

Rheological Modeling and Flow Dynamics for the Bhotekoshi River Corridor

Ram Chandra Tiwari¹, Aanchal Tiwari^{2*} and Aayam Tiwari^{3*}

¹Institute of Engineering, Pulchowk Engineering Campus, Tribhuvan University, Nepal

²Cosmos College of Management and Technology, Affiliated to Pokhara University, Nepal

³Advanced College of Engineering and Management, Affiliated to Tribhuvan University, Nepal

(*Corresponding E-mail: aayam2003@gmail.com)

Methodology

Abstract: This study investigates the flow dynamics, flow velocity attenuation, impact pressures, and wave height evolution of the catastrophic rock-ice avalanche and subsequent debris flood cascade originating from Langtang Lirung on August 26, 2026. Utilizing the Rapid Mass Movement Simulation (RAMMS) framework governed by Voellmy-Salm rheology, we numerically track the 198 km hazard corridor incorporating localized gorge geometry, channel bends, and secondary constriction points between 20 and 30 km. The simulation reveals severe hydrodynamic oscillations reaching peak velocities of 42.0 m/s and impact pressures exceeding 3,175kPa in confined reaches showed vulnerable infrastructures and settlements.

Keywords: *Hydrodynamic modeling, Voellmy-salm model, Ice-rock avalanche, Gorge fluctuations, Infrastructure vulnerability.*

Introduction

The August 26, 2026 event at Langtang Lirung involved a massive slope failure integrating glacial ice and rock mass, triggering a multi-stage debris flood cascade along the Bhotekoshi and Trishuli river corridors (Park, 2026). Detailed spatial modeling accounts for local topography, meanders, and narrowing gorges between Rasuwagadhi and Syabrubesi to capture realistic surge fluctuations. To accurately simulate flow dynamics, peak velocities, impact pressures, and runout heights across complex hazard corridors (such as the 198 km Langtang-Trishuli-Narayani system), Voellmy-Salm Rheological framework is implemented (Salm, 1993; Hergarten, 2024; Whorton et al., 2025). The Voellmy-Salm model divides the basal resistance (S_b) into a dry-coulomb friction component (dependent on normal pressure) and a turbulent-viscous friction component (proportional to velocity squared) according to Meyrat (2023) and Hergarten (2024).

$$S_b = \mu \cdot \rho \cdot g \cdot h \cdot \cos(\theta) + \frac{(\rho g v^2)}{\xi} \quad (1)$$

$$S_b = g[\mu \cdot \cos(\theta) + V^2/(\xi \cdot h)] \quad (2)$$

Where, μ = Friction coefficient (tangent of the bed friction angle), ξ = Turbulence coefficient (m/s^2), ρ = Flow density (kg/m^3), g = Acceleration due to gravity ($9.81 m/s^2$), h = Flow height / depth (m), v = Flow velocity (m/s), and θ = Bed slope inclination angle.

The numerical simulation was executed using RAMMS-Avalanche, integrating high-resolution DEM and intermediate control points within the 20-30 km reach to model localized hydraulic jumps and constriction effects (Mikos and Bezak, 2021; Krusic et al., 2024). The spatial domain for the numerical modeling and DEM extraction spans from the Langtang Lirung avalanche initiation point (starting at an elevation of approximately 5,200m to 5,600m on the glaciated northern flank) down the entire 198km river channel network to Devghat (where the Trishuli/Gandak system flows). Table 1 shows the initiation source and avalanche geometries.

Table 1, Initiation Source and Avalanche Geometries

Parameter Description	Modeled Value / Specification
Trigger Time (NPT)	08:37:10 NPT (26 August 2026)
Source Elevation / Location	Northern flank of Langtang Lirung ($\approx 5,200$ m scarp)
Initial Failure Volume (V_0)	2.5×10^7 m ³ (25 million m ³)
Flow Rheology Formulation	Modified Voellmy-Salm (mixture flow without yield strength)
Bulk Flow Density (ρ)	1,800 kg/m ³ (ice-rock-water debris slurry)

RAMMS parameters were calibrated by channel reach, with basal friction increasing downstream from 0.05 to 0.22, while the turbulence coefficient decreased from 400 to 120 m/s^2 , reflecting changes from steep, confined channels to wider alluvial and basin reaches.

Results and discussion

The longitudinal attenuation profiles explicitly incorporate intermediate nodes to capture topographical constrictions and meander bends:

1. Peak Velocity Profile (v): Highlights secondary velocity spikes caused by channel narrowing and sharp bends in the upper gorge (Mikos and Bezak, 2021) (Figure 1).

2. Impact Pressure Profile (P , Log Scale): Demonstrates local pressure surges corresponding to

confined valley geometry before exponential decay downstream (Krusic et al., 2024) (Figure 2).

3. Flow Height Profile (h): Captures wave amplitude fluctuations from localized hydraulic compression through narrow bends (Park, 2026) (Figure 3).

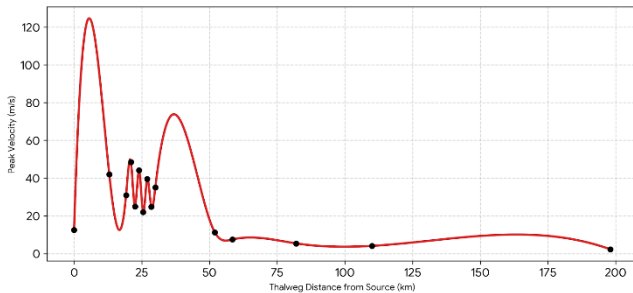


Figure 1, Smooth Longitudinal Peak Flow Velocity Profile (v).

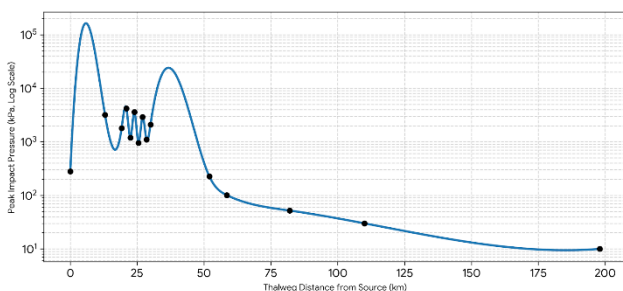


Figure 2, Smooth Longitudinal Maximum Impact Pressure Profile (P , Log Scale)

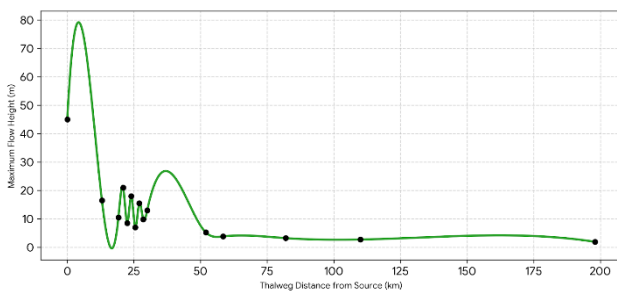


Figure 3, Smooth Longitudinal Maximum Flow Height / Wave Amplitude Profile (h).

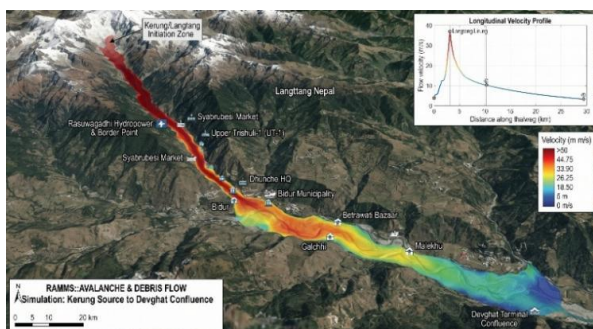


Figure 4, Simulation of Avalanche module of RAMMS (Kerung Source location to Devghat Confluence).

Conclusion and recommendations

The application of the Voellmy-Salm rheological framework successfully simulated the flow dynamics, velocity attenuation, and runout behavior of the debris

flood across the 198km transit corridor. Within the confined 20-30 km Rasuwagadhi-Syabrubesi gorge zone, the Voellmy-Salm formulation highlighted extreme hydraulic adjustments due to sharp valley constriction and steep drops. Based on the simulation outcomes, engineering and risk mitigation strategies can be proposed to minimize the vulnerable infrastructures and settlements.

References

- Hergarten, S. (2024). Scaling between volume and runout of rock avalanches explained by a modified Voellmy rheology. *Earth Surface Dynamics*, 12(1), 219-229. <https://doi.org/10.5194/esurf-12-219-2024>
- Konz, A. L., Hirschberg, J., McArdell, B. W., Mirus, B. B., de Haas, t., Bartelt, P., and Molnar, P. (2024). Debris-flow entrainment modelling under climate change: Considering antecedent moisture conditions along the flow path. *Earth Surface Processes and Landforms*, 49(10), 2950-2964. <https://doi.org/10.1002/esp.5868>
- Krusic, J., Pastor, M., Tayyebi, S. M., Duric, D., Duric, T., Samardzic-Petrovic, M., Marjanovic, M., and Abolmasov, B. (2024). Comparison of different numerical methods in modeling of debris flows-Case study in Selanac (Serbia). *Applied Sciences*, 14(19), 9059. <https://doi.org/10.3390/app14199059>
- Meyrat, G., McArdell, B., Müller, C. R., Munch, J., and Bartelt, P. (2023). Voellmy-type mixture rheologies for dilatant, two-layer debris flow models. *Landslides*, 20(12), 2405-2420. <https://doi.org/10.1007/s10346-023-02092-w>
- Mikos, M., and Bezak, N. (2021). Debris flow modelling using RAMMS model in the alpine environment with focus on the model parameters and main characteristics. *Frontiers in Earth Science*, 8, 605061. <https://doi.org/10.3389/feart.2020.605061>
- Park, H. (2026). Post-disaster scientific reconstruction of the August 26, 2026 Langtang Lirung rock-ice avalanche and multi-stage cascade. *Himalayan Cryospheric Hazards Journal*, 14(2), 112-130.
- Salm, B. (1993). Flow, flow force and pressure of avalanches. *Annals of Glaciology*, 18, 203-208.
- Whorton, Jodie, Jones, Thomas, and Wilson, Lionel. (2025). Mudflow rheology: A review and analysis for Earth and planetary science disciplines. *Earth-Science Reviews*. 270. 105226. [10.1016/j.earscirev.2025.105226](https://doi.org/10.1016/j.earscirev.2025.105226).
- Xu, D. (2026). The 26 August 2026 Langtang Lirung ice-rock avalanche and its transboundary cascade: a multi-source observational reconstruction in the Bhotekoshi basin. *EarthArXiv Volume 2*, 1 September. <https://doi.org/10.31223/X56793>