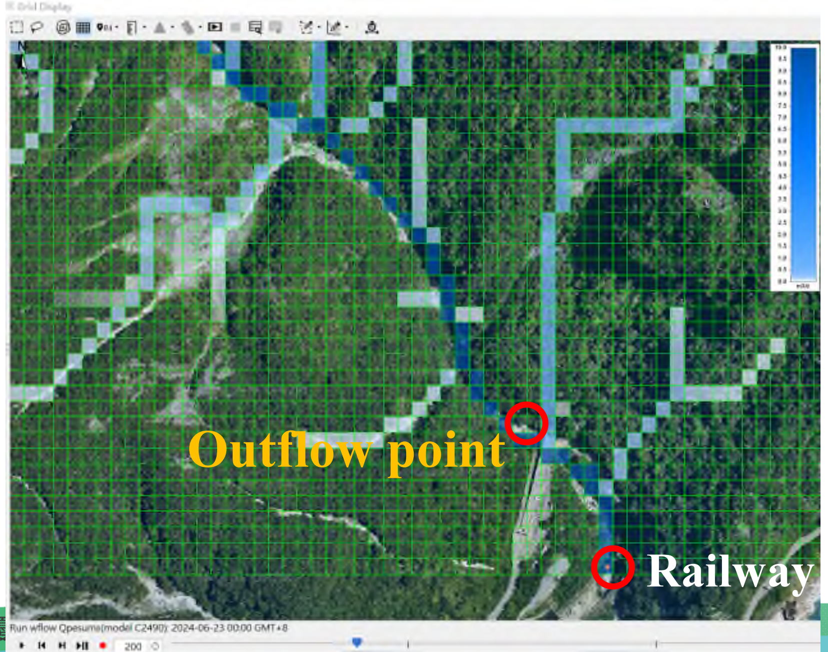
- ✓ 2024/06/20 Rainfall = 43.5 mm
- ✓ 2024/06/21 Rainfall = 12 mm and Train derail at 16:50
- ✓ Debris Flow Warning Criteria = 300mm
- ✓ 20240619 to 0621 Cumulated Rainfall = 58.5mm

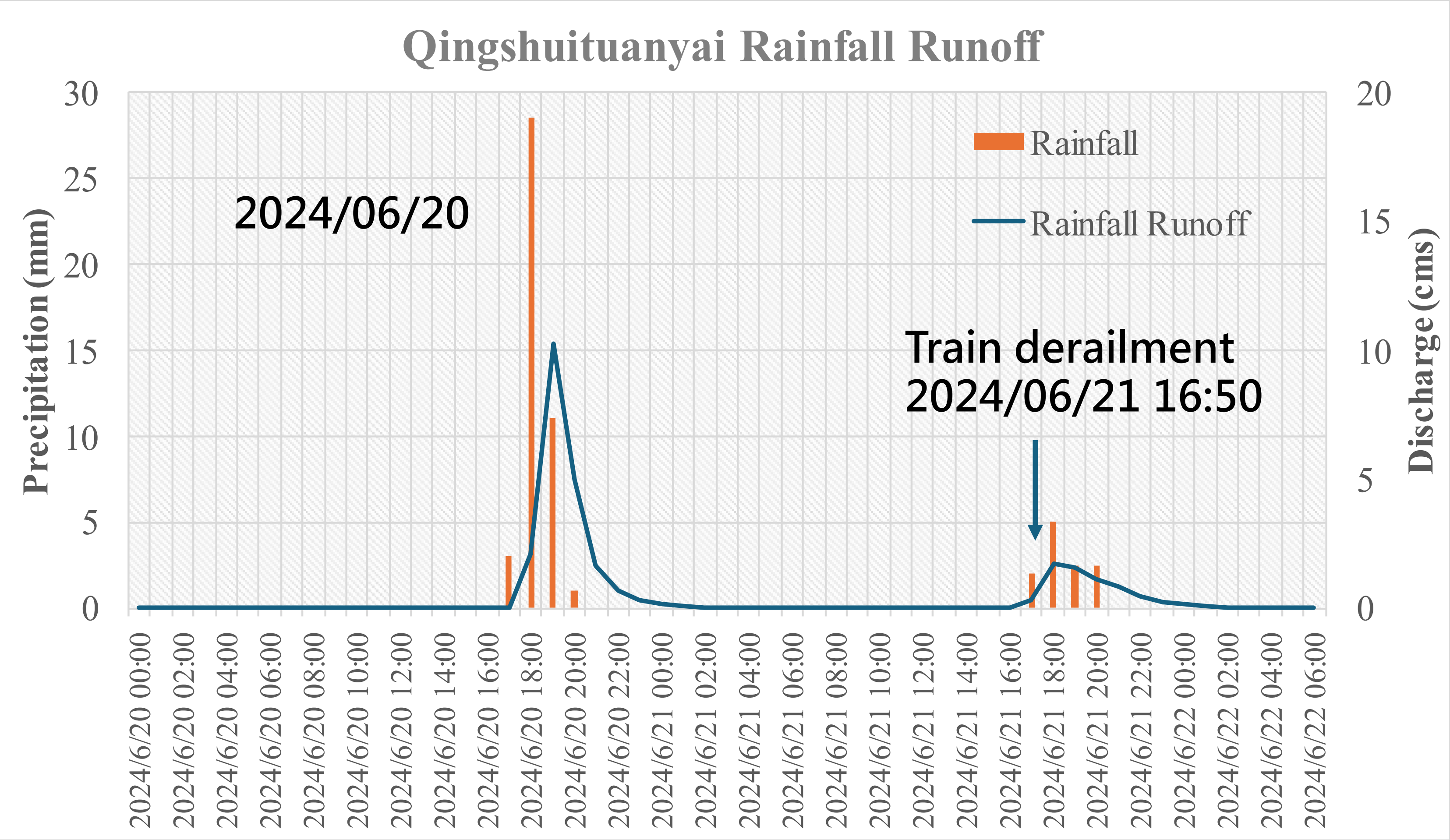


Rainfall Runoff

Based on rainfall data and Wflow rainfall runoff model, the **maximum rainfall was 28.5 mm** on June 20, and estimated **river flow was 10.24 cms.**





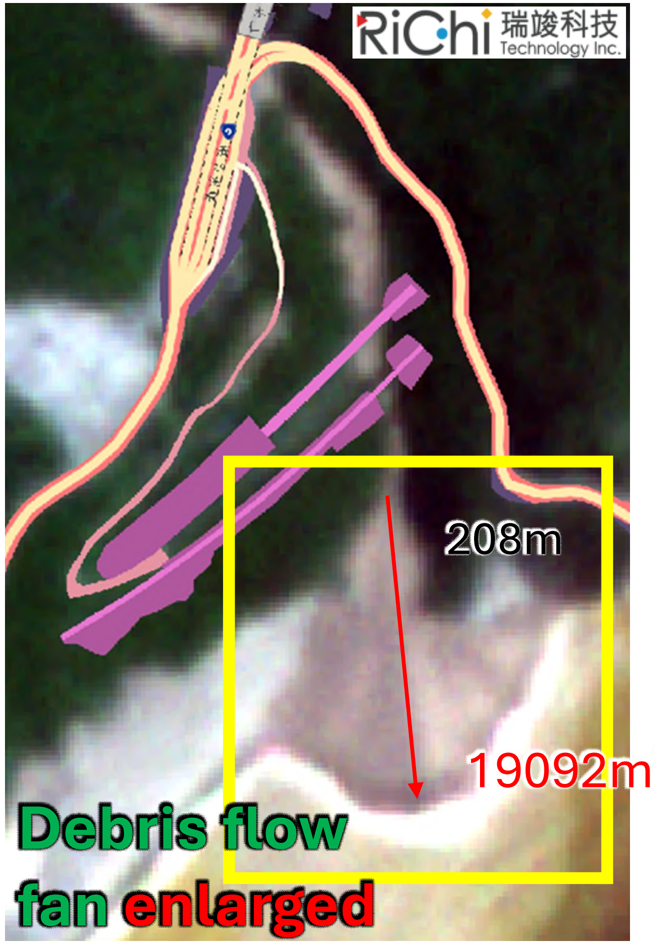


Satellite Image Comparison

- ✓ The 1st wave of debris flow occurred on June 20 at 17:00~20:00 ;
- ✓ The 2nd wave of debris flow occurred on June 21 at 16:30

2024/06/20 10:37 Planet

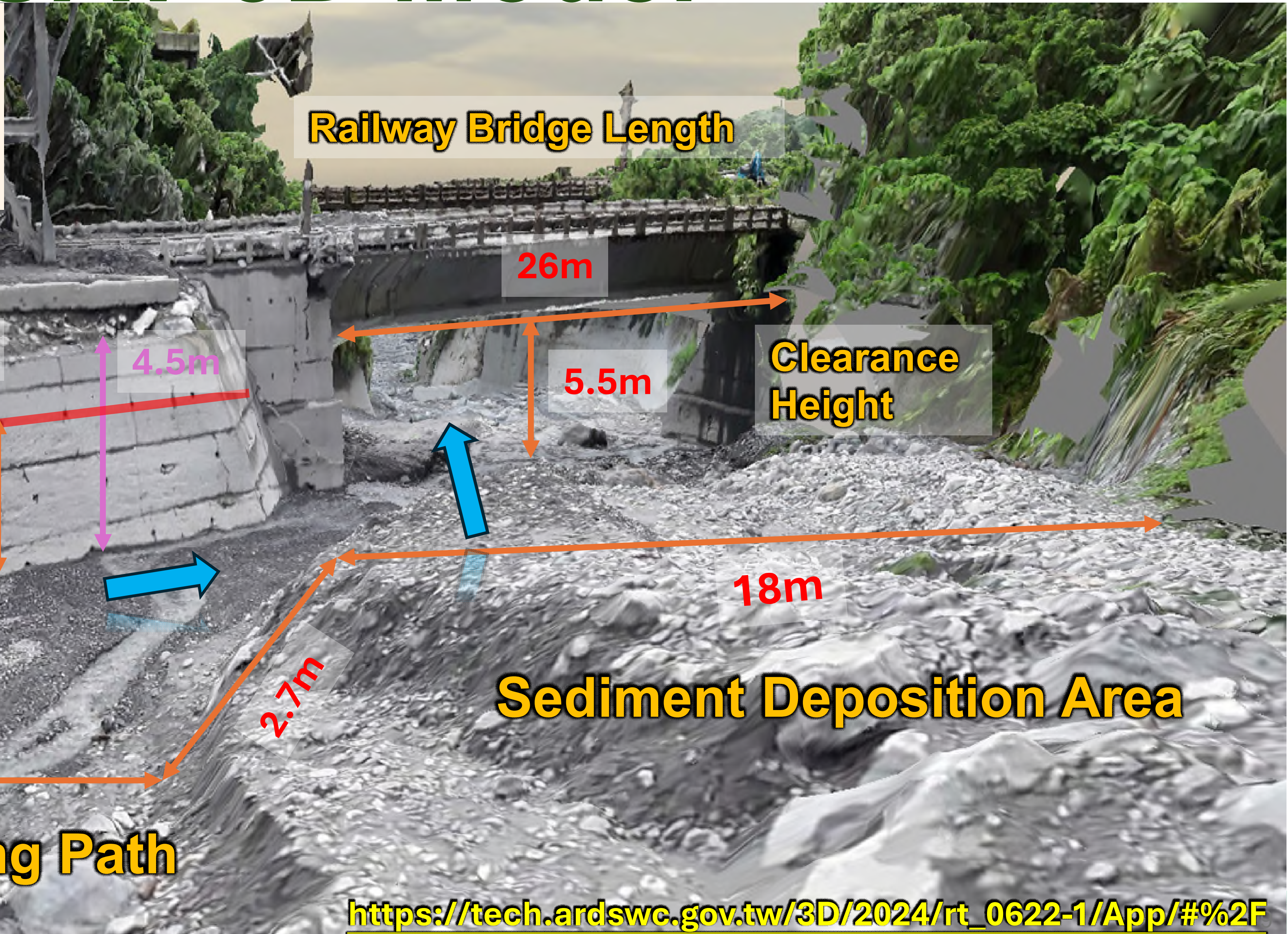
2024/06/21 10:02 Planet



2024/06/22 09:50 Planet

UAV-3D Model

Bridge Approach height 4.5 m
Bridge clearance height 5.5 m
Railway Bridge length 26 m
Flooding mark height 3 m

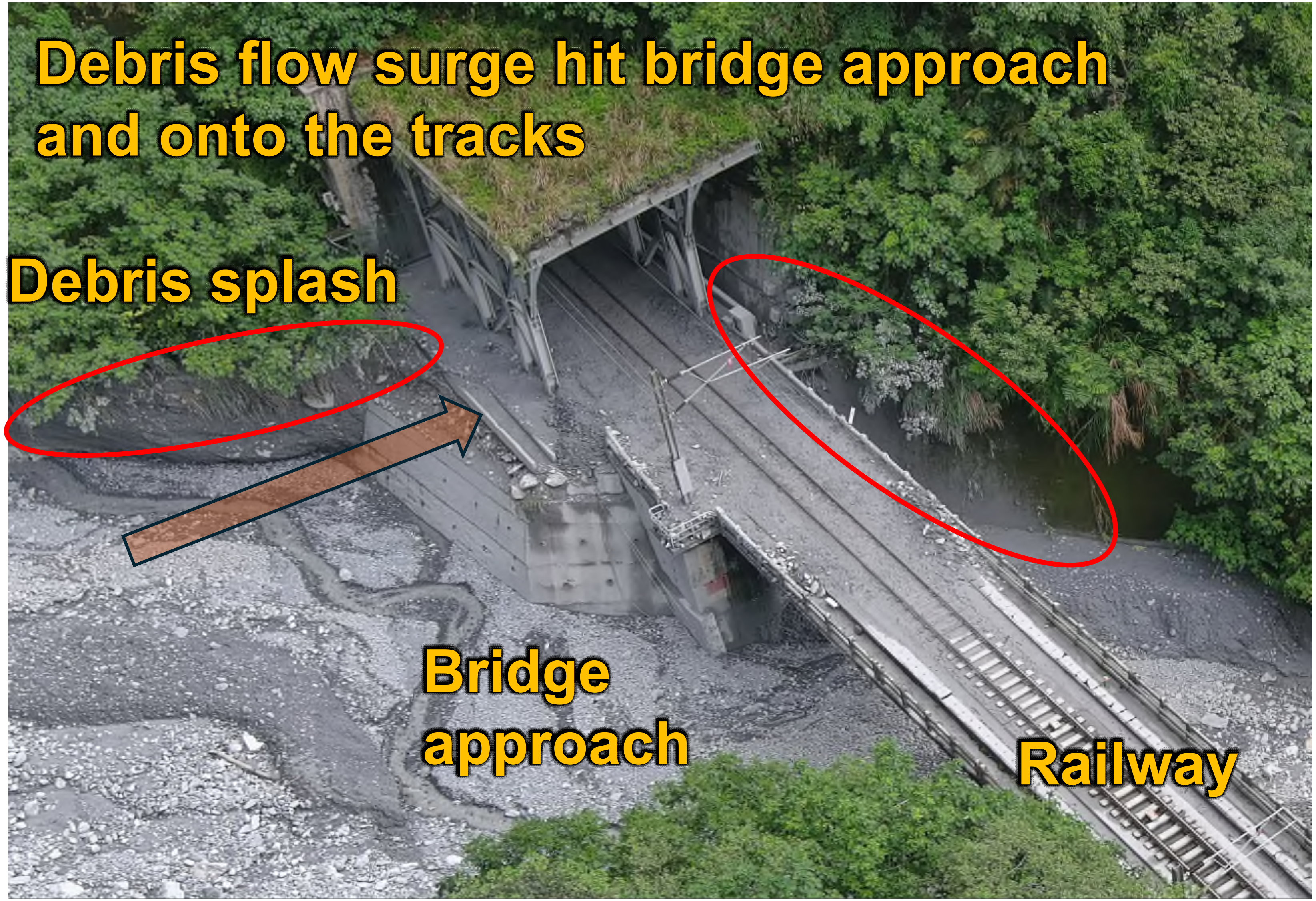


Debris Flow Event

影片來源：台鐵、鏡新聞

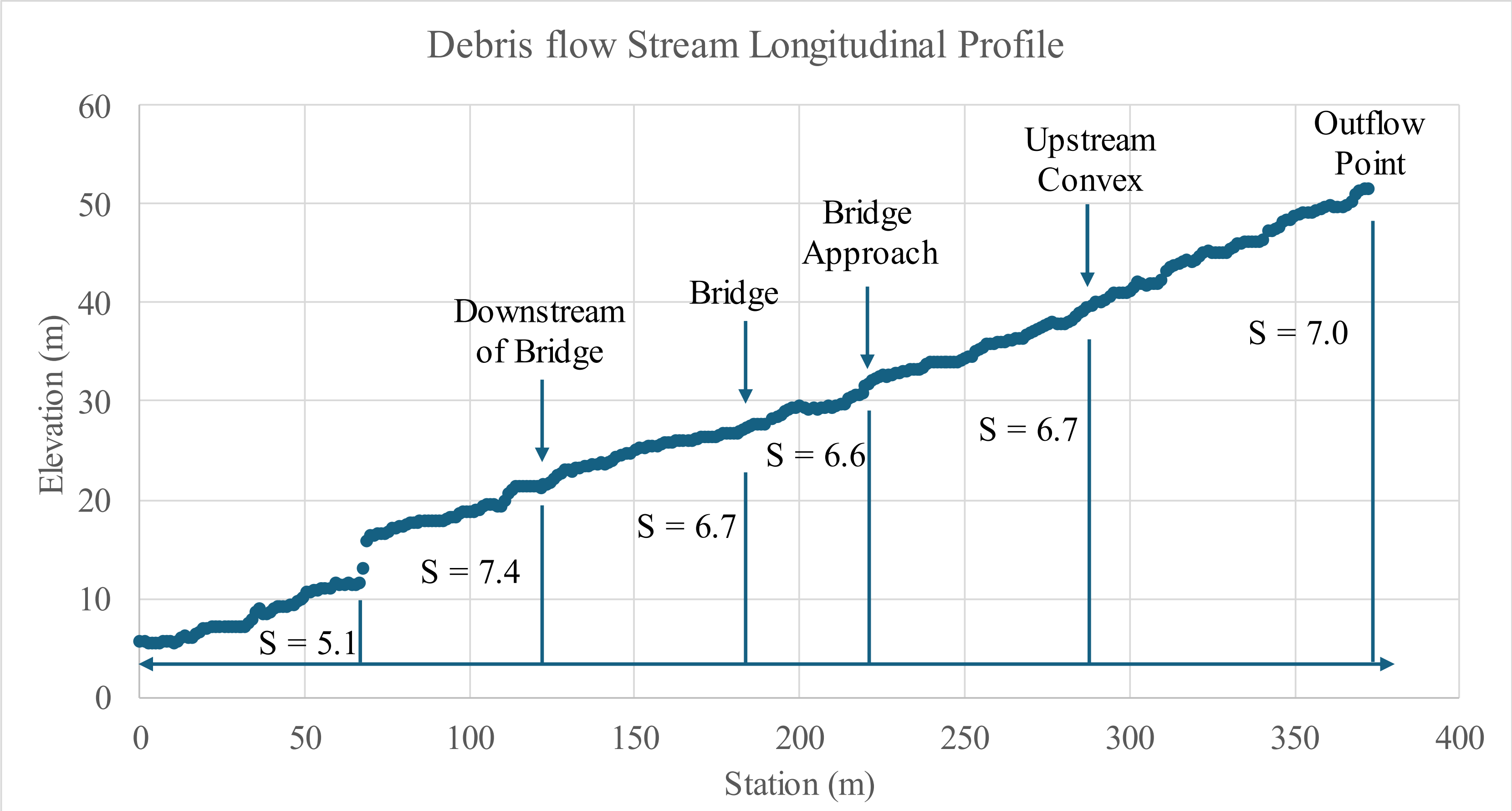
Field Survey Result

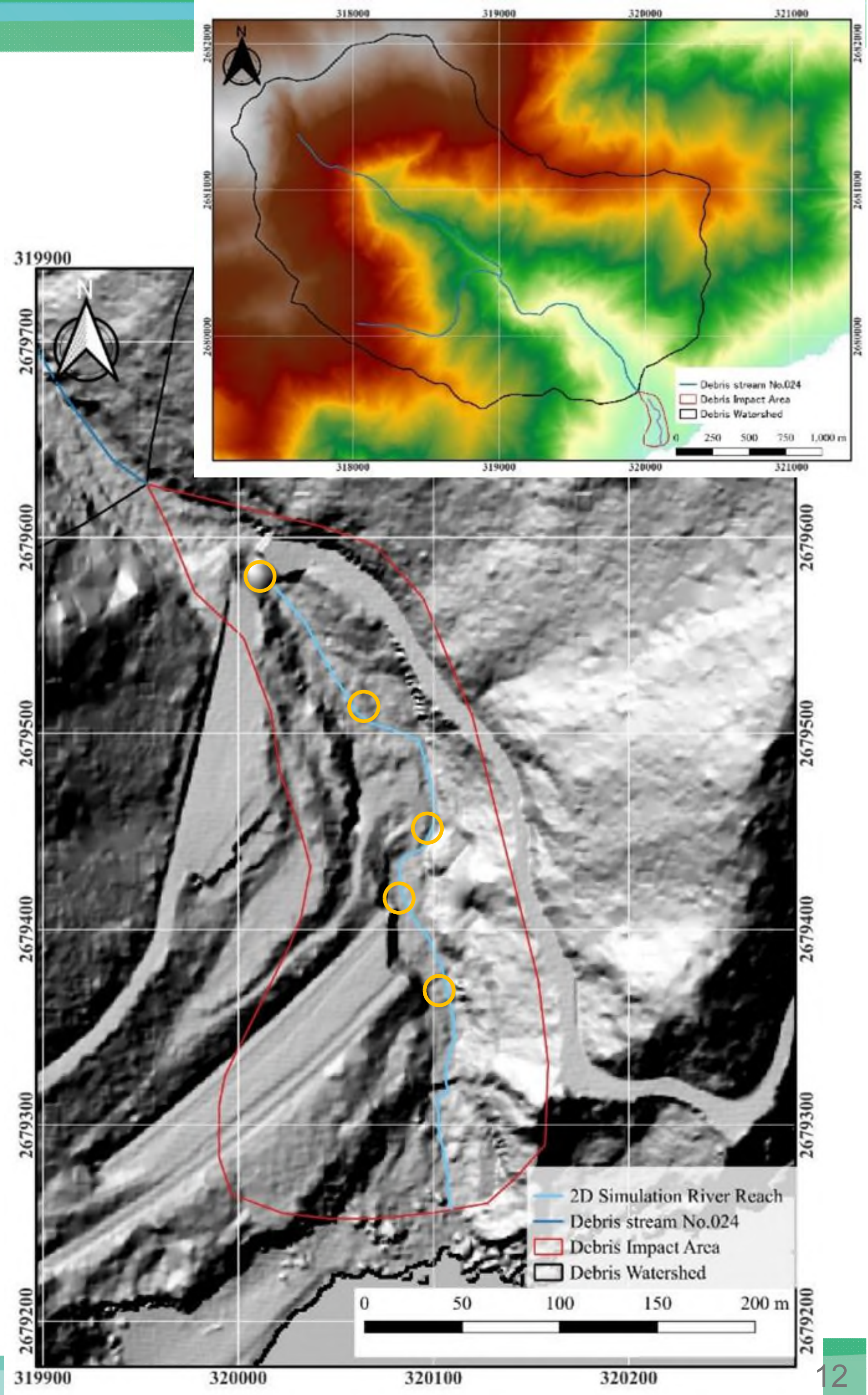
- ✓ The debris splashed on leaves showed that the debris flow had surged onto the tracks.
- ✓ Influenced by the channel curvature the main flow is directed towards the left bank.
- ✓ The debris flow deposited lots of sediment in the riverbed on June 20.
- ✓ The debris flow caused a surge that overtopped the bridge approach on June 21.



Longitudinal Profile

1. The downstream river slope is steep
2. The debris flow has better flowing capacity





Numerical Setup

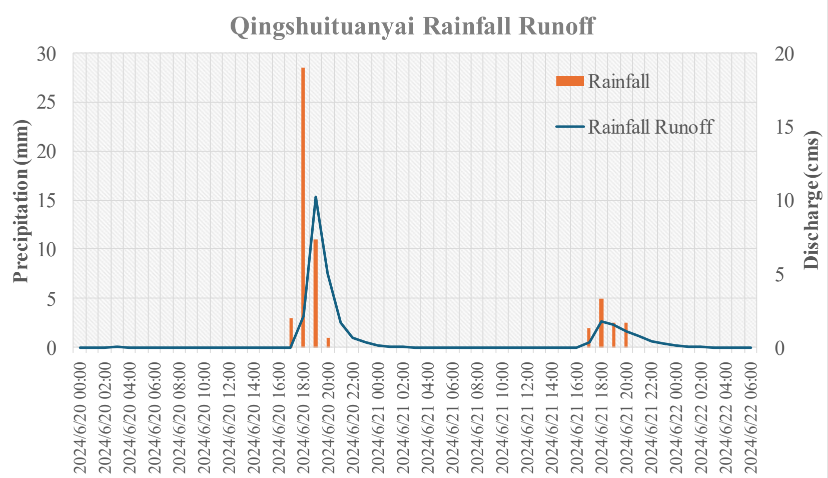
Hydrograph Data：

Time: 18000sec

- Total Cumulated rainfall 43.5 mm
- Max. Rainfall intensity 28 mm/hr

Geometric Data：

- Pre-Event: 2015 DEM (Resolution 1 m*1 m)
- Computation mesh: 2 m
- Post-Event: 2024/06/22 UAV-3D Model



Kanako2D Parameter

Calculation parameters	
Item	Value
Version	2.06
Time interval of calculation(sec)	0.01
Mass density of sediment(kg/m^3) MKS	2650
Mass density of fluide phase[water and mud,silt](kg/m^3) MKS	1000
Gravity acceleration(m/s^2)	9.8
Minimum flow depth(m)	0.01
Concentration of movable bed	0.65
Manning's roughness coefficient	0.03
Coefficient of erosion velocity	0.0007
Coefficient of deposition velocity	0.05
Coefficient of deposition velocity considering inertial force	0.9
Simulation continuance time(sec)	18000
Diameter of material(m)	0.2
pai	3.1415926536
Internal friction angle(deg)	37
Time interval of output hydrograph data(sec)	32
Time interval of output result data(sec)	600
Parameter using in 2D area; inflow direction[muki](deg)	0
inflow center X axis in 2D area[jc]	0
inflow center Y axis in 2D area[jr]	184
Interval of 2D-x calculation points(m)	2
Interval of 2D-y calculation points(m)	2
Minimum depth at the front of debris flow in 2D(m)	0.01
Number of calculation points in 2D-x direction	102
Number of calculation points in 2D-y direction	203
Thickness of the 2D plane unstable sediment(m)	0.00
Side Bank Erosion Velocity	1.00
Side Bank Gradient(deg)	37.00

Numerical Simulation Case

Table - Parameters and values used in the KANAKO-2D					
Case	Qp (cms)	Particle size (m)	Cv [%]	Protection work	Note
Run 1	10	0.1	30	Non	-
Run 2	135	0.1	30	Non	50-year return period
Run 3	135	0.1	30	Riverbed Dredge Half	50-year return period
Run 4	135	0.1	30	Riverbed Dredge All	50-year return period
Run 5	135	0.1	30	Riverbed Dredge + Embankment	50-year return period

Numerical

Run 1

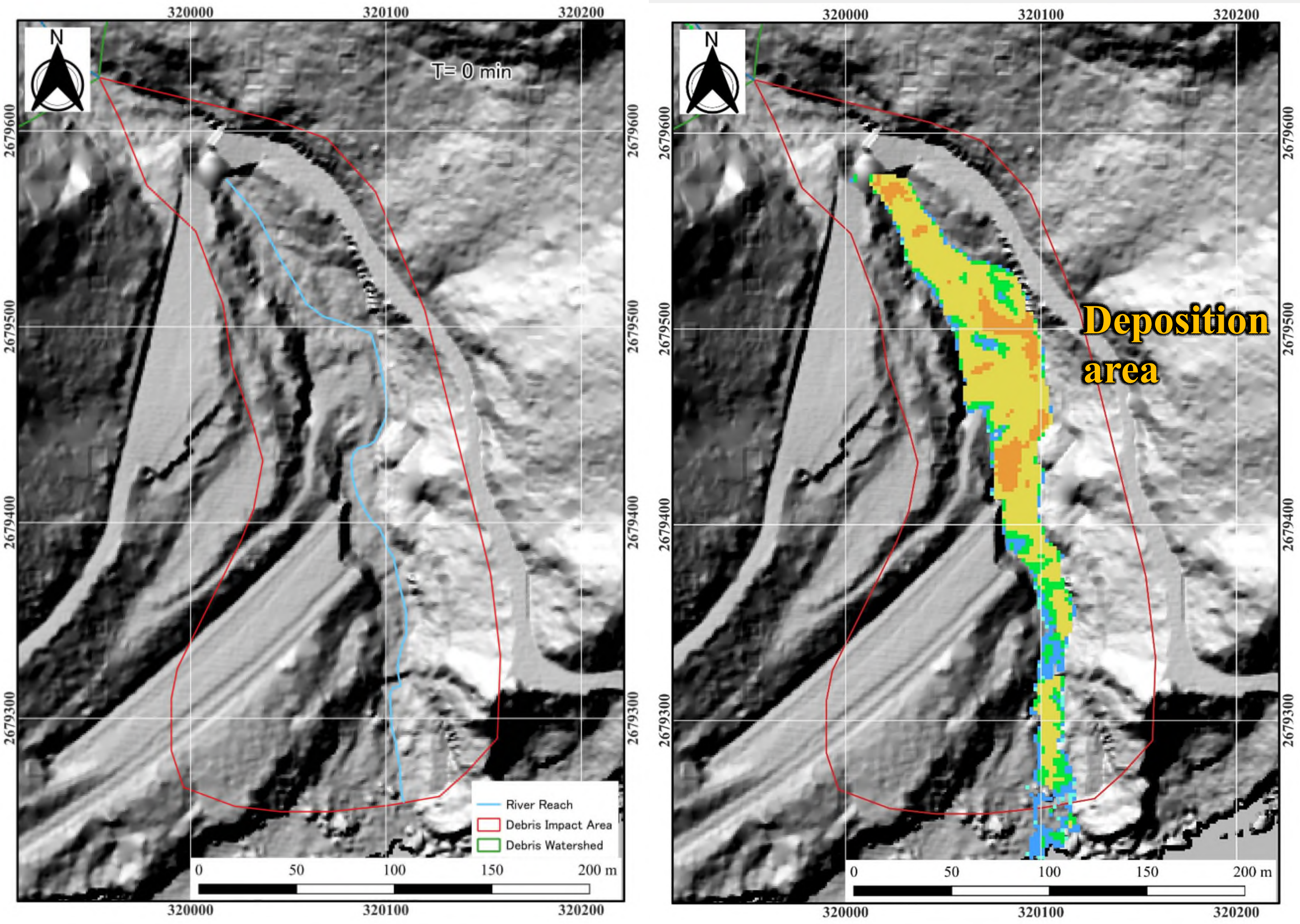
Concentration: 30%

Qpeak: 10.24 cms

Geometric Mesh: 2m

The river bend influence the **flow path toward left bank.**

Debris mostly deposited in the upper part of **convex bank and bridge.**



Numerical

Run 2

Concentration: 30%

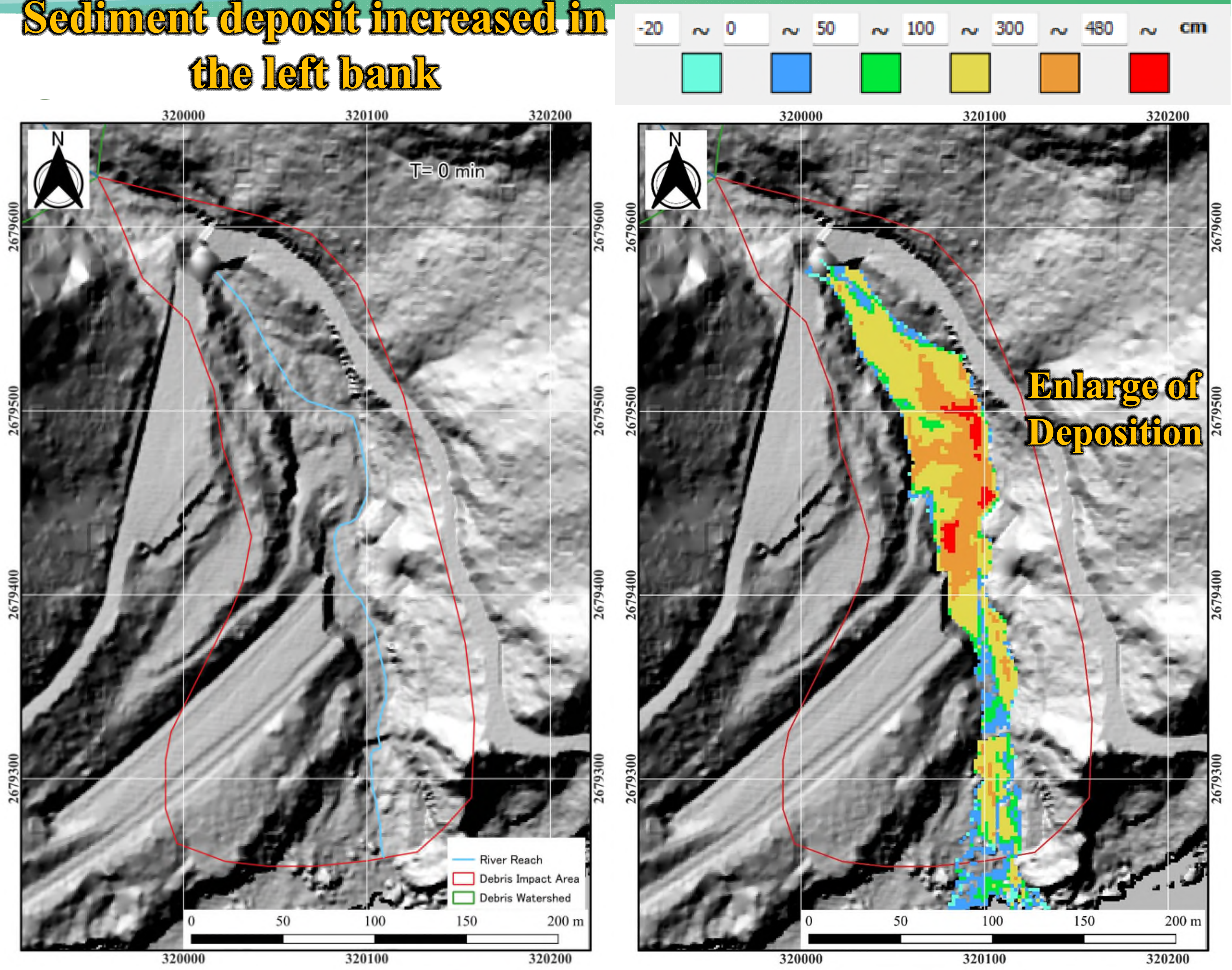
Qpeak: 135 cms

Geometric Mesh: 2m

The river bend influence the flow path toward left bank.

Bridge contraction effect influence debris mostly deposited in the upper part of bridge.

Sediment deposit increased in the left bank



Numerical

Run 3

Concentration: 30%

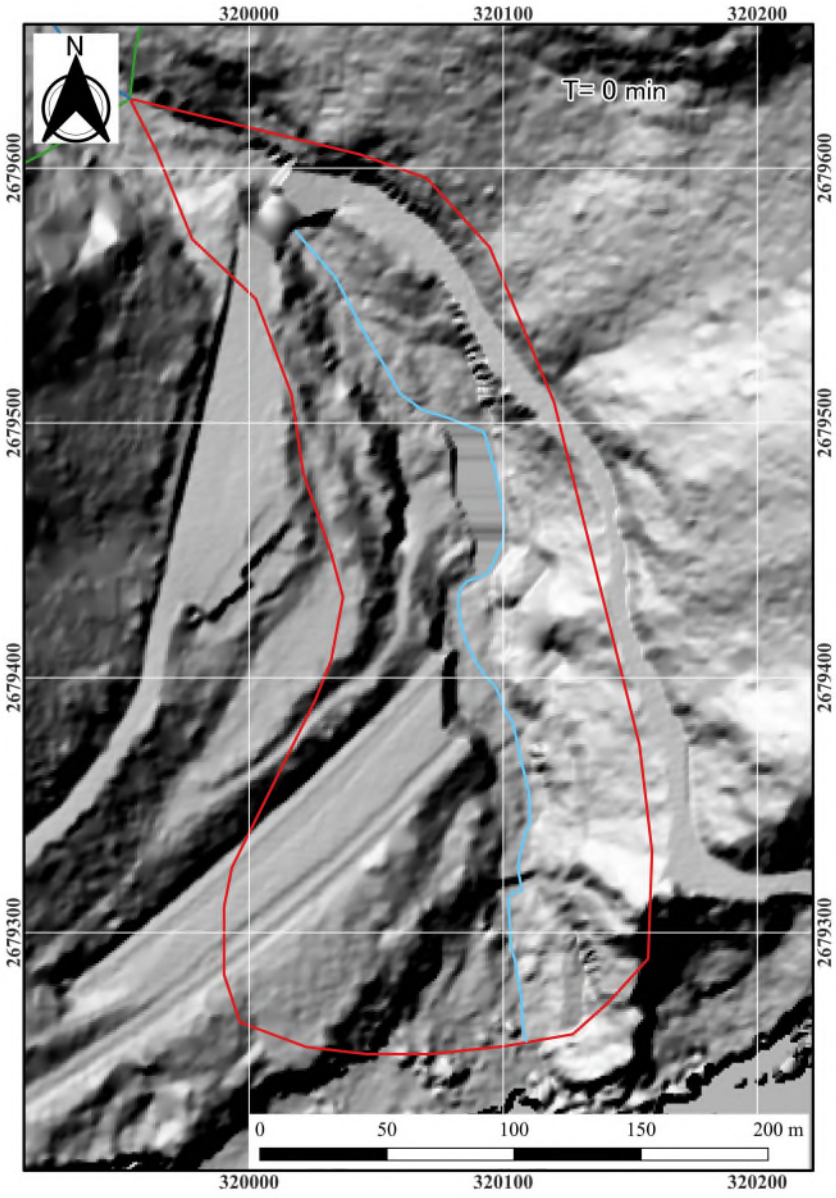
Qpeak: 135 cms

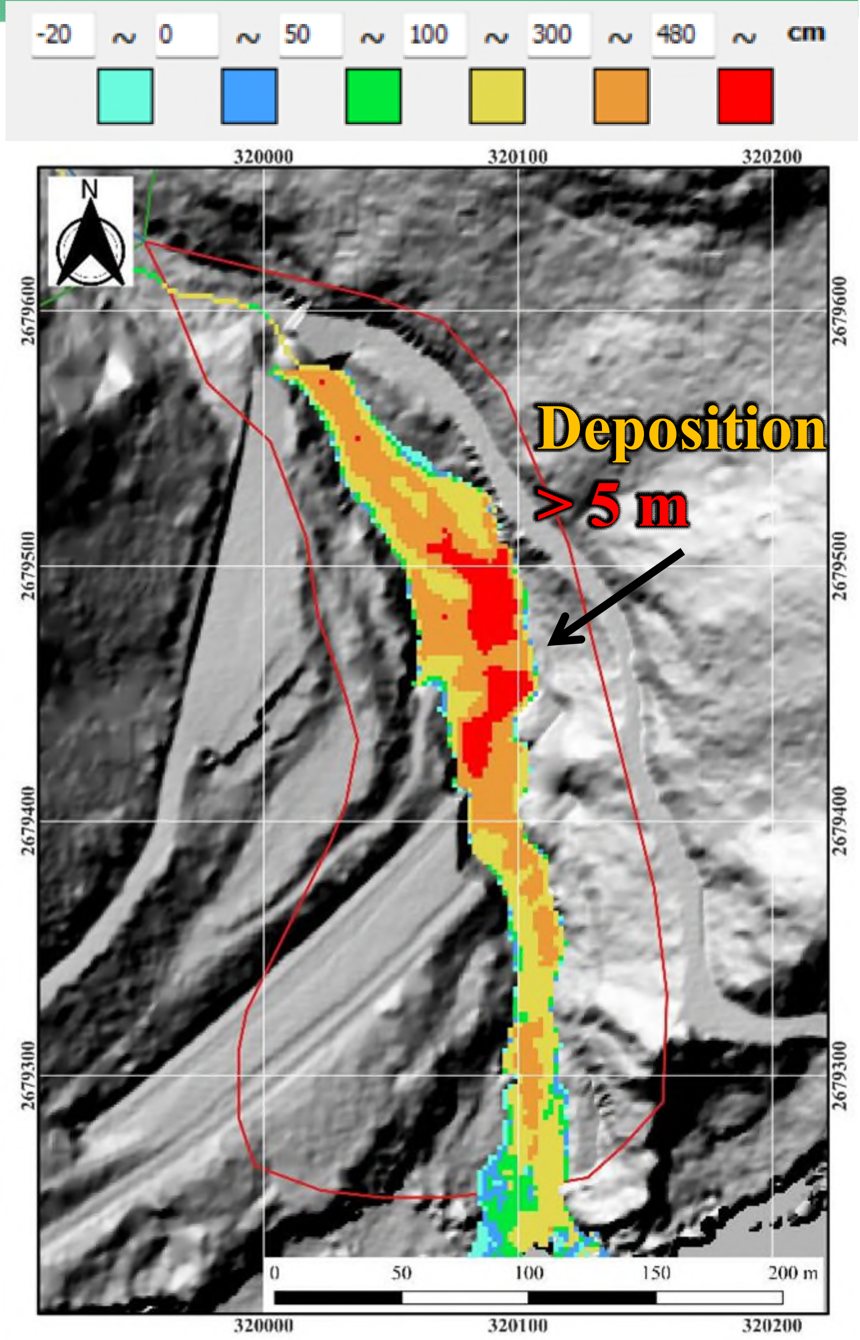
Geometric Mesh: 2m

Condition : dredge half

The most deposited Larger than 5 m.

The debris flow could be rush onto the railway.





Numerical

Run 4

Concentration: 30%

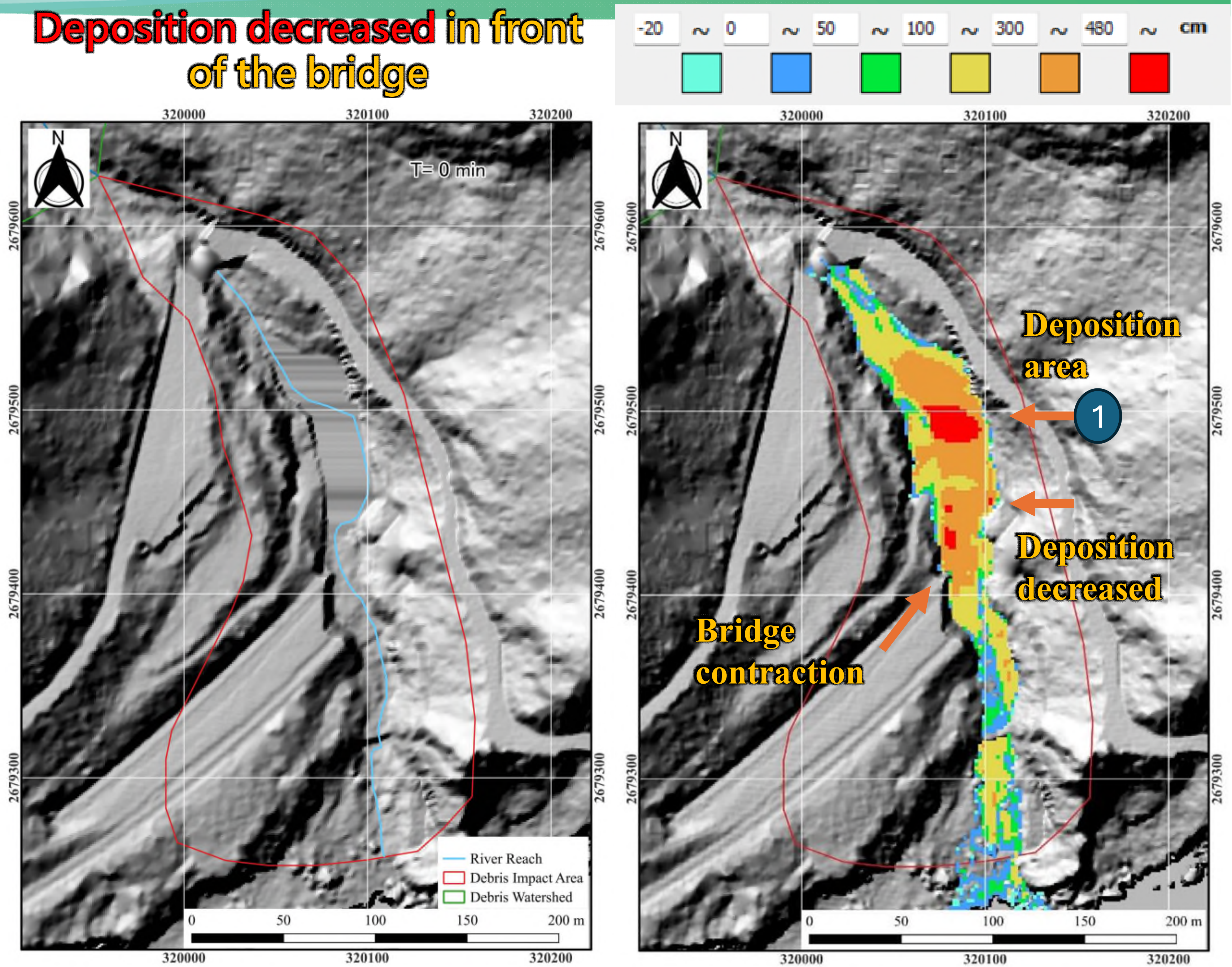
Qpeak: 135 cms

Geometric Mesh: 2m

Condition : dredge all

The debris mostly deposited in original convex bank and reduce the railway impact.

Deposition decreased in front of the bridge



Numerical

The debris deposited in front of bridge

Run 5

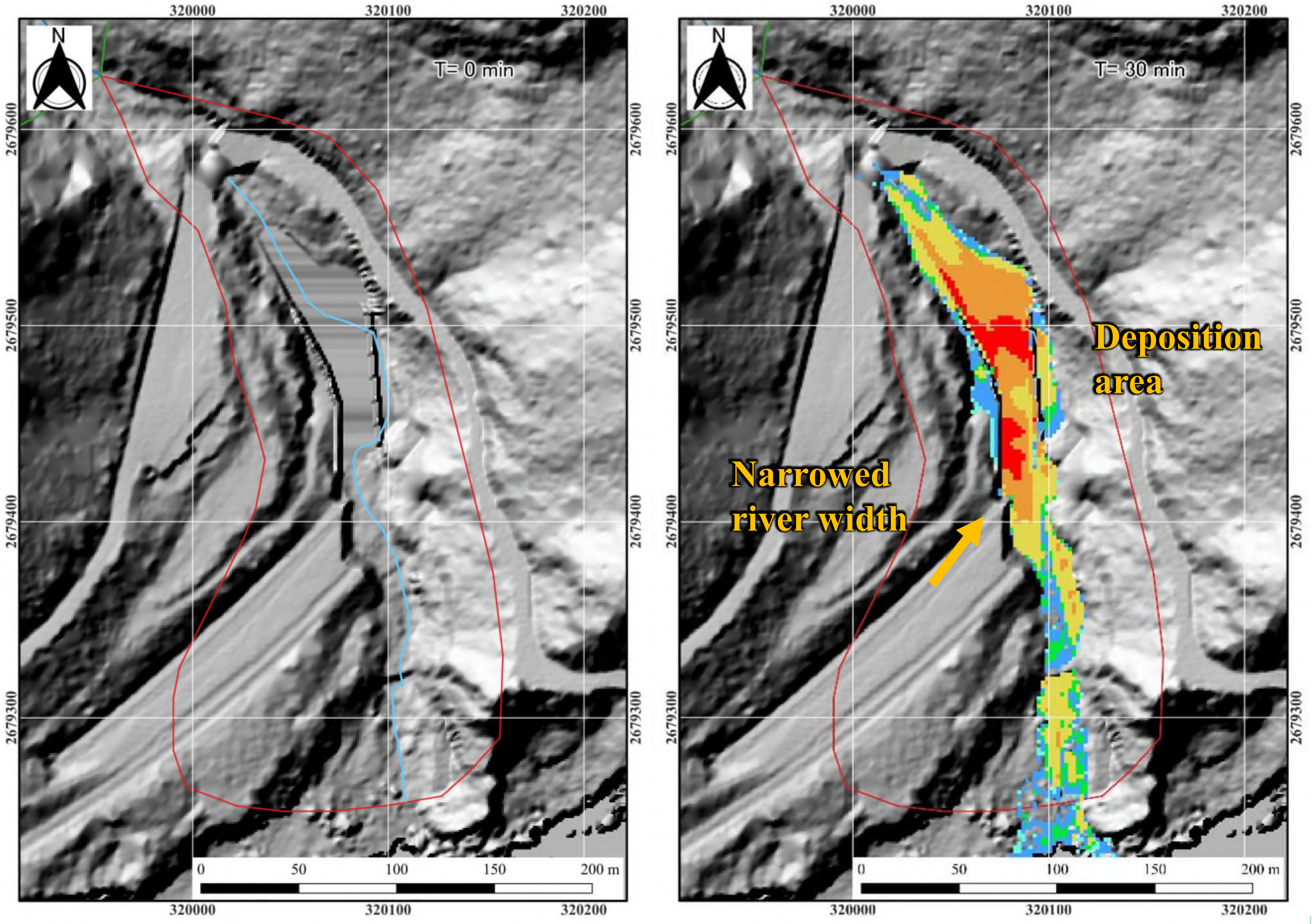
Concentration: 30%

Qpeak: 135 cms

Geometric Mesh: 2m

Condition : embankment

The embankment narrow river width to accelerate flow velocity may be not a good solution.



Conclusions

1. This case showed that large earthquakes **significantly lowered the rainfall threshold** required for **initial debris flows**.
2. The debris flow is primarily **along the left river bank** due to the **river bend characteristics**.
3. The sediment was **preferentially deposited upstream of the bridge** due to the **narrowed flow width.**
4. The engineering measures can reduce the debris flow impact and need **long-term maintenance**.
5. Further research is needed to address the problems of **narrowed flow width**, **river bend characteristics**, and **concave erosion**.

Discussion - Further Research

1. The upland area has **many new landslides** which may cause sediment-related disasters in the following years.
2. The **hyper-concentrated flow** may adjust the debris flow **deposits/erodes with flowing sediments**.
3. The convex bank forced the **flow path along the left bank** and more sediment erosion on the outer bank.
4. The **sediment transport capacity** is reduced due to the **narrowed flow width** of the bridge resulting in sediment deposits.

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Thank you for your listening

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